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Changes in the text for correction of typographical errors, and to take account of revisions, deletions and additions requested by committees. For other revisions and corrections of committee reports, see "Discussion."

Page 78, in diagrams for Floorbeam U_2U_2 and Floorbeam Posts U_2L_2, the lines for "AREA Design" should be at 64.6 percent instead of 74.1 percent, as drawn.

Page 164, fourth line from bottom, "Field welds" should read "Butt welds."

Page 292, caption for diagram, change "Wheel" to "Axle."

Page 302, end of second paragraph under 1. General, change "H 9" to "H 10."

Folded insert between pages 320 and 321, Table 4: In line for Mix 21, next to last column, change "4.47" to "4.74;" in line for Mix 22, fifth column, change "5¼" to "5¾."

Page 385, second line of table, "10/2/21" should read "10/2/41."

Page 455, last line of third paragraph, "submitted" should read "substituted."

Page 577, second line under "Test Measurements," "cracking" should read "backing."

Design of Tie Plates

Advance Report on Assignment 6 of Committee 5—Track*

J. de N. Macomb (chairman, subcommittee), C. A. Anderson, W. G. Arn, F. J. Bishop, Blair Blowers, C. W. Breed, M. D. Carothers, E. W. Caruthers, H. R. Clarke, R. W. Claypoole, B. E. Crumpler, J. W. Fulmer, B. F. Handloser, J. P. Hiltz, C. T. Jackson, G. M. Magee, E. E. Martin, J. B. Myers, J. A. Reed, I. H. Schram, M. J. Zeeman.

This is a report of progress concerning the investigations of tie plate design and is submitted as information. It is comprised of the following parts:

1. Stress Measurements in Seven Designs of Tie Plates for 112-lb. RE Rail on the Illinois Central System.
2. Relative Vertical Movement and Rocking of Tie Plates on the Ties Under Traffic.
3. Measurement of the Magnitude and Eccentricity of Tie Plate Loads.
4. Service Test Data for Seven Designs of Tie Plates in 112-lb. and 131-lb. RE Rail.
5. Supplemental Measurements of Mechanical Wear of Ties.

Foreword

In order to gain needed information for a more economical design of tie plates, a test installation of various designs of tie plates for 112-lb. rail was placed on the Illinois Central System in October 1944 and for 131-lb. rail on the Southern Railway System in November 1944. The designs of tie plates included in the test were selected to develop information on the area of plate, thickness, eccentricity, and shape of rail seat; i.e., flat, beveled, or rolled crown. Each test installation included a length of tangent track and a sharp curve. Periodically, measurements are being made to determine the rate of tie plate wear, bending of tie plates, and change in track gage. In addition, extensive stress measurements were made on the 131-lb. test tie plates in August 1945 and reported in the Proceedings, Vol. 47, 1946, page 491. In the summer of 1946 similar measurements were made on the 112-lb. test tie plates, augmented with measurements to determine under regular trains the relative vertical movement of the tie plate on the tie and also the amount of vertical load applied to an individual tie plate and its eccentricity.

1. Stress Measurements in Seven Designs of Tie Plates for 112-lb. RE Rail on the Illinois Central System

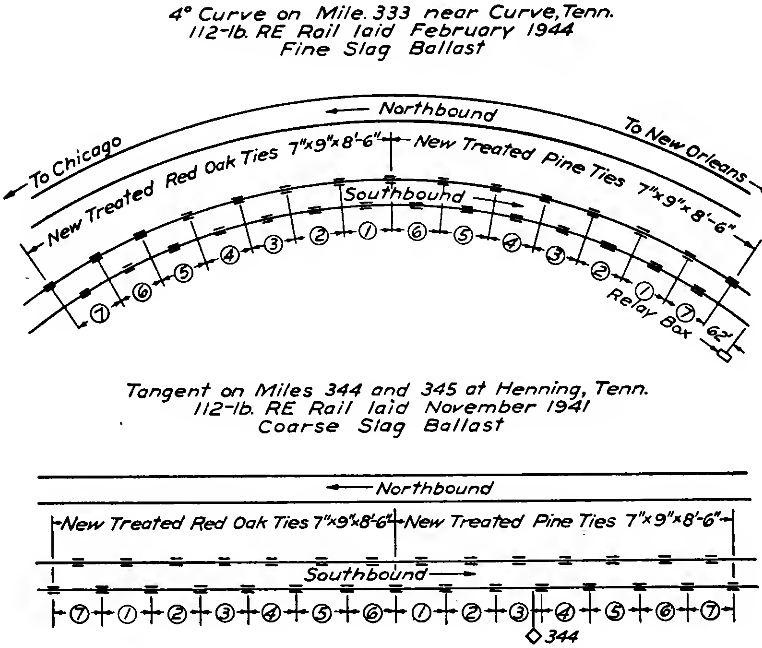
The general test procedure and type of measuring equipment used were the same as described in the report of the 131-lb. tie plate test previously mentioned.

Description of the Test Track

The 112-lb. tie plate test installation was placed in the southbound main track of the Illinois Central System; the tangent portion is near Henning, Tenn., and the curve portion 11 miles north on Mile L–333, near Curve, Tenn. This curve is located in a wide, deep cut and was laid with new 112-lb. RE rail and 4-hole joint bars in February

* Calls for collaboration with Committees 3 and 4.

A



Legend for Tie Plates

①	$7\frac{3}{4}''$ × 13"	$\frac{27}{32}''$ Thick	Flat Seat	TP 419
②	$7\frac{3}{4}''$ × 11"	$\frac{27}{32}''$ Thick	Flat Seat	TP 419-Z
③	$7\frac{3}{4}''$ × 11"	$\frac{11}{16}''$ Thick	Flat Seat	TP 419-Y
④	$7\frac{3}{4}''$ × 11"	$\frac{9}{16}''$ Thick	Flat Seat	TP 419-X
⑤	8" × 11"	$\frac{23}{32}''$ Thick	Beveled Seat	TP 366
⑥	$7\frac{3}{4}''$ × 11"	$\frac{23}{32}''$ Thick	Rolled Crown	TP 400
⑦	$8\frac{1}{2}''$ × 11"	$\frac{3}{4}''$ Thick	Pressed Camber	TP 3170

Fig. 1.—Tie Plate Test Installations in Southbound Main Track of Illinois Central System.

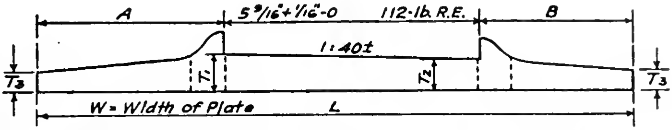
1944 on fine slag ballast. The tangent test section is laid with 1941–112-lb. RE rail, 4-hole joint bars and moderately coarse slag ballast, and is on a fill about 15 ft. high. New ties and tie plates were placed in the track according to the arrangement of track panels shown in Fig. 1.

Operating Characteristics Over the Test Track

The 4-deg. test curve was near the summit of a 5-mile ascending grade where the operating speeds of freight trains ranged from 10 to 35 mph., and the passenger trains from 40 to 45 mph. Superelevation of the curve at the time of the tests averaged $4\frac{1}{8}$ in. which is equivalent to a balanced speed of 40 mph. The tangent test section was located on a descending grade three miles from the summit and the predominant speeds for freight and passenger trains were 55 and 70 mph., respectively.

Passenger trains were hauled by Mountain type (4–8–2) locomotives, classes 2300 and 2400, with average driving axle loads of 64,000 and 62,000 lb., respectively. Freight

TABLE 1



Tie Plate Designation	Size W × L	A	B	Eccentricity	T_1	T_2	T_3	Rail Seat	Ratio $T_1 \div A$	Net Area of Plate-Sq. In	Estimated Net Weight-lb.
112-lb. R.E. Rail											
419	7¾" × 13"	4⅛"	3 5/16"	⅜"	27/32"	23/32"	7/16"	Flat	.205	95.7	19.7
419-Z	7¾" × 11"	3⅛"	2 5/16"	⅜"	27/32"	23/32"	17/32"	Flat	.270	81.6	17.8
419-Y	7¾" × 11"	3⅛"	2 5/16"	⅜"	11/16"	9/16"	⅜"	Flat	.220	81.6	14.2
419-X	7¾" × 11"	3⅛"	2 5/16"	⅜"	9/16"	7/16"	¼"	Flat	.180	81.6	11.3
366	8" × 11"	3⅛"	2 5/16"	⅜"	23/32"	19/32"	⅜"	Beveled	.230	85.0	14.7
400	7¾" × 11"	3⅛"	2 5/16"	⅜"	23/32"	19/32"	11/32"	Rolled Crown	.230	81.1	13.7
3170	8½" × 11"	3¼"	2 3/16"	½"	¾"	⅝"	13/32"	Pressed Crown	.231	91.2	16.4

trains were hauled by Mikado (2–8–2) and Berkshire (2–8–4) types of locomotives, and the latter type had the heavier average driving axle load of 68,000 lb.

The operating speeds for both the curve and tangent were excellent for setting up maximum loads on the tie plates by having a wide range of speed on the curve and moderately high speed on tangent. Operation of the 2–8–4 type locomotives at slow speed on the curve subjected the inner rail to heavy dynamic wheel loads and the high speeds on the tangent would be expected to produce maximum tie plate loads for tangent track.

Tie Plate Designs Included in the Test

In Fig. 1 the arrangement of the test track panels is shown and in Figs. 2 to 8, incl., dimensional features of the 7 designs of 112-lb. rail tie plates are given. A summary of the tie plate dimensions and other physical properties is shown in Table 1. Tie plate design 419, 13 in. in length, corresponds to AREA emergency Plan C. Designs 419–Z, 419–Y and 419–X, were machined from design 419 to provide plates of three different thicknesses in the 11-in. length. The thicknesses of the Z, Y and X designs at the outer shoulder are 27/32, 11/16 and 9/16 in., respectively. These four designs of tie plates all have flat rail seats. Designs 366 and 400, both 11 in. in length, have similar dimensions and differ, principally, in that the former has a beveled rail seat and the latter a rolled circular crown. Design 3170, another 11-in. tie plate but having a width of 8½ in., had 1/16-in. pressed camber which provided a circular crown rail seat. All designs of tie plates had a flat bottom and ⅜-in. eccentricity except the 3170 section which had ½ in.

Test Procedure

It will be observed in Fig. 1 the seven designs of tie plates are on both creosoted oak and pine ties in the curve and tangent test sections. Stress measurements at all test sections would have required a prohibitive amount of field work. Accordingly, all tie plate and rail stress measurements were made only for creosoted oak panels on the curve since hardwood ties are generally used in curves as sharp as 4 deg. In the tangent section the stress measurements were made only in the creosoted pine panels since previous tests had indicated that larger tie plate stresses occur on softwood ties than on hardwood. Stress measurements were made in both rails of the curve and in the east or

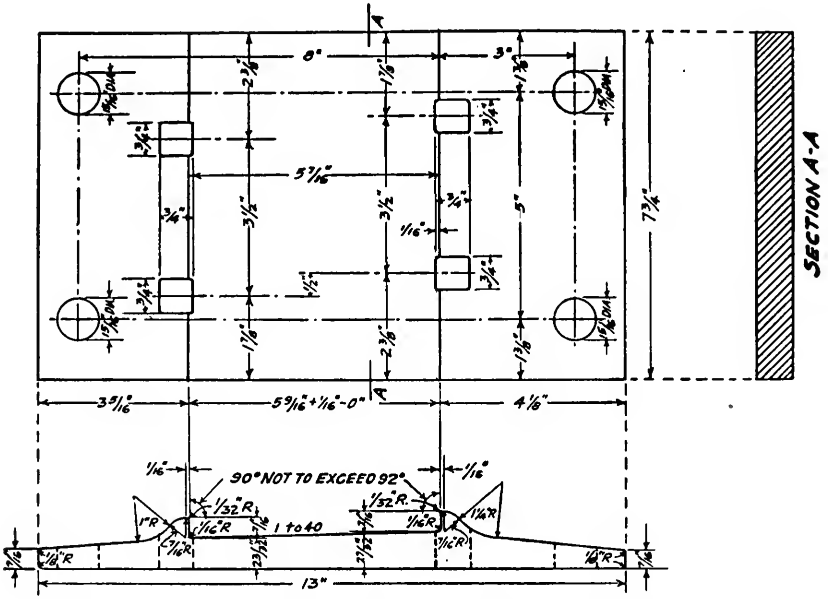


Fig. 2.—Plan T.P. 419 (AREA Plan C) Test Tie Plate for 112-lb. Rail.

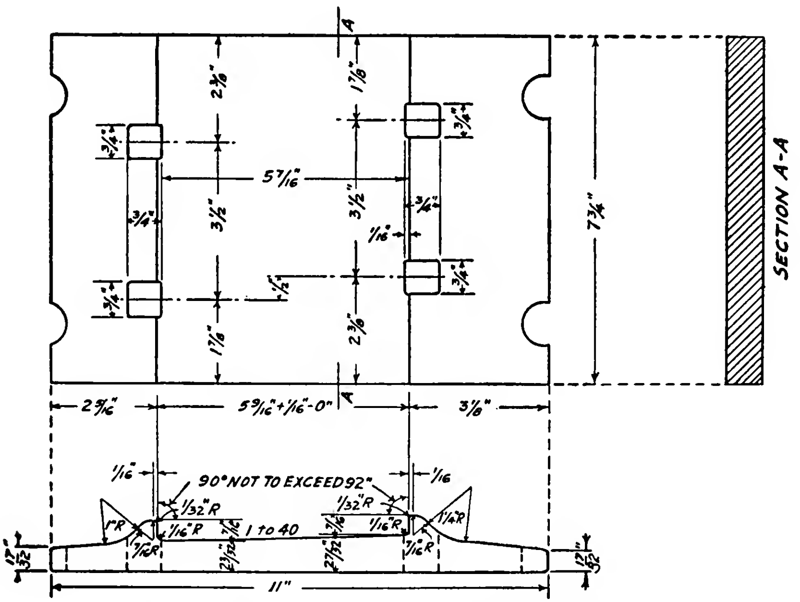


Fig. 3.—Plan T.P. 419Z Test Tie Plate for 112-lb. Rail.

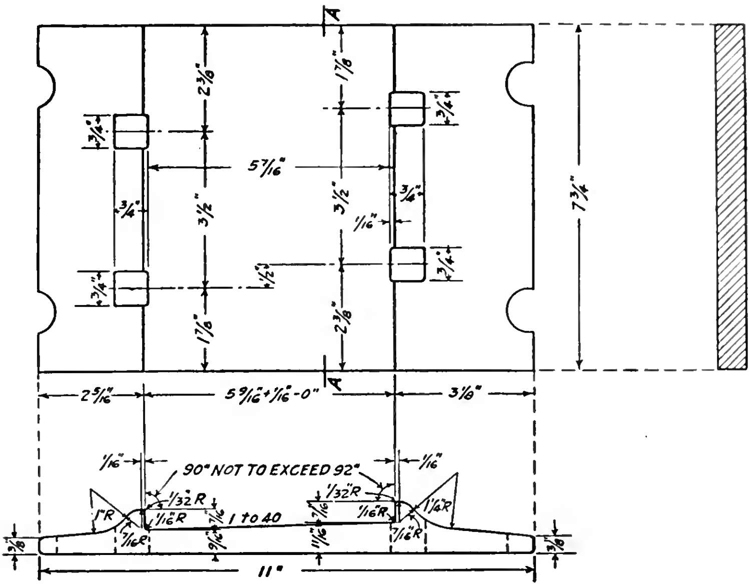


Fig. 4.—Plan T.P. 419Y Test Tie Plate for 112-lb. Rail.

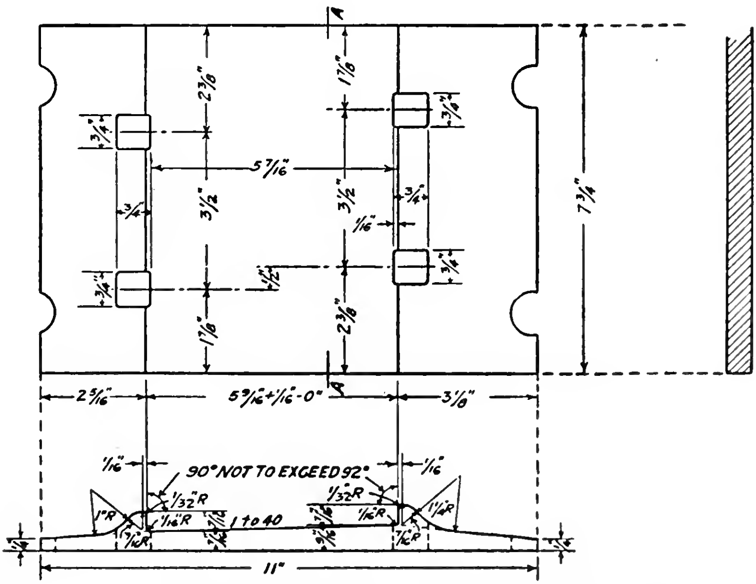


Fig. 5.—Plan T.P. 419X Test Tie Plate for 112-lb. Rail.

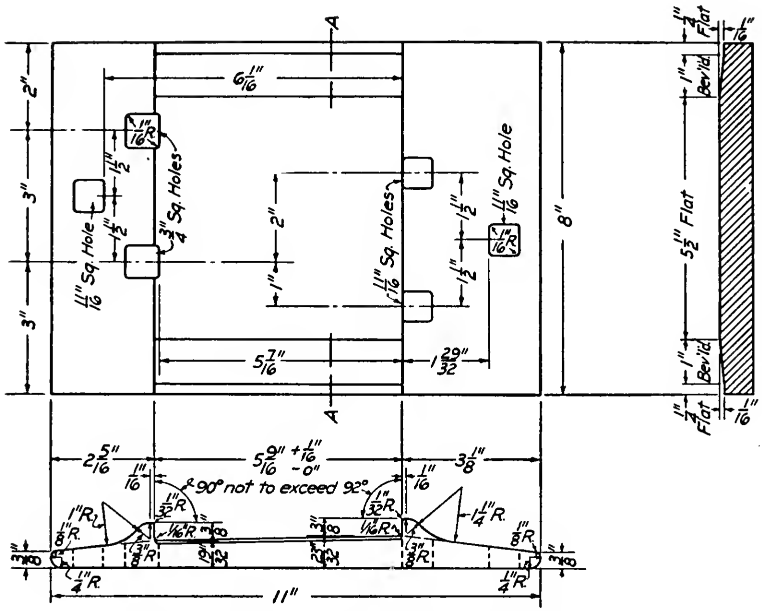


Fig. 6.—Plan T.P. 366 Test Tie Plate for 112-lb. Rail.

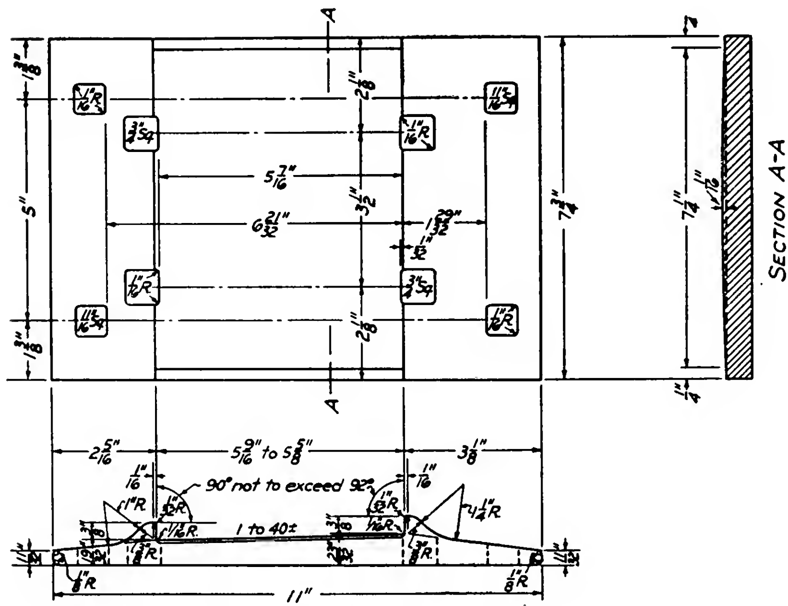


Fig. 7.—Plan T.P. 400 (AREA Plan No. 2) Test Tie Plate for 112-lb. Rail.

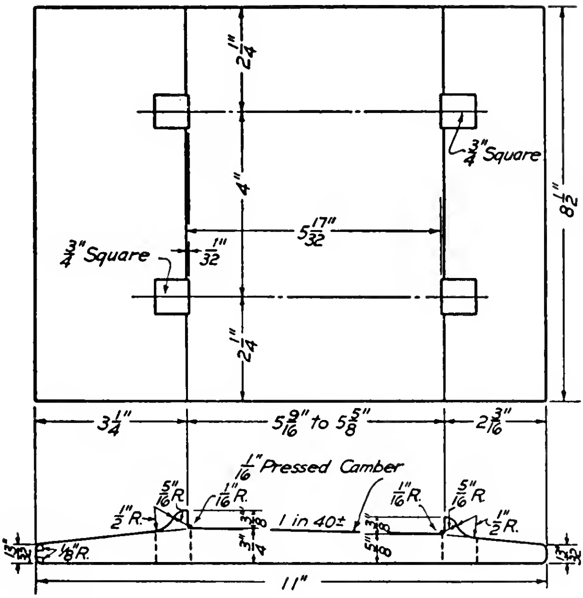


Fig. 8.—Plan T.P. 3170 Test Tie Plate for 112-lb. Rail.

left rail of the tangent section. It was believed the stresses would be higher in the left rail on tangent because of the greater dynamic augment in the left main drivers of the steam locomotives operated.

As in the previous test on the Southern Railway System, the tie plates selected were located at least two ties from the rail joints to avoid the effect of joint impacts and to insure that the tie plates had a solid bearing on the ties. In this test it was decided to measure the stresses in three tie plates to the rail length instead of two as previously done, in order to secure data on as many plates of the same design as possible for averaging out the variations in the track support and obtaining a better comparison of the stresses in the seven tie plate designs. In the upper portion of Fig. 9 a diagram of the gage positions on the tie plates is shown for each panel of track tested, and in the lower portion of the figure the same information is given for the tie plate and rail stress schedules for only the 419Y and 400 design tie plates on which it was desired to compare the stresses in the rail when supported by plates having a flat rail seat and when supported on plates having a rolled circular crown.

Altogether, oscillograph records were taken under 247 trains and the field test required two months' time. Fig. 10 is typical of the records obtained. This is an oscillogram of stresses measured in two tie plates of design 3170 under one of the 2–8–4 type locomotives hauling a heavy freight train at 17 mph. on the 4-deg. curve, and it will be noted that the transverse stress at gage position 2P was the highest one measured in the tie plate under the inner rail. This design of tie plate had pressed camber.

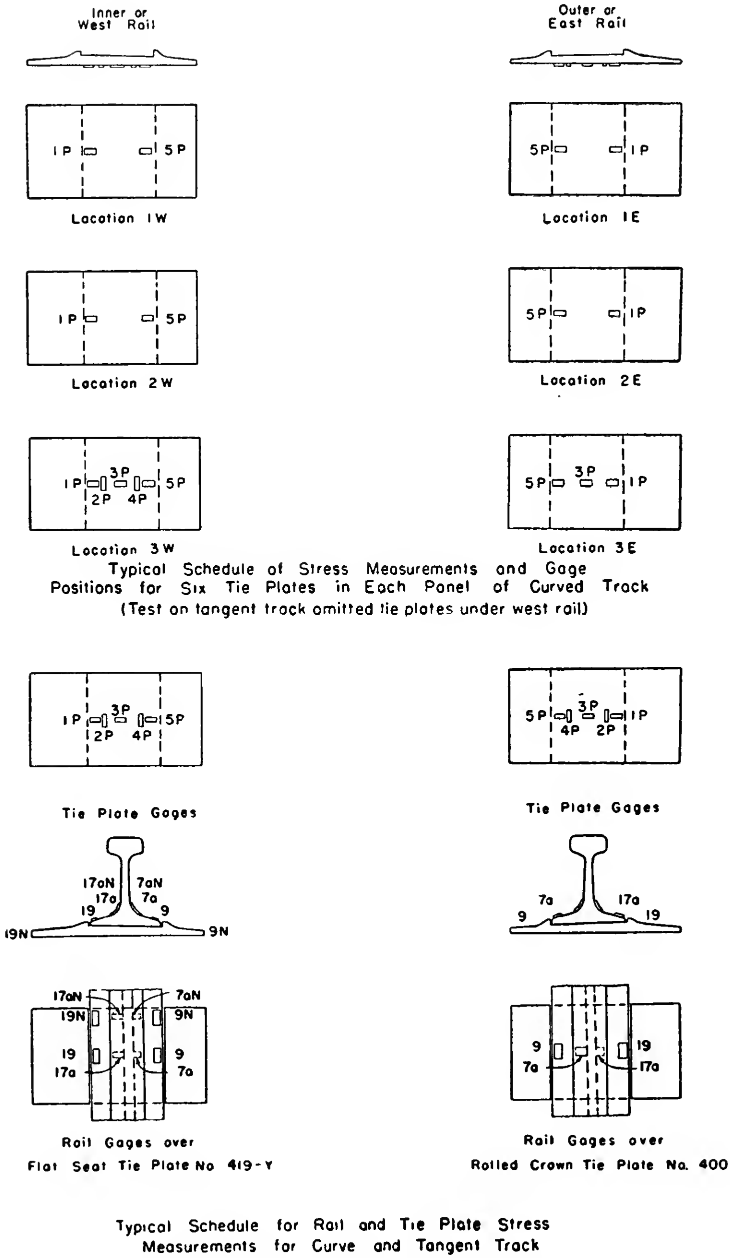


Fig. 9.—Gage Positions for Tie Plate and Rail Stress Measurements.

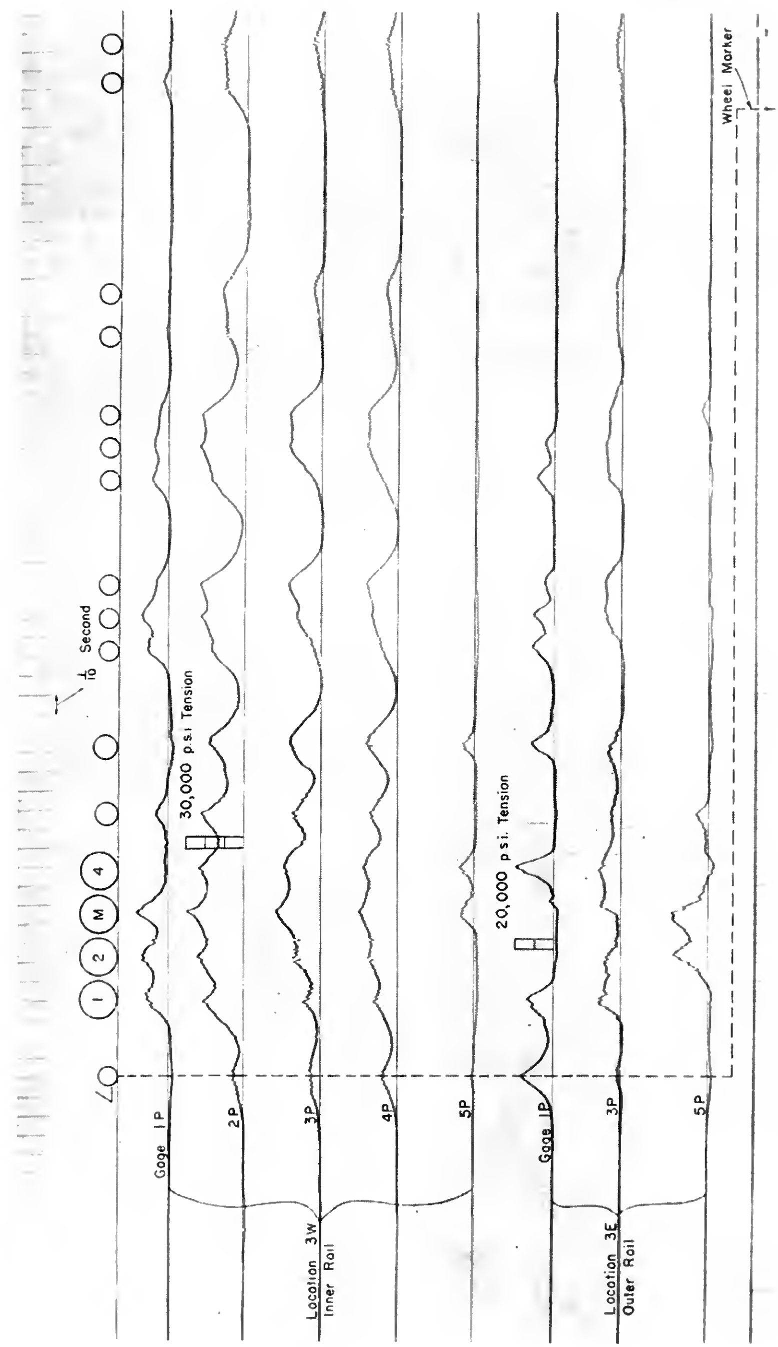


Fig. 10.—Oscillograph Record of Stresses in Two Tie Plates of Design No. 3170, Run No. 83, Locomotive 8023 (2-8-4), Southbound Freight Train, Speed 17 mph. (4-deg. Curve).

Discussion of Test Data

Tie Plate Stresses

Previous studies have shown that stress measurements in tie plates at gage locations 1P to 5P, incl., give a very informative picture of the loads applied to the plates. For example, the mean stress at gages 1P and 5P is indicative of the total vertical load. If 1P is higher than 5P then that load is applied with an eccentricity toward the outer toe of the plate; if less, toward the inner toe. The ratio of the stress at 3P to the mean of 1P and 5P indicates the uniformity of pressure distribution along the length of the plate. A low relative value of 3P shows that the bearing pressure is greater under the rail than at the tie plate ends; a high relative value shows a more uniform pressure distribution along the tie plate length. (See Proceedings, Vol. 45, 1944, pages 300–301).

Gages 2P and 4P show the transverse bending stresses in the plate. These are particularly significant for the plates with rolled or pressed circular crown.

Fig. 11 shows a summary of the maximum stress measured at each gage position under locomotives during each test run. This summary represents 9 to 15 test runs for each gage location. Each gage location also represents 3 to 4 tie plates in each test section, with the total shown at the bottom of the figure for all tie plates representing measurements of from 9 to 12 plates. However, the number of plates involved was not sufficient to compensate entirely for the variations in supporting conditions and resulting tie plate loads. Accordingly, comparison of tie plate stresses with the various designs can only be made in general terms. For each gage location in Fig. 11, the bar shows the range of measured maximum stresses for the individual test runs and the mean stress is shown by the transverse line near the midlength of the bar. The mean values are connected with a dashed line for gages 1P, 3P and 5P.

A comparison of plates 419X, 419Y and 419Z (all 11-in. plates of 3 different thicknesses) shows that the plate stress increases as the plate thickness decreases; rather

Table 2.—Summary of Maximum Stresses Measured in All Tie Plates of Each Design on the 4-Deg. Curve and Tangent Track Under Tenders and Cars Separately

(Units of 1000 lb. per sq. in. Minus signs denote compressive stresses)

Description of Tie Plate and Designation		Speed m.p.h.	1P		2P		3P		4P		5P	
			Tend.	Cars	Tend.	Cars	Tend.	Cars	Tend.	Cars	Tend.	Cars
7 3/4"x13"x27/32"	High		25.2	21.6	12.8	10.8	17.2	16.4	12.3	9.4	20.0	20.0
Flat Seat	Avg.	32	13.0	9.2	4.2	3.8	10.6	8.2	2.2	1.7	9.0	8.1
No. 419	Low		4.0	2.8	-3.1	-2.0	4.8	3.6	-3.8	0.0	0.0	0.0
7 3/4"x11"x27/32"	High		21.3	17.6	11.6	8.4	16.4	12.7	4.5	4.2	11.2	14.0
Flat Seat	Avg.	33	8.9	6.6	6.8	4.2	10.0	7.3	2.8	1.5	5.5	4.4
No. 419-Z	Low		0.0	0.0	3.2	1.6	4.4	2.0	2.0	0.0	0.0	0.0
7 3/4"x11"x11/16"	High		23.2	20.0	20.9	15.2	22.6	17.2	26.7	22.6	18.0	21.2
Flat Seat	Avg.	34	11.8	9.1	10.6	9.0	12.0	10.2	10.5	9.2	8.4	6.9
No. 419-Y	Low		0.0	0.0	4.8	3.4	3.7	2.0	4.1	2.9	0.1	0.0
7 3/4"x11"x9/16"	High		22.3	33.6	14.4	14.0	18.0	18.0	13.1	13.1	29.6	25.1
Flat Seat	Avg.	34	11.5	7.8	3.0	3.2	10.9	7.9	3.7	3.3	10.7	7.7
No. 419-X	Low		0.4	0.4	-0.8	-0.4	4.4	1.6	-0.4	-0.4	0.4	0.4
8"x11"x23/32"	High		28.7	22.6	5.6	5.6	14.3	13.9	5.3	4.9	15.2	25.1
Beveled Seat	Avg.	30	12.8	9.0	3.9	2.2	8.0	6.0	3.7	2.1	5.8	4.7
No. 366	Low		0.2	0.4	1.6	1.2	4.1	0.4	2.0	0.4	0.4	0.4
7 3/4"x11"x23/32"	High		42.0	51.2	22.6	24.6	24.8	22.0	24.9	29.0	26.0	31.6
Rolled Crown	Avg.	31	15.5	11.8	13.8	10.0	13.0	10.1	10.9	8.1	11.0	9.5
No. 400	Low		0.4	0.4	8.6	2.8	3.3	0.4	7.0	0.8	0.0	0.0
8½"x11"x3/4"	High		27.3	18.9	34.0	28.0	20.8	15.2	20.0	15.2	16.4	16.8
Pressed Camber	Avg.	40	12.0	8.0	16.1	12.4	12.1	8.5	14.8	11.2	5.1	4.0
No. 3170	Low		0.4	0.4	4.9	4.1	4.5	2.0	9.5	5.3	0.4	0.4

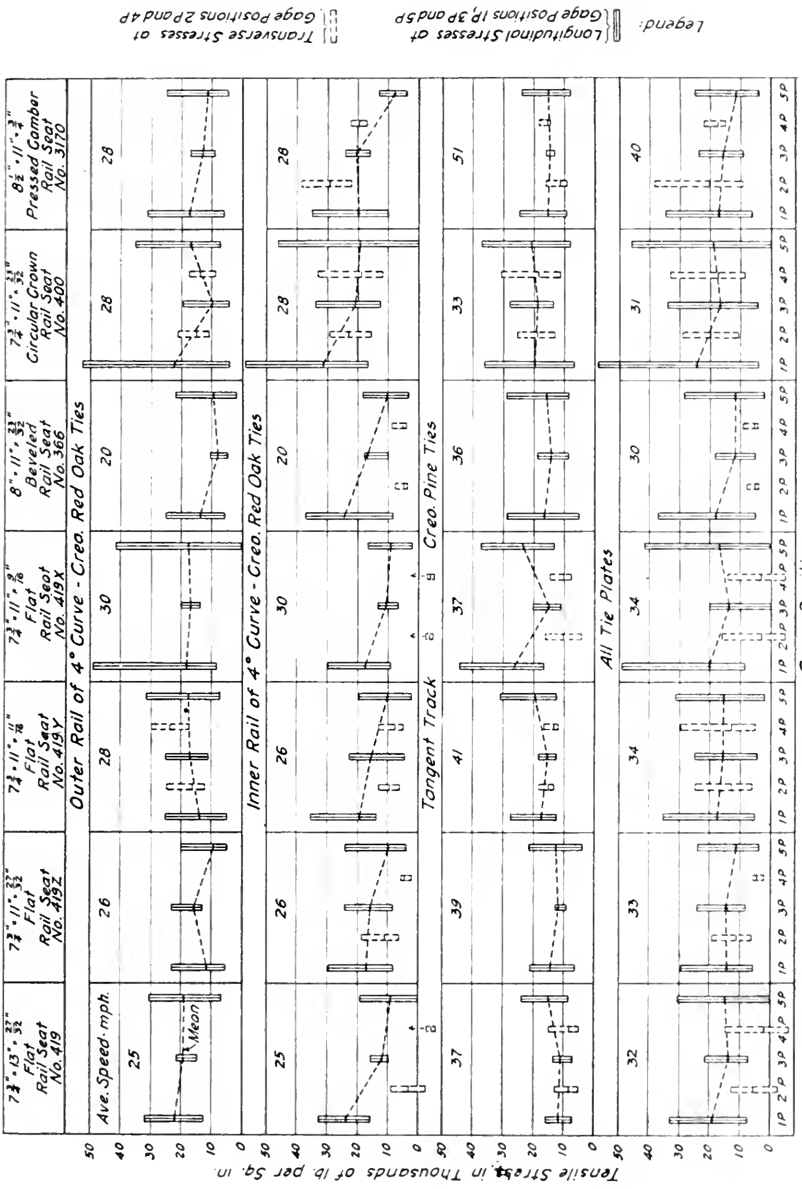


Fig. 11.—Summary of Maximum Flexural Stresses Measured in the Bottom Surface of Seven Designs of 112-lb. Tie Plates Under Locomotives.

high stresses were measured under the plate with 9/16-in. thickness. Generally, a thickness of 11/16 in. has been used with the 11-in. plate. The increase in the ratio of the stresses at 3P to the mean of 1P and 5P shows that the thicker plates are providing a more uniform pressure distribution along the length of the plate.

The 13-in. length plate, 27/32 in. thick, has about the same bending stresses as the 11-in. plate, 11/16 in. thick. The pressure distribution appears to be somewhat less favorable for the 13-in. plate.

The 11-in. beveled rail seat plate does not show any significant difference in plate stress compared to the flat rail seat plate 419Y. Neither the rolled circular crown nor the pressed camber 11-in. plates show any advantage over the 11-in. plate with the flat rail seat. In fact, the transverse stresses are considerably higher and the mean values are somewhat higher than the longitudinal bending stresses in the same plates. The longitudinal bending stresses are higher in the plate with the rolled circular crown. Part of this effect may be due to variations in loads on the individual plates, but these stresses may be expected to be somewhat higher due to the load from the rail being concentrated near the midwidth of the plate.

The maximum stresses measured in all tie plates of each design on the curve and tangent for the tenders and cars, separately, are summarized in Table 2. These data, in tabular instead of graphical form for the tenders and cars, correspond with the lower tier of diagrams in Fig. 11 for the maximum tie plate stresses measured under the locomotives. With few exceptions, the average maximum tie plate stresses under the tenders were greater than under the cars. The average values for the tenders and cars were somewhat smaller than for the locomotives.

Effect of Tie Plates on Rail Stresses

Stresses in the rail base flanges and the lower fillets were measured directly above tie plates of design 400 with the rolled circular crown, and 419Y with the flat rail seat, to determine the influence on these values attributable to the shape of the rail seat. The arrangement of strain gages used is shown in the lower portion of Fig. 9. These data were summarized as to maximum values obtained under each locomotive and are shown graphically in Fig. 12. The upper portion of the figure covers the longitudinal bending stresses in the rail base flanges and the lower part, the vertical bending stresses in the lower rail fillets. For the rolled circular crown tie plate design 400 the line of rail gages was located directly over the center line of the bearing area on the crown as determined from the wear on the rail seat. In the case of the flat seat tie plate of design 419Y, two lines of rail gages transversely to the rail were used, as the maximum stresses in the rail base flanges and lower fillets may occur over the longitudinal center line of the plate or directly above the edge of the contact area between the rail base and the tie plate rail seat.

It will be observed from Part 1 of Fig. 12 that the mean maximum longitudinal tensile stresses in the rail base flanges over the rolled crown tie plate are greater than the corresponding values over the flat seat tie plate. The percentage increase of these mean values for the rolled circular crown tie plate over that for the flat seat tie plate follows:

Location	*Percent*
Inner flange, outer rail	26
Outer flange, outer rail	36
Inner flange, inner rail	13
Outer flange, tangent rail	87

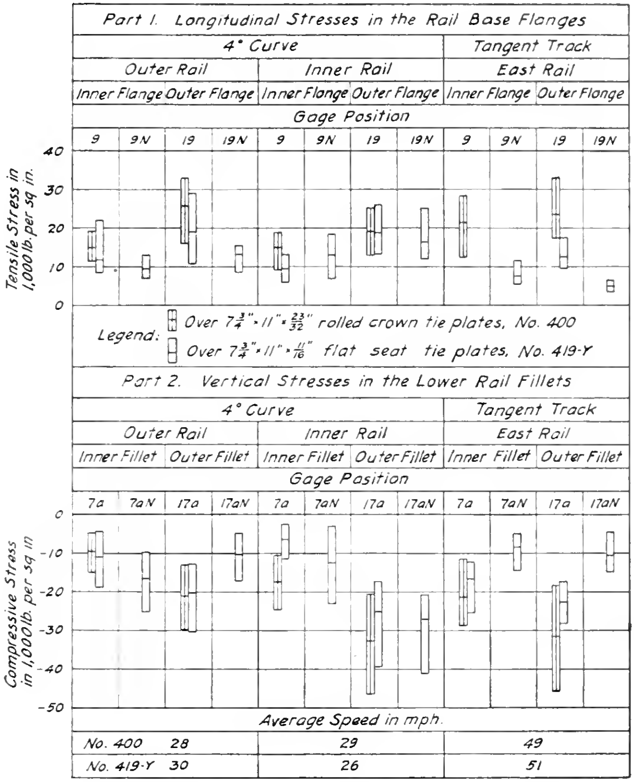


Fig. 12.—Maximum stresses in 112-lb. RE Rail Measured Under Locomotives with the Rail Supported on Rolled Crown (No. 400) and Flat Seat (No. 419Y) Tie Plates.

In Part 2 of Fig. 12 a comparison is shown for the maximum lower rail fillet compressive stresses measured over the two designs of tie plate rail seats. In the inner fillet of the outer rail of the curve the mean maximum stress was greater over the flat seat tie plate, and in the outer fillet of the outer rail the two values were about the same. At all other locations the mean values were higher over the rolled circular crown tie plate. The highest mean maximum compressive stresses measured in the rail were in the lower outer fillet of the inner rail of the curve, and in tangent rail supported on tie plates having the rolled crown. Considering the test conditions which involved some slow speed traffic on the 4-deg. curve and moderately high speed on tangent, these rail stress values are of reasonable magnitude.

Conclusions

These tests on the tie plates for 112-lb. rail and those previously reported for the 131-lb. rail have shown that the tie plate stress increases as the plate thickness is reduced. They also furnish information on the range of tie plate stress developed in regular train service for tie plates of generally used designs. This may be correlated with the fatigue strength of tie plate steel determined from laboratory tests when that information becomes available.

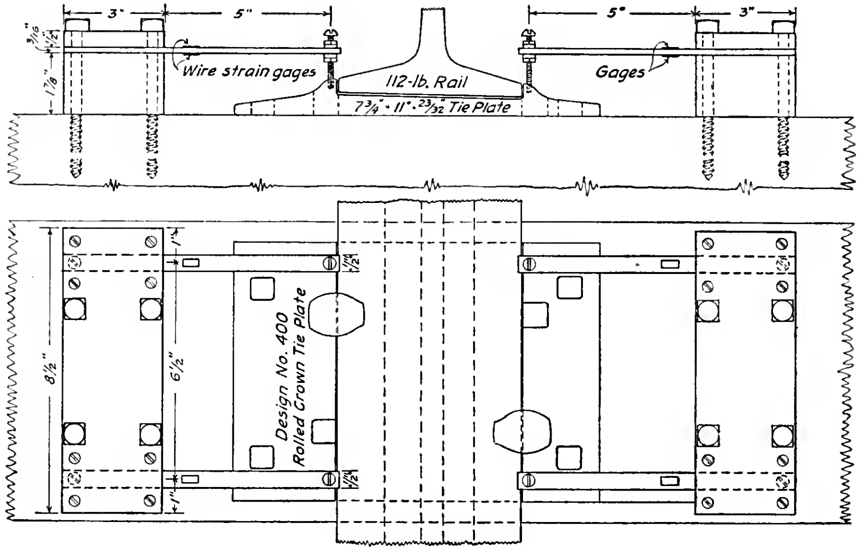


Fig. 13.—Deflection Bars for Measurement of Vertical Movement of Tie Plates.

The test results for the flat seat and beveled crown tie plates are more favorable than those for the rolled circular crown or pressed camber plates, both from the standpoint of tie plate stress and localized stress developed in the rail base and lower rail fillets over the tie plate bearing.

Acknowledgment

M. F. Smucker, assistant electrical engineer, research staff, was in direct charge of the field tests, and H. E. Durham, track engineer, planned the test and supervised preparation of the report under the general direction of G. M. Magee, research engineer. The committee is indebted to the Illinois Central System for its excellent assistance and cooperation in conducting the several phases of the field work.

2. Relative Vertical Movement and Rocking of Tie Plates on the Ties Under Traffic

It has been contended by some railway engineers that tie plates with a flat rail seat rock more and cause a greater track noise than those with the rolled circular crown. The purpose of these measurements was to determine the compression of the plate into the tie and the rocking action parallel with the rail of tie plates having a flat rail seat and a rolled circular crown.

For these comparative tests the 419Y design (Fig. 4) with a flat rail seat and tie plate No. 400 (Fig. 7) with a rolled circular crown were selected, and the data were obtained in the schedules of rail and tie plate stress measurements described in Part 1 of this report.

Test Procedure

The apparatus used for measuring the vertical movement of the tie plates with respect to the ties is shown in Fig. 13. Two sets of these deflection bars were used for obtaining the data for both designs of tie plates in the same test runs. Two cantilever

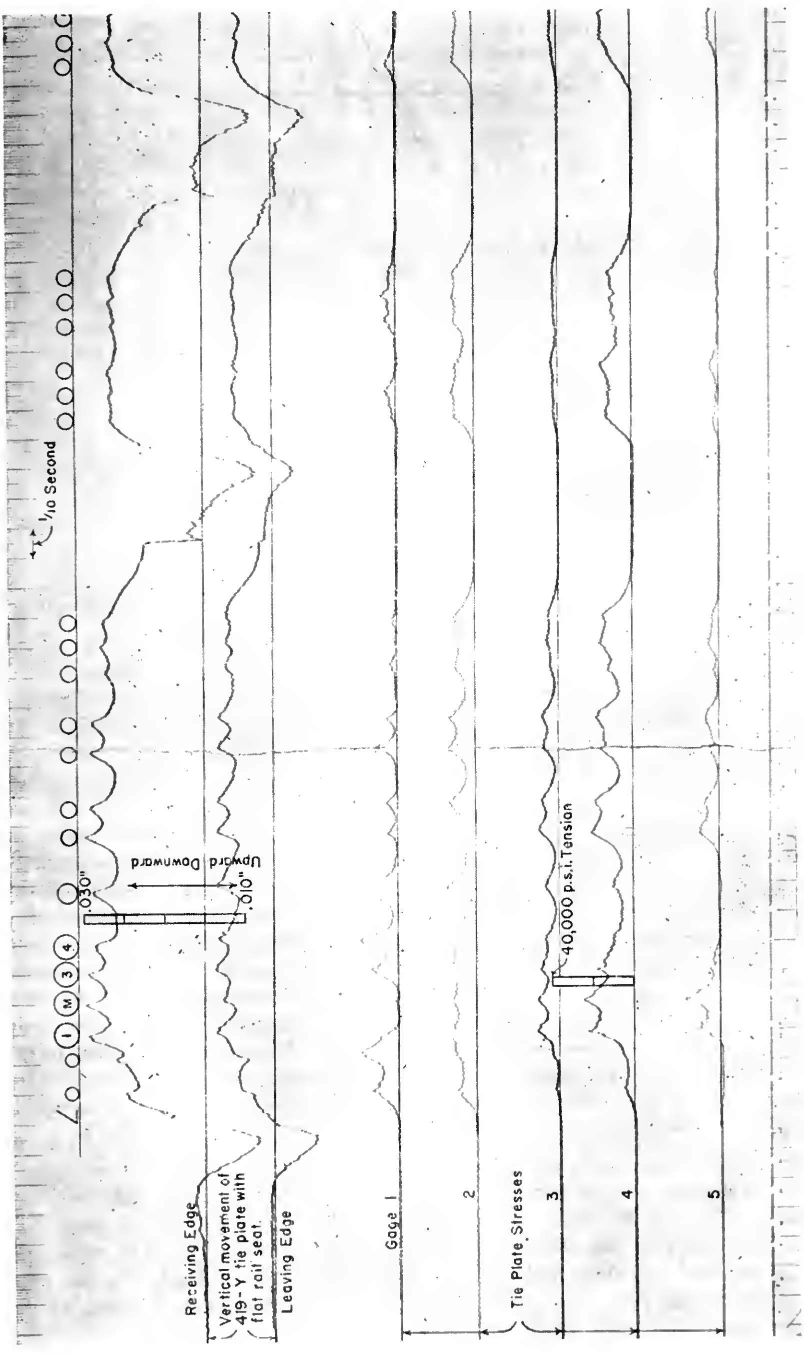


Fig. 14.—Oscillograph Record of Run No. 86, Engine No. 2303 (4–8–2), Passenger Train No. 3, 42 mph.,—Outer Rail of 4-deg. Curve.

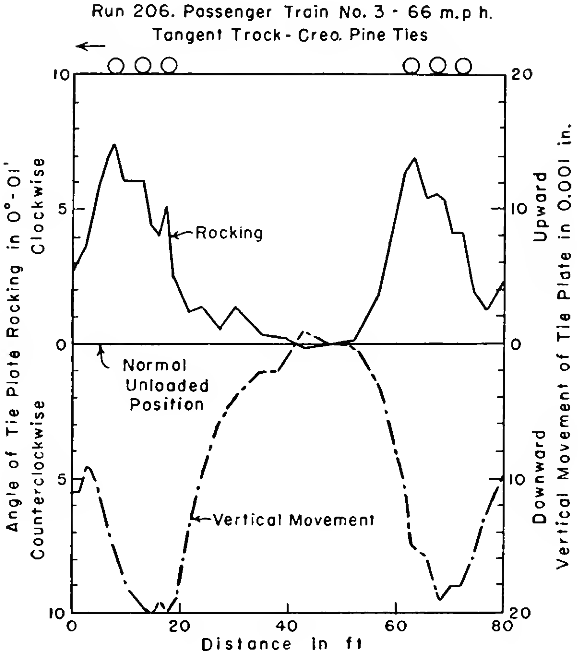


Fig. 15.—Typical Curves of Rocking and Vertical Movement with Respect to the Tie of Design 419Y Tie Plate with a Flat Rail Seat During the Passage of a Passenger Car with 6-Wheel Trucks.

beams were rigidly fastened to a common reaction block which was attached to the tie with lag screws for each shoulder of the tie plate. The free end of the cantilever beam was attached to the tie plate shoulder with a No. 8–32 screw, fiber washers and hex nuts. Provision for horizontal movement of the tie plate was made by having play between the screws and the wall of the holes in the measuring beams. SR–4 wire strain gages, ½ in. in length, were cemented to the top and bottom faces of each beam. To simplify the strain records and minimize the work required to analyze them, the four gages on two beams resting on the receiving or leaving edge of the tie plates were connected to one amplifier and oscillograph channel. The four gages were placed in the balancing bridge so that all would be additive in the tensile direction for a downward movement of the tie plate and the channel was calibrated for a sensitivity of 1-in. galvanometer deflection equals 0.020 in. vertical movement of one edge of the tie plate.

Vertical tie plate movement records were taken simultaneously for both designs of tie plates in their original location, and a few runs were made with the tie plates reversed as to location to determine the influence of the difference in the tie support at the two locations. This procedure was followed in three lines of rail: The outer and inner rails of the 4-deg. curve and the east or left rail of tangent track. The ties were creosoted oak on the curve and creosoted pine on the tangent and were a part of the service test installation made in October 1944.

Discussion of Test Data

One of the oscillograph records of vertical movement of the 419Y tie plate in its original location under the outer rail of the 4-deg. curve is reproduced in Fig. 14. The two upper traces show the tie plate movement with respect to the tie, and the lower five traces the stresses in the bottom surface of the same tie plate. The deflection of each of the two upper traces from its base line indicates the vertical movement of one sheared edge of the tie plate with respect to the tie. Uplift of the tie plate occurred ahead of the locomotive and behind the center of each passenger car. This uplift diminished in succeeding test runs. In most of the runs for other tie plate locations there was no uplift near the center of the passenger cars. The average of simultaneous deflections of the two upper traces is indicative of the depression of the tie plate into the tie. The difference between the two readings indicates the angular position or angle of tie plate rocking on the tie.

Fig. 15 is a typical graph showing the curves of rocking and depression of a 419Y tie plate with a flat rail seat for a passenger car length on tangent track with creosoted pine ties at a train speed of 66 mph. A clockwise angle of tie plate rocking is defined as the angle of deviation from the normal unloaded position of the tie plate when the vertical movement is such that the receiving edge is lower than the leaving edge of the tie plate. The depression curve indicates a slight uplift of the tie plate near the center of the passenger car. All runs analyzed were for passenger cars with 6-wheel trucks because only a few records included a passenger car with 4-wheel trucks. For run 206 in Fig. 15 the maximum values of angle of tie plate rocking and compression in the wood were 7½ min. and 0.020 in., respectively.

Several runs on the curve and tangent were analyzed in the foregoing manner for six tie plates, three of each design in their original location without anchor spikes. The angle of rocking never reverses from clockwise to counter-clockwise, or vice versa, while the tie plate is loaded and resting on its own tie seat, except that when the tie plate load was small a slight reversal of rocking was noted with the 400 design tie plate under the outer rail of the curve. It was developed from this study that while the tie plate was loaded the amplitude of the rocking motion under the wheels of a truck was too small to cause first one sheared edge and then the other to rise off the tie. For each tie plate location consistent patterns of tie plate rocking and vertical movement were obtained for two or more passenger cars in the same train and also for two or more runs at approximately the same speed. The results for a representative run for each of the six tie plate locations appear in the small table. The minus sign denotes a counter-clockwise angle of tie plate rocking. The higher values of the rocking angle and tie compression occurred on tangent track with softwood ties and the highest train speed.

DATA ON ROCKING OF TIE PLATES

All data are for passenger cars with 6-wheel trucks and tie plates in original location.

				Maximum Angle of Rocking of Tie Plates in min.		*Maximum Compression of tie in 0.001 in.*	
Run No.	*Mph.*	*Location*	*Kind of Ties*	*419Y Flat Seat*	*400 Rolled Crown*	*419Y Flat Seat*	*400 Rolled Crown*
98	45	Outer rail 4° Cv.	Creo. oak	3.8	—2.2	11	6
126	43	Inner rail 4° Cv.	Creo. oak	2.9	5.4	5	9
206	66	Tangent	Creo. pine	7.5	13.5	20	23
			Average	4.7	7.0		

Test were repeated by interchanging the flat seat and rolled crown tie plates on their respective ties and generally it was found that the rocking characteristics remained the same on a particular tie, irrespective of which type of plate was used. Evidently, the tie condition had more effect on the amount of rocking than did the shape of the rail seat of the tie plate.

Of most significance, however, was the small magnitude of the tie plate rocking for any tie plate or tie condition. It is difficult to see how the smaller angular change of only a few minutes in conjunction with the relatively large depression of the tie into the ballast could be of any consequence.

3. Measurement of the Magnitude and Eccentricity of Tie Plate Loads

After stresses were measured in seven designs of tie plates in 131-lb. RE rail territory on the C. N. O. & T. P. Ry. (Southern Railway System) near Chattanooga, Tenn., in 1945, a theoretical analysis of simultaneous values recorded at gage positions 1P, 3P and 5P (Fig. 9) was made for one design of the 14-in. tie plate to determine the vertical load on the plate and the position of the resultant with respect to the center line of the rail base. These results were not reported as it was believed that the method was not accurate because the procedure was based on assuming the position of the rail reactions to be just inside of the edges of the rail base, and in several instances simultaneous sets of stress values indicated this was not entirely correct. Accordingly, it was decided to develop a dynamometer tie plate with which the tie plate loads and eccentricity of loading could be accurately determined.

Dynamometer Tie Plates

From plans prepared by the research staff, the Chicago, Burlington & Quincy Railroad manufactured two dynamometer tie plates as shown in Fig. 16. This figure also indicates the position of the SR–4 wire strain gages, ½ in. in length, used with the dynamometer tie plate to measure the tie plate loads and rail stresses. Each cantilever beam for measuring the rail reaction had a strain gage on both the top and bottom surfaces for the purpose of compensating the direct stress caused by a lateral thrust from the rail. The two gages were operated in the same amplifier circuit and connected in the balancing bridge so that the strain in both would be additive in the tensile direction on the oscillogram. Gages 3 and 13 located on the upper rail web were used to determine the wheel load. Previous tests had indicated that the mean value of simultaneous stresses at these two positions is directly proportional to the wheel load. Stresses at gage positions 7a and 17a are directly related to the magnitude of the respective rail reactions. Prior to the field tests the dynamometer tie plates were calibrated to determine the ratio of load to flexural stress for each beam. The ratios were approximately 0.66 of the flexural stress.

Test Procedure

The dynamometer tie plates were installed on a new white oak tie, 9 in. wide, which had its top surface planed. Each one was fastened to the tie with four ⅝-in. by 6-in. lag screws and positioned to conform to the existing gage of track. The installation was first made at about the center of the creosoted oak tie test section on the 4-deg. curve several days before taking records. The tie was tamped up several times to give it a good bearing. The second installation was made near the center of the creosoted pine test section on tangent track at Henning, Tenn., (Fig. 1). In each case the shims supporting the rail were selected to fit the existing cant of the rail. On the curve, four test

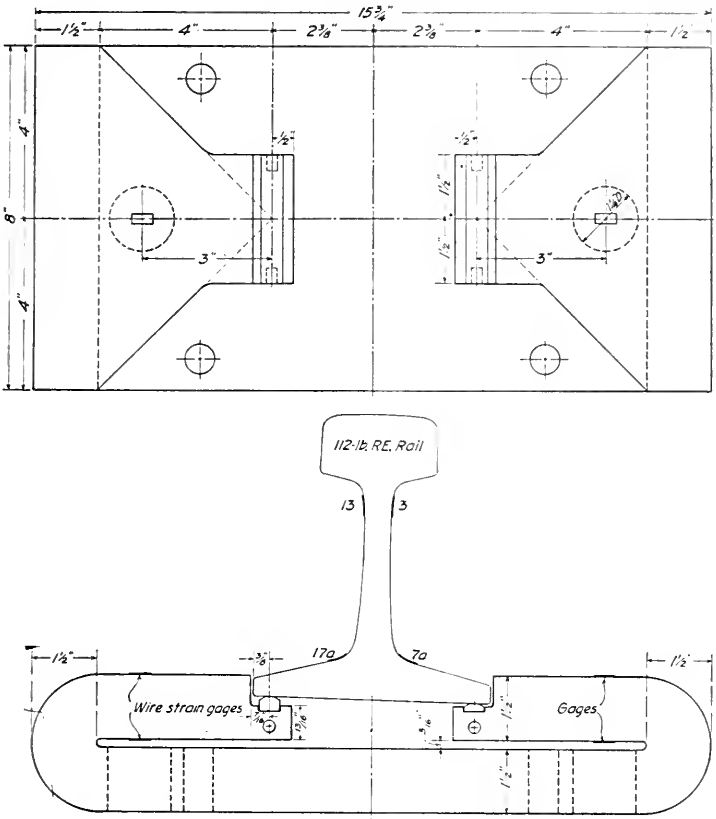


Fig. 16.—Dynamometer Tie Plate.

series were conducted with different conditions of rail support. Condition A was with a normal rail bearing on the test tie as finally tamped. For condition B the play between the rail and tie plate was shimmed out for five ties each side of the test tie in order to obtain data for what might approximate an average condition. For condition C the shims were left in place on the adjoining ties and the rail over the dynamometer tie plates was shimmed up 1/16 in. above the normal position. This condition would represent a tie tamped a little high. Condition D was similar to B except the rail was shimmed ⅛ in. high at the test tie. This condition might exist in track temporarily. Although this method is accurate for measuring the magnitude and eccentricity of tie plate loads, it is important to reproduce practical conditions of rail support. The test tie on the curve assumed a solid bearing in the fine slag ballast and it was not necessary to tamp the tie after starting the test. During the tangent test the dynamometer tie was tamped up a few times after starting because the coarse slag ballast required a much longer period to compact and provide a solid tie bearing. The test on tangent was conducted in the same manner as on the curve except that condition A was omitted.

Fig. 17 shows one of the oscillograph records of the rail and dynamometer tie plate stresses for the inner rail of the 4-deg. curve taken under passenger train No. 25, hauled

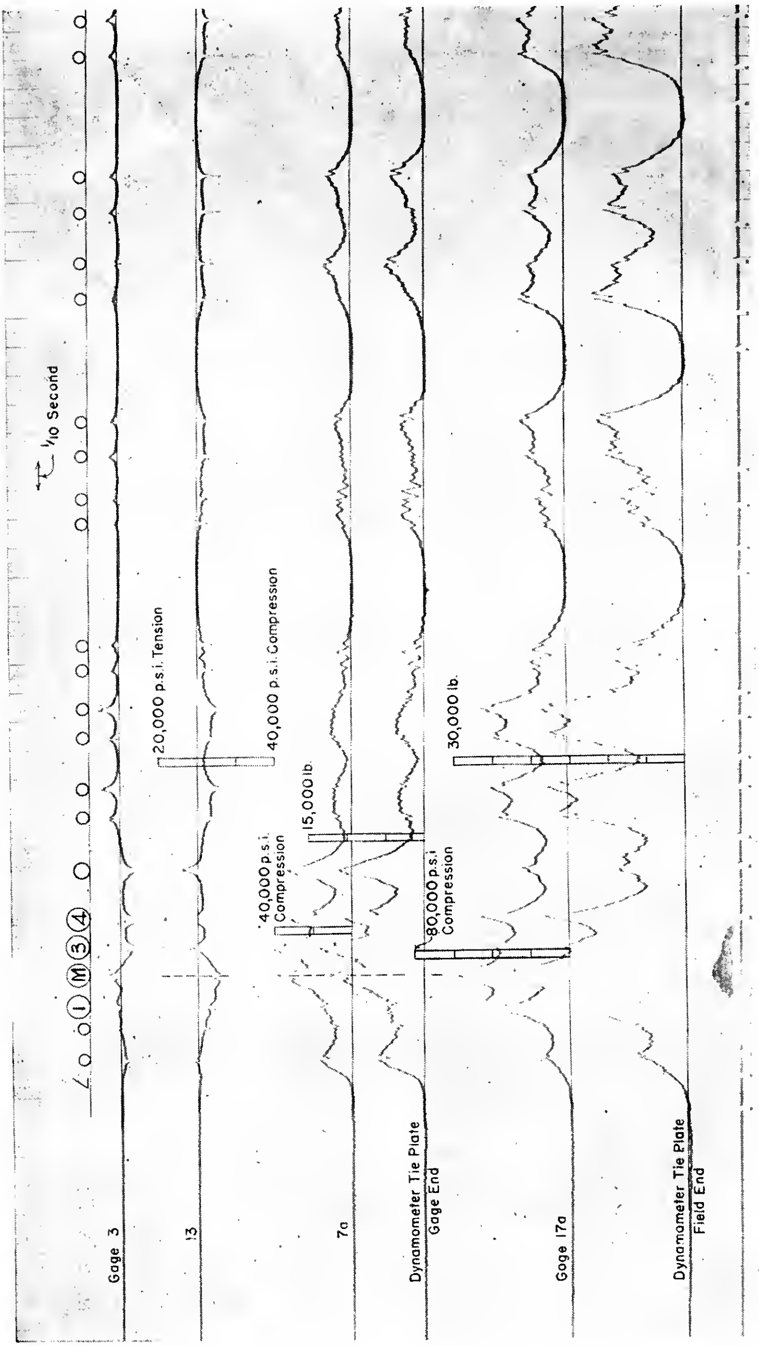


Fig. 17.—Oscillograph Record of Run No. 149, Engine No. 2450 (4–8–2), Passenger Train No. 25, 44 mph., Inner Rail of 4-deg. Curve. Rail Shimmed 1/8 in. Above Normal.

by a 4–8–2 type locomotive. Another record was taken simultaneously for the outer rail of the curve. The two upper traces show the stresses in the upper rail web at gage positions 3 and 13. The third and fifth traces give the stresses in the lower rail fillets for the gage and field sides, respectively. The fourth and sixth traces indicate, respectively, the rail reactions in 1000-lb. load for the gage and field beams of the dynamometer tie plate. There is a marked similarity of the pattern of the traces of gage 7a and the gage end of the test plate directly below the rail gage, and also for the corresponding traces on the field side. The tie plate load is the sum of the two simultaneous rail reactions recorded by the fourth and sixth traces, and the eccentricity of the resultant load was determined from the ratio of the small to large rail reaction for a simple beam length of 4¾ in. which was the distance between the center lines of the supporting shims.

Discussion of Test Data

To show the variation of tie plate loads and their relative frequency of application, tie plate loads measured under the locomotives and tenders were grouped in increments of 5000-lb. load and plotted in percentage of the total number of values included. The loads measured under cars included both passenger and freight cars and the data for the latter were divided equally between light cars and the heaviest cars shown on each oscillogram. The eccentricity of a tie plate load is the distance in inches from the center line of the rail base to the position of the resultant of the two simultaneous rail reactions in the plane of the rail base. An outward or positive eccentricity is defined as that occurring when the load resultant intersects the bottom of the rail base on the field side of the center line of the rail base, and a negative value is inward of the track or on the gage side of the reference line. These values were grouped in ½-in. increments and plotted in percentage of the number of items.

4-Deg. Test Curve

Graphs of the magnitude and frequency of the tie plate loads and values of eccentricity for both rails of the 4-deg. curve, and the four conditions of rail support are shown in Figs. 18 to 25, incl. The left portion of each figure applies to the locomotives and tenders and the right portion to passenger and freight cars. There is a marked range of values of the tie plate loads and eccentricity of the rail reactions for locomotives and tenders and to a lesser extent for the cars. A summary of the mean values is given in Table 3. The average tie plate loads were the lowest for condition of rail support B

(text continued on page 30)

TABLE 3.—SUMMARY OF AVERAGE DYNAMOMETER TIE PLATE LOADS AND ECCENTRICITY OF THE CENTROID OF PRESSURE FROM CENTER LINE OF RAIL BASE FOR BOTH RAILS OF THE 4° CURVE AND FOUR CONDITIONS OF RAIL SUPPORT IN THE SOUTHBOUND MAIN TRACK, ILLINOIS CENTRAL SYSTEM, NEAR CURVE, TENN.
(Tie plate loads are shown in 1000 lb. and eccentricities in in. + = outward from center line rail base, - = inward)

Rail Support	Avg. Speed mph.	Average Tie Plate Loads				Eccentricity of Tie Plate Loads						
		Locos. and tenders		Cars		Locos. and tenders			Cars			All
		Outer Rail	Inner Rail	Outer Rail	Inner Rail	Outer Rail	Inner Rail	Both Rails	Outer Rail	Inner Rail	Both Rails	Both Rails
Condition A	29	16.4	20.8	9.0	10.3	+0.28	+1.22	+0.75	+0.14	+1.85	+1.00	+0.88
Condition B	26	13.8	17.0	7.2	8.2	+0.48	+1.40	+0.94	-0.06	+2.15	+1.04	+0.99
Condition C	25	18.1	28.5	9.8	15.4	+0.25	+1.19	+0.72	-0.29	+1.68	+0.70	+0.71
Condition D	29	20.6	30.9	9.9	15.5	+0.41	+1.07	+0.74	-0.09	+1.44	+0.68	+0.71

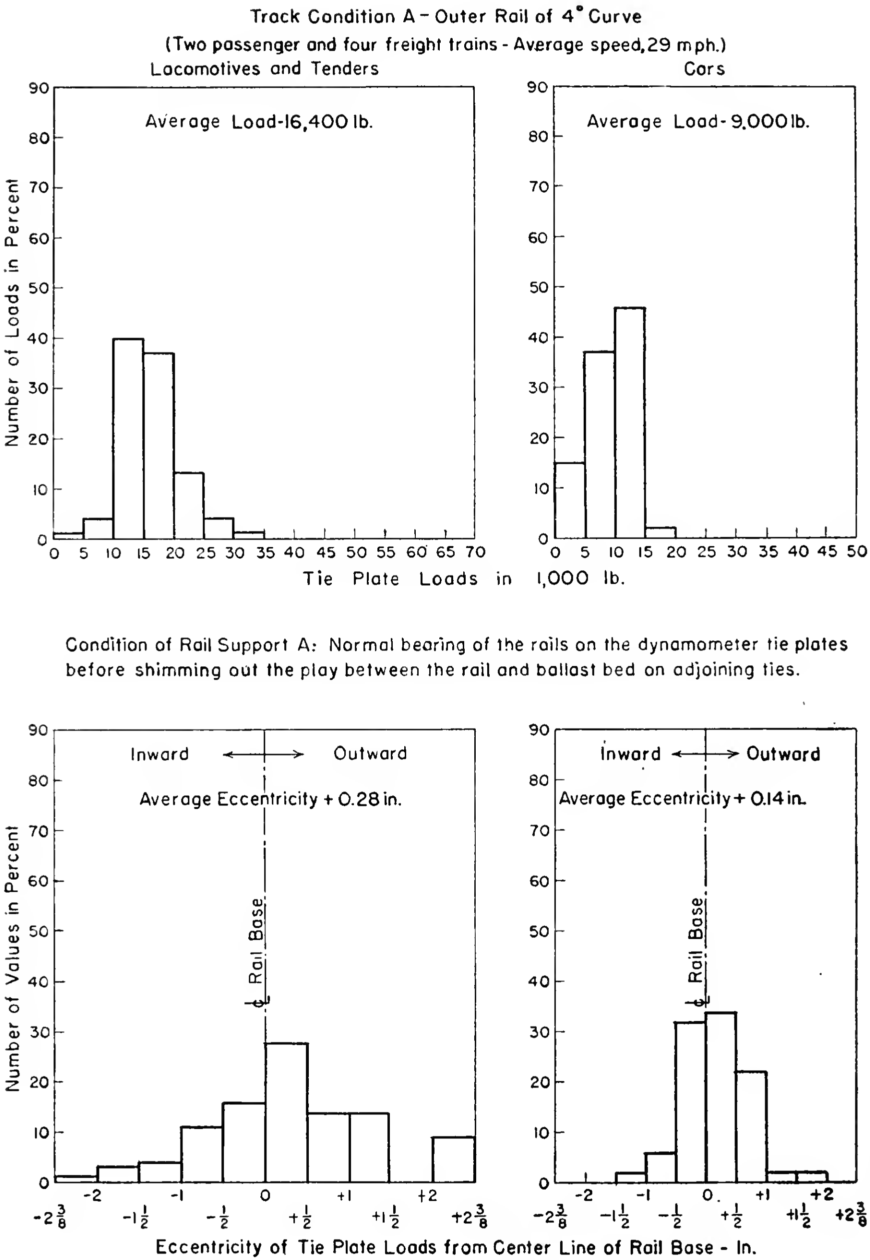


Fig. 18.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—Outer Rail of 4-deg. Curve.

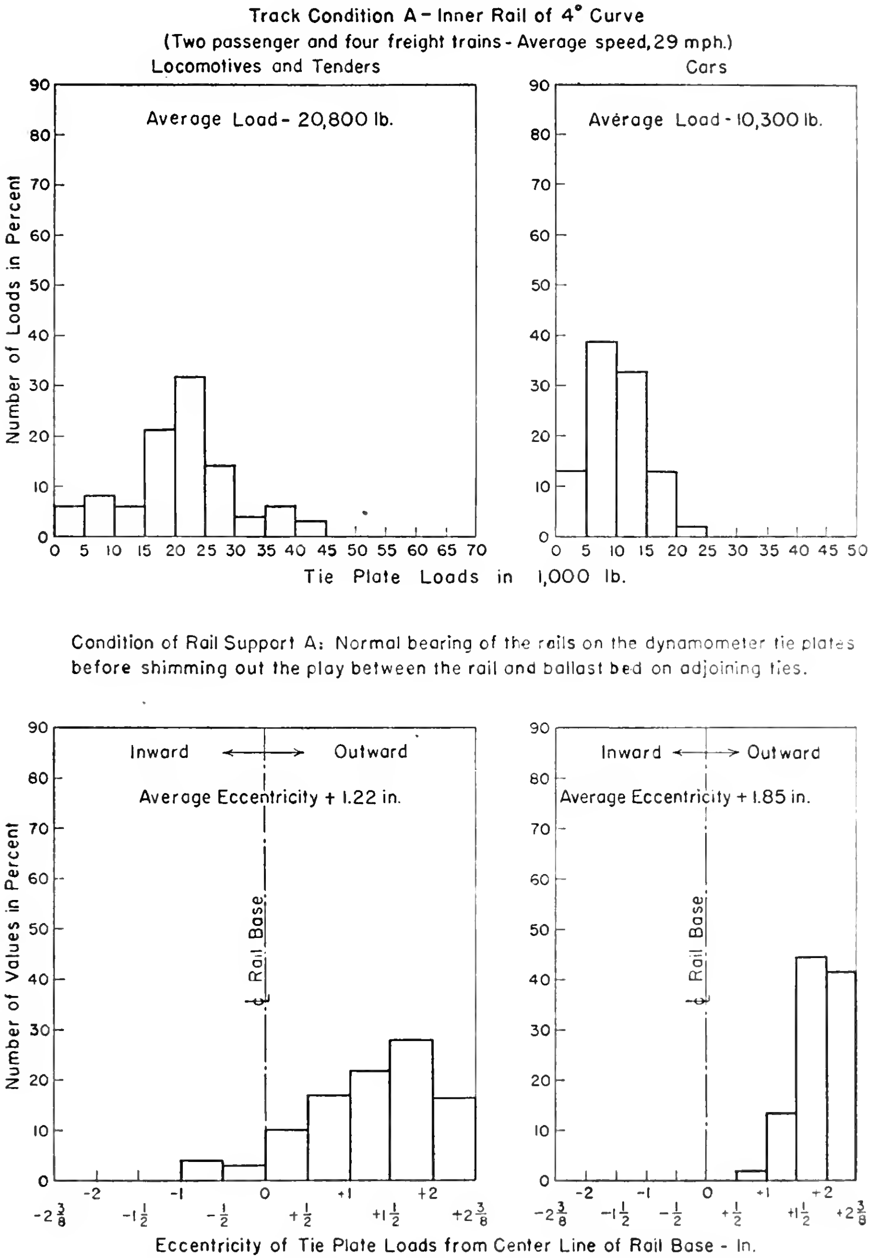
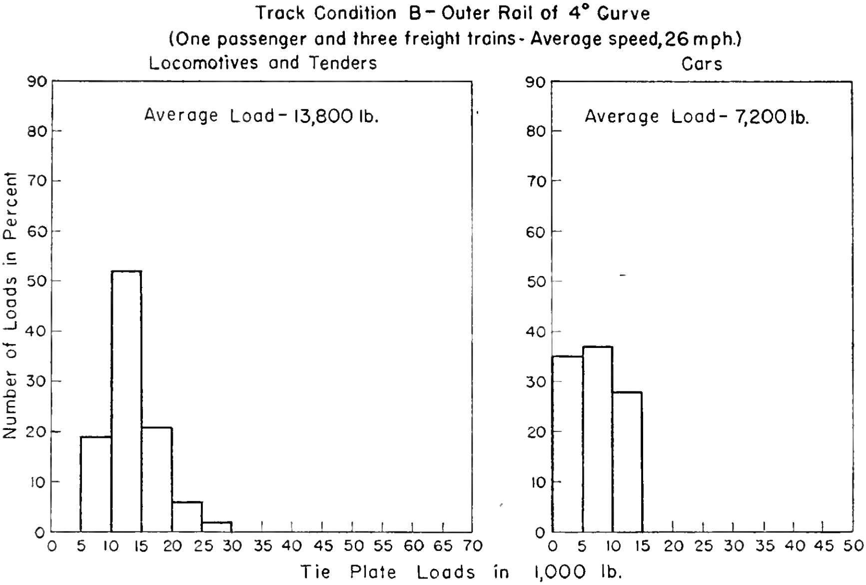


Fig. 19.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—Inner Rail of 4-deg. Curve.



Condition of Rail Support B: Normal bearing of the rails on the dynamometer tie plates after shimming out the play between the rail and ballast bed on five ties each side of the test tie.

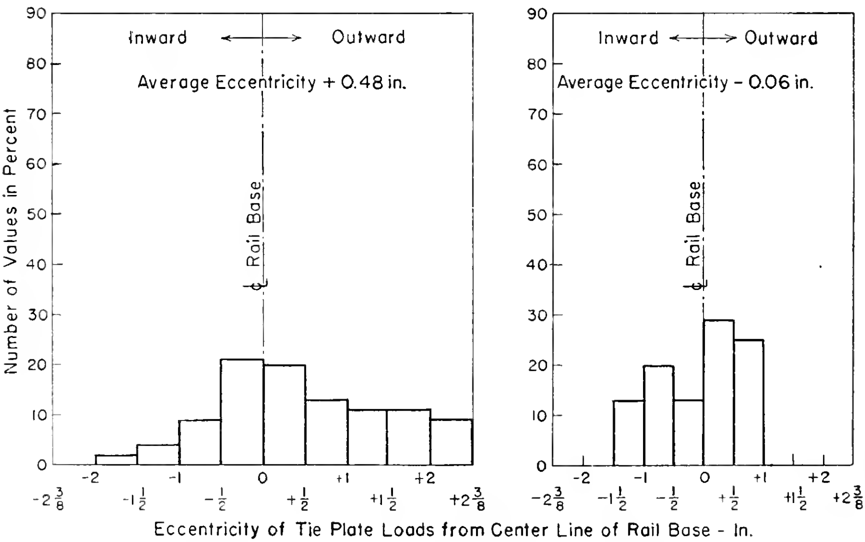


Fig. 20.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—Outer Rail of 4-deg. Curve.

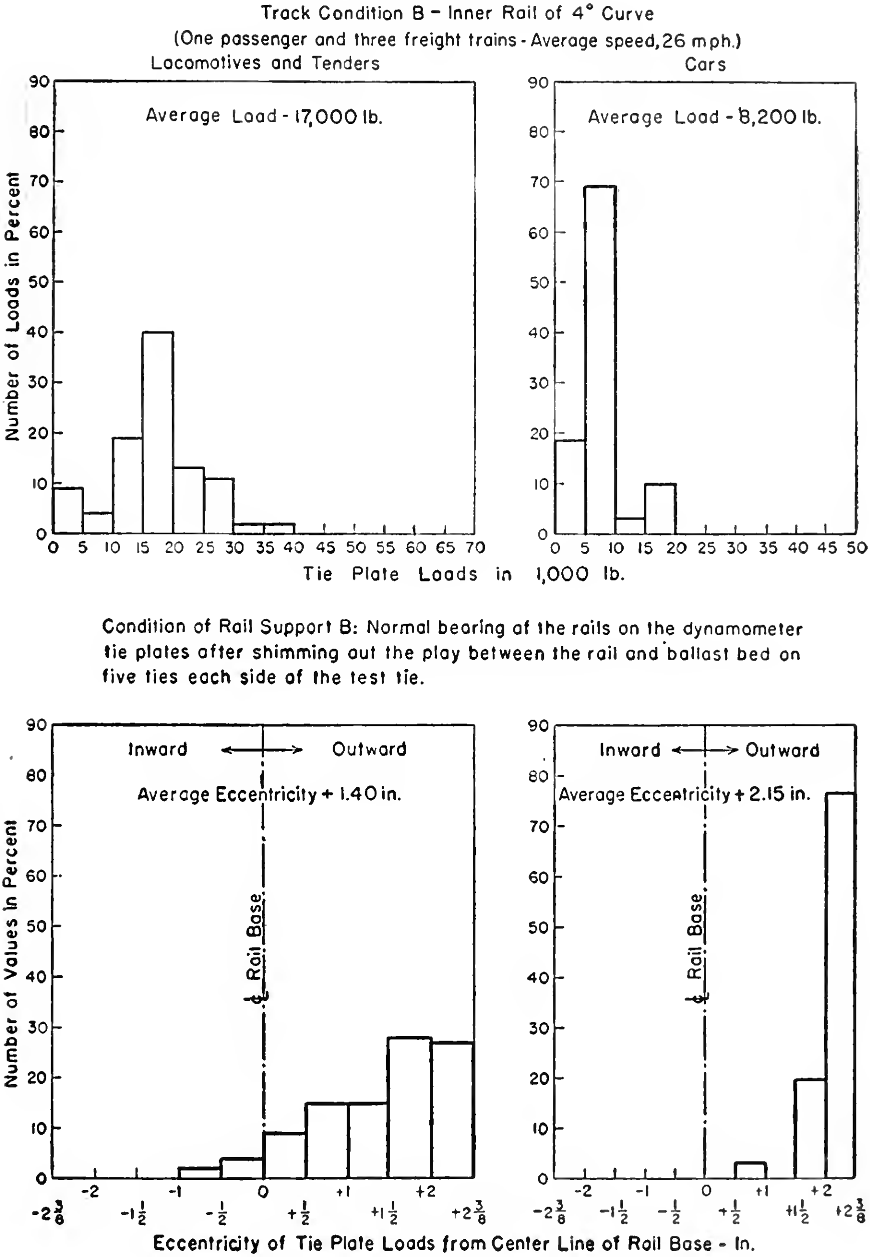


Fig. 21.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—Inner Rail of 4-deg. Curve.

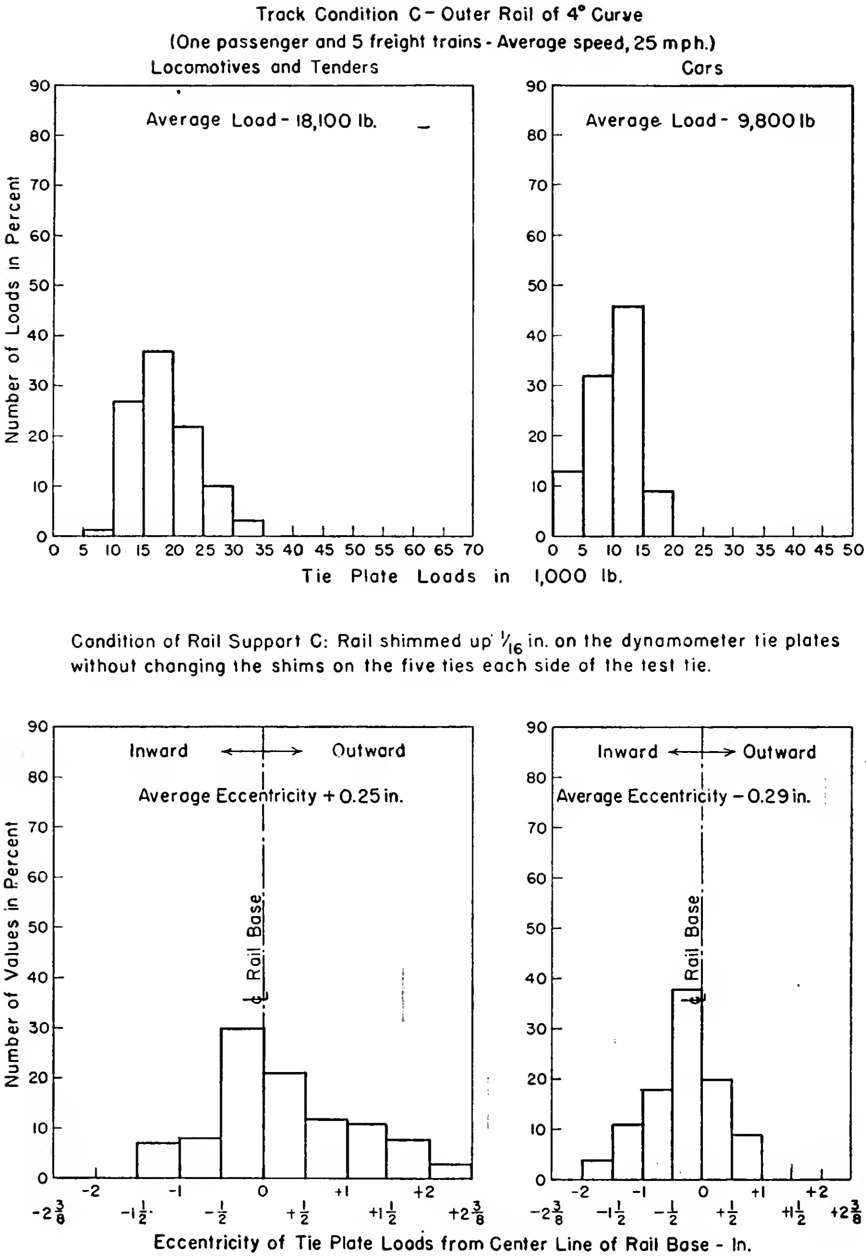


Fig. 22.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—Outer Rail of 4-deg. Curve.

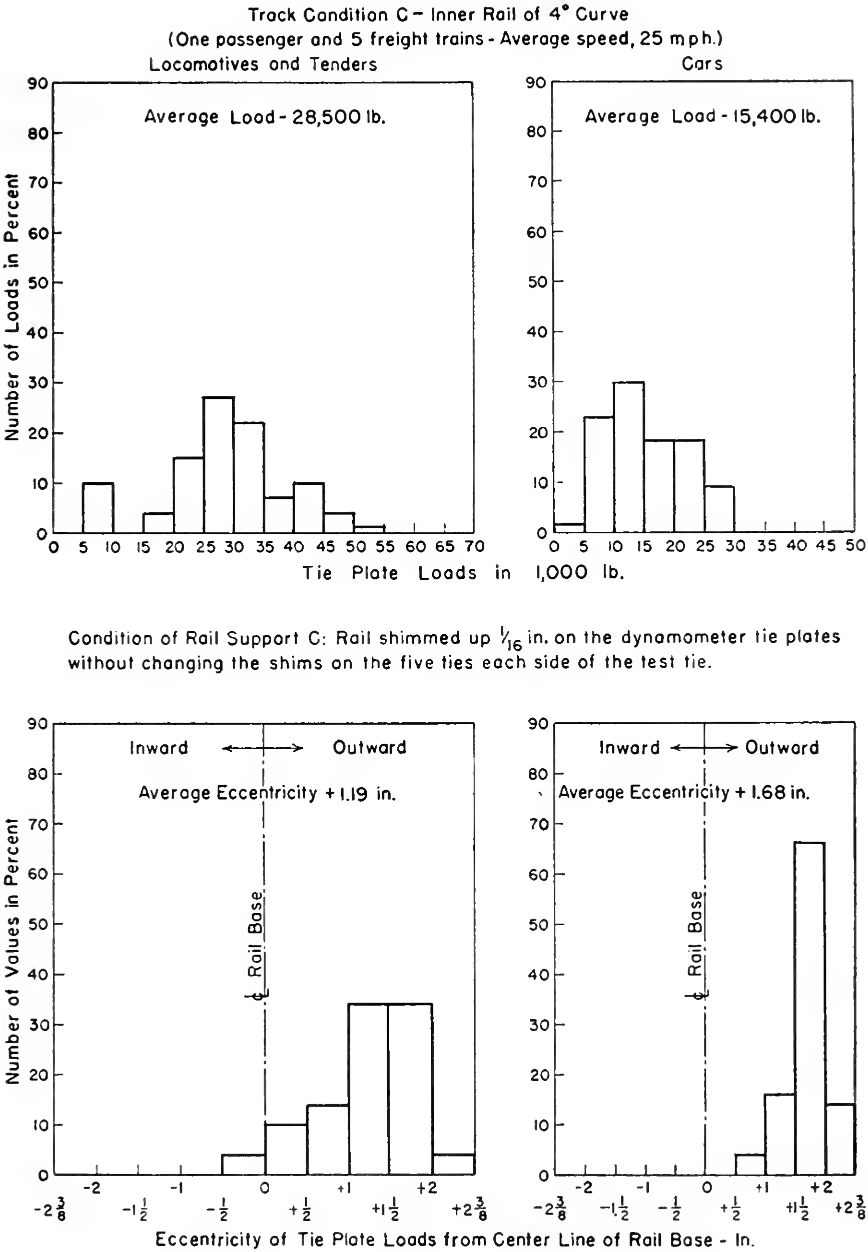


Fig. 23.—Magnitude, Frequency and Eccentricity of Tie Plate Load—Inner Rail of 4-deg. Curve.

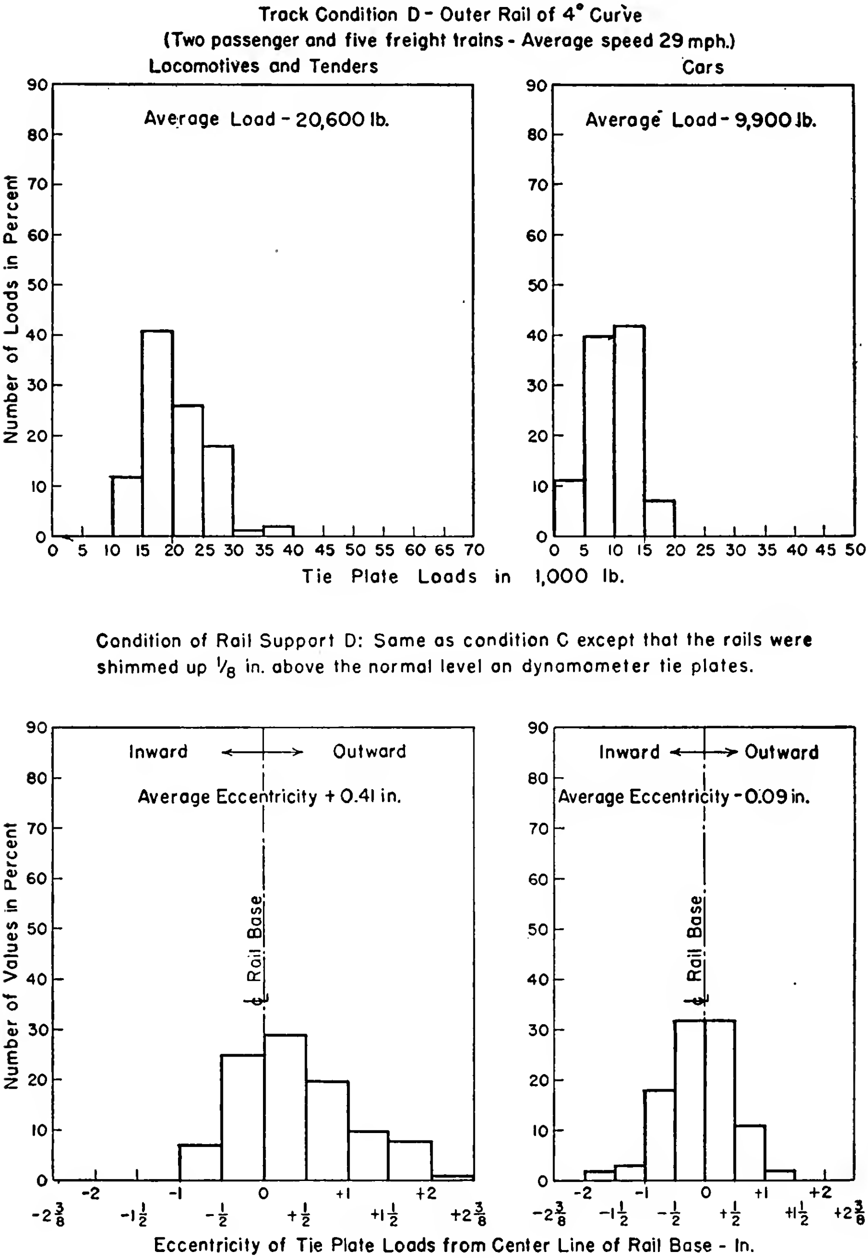
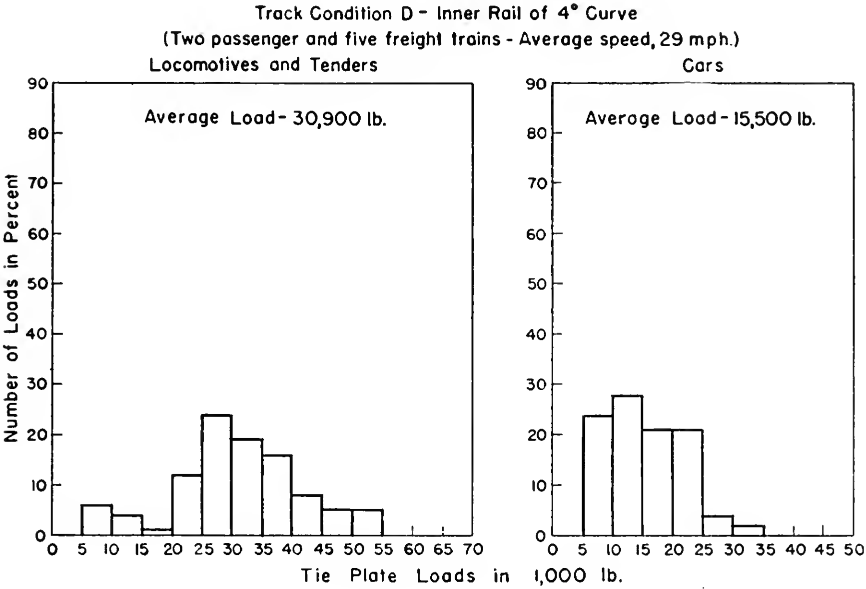


Fig. 24.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—Outer Rail of 4-deg. Curve.



Condition of Rail Support D: Same as condition C except that the rails were shimmed up 1/8 in. above the normal level on dynamometer tie plates.

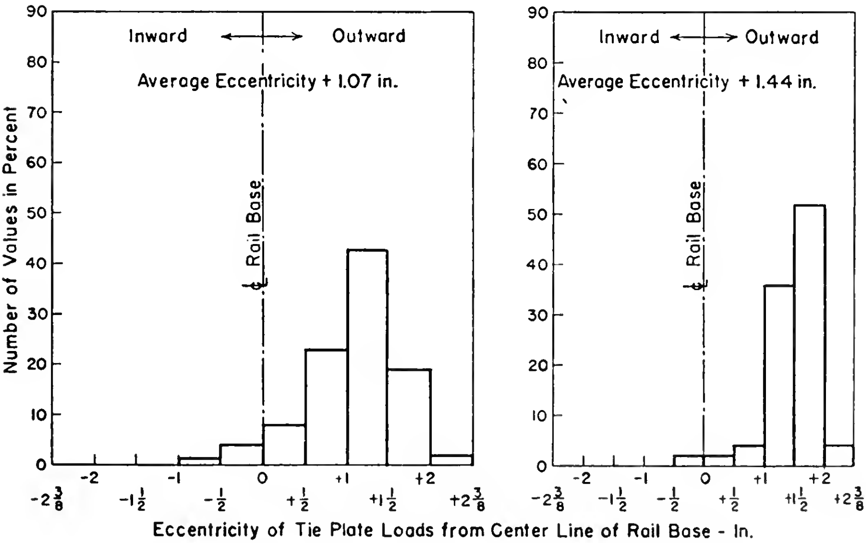


Fig. 25.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—Inner Rail of 4-deg. Curve.

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and highest for condition D with the rail shimmed ⅛ in. above normal on the dynamometer tie plates. The reduction in mean loads in changing from condition A to B indicates that the test tie might have been tamped a little stiff for condition A. There was a marked increase in mean tie plate loads of the inner rail of the curve in changing from condition B to C. This change in rail support was accomplished by shimming the rail 1/16 in. above normal on the measuring plates. The mean loads increased very moderately in changing from condition C to D by shimming the rail up another 1/16 in. This indicates the tie settled more when the rail was raised ⅛ in. than with the raise of 1/16 in. It seems reasonable to assume that the mean tie plate load of 30,900 lb. under the inner rail, as obtained in condition D for locomotives and tenders was about the load carrying capacity of the tie in the fine slag ballast for the test conditions.

The eccentricity of tie plate loads had a wide range of values, particularly under the locomotives and tenders. This reflects the effect of outward and inward lateral forces on the rail as well as the position of the centroid of the wheel load on the rail head. It is believed the most suitable data for determining the average eccentricity of tie plate loads were obtained in condition B where the track play was shimmed out on the adjoining ties to more nearly equalize the load on the dynamometer tie plates with a few tie plates located on each side.

By setting up conditions conducive to obtaining equal loads on consecutive tie plates the position of the resultant load should be close to what would be obtained from a number of consecutive ties in standard track. Therefore, it is believed that the eccentricities as found for condition B, shown in Table 3, are more representative of track of standard construction than any of the other conditions of rail support. For the locomotives and tenders in condition B, the tie plate load resultants were at a mean position of + 0.48 in. and + 1.40 in. outside of the center line of the outer and inner rails, respectively. The corresponding values for cars were — 0.06 in. and + 2.15 in. The average for the two rails ranged from + 0.94 in. to + 1.04 in. in condition B. In other words, assuming that the canting of the rail caused by unequal penetration in the ties is chiefly influenced by the heavier loads under the locomotives and tenders, tie plates with 0.48 in. and 1.40 in. eccentricity for the outer and inner rails, respectively, would be expected to equalize the penetration at the two ends of the plates and practically eliminate gage widening from that cause. Under the test conditions most of the above mentioned gage widening could be eliminated by using a special tie plate with 1.40 in. eccentricity for the inner rail of the 4-deg. curve.

Tangent Track

Graphs of the magnitude and frequency of tie plate loads and eccentricities of the resultants are given in Figs. 26 to 31, incl., for both rails on tangent track and for conditions of rail support B, C and D. Mean values from these figures are summarized in the upper part of Table 4. In this test the average dynamometer tie plate load was greater under the west rail than under the east rail. Two weeks prior to starting these measurements the track was given a 1-in. lift for 3½ panels of track each way from the dynamometer tie plate location and one week later the test plates were installed. The test tie was tamped up several times before and during the test because after the moderately coarse slag ballast was disturbed it was difficult to keep the tie from swinging. This condition and possibly a moderately unstable roadbed probably affected the test results adversely. The mean tie plate loads for condition B were of reasonable magnitudes but the mean position of the resultant of these loads was at a greater distance

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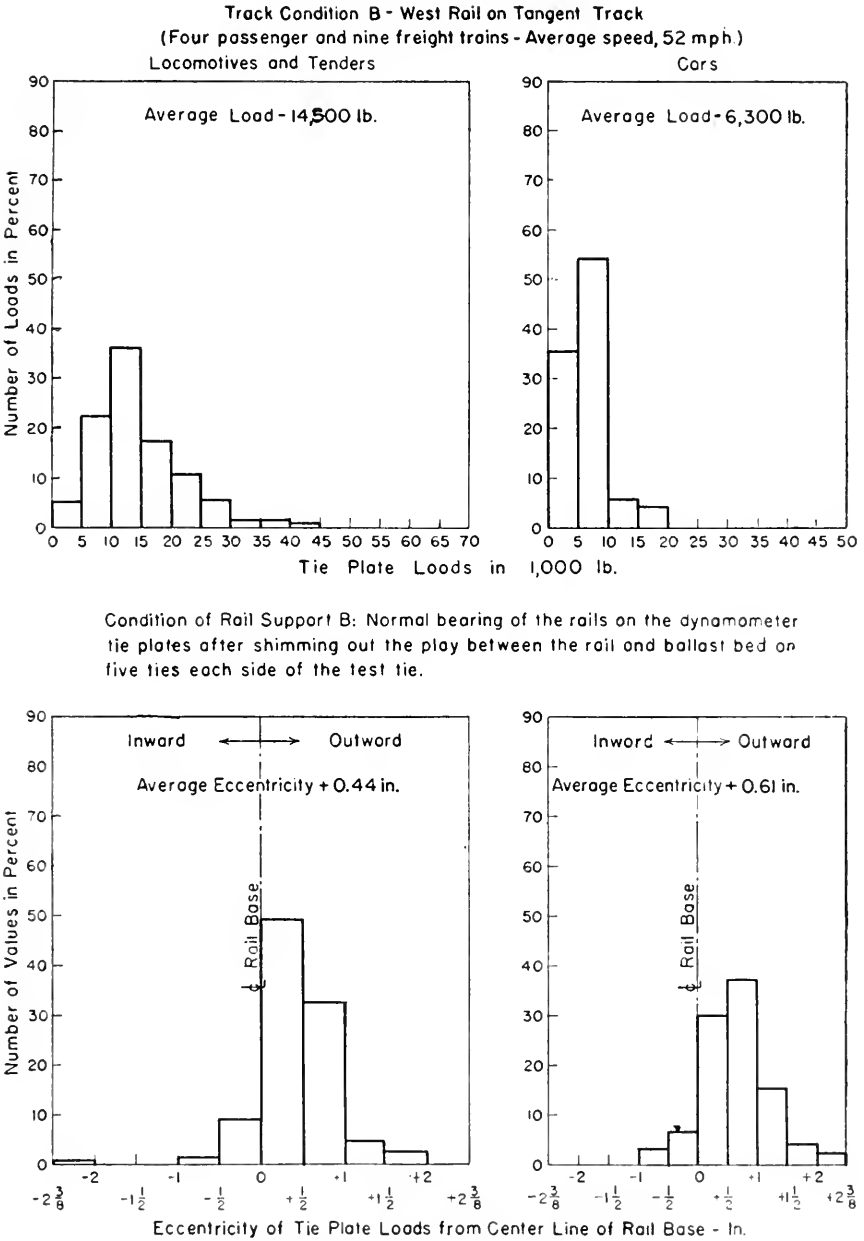


Fig. 26.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—West Rail, Tangent Track.

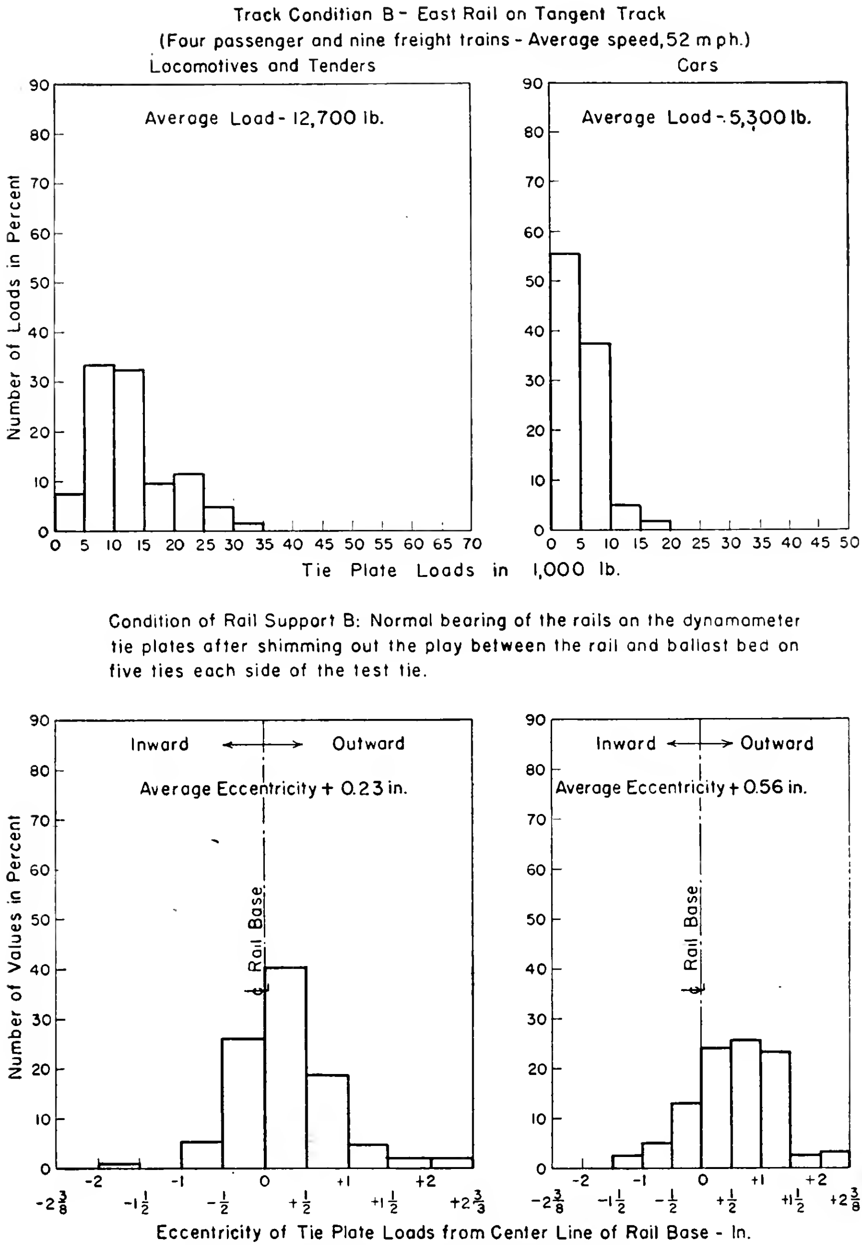


Fig. 27.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—
East Rail, Tangent Track.

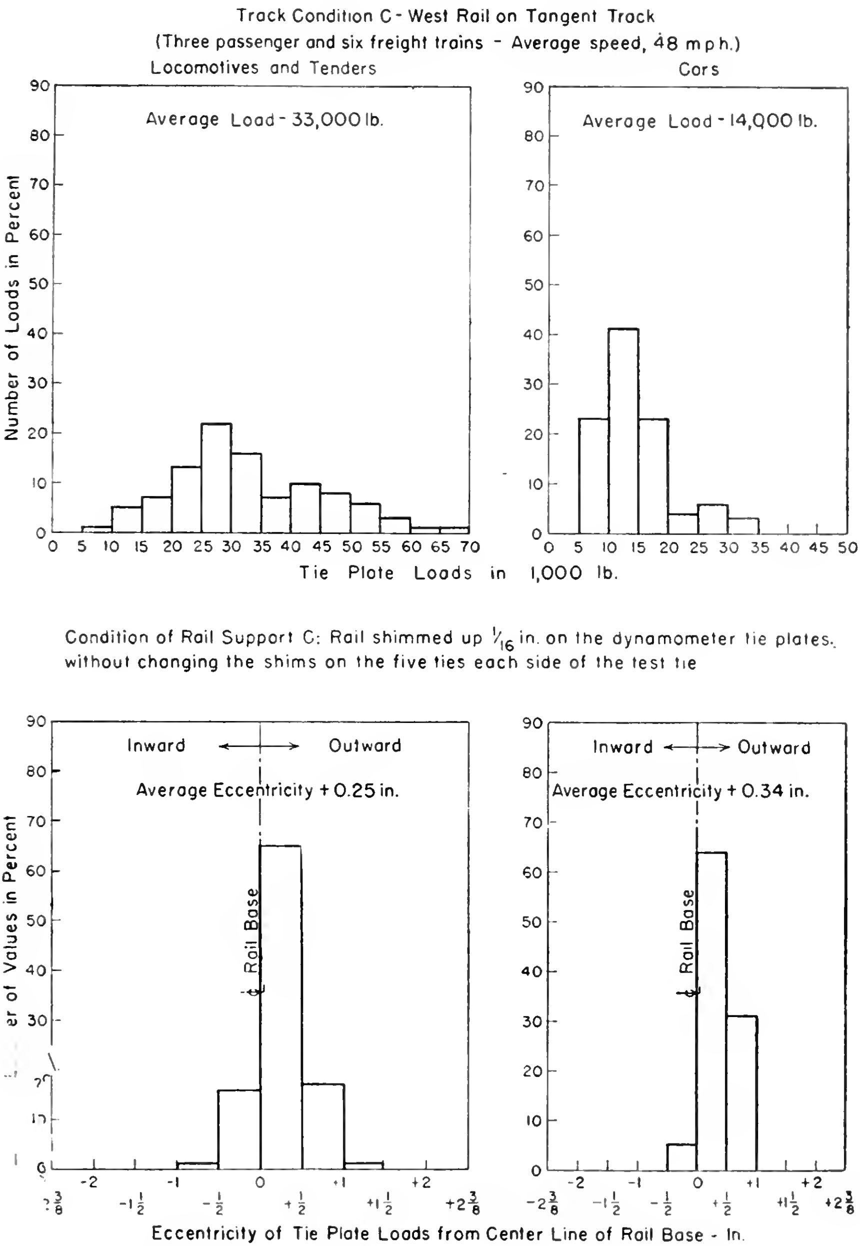


Fig. 28.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—West Rail, Tangent Track.

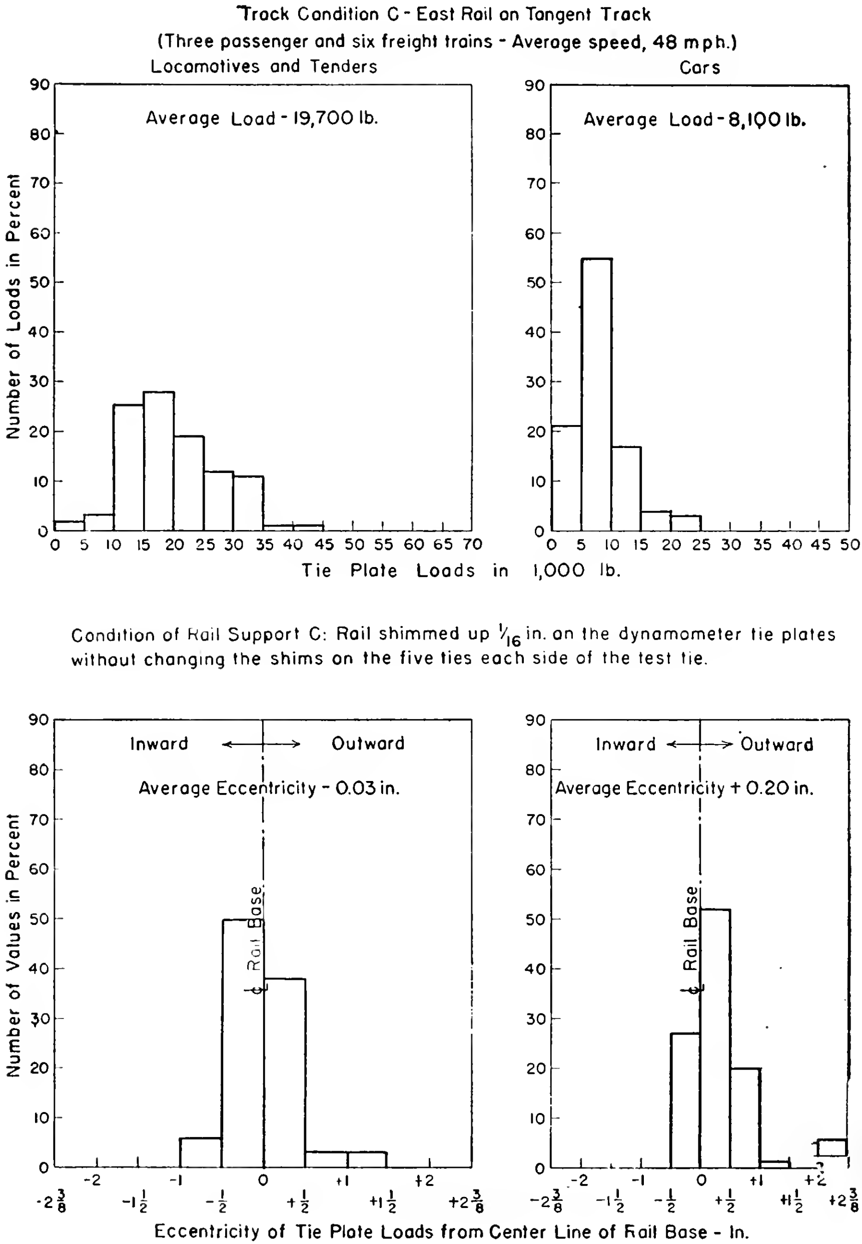


Fig. 29.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—East Rail, Tangent Track.

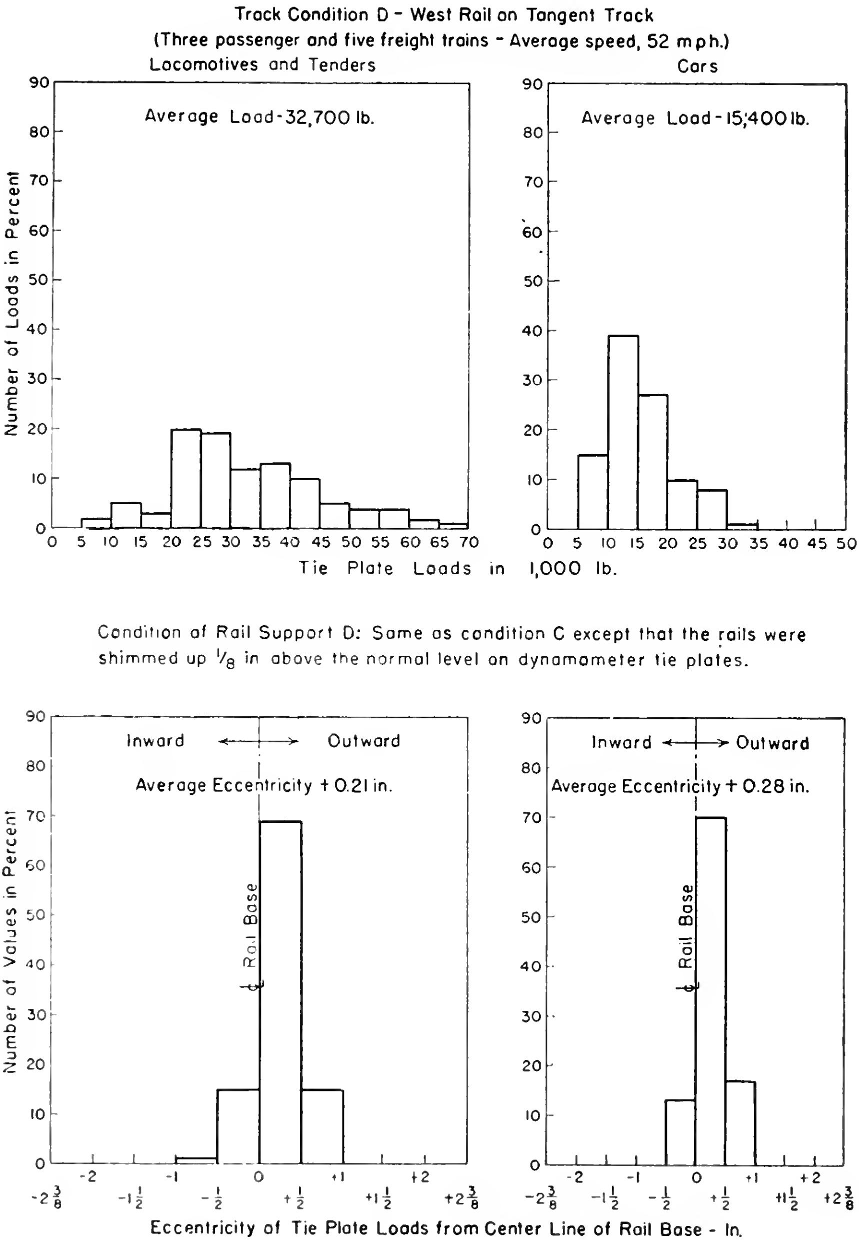


Fig. 30.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—West Rail, Tangent Track.

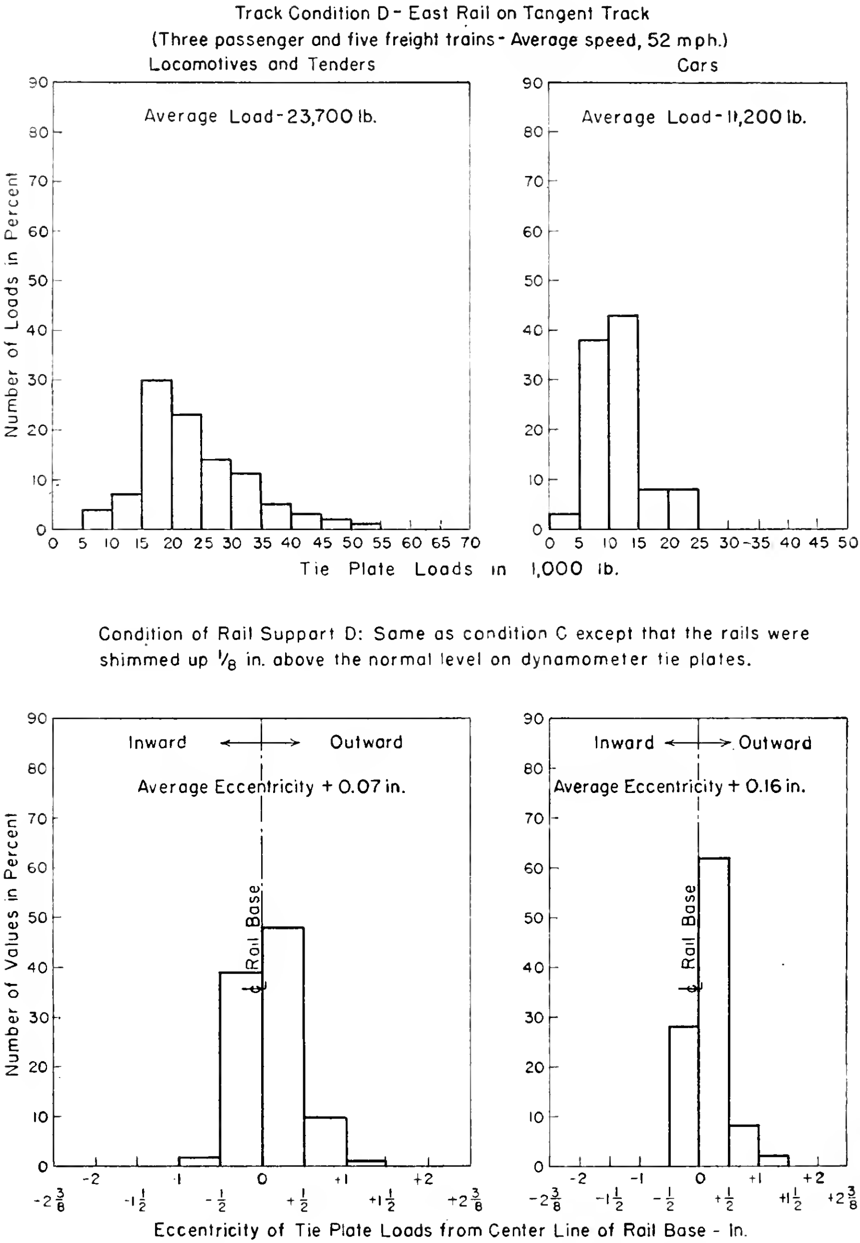


Fig. 31.—Magnitude, Frequency and Eccentricity of Tie Plate Loads—East Rail, Tangent Track.

TABLE 4.—SUMMARY OF AVERAGE DYNAMOMETER TIE PLATE LOADS AND ECCENTRICITY OF CENTROID OF PRESSURE FROM CENTER LINE OF RAIL BASE FOR BOTH RAILS OF TANGENT TRACK AND THREE CONDITIONS OF RAIL SUPPORT IN THE SOUTHBOUND MAIN LINE, ILLINOIS CENTRAL SYSTEM AT HENNING, TENN.
(Tie plate loads are shown in 1000 lb. and eccentricities in in. + = outward from center line rail base, - = inward)

		Average Tie Plate Loads						Average Eccentricity of Tie Plate Loads						
		Locos. and tenders			Cars			Locos. and tenders			Cars			All
Rail Support	Avg. Speed mph.	West Rail	East Rail	Avg.	West Rail	East Rail	Avg.	West Rail	East Rail	Avg.	West Rail	East Rail	Avg.	Both Rails
Condition B	52	14.5	12.7	13.6	6.3	5.3	5.8	+0.44	+0.23	+0.34	+0.61	+0.56	+0.58	+0.46
Condition C	48	33.0	19.7	26.4	14.0	8.1	11.0	+0.25	-0.03	+0.11	+0.34	+0.20	+0.27	+0.19
Condition D	52	32.7	23.7	28.2	15.4	11.2	13.3	+0.21	+0.07	+0.14	+0.28	+0.16	+0.22	+0.18

SELECTED RUNS TO SHOW THE VARIABILITY OF THE ECCENTRICITY OF THE PLATE LOADS FOR CONDITION B, TANGENT TRACK

				Average Eccentricity						
				Locos and tenders			Cars			All
Run No.	Eng. No.	Type	Speed mph.	West Rail	East Rail	Avg.	West Rail	East Rail	Avg.	Avg.
219	1413	2-8-2	54	-0.08	+0.52	+0.22	-0.14	+0.70	+0.28	+0.25
222	8035	2-8-4	54	+0.57	+0.31	+0.44	+0.82	+0.49	+0.66	+0.55
226	2300	4-8-2	67	+0.68	+0.40	+0.54	+1.54	+0.82	+1.18	+0.86

(text continued from page 30)
outward from the center line of the rail than had been determined from mechanical wear measurements which will be presented in Part 5. The eccentricities determined in conditions C and D compare well with other tests, but with the heavy loads brought about by shimming up the rail on the test plates 1/16 in. or ⅛ in., it is believed that they are not representative of the average that would be found in normal track of standard construction. The average tie plate loads were increased considerably when changing from condition B to C but were only moderately further increased in condition D. In the lower portion of Table 4 the results for three representative runs in condition B are tabulated to show the wide scatter in the mean values of the eccentricity of the load resultants for both rails.

It is believed the test on tangent should be repeated at some other location. The results obtained in these measurements are not what would generally be expected in tangent track and should be verified by additional tests.

Applied Vertical Wheel Loads and Position of the Centroid of Pressure

In the static rail stress test at the Proviso yard of the Chicago & North Western Railway (Proceedings, Vol. 46, 1945, page 681) it was shown that the applied vertical wheel load was directly proportional to the direct stress in the upper rail web at gages 3 and 13 (Fig. 16), and the amount of eccentricity of the wheel bearing centroid was also directly proportional to the bending stress in the plane of the two gages.

Simultaneously, with measurement of the rail stresses at gages 3 and 13 over the dynamometer tie plates, the loads on the test plates were also recorded and these data will permit the study of the plate loads with respect to the applied wheel loads as calculated from the direct stress at the two gage positions. A study of the summation of these direct stresses for each type of locomotive was made for the runs in track condition B for both curve and tangent and a factor of 2.75 was obtained for converting the direct web stress to applied vertical wheel load. Four runs on the 4-deg. curve (which had

TABLE 5.— CONDITION B. APPLIED VERTICAL WHEEL LOADS AND POSITION OF CENTROID OF WHEEL BEARINGS ON 112-LB. RE RAIL HEAD AS CALCULATED FROM MEASURED VERTICAL WEB STRESSES IN GAGES 3 AND 13 AND RESULTING TIE PLATE LOADS - I.C.R.R.
(+ Eccentricity = Inward from center line railhead, - = Outward)

Locomotive Wheel	East or Outer Rail			West or Inner Rail			Axle Load	
	Wheel Load		Tie Plate Load 1000 lb.	Wheel Load		Tie Plate Load 1000 lb.	Dynamic in 1000 lb.	Nominal Static in 1000 lb.
	in 1000 lb.	Ecc. in.		in 1000 lb.	Ecc. in.			
4° Curve								
Run 137, Loco. 8000 (2-8-4) 19 mph. Loco. weight 393,400 lb.								
Eng. Truck	19	+1.0	9.5	7	-1.3	4.9	26	-
1st Driver	37	+0.4	18.7	29	-1.1	20.3	66	68
2nd Driver	13	-1.1	15.2	37	-1.2	23.7	50	68
Main Driver	20	-1.0	14.5	62	+0.4	35.6	82	68
4th Driver	20	-1.1	14.8	37	+1.0	26.6	57	68
1st Trailer	10	-1.1	8.5	22	+1.1	14.7	32	-
2nd Trailer	19	-1.0	13.7	25	+1.3	17.7	44	-
Ratio: Dynamic locomotive weight ÷ static weight ——— 0.91								
Run 139, Loco. 8039 (2-8-4) 11 mph. Loco. weight 393,400 lb.								
Eng. Truck	20	+0.8	10.0	10	-0.5	3.0	30	-
1st Driver	29	+0.4	18.2	32	-0.7	15.7	61	68
2nd Driver	22	-0.5	12.2	43	-0.8	22.3	65	68
Main Driver	45	-0.8	24.2	51	+0.4	28.7	96	68
4th Driver	22	-0.5	12.9	42	+1.0	25.9	64	68
1st Trailer	17	-0.8	9.0	31	-0.7	17.0	48	-
2nd Trailer	24	-0.5	12.9	30	+1.3	18.4	54	-
Ratio: Dynamic locomotive weight ÷ static weight ——— 1.06								
Run 138, Loco. 2458 (4-8-2) 46 mph. Loco. weight 376,350 lb.								
1st E. T.	18	+1.1	9.8	8	-0.3	2.7	26	-
2nd E. T.	23	+0.6	13.9	11	-0.5	6.6	34	-
1st Driver	35	+0.3	20.7	35	-0.2	19.7	70	64
Main Driver	14	-1.3	17.3	50	-0.3	25.2	64	64
3rd Driver	26	-0.7	16.4	32	+1.2	22.8	58	64
4th Driver	37	-0.5	22.8	20	+1.3	15.3	57	64
Trailer	49	-0.2	29.2	9	-1.2	6.3	58	-
Ratio: Dynamic locomotive weight ÷ static weight ——— 0.98								
Run 136, Loco. 1228 (2-8-2) 29 mph. Loco. weight 308,000 lb.								
Eng. Truck	18	+0.4	7.0	7	+0.1	2.5	25	-
1st Driver	24	+0.7	12.4	27	-0.1	14.3	51	59
2nd Driver	24	+0.6	13.4	36	-0.1	19.5	60	59
Main Driver	25	-0.4	13.6	41	+0.7	27.1	66	59
4th Driver	40	0.0	19.2	30	+1.0	17.4	70	59
Trailer	24	+0.3	10.8	15	-1.3	12.4	39	-
Ratio: Dynamic locomotive weight ÷ static weight ——— 1.01								
Tangent								
Run 222, Loco. 8035 (2-8-4) 54 mph. Loco. weight 393,400 lb.								
Eng. Truck	12	-0.2	3.1	8	-0.3	4.5	20	-
1st Driver	47	+0.1	21.7	34	-0.3	19.8	81	68
2nd Driver	29	-0.1	12.3	19	-0.1	9.5	48	68
Main Driver	67	0.0	34.3	32	0.0	17.3	99	68
4th Driver	37	-0.1	20.0	34	-0.4	22.0	71	68
1st Trailer	16	-0.7	6.4	26	+0.1	15.1	42	-
2nd Trailer	16	+0.5	5.9	24	-0.6	14.1	40	-
Ratio: Dynamic locomotive weight ÷ static weight ——— 1.02								

4⅛ in. elevation) for condition B and one of the runs for the same condition of rail support on tangent track are summarized in Table 5. In run 137, the first listed in the table, the greatest dynamometer tie plate load of 35,600 lb. occurred in the inner rail of the curve under the main driver of the 2–8–4 type locomotive when the applied vertical wheel load was calculated to be 62,000 lb. This dynamic wheel load was almost as large as the static axle load of the driver. A large tie plate load was also recorded on tangent track in run 222 under the left main driver of the same type of locomotive. The tie plate load was 34,300 lb. under a calculated wheel load of 67,000 lb. These heavy wheel loads are greatly influenced by the lateral forces exerted on the rails as well as the speed of operation with respect to the elevation on the curve. The resulting lateral rail reactive forces produce a couple acting in a vertical plane transversely to the rail and transfer load from one wheel to another on the same axle. This subject is more fully explained in the report on Stress Measurements in 131-lb. RE Rail on Tangent and a 6-deg. Curve of the Norfolk & Western Railway, Proceedings, Vol. 48, 1947, page 788. The heavy dynamic wheel loads serve to explain how a tie plate load can be greater than the nominal wheel load of the locomotive.

The data for the eccentricity of the wheel bearing centroid in Table 5 refer to the center line of the rail head and indicate the position of the resultant of the total wheel pressure on the rail. Positive values are toward the gage side of the rail head and negative ones are in the opposite direction. The wheel bearing area on the rail may not coincide with the point indicated since it is possible to have two areas of contact; one on the flange and another on the wheel tread, as in the case of a tread worn hollow wheel. Some of the values were up to plus or minus 1.3 in., which indicates the entire wheel load was concentrated on the gage or field corner of the rail head. It will be observed from Fig. 17, the load on a tie plate is influenced by more than one wheel at a time and other tests have indicated that the lateral forces on the rail are the result of several wheels closely spaced. These characteristics precluded the computation of the lateral force on the rail by using the angle of the resultant load extending from the wheel bearing centroid to the center of pressure on the tie plate.

The range of the stresses measured at gage positions 3 and 13 in 112-lb. RE rail for locomotives in condition B are tabulated below. These values are given in units of 1000 psi., and the negative signs indicate compressive stresses.

	Gage Side *Gage 3*	*Field Side* *Gage 13*
Outer rail —4-deg. curve	—24 to + 10	—43 to + 8
Inner rail —4-deg. curve	—47 to + 21	—48 to + 17
Tangent	—53 to + 8	—37 to + 17

Vertical Stresses in Lower Rail Fillets Measured over the Dynamometer Tie Plates

These stresses were measured at gage positions 7a and 17a on the rail (Fig. 16) directly above the dynamometer tie plates. A study was made of the relation between the lower rail fillet stresses and the load applied to the dynamometer tie plate cantilever beam directly below each rail gage. For condition B on the curve, the relation was found to be linear, and the load on each beam of the outer rail test plate and the beam on the gage side of the inner rail plate was approximately 0.3 of the lower fillet stress measured above corresponding beams. This factor for the field beam of the inner rail plate was approximately 0.5. Because of the variable conditions of conventional tie plate bearing on the tie and positions of the rail reactions on those tie plates, it is not practical to determine loads on standard tie plates from the stresses measured in the lower rail fillets.

Further analyses of the data indicated that the lower rail fillet stresses did not afford a reliable basis for determining the eccentricity of the tie plate load. Lateral loads on the rail could not be measured in the cantilever beams of the dynamometer tie plates because they were too short and irregular in cross section. This precluded the possibility of determining the relation between the lateral load that is carried by a single tie and the lower rail fillet stresses. A summary of the range in magnitude of the lower rail fillet stresses measured under locomotives for condition B is tabulated below. Stresses are given in units of 1000 psi., and negative signs denote compressive stresses.

	Gage Side Gage 7a	*Field Side Gage 17a*
Outer rail — 4-deg. curve	—45 to 0	—54 to —10
Inner rail — 4-deg. curve	—29 to —2	—67 to — 2
Tangent	—55 to —2	—60 to — 1

The maximum values are somewhat higher than similar rail stresses measured over standard tie plates as shown in the lower portion of Fig. 12.

The measurement of the magnitude and eccentricity of tie plate loads would be simplified if it were possible to determine these properties from rail stress measurements above conventional tie plates which could be left undisturbed in the track.

4. Service Test Data For Seven Designs of Tie Plates in 112-lb. and 131-lb. RE Rail

This is the first published progress report concerning an important phase of the investigation leading to the redesign of tie plates and concerns the test measurements taken periodically of tie plate penetration (or wear of ties), tie plate deflection (or bending upward of the shoulder extension), the gage of track, elevation of the curve and the curvature of each outer rail of the curves.

Three gages were designed to measure the first three items listed above. The tie plate penetration gage, shown in Fig. 32, is used to measure the mechanical wear of ties with reference to the top of a brass screw or pin opposite each end of the tie plate. The conical points on the gage frame rest in a punch mark at the field end of the tie plate and in a chisel mark at the gage end. The gage frame has five changeable connecting bars to span properly the five lengths of tie plates, ranging from 11 in. to 14¾ in. in length. A reference bar is used in the field to maintain a constant setting of the Ames dials.

The tie plate deflection or bending gage, shown in Fig. 33, is used to measure the upward bending of the tie plate shoulder extensions with respect to the shoulders. The conical points of the gage frame rest in punch and chisel marks as above described, but placed on the shoulders of the tie plates. Dial readings are taken on top of the plates approximately ⅝ in. from each end. The dials are maintained to a standard base reading by means of a reference bar. Although these readings do not reflect the total amount of bending, the gage will detect any appreciable bending without removing the tie plates from the track.

A track gage was designed and built for convenient measurement of the variation in gage of track. It was made of a ½-in. round invar steel rod with a screwed joint near its midlength and fitted with two end pieces of stainless steel. The shape of the end pieces next to the rail was made to conform with that of the double pronged end of AREA standard steel track gage and one of the fittings is movable along the rod for reading the gage of track from a scale attached to the fitting. In these tests the gage of track was measured at six points in each panel of track.

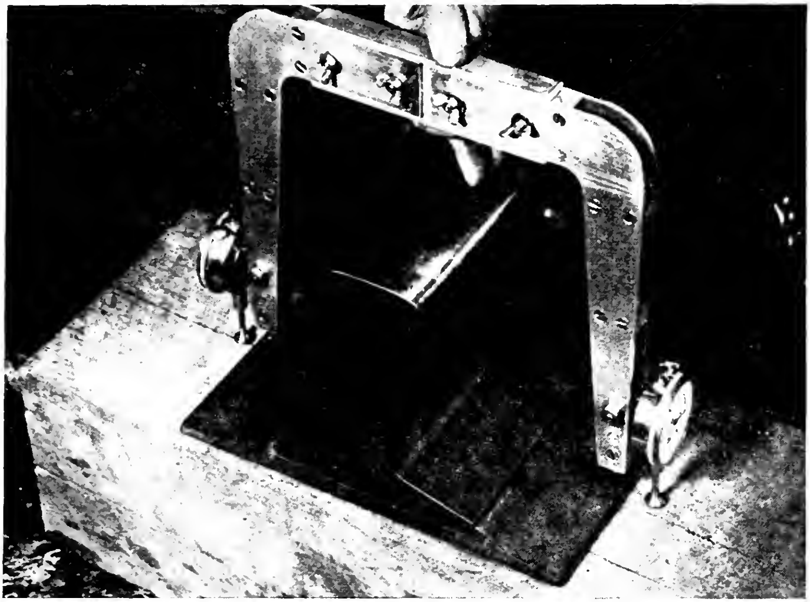


Fig. 32.—Tie Plate Penetration Gage.

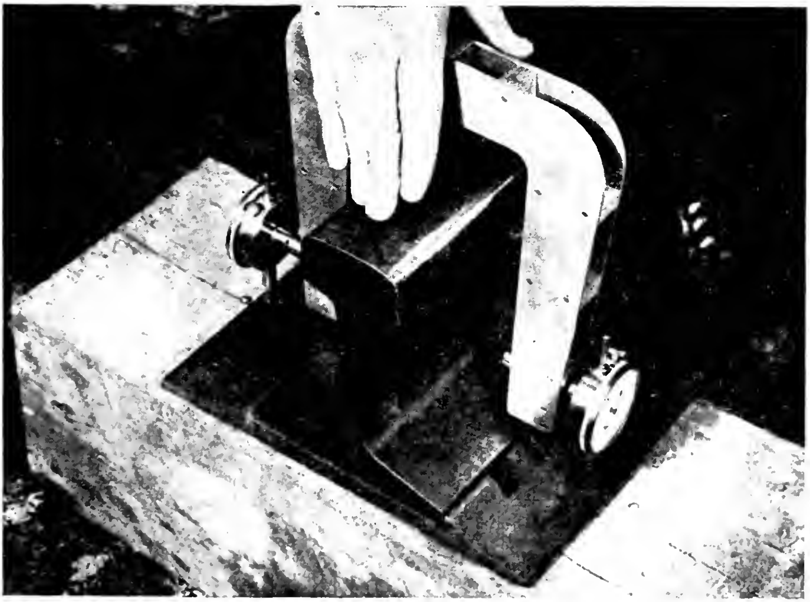


Fig. 33.—Tie Plate Deflection Gage.

Tie Plate Penetration Into the Ties

The arrangement of the test tie plates for 112-lb. rail on the Illinois Central System has been shown in Fig. 1, and Fig. 34 shows the arrangement of the test tie plates for 131-lb. rail on the C. N. O. & T. P. Ry. (See Proceedings, Vol. 47, 1946, page 494 for a detailed description of the latter installation). Tables 6 and 7 show the amount of tie plate penetration or wear into the ties after a service period of 22 months on the 112-lb. rail installation and 31 months on the 131-lb. rail installation. The amount of penetration that has occurred during these relatively short service periods is too small to permit evaluations of tie plate design. However, the data do have sufficient interest to justify presentation at this time.

The plates of larger area included in both tests do not as yet show any well defined reduction in the amount of tie plate penetration compared to the plates of lesser area. This may develop after a more extended service period. The amount of tie plate penetration into creosoted oak ties is about 65 percent as great as that for creosoted pine ties for corresponding service conditions in 112-lb. rail.

For the 112-lb. rail test (Table 6), the amount of penetration on the tangent seems relatively larger than would be expected when compared with that on the 4-deg. curve. On the tangent, the tie plates showed evidence of considerable lateral motion under traffic. Also, the penetration at the gage end of the plates exceeded that at the field end

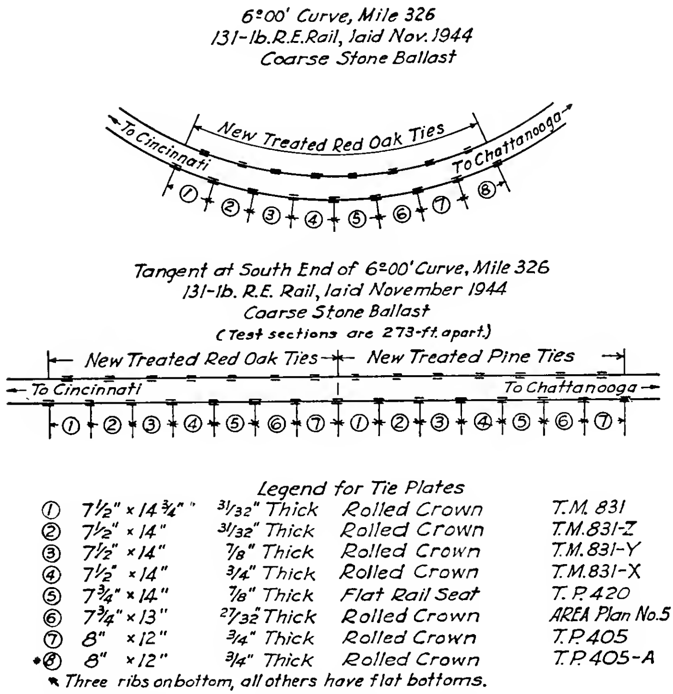


Fig. 34.—Tie Plate Installations on Southern Railway System (C.N.O. & T.P. Ry.) Near Chattanooga, Tenn.

TABLE 6.—SERVICE TEST OF MECHANICAL WEAR OF TIES WITH SEVEN DESIGNS OF TIE PLATES FOR 112-LB. RE RAIL IN THE SOUTHBOUND MAIN LINE OF THE ILLINOIS CENTRAL SYSTEM NEAR CURVE AND HENNING, TENN.

Tie Plate Design No.	Tie Plate Dimensions	Rail Seat	Tie Plate Penetration from Oct.1944 to Aug.1946 in 0.001 in. - 39 million gross tons of traffic						
			Inner or West Rail		Outer or East Rail		Average Both Rails		
			Field End	Gage End	Gage End	Field End	Field End	Gage End	Mean
4° Curve - Creo. Oak Ties									
(1) 419	7 3/4"x13"x21/32"	Flat	38	28	15	36	37	22	30
(1) 419-Z	7 3/4"x11"x27/32"	Flat	74	23	39	49	62	31	46
(1) 419-Y	7 3/4"x11"x11/16"	Flat	66	21	24	57	62	22	42
(1) 419-X	7 3/4"x11"x9/16"	Flat	88	29	55	64	76	41	58
(1) 366	8"x11"x23/32"	Beveled	94	31	13	36	65	22	44
(1) 400	7 3/4"x11"x23/32"	Rolled Circular	119	11	29	30	74	20	47
(2) 3170	8½"x11"x3/4"	Pressed Circular	94	40	30	59	76	35	58
4° Curve - Creo. Pine Ties									
(1) 419	7 3/4"x13"x27/32"	Flat	144	40	32	39	92	36	64
(1) 419-Z	7 3/4"x11"x27/32"	Flat	165	37	63	61	113	50	82
(1) 419-Y	7 3/4"x11"x11/16"	Flat	148	45	46	46	97	46	72
(1) 419-X	7 3/4"x11"x9/16"	Flat	189	44	84	57	123	64	94
(1) 366	8"x11"x23/32"	Beveled	167	44	23	33	100	34	67
(1) 400	7 3/4"x11"x23/32"	Rolled Circular	183	55	64	50	116	60	88
(2) 3170	8½"x11"x3/4"	Pressed Circular	146	54	62	45	96	58	77
Tangent - Creo. Oak Ties									
(1) 419	7 3/4"x13"x27/32"	Flat	32	98	60	35	34	79	56
(1) 419-Z	7 3/4"x11"x27/32"	Flat	35	83	77	51	43	80	62
(1) 419-Y	7 3/4"x11"x11/16"	Flat	41	64	58	26	34	61	48
(1) 419-X	7 3/4"x11"x9/16"	Flat	42	61	62	39	40	62	51
(1) 366	8"x11"x23/32"	Beveled	34	72	47	51	42	60	51
(1) 400	7 3/4"x11"x23/32"	Rolled Circular	67	89	84	52	60	86	73
(2) 3170	8½"x11"x3/4"	Pressed Circular	30	70	85	39	34	78	56
Tangent - Creo. Pine Ties									
(1) 419	7 3/4"x13"x27/32"	Flat	74	93	80	44	59	86	72
(1) 419-Z	7 3/4"x11"x27/32"	Flat	68	107	109	52	60	108	84
(1) 419-Y	7 3/4"x11"x11/16"	Flat	53	113	94	43	48	104	76
(1) 419-X	7 3/4"x11"x9/16"	Flat	69	99	86	32	50	92	71
(1) 366	8"x11"x23/32"	Beveled	69	101	107	75	72	104	88
(1) 400	7 3/4"x11"x23/32"	Rolled Circular	61	96	102	43	52	99	76
(2) 3170	8½"x11"x3/4"	Pressed Circular	54	109	92	46	50	100	75

(1) - 3/8" Eccentricity. (2) - ½".

by a greater amount than would be expected. It is possible that the disturbance of the ballast with the insertion of the new ties in conjunction with a somewhat unstable roadbed support resulted in a condition of tie support which caused the abnormal tie plate penetration.

It will be noted for the 112-lb. rail on the 4-deg. curve, that the field end of the plates penetrated into the ties more than the gage end, particularly for the inner rail and to a lesser extent for the outer rail. This is due to the fact that the predominating operating speed around the curve is considerably less than the speed of superelevation, which results in a relatively large outward lateral force being exerted on the inner rail. For the 131-lb. rail on the 6-deg. curve, the predominating speed approximates that of superelevation; the tie plate penetration at the field end is greater than at the gage end but not nearly so much greater as for the inner rail of the 4-deg. curve.

It seems reasonable to assume that the depth of penetration at each end of a tie plate is proportional to the damaging pressure produced by passing wheel loads. Accord-

TABLE 7.--SERVICE TEST OF MECHANICAL WEAR OF TIES WITH SEVEN DESIGNS OF TIE PLATES FOR 131-LB. RE Rail on C.N.O. & T P. RY., MILE 326 (SOUTHERN RAILWAY SYSTEM) NEAR CHATTANOOGA, TENN.

Tie Plate Design No.	Tie Plate Dimensions	Rail Seat	Tie Plate Penetration from Nov. 1944 to June 1947 in 0.001 in. - 55 million tons of traffic											
			2 Anchor Cut Spikes					No Anchor Spikes					All Tie Plates	
			Inner or East Rail		Outer or West Rail		Both Rails	Inner or East Rail		Outer or West Rail		Both Rails	Both Rails	
			Field End	Gage End	Gage End	Field End	Mean	Field End	Gage End	Gage End	Field End	Mean	Mean	Percent of Loose Plates
6° Curve - Creosoted Oak Ties														
831	7½"x14 3/4"x31/32"	Rolled Circular	55	50	52	71	57	62	54	55	77	62	60	77
831-Z	7½"x14"x31/32"	Rolled Circular	60	49	51	83	61	56	49	45	96	62	61	44
831-Y	7½"x14"x7/8"	Rolled Circular	55	45	46	75	55	63	55	51	89	65	60	40
831-X	7½"x14"x3/4"	Rolled Circular	55	43	43	61	51	56	49	60	78	61	56	18
420	7 3/4"x14"x7/8"	Flat	52	57	46	81	59	70	52	49	100	68	63	51
Plan 5	7 3/4"x13"x27/32"	Rolled Circular	61	52	55	79	62	66	61	56	82	66	64	40
405	8"x12"x3/4"	Rolled Circular	-	-	-	-	-	51	49	52	78	58	58	50
*405-A	8"x12"x3/4"	Rolled Circular	-	-	-	-	-	68	137	113	119	109	109	39
Tangent - Creosoted Oak Ties														
831	7½"x14 3/4"x31/32"	Rolled Circular	59	58	58	48	56	41	59	49	58	52	54	85
831-Z	7½"x14"x31/32"	Rolled Circular	52	42	34	57	46	53	48	45	60	52	49	63
831-Y	7½"x14"x7/8"	Rolled Circular	48	42	37	51	45	48	28	35	51	41	43	81
831-X	7½"x14"x3/4"	Rolled Circular	61	41	43	51	49	50	46	44	45	46	48	67
420	7 3/4"x14"x7/8"	Flat	69	44	50	55	54	44	52	49	54	50	52	73
Plan 5	7 3/4"x13"x27/32"	Rolled Circular	55	44	63	60	55	51	43	41	52	47	51	59
405	8"x12"x3/4"	Rolled Circular	-	-	-	-	-	44	53	51	41	47	47	31
Tangent - Creosoted Pine Ties														
831	7½"x14 3/4"x31/32"	Rolled Circular	57	66	75	65	66	77	89	98	78	85	75	75
831-Z	7½"x14"x31/32"	Rolled Circular	57	77	71	67	68	53	69	56	68	62	65	61
831-Y	7½"x14"x7/8"	Rolled Circular	61	69	61	54	61	55	71	58	62	62	61	54
831-X	7½"x14"x3/4"	Rolled Circular	43	49	53	57	51	34	45	44	61	46	48	52
420	7 3/4"x14"x7/8"	Flat	50	48	44	72	54	56	71	52	73	63	59	62
Plan 5	7 3/4"x13"x27/32"	Rolled Circular	56	58	62	57	58	57	70	58	86	68	63	56
405	8"x12"x3/4"	Rolled Circular	-	-	-	-	-	47	55	66	57	56	56	55

Note: All tie plates have 3/8" eccentricity except design 831 has ½" and Plan 5, ¼".
All tie plates have flat bottom, except design No. 405-A has three transverse ribs.
*Penetration measurements include cutting of the ribs into the ties.

ingly, the vertical cross section of the recess in the tie along the tie plate length may be considered to constitute the diagram of damaging pressure and the centroid of this trapezoid represents the resultant of this pressure. If the tie plate were given an eccentricity which would place its midlength at this point, a uniform penetration at the gage and field ends of the tie plate would be expected. This resultant eccentricity has been calculated for both of the test installations and is shown in the tabulation.

CALCULATED LOAD ECCENTRICITIES UNDER FOUR CONDITIONS

Condition	*Eccentricity of Tie Plate Load in in.* Inner Rail	Outer Rail	Mean Both Rails
5 track panels each of creosoted oak and pine ties with 11-in. tie plates and 3/8-in. eccentricity —4-deg. curve	+ 1.42	+ 0.44	+ 0.93
4 track panels of creosoted oak ties with 14-in. tie plates and 3/8-in. eccentricity — 6-deg. curve	*+ 0.76	*+ 1.13	*+ 0.94
5 track panels each of creosoted oak and pine ties with 11-in. tie plates and 3/8-in. eccentricity—tangent			— 0.03
4 track panels each of creosoted oak and pine ties with 14-in. tie plates and 3/8-in. eccentricity—tangent	....	....	+ 0.49

Positive values are outward from center line of rail base.
Negative values are inward from center line of rail base.
*Based on tie plate penetration from August 1945 to June 1947.
All other values are based on data shown in Tables 6 and 7.

It is interesting to note that the resultant eccentricities so determined for the 4-deg. curve agree quite well with the eccentricities of loading determined from the dynamometer tie plates with the 112-lb. rail for the locomotives and tenders in condition B (Table 3).

Tie Plate Bending

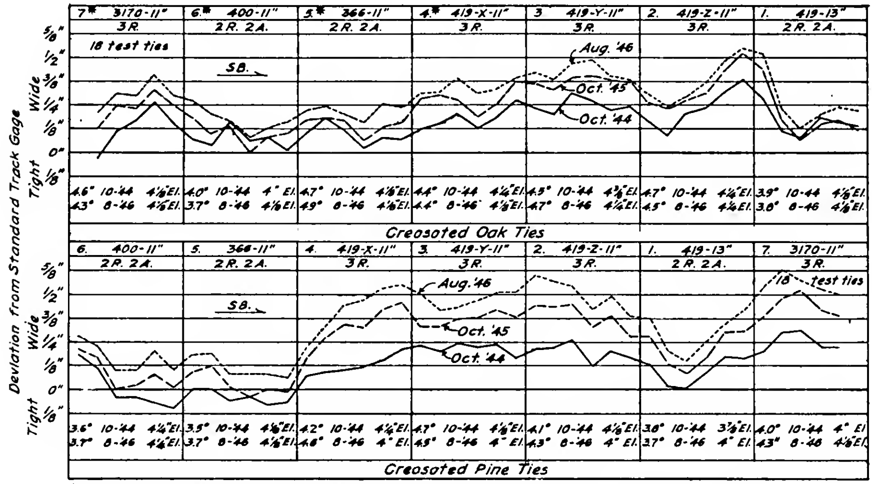
These measurements for both test installations indicated there had been no tie plate bending except in the inner rail of the 4-deg. curve where two of the 419X design tie plates had bent on the field end in the rail length supported on creosoted pine ties. Insufficient tie plate penetration has been developed to permit any appreciable permanent bending of the shoulder extensions. Future reports are expected to develop more information on this phase of the tests.

Gage of Track

A graphical record of the gage of track for the service periods reported is presented in Figs. 35 to 38, incl., for both test installations. The degree of curvature based on the middle ordinate of the outer rail and the average elevation of track in each panel are shown for the two test curves.

Some wide gage developed on the creosoted pine ties of the 4-deg. curve (Fig. 35), particularly where only three spikes per plate were used. Approximately 0.1 in. of the gage widening on the curve was caused by rail wear. The irregularities in gage on the tangent track in Fig. 36 increased during the service period. After all tests were concluded in 1946 all test panels on the Illinois Central were regaged and a new set of base readings were taken. It is of interest to note from Figs. 35 and 36 that the initial irregularities in the track gage were perpetuated and sometimes accentuated.

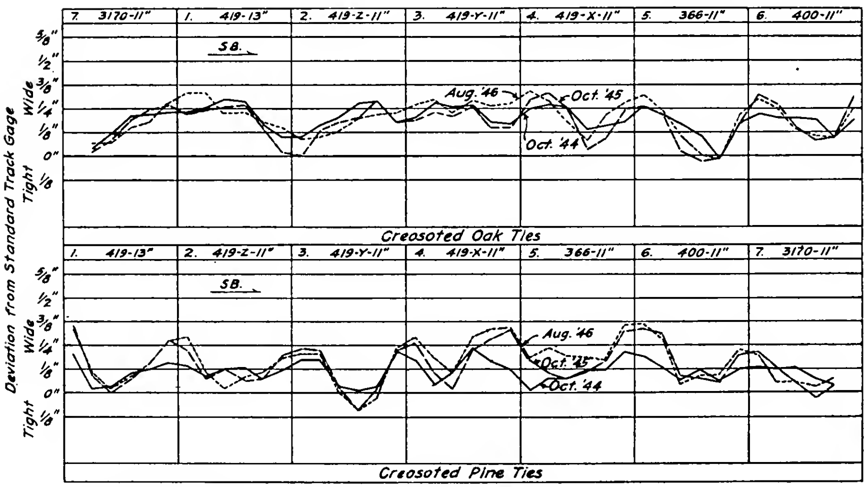
Similar records of the gage of track for the Southern Railway test installations are shown in Figs. 37 and 38. This curve also had 0.1-in. rail wear and considering the effect of the unequal tie plate penetration the gage has held remarkably well.



* These panels have 38-ft. rails, all others 39-ft.

2R or 3R indicate the number of rail spikes per tie plate; 2A, the number of anchor spikes per tie plate.

Fig. 35.—Gage, Curvature and Elevation of Each Panel of Test Track on the 4-deg. Curve, Mile L–333, I.C. R.R.

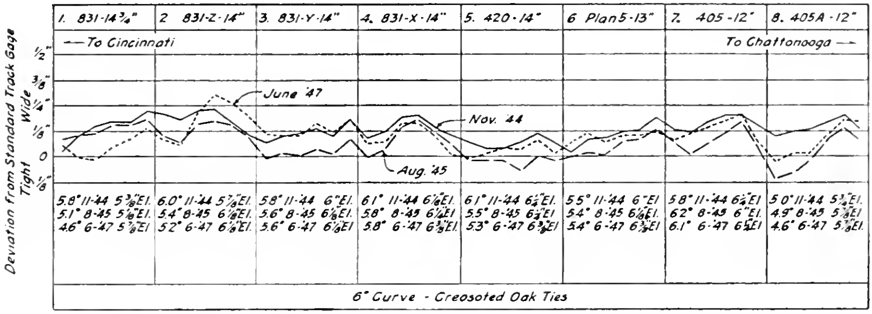


All panels have 39-ft. rails.

Each tie plate has 2 rail and no anchor spikes

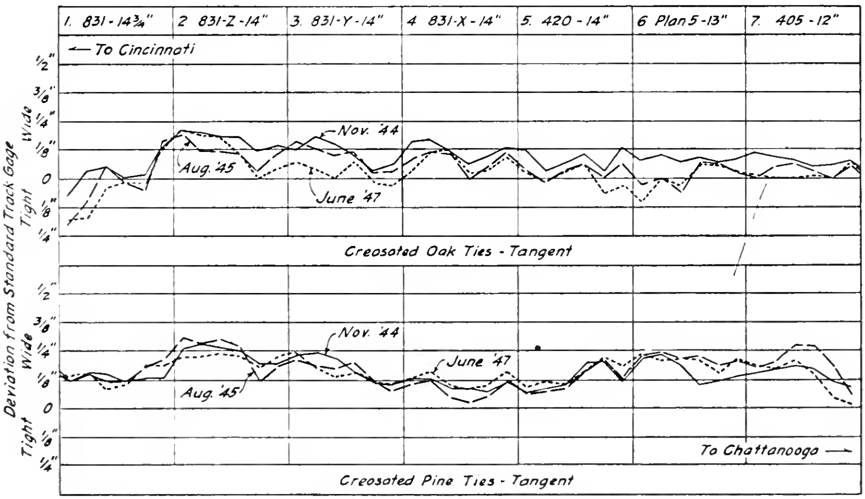
Each panel of test track has 23 ties except panels No. 7 which have only 18 test ties.

Fig. 36.—Gage of Each Panel of Test Track on Tangent at Henning, Tenn., I.C. R.R.



All Track Panels are 39 ft. in length
Each Tie Plate has 3 Line Spikes and, in addition, 2 Cut Spikes for Anchors in the North Half of Each Panel of Track

Fig. 37.—Gage, Curvature and Elevation of Each Panel of Test Track on the 6-deg. Curve, C.N.O. & T.P. Ry., Mile 326.



Each Tie Plate has 2 Line Spikes and, in addition, 2 Cut Spikes for Anchors in the North Half of Each Panel of Track

Fig. 38.—Gage of Each Panel of Test Track on Tangent, C.N.O. & T.P. Ry., Mile 326.

5. Supplemental Measurements of Mechanical Wear of Ties

Data on wear were obtained by measuring the depth of tie plate penetration in ties removed from the track on the Chicago, Milwaukee, St. Paul & Pacific and where tie plates were removed temporarily on the New York, Chicago & St. Louis and the Chicago, Burlington & Quincy. Only a small amount of data has been accumulated so far but the results indicate the method is dependable and sufficiently accurate to be used more extensively for obtaining information on wear of ties for various lengths of tie plates, kinds of wood and operating conditions to aid in determining the economical size of tie plates for various conditions and traffic density. In this report, only the tangent test data will be presented, primarily to show the position of the tie plate load resultant with respect to the center line of the rail base, which will clarify the inconsistent results obtained at Henning, Tenn., by the two methods.

Most of the tie plate penetration measurements were made with the same penetration gage as used in the tests on the Illinois Central System and the Southern Railway System. The conical points on the gage frame were replaced with longer tips having flat ends for setting in the tie plate recess while the tip of the Ames dial stems rested on the shoulders of the recess.

Chicago, Milwaukee, St. Paul & Pacific

The location selected for these measurements was in the Milwaukee eastbound main track on Mile 54 near Truesdell, Wis., where there was a long stretch of high speed tangent track. The track had 130-lb. PS rail, laid in 1929 and was well ballasted with gravel. The 7-in. by 11-in. by ¾-in. double shoulder tie plates had a flat rail seat with 1:40 cant, two transverse ribs on the bottom and ½-in. eccentricity.

Data were taken for 25 tie plates from old treated oak and pine ties removed from the track by an extra gang. Because of decay only 25 sets of readings were taken on the ties removed along ⅜ mile of track. The data were divided about equally between the two rails. The average depth of the plate penetration was 0.49 in. and 0.76 in. for the field and gage ends of the plates, respectively. By the previously explained method the resultant of the tie plate load was computed to be 0.15 in. outside of the center line of rail base. For subsequent investigations it was decided to avoid the influence of excessive decay by confining the measurements to ties still in track that had been inserted after the last rail change.

New York, Chicago & St. Louis

Penetration data were taken near the midpoint of a 2¾-mile tangent on the single track main line of New York, Chicago & St. Louis Railroad about two miles west of Knox, Ind. The track was laid with 1931 110-lb. RE rail, 6-hole angle bars and ballasted with gravel. The 7½-in. by 10-in. by ⅝-in. single shoulder tie plates had a rolled circular crown with 1:40 cant, diamond bottom and ½-in. eccentricity for the 5½-in. rail base. Average depth of tie plate cutting in creosoted oak ties was 0.25 in. and 0.36 in. at the field and gage ends, respectively. From these readings the position of the tie plate load resultant was calculated to be 0.20 in. outside the center line of the rail base.

Chicago, Burlington & Quincy

A check of tie plate penetration was made in two tangent locations on the Burlington; one on the single track main line near Hinckley, Ill.; the other on the middle main track near Lisle, Ill. At both locations the track was laid with 112-lb. RE rail and 8-in.

by 11-in. by 23/32-in. double shoulder tie plates having a beveled rail seat with 1:40 cant, two transverse ribs on the bottom and ⅜-in. eccentricity. From measurement of tie plate cutting for 58 tie plates on 29 creosoted oak ties on Miles 52, 53 and 54 near Hinckley, Ill., the average tie plate cutting was 0.077 in. and 0.092 in. at the field and gage ends, respectively. These data indicated the position of the resultant of the tie plate load was 0.21 in. outside the center line of the rail base.

The measurements on creosoted oak ties near Lisle, Ill., for 22 tie plates averaged 0.104 in. and 0.127 in. at the field and gage ends, respectively, and the load resultant was calculated to be 0.19 in. outward from the center line of rail base.

Summary

From the data on three railroads at four locations on tangent track it has been shown that the position of the resultant of the tie plate load was approximately 0.2 in. outward from the center line of rail base. Tie plates with 1:40 cant and ¼-in. eccentricity would be expected to hold the gage close to standard on tangent track and plates with ⅜-in. eccentricity to cause the gage to tighten 1/16 to ⅛ in. which is perhaps not objectionable, and may in fact have some advantages.

Advance Report of the Committee on Impact and Bridge Stresses

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Impact Tests on the Quincy Viaduct Detroit, Toledo & Ironton

Investigation Embraced Stress Measurements of Tower Columns and Bracing as Well as Truss Members and Girder Spans

Advance Report of Committee 30—Impact and Bridge Stresses

1. Digest

This report embraces a description and analysis of tests made by the research staff of the Engineering Division, Association of American Railroads, on a steel viaduct of the Detroit, Toledo & Ironton Railroad. The viaduct consists of 30-ft. and 45-ft. deck girder spans and one 150-ft. deck truss span supported by steel towers. The tests were made under a double-headed test train operating over a complete range of speeds from 5 mph. to 45 mph., which was the maximum allowable speed in this territory. The tests were made at the request and at the expense of the railroad for the purpose of determining the carrying capacity or rating of the superstructure by strain gage readings.

The stresses were measured in the various members of the 150-ft. span, in girder spans, and in columns and longitudinal and transverse bracing of the viaduct towers. The stresses were measured by means of electromagnetic strain gages with oscillograph recording on sensitized photographic paper and a total of 1680 individual stresses were recorded at the various points under the 70 test runs of the double-headed test train.

The results of these tests are of particular interest to bridge engineers for they are the first published data on the dynamic stresses in viaduct columns and they afford a comparison of the simultaneous stresses in several members of a truss as well as the simultaneous stresses at the four corners of the built-up members of the trusses and columns.

The data were analyzed for determining the carrying capacity of the span and the magnitude of the individual effects which make up the total static and dynamic stresses.

A brief summary of the analysis of the data as found from this study is as follows:

1. There was considerable variation between the direct stresses recorded in the members of the 150-ft. deck truss span under the passage of the test train crossing the bridge at 5 mph. and those calculated for the same load and position of load (See Table 1). The variation between the calculated and actual stresses appears to be due to the action of the stringers in taking direct stress. In these tests the stresses in the top chord were reduced to an average of 84 percent of the calculated direct stress.

There was fair agreement between the recorded and calculated stresses in the columns of the viaduct towers (See Table 2), the difference varying from 13 percent over the calculated down to 6 percent under the calculated.

2. The simultaneous stresses at the four corners of the test members were measured by placing a gage on each corner. It was found that there was considerable variation between the stresses on the four corners, indicating bending or eccentrically applied direct loads. A summary of these bending stresses is shown in Table 3 for the 150-ft. truss span and in Table 4 for the viaduct columns. The result of high secondary stresses in tension

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members is to make the member subject to fatigue failure. The result on compression members is to increase the eccentricity of the direct load at the center, thus lowering the buckling strength of the member. The high bending stress of 117.2 percent in the west column of bent 26 (See Table 4, Col. 21) reduced the carrying capacity of this column by a considerable amount.

3. An increase in stress produced by an increase in speed which is entirely distinct from the vibrations developed by the moving load has been termed "speed effect" and this effect was found throughout the tests on the 150-ft. truss span. However, it can be seen from the left diagram of Fig. 10 that the speed effect percentages were quite small for this span, the maximum effect being 8 percent.

4. The stress measurements usually showed an increase in stress in the steel under one rail with a corresponding decrease under the other rail. This change in stress is termed "roll effect" and is presumably caused by the oscillation of the spring-borne weight of the locomotive about a longitudinal axis. The roll effects for the 150-ft. truss span in percentages of the recorded static stress, are shown in the right diagram of Fig. 10. It can be seen that the roll effects for this span are in fair agreement with the AREA design allowance and that the effect is about the same for all locomotive speeds.

5. A summary of the vibrational effects induced in the truss members by the condition of the track and by the locomotive hammer blow, in terms of the magnification of the locomotive hammer blow stresses, is shown in the left diagrams of Figs. 11 and 12. The vibrational effects in the viaduct columns are shown in the left diagrams of Figs. 13 to 16, incl.

The damping characteristics of the structure were computed from the diagrams of dynamic magnifiers, and considerable damping was found in the truss span, apparently due to the spring action of the columns.

6. The increase in the direct stresses under the locomotives at various speeds over that recorded at a speed of approximately 5 mph. has been termed "total impact."

The total impacts recorded in the individual chord and web members of the 150-ft. truss span are summarized in the right diagrams of Figs. 11 and 12. There is considerable variation in the magnitude of these total impacts at the same speed, but all the values are below those calculated by the AREA design specification. The high damping characteristics of this structure reduce the total impacts by a considerable amount.

The total impacts recorded in the floorbeams, stringers and floorbeam posts are shown in Fig. 17 and it can be seen that their maximum values are appreciably below the AREA design allowance. These low impacts in these members could be attributed to their elastic supports, as similar results have been found in other members so supported.

The total impacts in the viaduct columns are shown in the right diagrams of Figs. 13 to 16, incl. The impacts are considerably below the AREA design allowance but no final conclusions can be made regarding the impacts in viaduct columns as these are the first dynamic tests ever made on such members.

7. The stresses in the longitudinal and transverse bracing of the viaduct towers were measured under the passage of the test train at all speed variations and the recorded direct stresses in these members are shown in the diagrams of Figs. 19 to 21, incl. There was no evidence of large longitudinal or transverse forces even with heavy braking, as shown by the special symbol on Fig. 21. The principal stresses in the longitudinal and transverse bracing appear to be a result of the compression stress in the columns.

2. Foreword

The bridge impact tests analyzed in this report were conducted at the request of the Detroit, Toledo & Ironton Railroad and the salaries and expenses of the members of the research staff who operated the instruments were borne entirely by the railroad. The tests were made in the spring of 1945 and were carried out under the general direction of G. M. Magee, research engineer, Engineering Division, AAR. The conduct of the tests, analysis of data and preparation of the report were in charge of E. J. Ruble, structural engineer, research staff, AAR.

The structure tested, see Figs. 1 and 2, was built in 1911 and was designed for Cooper E–53 loading. Since the railroad has been operating heavier power over this structure, the engineering department of the railroad requested the research staff of the AAR to measure the strains in the various members under the heavier power by means of electrical strain gages.

The general procedure in conducting these tests was to first erect the 6-ft. by 8-ft. sectional test building on a platform especially prepared at the north end of the 150-ft. truss span, see Fig. 3. The instruments were then placed in the building, special care being taken to place the recording oscillographs and power units on sponge rubber pads to eliminate any damage to the equipment from vibrations. The 24 electromagnetic gages were calibrated individually and then placed on the members. The double-headed test train was then run across the structure at speeds ranging from 5 mph. up to the maximum speed of 45 mph. permitted in this territory. Usually 10 or 15 test runs were made for each set-up of the gages and a total of 70 runs were made during the testing of the structure.

3. Instruments

The instruments used in these tests were of the electrical type and were fully described in the Proceedings, Vol. 42, 1941, page 402. The gages used were of the electromagnetic type having a 2-in. gage length. Two 12-element oscillographs were used, so 24 simultaneous stresses were recorded for each test run of the locomotive.

The relative position of each locomotive wheel with respect to certain points on the structure was indicated by the two solenoid marker units in each oscillograph through the use of a spring-type switch on the wheel position markers located at the points.

The speed of the locomotive was readily obtained from the oscillograms by determining the elapsed time for the first wheel to travel the known distance between the wheel position markers. With the locomotive speed known the position of any wheel at any time, such as the time of maximum stress in any member, could readily be ascertained.

The strain gages were calibrated individually before the test runs were started and after completing the test runs. The average values obtained for each gage were used in arriving at the stress factors or the amount of unit stress in the steel per inch of deflection of the light trace on the film for that particular gage. Usually a variation of only 100 or 200 psi. in the stress factor was found between the first and final calibration of each gage. In general, a 1-in. deflection of the light trace on the film indicated a strain in the steel of 0.0008 in. for the 2-in. gage length, which is equivalent to a unit stress of 12,000 psi., assuming a modulus of elasticity of 30,000,000 psi.

No effort was made to measure the vertical or lateral deflections.

(text continued on page 64)

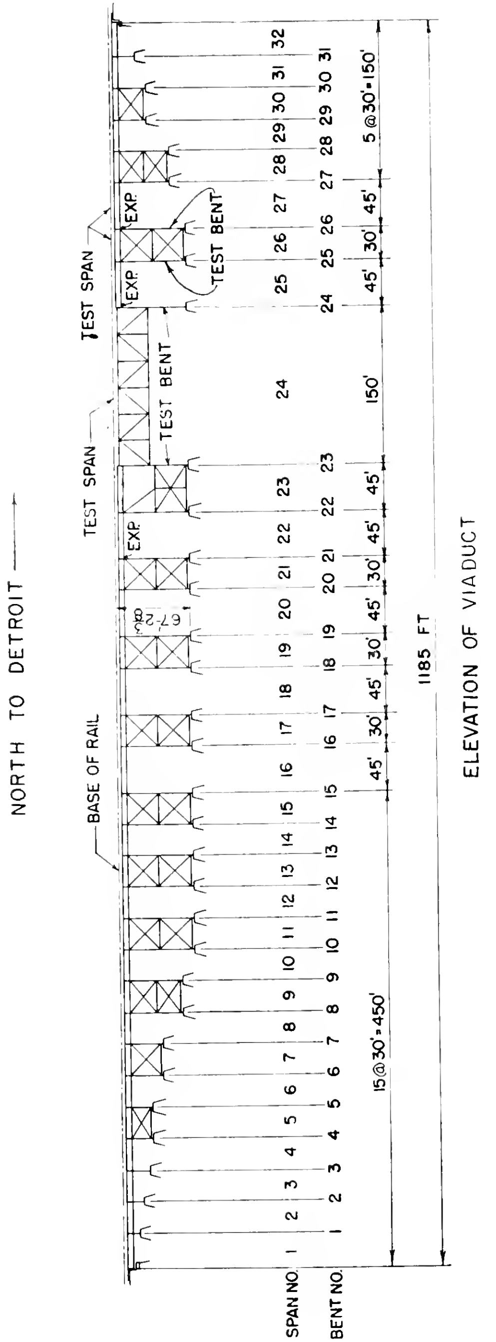


FIG. I
D.T. & I.R.R. BRIDGE TESTS
QUINCY VIADUCT
OPEN TIMBER FLOOR
LOCATION OF TEST SPANS

Fig. 2.—The Test Locomotives on the Viaduct.

Fig. 3.—Location of the Test Building.

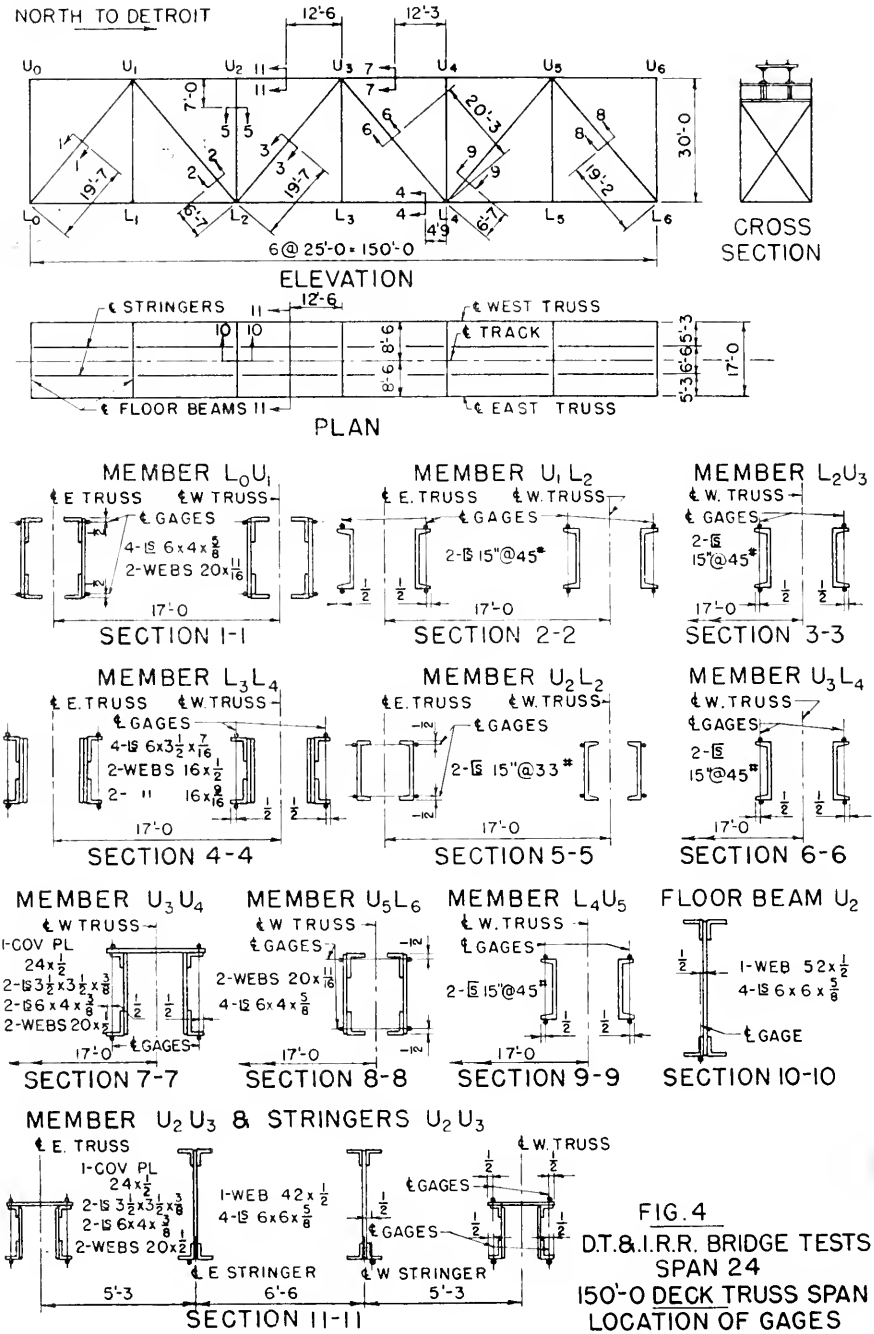


FIG. 4
D.T.&I.R.R. BRIDGE TESTS
SPAN 24
150'-0 DECK TRUSS SPAN
LOCATION OF GAGES

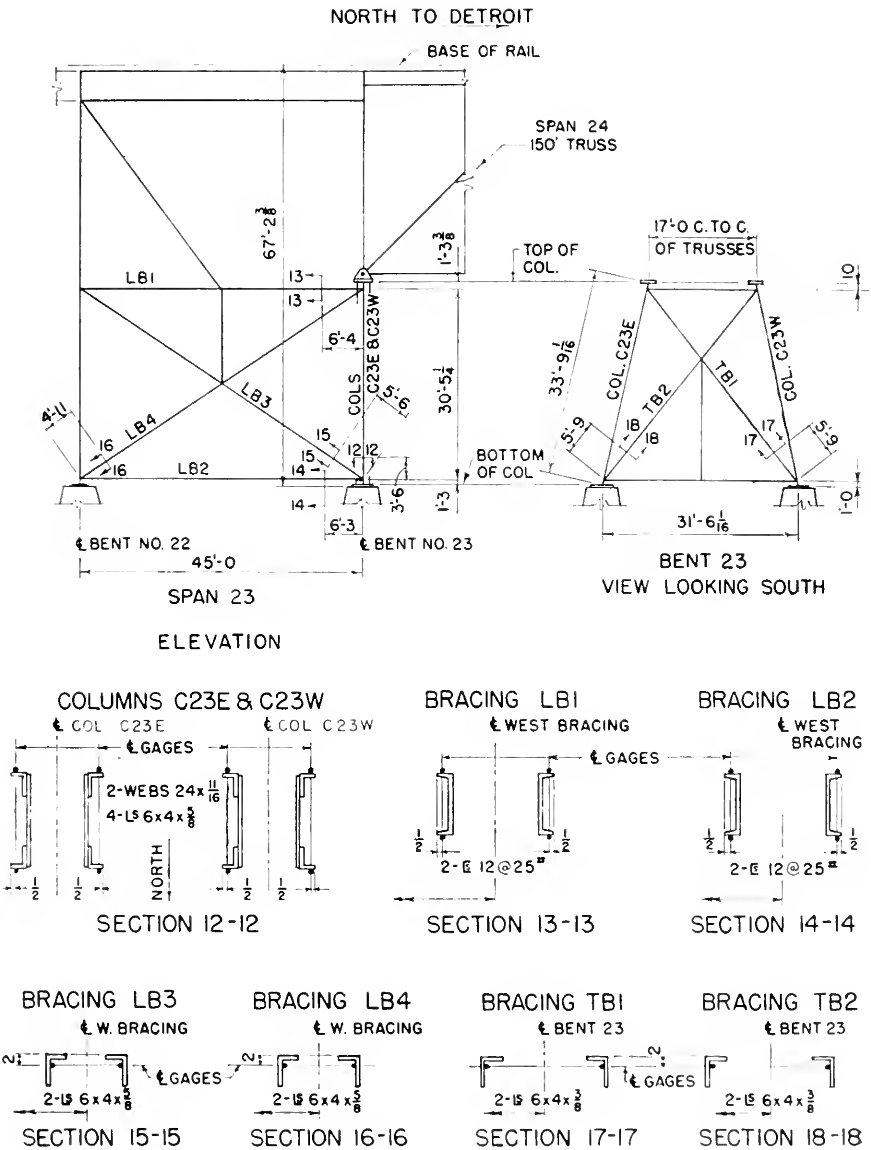


FIG. 5
D.T. & I. R.R. BRIDGE TESTS
TOWER - SPAN 23
COLUMNS AND BRACING
LOCATION OF GAGES

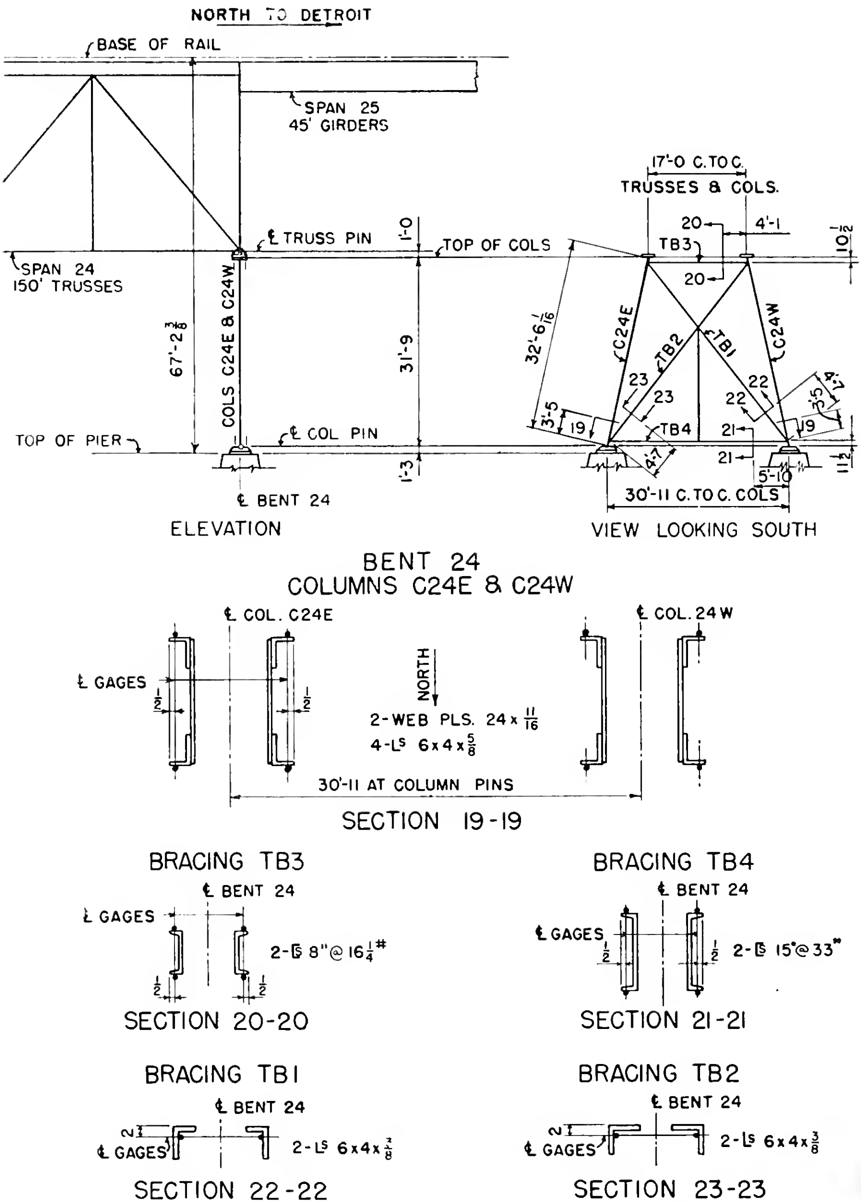


FIG. 6
D.T. & I. R.R. BRIDGE TESTS
BENT 24
COLUMNS & BRACING
LOCATION OF GAGES

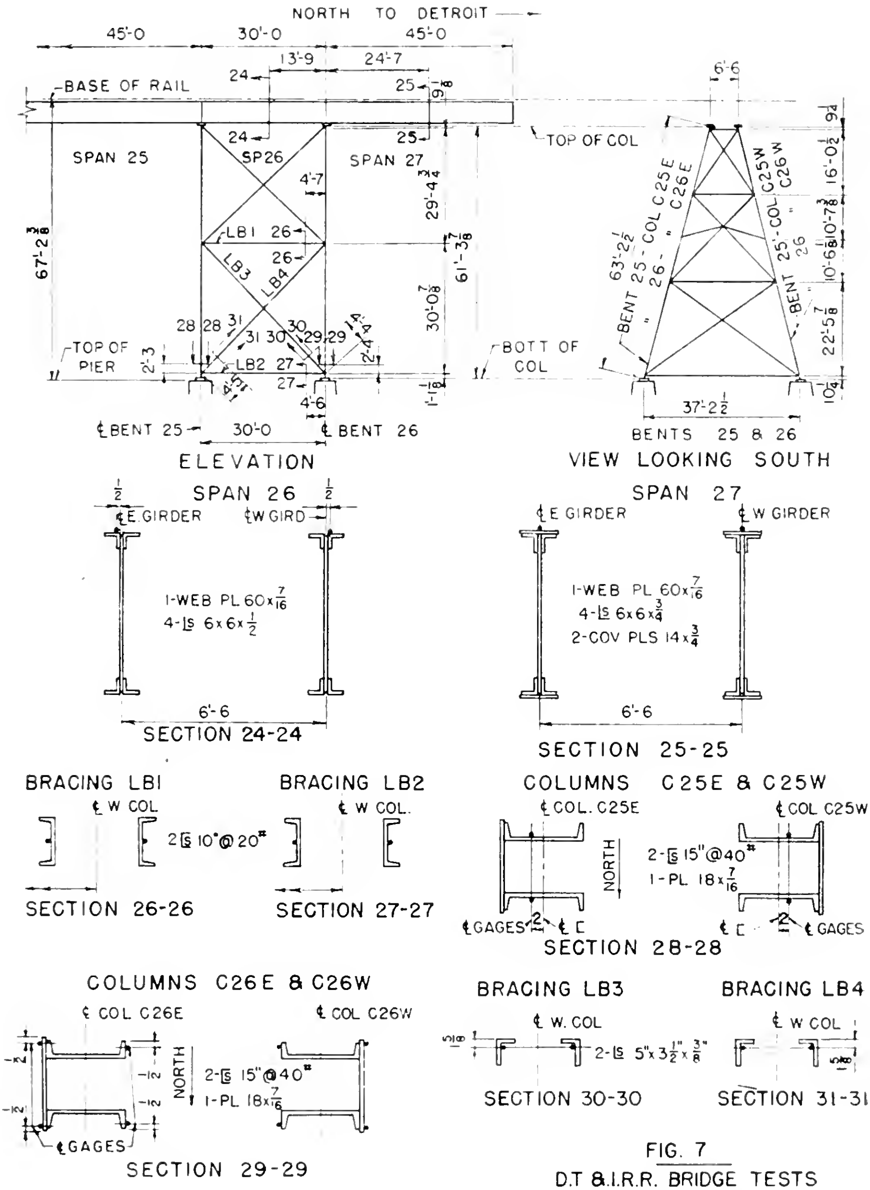
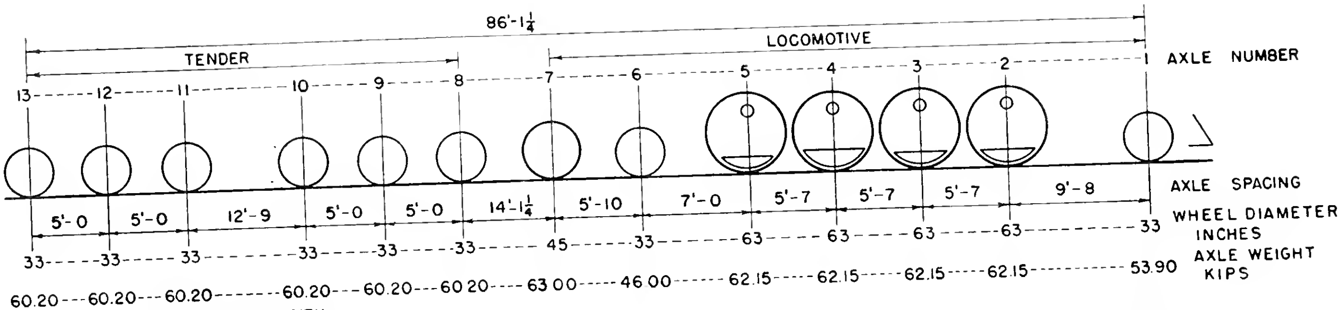
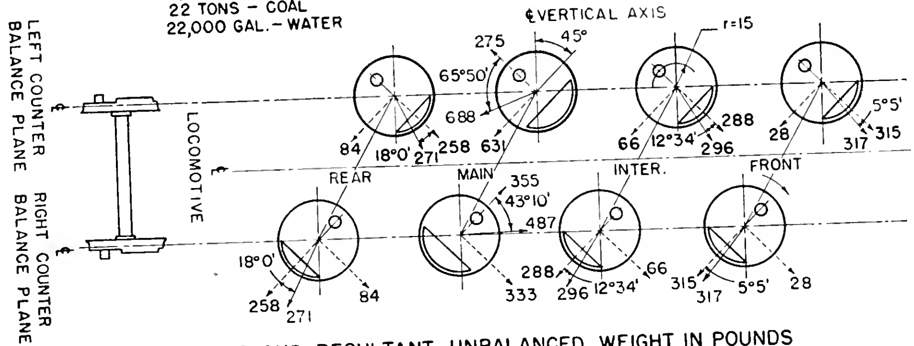


FIG. 7
D.T & I.R.R. BRIDGE TESTS
SPAN 26 & 27
GIRDERS, COLUMNS & BRACING
LOCATION OF GAGES





TOTAL WEIGHT OF LOCOMOTIVE IN WORKING ORDER - POUNDS 411,500

AVERAGE RECIPROCATING WEIGHT PER SIDE - POUNDS 2415

AVERAGE RECIPROCATING COMPENSATION PER SIDE - POUNDS 1206

AVERAGE RECIPROCATING UNBALANCE PER SIDE - POUNDS 1209

AVERAGE RECIPROCATING UNBALANCE PER SIDE PER 1000 LBS. OF LOCOMOTIVE WEIGHT IN WORKING ORDER - POUNDS 2.94

AVERAGE RECIPROCATING COMPENSATION 0.50

FIG. 8

D.T. & I. RAILROAD BRIDGE TESTS

LOCOMOTIVE DATA
BERKSHIRE TYPE 2-8-4
D.T. & I. CLASS 700

COMPONENTS AND RESULTANT UNBALANCED WEIGHT IN POUNDS

HAMMER BLOW AT ONE REVOLUTION PER SECOND

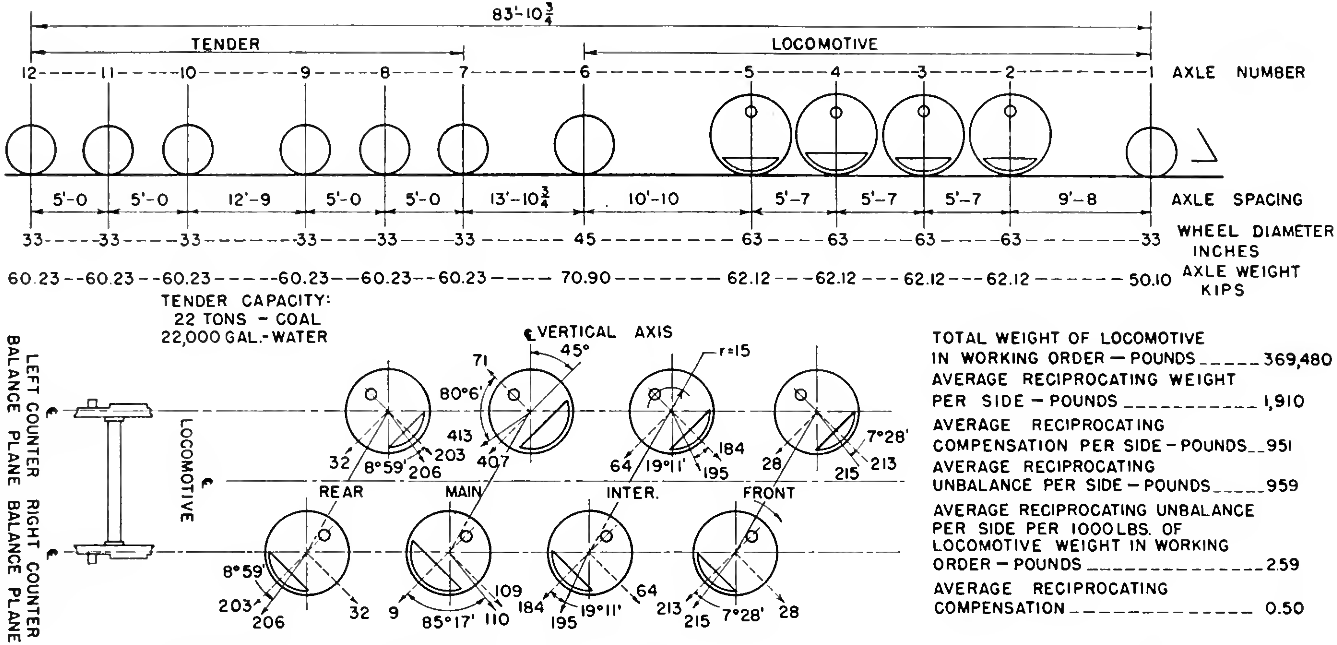
		LEFT SIDE	RIGHT SIDE
FRONT	DRIVER	484	484
INTER.	DRIVER	453	453
MAIN	DRIVER	1052	745
REAR	DRIVER	414	414

RECIPROCATING COMPENSATION

		LEFT SIDE	RIGHT SIDE
FRONT	DRIVER	343	343
INTER.	DRIVER	354	354
MAIN	DRIVER	58	276
REAR	DRIVER	342	342
	TOTAL	1097	1315
	AVERAGE	1206	

RECIPROCATING WEIGHTS AVERAGE FOR ONE SIDE

PISTON (COMPLETE)	915
CROSSHEAD & UNION LINK	907
MAIN ROD	593
TOTAL	2415



COMPONENTS AND RESULTANT UNBALANCED WEIGHT IN POUNDS

HAMMER BLOW AT ONE REVOLUTION PER SECOND

	LEFT SIDE	RIGHT SIDE
FRONT DRIVER	329	329
INTER. DRIVER	298	298
MAIN DRIVER	631	168
REAR DRIVER	315	315

RECIPROCATING COMPENSATION

	LEFT SIDE	RIGHT SIDE
FRONT DRIVER	241	241
INTER. DRIVER	248	248
MAIN DRIVER	38	416
REAR DRIVER	235	235
TOTAL	762	1140
AVERAGE	951	

RECIPROCATING WEIGHTS AVERAGE FOR ONE SIDE

PISTON COMPLETE	554
CROSSHEAD	866
UNION LINK	55
MAIN ROD	435
TOTAL	1910

FIG. 9

D. T. & I. RAILROAD
BRIDGE TESTS

LOCOMOTIVE DATA
MIKADO TYPE 2-8-2
D. T. & I. CLASS 800

(text continued from page 55)

4. Test Spans and Location of Gages

The viaduct tested is located near Quincy, Ohio, and spans the Miami river. The single track, open floor structure consists of 31 short deck girder spans and one deck truss span supported by steel towers (See Figs. 1 and 2). Representative members of the truss span, girder spans and towers including longitudinal and transverse bracing, were tested as shown in Figs. 4 to 7, incl.

In order to measure the stresses resulting from the bending of the members as well as those due to direct loads, four gages were placed on each of the main truss and column members. The members of both trusses, girders and columns were tested to determine the effects of any track eccentricity, differences in locomotive static loading as well as the rolling effect of the moving locomotive.

As previously mentioned, 24 gages were available, so 3 members of each truss or tower could be tested at one time. As soon as a sufficient number of runs, usually about 12, had been secured for the one location of the gages, called a series, the gages were changed to 3 more members for the next series.

5. Test Locomotives

A special train consisting of two steam locomotives was provided by the D. T. & I. R. R. for all the test runs on this structure. The necessary information regarding these locomotives, such as axle weight, axle spacing, nominal wheel diameter, and all information required to calculate the components and resultant weights on the driving wheels, was furnished by the mechanical department of the railroad.

The locomotives used in these tests were of the two-cylinder type, the right pin leading by 90 deg. and with the eccentric crank trailing. There were no diesel or electric locomotives operating over the bridge.

Steam Locomotive—Berkshire Type 2-8-4 (Class 700)

The locomotives of this class are used in regular freight service and all general data regarding them are shown in Fig. 8.

The drivers are all straight balanced with the left main underbalanced by 275 lb. and an out-of-plane effect of 631 lb. with a resultant of 688 lb. The right main is underbalanced by 355 lb. and an out-of-plane effect of 333 lb. with a resultant of 487 lb.

Steam Locomotive—Mikado Type 2-8-2 (Class 800)

The locomotives of this class are used in regular freight service and all general data regarding them are shown in Fig. 9.

The drivers are all straight balanced with the left main underbalanced by 71 lb. and the right main overbalanced by 9 lb. There is considerable out-of-plane on the left main driver with a resultant of 413 lb. on this driver.

6. Analysis of Field Records

The test records were read and the stresses tabulated in the same manner as described in the report on the Toledo Terminal Railroad tests, Proceedings, Vol. 49, 1948, page 677. The tables containing all the data taken from the oscillograms and entitled "Tabulation of Recorded Stresses" and "Analysis of Strain Gage Readings" are on file in the Engineering Division offices, AAR.

7. Static and Dynamic Effects

The data, as taken from the oscillograms and summarized in the previously mentioned tables, were analyzed for the particular purpose of segregating and determining the magnitude of the various static and dynamic effects of the live load. The results of this study are as follows:

Static Stresses

The recorded direct stresses for each truss or column member resulting from the test locomotives crossing the structure at slow speeds were determined by averaging the maximum simultaneous mean stresses recorded on the four corners of the member. When the members were unsymmetrical, such as the top chord member having a cover plate, it was necessary to correct the average stress to determine the direct stress at the neutral axis of the member. The direct stresses recorded in the east and west trusses or columns were then averaged to secure the recorded static stress.

The recorded static stresses in the stringers and girder spans were secured by averaging the simultaneous greatest mean stresses recorded by the two gages on the lower flanges of the stringers and on the top flanges of the girder spans. The recorded static stress in the floor beam was the greatest mean stress recorded at slow speeds by the one gage on the lower flange.

The static direct stresses in the various truss members, columns, stringers, floor beams and girders under the test locomotives were calculated for comparison with the recorded static stresses. The exact position of the locomotive wheels which produced the maximum recorded stress was secured from the oscillograms and this same locomotive position was used for the calculated stresses. The amount of coal and water used out of the tender at the time of the test run was subtracted from the tender weights and the calculated stresses are based upon the revised tender weights.

The comparison of the recorded and calculated live load static stresses and the stress factors, or the ratio of the recorded to the calculated stresses are shown in Table 1 for the truss members, including the stringers and floor beams, while those for the columns and girders are shown in Table 2. It can be seen that there is considerable variation between the recorded and calculated stresses, especially in the top chord members of the truss. It appears from the results shown in Table 1 that the stringers have a marked influence on the static stresses in the chords. For example, the recorded static stress in member $U_2 U_3$ varied from 79 to 87 percent of the calculated stress with an average of 82 percent. Low stress factors were also found in the top chord members of the 142-ft. deck span of the Toledo Terminal impact tests, see Proceedings, Vol. 49, 1948, page 694.

The low stress factors in the stringers of panel $U_2 U_3$ and the floor beam post $U_2 L_2$ are about the same as those found in previous tests. There is good agreement between the calculated and the recorded static stresses in the floor beam which has been also found in other tests.

There is fair agreement between the calculated and recorded static stresses in the columns as shown in Table 2. The maximum variation was in the columns of bent 23 where the recorded stresses were 13 percent greater than the calculated.

The stress factors in the girders of spans 26 and 27 are less than unity, as shown in Table 2, which is usual for spans of this length.

Secondary Stresses

The data secured with four gages on the various truss members and columns afforded an opportunity for the study of the secondary stresses and derived eccentricity in these members under the test locomotives at various speeds. The summary of this study is shown in Table 3 for the truss members and in Table 4 for the columns of bents 23, 24 and 26. It should be kept in mind that the tests were planned to determine the rating of the bridge and not the maximum secondary stresses. For example, it was realized that the maximum secondary stress occurs at the ends of the compression members but the gages were generally placed at the center of these members as it was felt the allowed compressive stress should be based on the center eccentricity because buckling would be most likely to start at this location.

The maximum direct stresses shown in column 8 of Tables 3 and 4 were determined in the same manner as those shown for the static stresses, except that the simultaneous maximum stresses at the four corners were used instead of the simultaneous mean stresses.

The bending stresses about the horizontal axis shown in column 9 of Tables 3 and 4 were determined by subtracting the maximum direct stress in column 8 from the average of the two gages on either the top or bottom of the member, whichever was the largest. The bending stresses about the vertical axis shown in column 14 were determined by subtracting the direct stress from the average of the two gages on one side of the member. The bending stresses shown in column 19 were determined by substracting the direct stress from the maximum recorded value on one of the four corners. The values shown in columns 10, 15 and 20 of these tables are the percentages of the direct stresses which would produce the bending stresses.

The derived eccentricities shown in columns 12, 17 and 20 of Tables 3 and 4 were determined in the same manner as described in the Toledo Terminal impact tests. Proceedings, Vol. 49, 1948, page 694.

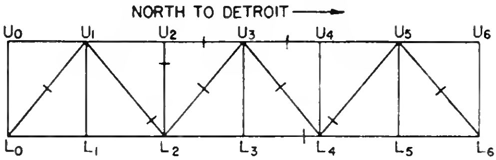
The bending stresses and derived eccentricities in Tables 3 and 4 are shown for three locomotive speeds, usually a slow speed, intermediate speed and a high speed, and it is interesting to note that the percent of bending and the derived eccentricities are about constant in each member at all the speeds. However, there is considerable variation in these values between the same members of the two trusses or columns. For example, the total bending stress about both axes (column 21, Table 3) for the east truss of member $L_0 U_1$ is 17.4 percent while a bending stress of 42.5 percent was recorded in the west truss.

It should be pointed out that there was considerable variation between the derived eccentricities as determined from the test results and those that would have been estimated from the relation of the neutral axis of the member and the working line of the truss, indicating that the rotation of the joints resulting from the vertical deflection of the truss and the moments induced by the stringer and floorbeam deflections should be considered in determining the carrying capacity of the structure. For example, the horizontal and vertical neutral axes of the symmetrical member $L_0 U_1$ of the 150-ft. deck truss span are on the working line of the truss. The average eccentricity about the horizontal axis, as determined by the test results (See column 12, Table 3) varied from 1.08 in. at slow speed to 1.14 in. at high speed with an average of 1.12 in. The average eccentricity about the vertical axis (See column 17, Table 3) amounted to an average value of 0.79 in. Normally one would not expect any eccentricity about either axis except that due to inherent crookedness.

The stresses in bents 23, 24 and 26 were recorded on a section close to the base and considerable eccentricity was found in these members. For example, the maximum stresses on the one corner of the west column of bent 26, see column 21, Table 4, averaged 117.2 percent greater than the direct stress. A field inspection of this bent indicated that the west column was bearing on one corner which explained the high bending stress.

(text continued on page 83)

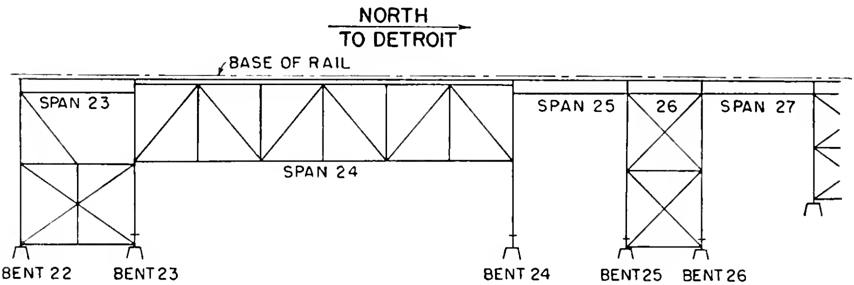
TABLE I
COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES
SPAN 24
150'-0 DECK TRUSS SPAN



MEMBER	TEST LOCOMOTIVE	DIRECTION	RECORDED STATIC STRESS			CALCULATED STATIC STRESS	STRESS FACTOR = RECORDED / CALCULATED	
			EAST	WEST	AVERAGE			
COLUMN 1	2	3	4	5	6	7	8	9
L_0U_1	701 AND 811	SOUTH	-6.51 -7.26 -6.84 -7.22 -7.50	-7.55 -7.32 -7.34 -7.19 -7.17	-7.03 -7.29 -7.09 -7.20 -7.34	-6.42	1.09 1.13 1.10 1.12 1.14	1.12
U_2U_3	811 AND 701	NORTH	-5.34 -4.65 -5.00	-7.43 -6.91 -6.89	-6.38 -5.78 -5.95	-7.34	0.87 0.79 0.81	0.82
U_3U_4	811 & 701	NORTH	——	-6.42 -6.03	——	-7.17	0.90 0.83	0.86
U_5L_6	811 & 701	NORTH	——	-6.11 -6.31	——	-6.23	0.98 1.01	0.99
L_3L_4	811 & 701	NORTH	+7.48 +7.75	+7.20 +7.80	+7.34 +7.78	+7.31	1.00 1.07	1.03
U_1L_2	701 AND 811	SOUTH	+9.41 +9.25 +9.71 +9.47 +8.80	+8.81 +8.69 +9.23 +9.13 +7.77	+9.11 +8.97 +9.47 +9.30 +8.29	+8.10	1.13 1.11 1.17 1.15 1.02	1.12
L_2U_3	701 AND 811	SOUTH	——	-5.56 -5.09 -5.53 -5.89 -5.86	——	-4.64	1.20 1.10 1.19 1.27 1.26	1.20
U_3L_4	811 & 701	NORTH	——	-4.82 -4.49	——	-4.46	1.08 1.02	1.05
L_4U_5	811 & 701	NORTH	——	+7.81 +8.26	——	+7.75	1.01 1.07	1.04
POST U_2L_2	701	NORTH	-5.92 -5.04 -5.11	-5.51 -5.35 -5.22	-5.72 -5.20 -5.17	-6.13	0.93 0.85 0.84	0.86
	811	NORTH	-4.94 -4.80 -4.89	-4.82 -5.07 -5.10	-4.88 -4.94 -5.00	-5.82	0.84 0.85 0.86	
FLOOR BEAM U_2	811	NORTH	——	——	+7.92 +8.04 +8.05	+8.01	0.99 1.00 1.00	1.01
	701	NORTH	——	——	+7.83 +8.58 +8.70	+8.14	0.96 1.05 1.07	
STRINGER U_2U_3	701	NORTH	+5.22 +5.71 +5.84	+4.59 +4.28 +5.11	+4.91 +5.00 +5.48	+7.31	0.67 0.68 0.75	0.71
	811	NORTH	+6.31 +6.32 +6.19	+5.42 +4.69 +5.32	+5.87 +5.51 +5.76	+7.84	0.75 0.70 0.74	

NOTE: STRESSES SHOWN ARE IN KIPS PER SQUARE INCH.

TABLE 2
COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES
COLUMNS AND GIRDER SPANS



MEMBER	TEST LOCOMOTIVE	DIRECTION	RECORDED STATIC STRESS			CALCULATED STATIC STRESS	STRESS FACTOR = RECORDED / CALCULATED	
			COLUMN OR GIRDER		AVERAGE			
			EAST	WEST				
COLUMN 1	2	3	4	5	6	7	8	9
COLUMNS BENT 23	701 AND 811	SOUTH	-7.07 -7.09 -6.84	-8.40 -8.29 -8.49	-7.73 -7.69 -7.67	-6.79	1.14 1.13 1.13	1.13
COLUMNS BENT 24	811 AND 701	NORTH	-6.08 -5.82 -6.07 -5.45	-7.73 -6.60 -6.40 -6.44	-6.91 -6.21 -6.24 -5.95	-6.69	1.03 0.93 0.93 0.89	0.94
COLUMNS BENT 25	811 AND 701	NORTH	-5.49 -5.22	-6.08 -5.70	-5.79 -5.46	-5.20	1.11 1.05	1.08
COLUMNS BENT 26	811 AND 701	NORTH	-4.22 -4.18	-6.15 -5.83	-5.19 -5.00	-5.22	1.00 0.96	0.98
GIRDERS SPAN 26	811	NORTH	-7.15 -7.31	-7.38 -7.86	-7.27 -7.59	-7.65	0.95 0.99	0.96
	701	NORTH	-7.31 -7.31	-7.67 -7.67	-7.49 -7.49	-7.96	0.94 0.94	
GIRDERS SPAN 27	811	NORTH	-7.30 -7.54	-6.64 -6.64	-6.97 -7.09	-7.95	0.88 0.89	0.87
	701	NORTH	-7.42 -7.54	-6.42 -6.64	-6.92 -7.09	-8.20	0.84 0.86	

NOTE: STRESSES SHOWN ARE IN KIPS PER SQUARE INCH

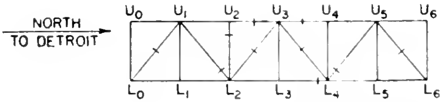
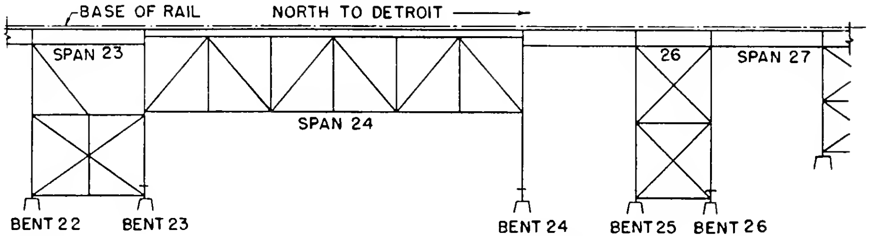


TABLE 3
SECONDARY STRESSES
SPAN 24
150'-0 DECK TRUSS SPAN

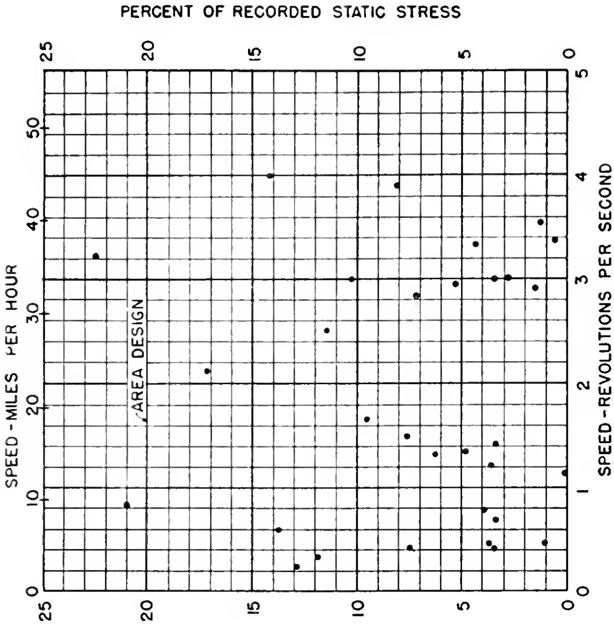
MEMBER	DEPTH/LENGTH HORIZ. AXIS (1-1)	DEPTH/LENGTH VERT. AXIS (2-2)	TEST LOCOMOTIVE	DIRECTION	TRUSS	SPEED IN MPH.	MAXIMUM DIRECT STRESS	BENDING HORIZONTAL AXIS (1-1) STRESS	STRESS IN PERCENT		DERIVED ECCENT. INCHES		BENDING VERTICAL AXIS (2-2) STRESS	STRESS IN PERCENT		DERIVED ECCENT. INCHES		BENDING BOTH AXIS STRESS	STRESS IN PERCENT	
COL 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
L_0U_1	0044	0.031	701 AND 811	SOUTH	EAST	37 237 38.0	-739 -757 -751	1.19 1.08 1.06	16.1 143 141	14.8	0.84 0.74 0.74	0.77	0.20 0.28 0.15	2.7 3.7 2.0	2.8	0.14 0.19 0.10	0.14	140 123 127	190 163 169	174
					WEST	37 237 38.0	-743 -746 -791	154 161 172	208 216 217	214	1.08 113 1.14	112	1.16 119 108	156 16.0 137	15.1	082 084 072	079	317 3.14 338	426 421 428	42.5
U_2U_3	0.070	0.082	811 AND 701	NORTH	EAST	4.7 342 448	-5.62 -572 -6.17	0.51 0.36 0.45	91 63 73	76	0.63 044 051	0.53	0.54 0.57 0.55	9.6 10.0 8.9	9.5	0.56 0.57 0.52	0.55	0.91 0.82 1.04	16.2 143 169	158
					WEST	47 342 448	-756 -754 -8.14	0.01 0.58 0.42	01 7.7 5.2	4.3	0.01 0.35 0.24	0.20	0.87 0.75 0.83	115 10.0 10.2	10.6	0.65 0.56 0.57	0.59	0.97 1.58 1.64	128 210 202	18.0
U_3U_4	0070	0082	811 AND 701	NORTH	WEST	5.3 320 440	-650 -750 -759	023 0.05 0.14	3.5 0.7 1.8	2.0	0.16 0.05 0.13	0.11	0.16 0.06 0.05	2.5 0.8 0.7	1 3	0.14 0.05 0.04	0.08	034 006 0.22	5.2 0 8 2 8	2.9
U_5L_6	0044	0031	811 AND 701	NORTH	WEST	53 320 440	-623 -666 -681	069 060 021	111 90 31	77	058 0.47 016	037	047 059 018	7.5 8.9 2.6	63	040 046 0.14	033	107 1.00 0.48	172 15.0 7.1	13.1
L_3L_4	0055	0082	811 AND 701	NORTH	EAST	5.3 320 440	+765 +854 +961	032 0.30 035	42 35 36	38	014 011 0.12	0.12	024 0.28 0.28	31 3.3 2.9	31	021 022 019	021	0.56 067 078	7.3 7.9 81	78
					WEST	53 320 440	+733 +849 +893	044 0.30 099	60 3.5 111	69	0.19 0.11 0 36	022	047 0.42 028	64 50 31	48	042 033 021	032	1.17 107 104	160 126 11.7	135
U_1L_2	0.032	0.049	701 AND 811	SOUTH	EAST	27 328 380	+954 +1133 +1067	026 037 031	27 33 29	30	010 012 010	011	056 057 0.52	59 50 49	53	040 034 033	036	080 0.77 087	84 68 82	78
					WEST	27 328 380	+892 +10.10 +9.24	0.74 088 097	84 87 10.5	9.2	030 031 038	033	006 001 010	07 01 11	06	0.05 001 007	04	134 148 167	150 147 16.0	159
L_2U_3	0032	0.049	701 AND 811	SOUTH	WEST	27 32.8 380	-568 -662 -628	034 047 043	6.0 7.1 6.8	6.6	021 025 025	024	002 007 008	04 11 13	09	002 007 009	006	042 0.56 072	74 85 115	91
U_3L_4	0032	0049	811 AND 701	NORTH	WEST	5.3 320 440	-493 -576 -575	026 007 007	53 12 12	26	019 004 004	009	066 059 060	134 103 105	114	092 0.70 0.71	078	097 090 080	197 156 137	164
L_4U_5	0032	0049	811 AND 701	NORTH	WEST	53 320 440	+793 +9.14 +926	105 130 085	132 142 92	122	048 051 033	044	034 038 024	43 42 26	37	029 028 018	025	110 153 086	139 168 93	133
U_2L_2	0.042	0040	701	NORTH	EAST	47 342 448	-599 -635 -688	074 045 082	124 71 119	105	056 032 0.54	047	183 189 1.96	306 29.8 28.5	297	169 165 1.58	164	210 204 241	351 321 35.0	341
			811		EAST	47 342 448	-506 -619 -654	019 053 007	38 86 11	45	017 039 005	020	178 168 179	352 271 274	299	1.95 151 152	166	246 295 217	486 477 332	432
			701	NORTH	WEST	47 342 448	-557 -619 -674	075 068 086	135 110 128	124	062 050 058	057	207 231 253	372 373 376	374	206 207 208	207	327 340 371	587 550 551	56.3
			811		WEST	47 342 448	-496 -596 -6.16	003 003 007	06 05 1.1	0.7	003 002 005	003	187 2.17 198	376 364 321	354	209 201 178	196	204 233 203	41.1 39.1 330	37.8

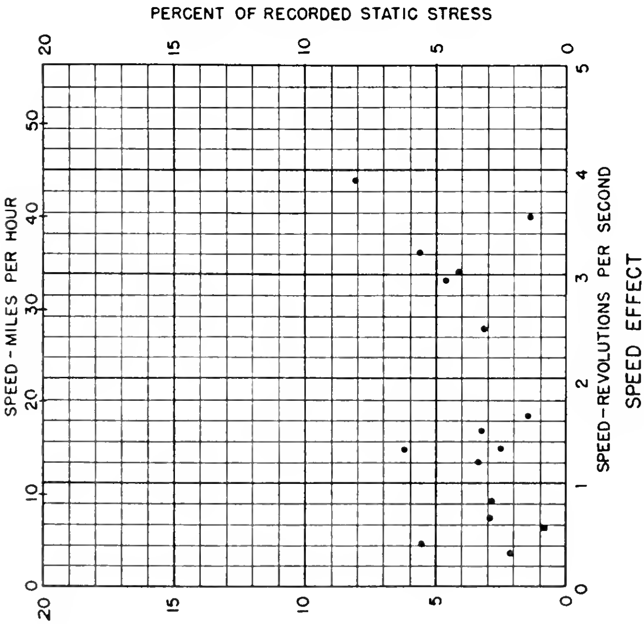
TABLE 4
SECONDARY STRESSES
COLUMNS



MEMBER	COLUMN	DEPTH/LENGTH HORIZ AXIS 1-1	DEPTH/LENGTH VERT AXIS 2-2	TEST LOCOMOTIVE	DIRECTION	SPEED MPH.	MAXIMUM DIRECT STRESS	BENDING HORIZONTAL AXIS 1-1 STRESS	STRESS IN PERCENT		DERIVED ECCENTRICITY INCHES		VERTICAL AXIS 2-2 STRESS	STRESS IN PERCENT		DERIVED ECCENTRICITY INCHES		BOTH AXIS STRESS	STRESS IN PERCENT	
COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
BENT 23	EAST	0.061	0.058	701 AND 811	SOUTH	3.5 33.0 40.0	−7.45 −8.20 −8.60	0.72 1.10 0.92	9.7 13.4 10.7	11.3	0.56 0.77 0.62	0.65	0.80 0.83 1.12	10.7 10.1 13.0	11.9	0.61 0.58 0.74	0.64	2.59 3.00 3.00	34.8 36.6 34.9	35.4
	WEST	0.061	0.058	701 AND 811	SOUTH	3.5 33.0 40.0	−8.83 −9.26 −9.91	3.06 2.94 3.07	34.7 31.8 31.0	32.8	2.00 1.83 1.79	1.87	3.19 4.26 4.45	36.1 46.1 44.9	42.4	2.06 2.62 2.56	2.41	6.79 8.62 9.91	76.9 93.0 100.0	90.0
BENT 24	EAST	0.063	0.057	811 AND 701	NORTH	7.5 31.9 46.4	−6.05 −6.25 −6.58	0.86 0.65 0.71	14.2 10.4 10.8	11.8	0.82 0.60 0.62	0.68	0.76 0.84 0.83	12.6 13.4 12.6	12.9	0.72 0.77 0.72	0.74	1.63 1.56 1.71	26.9 25.0 26.0	26.0
	WEST	0.063	0.057	811 AND 701	NORTH	7.5 31.9 46.4	−6.71 −6.69 −7.73	1.49 1.25 1.53	22.2 18.7 19.8	20.2	1.28 1.08 1.14	1.17	1.82 1.69 1.73	27.1 25.3 22.4	24.9	1.55 1.44 1.28	1.42	3.91 3.50 3.87	58.2 52.3 50.1	53.5
BENT 26	EAST	0.042	0.048	811 AND 701	NORTH	6.9 29.9 45.7	−4.17 −4.15 −5.40	1.61 1.90 2.26	38.6 45.8 41.8	42.1	1.31 1.55 1.42	1.43	0.37 0.36 0.72	8.9 8.7 13.3	10.3	0.33 0.32 0.49	0.38	2.28 2.68 3.26	54.8 64.6 60.4	59.9
	WEST	0.042	0.048	811 AND 701	NORTH	6.9 29.9 45.7	−5.51 −5.74 −6.15	5.06 5.17 4.65	91.6 90.0 70.6	84.1	3.10 3.05 2.56	2.90	0.73 0.69 1.28	13.2 12.0 20.8	15.3	0.45 0.41 0.72	0.53	6.62 6.69 7.10	120.0 116.5 115.2	117.2

NOTE: STRESSES SHOWN ARE IN KIPS PER SQUARE INCH





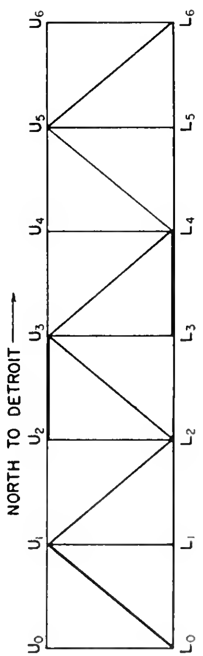


FIG. 10

D.T.&I.R.R. BRIDGE TESTS
SPAN 24
150'-0 DECK TRUSS SPAN
END POSTS AND CHORD MEMBERS
SPEED EFFECT
ROLL EFFECT

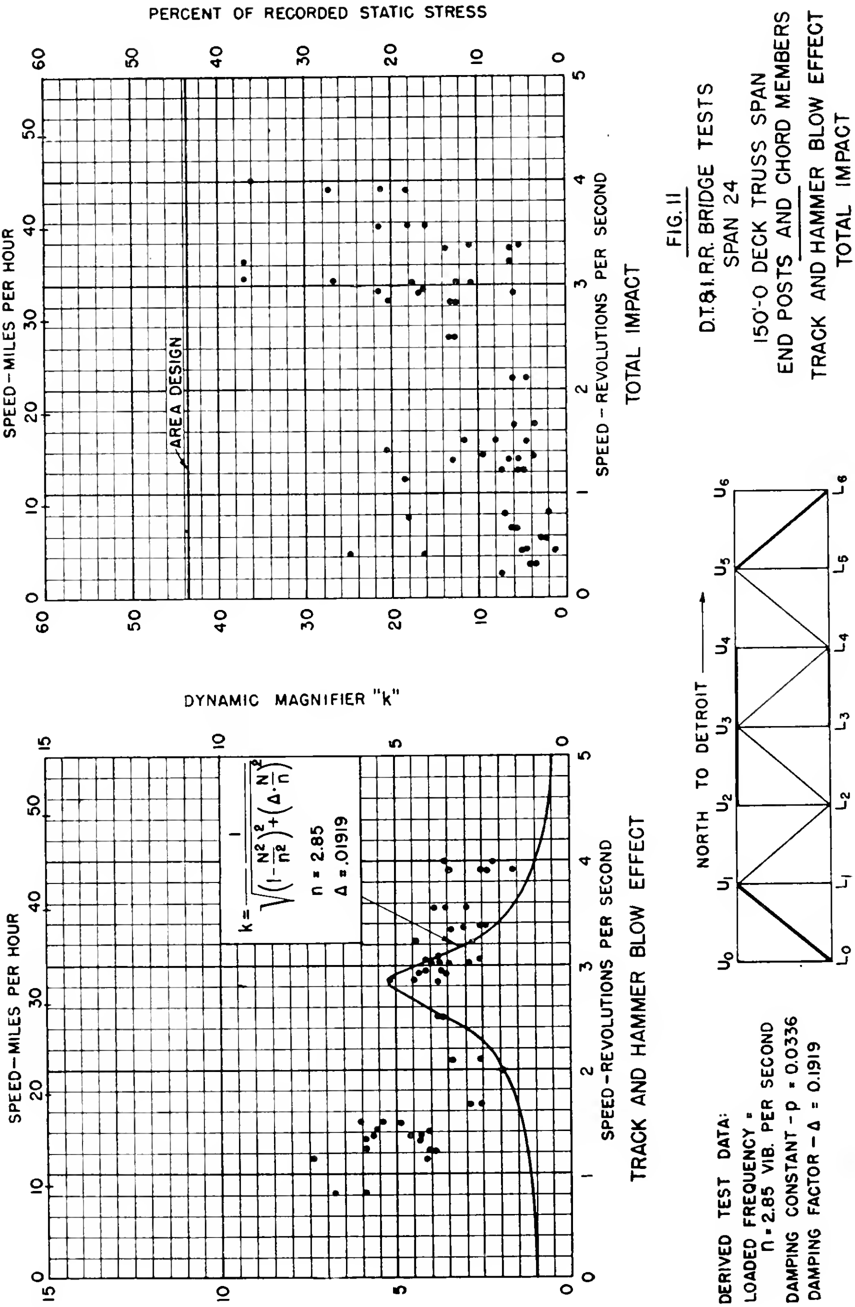


FIG. 11
D.T.&I. R.R. BRIDGE TESTS
SPAN 24
150'-0 DECK TRUSS SPAN
END POSTS AND CHORD MEMBERS
TRACK AND HAMMER BLOW EFFECT
TOTAL IMPACT

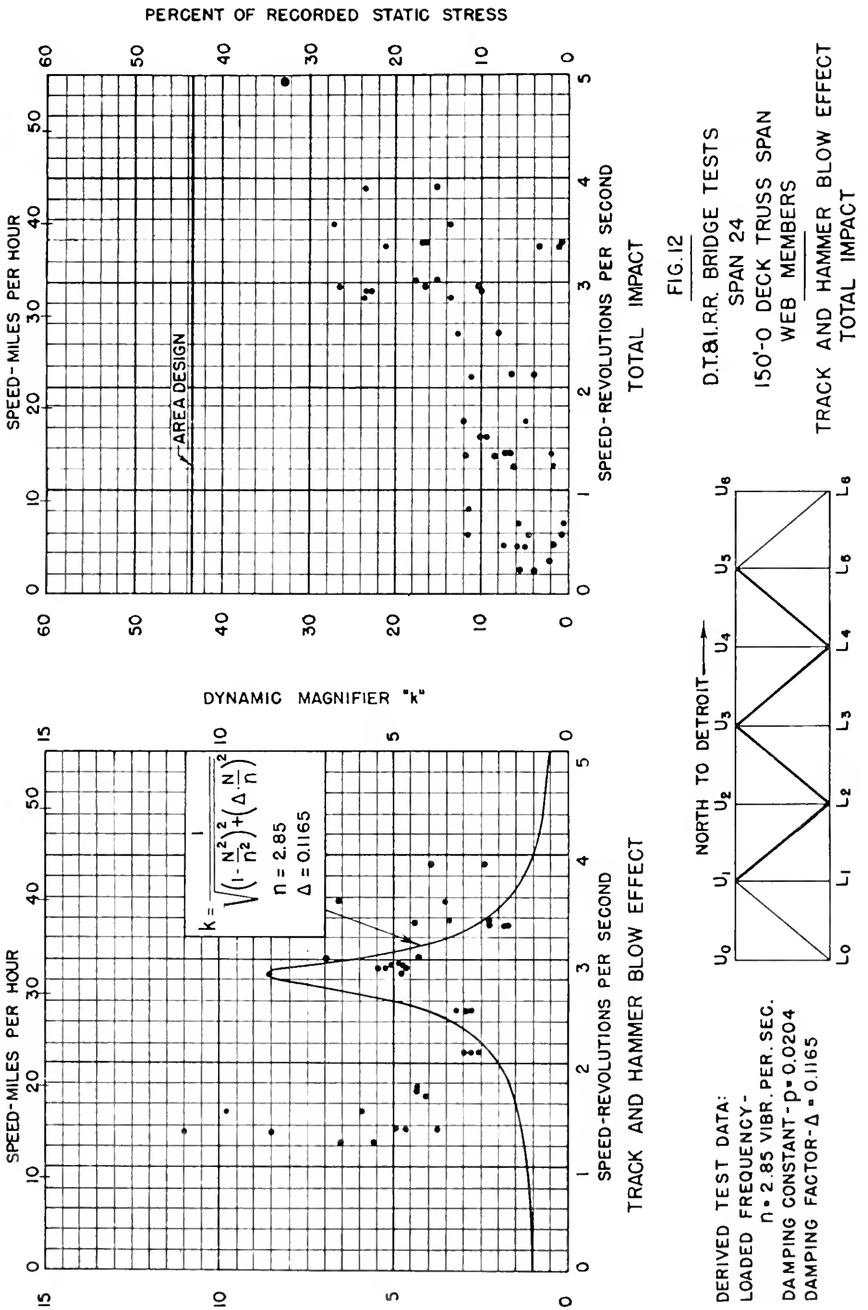


FIG. 12
D.T.&I.R.R. BRIDGE TESTS
SPAN 24
150'-0 DECK TRUSS SPAN
WEB MEMBERS
TRACK AND HAMMER BLOW EFFECT
TOTAL IMPACT

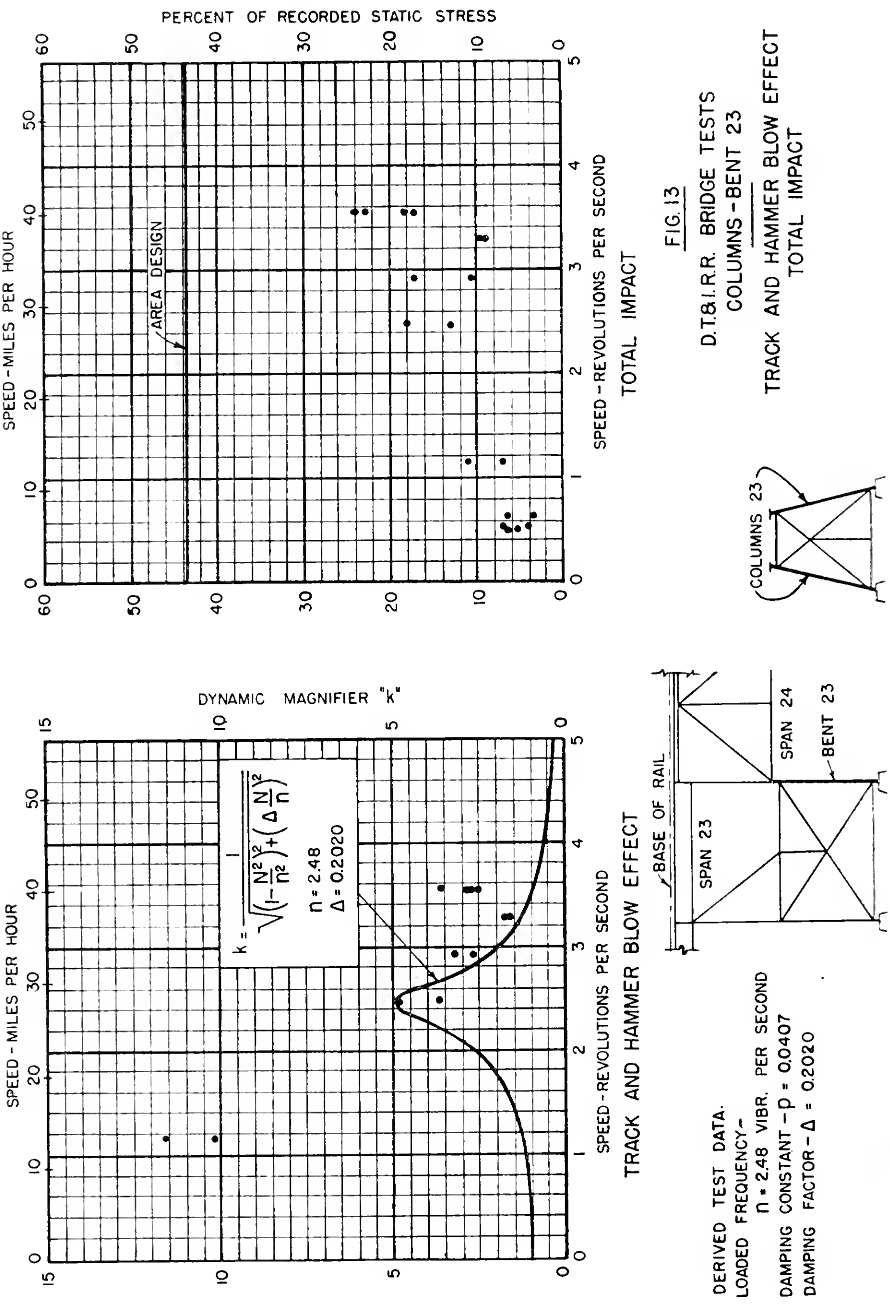


FIG. 13
D.T.&I.R.R. BRIDGE TESTS
COLUMNS-BENT 23
TRACK AND HAMMER BLOW EFFECT
TOTAL IMPACT

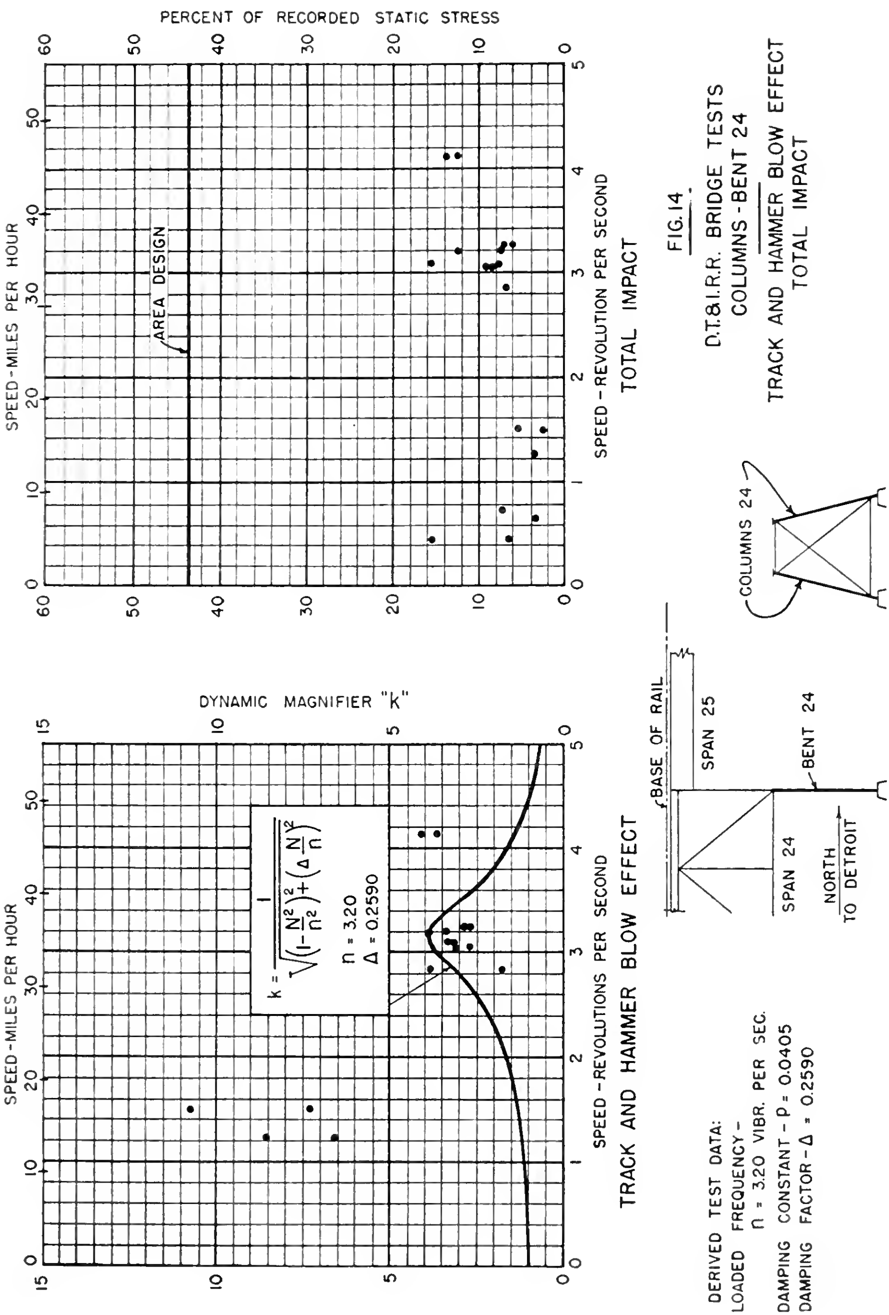


FIG. 14

D.T.&I.R.R. BRIDGE TESTS
COLUMNS-BENT 24
TRACK AND HAMMER BLOW EFFECT
TOTAL IMPACT

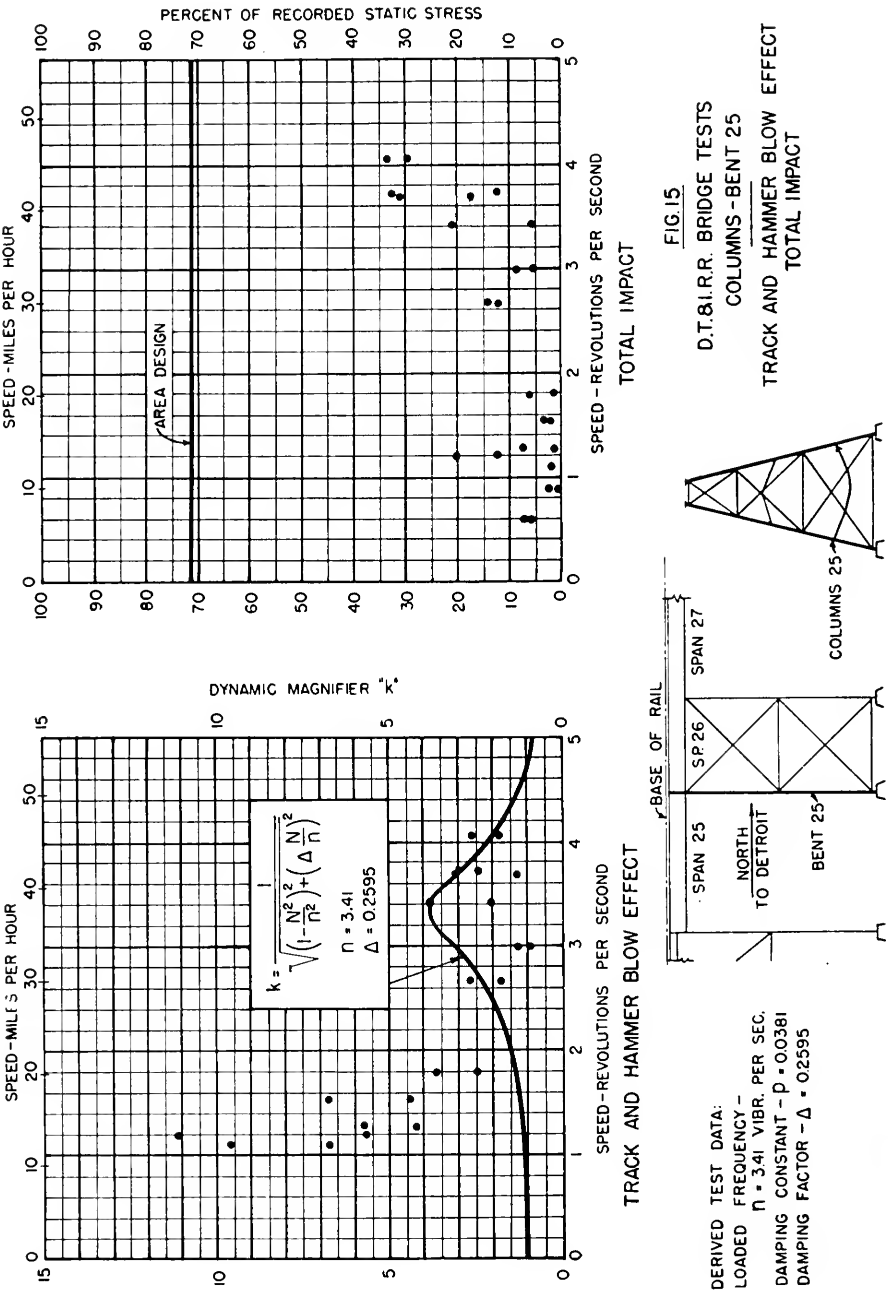


FIG. 15
D.T. & I. R.R. BRIDGE TESTS
COLUMNS – BENT 25
TRACK AND HAMMER BLOW EFFECT
TOTAL IMPACT

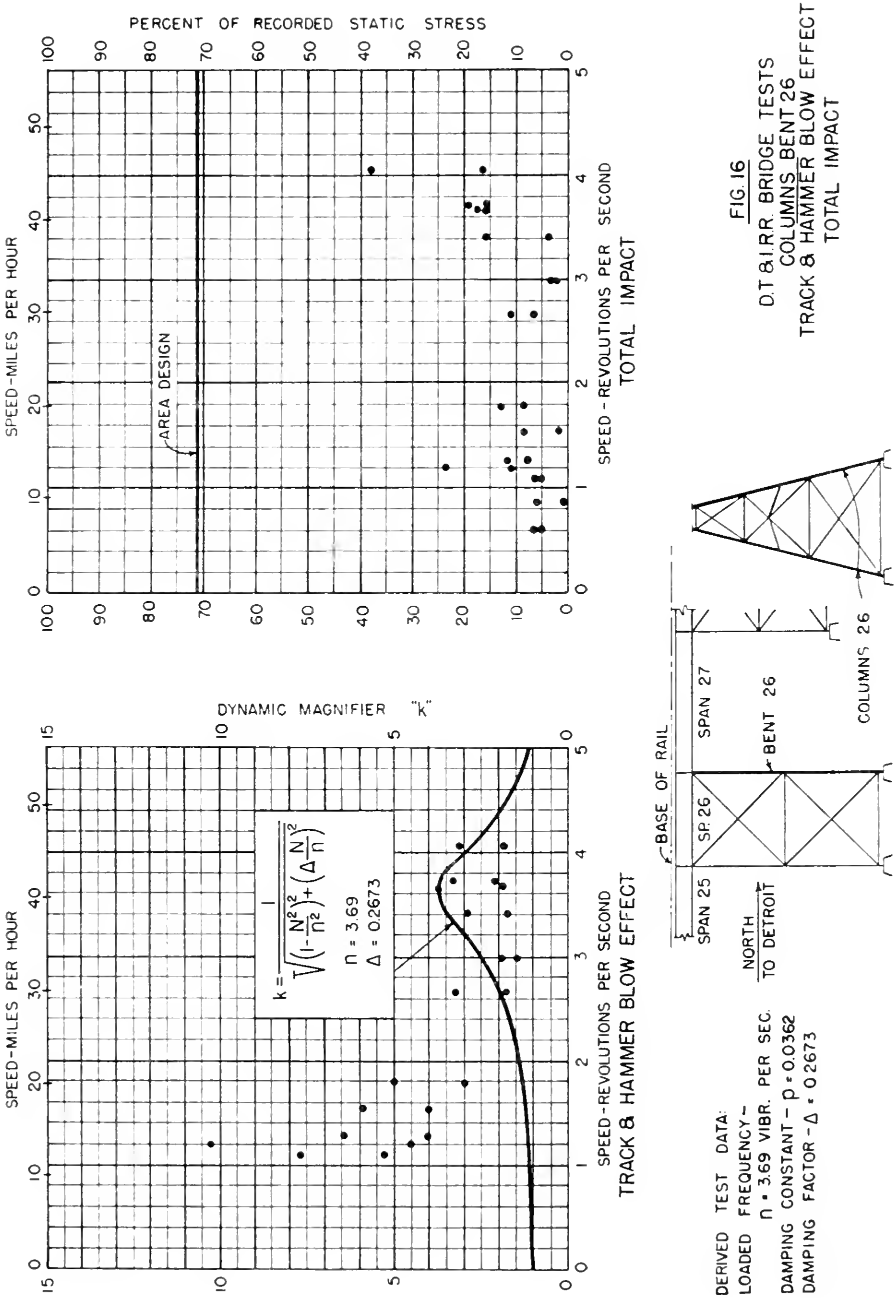


FIG. 16
D.T.&I.R.R. BRIDGE TESTS
COLUMNS BENT 26
TRACK & HAMMER BLOW EFFECT
TOTAL IMPACT

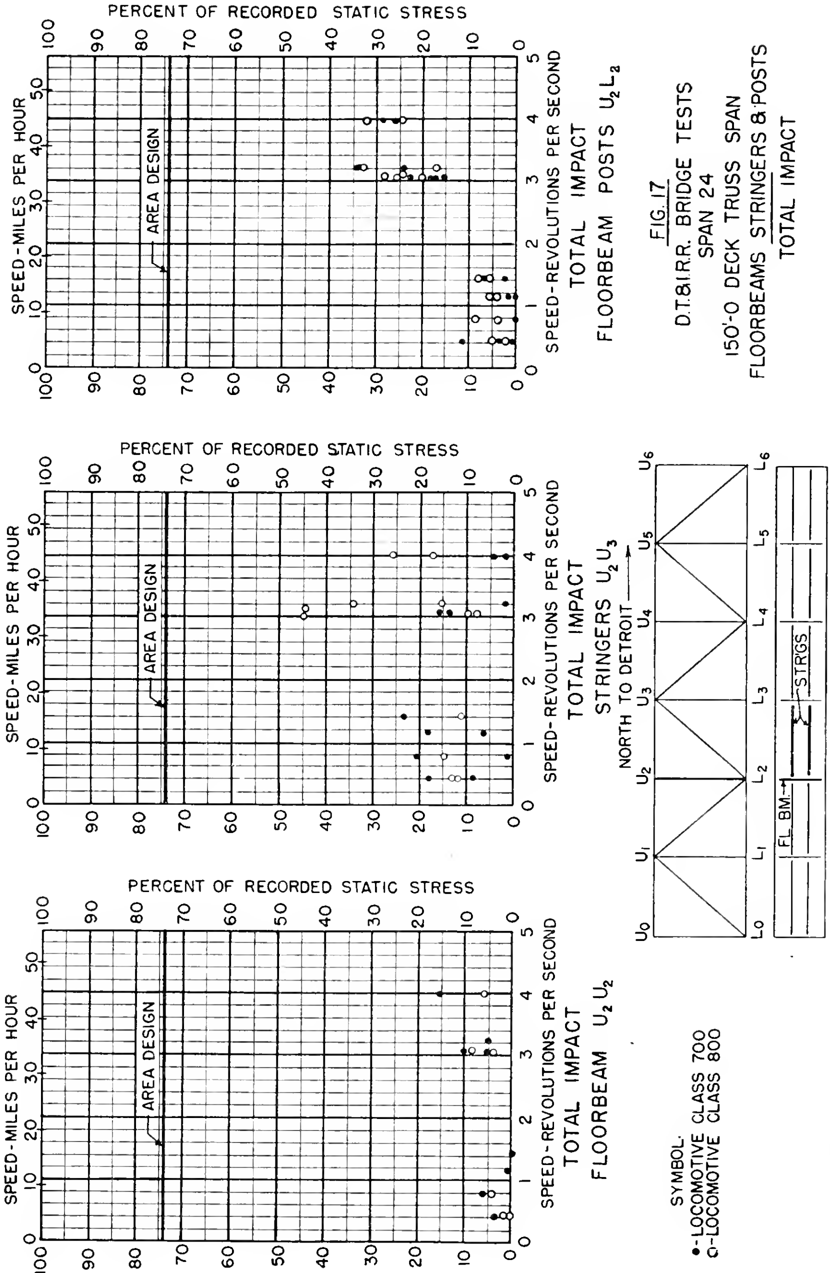


FIG. 17
D.T.&I.R.R. BRIDGE TESTS
SPAN 24
150'-0 DECK TRUSS SPAN
FLOORBEAMS STRINGERS & POSTS
TOTAL IMPACT

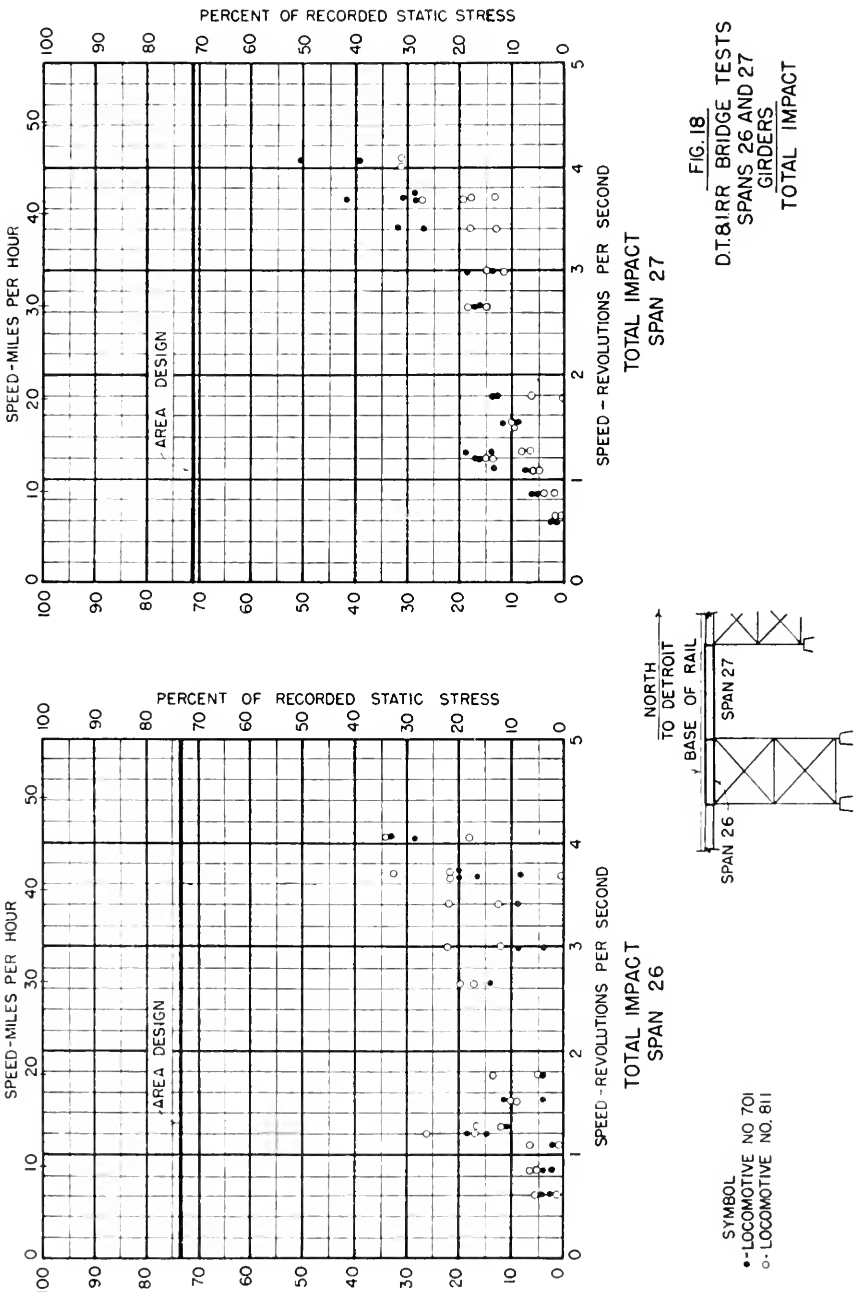


FIG. 18
D.T.&I.RR BRIDGE TESTS
SPANS 26 AND 27
GIRDERS
TOTAL IMPACT

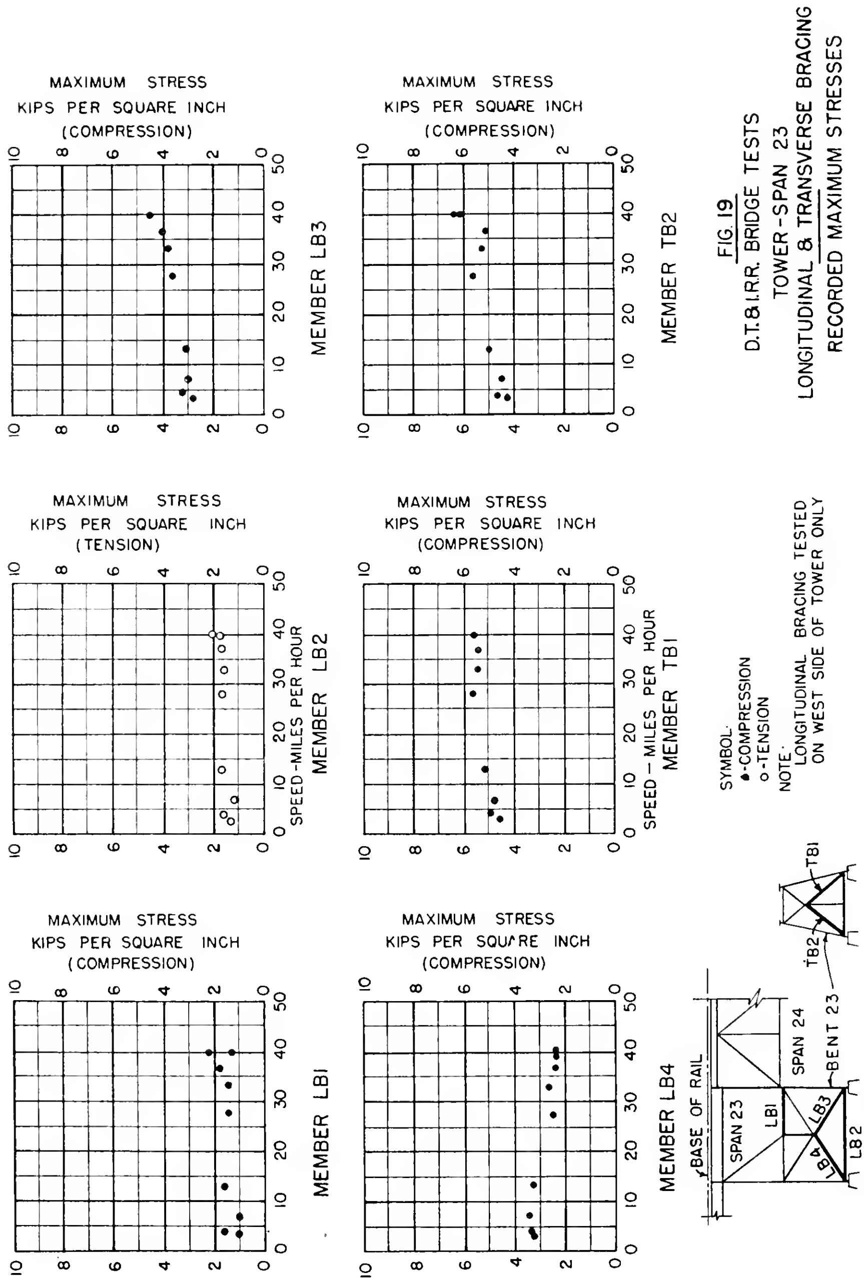


FIG. 19
D.T.&I.R.R. BRIDGE TESTS
TOWER-SPAN 23
LONGITUDINAL & TRANSVERSE BRACING
RECORDED MAXIMUM STRESSES

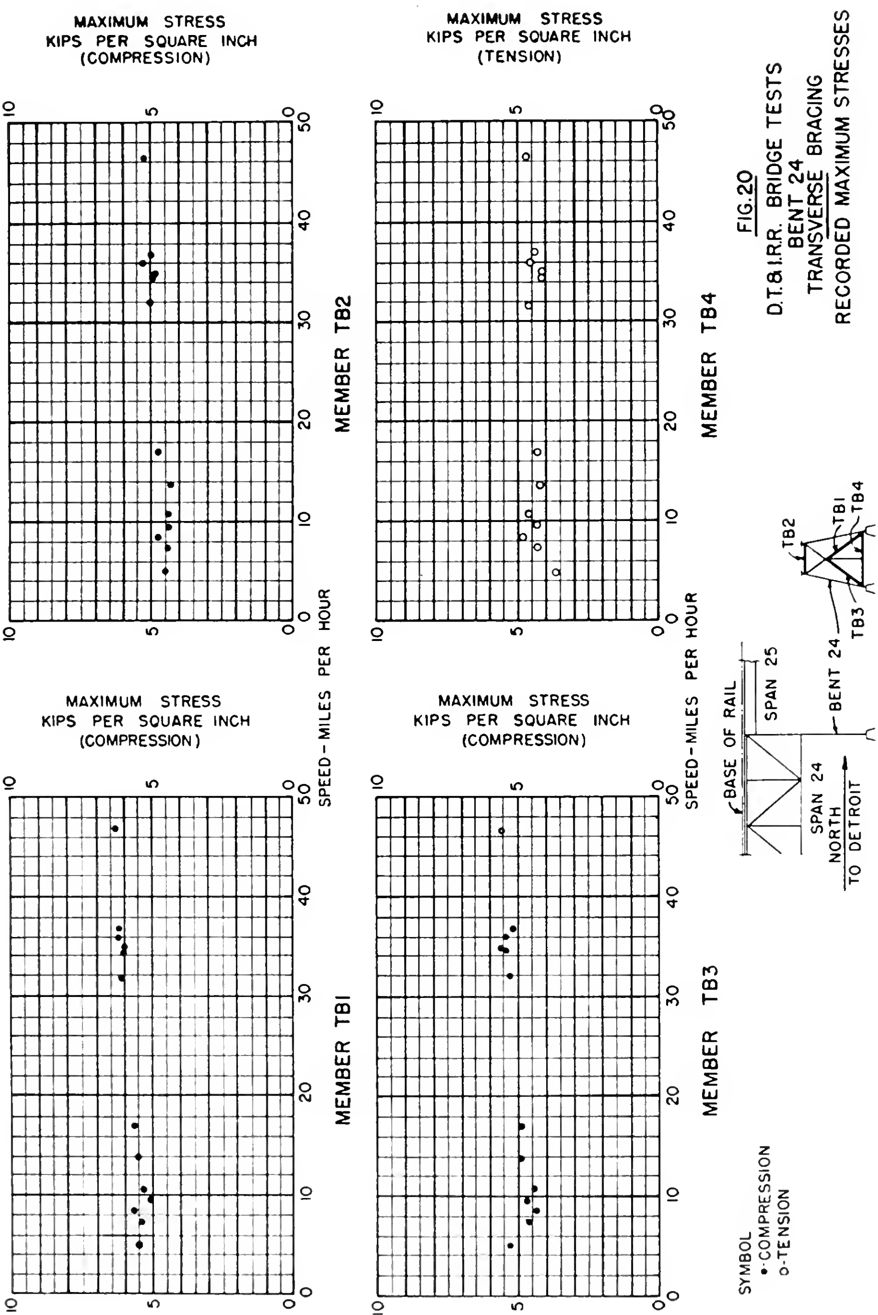


FIG. 20
D.T.&I.R.R. BRIDGE TESTS
BENT 24
TRANSVERSE BRACING
RECORDED MAXIMUM STRESSES

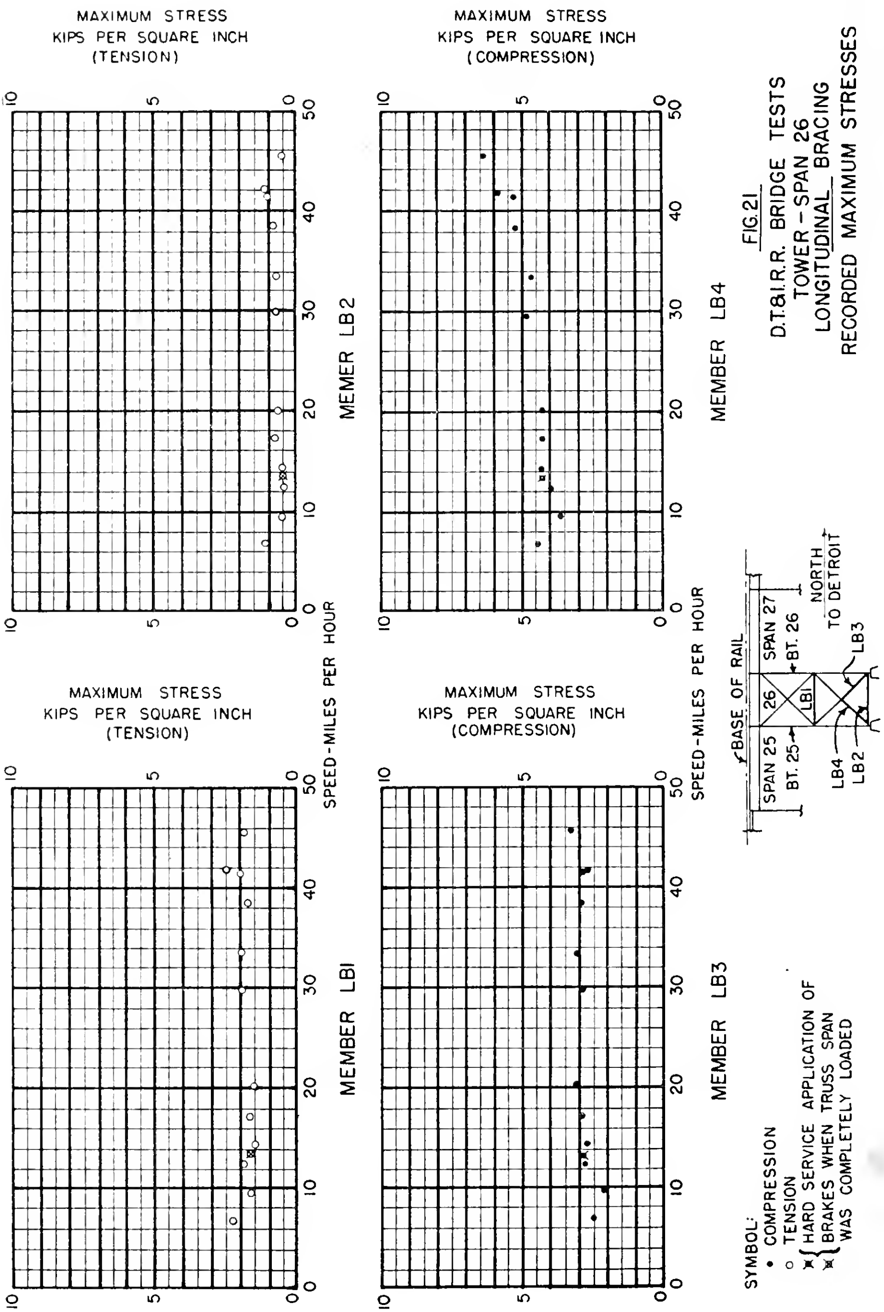


FIG. 21
D.T.&I.R.R. BRIDGE TESTS
TOWER - SPAN 26
LONGITUDINAL BRACING
RECORDED MAXIMUM STRESSES
MAXIMUM STRESS
KIPS PER SQUARE INCH
(TENSION)
(COMPRESSION)
SPEED-MILES PER HOUR
MEMER LB2
MEMBER LB4
MEMBER LBI
MEMBER LB3
BASE OF RAIL
SPAN 25
SPAN 27
BT. 25
BT. 26
26
LBI
LB2
LB3
LB4
NORTH TO DETROIT
SYMBOL:
• COMPRESSION
○ TENSION
HARD SERVICE APPLICATION OF BRAKES WHEN TRUSS SPAN WAS COMPLETELY LOADED

(text continued from page 66)

Speed Effect

Examination of the mean stresses disclosed evidence of a slight increase in stress with an increase in speed and this increase has been called speed effect in all the previous tests. The measured speed effects for the end post and chord members, in percent of the measured crawl stress, have been plotted in the left diagram of Fig. 10. The effect appears to be quite small for this length of span, the maximum value being about 8 percent.

The indicated speed effects at the low speeds are actually variations in the static readings. For example, in member L_0 U_1 the static mean stress varied from 7.03 to 7.34 with an average of 7.19 ksi., (See column 6, Table 1). The average value of 7.19 was taken as the static stress in this member but the value of 7.34 resulted in an indicated speed effect of 2.1 percent for this particular slow speed run.

Roll Effect

The effect of the spring-borne weight of the locomotives oscillating about a longitudinal axis is to increase the pressure on one rail with a corresponding decrease in pressure on the other rail. The variation in pressure on the rails produces a change in the direct mean stresses of the truss members.

The magnitude of the increase in stress in the end post and chord members of the 150-ft. span was found by subtracting the average direct mean stress from the maximum direct mean stress. The increase in pressure on the rail which would produce the difference in stress in the end post and chord members, in percentage of the recorded static stress, is shown in the right diagram of Fig. 10. For example, when the test locomotives crossed the bridge at 3.22 rps. the stress in the east truss was found to be 6.6 percent greater than the average stress in both trusses due to an increase in pressure on the east rail of 22.5 percent for this particular run. There is considerable variation in the rolling effect on this span but it appears that this effect is about the same at all speeds and that the present AREA allowance for roll is about correct.

Track and Hammer Blow Effect

The semi-amplitudes of stress in the truss members and columns result principally from the periodic disturbing force of the counterweights of the locomotives. This disturbing force, or hammer blow, is due to the centrifugal force of the unbalanced weights on the revolving driving wheels (See Figs. 8 and 9). It is quite possible that in some cases the condition of the track would tend to either increase or decrease the oscillations caused by the hammer blow. However, examination of the strain records indicated very regular curves when the locomotive speeds were at or close to the natural period of vibration of the span and the frequency of the oscillations was the same as the frequency of the driver revolutions. The strain records indicated considerable vibrational effects at the lower locomotive speeds but their magnitude was quite small with a high frequency of vibration. It appears that these small vibrational effects are produced by the condition of the track.

The dynamic magnifiers or the ratio of the measured semi-amplitudes to the calculated hammer blow stresses in the members of the trusses and columns were obtained in the same manner as in the Toledo Terminal tests. The dynamic magnifiers for these members are shown in the left diagrams of Figs. 11 to 16, incl. It should be pointed out that the values for the dynamic magnifiers at the lower speeds are quite large, but at these speeds the actual values of the semi-amplitudes of stress are appreciably lower than they are at the critical speed. It must also be remembered that undoubtedly the greater portion of the semi-amplitudes at the lower speeds represent track effect.

It is apparent from the dynamic magnifier values plotted for the members of the trusses, Figs. 11 and 12, that the loaded frequency of the span is about 2.85 vibrations per second and this value has been used to calculate the curves for the value of k shown on these diagrams. The loaded frequency of each column was determined from the plotted values and the k curves calculated and drawn on each diagram, Figs. 13 to 16, incl.

The values for the damping constant p and the damping factor Δ were then computed and these values are shown in the lower left side of the figures. The following comparison of the values obtained for this 150-ft. span with those obtained for the 142-ft. Toledo Terminal span clearly indicates that the damping forces in this span are quite large, probably due to the fact that the trusses are supported on columns which act as springs.

	Toledo Terminal 142-ft. span		*D. T. & I. R. R. 150-ft. span*		*Column 23*	*Column 24*	*Column 25*	*Column 26*
	Chords	*Webs*	*Chords*	*Webs*				
Damping constant p	0.0111	0.0136	0.0336	0.0204	0.0407	0.0405	0.0381	0.0362
Damping factor Δ	0.0645	0.0789	0.1919	0.1165	0.2020	0.2590	0.2595	0.2673

Total Impact

The total impact percentage is the increase in the direct stress in the member over the direct static stress occurring at a slow speed. The total impacts are the combinations of (1) speed effect, (2) roll effect and (3) track and hammer blow effects, although it would be only by chance that the maximum for all effects would occur simultaneously.

It should be mentioned that the total impacts determined from the results of these tests were obtained under test locomotives at comparatively low speeds. However, it can be seen from the diagrams of dynamic magnifiers that the speed of the locomotive drivers in revolutions per second exceeded the natural loaded frequency of vibration of the truss span. It is quite possible that at still higher speeds a second critical speed might have been attained, resulting in possibly still higher total impacts. The maximum speeds of the test locomotives were considerably below the natural loaded frequency of the stringers, floorbeams, floorbeam posts and girder spans, but the tests on short span bridges, Proceedings Vol. 46, 1945, page 189, indicated that even on short spans the maximum impacts were attained at a speed of 40 to 50 mph.

150-Ft. Deck Truss Span-Chord and Web Members

The total impact percentages, as determined from these tests for the end post and chord members of the 150-ft. deck truss span, are shown in the right diagram of Fig. 11, while those obtained in the web members are shown in the right diagram of Fig. 12. These diagrams also show the impact percentage as computed by the 1948 AREA design specifications.

The impacts in these members are lower than those found on other truss spans of about the same length, indicating that the high damping characteristics of this structure materially reduced the impacts.

150-Ft. Deck Truss Span—Stringers, Floor Beams and Floor Beam Posts

The total impact percentages as determined from these tests for the stringers, floorbeams and floorbeam posts are shown in the three diagrams of Fig. 17. The calculated values as recommended by the 1948 AREA design specifications are also shown on these diagrams.

Separate values for each locomotive designated by different symbols in the diagrams were obtained as the coupled test locomotives crossed over the stringers, floorbeams or floorbeam posts.

It can be seen from these diagrams that the total impacts in these members are quite low. The low impact values could be the result of relatively low locomotive speeds or to the elastic supports of the members.

Columns—Bents 23, 24, 25 and 26

The total impact percentages for the columns of bents 23, 24, 25 and 26 are shown in the right diagrams of Figs. 13 to 16, incl. The calculated values as recommended by the 1948 AREA design specifications are also shown on these diagrams.

It is apparent from these diagrams that there is an increase in impact with an increase in speed but the maximum total impact values are considerably below the AREA design allowance.

Girders—Spans 26 and 27

The total impact percentages for the 30-ft. and 45-ft. girders of spans 26 and 27 are shown in the two diagrams in Fig. 18. The calculated values as recommended by the 1948 AREA design specification are also shown on these diagrams.

Separate values for each locomotive designated by different symbols in the diagrams were obtained as the coupled test locomotives crossed over the girders.

It is interesting to note that the maximum impacts in the 45-ft. span were greater than those obtained in the 30-ft. span. The test runs were made on both girders at the same time and the locomotive driver diameters are such that the angular position of the pins are about the same as both spans so that apparently the variation between the impacts in the two spans must be due to some track condition.

Maximum Stresses in Bracing

The maximum direct stresses recorded in the longitudinal bracing of tower span 23 and in the transverse bracing of bent 23 are shown in the diagrams of Fig. 19.

The longitudinal and transverse bracing members shown in Fig. 19 were all in compression, except the longitudinal member LB2 which was in tension. These compressive stresses were apparently due to the shortening of the columns thus introducing a vertical component in the bracing members.

The direct stresses in the transverse bracing of bent 24 are shown in the diagrams of Fig. 20. The magnitude and sign of the stresses in these bracing members are about the same as those in bent 23.

The direct stresses recorded in the longitudinal bracing of tower span 26 are shown in the diagrams of Fig. 21. The magnitude and sign of the stresses in these bracing members are about the same as those in tower span 23.

The stresses in the longitudinal and transverse bracing members shown in Figs. 19 to 21, incl., were secured under regular operation of the test locomotives. The locomotives were generally working steam until they were across the span being tested. One run was secured at about 15 mph. during the testing of the longitudinal bracing of tower span 26, Fig. 21, in which a hard service application of the brakes was made just as the drivers of the first locomotive were coming onto span 25. It is apparent from the recorded stresses shown in the diagrams of Fig. 21 by the special stress symbol that no longitudinal force was carried by the bracing of this tower.

8. Conclusions

These tests afforded an opportunity to measure and compare the simultaneous stresses on the four corners of any member as well as the simultaneous stresses in several members, providing certain information not heretofore available.

Many interesting and valuable data regarding the action of a viaduct were obtained but it must be kept in mind that these tests represent but one viaduct so that it is impossible to arrive at any design recommendations for such a structure.

From the data, as found from these tests, it seems logical to conclude that:

1. *Static Stresses.*—Variation between the calculated and the recorded stresses in the members of the 150-ft. truss span is believed to be due to the action of the stringers in taking direct stress, since the upper chord stresses are lower and the lower chord stresses are in agreement or slightly higher than the calculated stresses.

There is fair agreement between the actual and calculated static stresses in the columns, the maximum variation occurring in the columns of bent 23 where the actual stress was 13 percent greater than the calculated stress.

The actual stresses in the girders were slightly below the calculated stresses and this relation has been found for other tests.

2. *Secondary Stresses.*—The secondary stresses or the bending stresses resulting from the rotation of the joint were greater in the 150-ft. trusses than would normally be expected. It appears that the deflection of the stringers and floor beams has a marked influence on the bending stresses in the members.

The secondary stresses in the viaduct columns are very large, the maximum occurring in the west column of bent 26 where the bending stress was 117.2 percent of the direct stress.

The secondary stresses in both the truss members and column increase in about the same proportion as the increase in the direct stresses with an increase in speed.

3. *Speed Effect.*—The increase in the direct stresses in the truss members due to speed was very small for this 150-ft. span.

4. *Roll Effect.*—A few of the direct stresses in the 150-ft. truss span due to roll were greater than the AREA design allowance and this rolling effect did not bear any relation to speed.

5. *Track and Hammer Blow Effects.*—The track and hammer blow effects in the 150-ft. truss members were considerably below those found in previous tests of similar trusses, indicating that the type of support plays an important part in these effects. The damping characteristics were found to be quite large in the truss span and in the columns.

6. *Total Impacts.*—The total impacts in all the members of this structure were below those specified by the AREA design specification.

7. *Longitudinal and Transverse Bracing.*—The stresses in the longitudinal and transverse bracing of the viaduct towers appear to be the result of the compressive stresses in the columns. No evidence of large longitudinal or transverse forces was found even though the brakes were applied for one test.

9. Acknowledgment

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are indebted to the Detroit, Toledo & Ironton Railroad for the use of the data covering these tests.

Impact Tests of a Pin-Connected Truss Span

Paint Creek Bridge, Detroit, Toledo & Ironton Railroad

Advance Report of Committee 30—Impact and Bridge Stresses

1. Digest

This report embraces a description and analysis of tests made on a truss bridge of the Detroit, Toledo & Ironton Railroad. The bridge consists of two 136-ft. 9-in. through truss spans with an open floor, supported by a concrete substructure. The tests were made under both a single and double-headed test train operating over a complete range of speeds from 5 mph. up to 45 mph. which was the maximum allowable speed in this territory. The tests were made by the research staff of the Engineering Division, Association of American Railroads, at the request and at the expense of the railroad for the purpose of determining the carrying capacity or rating of the superstructure by strain gage readings.

The stresses were measured by means of electromagnetic strain gages with oscillograph recording on sensitized photographic paper and a total of 80 test runs were recorded under the special test trains.

The results of these tests are of particular interest to bridge engineers for they are the first published data on the static and dynamic stresses in a pin-connected truss span having eyebar members where the stresses were recorded by modern electrical strain gages. The data were analyzed principally for the purpose of determining the carrying capacity of the span but also analyzed for the purpose of studying the magnitude of the individual effects which make up the total static and dynamic stresses.

A brief summary of the analysis of the data as found from this study is as follows:

1. The recorded static stresses in the end posts and top chord members agreed very well with those calculated for the same loads and position of loads but the actual lower chord stresses varied from 54 to 78 percent of the calculated stresses (see Table 1). The variation between the calculated and actual stresses appears to be due to the action of the stringers in taking direct stress.

2. The simultaneous stresses at the four corners of the built-up main truss members were obtained by placing gages on each corner and a summary of the analysis of these stresses is shown in Table 2. The bending stresses were quite low, except in one top chord member where the bending stress amounted to 35.7 percent of the direct stress. The bending stress, acting as an eccentrically applied direct load, reduces the carrying capacity of the member.

The bending stresses in the floorbeam hangers, member U_1 L_1, are shown in Table 2 and were found to be 56.4 percent of the direct stress in the east truss and 49.0 percent in the west truss. The high bending stresses in these hangers are induced by the stringer and floorbeam deflections and are common for such members.

The amount of the direct stress carried by each bar of the eyebar members, as well as the bending stresses in each bar, were obtained by placing two gages on each bar. The distribution and bending stresses are summarized in Table 3. It was found that each bar was carrying its proportion of the direct load within 5 percent, which is unusual for eyebar members. However, the loose bars of these members had recently been shortened. The stresses on one edge of one eyebar were found to be 32 percent greater than the direct stress in this bar, resulting from either bending or eccentrically applied direct load caused by pin hole wear.

3. The speed effect stresses were quite small for this span as shown in Figs. 3 and 4 and appear to be about 11 percent.

4. The increase in stress in one truss with a corresponding decrease in stress in the other truss, presumably caused by oscillating of the spring-borne weight of the locomotive about a horizontal axis, has been termed "roll effect." These effects are shown in Figs. 3 and 4 and exceeded the AREA design allowance by an appreciable amount. Rolling effects as high as 20 percent were recorded at speeds as low as 10 mph.

5. A summary of the vibrational effect, in terms of the magnification of the locomotive hammer blow stresses is shown in the left diagrams of Figs. 5 and 6. The damping characteristics of the structure were computed from the diagrams of dynamic magnifiers and these values were found to be about the same as those found in the Toledo Terminal tests, but considerably lower than those found for the Quincy viaduct. It appears that the type of substructure plays an important part in the vibrations of truss spans.

6. The "total impact" is the amount by which the maximum direct stress occurring under the locomotives at various speeds exceeds the static direct stress recorded at a speed of about 5 mph. The total impacts in the main truss members are shown in the right diagrams of Figs. 5 and 6. As shown in these diagrams, the total impacts at a speed of about 3.0 rps., or 35 mph., exceeded the AREA design allowance.

The total impacts in the stringers, floorbeams and floorbeam hangers are shown in Fig. 7 and these values are considerably below the AREA design allowance, especially for the stringers and floorbeams.

2. Foreword

The bridge impact tests analyzed in this report were conducted at the request of the Detroit, Toledo & Ironton Railroad and the salaries and expenses of the members of the staff who operated the instruments were borne entirely by the railroad. The tests were made in the spring of 1945 after the tests on the Quincy viaduct were completed. The tests were carried out under the general direction of G. M. Magee, research engineer, Engineering Division, Association of American Railroads. The conduct of the tests, analysis of data and preparation of the report were in charge of E. J. Ruble, structural engineer, research staff, AAR.

The structure tested (see Fig. 1), is a two-span structure consisting of 136-in. 9-in. through pin-connected trusses with open floor, supported by a concrete substructure. The bridge was designed for a Cooper E 45 loading and was built in 1904 and reinforced in 1943. Since the railroad has been operating heavier classes of power over this structure, the engineering department of the railroad requested the research staff of the AAR to measure the strains in the various members under the heavier power by means of electrical strain gages.

Readings were secured under both single-headed and double-headed test trains at speeds varying from 5 mph. up to the maximum speed of 45 mph. permitted in this territory. A total of 80 runs was made during the testing of the bridge.

3. Instruments and Test Locomotives

The electrical instruments used in these tests were the same as those used in the Quincy viaduct tests as reported elsewhere in this volume.

The locomotives used were of the same class as those used in the tests on the Quincy viaduct. However, since this truss span was shorter than the truss span in the viaduct, the majority of the tests were made under a single-headed test train followed by loaded coal cars. Several runs were made under a double-headed test train for comparison with those made with one locomotive.

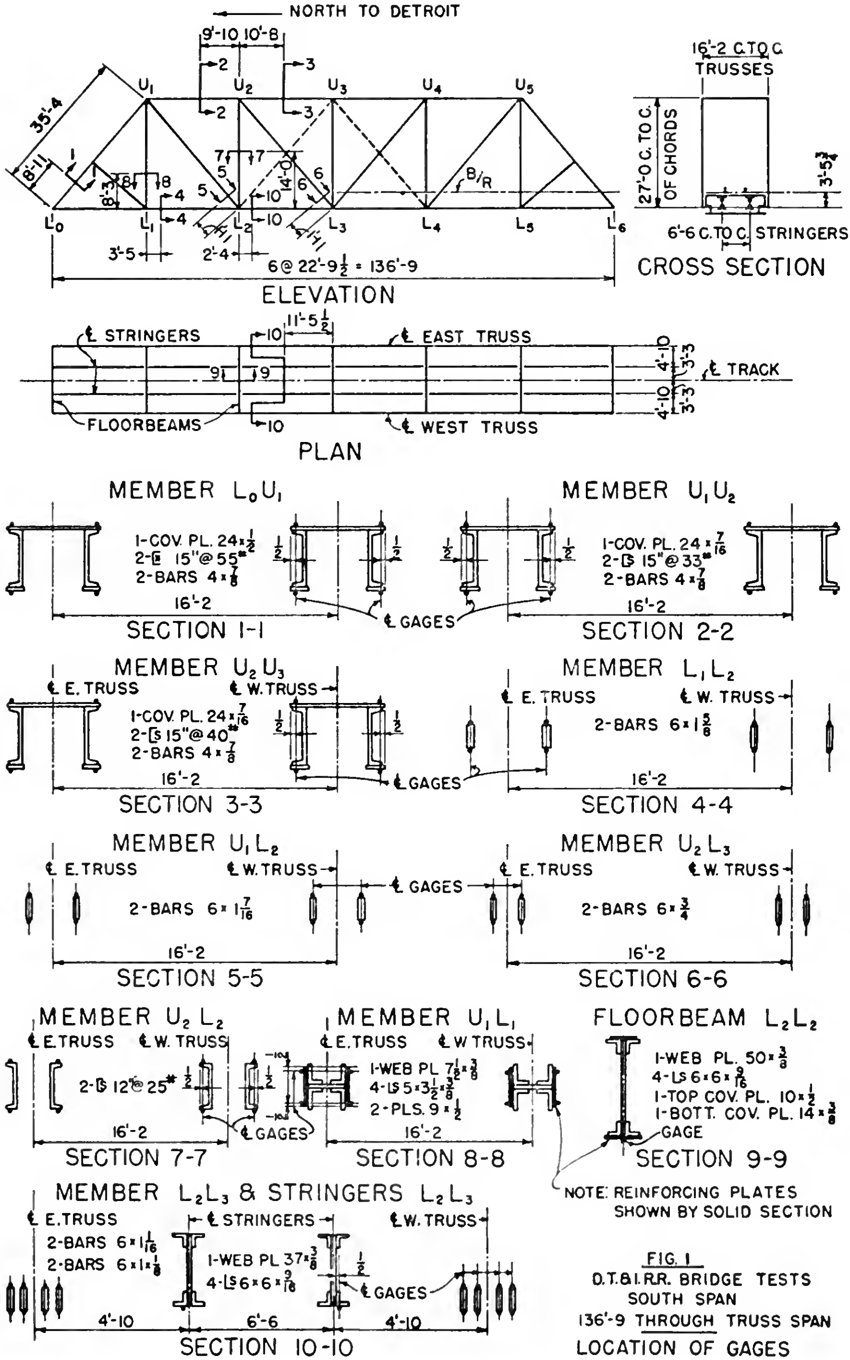


FIG. 1
D.T.& I. R.R. BRIDGE TESTS
SOUTH SPAN
136'-9 THROUGH TRUSS SPAN
LOCATION OF GAGES

4. Test Spans and Location of Gages

The bridge tested is located near Bainbridge, Ohio and spans Paint creek. The single-track, open floor bridge consists of 2 through pin-connected truss spans each having a span length of 136 ft. 9 in. supported on concrete abutments with a center concrete pier. Representative members of one truss span, including the floor system were tested as shown in Fig. 1.

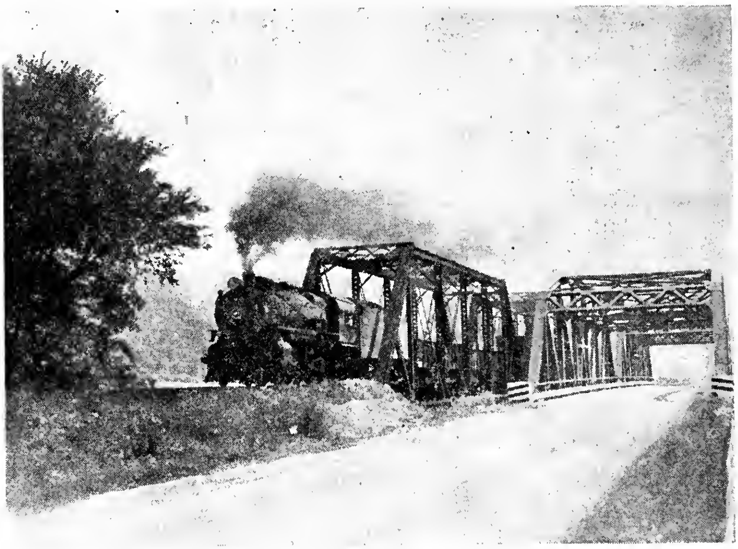


Fig. 2.—Test Locomotive Crossing the Bridge.

The members of both trusses were tested at the same time and gages placed on each of the four corners of the built-up member in the same manner as for the Quincy viaduct. Two gages were placed on each of the eyebars as it has been found from previous tests that the stresses are not always equal on the two edges of such members.

The end posts, top chords, hangers and floorbeams had been reinforced in 1943 by riveting or welding additional plates to the members (see Fig. 1). The loose eyebars had been tightened by cutting the bars and welding on plates and turnbuckles.

5. Analysis of Field Records

The test records were read and the stresses tabulated in the same manner as described in the report on the Toledo Terminal Railroad tests, Proceedings, Vol. 49, 1948, page 677. The tables containing all the data taken from the oscillograms and entitled "Tabulation of Recorded Stresses" and "Analysis of Strain Gage Readings" are on file in the Engineering Division offices, AAR.

6. Static and Dynamic Effects

The data, as taken from the oscillograms and summarized in the previously mentioned tables, were analyzed for the particular purpose of studying the static and dynamic effects in the same manner as was done in the report on the Quincy viaduct appearing in this volume. The results of this study are as follows:

Static Stresses

The comparison of the recorded and calculated live load static stresses in the various truss members, including the stringers, floorbeams and hangers, is shown in Table 1. There is excellent agreement between the calculated and static stresses in the end posts and top chord members, where the recorded stress varied from 11 percent below to 5 percent above the calculated stress. The recorded stresses in the lower chord members were far below the calculated stresses but it should be kept in mind that these spans are of the through type so that the stringers were undoubtedly taking part of the lower chord direct stress.

The recorded stresses in the floorbeams are about 10 percent below the calculated stresses while those in the hanger are only 3 percent below the calculated. It is interesting to note that the recorded stresses in the stringers are about 14 percent greater than the calculated stress which is very unusual in such short span members.

Secondary Stresses

The bending stresses and derived eccentricities for the built-up truss members are shown in Table 2 for three locomotive speeds, usually a slow speed, an intermediate speed and a high speed. It can be seen that the percent of bending and the derived eccentricities are about constant in each member at all the speeds. The maximum eccentricity in the truss chords was recorded in the east truss of member U_2 U_3, where the eccentricity was 1.08 in. about the horizontal axis and 0.67 in. about the vertical axis. As shown in column 21 of Table 2, the maximum stress on one corner of the member at mid length was 35.7 percent greater than the direct stress. The bending stress in the floorbeam hangers, member U_1 L_1, amounted to 56.4 percent in the east truss and 49.0 percent in the west truss but large bending stresses can be partially accounted for in these members by the floorbeam deflection.

The percentage of bending and the distribution of stresses between the bars in the eyebar members are shown in Table 3 for three locomotive speeds and it can be seen that the effect of speed is negligible on these factors. The distribution of live load stresses between the bars was excellent on this bridge. For example, in member L_2 L_3 of the east truss (see columns 22 to 25, incl.), the outside bar of the 4 bars was carrying 26.0 percent of the total direct stress recorded at 8.7 mph., the interior bars 26.3 and 26.4 percent and the inside bar 21.3 percent. In this same member, the stress on one edge of the outside bar was 26.3 percent greater than the average stress in the bar (see column 12). The percentage of bending stress in the remaining bars is shown in columns 15, 18 and 21. The values shown in columns 8 and 9 are the total percentage of increase in stress in the member resulting from both bending and distribution. For example, in the east truss of member L_1 L_2, the recorded stress on one edge of one of the bars was 45.3 percent greater than the direct stress in the member. As previously mentioned, the eyebars of this bridge had recently been adjusted, which accounts for the excellent distribution of stress between the bars.

Speed Effect

The recorded speed effects for the end posts and chord members, in percent of the measured crawl stress, are shown in the left diagrams of Fig. 3. The speed effects on this bridge are somewhat larger than those recorded on the Quincy viaduct under the same locomotive classes. The increase in mean stresses due to speed in these members appears to be about 11 percent.

The recorded speed effects for the web members are shown in the left diagrams of Fig. 4 and they are somewhat lower than those recorded in the end posts and chord members.

(text continued on page 100)

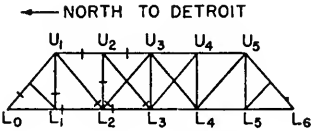


TABLE I
COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES
136'-9 THROUGH TRUSS SPAN

MEMBER	TEST LOCOM.	DIRECTION	RECORDED STATIC STRESS			CALCULATED STATIC STRESS	STRESS FACTOR = RECORDED / CALCULATED	
			EAST TRUSS	WEST TRUSS	AVERAGE			
COL. 1	2	3	4	5	6	7	8	9
L_0U_1	807	NORTH	−5.64 −5.49 −5.54	−4.87 −4.58 −4.89	−5.25 −5.04 −5.22	−4.99	1.05 1.05 1.01	1.04
U_1U_2	702	NORTH	−8.25 −7.91 −8.11	−8.02 −7.61 −7.73	−8.14 −7.76 −7.92	−7.89	1.03 0.98 1.01	1.01
U_2U_3	807	NORTH	−6.93 −6.39 −6.50	−6.18 −6.21 −6.17	−6.56 −6.30 −6.34	−7.04	0.93 0.89 0.90	0.94
	800	NORTH	−6.49 −6.66	−6.73 −6.50	−6.61 −6.58	−6.67	0.99 0.99	
	703	NORTH	−7.83 −7.82 −7.40 −7.49	−7.25 −7.39 −7.01 −7.53	−7.54 −7.61 −7.21 −7.51	−7.79	0.97 0.98 0.93 0.97	
	802	NORTH	−6.45 −6.25 −6.10	−6.08 −5.70 −5.97	−6.27 −5.98 −6.04	−6.75	0.93 0.89 0.90	
L_1L_2	800	NORTH	+4.95 +5.13	+4.17 +4.27	+4.56 +4.70	+8.45	0.54 0.56	0.56
	703	NORTH	+5.38 +5.29 +5.75 +5.73	+5.26 +5.26 +5.21 +4.90	+5.32 +5.27 +5.48 +5.32	+9.55	0.56 0.55 0.57 0.56	
L_2L_3	701	SOUTH	+8.71 +8.29 +7.95	+7.93 +7.18 +7.35	+8.32 +7.74 +7.65	+10.68	0.78 0.72 0.72	0.74
U_1L_2	807	NORTH	+9.85 +8.97 +9.54	+9.24 +8.86 +9.03	+9.55 +8.92 +9.29	+10.21	0.93 0.87 0.91	0.91
U_2L_2	702	NORTH	−5.39 −5.08 −5.10	−5.52 −5.46 −5.29	−5.46 −5.27 −5.20	−6.06	0.90 0.87 0.86	0.88
U_2L_3	802	NORTH	+9.28 +9.02 +9.45	+9.29 +9.11 +9.25	+9.28 +9.07 +9.35	+11.92	0.78 0.76 0.78	0.81
	702	NORTH	+8.81 +8.40 +8.37	+8.65 +8.25 +8.47	+8.73 +8.33 +8.42	+10.12	0.86 0.82 0.83	
HANGER U_1L_1	800	NORTH	+4.47 +4.68	+3.67 +3.90	+4.07 +4.29	+4.33	0.94 0.99	0.97
	703	NORTH	+4.52 +4.68 +5.10 +4.97	+3.92 +4.20 +4.07 +4.04	+4.22 +4.44 +4.59 +4.50	+4.59	0.92 0.96 1.00 0.98	
FLOOR BEAM L_2L_2	701	SOUTH	——	——	+6.01 +5.71 +5.91	+6.51	0.92 0.88 0.91	0.90
STRINGERS L_2L_3	701	SOUTH	+9.76 +9.28	+10.38 +11.20	+10.12 +10.24	+8.93	1.13 1.15	1.14

NOTE: STRESSES SHOWN ARE IN KIPS PER SQUARE INCH

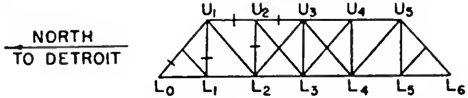
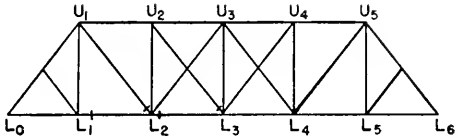


TABLE 2
SECONDARY STRESSES
FABRICATED MEMBERS
136'-9 THROUGH TRUSS SPAN

MEMBER	DEPTH/LENGTH HORIZ. AXIS 1-1	DEPTH/LENGTH VERT. AXIS 2-2	TEST LOCOMOTIVE	DIRECTION	TRUSS	SPEED M.P.H.	MAXIMUM DIRECT STRESS	BENDING — HORIZONTAL AXIS 1-1: STRESS	STRESS IN PERCENT		DERIVED ECCENTRICITY INCHES		BENDING — VERTICAL AXIS 2-2: STRESS	STRESS IN PERCENT		DERIVED ECCENTRICITY INCHES		BENDING — BOTH AXIS: STRESS	STRESS IN PERCENT	
COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
L_0U_1	0.039	0.057	807	NORTH	EAST	6.3	-5.97	0.26	4.3		0.22		0.61	10.2		0.66		0.86	14.4	
						29.7	-6.41	0.32	5.0	4.9	0.25	0.25	0.75	11.7	9.5	0.76	0.62	1.10	17.2	14.9
						41.7	-6.24	0.33	5.3		0.27		0.41	6.6		0.43		0.82	13.2	
					WEST	6.3	-5.11	0.21	4.1		0.21		0.93	18.2		1.18		0.55	10.8	
						29.7	-5.73	0.23	4.0	4.5	0.20	0.23	0.89	15.5	17.0	1.01	1.10	1.16	20.2	17.9
						41.7	-5.44	0.29	5.3		0.27		0.93	17.2		1.11		1.23	22.6	
U_1U_2	0.060	0.088	702	NORTH	EAST	6.7	-8.81	0.47	5.3		0.31		0.52	5.9		0.38		1.22	13.9	
						30.1	-9.64	0.54	5.6	6.8	0.33	0.40	0.66	6.7	6.6	0.44	0.43	1.42	14.7	16.0
						45.9	-10.50	1.01	9.6		0.57		0.76	7.2		0.47		2.04	19.5	
					WEST	6.7	-8.57	0.54	6.3		0.37		0.46	5.4		0.35		1.42	16.6	
						30.1	-9.27	0.68	7.3	6.9	0.43	0.41	0.39	4.2	4.7	0.27	0.30	1.47	15.9	16.0
						45.9	-9.97	0.72	7.2		0.42		0.45	4.5		0.29		1.53	15.4	
U_2U_3	0.060	0.088	703	NORTH	EAST	5.0	-8.35	1.62	19.4		1.08		0.90	10.8		0.71		3.12	37.4	
						31.2	-9.60	1.78	18.6	19.4	1.04	1.08	0.91	9.5	10.2	0.62	0.67	3.31	34.5	35.7
						45.3	-9.24	1.87	20.3		1.13		0.96	10.4		0.69		3.25	35.2	
					WEST	5.0	-7.68	0.66	8.6		0.48		0.33	4.3		0.28		1.10	14.3	
						31.2	-9.33	1.01	10.8	10.3	0.60	0.58	0.37	4.0	3.8	0.26	0.25	1.48	15.9	15.7
						45.3	-8.93	1.03	11.6		0.65		0.28	3.1		0.21		1.50	16.8	
U_1L_1	0.032	0.028	703	NORTH	EAST	5.0	+5.05	2.70	53.5		1.49		0.07	1.4		0.02		2.99	59.2	
						31.2	+5.65	2.75	48.7	48.8	1.35	1.36	0.13	2.3	2.5	0.03	0.03	3.24	57.3	56.4
						45.3	+6.28	2.78	44.3		1.23		0.24	3.8		0.05		3.32	52.8	
					WEST	5.0	+4.45	2.07	46.5		1.29		0.34	7.6		0.11		2.41	54.1	
						31.2	+5.30	2.12	40.0	44.1	1.11	1.23	0.10	1.9	4.2	0.03	0.05	2.38	44.9	49.0
						45.3	+5.60	2.57	45.9		1.28		0.17	3.0		0.04		2.69	48.1	
U_2L_2	0.037	0.047	702	NORTH	EAST	6.7	-5.99	0.20	3.3		0.10		0.51	8.5		0.30		1.06	17.7	
						33.0	-7.71	0.09	1.2	2.3	0.04	0.07	0.41	5.3	6.9	0.19	0.25	0.84	10.9	13.8
						45.9	-7.27	0.18	2.5		0.08		0.51	7.0		0.25		0.03	12.8	
					WEST	6.7	-6.00	0.34	5.7		0.17		0.20	3.3		0.12		0.39	6.5	
						33.0	-7.18	0.25	3.5	4.5	0.11	0.14	0.08	1.1	2.0	0.04	0.07	0.54	7.5	7.9
						45.9	-8.08	0.34	4.2		0.13		0.13	1.6		0.06		0.79	9.8	

NOTE: STRESSES SHOWN ARE IN KIPS PER SQUARE INCH



NORTH
TO DETROIT

TABLE 3
SECONDARY STRESSES
EYEBAR MEMBERS
136'-9 THROUGH TRUSS SPAN

MEMBER	TEST LOCOMOTIVE	DIRECTION	TRUSS	SPEED M.P.H.	SECONDARY STRESS IN MEMBER: AVERAGE STRESS	SECONDARY STRESS IN MEMBER: MAXIMUM STRESS	SECONDARY STRESS IN MEMBER: PERCENT INCREASE		SECONDARY STRESS IN EACH BAR — OUTSIDE BAR: AVERAGE STRESS	OUTSIDE BAR: MAXIMUM STRESS	OUTSIDE BAR: PERCENT INCREASE	INTER. BAR: AVERAGE STRESS	INTER. BAR: MAXIMUM STRESS	INTER. BAR: PERCENT INCREASE	INTER. BAR: AVERAGE STRESS	INTER. BAR: MAXIMUM STRESS	INTER. BAR: PERCENT INCREASE	INSIDE BAR: AVERAGE STRESS	INSIDE BAR: MAXIMUM STRESS	INSIDE BAR: PERCENT INCREASE	DISTRIBUTION OF STRESSES BETWEEN BARS PERCENT: OUT. BAR	INT. BAR	INT. BAR	INS. BAR
COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
L_1L_2	703	NORTH	EAST	7.2 31.2 45.3	+6.02 +7.23 +7.23	+8.96 +10.39 +10.37	48.9 43.7 43.4	45.3	+6.82 +7.88 +8.03	+8.96 +10.39 +10.37	31.5 32.0 29.1	—	—	—	—	—	—	+5.23 +6.59 +6.43	+5.72 +7.09 +6.77	9.4 7.6 5.3	56.6 54.5 55.5	—	—	43.4 45.5 44.5
	703	NORTH	WEST	7.2 31.2 45.3	+5.56 +6.53 +7.68	+5.70 +6.77 +8.49	2.5 3.7 10.6	5.6	+5.61 +6.55 +8.12	+5.70 +6.77 +8.49	1.6 3.4 4.6	—	—	—	—	—	—	+5.51 +6.51 +7.23	+5.52 +6.57 +7.23	0.2 0.9 0.0	50.5 50.1 52.9	—	—	49.5 49.9 47.1
L_2L_3	701	SOUTH	EAST	8.7 31.7 42.2	+9.07 +10.07 +9.37	+11.91 +13.24 +12.36	31.3 31.5 31.9	31.6	+9.43 +10.32 +9.93	+11.91 +12.66 +12.22	26.3 22.6 23.1	+9.54 +10.95 +9.52	+9.94 +11.43 +9.79	4.2 4.4 2.8	+9.59 +10.79 +10.20	+11.79 +13.24 +12.36	23.0 22.7 21.2	+7.74 +8.21 +7.86	+8.03 +8.52 +8.03	3.8 3.8 2.2	26.0 25.6 26.4	26.3 27.2 25.4	26.4 26.8 27.2	21.3 20.4 21.0
	701	SOUTH	WEST	8.7 31.7 42.2	+8.32 +9.00 +8.64	+9.85 +10.44 +10.66	18.4 16.0 23.4	19.3	+8.13 +8.92 +8.75	+8.27 +8.93 +8.81	1.7 0.1 0.7	+8.41 +9.04 +8.81	+9.85 +10.44 +10.66	17.1 15.5 21.0	+8.65 +9.64 +8.96	+9.41 +10.33 +9.37	8.8 7.2 4.6	+8.09 +8.43 +8.03	+9.19 +9.42 +9.19	13.6 11.8 14.5	24.4 24.8 25.3	25.3 25.1 25.5	26.0 26.7 26.0	24.3 23.4 23.2
U_1L_2	807	NORTH	EAST	8.1 32.1 41.7	+10.09 +13.00 +11.91	+12.05 +14.73 +13.53	19.5 13.3 12.0	14.9	+10.01 +12.85 +12.19	+11.80 +14.52 +13.10	17.9 13.0 7.5	—	—	—	—	—	—	+10.17 +13.15 +11.63	+12.05 +14.73 +13.53	18.5 12.1 16.3	49.6 49.4 51.1	—	—	50.4 50.6 48.9
	807	NORTH	WEST	8.1 32.1 41.7	+9.83 +11.98 +11.54	+10.58 +12.46 +12.46	7.6 4.0 8.0	6.5	+9.60 +11.55 +11.07	+10.58 +12.46 +12.46	10.2 7.9 12.6	—	—	—	—	—	—	+10.07 +12.41 +12.00	+10.52 +12.46 +12.43	4.5 0.4 3.6	48.8 48.2 48.0	—	—	51.2 51.8 52.0
U_2L_3	802	NORTH	EAST	6.0 36.3 42.8	+9.59 +11.65 +11.47	+10.28 +12.89 +12.67	7.2 10.7 10.5	9.5	+9.82 +11.63 +11.40	+10.28 +12.89 +12.67	4.7 10.8 11.1	—	—	—	—	—	—	+9.35 +11.68 +11.53	+9.38 +12.04 +11.74	0.3 3.1 1.8	51.2 49.9 49.7	—	—	48.8 50.9 50.3
	802	NORTH	WEST	6.0 36.3 42.8	+9.56 +11.39 +11.71	+12.43 +13.49 +14.78	30.2 18.5 26.2	25.0	+8.96 +10.91 +10.91	+9.46 +11.49 +11.61	5.6 5.3 6.4	—	—	—	—	—	—	+10.15 +11.87 +12.52	+12.43 +13.49 +14.78	22.5 13.7 18.0	46.8 47.9 46.6	—	—	53.2 52.4 53.4

NOTE: STRESSES SHOWN ARE IN KIPS PER SQUARE INCH

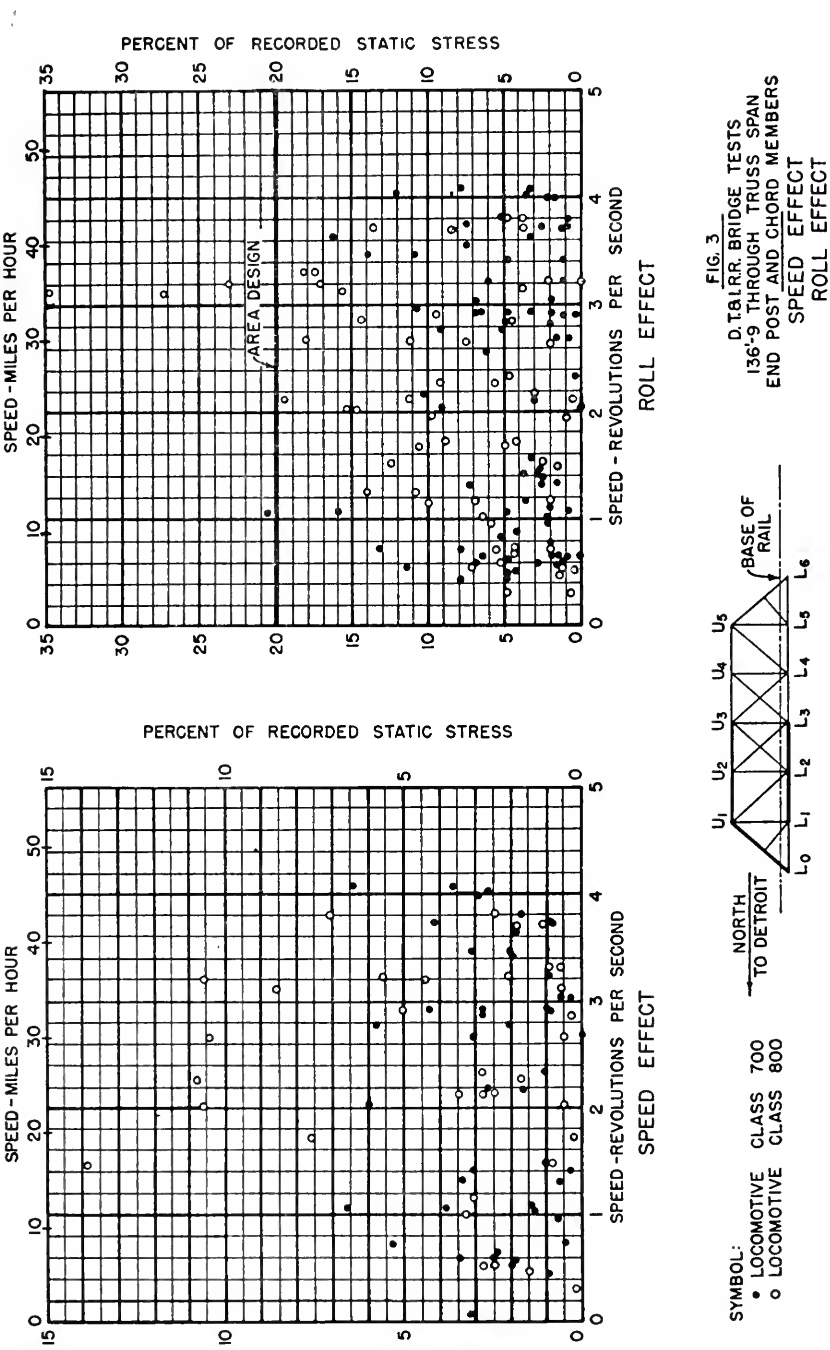


FIG. 3
D.T.&I.R.R. BRIDGE TESTS
136'-9 THROUGH TRUSS SPAN
END POST AND CHORD MEMBERS
SPEED EFFECT
ROLL EFFECT

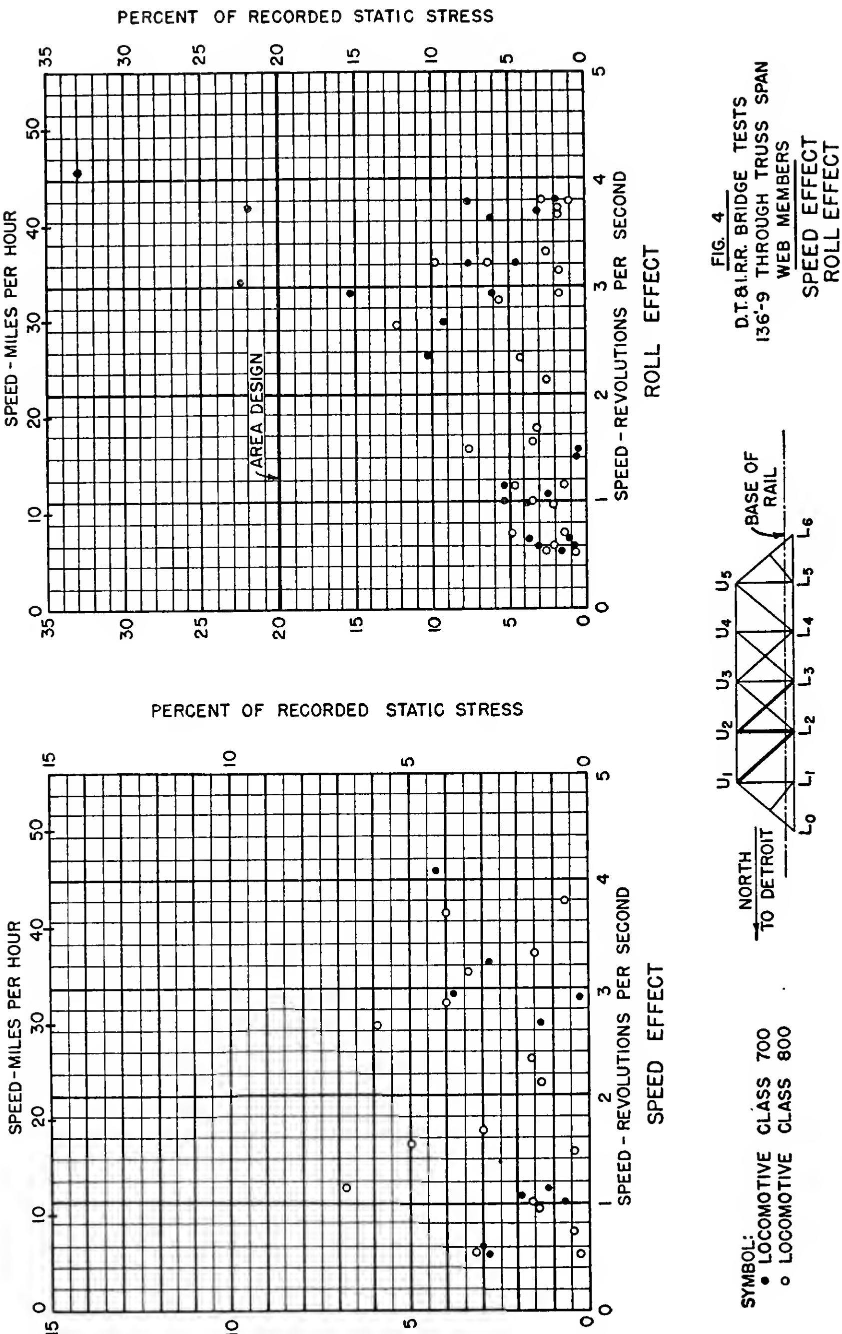


FIG. 4
D.T.&I.R.R. BRIDGE TESTS
136'-9 THROUGH TRUSS SPAN
WEB MEMBERS
SPEED EFFECT
ROLL EFFECT

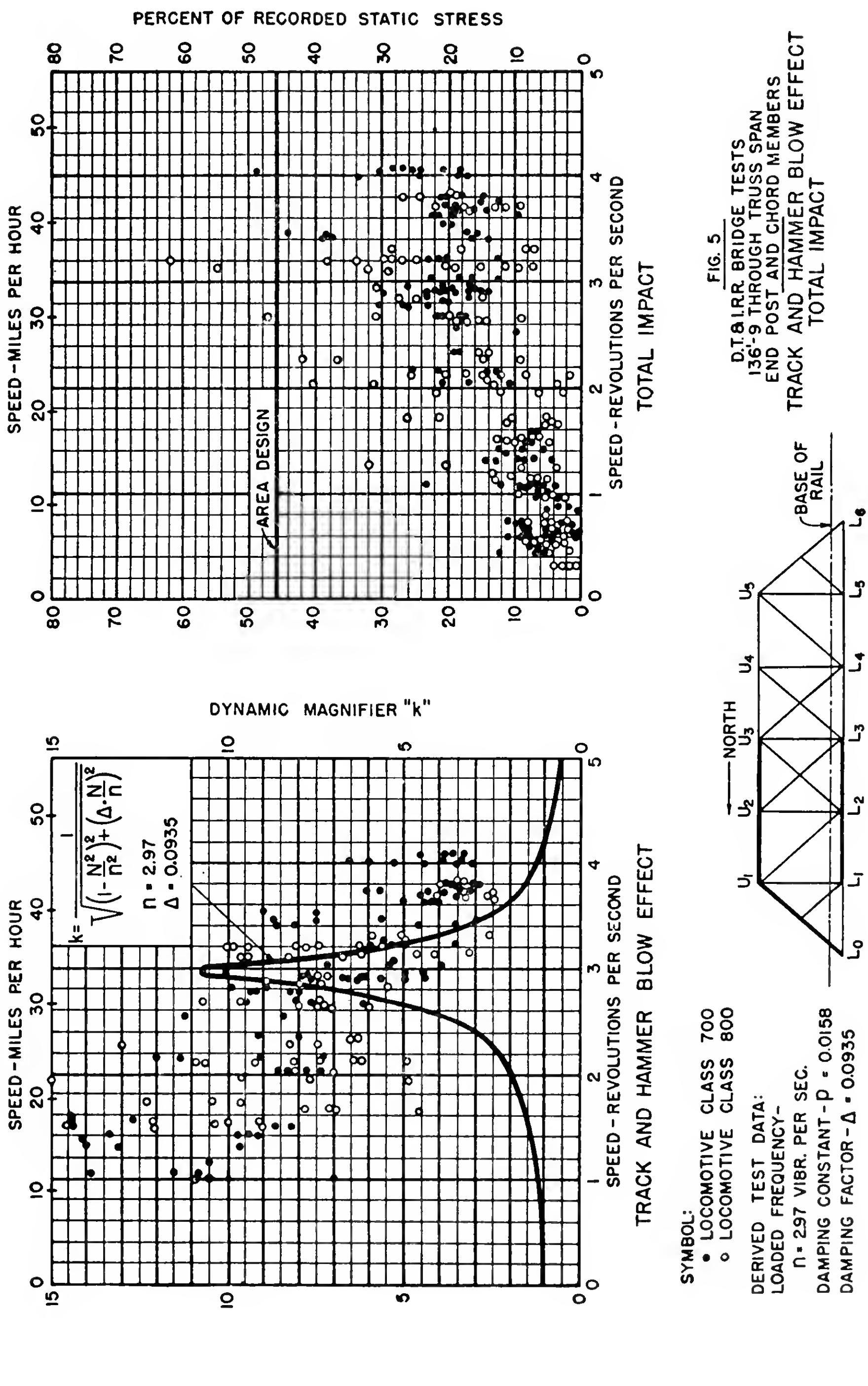


FIG. 5
D.T.&I.R.R. BRIDGE TESTS
136'-9 THROUGH TRUSS SPAN
END POST AND CHORD MEMBERS
TRACK AND HAMMER BLOW EFFECT
TOTAL IMPACT

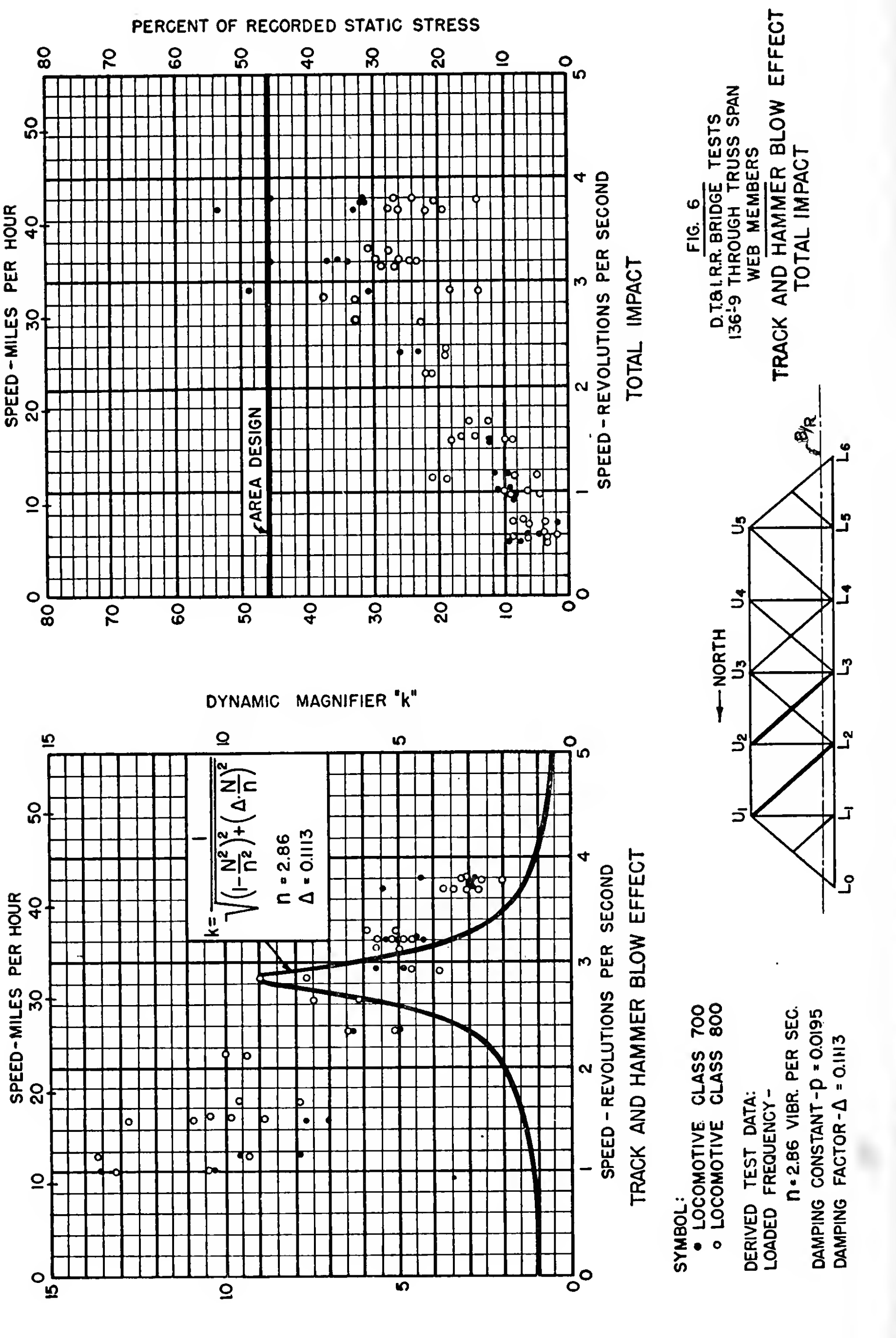


FIG. 6
D.T.&I. R.R. BRIDGE TESTS
136'-9 THROUGH TRUSS SPAN
WEB MEMBERS
TRACK AND HAMMER BLOW EFFECT
TOTAL IMPACT

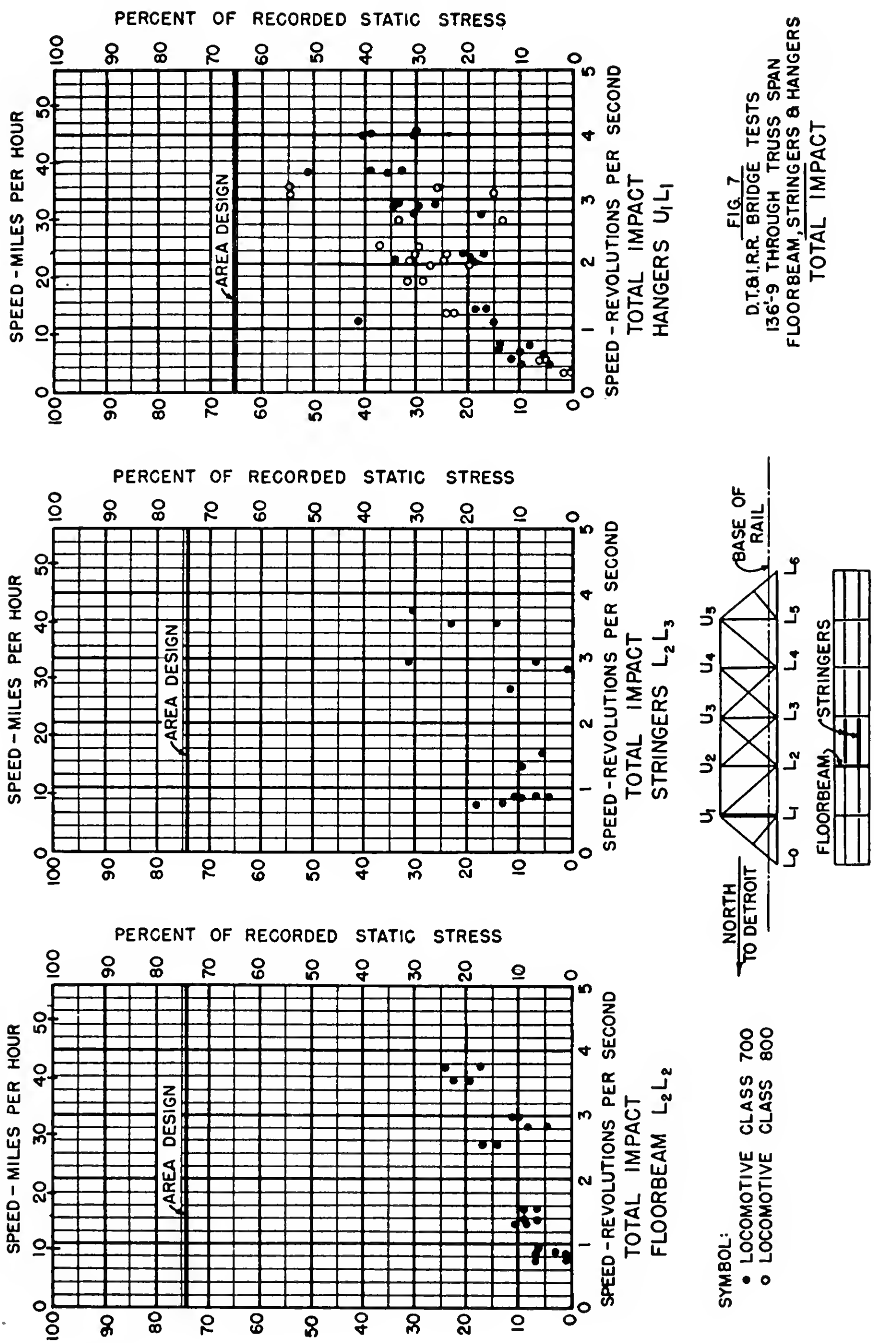


FIG. 7
D.T.&I.R.R. BRIDGE TESTS
136'-9 THROUGH TRUSS SPAN
FLOORBEAM, STRINGERS & HANGERS
TOTAL IMPACT

(text continued from page 91)

Roll Effect

The magnitude of the increase in wheel pressure on one rail which would produce the difference in stress in the end posts and chord members, in percentage of the recorded static stress, is shown in the right diagram of Fig. 3, and the percentage increase in the web members is shown in Fig. 4. It can be seen from these diagrams that there was considerable rolling of the locomotive as it crossed over this span, and values as high as 35 percent were recorded in comparison with a 20 percent provision by the AREA design specification.

An increase in speed does not appear to have much influence on the rolling effect in the end post and chord members, as values as high as 20 percent were recorded at the lower speeds. The increase in the rolling effects in the web members with an increase in speed is very definite, as shown in Fig. 4.

Track and Hammer Blow Effect

The dynamic magnifiers, or the ratio of the measured semi-amplitudes to the calculated hammer blow stresses in the members of the trusses, were obtained in the same manner as described in the Toledo Terminal impact tests. The dynamic magnifiers for the end post and chord members are shown in the left diagrams of Fig. 5 and for the web members in Fig. 6. It can be seen that the dynamic magnifier values at the lower speeds are quite large, but at these speeds the recorded values of the semi-amplitudes of stress are appreciably lower than they are at the critical speed.

The critical loaded frequency of the span was determined by plotting the semi-amplitudes of stress for the various members, and it was apparent from this diagram that the maximum semi-amplitudes of stress were recorded at a locomotive speed of about 3.0 rps. The maximum dynamic magnifier was obtained at a speed close to 3.0 rps. and this speed was then selected as the loaded frequency of the span. A value of n equal to 2.97 vibrations per second was selected as the loaded frequency in the end post and chord members and n equal to 2.86 vibrations per second in the web members (see Figs. 5 and 6). The k curves were then calculated and drawn on these diagrams as shown.

The values for the damping constant p and the damping factor Δ were then computed and these values are shown in the lower left side of Figs. 5 and 6. The following comparison of the values obtained for this 136-ft. 9-in. span with those obtained for the 150-ft. span of the Quincy viaduct and for the 142-ft. Toledo Terminal span clearly indicates that the damping forces in this span are slightly larger than those obtained in the 142-ft. span but considerably below those obtained for the 150-ft. Quincy span.

	Toledo Terminal 142-ft. Span		*D.T.& I.R.R. 150-ft. span (Quincy)*		*D.T.& I.R.R. 136-ft. 9-in. (Paint Creek)*	
	chords	*webs*	*chords*	*webs*	*chords*	*webs*
Damping constant p	0.0111	0.0136	0.0336	0.0204	0.0158	0.0195
Damping factor Δ	0.0645	0.0789	0.1919	0.1165	0.0935	0.1113

Total Impact

The total impact percentages, as determined from these tests for the end post and chord members, are shown in the right diagrams of Fig. 5 and for the web members in the right diagrams of Fig. 6. These diagrams also show the impact percentage as computed by the 1948 AREA design specification.

There are several values on these diagrams that exceed the design allowance, but it should be kept in mind that the roll effects were quite large for this span and this fact possibly accounts for these high total impact values. The increase in total impact with an increase in speed is very definite with a value of about 20 percent at 10 mph.

The total impacts in the stringers, floorbeams and hangers are shown in Fig. 7. These diagrams also show the impact percentage as computed by the 1948 AREA design specification. It can be seen from these diagrams that the recorded impacts in the stringers and floorbeams are appreciably below the calculated values but these low values are quite common for such members. The total impacts in the hangers are higher than those in the stringers and floorbeams but still somewhat below the AREA design allowance.

7. Conclusions

The tests on this truss span supported on concrete abutments and a center pier afforded an opportunity to compare its behavior with that of a slightly longer span at Quincy, Ohio, supported on steel columns and carrying the same classes of power.

On the basis of the data, as found from these tests, it seems logical to conclude that:

1. *Static Stresses.*—There is excellent agreement between the recorded and calculated stresses in the end post and top chord members, but the stringers are definitely reducing the direct stresses in the lower chord.

2. *Secondary Stresses.*—The bending stresses in the built-up members are small except in one member of one truss where they are appreciably greater than would be normally expected.

The bending stresses in the floorbeam hangers are quite large which agree with values found in other spans.

The distribution of stresses between bars of the eyebar members was excellent, indicating the bars were in good adjustment.

The percentage increase in stress due to bending in both the built-up members and in the eyebars is about the same at high speed as at low speed.

3. *Speed Effect.*—The increase in the direct stresses in the truss members due to speed was small for this 136-ft. 9-in. truss span, the maximum values being about 11 percent.

4. *Roll Effect.*—The effect of locomotive roll was appreciably greater than the AREA design allowance and appears to be about as great at the lower speeds as at the higher speeds.

5. *Track and Hammer Blow Effects.*—The track and hammer blow effects in the end post and chord members were about the same as those found in spans having the same length and similar substructure, but were appreciably greater than those found in tests of the Quincy bridge which is supported on steel columns.

6. *Total Impacts.*—The total impacts in the main truss members were greater than those specified by the AREA design specifications. The high total impacts appear to be a combination of high roll effects and track and hammer blow effects.

The total impacts in the stringers, floorbeams and hangers are below the AREA design allowance.

8. Acknowledgment

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are indebted to the Detroit, Toledo & Ironton Railroad for the use of the data covering these tests.

Tests of an Open Floor Wood Pile Trestle

Missouri–Kansas–Texas Railroad

Advance Report of Committee 30—Impact and Bridge Stresses

1. Digest

This report embraces a description and analysis of tests made on a wood pile trestle of the Missouri–Kansas–Texas Railroad. The trestle consists of 49 spans and forms the south approach to 3 long steel spans across the Colorado river near La Grange, Tex. The tests were made under a test train consisting of a single Mikado type (2–8–2) locomotive and 3 loaded hopper cars operating over a complete range of speeds from 5 mph. up to 45 mph., which is the maximum allowable speed in this territory. Extensive tests were made on the steel spans at the request of the railroad, so it was considered advisable to secure exploratory data on the timber approach trestle on account of its availability.

The stresses were measured by means of electromagnetic strain gages with oscillograph recordings in the top and bottom of the stringers at the center of one span, in the top of the continuous stringers over the bent, in the piles of one bent and in the longitudinal bracing between two bents. A total of 1200 individual stresses was recorded at the various points under the 50 runs of the test train.

The results of these tests are of particular interest to bridge engineers for they are the first published data on the dynamic stresses in timber trestles. The results are also of interest, as they afforded a comparison of the simultaneous stresses in the four stringers of the chord under each rail as well as the simultaneous stresses in the continuous stringers over the bent and the simultaneous stresses in the six piles of the bent.

A brief summary of the results as found from the analysis of the data is as follows:

1. The recorded static stresses in the stringers at the center of the span are lower than those calculated for a simple span but greater than those calculated on the assumption that the stringers are fully continuous, as shown in the left diagram of Fig. 5. The stress in one of the stringers over the bent was quite high and it appears from the right diagram of Fig. 5 that there was some continuous action of all the stringers.

There was fair agreement between the recorded stresses in the top and bottom of the stringers at the center of the span, indicating that the neutral axis was close to the center of the section.

The recorded static stress in the piles was larger than the calculated stress as shown in Fig. 6. However, both the calculated stress and recorded stress are quite small.

2. The dynamic stresses in timber bridges are not generally considered in the design of such structure since laboratory data secured by dropping a weight on a timber beam have indicated that the strength of timber under these conditions is about twice what it is under normal test machine loading. Recent drop tests on steel beams indicate that the time required for the stress to go from zero to a maximum under this type of loading is about 0.006 sec., and that the duration of the load is extremely short. The typical oscillogram shown in Fig. 3 indicates that timber stringers are not subjected to a high speed of loading, such as that produced by dropping a weight on a beam. The loading time for these stringers, under the passage of the test train at 46.2 mph. was 0.39 sec. in comparison with a loading time of 0.006 sec. for the drop tests.

3. The total impacts recorded in the stringer chords are shown in the left and center diagrams of Fig. 7. There is considerable variation in the magnitude of the total impacts even at the same speed, but the range and magnitude are about the same as those found in short steel spans.

The total impacts in the piles are shown in the right diagram of Fig. 7 and these values are appreciably lower than those found in the stringers.

4. The simultaneous stresses were measured in each stringer of the chord and the variation between these stresses is shown in Fig. 5. There is some variation but, in general, the maximum stress in one stringer of the chord is only about 30 percent greater than the average of all 4 stringers.

The variation in stresses between the piles is shown in Fig. 6 and it is evident that the outside piles were not carrying their proportion of the load. The variation in stresses is about the same at 40 mph. as it is for the crawl speed runs.

5. The bending stresses in the piles resulting from eccentricity of load on the pile, or from longitudinal forces produced by a hard service application of the brakes are shown in Fig. 8. It can be seen by a comparison of the open and closed circles that the braking of the test train did not produce any measurable effect on the piles. It can also be seen that a fast start of the test train, as shown by the open squares, did not increase the bending stresses in the piles.

The strains in the longitudinal braces, which are bolted to each pile by one ¾-in. bolt, were negligible with no indication of any increase in the bracing stresses under the braking and tractive effort of the locomotive.

2. Foreword

The timber trestle tests analyzed in this report were conducted in the spring of 1948 and were carried out under the general direction of G. M. Magee, research engineer, Engineering Division, Association of American Railroads. The conduct of the tests, analysis of data and preparation of the report were in charge of E. J. Ruble, structural engineer, research staff, AAR.

(text continued on page 111)

Fig. 1.—General View of Colorado River Bridge Showing Timber Trestle Approach.

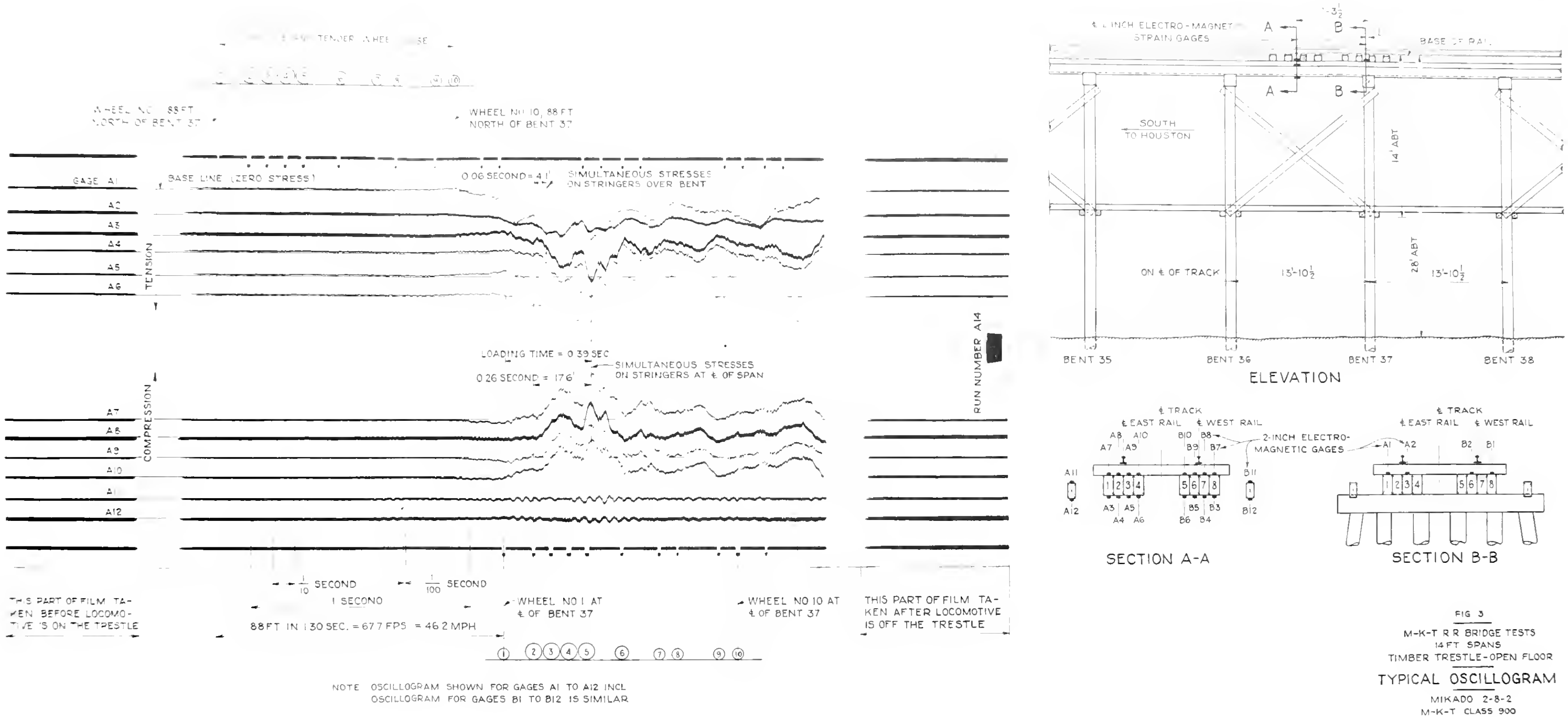


FIG 3
M-K-T R R BRIDGE TESTS
14 FT SPANS
TIMBER TRESTLE-OPEN FLOOR

TYPICAL OSCILLOGRAM

MIKADO 2-8-2
M-K-T CLASS 900

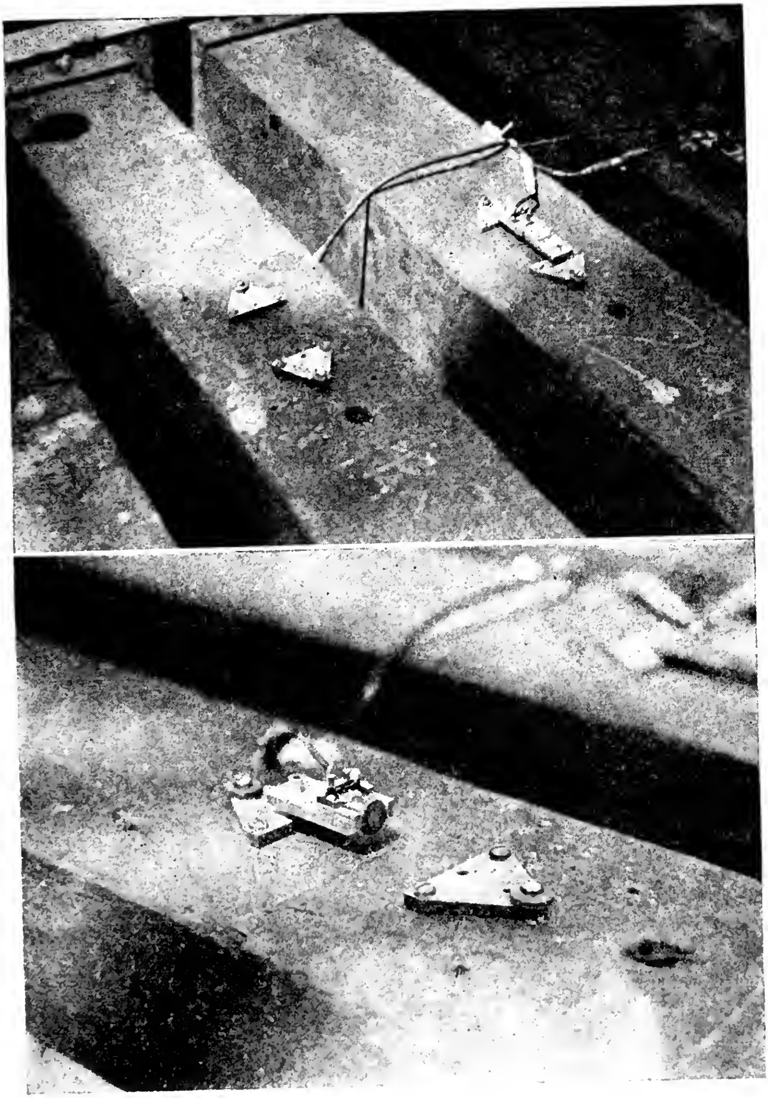


Fig. 2.—Method of Attaching Electromagnetic Gages to Timber.

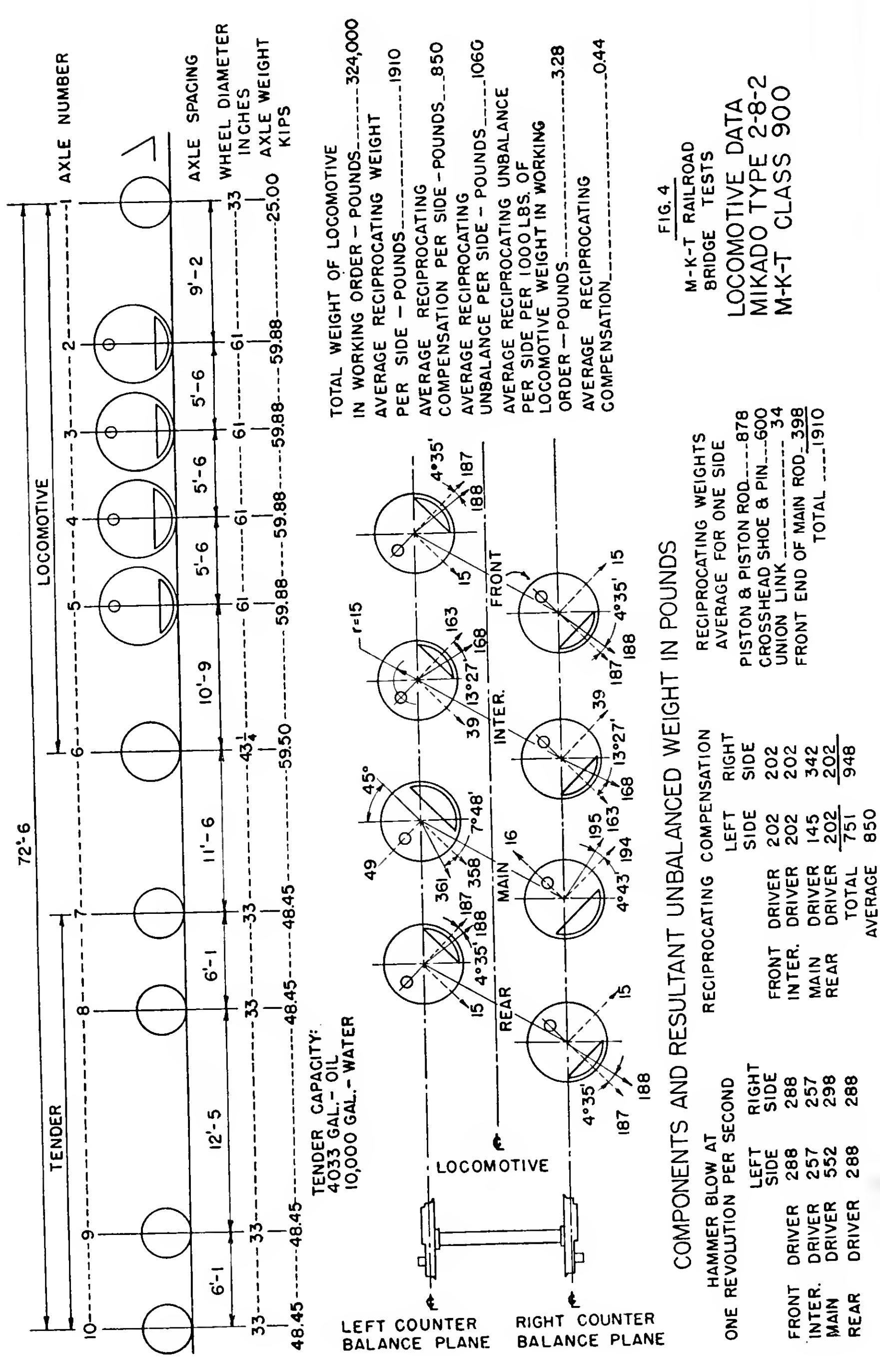


FIG. 4
M-K-T RAILROAD BRIDGE TESTS
LOCOMOTIVE DATA
MIKADO TYPE 2-8-2
M-K-T CLASS 900

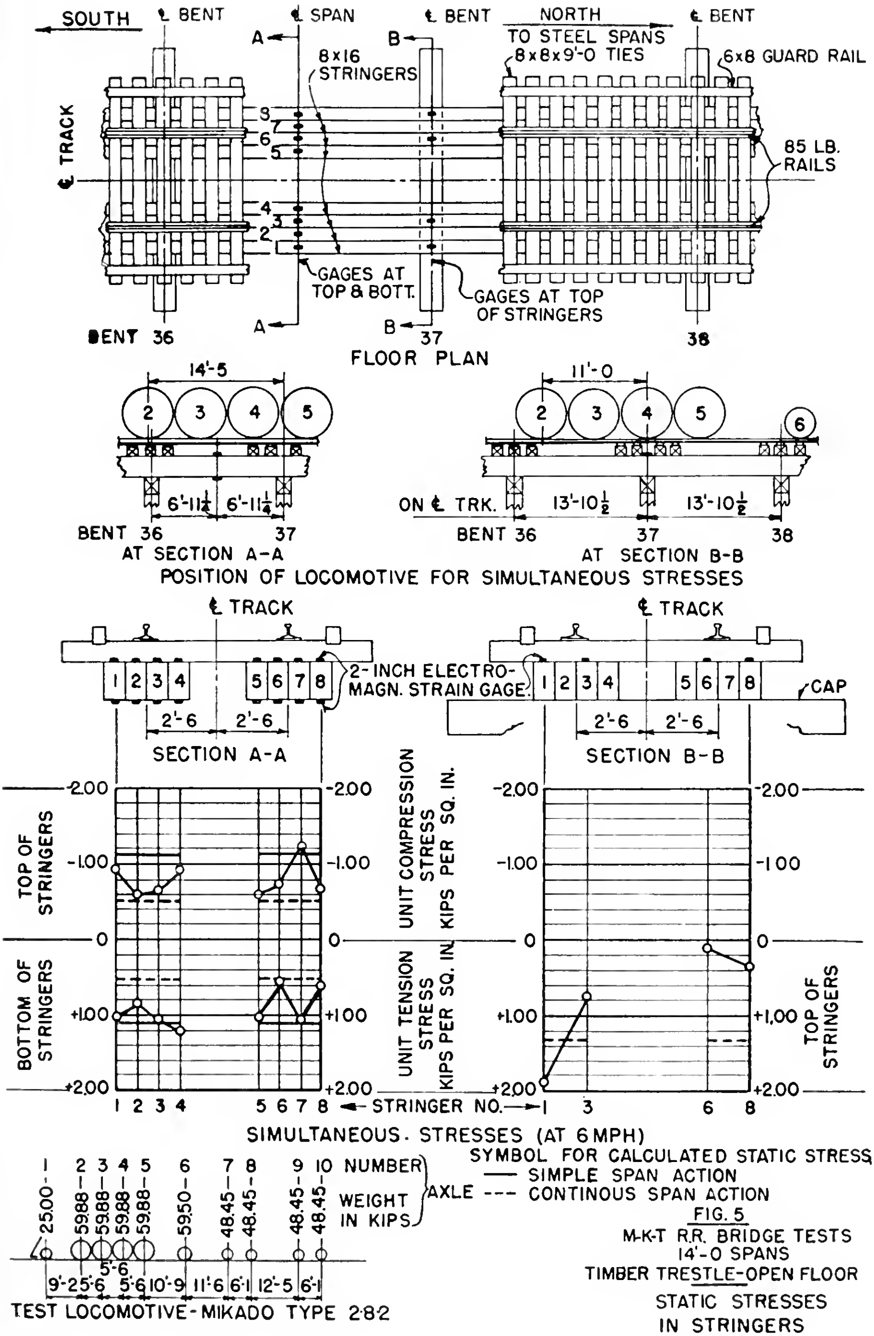


FIG. 5
M-K-T R.R. BRIDGE TESTS
14'-0 SPANS
TIMBER TRESTLE-OPEN FLOOR
STATIC STRESSES
IN STRINGERS

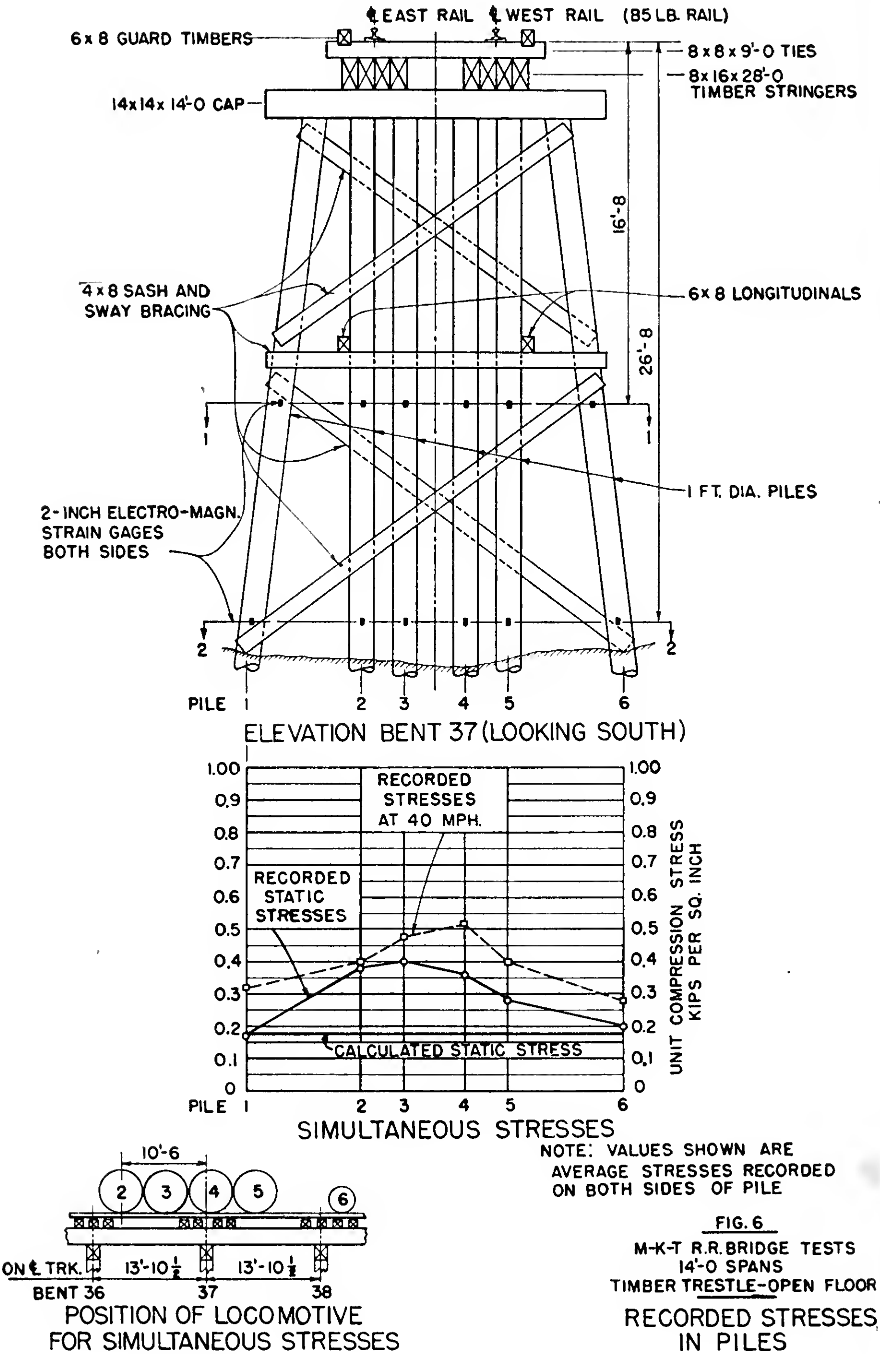


FIG. 6

M-K-T R.R. BRIDGE TESTS
14'-0 SPANS
TIMBER TRESTLE-OPEN FLOOR

RECORDED STRESSES IN PILES

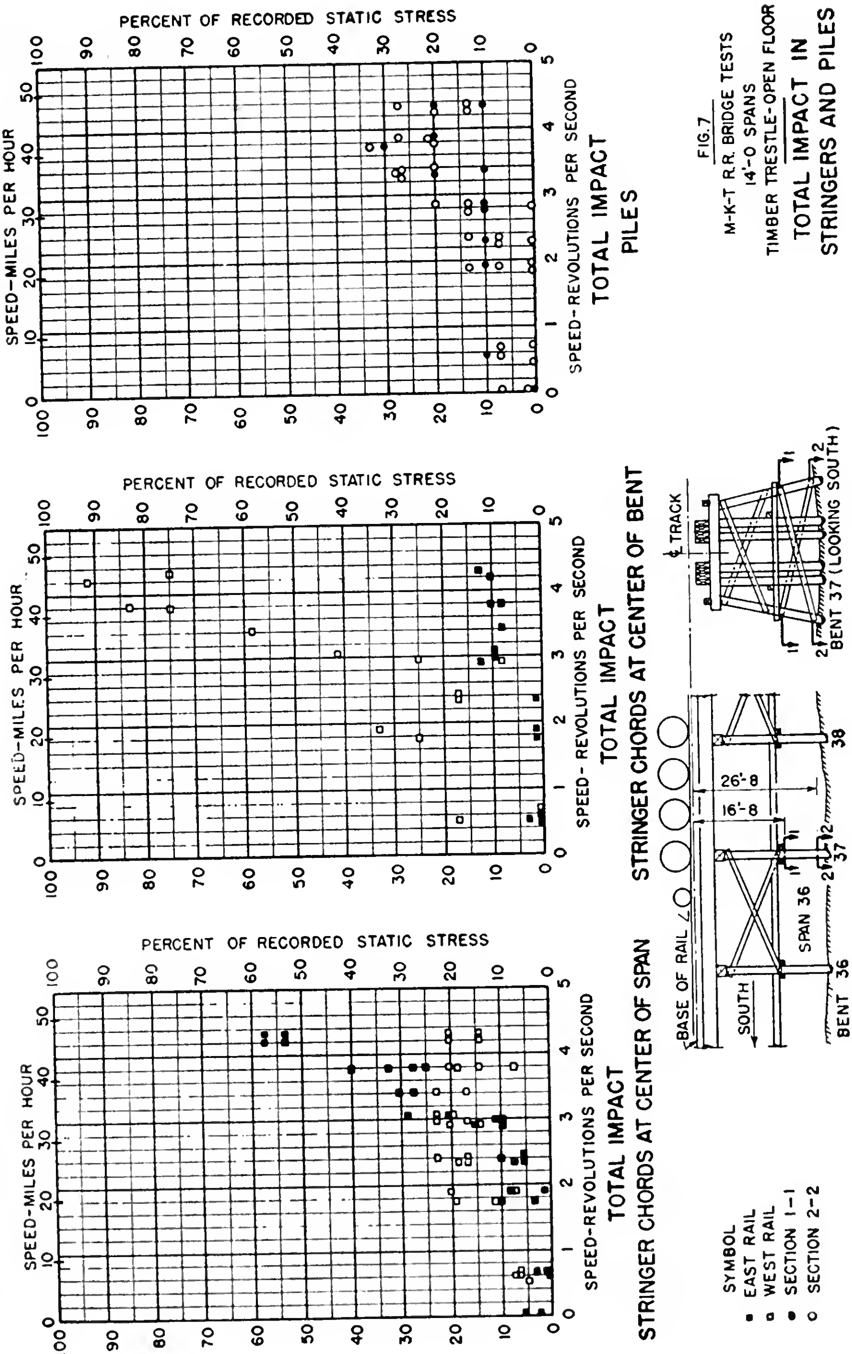


FIG. 7
M-K-T R.R. BRIDGE TESTS
14'-0 SPANS
TIMBER TRESTLE-OPEN FLOOR
TOTAL IMPACT IN
STRINGERS AND PILES

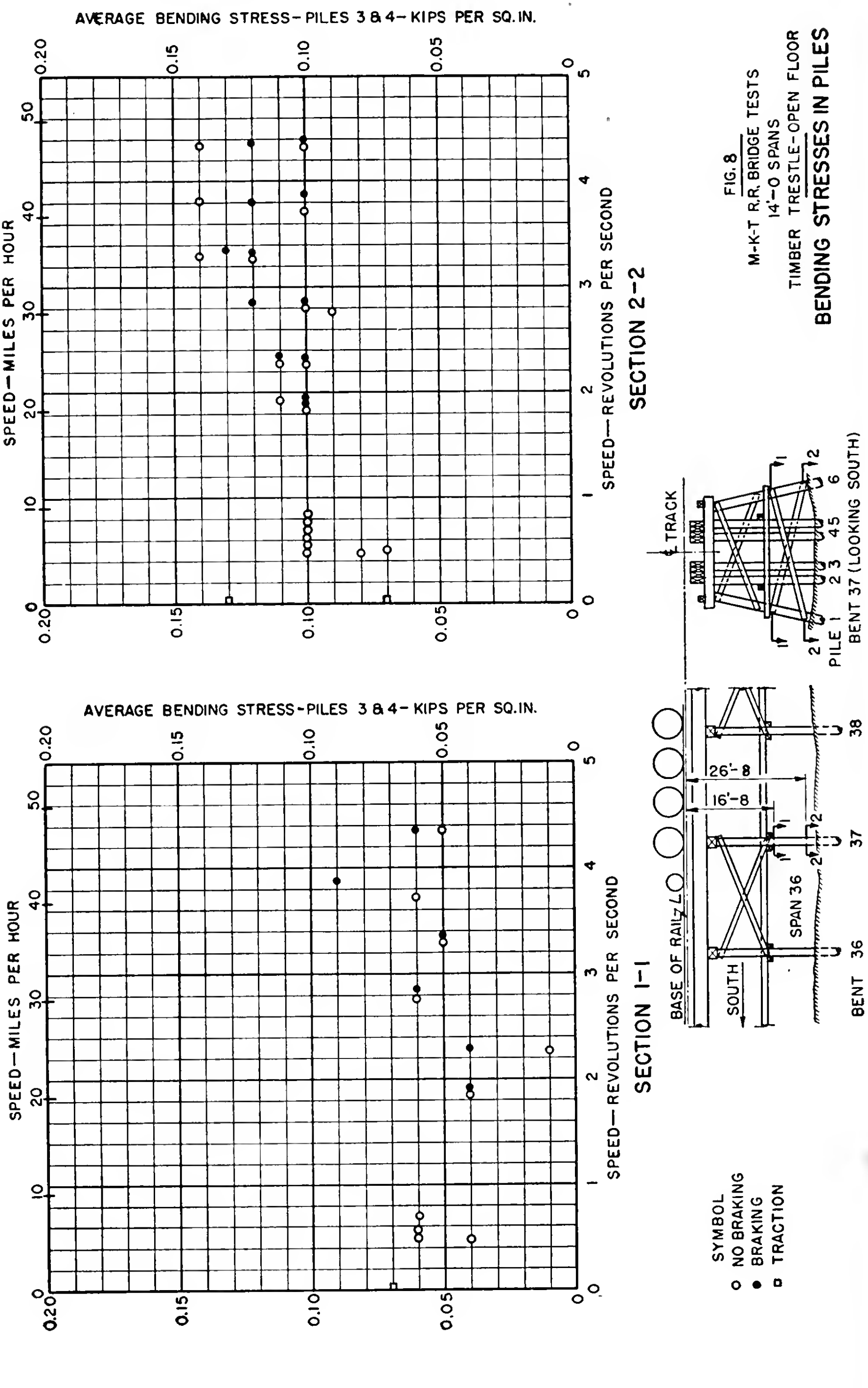


FIG. 8
M-K-T R.R. BRIDGE TESTS
14'-0 SPANS
TIMBER TRESTLE-OPEN FLOOR
BENDING STRESSES IN PILES

(text continued from page 104)

The bridge testing equipment was moved to this location at the request of the engineering department of the railroad to measure the strains in the various members of the three long single-track truss spans (See Fig. 1) as a means of determining their carrying capacity. The availability of the recently rebuilt timber pile trestle approach span afforded an excellent opportunity for the research staff to secure additional exploratory data on the stresses in stringers and piles and the effects of braking and traction forces. Hence, arrangements were made with the railroad to conduct tests on the trestle.

The general procedure in making the tests on the stringers of the trestle was to secure readings under the test train as it crossed the bridge at various speeds ranging from 5 mph. up to the maximum of 45 mph., with the locomotive working steam for every run. In making the tests on the piles and longitudinal bracing, the test train would first cross the bridge with the locomotive working steam and then make another run at approximately the same speed with the locomotive engineman making a hard service application (20 to 25 psi. air pressure) of the brakes when the drivers were on the test span. These runs were continued until a complete range of speeds was covered from 5 mph. up to 45 mph. Additional tests were made by stopping the test train with the locomotive over the span and then making a fast start in an effort to determine the effects of traction.

3. Instruments

The instruments used in these tests were of the electrical type and were fully described in the Proceedings, Vol. 42, 1941, page 402. The gages used were of the electromagnetic type having a 2-in. gage length and were mounted on two triangular attaching plates fastened to the timbers (See Fig. 2). As two 12-element oscillographs were used, 24 simultaneous stresses were recorded for each test run of the locomotive.

The attaching plates are small hardened steel plates with a knife-edge cutting into the timber transverse to the gage line. The plates were fastened to the timber by long wood screws, and a template was used to maintain the gage length. A rubber washer was used under the back screw head to eliminate any friction between the screw head and plate.

The strain gages were calibrated individually so that, in general, a 1-in. deflection of the light trace on the film indicated a strain in the timber of 0.002 in. for the 2-in. gage length, which is equivalent to a unit stress of 1500 psi., assuming a modulus of elasticity of 1,500,000 psi.

4. Test Trestle and Location of Gages

The pile trestle tested is located near La Grange, Tex., and forms the south approach to three long steel spans over the Colorado river (See Fig. 1). The single-track, 4-ply chord, 6-pile bent open floor trestle approach consists of 49 spans, each having a 14-ft. span, center to center of bents, and is about 28 ft. in height, base of rail to ground line. The trestle was rebuilt in 1945 with new treated timber and is well braced with longitudinal and transverse bracing. The chord under each rail consists of four 8-in. by 16-in. stringers 28 ft. long, packed together and is continuous over two spans with staggered joints.

Span 36 and bent 37 were selected for testing, as they were considered representative and are at a location where the distance from base of rail to ground line is a maximum. The gages were placed on the top and bottom of all the stringers under each rail at the center of the span, and on top of the four continuous stringers over bent 37 (See Figs. 3 and 5). After completing the tests on the stringers, the gages were moved to the piles of bent 37. Two gages were placed on each pile, one on the north side and another on the south side, at the mid height of the pile and two gages on each pile just above the ground (See Fig. 6). After the pile tests were completed, the gages were moved to the longitudinal bracing in span 36 and two gages were placed on each longitudinal member.

5. Test Train

A special test train consisting of a heavy Mikado type (2–8–2) freight locomotive and three 70-ton capacity hopper cars loaded with ballast was provided by the railroad for all the test runs on this trestle. The necessary information regarding these locomotives, such as axle loads, axle spacing, nominal wheel diameter, and all information required to calculate the components and resultant weights on the driving wheels, was furnished by the mechanical department of the railroad.

The locomotive was of the two-cylinder type, the right pin leading by 90 deg. and with the eccentric crank trailing. The locomotives of this class are used in regular freight service and all general data regarding them are shown in Fig. 4.

The drivers are all straight balanced with the left main underbalanced by 49 lb. and an out-of-plane effect of 358 lb. with a resultant of 361 lb. The right main is underbalanced by 16 lb. and an out-of-plane effect of 194 lb. with a resultant of 195 lb.

6. Analysis of Field Records

The test records were photographed on sensitized paper 10 in. wide and 200 ft. long. The oscillograph and run number, which is photographed on the record after each run, refers to the log of test runs which shows the engine number, direction, approximate speed, type of train and all other necessary information regarding the test run. The oscillogram for each run is only 2 or 3 ft. in length and is cut from the 200-ft. rolls after developing. A typical oscillogram is shown in Fig. 3, and the remaining records as well as the tables containing all the data taken from the oscillograms are on file in the Engineering Division offices, AAR, at Chicago.

7. Static and Dynamic Effects

The stress data taken from the oscillograms were analyzed for the purpose of determining the various static and dynamic effects of the live load. The results of this study are as follows:

Static Stresses

The recorded static stresses in each of the stringers at the center of the span under the passage of the test train at crawl speeds are shown in the left diagram of Fig. 5. The stresses shown are the averages recorded for five test runs but the variation between the values was very small. The values shown at the top of the left diagram were those recorded in the top of the stringer, while those in the lower part were recorded in the bottom of the stringer. For example, the recorded stress in the top of the outside stringer (stringer 1) was 950 psi., while the simultaneous stress in the bottom of the stringer was 1021 psi. The values shown for the eight stringers, both tension and compression, were recorded simultaneously with wheel 2 of the locomotive 14 ft. 5 in. from bent 37, as shown in Fig. 5.

The recorded static stresses in each of the four continuous stringers over bent 37 are shown in the right diagram of Fig. 5. It is evident from this diagram that part of the stringers in the chords were acting as continuous members, as a tension stress of 1900 psi. was recorded in the top of one of the stringers when wheel No. 2 of the locomotive was 11 ft. from bent 37, as shown.

The calculated stresses in the stringer chords, assuming that the stringers act as simple spans, are shown in these diagrams by the solid lines, while those shown by the dashed lines are based upon the assumption that the chords are fully continuous for moment distribution, but this moment over the support is resisted only by the four continuous stringers at this point. It can be seen that the average recorded static tensile stresses of 1030 psi. in the east chord and 810 psi. in the west chord are between the two calculated values. It appears that the continuous action of the chords as well as the frame action of the locomotive tends to reduce the stresses at the center of the span.

It is interesting to note from the left diagrams of Fig. 5 that the stresses in the top of the stringers at the center of the span are about the same as those in the bottom of the stringers, indicating that the neutral axis is close to the center of the section.

The average static stresses recorded in the piles at the bottom of bent 37 (section 2–2) under the passage of the test train at crawl speeds are shown in Fig. 6. The stresses shown are the average values of the two gages on each pile recorded for 10 runs. The average calculated static stress in the six piles, based upon the measured diameter of the pile at section 2–2, and with wheel 2 of the locomotive 10 ft. 6 in. from bent 37 as shown, is 175 psi., while the average recorded stress is 300 psi.

Loading Time

The fact that timber can carry a load for a short interval of time equal to twice what it can carry for a long interval of time has been known for many years, but the "short interval of time" has never been defined. The strength of timber for short time loading was determined by dropping a "tup" on a timber beam and determining the tup weight required to break the beam. Recent tests on steel beams conducted in the same manner, but with oscillograph recording of the stress, have shown that the "loading time" or the time for the stress to go from zero to a maximum varies from 0.003 to 0.006 sec., depending upon the height of drop, for this type of impact loading.

In a short span railroad bridge, such as a timber trestle, the stress in the stringer at the corner of the span is about zero when the first locomotive wheel is over the support and then increases as the locomotive driving wheels approach the center. The time required for the stringer stress at the center of the span to go from zero to a maximum for these tests is shown in the typical oscillogram, Fig. 3, and amounted to 0.39 sec. for a test train speed of 46.2 mph. It is evident that the actual loading time for the stringers of timber trestles is relatively slow in comparison with those occurring under a free falling weight.

Total Impacts

The total impact percentage is the increase in the stress over the static stress occurring at a slow speed. The total impacts are the combinations of (1) speed effect, (2) roll effect and (3) track and hammer blow effect, although it would be only by chance that the maximum for all the effects would occur simultaneously.

The total impact percentages, as determined from these tests for the stringer chords at the center of the span, are shown in the left diagram of Fig. 7. Values as high as 57 percent were recorded in the chord under the east rail at a speed of 4.30 rps., or 46.2 mph., as shown on this diagram.

The total impact percentages for the stringer chords at the center of bent 37 are shown in the center diagram of Fig. 7. It should be noted that high impact percentages were recorded in the chord under the west rail, but the static stress in this chord, as shown in Fig. 5, was quite small in comparison with the static stress in the east chord over the support.

The total impact percentages recorded in the piles of bent 37 are shown in the right diagram of Fig. 7. The impact values obtained at the center of the pile (section 1–1) as well as those secured at the bottom of the pile (section 2–2) are shown, and it appears that the impacts are about the same at both sections. It can be seen that the maximum impact recorded in the piles was 33 percent, which is considerably below the maximum measured in the stringer chords.

Distribution of Load

The impact data shown in this report are based upon the average stress in the chord under each rail or in the pile group. The variation of stresses between the stringers of the chord or between the piles of the bent is not an impact effect but it should be considered in the design or rating of the older timber trestles.

The stresses at the center of the span in each of the four stringers under each rail are shown in the left diagram of Fig. 5. In general, the variation between the stresses was about 30 percent from the average in the chord.

The variation in stresses between the two continuous stringers of the chord under each rail over the support is shown in the right diagram of Fig. 5. There was considerable variation in these stresses, especially under the east rail where the stress in one stringer was 1900 psi. and only 750 psi. in the other stringer. The stresses in the stringers over the bent depend upon the rigidity of the support and this large variation is probably due to poor bearing under stringer 3. It is also quite possible that the low static stresses in the two continuous stringers over the bent under the west rail are due to poor bearing.

The variation in stresses between the piles of bent 37 is shown in Fig. 6. The stress in each pile is a measure of the load carried by the pile and it can be seen that the outside piles are only carrying about half the load carried by the inside piles. A study of the records at various speeds indicated that the maximum stress in the outside piles was secured at a speed of 40 mph., and the stresses recorded in all the piles for this particular run are shown on this diagram.

Longitudinal Forces

The effect on the stresses in the piles resulting from a longitudinal force on the trestle, such as that produced by locomotive braking or traction, would be to increase the stresses on one side of the piles with a corresponding decrease on the other side. The average bending stresses recorded in piles 3 and 4 at section 1–1 and section 2–2 resulting from locomotive braking and tractive efforts, as well as those resulting from normal operation of the locomotive are shown in the two diagrams on Fig. 8.

The bending stress values shown by the open circles were recorded as the locomotive crossed the trestle under normal operating conditions. It is natural to expect some variation in stress between the two sides of the piles and this stress is undoubtedly due to some eccentricity of the vertical load on the pile.

The bending stress values shown by the solid circles were recorded as the locomotive engineman made a very hard service application of the brakes just as the locomotive drivers were over the test bent. The application of the brakes was so severe in several runs that the locomotive drivers were sliding. It can be seen from the diagrams of Fig. 8 that there was no indication of a longitudinal force acting on the piles of this bent.

The bending stress values shown by the open squares were recorded as the locomotive stopped on the trestle with the drivers equally spaced on each side of the bent and then made a fast start. Here again it is evident that bent 37 was not taking any of the longitudinal force.

As previously mentioned, gages were placed on all the longitudinal bracing between bents 36 and 37 and test runs made in the same manner as when the gages were on the piles. The recorded stresses in the bracing members were less than 100 psi., with no indication of any increase resulting from the braking and the tractive effort of the locomotive.

8. Conclusions

These tests afforded an opportunity to measure and compare the simultaneous stresses in all the stringers and piles of a new 4-ply timber trestle, providing for the first time extensive data on the action of a timber structure under moving train loads. The results of the tests may be summarized as follows:

1. Static Stresses

The static stresses in the stringers at the center of the span are slightly below the calculated stresses based on the assumption that the stringers act as simple spans.

The static stresses in the stringers over the bent indicate that there is some continuous action of the chords.

The static stresses in the piles are greater than those calculated on the assumption that the stringers act as simple beams.

2. Loading Time

The time for the stress in the stringers to go from zero to a maximum under the passage of a train is relatively slow when compared with the loading time when a weight is dropped on a beam.

3. Total Impacts

The total impacts in the stringers appear to be about the same as those found in short span steel bridges.

The total impacts in the piles were smaller than those recorded in the stringers.

4. Distribution of Stresses

Each stringer of the 4-ply chords was carrying its proportion of the total load within about 40 percent.

Each outside pile of the 6-pile bent was only carrying about half the load carried by an inside pile.

5. Longitudinal Forces

There was no evidence that the piles or the longitudinal bracing were carrying any appreciable longitudinal forces produced by the locomotive braking or tractive efforts.

9. Acknowledgement

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are indebted to the Missouri–Kansas–Texas Railroad for its cooperation in conducting these tests.

Tests of an Open Floor Timber Trestle

Southern Railway System

Advance Report of Committee 30—Impact and Bridge Stresses

1. Introduction

The research staff of the Engineering Division, Association of American Railroads, conducted tests on several steel viaducts and one truss span of the Southern Railway System during the spring of 1947, at the request and expense of the railway, as a means of determining the carrying capacity of these structures. As the frame timber trestle shown in Fig. 1 was near one of these steel bridges, arrangements were made with the railroad to conduct a few exploratory tests on the stringers of this trestle.

The testing equipment was the same as that used on the Missouri–Kansas–Texas Railroad trestle tests and, in general the tests were conducted in the same manner. A consolidation type locomotive (2–8–0), having about 47,000 lb. on the driving axles was used for all the tests, as this is the heaviest power allowed to operate in this territory.

The single track timber trestle is located near English, Ind., and spans one of the deep gullies which are quite common in southern Indiana. The chord under each rail consists of three 9-in. by 16-in. stringers 28 ft. long continuous over two spans with staggered joints. The 12-in. by 14-in. timber cap rests on two vertical and two batter posts, each 12-in. by 12-in., as shown in Fig. 1. There are 29 spans in this structure with a maximum height, base of rail to ground line, of about 30 ft.

The strain gages were placed on the top and bottom of the six stringers at the center of span 19 and on top of the four continuous stringers over bent 20 (See Fig. 2). The stresses at these locations were recorded under a complete range of speeds from about 5 mph., which is considered static, up to a maximum of 40 mph., which was the maximum allowable speed in this territory.

The tests were carried out under the general direction of G. M. Magee, research engineer, Engineering Division, Association of American Railroads with E. J. Ruble, structural engineer of the research staff, in direct charge.

2. Static Stresses

The recorded static stresses in each of the stringers at the center of the span under the passage of the test locomotive at crawl speeds are shown in the left diagram of Fig. 2. The stresses shown are the average recorded for four test runs, with a maximum variation of only 4 percent from the average for any one run. The values shown at the top of the left diagram are the compressive stresses recorded in the top of the stringer, while those in the lower part are the recorded tensile stresses in the bottom.

The average static tensile stress in the three stringers under the south rail was 780 psi., compared with a simultaneous compressive stress of 1190 psi. in the top of the stringers. This indicates that there was a shift in the neutral axis of the chord toward the tension side. The average static tensile stress in the three stringers under the north rail was 960 psi., compared with a simultaneous stress of 1420 psi. in the top of the stringer.

The calculated static stresses in the stringer chords, assuming that the stringers act as simple spans, are shown in these diagrams by the solid lines, while those shown by the dashed lines are based upon the assumption that the cords are continuous. The average recorded static tension stresses of 780 psi. in the south chord and 960 psi. in the

Fig. 1.—General Views of Framed Timber Trestle.

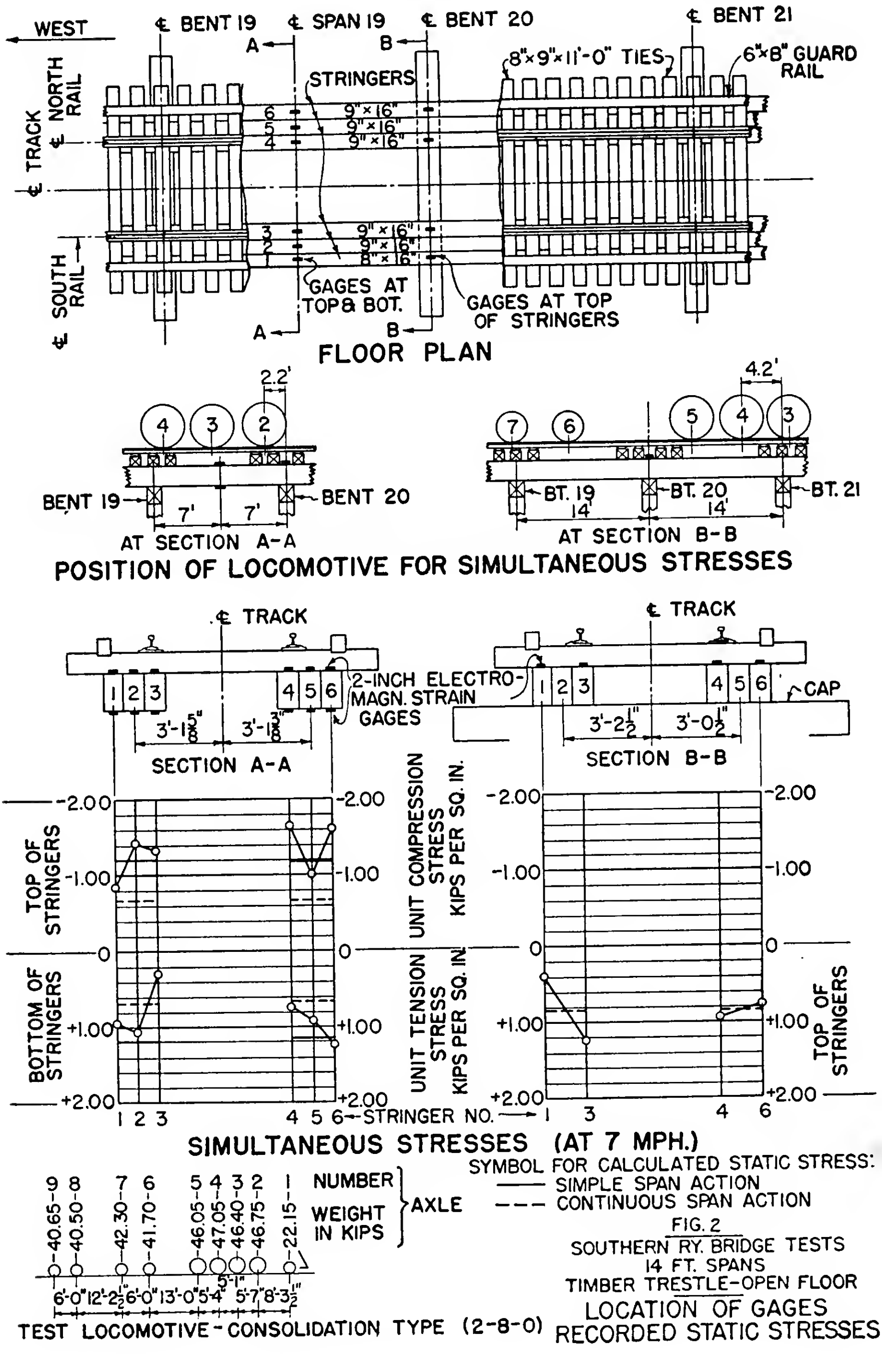


FIG. 2

SOUTHERN RY. BRIDGE TESTS

14 FT. SPANS

TIMBER TRESTLE-OPEN FLOOR

LOCATION OF GAGES

RECORDED STATIC STRESSES

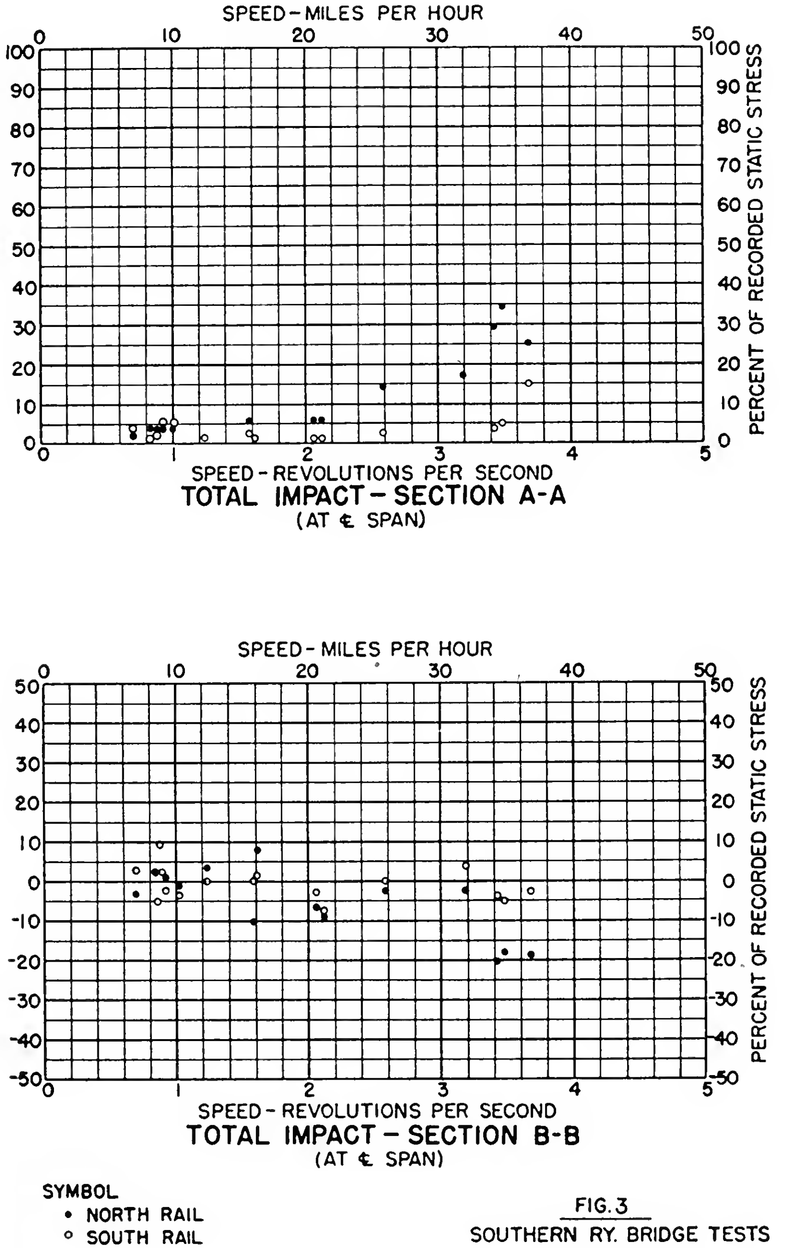


FIG. 3

SOUTHERN RY. BRIDGE TESTS

14 FT. SPANS

TIMBER TRESTLE-OPEN FLOOR

TOTAL IMPACT IN STRINGERS

north chord are about midway between the two calculated stresses. It appears that the continuous action of the chords as well as the frame action of the locomotive tends to reduce the stresses at the center of the span.

The recorded static stresses in each of the four continuous stringers over the bents, as well as the calculated stresses are shown in the right diagram of Fig. 2. In calculating the static stresses over the bents, it was assumed that the stringers were continuous for moment distribution but the moment was resisted by the two continuous stringers of each chord. It is evident that the stringers are well supported at this bent as there is close agreement between the recorded and calculated stresses.

There is considerable stress variation in the three stringers of each chord as shown in Fig. 2. For example, the stress in stringer 3 is only 39 percent of the average stress in the chord. From the position of the chords with respect to the rails, high static stresses would normally be expected in stringers 3 and 4, but there does not appear to be any reasonable assumption that can be made which will account for the recorded variation of stresses.

3. Total Impacts

The total impact percentages, as determined from these tests for the stringer chords at the center of the span, are shown in the top diagram of Fig. 3. It should be noted that the impacts under the north rail were higher than those under the south rail. A maximum value of 35 percent was recorded at a speed of 3.50 rps.

The total impact percentages for the stringer chords at the center of the bent are shown in the lower diagram of Fig. 3. It is interesting to note that the recorded stresses in the stringers over the bent, as shown by the negative impacts, became less than the recorded static stress as the speed increased.

4. Conclusions

The tests on this trestle were conducted in an effort to obtain data on the action of continuous stringers over two panels with staggered joints and the results may be summarized as follows:

1. The static stresses in the stringers at the center of the span are slightly lower than the calculated stresses (based on a simple span) but are higher than those calculated on the assumption that the stringers are continuous.
2. The static stresses in the stringers over the bent indicate that the stringers are acting as fully continuous beams.
3. The compressive stresses at the center of the span are greater than the tensile stresses.
4. There is considerable variation in the stresses in the several stringers.
5. The total impacts at the center of the span are lower than would be expected on a steel span of the same length.
6. The stresses in the stringers over the support became less than the static stresses as the speed increased, as shown by the negative impacts.

5. Acknowledgement

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are indebted to the Southern Railway System for its cooperation in conducting these tests.

Tests of a Ballasted Floor Wood Pile Trestle

Southern Railway System

Advance Report of Committee 30—Impact and Bridge Stresses

1. Introduction

The tests of the ballasted floor timber pile trestle described in this report were made on a bridge of the Southern Railway System during the early spring of 1947. The wood pile trestle forms the north approach to a 150-ft. steel truss span as shown in Fig. 1. Extensive tests were made on the steel truss span at the request of the railroad and arrangements were also made to conduct a few exploratory tests on the floor timbers of the trestle at the same time.

The single track structure spans the Chicasabogue river and is located on a branch line of the railway just north of Mobile, Ala. The floor timbers, consisting of ten 10-in. by 14-in. timbers under the ties and three 8-in. by 10-in. timbers on each side, are continuous over two spans with staggered joints as shown in Fig. 2. The 14-in. by 14-in. timber cap rests on six wood piles. The trestle approach consists of 40 spans varying in length from 11 ft. to 13 ft. 9 in.

The testing equipment was the same as that used on the Missouri–Kansas–Texas Railroad trestle tests and, in general, the tests were conducted in the same manner. A very light consolidation type (2–8–0) locomotive having only about 26,000 lb. on the driving axles was used for all the tests, as this is the heaviest power allowed to operate in this territory.

The strain gages were placed on the bottom of the 12 floor timbers at the center of the span and on top of 5 continuous floor timbers over the pile bent as shown in Fig. 2. The stresses at these locations were recorded under a complete range of speeds from about 5 mph., which is considered static, up to a maximum about 40 mph., which was the maximum speed obtainable with this locomotive.

The tests were carried out under the general direction of G. M. Magee, research engineer, Engineering Division, Association of American Railroads, with E. J. Ruble, structural engineer of the research staff, in direct charge.

2. Static Stresses

The recorded static stresses in each of the floor timbers at the center of the span under the passage of the test locomotive at crawl speeds are shown in the left diagram of Fig. 2. The stresses shown are the average recorded for two test runs but the variation between the two runs was very small.

The calculated static stress in the floor timbers, assuming that the timbers act as simple spans and the entire moment is resisted by the 10 timbers under the tie, is shown in this diagram by the solid line, while that shown by the dashed line is based upon the assumption that the floor is fully continuous. The average recorded static stress in the 12 timbers is 380 psi. and this stress is between the two calculated values.

The recorded static stresses in each of the continuous timbers over the bent as well as the calculated stresses are shown in the right diagram of Fig. 2. In calculating the static stresses over the bent, it was assumed that the timbers were fully contniuous for moment distribution, but the bending moment at this section was resisted by the five continuous timbers under the track. The average recorded static stress in the five continuous timbers over the bent is 510 psi., which is somewhat smaller than the calculated

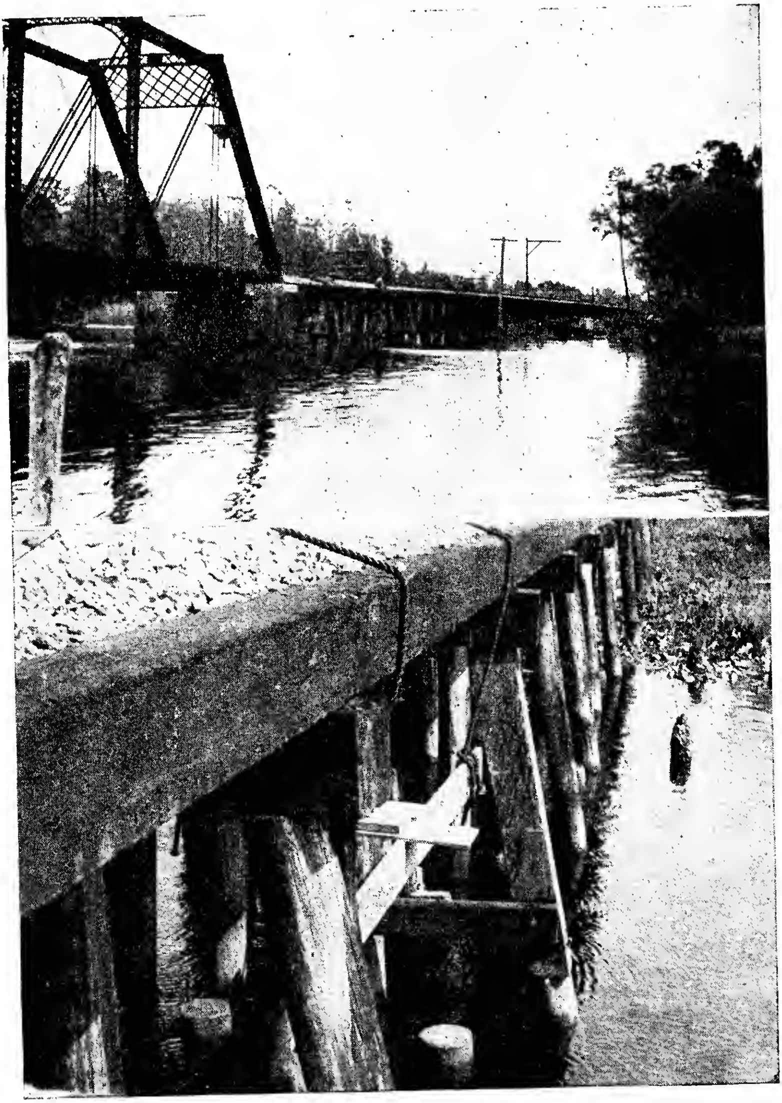


Fig. 1.—General Views of Timber Pile Trestle.

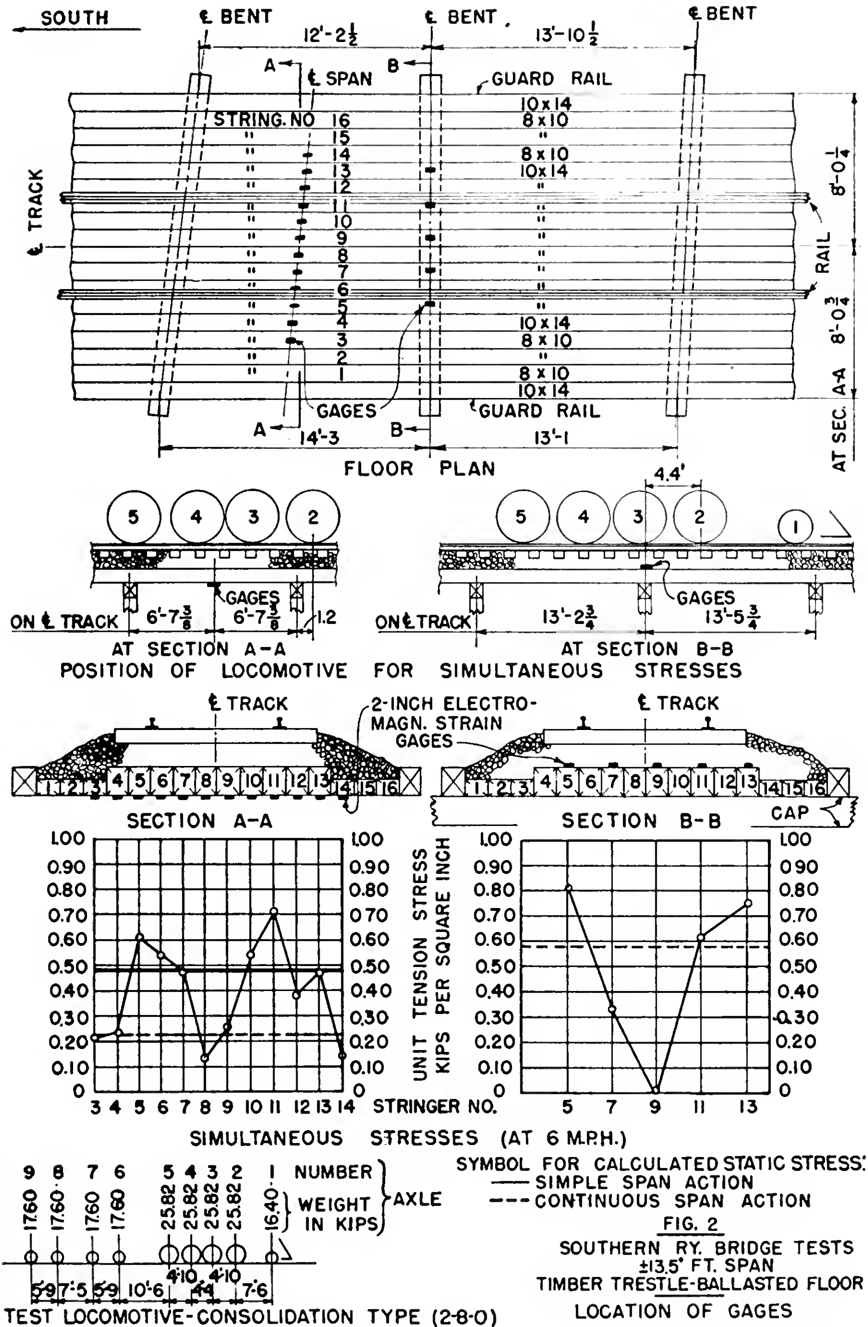
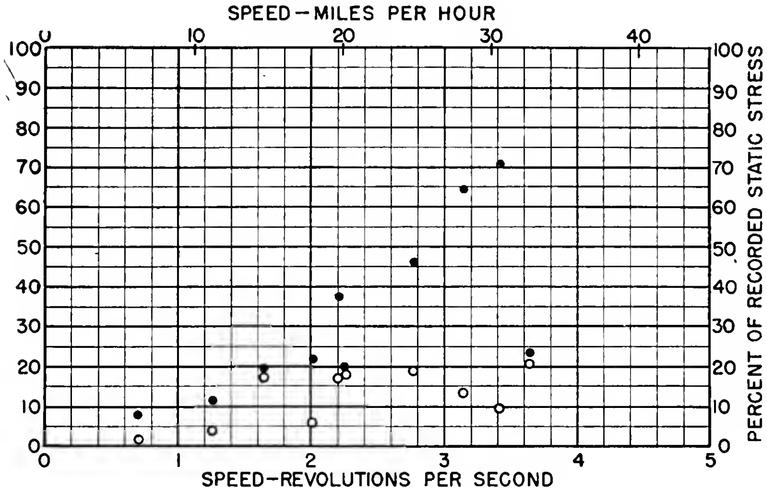


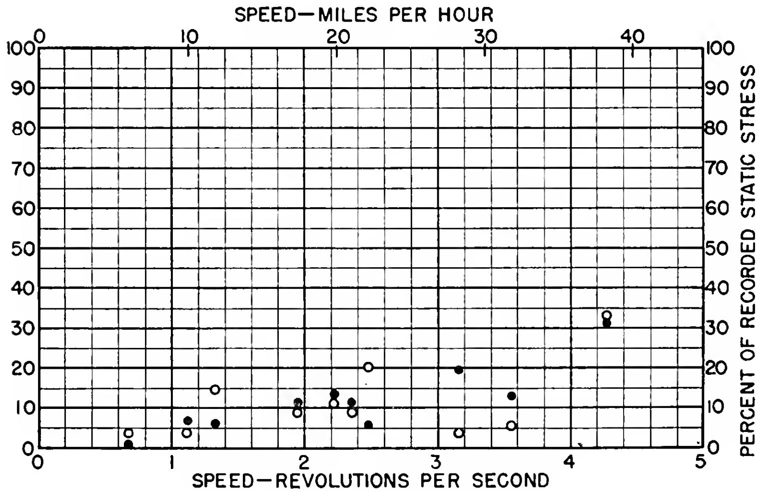
FIG. 2

SOUTHERN RY. BRIDGE TESTS
±13.5' FT. SPAN
TIMBER TRESTLE-BALLASTED FLOOR
LOCATION OF GAGES
RECORDED STATIC STRESS



TOTAL IMPACT—SECTION A-A
(AT ℄ SPAN)

NOTE:
IMPACT BASED ON STRESSES IN TIMBERS 5, 6 & 7 FOR EAST RAIL AND 10, 11 & 12 FOR WEST RAIL, SEE FIG. 2.



TOTAL IMPACT—SECTION B-B
(AT ℄ BENT)

NOTE:
IMPACT BASED ON STRESSES IN TIMBERS 5 & 7 FOR EAST RAIL AND 11 & 13 FOR WEST RAIL, SEE FIG. 2.

SYMBOL:—
● WEST RAIL
○ EAST RAIL

FIG. 3
SOUTHERN RY. BRIDGE TESTS
± 13.5 FT. SPAN
TIMBER TRESTLE—BALLASTED FLOOR
TOTAL IMPACT IN TIMBERS

value of 580 psi. It is quite evident from the right diagram of Fig. 2 that the four timbers under the rails are acting as continuous members.

There is considerable variation in the stresses recorded in the floor timbers at the center of the span, as shown in Fig. 2. For example, the stress in timber 11 at the center of the span is 88 percent greater than the average of the 12 timbers. It appears that the ballast was well tamped under the ties for a short distance on each side of the rail, as required for good track maintenance, as the stresses in the timbers under the rails are higher than the average, while those at the center of the track are lower.

3. Total Impacts

The total impact percentages, as determined from these tests on the floor timbers at the center of the span, are shown in the top diagram of Fig. 3. The impact values shown on this diagram are based upon the recorded stresses in timbers 5, 6 and 7 for the east rail and timbers 10, 11 and 12 for the west rail. For example, the static stress under the west rail is the average stress recorded in timbers 10, 11 and 12, which is 510 psi. The maximum average value recorded in these 3 timbers was 870 psi., which is 70.6 percent greater than the static stress. However, a stress of 1000 psi. was recorded in timber 11 for this same run as the result of the uneven distribution.

The total impact percentages for the floor timbers over the bents are shown in the lower diagrams of Fig. 3. The impact values shown on this diagram are based on the recorded stresses in timbers 5 and 7 for the east rail and timbers 11 and 13 for the west rail. It should be noted from Fig. 3 that the impacts in the timbers over the bents are considerably smaller than those at the center of the span.

4. Conclusions

The tests on this trestle were conducted in an effort to obtain data on the static and dynamic effects of a train moving over a timber pile trestle with a ballasted floor and the results may be summarized as follows:

1. The average static stresses in the floor timbers at the center of the span are slightly lower than the calculated stresses based on a simple span but are higher than those calculated on the assumption that the timbers are continuous.
2. The static stresses in the timbers over the bent indicate continuous action.
3. There is considerable variation in the stresses in the several timbers, the timbers under the rails carrying most of the load.
4. The total impacts in the timbers at the center of the span are about the same as those found in short span steel bridges.
5. The total impacts in the timbers over the bents are considerably smaller than those obtained at the center of the span.

5. Acknowledgements

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are indebted to the Southern Railway System for its cooperation in conducting these tests.

Tests of Bridge Ties of Open Floor Bridges and of the Floor Timbers of Ballasted Floor Bridges

Investigation of Stresses in the Floor Members of Bridges on Three Railroads Provides Data on Longitudinal Distribution of Wheel Loads

Advance Report of Committee 30—Impact and Bridge Stresses

1. Introduction

The amount of axle load carried by each bridge tie or floor timber is of considerable interest to the bridge designer in both the design of the tie and in determining the amount of vertical load carried by the top flange rivets of deck girder spans. The present AREA Specifications for Steel Railway Bridges recommend that the wheel load be distributed over three ties, but it is recognized that this distribution is only an assumption.

In an effort to secure some data on the distribution of the axle loads to the bridge ties and floor timbers under actual operating conditions, the stresses were recorded in the timbers of two open floor bridges and two ballasted floor spans of another bridge during the testing of the steel spans. The instruments used were of the electrical type and 12 gages, having a gage length of 4 in., were mounted on triangular attaching plates fastened to the timbers. A 12-element oscillograph was used to record the simultaneous stresses in the 12 timbers for any position of the wheels.

The tests were carried out under the general direction of G. M. Magee, research engineer, Engineering Division, Association of American Railroads, with E. J. Ruble, structural engineer of the research staff, in direct charge.

2. Nashville, Chattanooga & St. Louis Railway Tests

The research staff of the AAR conducted tests on a 364-ft. through truss draw span across the Tennessee river at Bridgeport, Ala., during the spring of 1945 at the request and expense of the Nashville, Chattanooga & St. Louis Railway. The trusses of this bridge are at 16-ft. centers and the track is supported by 8-in. by 16-in. timber ties at 1-ft. centers resting directly on the center line of the lower chord by means of special rocker bearings (See typical section in Fig. 1). The timber ties had recently been renewed and special care had been taken in securing uniform bearing for the rail. Arrangements were made with the railway to conduct a few exporatory tests on these ties.

The 4-in. strain gages were placed on the top of 12 consecutive ties, as shown in Fig. 1, and readings were taken at a crawl speed of about 5 mph., under the passage of a northern type (4–8–4) locomotive having 57,000 lb. on the driving axles, which was the heaviest power operating in this territory.

The simultaneous and maximum stresses recorded in the 12 ties are shown in the lower diagram of Fig. 1. The maximum stress recorded in each tie as the locomotive drivers passed over the bridge is shown by the circles connected by solid lines. For example, the maximum stress in tie 4 was 1750 psi., and occurred when locomotive wheel 3 was 7 in. north of the center of the tie while the maximum stress in tie 8 was only 650 psi. when wheel 3 passed over this tie.

As the locomotive drivers passed over the bridge, the recorded maximum stress in each tie should be of the same magnitude, provided each tie had the same amount of play and the same cross section, but these conditions are never found in actual structures.

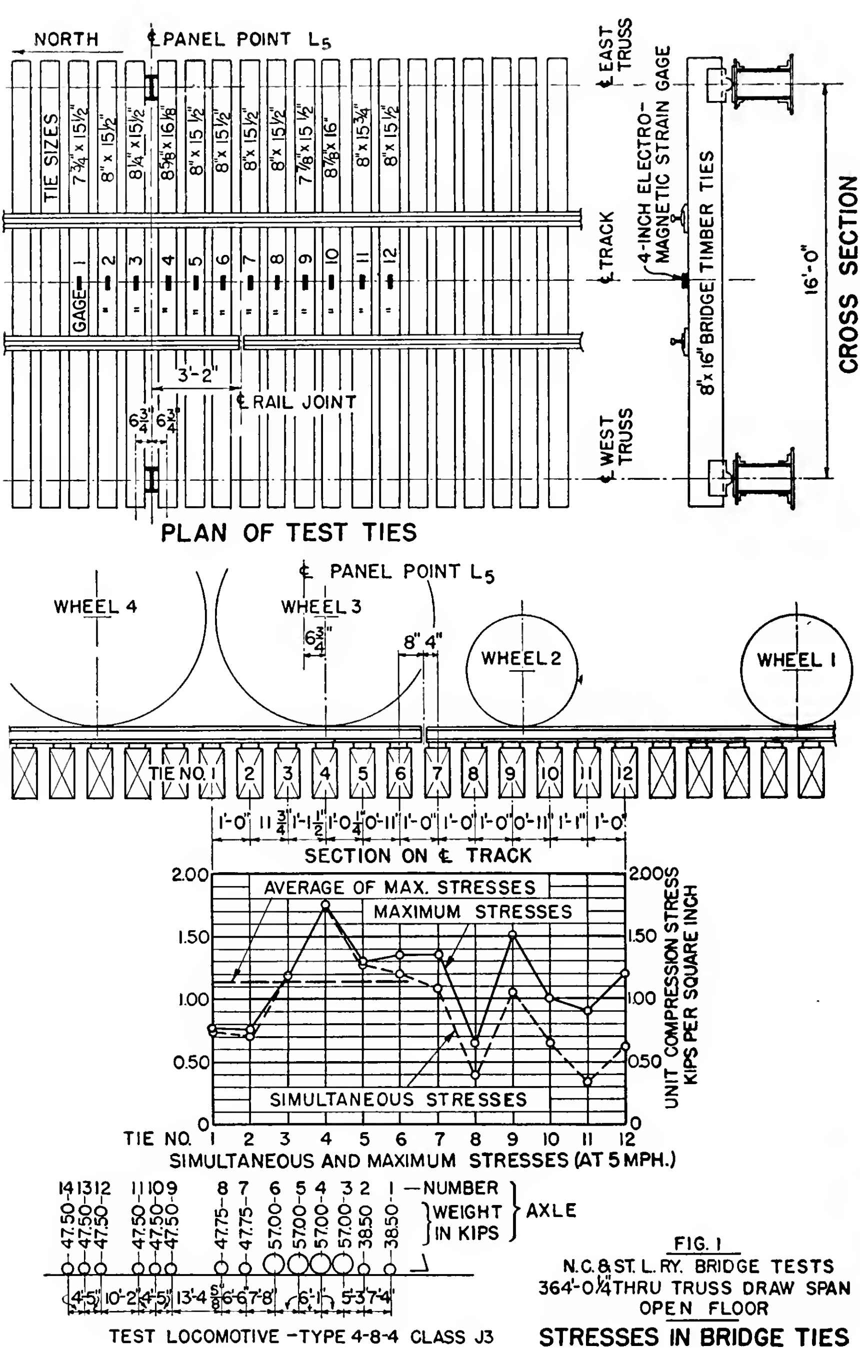


FIG. 1

N.C. & ST. L. RY. BRIDGE TESTS
364'-0¼" THRU TRUSS DRAW SPAN
OPEN FLOOR

STRESSES IN BRIDGE TIES

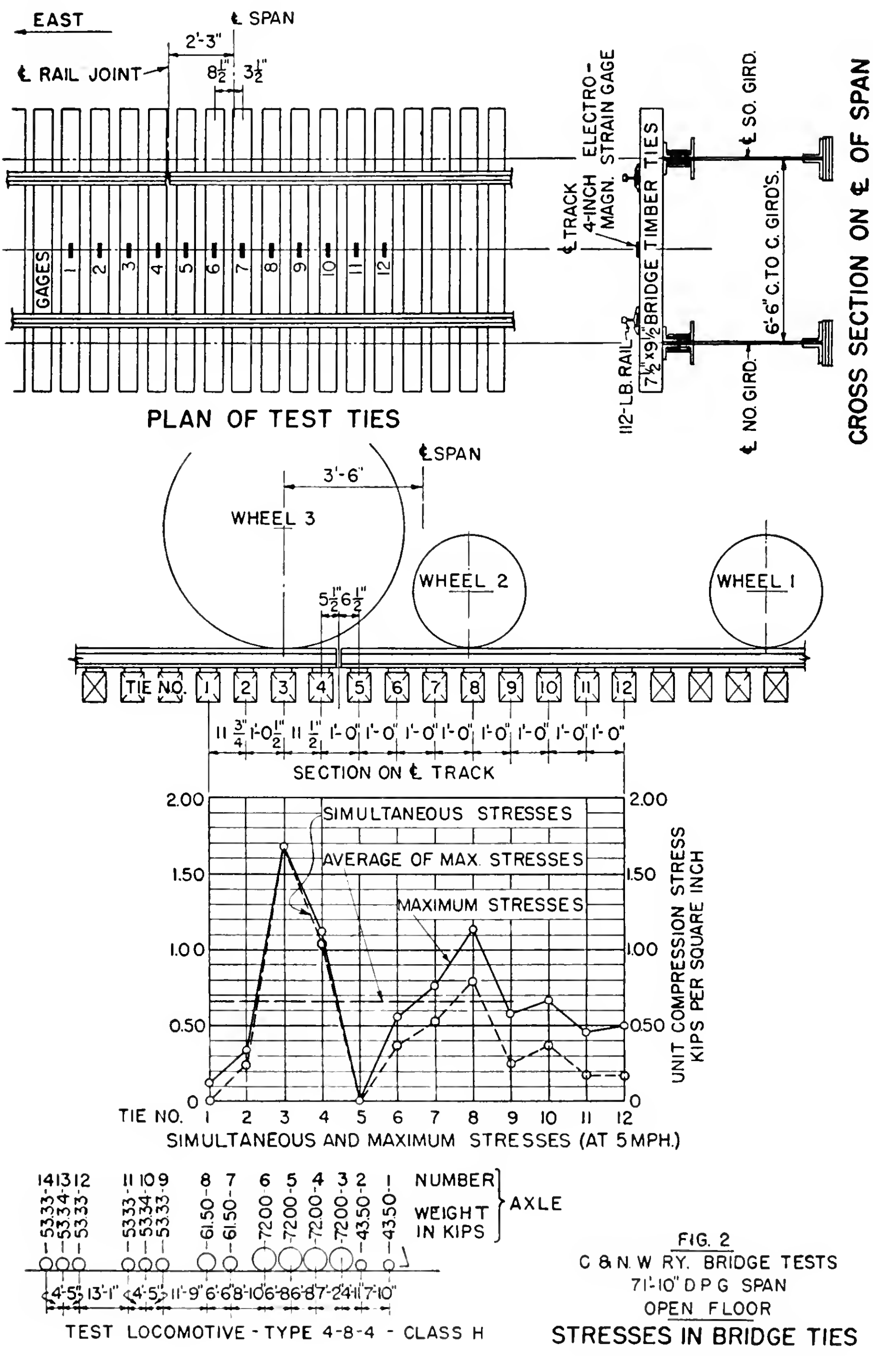


FIG. 2
C & N. W RY. BRIDGE TESTS
71'-10" D P G SPAN
OPEN FLOOR
STRESSES IN BRIDGE TIES

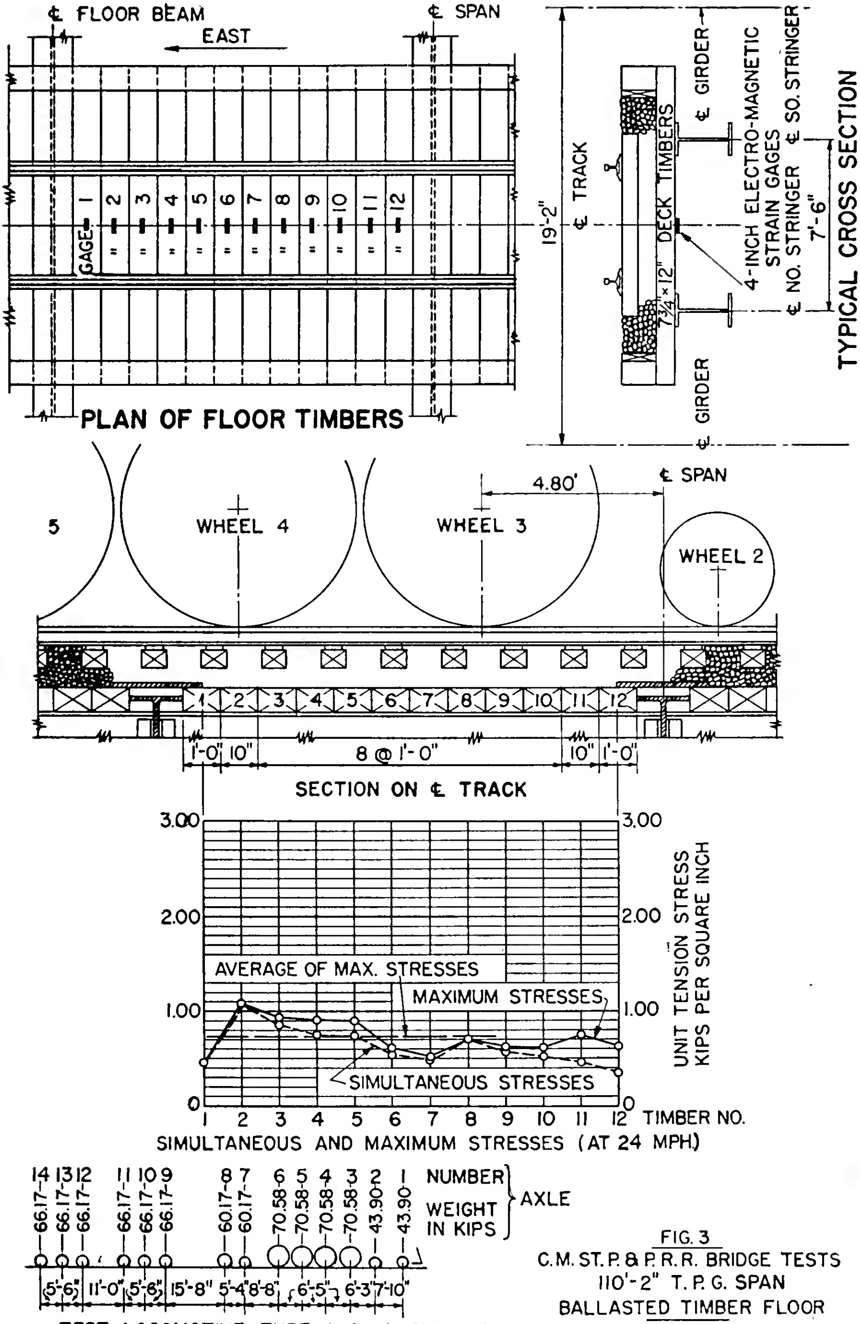


FIG. 3
C.M. ST. P. & P. R.R. BRIDGE TESTS
110'-2" T. P. G. SPAN
BALLASTED TIMBER FLOOR
STRESSES IN FLOOR TIMBERS

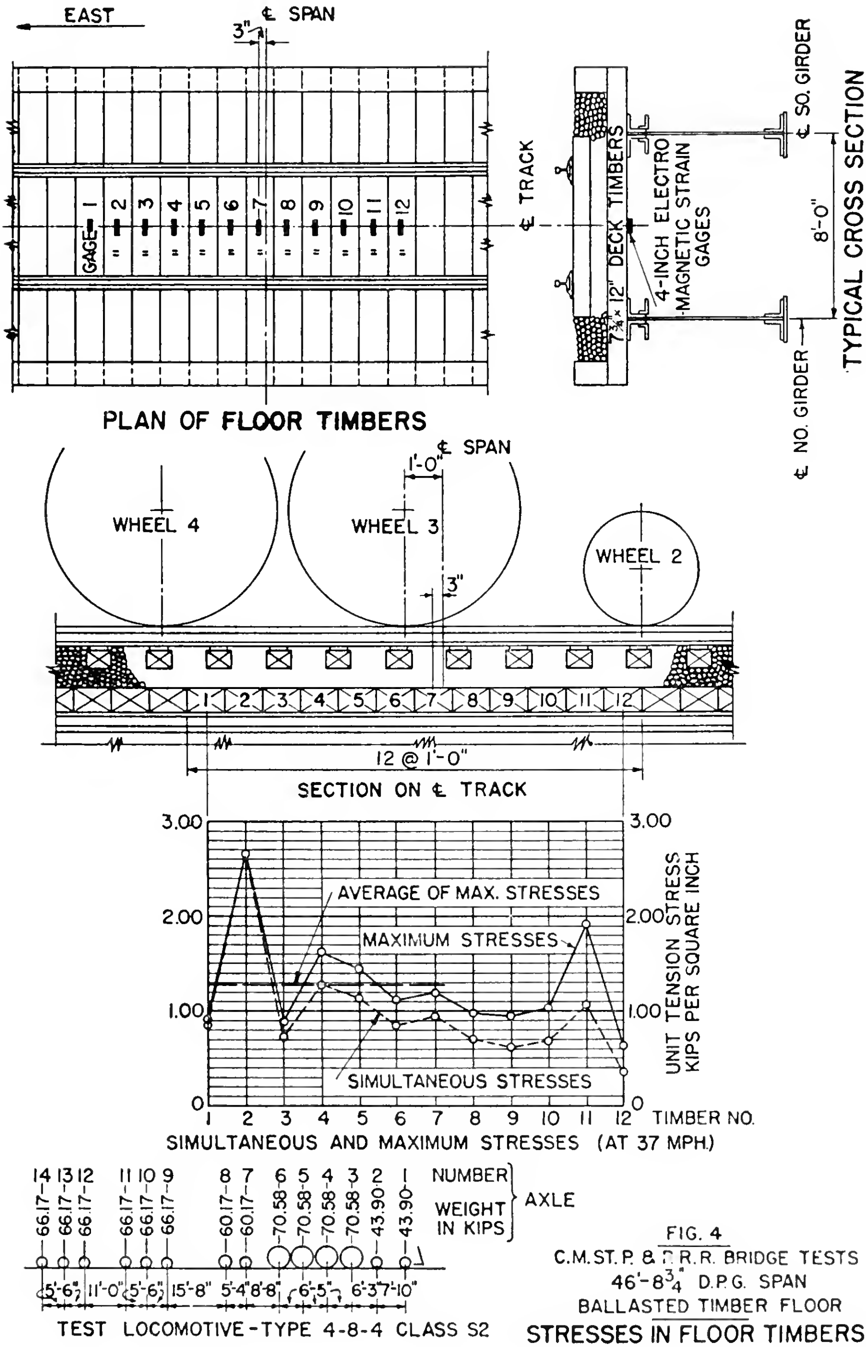


FIG. 4
C.M.ST.P. & P.R.R. BRIDGE TESTS
46'-8¾" D.P.G. SPAN
BALLASTED TIMBER FLOOR
STRESSES IN FLOOR TIMBERS

Under perfect conditions, the stress in each tie would be about equal to the average stress recorded in the 12 ties, which amounts to 1140 psi. However, due to variations in the size of ties and in the amount of tie play, the stress in tie 4 was found to be 54 percent greater than the average while the stress in tie 8 was only 57 percent of the average value.

The calculated stress in tie 4, based on the assumption that the axle load is carried by 3 ties, is 1680 psi., which is in close agreement with the recorded value of 1750 psi. The recorded stress in tie 4 could be checked by assuming a distribution factor of 2.88 ties per axle load instead of the 3.00 ties.

The simultaneous stress in each tie when locomotive wheel 3 was 7 in. north of the center of tie 4 is shown by the open circles connected by dashed lines. As previously mentioned, the maximum stress occurred in tie 4 for this locomotive position while the stress in tie 8 was only 400 psi.

3. Chicago & North Western Railway Tests

Tests were conducted on a 71-ft. 10-in. deck plate girder span on the Chicago & North Western Railway near Rochelle, Ill., during the fall of 1946 by the research staff of the AAR, as part of its study of the impact effects in girder spans. The girders of this bridge are spaced at 6 ft. 6 in. centers and the track is carried by 7½-in. by 9½-in. timber ties at about 1-ft. centers (See cross section through span in Fig. 2). As the ties were in excellent condition, it was decided to measure the static stresses in these timbers.

The 4-in. strain gages were placed on the top of 12 consecutive ties, as shown in Fig. 2, and readings taken under the passage of a northern type (4–8–4) locomotive having 72,000 lb. on the driving axles, at a crawl speed of 5 mph.

The simultaneous and maximum stresses recorded in the 12 ties are shown in the lower diagram of Fig. 2. The maximum stress recorded in each tie as the locomotive drivers passed over the bridge is shown by the circles connected by solid lines. The maximum stress in tie 3 was 1680 psi., and occurred when locomotive wheel 3 was directly over the tie. It is interesting to note that the stress in tie 5, which is on the receiving end of the rail, was always zero, even when wheel 3 was directly over the tie.

The average of the maximum stresses recorded in the 12 ties is 660 psi., which would have been about the maximum stress in each tie as the locomotive drivers passed over if the play in all the ties had been the same. However, the stress in tie 3 was found to be 2½ times greater than the average. It appears that this tie is in close contact with both the rail and the steel and is, therefore, taking most of the axle load.

The calculated stress in tie 3, based on the assumption that the axle load is carried by three ties, is 960 psi., which is considerably below the recorded maximum value of 1680 psi. It would be necessary to assume that only 1.75 ties were carrying the axle load in order for the calculated stress to agree with that recorded.

The simultaneous stress in each tie, when locomotive wheel 3 was over tie 3, is shown by the open circles connected by dashed lines. As previously mentioned, the maximum stress occurred in tie 3 for this locomotive position and the stresses in the remaining ties are as shown, indicating some longitudinal distribution through the continuity of the rail.

4. Chicago, Milwaukee, St. Paul & Pacific Railroad Tests

Tests were conducted on a 110-ft. 2-in. through plate girder span and a 46-ft. 8¾-in. deck girder span on the Chicago, Milwaukee, St. Paul & Pacific Railroad near Elberon, Iowa, during the summer of 1945 by the research staff of the AAR as part of its study of the impact effects in girder spans. The girders of the long through span are spaced at 19-ft. 2-in. centers with stringers at 7-ft. 6-in. centers. The track and ballast are carried by 7¾-in. by 12-in. floor timbers (See typical cross section in Fig. 3). The girders of the deck girder span are spaced at 8-ft. centers and the track and ballast are carried by 7¾-in. by 12-in. floor timbers. Tests were made on the floor timbers of both spans since these timbers were quite new.

The 4-in. strain gages were placed on the bottom of 12 consecutive timbers of each span as shown in Figs. 3 and 4. Readings were taken under the passage at slow speeds of several northern type (4–8–4) locomotives having 70,580 lb. on the driving axles, but no runs were recorded at a crawl speed of 5 mph.

The simultaneous and maximum stresses recorded in the 12 timbers at the speeds indicated are shown in the lower diagrams of Figs. 3 and 4. The maximum stress recorded in each timber as the locomotive drivers passed over the bridge is shown by the circles connected by the solid lines. The maximum stress in timber 2 of the through span was 1080 psi., and occurred for the locomotive position shown in Fig. 3. The maximum stress in timber 2 of the deck span was 2670 psi., and occurred for the locomotive position shown in Fig. 4.

The average of the maximum stresses recorded in the 12 timbers of the long through span is 720 psi., which would have been about the maximum stress in each timber under uniform tie play and ballast conditions. However, the stress in timber 2 of this span was found to be 50 percent greater than the average. The average of the maximum stresses recorded in the 12 timbers of the short deck span is 1280 psi., but the maximum stress of 2670 psi. in timber 2 of this span is slightly greater than twice the average stress.

The simultaneous stress in each tie for the locomotive position indicated, as shown by the open circles and dashed lines of Figs. 3 and 4, indicates that the continuity of the rail is helping to distribute the axle loads to some extent.

5. Conclusions

The tests on these bridge ties and floor timbers afforded an opportunity to study the longitudinal distribution of the locomotive axle loads as well as the effects of uneven tie play and ballast conditions on the maximum stresses.

On the basis of the data, as found from these tests, it seems logical to conclude that:

1. The continuous action of the rails tends to distribute the axle loads longitudinally.
2. On the open deck spans, the distribution of the wheel loads to the ties was quite irregular due to variations in modulus of elasticity, tie dimensions and in play between rail base, tie plate and tie. An individual tie on one span was found to carry as much as 0.57 of the axle load. Some ties or timbers on the bridge do not carry any, or at the most a very small proportion, of the axle loads.
3. On the span with the ballasted floor, the load distribution was more uniform to the floor timbers, but even here an individual timber was found to carry as much as twice the average load on the timbers.

6. Acknowledgements

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are indebted to the officers of the Nashville, Chattanooga & S.t Louis Railway, the Chicago & North Western Railway and the Chicago, Milwaukee, St. Paul & Pacific Railroad for their cooperation in conducting these tests.

Tests of Lateral Bracing of Deck Girder Spans

Advance Report of Committee 30—Impact and Bridge Stresses

1. Introduction

The stresses in the bracing of railroad bridges resulting from the locomotives crossing at high speeds are of interest to bridge engineers since considerable difficulty has been encountered in recent years with the bracing of many of the older structures. The present AREA Specifications for Steel Railway Bridges embrace certain recommendations for the forces carried by this bracing, but it is recognized that these recommendations are based only upon judgment and are not substantiated by any data obtained under actual operating conditions.

In an effort to secure some data on the stresses in the angles of the bracing members under actual operating conditions, strain gages were placed on the bracing members of a girder span having a ballasted concrete floor and also on a girder span having an open timber floor during the testing of these spans for impact effects.

The instruments used on both spans were of the electrical type with oscillograph recording. The gages used on the angles of the ballasted floor span were SR–4 wire resistance gages having a 1-in. gage length, one gage being placed on each corner of the angle to measure the direct as well as the simultaneous bending stresses at each section of the angle. The gages used on the angles of the open floor span were of the electromagnetic type having a 2-in. gage length and a single gage was placed only at the neutral axis of the connected leg, hence, only the direct stresses were recorded.

The tests were carried out under the general direction of G. M. Magee, research engineer, Engineering Division, Association of American Railroads, with E. J. Ruble, structural engineer of the research staff, in direct charge.

2. Illinois Central Railroad Tests

During the summer of 1946, tests were conducted by the research staff on a 40-ft. deck plate girder span having a ballasted poured-in-place concrete deck. The span is on the main line of the Illinois Central Railroad near Tuscola, Ill., and carries both diesel and steam locomotives at high speeds.

The SR–4 wire resistance gages were placed on the angles of the lateral bracing, on an end cross frame and on an intermediate cross frame, as shown in Fig. 1, and the stresses were recorded in these members under the passage of both diesel and steam locomotives at all speeds ranging from 5 mph. up to 75 mph. for both the diesel and steam locomotives.

The maximum stresses recorded in the bracing angles of this bridge were quite low, no doubt because of the lateral rigidity of the poured-in-place concrete floor, and their magnitude did not appear to bear any relation to speed. For this reason, the stresses recorded at the various speeds are not shown in this report. Only the maximum tensile stress and the maximum compressive stress recorded on one corner of the angle at the various sections are shown in the diagrams of Fig. 2. The simultaneous stresses on the other two corners of the angles are also shown on these diagrams. For example, the maximum tensile stress in the angle of the end cross frame, section 1–1, was recorded by gage 2 and amounted to 3800 psi. The simultaneous stress on the other two corners was a 900-psi. compressive stress recorded by gage 1 and a 2100-psi. compressive stress by gage 3. The maximum compressive stress in the same angle and at the same section but under a different locomotive was also recorded by gage 2 and amounted to 3000 psi.

(text continued on page 140)

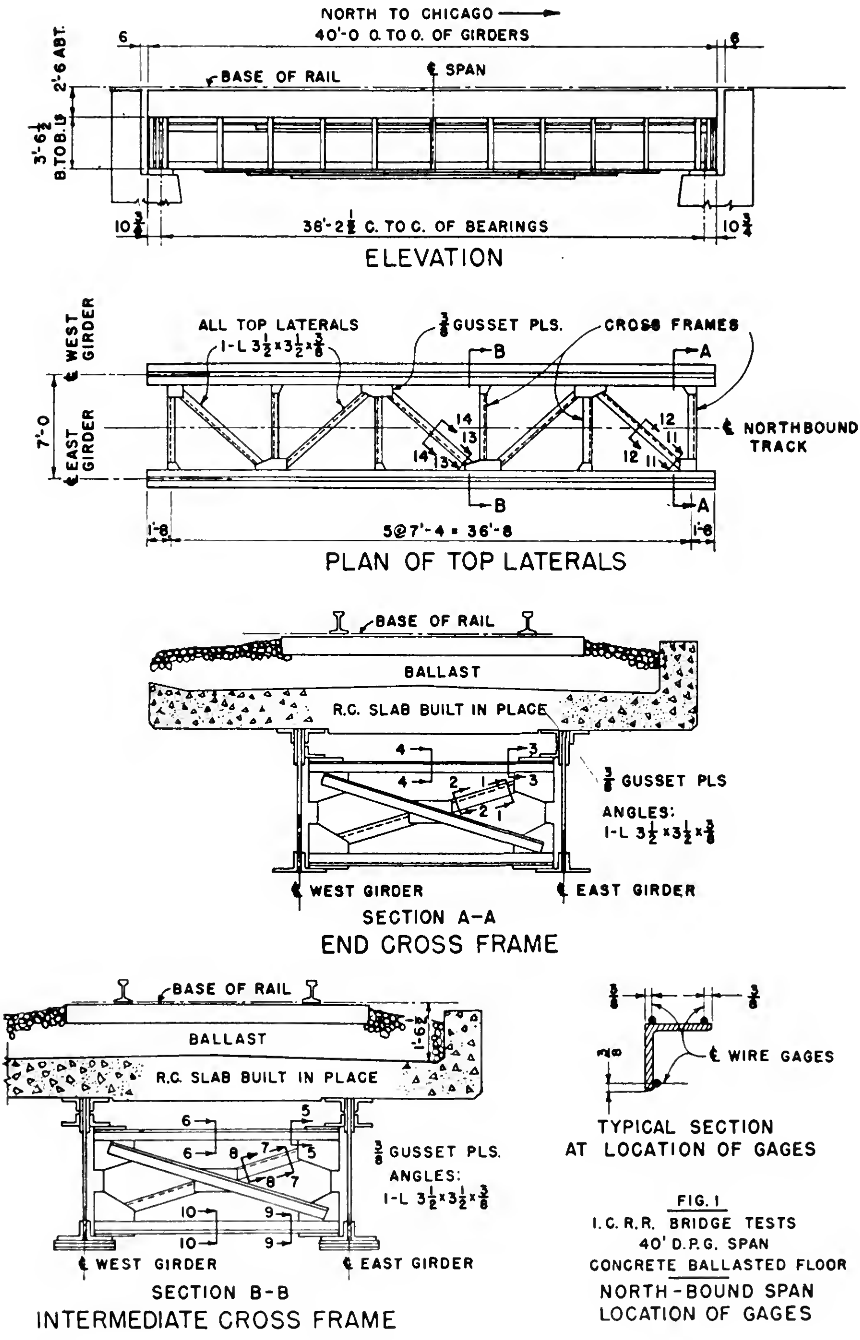
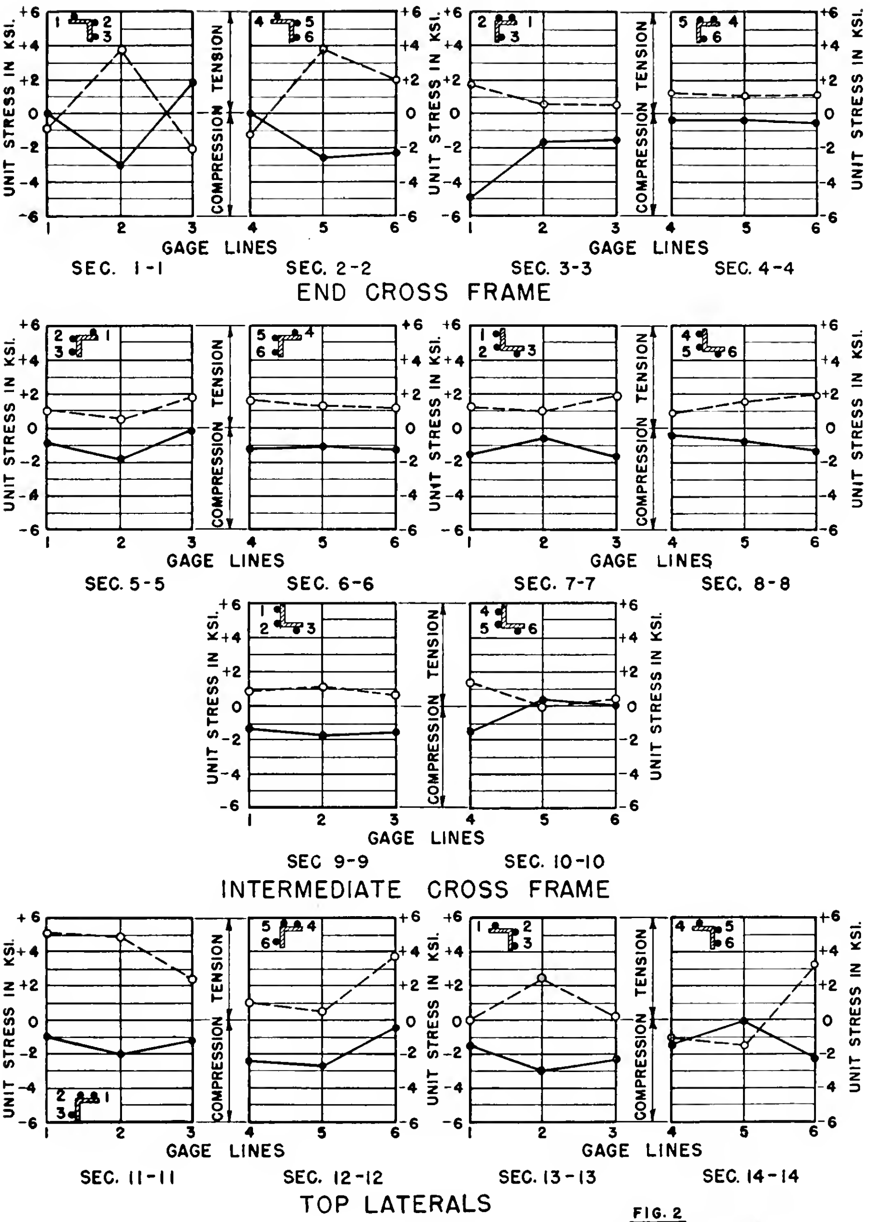


FIG. 1
I. C. R. R. BRIDGE TESTS
40' D. P. G. SPAN
CONCRETE BALLASTED FLOOR
NORTH-BOUND SPAN
LOCATION OF GAGES



SYMBOL
● MAXIMUM COMPRESSION
○ MAXIMUM TENSION

FIG. 2
I.C.R.R. BRIDGE TESTS
40' D.P.G. SPAN
CONCRETE BALLASTED FLOOR
RECORDED MAXIMUM STRESSES
IN CROSS FRAMES AND TOP LATERALS

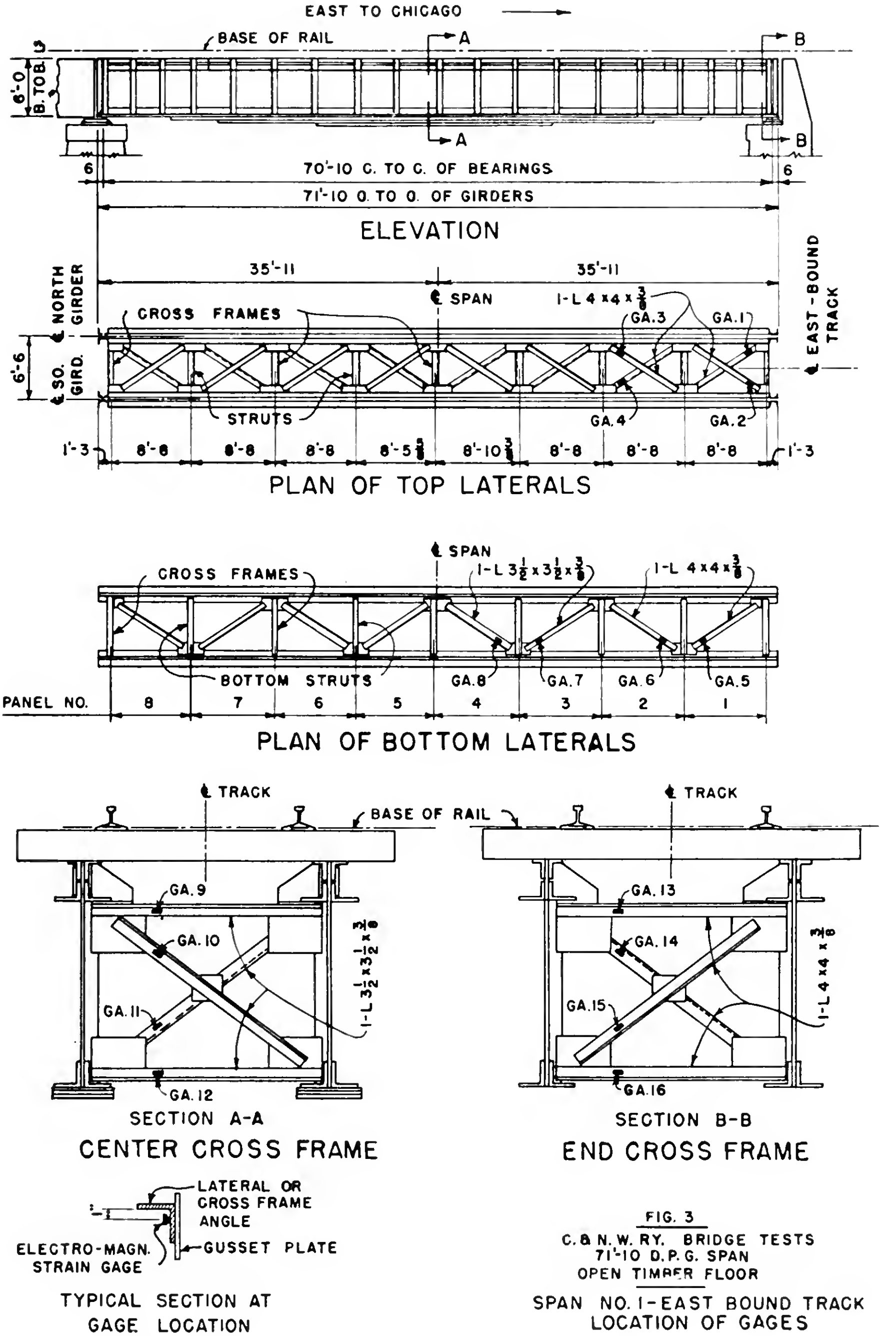
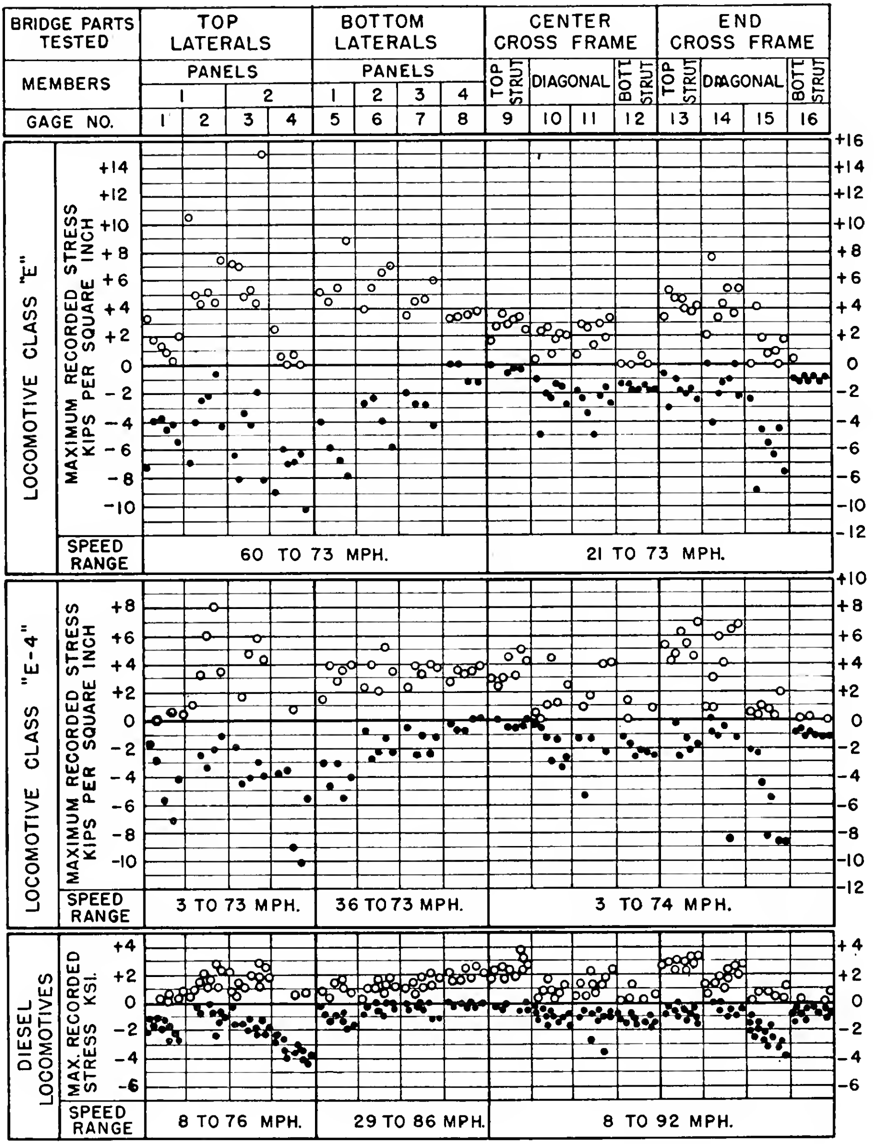


FIG. 3
C. & N. W. RY. BRIDGE TESTS
71'-10 D. P. G. SPAN
OPEN TIMBER FLOOR

SPAN NO. 1 - EAST BOUND TRACK
LOCATION OF GAGES



SYMBOL:
• MAXIMUM COMPRESSION
○ MAXIMUM TENSION

FIG. 4

C. & N. W. RY. BRIDGE TESTS
71'-10 D.P.G. SPAN
OPEN TIMBER FLOOR

RECORDED MAXIMUM STRESSES IN LATERALS AND CROSS FRAMES LOCOMOTIVE CLASSES "E", "E4" & DIESELS

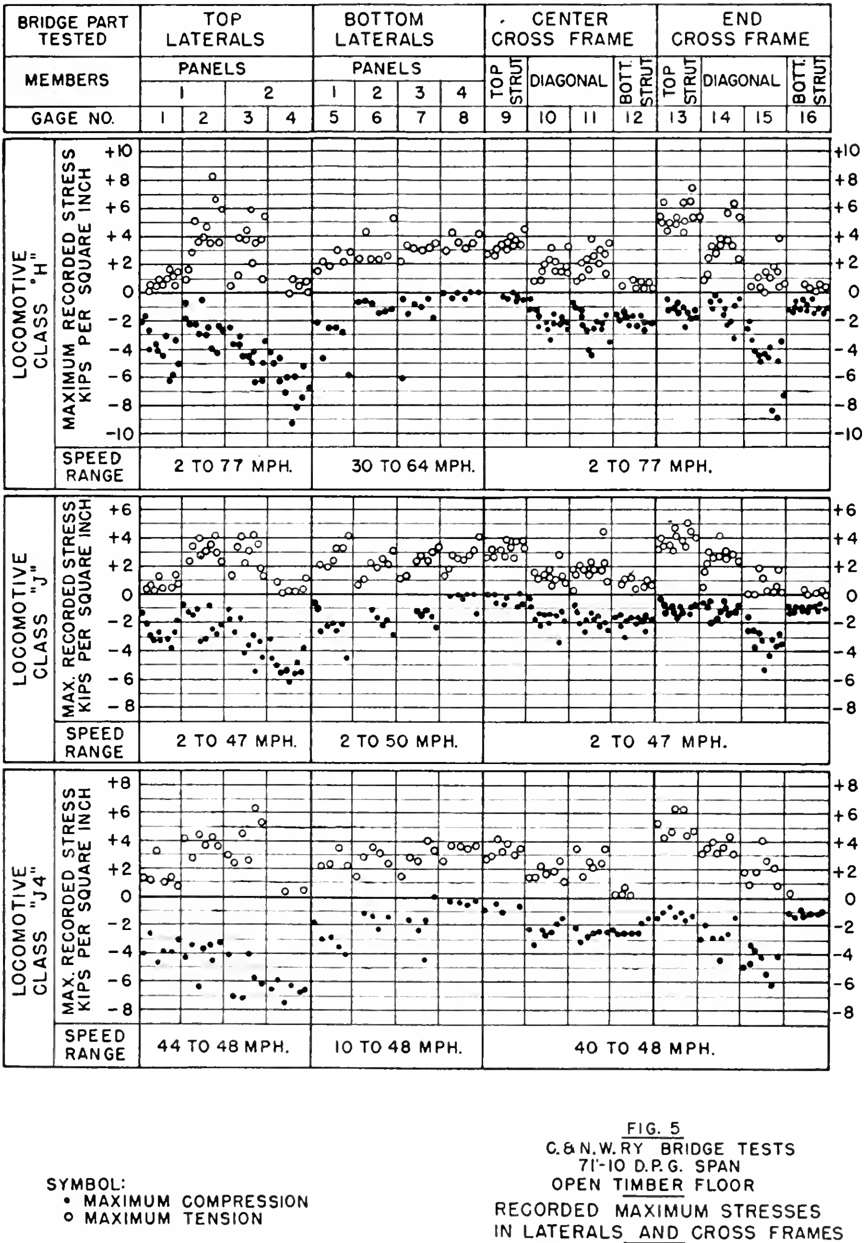


FIG. 5
C. & N.W. RY BRIDGE TESTS
71'-10 D.P.G. SPAN
OPEN TIMBER FLOOR
RECORDED MAXIMUM STRESSES
IN LATERALS AND CROSS FRAMES
LOCOMOTIVE CLASSES: "H", "J" & "J4"

(text continued from page 134)

The simultaneous stress on the other two corners was zero at gage 1 and a tensile stress of 1800 psi. at gage 3.

It is apparent from the diagrams in Fig. 2 that there is considerable variation in the stresses on the three corners of the angles, and in some angles a stress as great as two or three times the average stress was recorded on one corner. The large variation in stress is undoubtedly due to the eccentric application of the direct load, since the angles are usually connected by one leg.

3. Chicago & North Western Railway Tests

During the summer of 1946 the research staff conducted tests on a 71-ft. 10-in. deck plate girder span having an open floor. The span is on the main line of the Chicago & North Western Railway between Chicago and Omaha, Nebr. and carries both high speed diesel and steam locomotives.

Electromagnetic strain gages were placed on the inside of the angles of the top and bottom lateral bracing, on an end cross frame and on the center cross frame, as shown in Fig. 3. The stresses were recorded in these members under the passage of both diesel and steam locomotives at all speeds ranging from 5 mph. up to about 100 mph. for the diesels and 75 mph. for the steam locomotives.

A study of the oscillograms taken in the field indicates that, in general, there were about four cycles of stress under the passage of the locomotive and tender. The stress cycle usually consisted of a reversal from maximum tension to maximum compression but the tension and compression stresses were not always of the same magnitude.

The maximum stresses recorded in these bracing angles under the various locomotive classes, according to speed, are shown in the diagrams of Figs. 4 and 5. As previously mentioned, the gages were located close to the neutral axis of the angles so that the stresses shown in these diagrams represent only direct stress. It would appear logical to expect, from the results of the tests on the bracing agles of the I. C. R. R. bridge, that the stresses on the corners of the angles would be two or three times greater than those shown on these diagrams. The maximum compressive stresses are shown by the solid circles on these diagrams while the maximum tensile stresses are shown by the open circles.

In general, the direct stresses were quite low and the compressive and tensile stresses were about the same. A maximum stress of 14,900 psi. tension was recorded by gage 3 in panel 2 of the top laterals and occurred under a Class E locomotive at a speed of 70 mph. (See Fig. 4). There is an indication that the stresses in some members increase with an increase in locomotive speed, but in other angles the stresses remain about the same for all speeds.

The recorded simultaneous stresses in the four test angles of the top lateral bracing and the four angles of the end cross frame, under the Class E locomotive at 70 mph., were:

Gage	*psi.*	
1 —	5,400	(compression)
2 +	7,460	(tension)
3 +	14,950	
4 —	10,150	
13 +	4,190	
14 +	5,260	
15 —	7,630	
16 —	970	

It appears from the sign of the recorded stresses in the angles of the top laterals that the stresses are a result of a transverse force to the north acting on the girders, but it is difficult to understand why the stresses in the angles of the second panel are larger than those in the first panel since the size of the angles is the same. The sign of the recorded stresses in the end cross frame also indicates a transverse force to the north. A calculated transverse force of 43,000 lb. would be required to stress the angles of panel 2 up to the recorded values.

The recorded simultaneous stresses in the four angles of the center cross frame, under the Class E locomotive at 70 mph., were:

Gage	*psi.*
9	+ 3,400 (tension)
10	— 2,920 (compression)
11	+ 3,240
12	— 1,760

The signs of the recorded stresses in the angles of the center cross frame indicate that the north girder was deflecting more than the south girder and a study of the stresses recorded in the lower flanges at the center of the girders substantiates this conclusion.

4. Summary

The results of the tests conducted on the lateral bracing angles of the two bridges may be summarized as follows:

1. A poured-in-place concrete floor increases the rigidity of the span against lateral forces.
2. The stress on one corner of an angle connected by one leg may be two or three times the average stress in the angle.
3. The lateral bracing angles are usually subjected to a complete reversal of stress.
4. The sign of the stresses in the angles of the top laterals and end cross frames indicates that these stresses are the result of transverse forces acting in either direction on the girders.
5. The stresses in the center cross frames appear to be the result of unequal deflection of the girders resulting from the rolling of the locomotive about a longitudinal axis.

5. Acknowledgements

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are indebted to the officers of the Illinois Central Railroad and the Chicago & North Western Railway for their cooperation in conducting these tests.

Impact Tests of a Concrete Pier

Chicago, Burlington & Quincy Railroad

Advance Report of Committee 30—Impact and Bridge Stresses

1. Introduction

The tests on the concrete pier described in this report were made on a bridge of the Chicago, Burlington & Quincy Railroad during the summer of 1947. The pier supports the fixed end of a 100-ft. through plate girder span and the expansion end of a 75-ft. through plate girder span as shown in Fig.1. The bridge is a single track structure near Ft. Morgan, Colo., on the main line of the railroad between Omaha, Nebr., and Denver, Colo. Extensive tests were made on the steel girder spans to determine the impact effects in these spans and the pier tests were made after completing the girder tests. The tests on the pier were made under a special test train consisting of a northern type (4–8–4) locomotive and 10 cars. The axle weights of the locomotive and tender are shown in Fig. 1.

The gages used were of the electromagnetic type having a 4-in. gage length and were mounted on two triangular attaching plates fastened to the concrete. The attaching plates are the same as those used for timber tests and are fastened to the concrete by expansion units inserted in small drilled holes in the concrete. The gages were calibrated individually so that in general, a 1-in. deflection of the light trace on the film indicated a strain in the concrete of 0.0008 in. for the 4-in. gage length, which is equivalent to a unit stress of 500 psi., assuming a modulus of elasticity of 2,500,00 psi.

The strain gages were placed on both sides of the pier and in line with each girder as shown in Fig. 1. The lower gages were placed below the ground line by excavating a trench about six ft. deep on both sides of the pier. The simultaneous stresses were recorded at the 12 locations under a complete range of speeds from 5 mph. up to 55 mph. under normal operation of the test train. Additional runs were made at about 22 mph., in which a hard service application of the brakes was made with the locomotive on the 100-ft. span. Further tests were made by stopping the locomotive on the 100-ft span and then starting as fast as possible.

The tests were carried out under the general direction of G. M. Magee, research engineer, Engineering Division, Association of American Railroads. The conduct of the tests, analysis of data and preparation of the report were in charge of E. J. Ruble. structural engineer, research staff, AAR.

2. Static Stresses

The compressive stresses recorded in the pier under the passage of the test train at normal train operation are shown in the six diagrams of Fig. 2. The values shown in these diagrams by the cross symbol are the averages of the stresses recorded on the east and west side of the pier. The pier supports spans of unequal length, but due to the locomotive position, the resultant of all the live loads on both spans is to the east of the center line of the pier so that the concrete stresses on the east side are higher than those on the west side.

The stresses recorded at a crawl speed of 5 mph. are usually considered the same as static stresses and, for comparison, the static stresses in the concrete were calculated at the three sections. The calculated stresses are based upon the full concrete area at the section and these values are shown by the horizontal dashed lines on the six diagrams of Fig. 2.

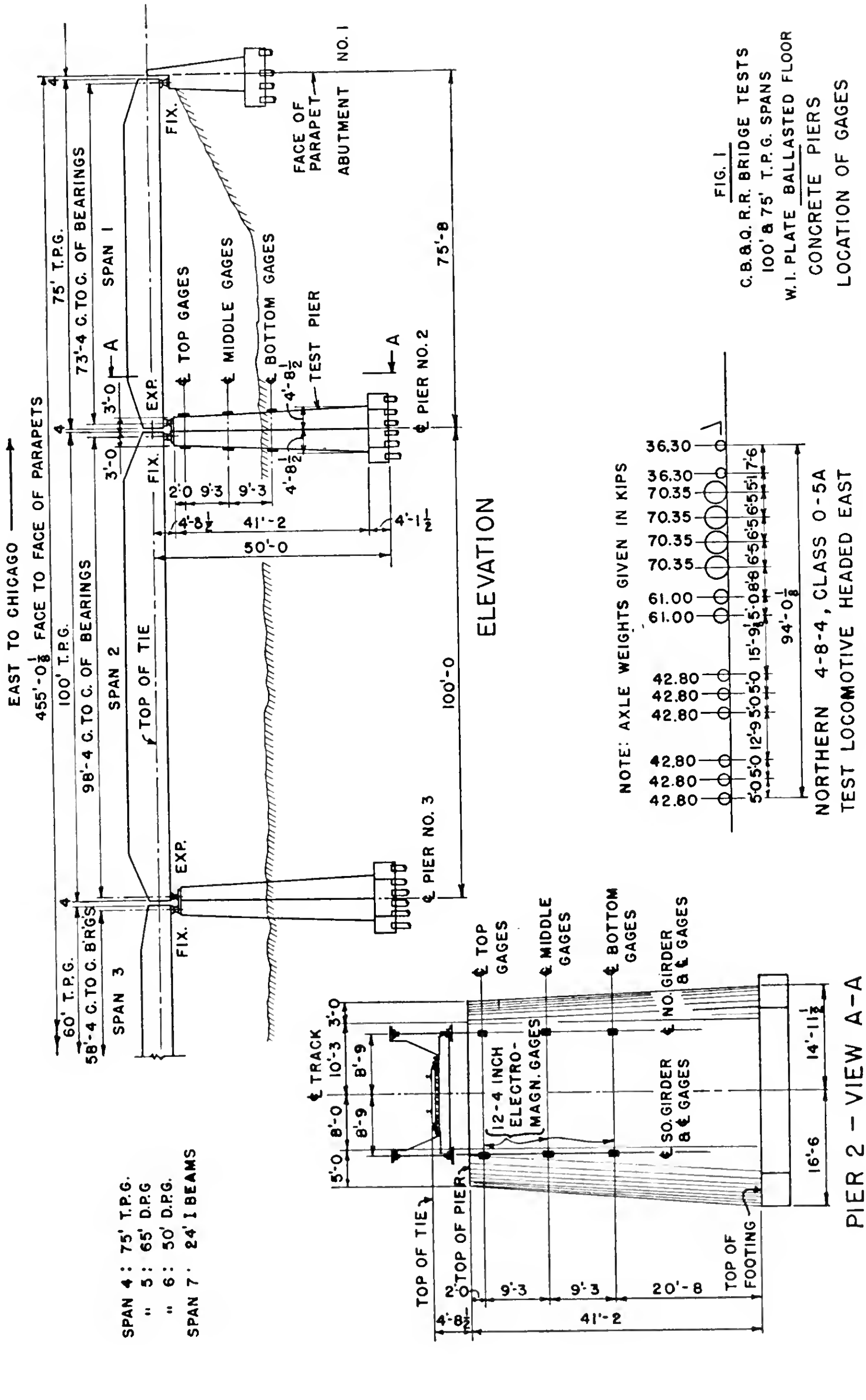


FIG. 1
C.B.&Q. R.R. BRIDGE TESTS
100' & 75' T.P.G. SPANS
W.I. PLATE BALLASTED FLOOR
CONCRETE PIERS
LOCATION OF GAGES

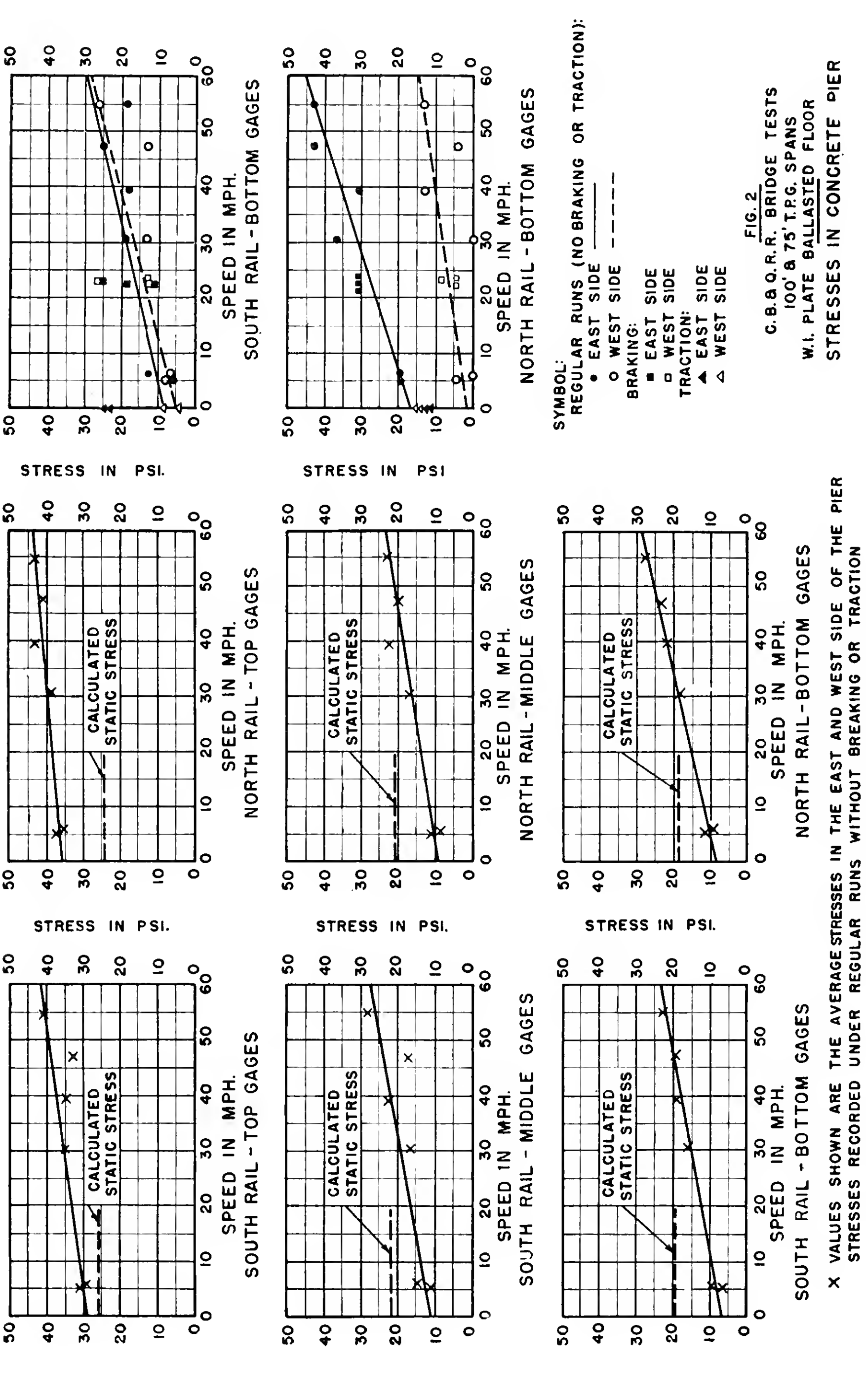


FIG. 2
C. B. & Q. R. R. BRIDGE TESTS
100' & 75' T. P. G. SPANS
W. I. PLATE BALLASTED FLOOR
STRESSES IN CONCRETE PIER

The recorded stresses at 5 mph. on the top section 2 ft. below the pier top were greater than those calculated, indicating that at this section the load is not distributed to the ends and center of the pier. The recorded stresses on the other two sections are lower than those calculated and this variation cannot be explained, although it is possible that the stresses on the inner part of the pier are greater than those on the outside.

3. Dynamic Stresses

The approximate compressive stresses in the pier at the various sections under normal train operation at speeds varying from static to 60 mph., are shown by the solid lines in the six diagrams on the left of Fig. 2. It can be seen from these diagrams that there was an increase in stresses in the pier with an increase in test train speed, and it appears evident that the increase in stress continues on down to the piles. An examination of the oscillograms taken in the field indicates that the pier was vibrating in a vertical direction and the period of the vibration was equal to the period of revolution of the locomotive driving wheels.

4. Longitudinal Forces

A longitudinal force applied to the top of the pier, such as that resulting from locomotive braking or traction, would tend to increase the stresses on one side of the pier and decrease those on the other side. The effect of locomotive braking would be to produce a longitudinal force towards the east which would tend to increase the compressive stresses on the east side of the pier and reduce those on the west side. The effect of locomotive traction would be to produce a longitudinal force towards the west which would reduce the compressive stresses on the east side of the pier and increase those on the west side.

As previously mentioned, the stresses on the east side of the pier were greater than those on the west side due to the locomotive position, and this variation in stresses under the test train operating without braking or traction is shown for the lower section of the pier in the two diagrams on the right side of Fig. 2. The stresses on the east side are shown by the solid circle connected by the solid line while those on the west side are shown by the open circle connected by the dashed line.

Three runs were made with the test train crossing the bridge at about 22 mph. with an air pressure of about 20 psi. applied to the brakes when the locomotive was on the 100-ft. span. The stresses recorded on the east side of the pier are shown by the solid squares while those recorded on the west side are shown by the open squares in the two diagrams of Fig. 2. For this condition of loading, the solid squares should be above the solid line, but there is no positive indication that the pier was subjected to any longitudinal force.

Two tests were made with the locomotive standing on the bridge and then starting as fast as possible. The stresses recorded on the east side of the pier are shown by the solid triangles while those shown by the open triangles were recorded on the west side. For this condition of loading, the solid triangles should be below the solid line but it can be seen that the results were very erratic.

An examination of the oscillograms taken for the braking and traction tests indicated that there was no abrupt change in stress such as would occur if a longitudinal force was suddenly applied to the top of the pier.

5. Conclusions

These tests afforded an opportunity for the first time to measure the static and dynamic stresses in a large concrete pier as a heavy locomotive crossed over the bridge, and from the data obtained in these tests, it seems logical to conclude that:

1. There is a definite increase in the concrete stresses with an increase in speed. The increase appears to be due partially to vertical vibrational effects and is larger at the mid height of the pier than at the top.
2. No evidence of any longitudinal forces resulting from the braking or tractive efforts of the locomotive was found.

6. Acknowledgments

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are greatly indebted to the Chicago, Burlington and Quincy Railroad for its cooperation in conducting these tests.

Report of Committee 16—Economics of Railway Location and Operation

C. H. Blackman, *Chairman,*	C. J. Henry	J. W. Barriger, *Vice Chairman,*
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	E. H. Roth	

Committee

To the American Railway Engineering Association:

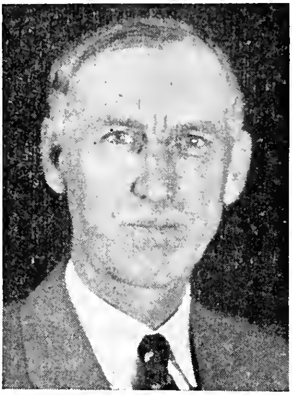
Your committee reports on the following subjects:

1. Revision of Manual.
   No report.
2. Methods for increasing the use of existing railway facilities.
   No report.
3. Methods and formulas for the solution of special problems relating to economics of railway operation.
   No report.
4. Effect of higher speed on railway revenues, operating expenses, and charges to capital account.
   No report.
5. Electrification and the development of modern power units, collaborating with Electrical Section, Engineering Division and Mechanical Division, AAR.
   Progress report, in the form of a monograph on the gas turbine locomotive, submitted as information .... page 149
6. Cost of railway transportation and operation over the past 100 years; principal controlling elements and economic significance.
   No report.
7. Yards; effect of their location on the economics of railway location and operation, collaborating with Committee 14.
   No report.
8. Economics of operation of union railway passenger terminals.
   Progress report, description of proposed New Orleans terminal, submitted as information .... page 157

The Committee on Economics of Railway Location and Operation,
C. H. Blackman, *Chairman.*

AREA Bulletin 476, November 1948.

James Moore Farrin



James Moore Farrin, son of Thomas and Julia Farrin, was born in Cairo, Ill., April 24, 1879 and died in a hospital at Lake Worth, Fla., July 25, 1948 in his 70th year. Interment was in the National Cemetery at Arlington, Va.

He was educated in the public schools of Cairo, and the University of Illinois from which he was graduated with the degree of B. S. in Civil Engineering in 1902.

He was employed as a track apprentice on the Illinois Central Railroad during the summer of 1900 and upon graduation entered the service of that railroad at Chicago as draftsman in the bridge and building department, continuing as draftsman, designer and as inspector on concrete and structural work until May 15, 1907, when he resigned.

He then became office engineer in the maintenance of way department of the Missouri Pacific Railroad at St. Louis where he remained until May 1909, when he entered the employ of the Cuba Railroad at Camaguey as engineer of bridges and buildings, remaining there until July 1912, when he returned to the United States and engaged in the contracting business until July 1915, specializing in power plant installations.

He re-entered the service of the Illinois Central at Chicago, July 16, 1915, as assistant engineer on valuation work and was transferred to the office of the chief engineer in 1916, where he was engaged in the design of terminal improvements incident to electrification.

Mr. Farrin entered military service September 1, 1917, and upon completion of the engineering course at Fort Leavenworth was commissioned and served 21 months overseas in engineering regiments as captain and major, Corps of Engineers, U. S. Army. He returned to Illinois Central service as assistant engineer January 12, 1920, and was promoted to special engineer engaged in economic studies February 15, 1923 with headquarters at Chicago, continuing in that capacity until ill health caused his retirement October 31, 1943. He then removed to West Palm Beach, Fla., where he resided until his death.

Mr. Farrin became a member of the American Railway Engineering Association in 1921. He was a member of Committee 21—Economics of Railway Operation and its successor, Committee 16—Economics of Railway Location and Operation, from 1924 to 1947, serving as chairman of Committee 21 for three years, 1926–1929. He was also a member of Committee 4—Rail, from 1927 to 1945.

Mr. Farrin was a member of the Fourth Illinois National Guard regiment in 1898 and served in the Spanish American War. He organized the 505th Engineer Battalion, an Illinois Central unit of the Engineer Reserve Corps, in 1926, and served as its commanding officer. For many years he was a member of the Society of Military Engineers, and was at one time a member of American Society of Civil Engineers.

Mr. Farrin was a loyal and devoted friend and an untiring worker, whose genial personality will be long remembered by his associates.

Mr. Farrin is survived by a son, Captain James M. Farrin, Jr., U. S. Navy, Washington; a daughter, Miss Fanell Farrin, New York; and his widow, the former Sabra Hart, Lake Worth, Fla.

Report on Assignment 5

Electrification and the Development of Modern Power Units

Collaborating with Electrical Section, Engineering Division, and Mechanical Division, AAR

L. K. Sillcox (chairman, sub-committee), E. G. Allen, J. W. Barriger, C. H. Blackman, C. W. Breed, H. S. Bull, S. B. Clement, Spencer Danby, Miss Olive W. Dennis, Benjamin Elkind, W. T. Elmes, W. B. Irwin, E. E. Kimball, F. H. McGuigan, Jr., P. E. Needham, F. N. Nye, J. F. Pringle, W. T. Rice, R. W. Rogers, E. H. Roth, J. A. Schoch, H. F. Schryver, H. M. Shepard, H. D. Walker.

The report of your committee this year comprises a monograph on the gas turbine locomotive which embraces a discussion of various estimates of fuel supplies.

The Gas Turbine Locomotive

By L. K. Sillcox
First Vice-President, New York Air Brake Company, Watertown, N. Y.

At no time in the history of American railway transportation has so much interest been displayed in, and so much thought and effort been expended toward the solution of the motive power problem. We have the conventional reciprocating steam locomotive, well familiar to us after more than one hundred years' experience with its characteristics. We know its limitations and we know its virtues. We are also thoroughly cognizant of the advantages and disadvantages of the straight-electric locomotive, having operated it for almost 50 years. The diesel-electric, while relatively new, has established its position in the railway field. These three power types would serve us well and our efforts would be largely limited to refining the designs of each in order that they could better perform their specified assignments—and there are ones for which each is best fitted—were it not for the problem of fuel supply. However, there is a very real uncertainty relative to our liquid fuel reserves, and the diesel-electric, to which the railways are turning in vast numbers, is a consumer of oil. Hence, the determined efforts to find a coal-burning substitute are understandable.

Previous reports of this committee have evaluated straight-electric (See Proceedings, Vol. 46, 1945, page 26) and diesel-electric (See Proceedings, Vol. 47, 1946, page 54) locomotives, relating each largely to steam power. Now a new application of electric traction is on the threshold of the railway industry—the gas-turbine electric-drive locomotive. In the absence of experience data it is obviously impractical to compile an economic evaluation, but the gas turbine displays certain known characteristics and an examination of those attributes is judged appropriate.

The Question of Fuel

Consideration of the gas-turbine locomotive immediately raises a question regarding the fuel with which it will be fired. Foreign applications of the principle have relied upon oil, a fuel admirably adapted to the purpose but one in short supply, and in this country comprehensive research is currently being conducted with a view toward burning coal in pulverized form. Various and widely varying estimates of our fuel resources are advanced by equally well-recognized authorities, and unfortunately it is difficult to compose them. These variations can usually be explained by analysis of factors considered when the estimate is made. For example, one authority will include oil-bearing shale reserves as a source of liquid fuel and add 50 or more years to his estimate, while another will insist that this oil can never be economically recovered and eliminate it from consideration. The latter will point to selected experiences of the oil industry where efforts to reclaim oil from shale have ceased, while the former will deem that shale must be reckoned with because of the present Bureau of Mines' program directed toward the economic recovery of this reserve. Coal reserves are generally estimated to provide a fuel supply for 3000 years, but early this year a speaker addressing the American Institute of Mining and Metallurgical Engineers insisted that such estimates are "fantastically" high and that a true estimate is 250 rather than 3000 or more years. Another will point out that new oil wells will be sunk each year, and bases his prediction on that factor; while still another will direct attention to the ever-increasing cost of locating new wells, and will emphatically state that many presently-known reserves will never be tapped since the cost will be prohibitive and synthesis of oil from coal will be more economical.

From evidence gained in this maze of conflicting opinions one can best conclude that our coal reserves are abundant for the foreseeable future, that within approximately ten years it will be economically feasible to transform coal into gaseous and liquid forms, and that our oil reserves are limited. These conclusions point to the necessity of conserving our oil reserves in the interest of national defense and the imperativeness of accelerating our efforts to transform coal to a liquid state.

Use of Coal Must Continue

In the absence of a national emergency we are not faced with an immediate shortage of petroleum products, and with the emphasis now being placed on the synthetic fuel program, the latter should be commercially available before any real shortage develops. Should we be faced with a fuel crisis because of a national emergency, it would be necessary to continue operation of the diesel-electrics now in service to carry the traffic load, even though they would draw on our oil supply. However, no more would be built and oil-burning steam locomotives would immediately be converted to coal. Therefore, the question of maintaining our steam locomotive-building plants in the interest of national security is a vital one. Its importance is emphasized in a statement made by James Forrestal, secretary of defense, in reply to a report submitted to him last January by the Locomotive Institute. Secretary Forrestal stated in part: "Military wartime requirements for transportation make imperative the continuation during peacetime of coal-steam operation over a large part of the railroads of the United States in order to conserve liquid fuels, to insure the maintenance of terminal and right-of-way facilities, and to perpetuate the technical skills needed in the construction, maintenance, and operation of coal-steam locomotives. The peacetime demand thus created for steam locomotives, which under normal conditions can be either coal or oil burning, should result in a demand for steam locomotives which would justify the member companies of your institute in maintaining production facilities and in carrying forward desirable experimental work."

If we displace the steam locomotive entirely and place no more reliance on it, we face the following alternatives: We must secure natural petroleum which we do not presently have, or failing that, we must manufacture synthetic petroleum products or revert to coal. A serious obstacle to the manufacture of synthetic petroleum products from coal on a large-scale basis is the short supply of steel. In addition to the high cost of constructing synthetic fuel plants of major size, the steel requirement is tremendous. Twelve to fourteen tons are required for each barrel capacity (usually expressed in terms of daily production) in synthetic plants, as compared with ¾ ton for each barrel capacity of natural petroleum refineries. This represents a major demand on a material, the lack of which is retarding production of many industries today.

Difficulties Involved

The pressures and temperatures developed during the process of obtaining synthetic fuel products from coal have presented difficulties. The Berguis process requires pressures of 3000 to 10,000 psi. and temperatures up to 800–900 deg. F. rendering the method both cumbersome and expensive. Because of this the development of the Fischer–Tropsch process, which employs a low pressure, 250 psi., and moderate temperature, 650 deg. F., has found preference over the previously widely used Berguis process.

Bruce K. Brown, vice president in charge of research and development of the Standard Oil Company of Indiana, has stated that to substitute oil by synthesis from coal for a daily consumption of five million barrels would mean the mining of twice as much bituminous coal as was mined in 1941. This production would leave no bituminous to be burned in its natural state. Therefore, if we accept the most optimistic estimate of coal reserves sufficient for a fuel supply of 3000 years, we immediately reduce the period by one-half. If we accept the most limiting estimate of 250 years, the reserve is reduced in like proportion. Should ultimate liquification of all fuel for mass uses eventuate, its transportation by pipe line to the exclusion of bulk movement in cars, barges, and boats can be envisioned. However, we cannot conceive of the program developing to a degree that no coal will be consumed as such; for example, in domestic heating. The matter is one of economics which only the future will determine. In any event, it is one which should receive serious consideration.

An inescapable fact which must be borne in mind when considering liquid fuel manufactured by synthesis from coal is that approximately 50 percent of the Btu. content of the coal is lost in the process. Therefore, through no fault of the motive-power design, thermal efficiency, as viewed from the standpoint of natural fuel reserves consumption, is, in effect, reduced in like proportion. Assuming a heat content of coal of 13,000 Btu. per pound and a thermal efficiency of the gas-turbine locomotive of 20 percent, but 1300 Btu. per pound of coal as mined is transformed into useful work. The diesel, displaying a thermal efficiency of 26 percent, would transform 1690 Btu. per pound into useful work. These statements are included to indicate the value of the development of a motive-power unit which can burn coal fuel in its solid state, either as mined or in pulverized form. Because of the tremendous loss of Btu. content during synthesis a real challenge is presented to conventional steam locomotive designers. Modern steam locomotives exhibit an efficiency factor of 7 percent and if, by refinement in design, this efficiency could be improved to 10 percent, the final result would be as efficient consumption of fuel as would be obtained with the gas turbine burning synthetic petroleum processed from coal fuel. Efforts are now directed toward the development of a reliable, highly available, efficient, compact, high-pressure, high-temperature boiler which will materially assist toward the accomplishment of this objective.

While the synthetic process involves an appalling waste of natural resources, the economic effect upon the railways as consumers is not so striking. While mining costs will be increased because a greater volume will be required, synthetic plants can be located adjacent to sources of supply, thereby largely eliminating distribution and transportation costs incident to movement from mines to points of consumption. Because of this circumstance the increased cost to the consumer is generally not predicted to approach the percentage loss of heat content. Early in 1948 E. V. Murphree, president of the Standard Oil Development Company, in testimony before the House Committee on Interstate and Foreign Commerce, submitted the following comparative costs of gasoline as derived from the several base materials:

Cost of Gasoline—Cents per Gallon

Base Material	*Price of Base Material*	*Gasoline Price*
Crude oil	$2.78 per bbl.	14.1
Natural gas	0.10 per Mcf.	12.8
Oil shale	1.00 per ton	16.0
Coal	3.20 per ton	In the East—16.6

Other authorities have estimated that the increased cost of synthetic gasoline derived from coal will approximate 3 to 7 cents per gal. On this basis the percentage increase would range from 18 to 50 percent.

Advantages of the Diesel Locomotive

In any event, the railways must have an effective tool of transport and the diesel-electric has proved itself to be such. In the diesel the railways have a motive-power unit which can be managed in terms of modern mass transport. Its widespread use is at least partially attributable to the lack of necessity for attention en route, with consequent delays which tie up not only the motive power but the entire transport movement for which it is responsible as well. The railways must provide continuity of movement and the diesel has answered that need more nearly than any other power design that has been available on a nation-wide basis. The inherent losses suffered in the absence of an effective motive-power tool justify the railways in paying a premium price for the fuel which it consumes, and it is not deemed likely that the railways will discard a liquid-fuel-consuming type because of a slight disparity in fuel costs.

The diesel-electric locomotive is criticized because of its oil consumption characteristics, and it cannot be denied that the power type is dependent upon liquid fuel. However, principally in the West, many steam locomotives burn oil and much less efficiently. Table 1, showing locomotive fuel consumption, was prepared by the House of Representatives Committee on Interstate and Foreign Commerce and it strikingly demonstrates the waste of oil attendant to the oil-burning steam locomotive. In 1947 fuel oil burned in locomotives amounted to over 3¾ billion gal., while the diesels of the country operated on less than ¾ billion gal. From this table, it is noted that on the basis of actual unit consumption of diesel power, and assuming that all other traffic would be handled as efficiently, slightly less than four billion gal. would be required if the railways were completely dieselized. This represents a saving of ½ billion gal. based upon 1947 traffic volume. Present consumption of diesel fuel is in the neighborhood of 56,000 bbl. daily, and it is estimated that about three million horsepower will be added to the diesel fleet each year for the next five years. At a fuel-consumption rate of three barrels per horsepower-year, railway diesel fuel demands would be expected to increase to 180,000 bbl. daily in 1953.

During the first half of 1947, railway diesel fuel consumption accounted for but one percent of the five million barrels produced daily, as demonstrated in Table 2. On the other hand, 40 percent of the production was consumed as gasoline, indicating the necessity of reducing automotive consumption by the use of more efficient engines or smaller cars. Unquestionably, there is a school of thought in the petroleum industry which believes the use of oil for heating should be limited and that efforts should be directed toward encouraging the substitution of other fuels for that purpose. Some authorities advocate an oil fuel price sufficiently high to render conversion attractive, if not economically mandatory, while others stress the importance of designing solid fuel heating plants that will offer the conveniences now enjoyed by those burning oil.

TABLE 1.—LOCOMOTIVE FUEL CONSUMPTION

Class I Railways (Exclusive of Electric Locomotives)

Actual 1947 and Estimated Diesel Oil Equivalent

Prepared by House of Representatives Committee on Interstate and Foreign Commerce—April 8, 1948

Freight Service	*Actual Fuel Consumption*	*Millions Gross Ton Miles*	*Fuel per Million Gross Ton Miles*	*Estimated Diesel Fuel Oil Equivalent—Gal.**
Coal burning steam	69,202,449 tons	990,366	70 tons	1,800,000,000
Oil burning steam	2,613,441,757 gal.	274,886	9,575 gal.	500,000,000
Diesel-electric	332,148,516 gal.	182,971	1,810 gal.	332,148,516
				2,632,148,516
Passenger Service		*Million Passenger Train Car Miles*	*Fuel per Million PTCM*	
Coal burning steam	15,743,066 tons	1,599.9	9,830 tons	457,000,000
Oil burning steam	829,943,937 gal.	794.1	1,045,140 gal.	227,000,000
Diesel-electric	279,927,074 gal.	983.2	284,700 gal.	279,927,074
				963,927,074
Switching Service		*Yard Locomotive Hours (1000)*	*Fuel per 1000 Locomotive Hours*	
Coal burning steam	15,467,227 tons	35,688	433 tons	223,000,000
Oil burning steam	327,474,937 gal.	5,331	61,430 gal.	33,320,000
Diesel-electric	121,065,221 gal.	19,452	6,223 gal.	121,065,221
				377,385,221
		Total Est. diesel Equiv.		3,973,460,811
		Actual 1947 fuel oil		3,770,860,631
		Actual 1947 diesel oil		733,140,811
		Total 1947 oil		4,504,001,442

TABLE 2.—PETROLEUM PRODUCTS USAGE—FIRST HALF OF 1947

Product	*Daily Production —Barrels*	*Percent of Total*
Gasoline	2,000,000	40
Residual fuels—asphalt	1,250,000	25
Heater—furnace—diesels (except railway)	750,000	15
Coke and gas	500,000	10
Kerosene	300,000	6
Lubricating oil	150,000	3
Railway diesel fuel	50,000	1
Total	5,000,000	100

* Diesel-electric consumption rate is as flagged in column (4).

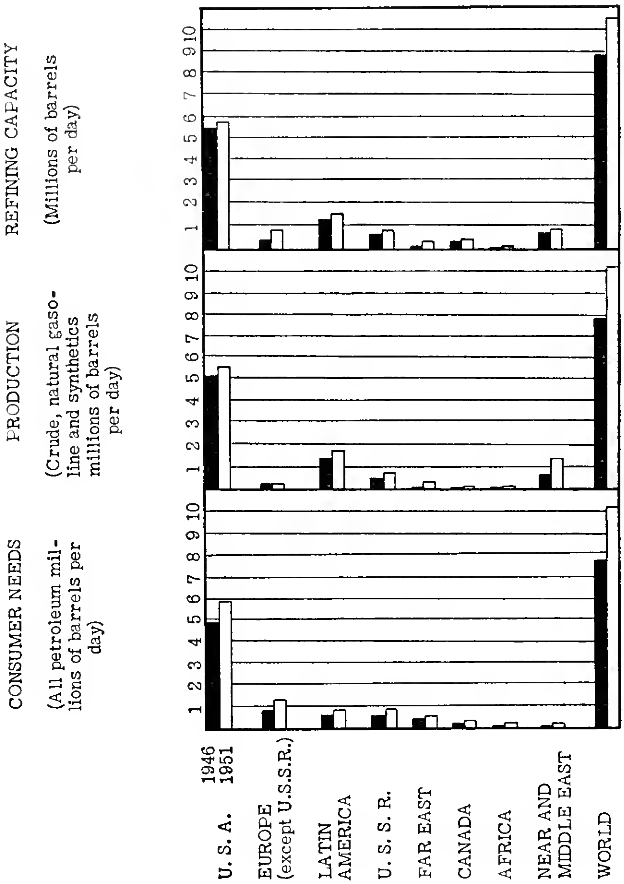


Fig. 1.—Petroleum Products Requirements Versus Supply—1946 and 1951.

Contrasted with the division of daily consumption in 1947, shown in Table 2, is that appearing in Table 3, predicted in annual terms for 1970. These estimates were made by R. E. Wilson and J. K. Roberts, chairman of the board and general manager of research, respectively, of the Standard Oil Company of Ind.

TABLE 3.—ESTIMATED 1970 DEMAND FOR PRODUCTS NOW MADE FROM PETROLEUM

	1970 Demand (Mils. of Barrels)	*1970 Percentages*
Gasoline:		
Gasoline and naphthas	1,086	41.8
Aviation fuel	65	2.5
Kerosene	161	6.2
Diesel fuel	242	9.3
Domestic heating oil	250	9.6
Res'dual fuel oil	464	17.8
Others	332	12.8
Total 1970 demand	2,600	100.0

Estimates of one authority relative to 1951 total consumers' needs, production, and refining capacity are graphically presented in the chart, compared with similar indexes for 1946. It will be noted that the estimated United States consumer needs will exceed production volume by 1951.

Powdered Coal as a Fuel

While developing his more efficient heat engine, Dr. Diesel thought of burning powdered coal as fuel. Although the type of fuel was secondary to the efficiency of the engine in Diesel's mind, there is the possibility of development along this line. To our knowledge, however, there is currently no definite research program directed toward the use of powdered coal for fuel in the diesel engine.

Utilization of coal in pulverized form for combustion purposes falls, in a sense, midway between the combustion of a solid and a gas. It also assumes the combustion characteristics of an atomized fuel, presenting at the same time some problems associated with solid fuel. The combustion of a gaseous fuel can be rapid or slow, according to the manner in which the air and gas are mixed. Pulverized fuel simulates gaseous combustion since an intimate mixture of small particles is effected with air. Many attempts were made during the century to burn coal in pulverized form, but it was not until 1894 that a practical application was discovered in cement kilns, where the liberated ash could be incorporated in the cement without detriment to its quality. In 1922, by an entirely different technique, American engineers adapted pulverized coal to the firing of stationary boilers, and now we have efforts to develop its application to railway motive power.

Opinion relative to the feasibility of burning pulverized coal in a mobile unit is divided, inasmuch as the plan now projected involves processing coal en route with the necessity of burdening the locomotive by hauling the processing plant with it as dead weight. This would immediately nullify the savings effected at considerable expense in the reduction of light weight. Because of space and weight limitations, any application to a locomotive is more difficult of accomplishment and presents more problems than does the same application in stationary practice. The space limitation is not confined to the overall size of the locomotive, since one of the difficulties to be overcome in the coal-burning gas turbine is the burning of the fuel completely within the space allotted. This again involves pulverization, because the smaller the combustion chamber the finer must the coal be pulverized. To avoid the necessity of mobile coal preparation facilities, central pulverizing plants have been suggested, the thought being that the coal-burning gas-turbine locomotive can be serviced en route much as is the conventional steam locomotive today. This would not be a disadvantage for the gas-turbine locomotive in competition with its diesel counterpart because they both would have to be fueled after running approximately the same distance.

Availability as a Consideration

One of the advantages the diesel locomotive enjoys is its high availability and consequent intensive utilization if traffic is available for movement. This is gained largely because it is composed of a number of more or less interchangeable and self-isolated units, any one of which can fail and the locomotive still operate. The steam locomotive possesses an inherent weakness in this respect, as will the gas turbine if built in a single unit as is now planned. This would suggest the advisability of dividing the horsepower capacity into several units, whether it be coal or oil-fired.

The boiler is the inherent weakness of the steam locomotive, and this characteristic has a very definite effect on its availability for service. Washouts, hydrostatic tests, renewal of arches, cleaning of flues, examination of and repair to grates, front ends, and similar assignments are all time-consuming operations directly chargeable to the boiler. Similarly, the coal-handling and processing equipment is the Achilles' heel of the gas-turbine locomotive. The formulation of this equipment comprises sensitive and complicated apparatus subject to the worst possible wear and tear, thereby necessitating constant rigid inspection and maintenance. Should it fail in the absence of an auxiliary fuel supply, the turbine locomotive would be as helpless as the steam locomotive with a boiler failure. The engine of the diesel-electric locomotive is a complicated machine composed of a multiplicity of moving parts which are sources of extensive inspection and maintenance as well as road failure, but as previously mentioned, the practice of combining two or more units to form a locomotive markedly reduces these potential causes of failure.

Summarizing, motive power types can be grouped in three categories; namely, established, exploratory, and projected, as follows:

A. Established
  1. Reciprocating steam
    (a) Coal-burning
    (b) Oil-burning
  2. Diesel-electric
  3. Straight-electric

B. Exploratory
  4. Steam-turbine
    (a) Direct drive
    (b) Electric drive

C. Projected
  5. Gas-turbine
    (a) Coal-burning
    (b) Oil-burning

There may be some opposition to listing the oil-burning gas-turbine locomotive as "projected" for the reason that whenever fuel has been available, one has operated in regular service since 1941 on the Swiss Federal Railway. However, the demands made upon the motive power of railways on this continent are far more exacting than elsewhere in the world. For this reason, it is considered more conservative to await trial under our operating conditions before designating the power type other than "projected."

Report on Assignment 8

Economics of Operation of Union Railway Passenger Terminals

W. B. Irwin (chairman, subcommittee), E. G. Allen, Herbert Ashton, J. W. Barriger, F. C. Berghaus, C. H. Blackman, H. S. Bull, Spencer Danby, Miss Olive W. Dennis, C. H. Fox, C. H. R. Howe, Fred Lavis, J. F. Pringle, W. T. Rice, C. P. Richardson, A. L. Sams, H. F. Schryver, B. J. Schwendt, H. A. Shinkle, J. F. Swenson, J. E. Teal, D. K. van Ingen, H. D. Walker, J. A. Wood.

Your committee discussed various union passenger terminals and concluded to study the problems involved and submit as information a preliminary report on the proposed union passenger terminal at New Orleans, La. The economics of the project can not be determined at this stage.

The railroads supplying passenger train service for the city of New Orleans now operate five passenger stations in the business district of the city.

Although the distances between these stations do not exceed 1½ miles, the railroad approaches to them from various directions embody a large number of street crossings at grade that cause considerable interference between railroad and vehicular traffic, particularly in waterfront and industrial sections. The city has an area of 196 square miles, with about 575,000 population.

The locations of present stations and their users are:

Canal Street and Mississippi river: Louisville & Nashville.
Annunciation and Thalia Streets: Missouri Pacific, and Texas & Pacific.
Rampart and Howard Streets: Illinois Central, Southern Pacific and Gulf Coast Lines of Missouri Pacific.
Rampart and Girod Streets: Louisiana & Arkansas.
Canal and Saratoga Streets: Southern, and Gulf, Mobile & Ohio.

The respective railroads are herein referred to by the names under which their operations are conducted, which do not in all cases conform to their names as corporate entities.

These stations are used by about 60 scheduled passenger trains daily, 30 inbound and 30 outbound. There are no through trains, nor is their any suburban train service.

Due to objectionable features of some of the existing stations and to satisfy civic pride, the city and a few civic organizations have from time to time attempted to interest the railroads in a union station. Nothing was accomplished until the increased street traffic congestion at some of the railroad grade crossings during the period between World Wars I and II became critical and resulted in a demand on the part of the city for the consolidation of railroad passenger facilities in a union station and the rearrangement of certain other railroad facilities to facilitate an economical program of grade crossing elimination.

An amendment to the Constitution of the State of Louisiana, Act 385 of 1938, enables the City of New Orleans, acting through the Public Belt Railroad Commission, or a committee to construct and operate one or more railroad passenger stations, to sell municipal bonds in the amount of $15,000,000 to finance such construction, and to require the railroads to use such station or stations. This act confers broad powers upon the city to accomplish its purpose of minimizing interference by railroad traffic with the use of streets and with the development of the city.

Although negotiations between the city and the railroads began in 1938, they were interrupted by the war. Meanwhile terminal studies and traffic surveys were made by the railroads, civic organizations, the state highway department, the Public Roads Administration and outside consultants, culminating in the passage of a $12,000,000 bond issue on April 15, 1947, to be used by the city for grade separations and other street improvements directly allied with the Union Passenger Terminal, and the signing of an agreement between the city and the railroads October 22, 1947, which authorizes the sale of municipal bonds in the amount of $15,000,000 to effectuate the "New Orleans Union Passenger Terminal" project and related grade separations.

The agreement provides for the construction of a union passenger station, with a plaza fronting on Rampart and Howard streets, the construction of 27 grade separations, the abandonment of five passenger stations, the removal of railroad tracks from many streets, the relocation of various railroad facilities and the improvement of certain streets as approaches to the station building at a cost, based on 1947 prices, of approximately $37,000,000. In general, freight yards, with the exception of Bernadotte yard of the Southern System, which is to be removed and Press Street yard of the same system, which is to be enlarged accordingly, remain unchanged except where relocation is required in conjunction with the passenger terminal project.

An integral part of the project is the filling of a portion of the New Basin (navigation) Canal, owned by the state, and sale of a portion of its 300 ft. right-of-way to provide, as a part of the union passenger terminal, a route for the relocated lines of the Louisville & Nashville, the Gulf, Mobile & Ohio, and the Southern, to reach the union passenger terminal, from the tracks of the New Orleans Terminal Company at Canal boulevard. The New Basin Canal project is authorized by constitutional amendment, Act 405 of 1946. A portion of the canal right-of-way will be reserved for a future arterial highway.

The New Orleans Terminal Board, created by city ordinance, represented the city in negotiating the contract with the railroads and selected the site adopted for the union station, on property now occupied by the Illinois Central station and yard and Louisiana & Arkansas tracks.

The following summarizes the preliminary allocation of costs of the project as estimated in 1947:

Union station and appurtenant facilities	$14,630,000
Grade separations (including $1,770,000 for state highways)	18,700,000
Miscellaneous railroad and street improvements	3,070,000
*Loan to New Orleans Terminal Company (Southern System)	600,000
Total approximately	$37,000,000

The union station facilities will be constructed and owned by the City of New Orleans, as empowered by Act 385 of 1938, with construction, operation and maintenance under the jurisdiction of the New Orleans Union Passenger Terminal Committee on which the city is represented by the New Orleans Public Belt Railroad Commission, and other representatives. Such other representation, up to the completion of the project, is the New Orleans Terminal Board.

A city bond issue of $15,000,000 revenue bonds will be used—so far as it will go—to pay for the union station, the railroads' share of the grade separations and the loan to the New Orleans Terminal Company. These bonds will be retired by the railroads' rental payments for the use of the station facilities. The railroads guarantee such rental payments, the bonds being secured by a mortgage of the passenger terminal facilities and by the pledge of the net revenues derived from their operation. The railroads will pay

* This loan is to be used to finance improvements to tracks and facilities of the New Orleans Terminal Company, which are to be used as one approach to the tracks of the Union Passenger Terminal.

outright the cost of the station and approaches, the railroads' share of the grade separations and the loan to the New Orleans Terminal Company in excess of $15,000,000, such excess being estimated in 1947 at approximately $3,000,000.

The city will use the $12,000,000 from the April 1947 bond issue to pay part of its share (85 percent) of the cost of city street grade separations. The railroads' $2,780,000 share (15 percent) will come from the $15,000,000 revenue bond issue by the city. The state's $1,770,000 share will come from highway and federal aid funds for state highway grade separations.

This apportionment summarized:

	City	*State*	*Railroads*	*Total*
Union station and appurtenant facilities	$ ...	$ ...	$14,630,000	$14,630,000
Grade separations	14,060,000	1,770,000	* 2,870,000	18,700,000
Loan to New Orleans Terminal Company	...	...	600,000	600,000
Miscellaneous paving and street changes, railroad yard and line improvements	3,070,000	...	...	3,070,000
Total, approximately	$17,130,000	$1,770,000	$18,100,000	$37,000,000

The foregoing costs do not include expense which will be incurred by the several railroads for rearrangement of their facilities not directly involved in the union passenger terminal project. It will also be recognized that there have been advances in the cost of labor and materials since those estimates were prepared which will increase the cost of the project.

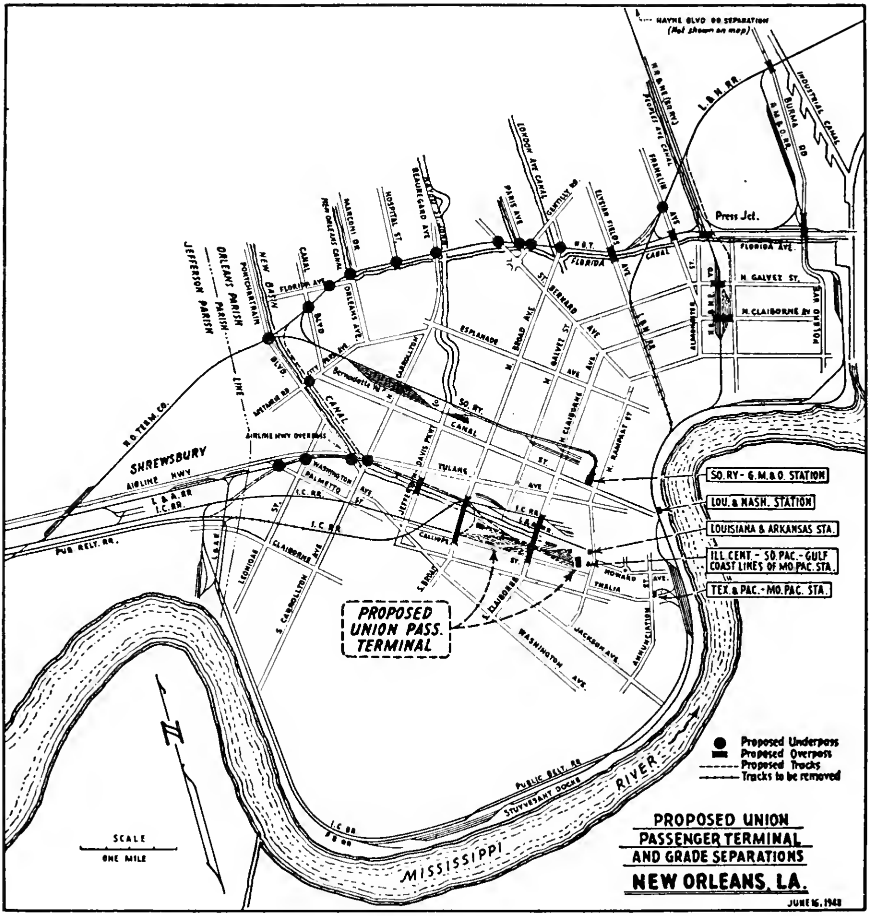
The New Orleans Union Passenger Terminal Committee, consisting of six members representing the city and ten members representing the railroads, will function as a board of direction with the broad powers of a public body of the State of Louisiana. In general, each member of the committee will have one vote, except that each railroad member has additional voting power determined by the car equivalent percentage of use, adjusted annually. The railroads' voting strength approximates 84 percent of the voting power of the committee. A terminal manager will be in charge of operation and maintenance under the jurisdiction of the committee.

Under the agreement signed October 22, 1947, each railroad obligates itself for the payment of rental, which will be used to pay interest on and to retire the $15,000,000 bond issue, plus the cost of the terminal, the railroads' share of the grade separations, and the loan to the New Orleans Terminal Company in excess of the bond issue. The revenue bonds are dated as of January 1, 1948, to mature serially from January 1, 1953 to January 1, 1989, except as to $100,000 bonds which will mature January 1, 1998. The duration of the contract is a term of 50 years from the completion of the project, with an option of extending the agreement 50 years.

The railroads will pay a rental—based on percentage of use—sufficient to pay interest on and to retire the bonds upon maturity. The union passenger terminal will be exempt from taxes, but after 50 years (effective January 1, 1998) the railroads will pay the city in the form of rental an amount equal to the ad valorum taxes which would be assessed against the terminal property at its then fair value.

Much interest has been shown by civic groups in the architectural treatment of the proposed union passenger station. It was suggested the city should have a functional union station "infused with a pattern of color and feeling of the French-Spanish city . . . broadly adjusted to the spirit and feeling of the Creole civilization." A final design is yet to be adopted but ground plans and estimates of cost have been prepared on the basis of a structure facing a parkway at Rampart street, with 12 stub tracks serving the

* Includes approximately $90,000 to be paid by the Public Belt Railroad.



station the coach yard and mechanical facilities to be located east of Broad avenue. The city will maintain the portion of the union passenger station plaza dedicated for park purposes.

With respect to grade separations, the city will maintain overpasses and will assume 35 percent of the cost thereof, and will at its expense maintain underpasses except structures supporting tracks.

Four zones will be established for the allocation of the cost of the operation and maintenance of the union passenger terminal based on percentage of use:

Zone	*Facilities*	*Basis of Apportionment*
1	Union station and appurtenances	Wheelage
2	Trackage—approach and station tracks	Wheelage
3	Coach yard	Cars handled
4	Mechanical terminal	Locomotives handled

Information presented to the ICC indicated that a net displacement of about 350 employees will be effected, of whom 9 are bridge tenders and 108 are crossing flagmen, but the opinion is expressed that the number eventually displaced will not exceed 300.

The railroads will revise their facilities and relocate trackage at their own expense to connect with the approach tracks to the union passenger station; some of these changes are of major importance, with compensating advantages from reduced hazard of operation over grade crossings. In some cases property now occupied by passenger stations will become available for industrial purposes, thus increasing the commercial potentialities of the business district.

The railroads will obtain the benefits from use of a modern union station for a rental charge of probably 4 percent or less on bonds—covering amortization, interest and service charges—free of ad valorem taxes for 50 years.

The demand for a union station became acute from the necessity for reducing traffic interference at grade crossings. From the standpoint of vehicular traffic the union passenger terminal plan, with its 27 grade separations, reduces by one-half the number of separations which would be required to provide adequate crossing elimination if the present five passenger stations and their appurtenant trackage were continued in service.

The Union Passenger Terminal Agreement of October 22, 1947 is effectively operative, and it is proposed to begin construction of the project as soon as the $15,000,000 bond issue can be sold. Construction will probably start in 1949.

Your committee believes that this project will be of general interest as representing a forward step in negotiations between a group of railroads and a municipality reaching a mutually satisfactory agreement pertaining to the financing and administration of a union passenger terminal, coupled with a large number of grade separations, as shown on the map.

This preliminary report is submitted as information, to be supplemented by a further report regarding the economics involved, following completion of the project.

Report of Committee 13—Water Service and Sanitation

H. E. SILCOX, *Chairman,*
R. C. BARDWELL
I. C. BROWN
R. W. CHORLEY
R. E. COUGHLAN
B. W. DEGEER
J. J. DWYER
C. E. FISHER
R. H. GEORGE
R. S. GLYNN
H. E. GRAHAM
E. M. GRIME
F. L. GUY
S. H. HAILEY
J. P. HANLEY
M. A. HANSON
T. W. HISLOP, JR.
H. M. HOFFMEISTER
K. P. HOWE
A. W. JOHNSON
H. F. KING
C. R. KNOWLES*
W. B. LEAF
O. E. MACE
RAY MCBRIAN
W. A. MCGEE
H. L. MCMULLIN
G. F. METZDORF
L. R. MORGAN
E. R. MORRIS
THEODORE MORRIS
A. R. NICHOLS
A. B. PIERCE
S. E. PRINTZ
G. E. MARTIN,
Vice-Chairman,
H. M. SCHUDLICH
R. W. SENIFF
H. M. SHEPARD
J. M. SHORT
H. M. SMITH
R. M. STIMMEL
D. C. TEAL
T. A. TENNYSON, JR.
J. E. TIEDT
J. W. USSHER
H. W. VAN HOVENBERG
R. E. WACHTER
C. L. WATERBURY
E. L. E. ZAHM
Committee

* Died August 5, 1948.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

THE COMMITTEE ON WATER SERVICE AND SANITATION,
H. E. SILCOX, *Chairman.*

AREA Bulletin 476, November 1948.

Clarence Richard Knowles

The Committee on Water Service and Sanitation records with sorrow the death on August 5, 1948, of a member and past chairman, Clarence Richard Knowles. An appropriate memoir to him appears elsewhere in this volume.

Report on Assignment 1

Revision of Manual

G. E. Martin (chairman, subcommittee), R. C. Bardwell, I. C. Brown, R. E. Coughlan, B. W. DeGeer, E. M. Grime. T. W. Hislop, Jr., A. W. Johnson, H. F. King, C. R. Knowles, W. B. Leaf, H. L. McMullin, G. F. Metzdorf, Theodore Morris, H. M. Shepard, T. A. Tennyson, Jr., J. W. Ussher, R. E. Wachter, E. L. E. Zahm.

Your committee recommends the following revisions in the Manual:

SPECIFICATIONS FOR WELDED STEEL TANKS FOR RAILWAY WATER SERVICE

Pages 13—38.2—38.5

1949

201. Quality of Metal—Present specification

All steel shall be made by the open-hearth or electric process and shall conform to the current ASTM Specifications A 7, A 10, or A 78. Copper bearing steel with about 0.20 percent copper shall be used when specified.

Proposed

All steel shall be made by the open-hearth or electric process and shall conform to either of the current ASTM Specifications A 7 or A 283, (Grade A, B, C, or D). Copper bearing steel of about 0.20 percent copper shall be used when specified.

301. Type of Joints—Present specification

Joints shall be either butt welded or lap welded as specified.

Proposed

Joints shall be either butt joints or lap joints as specified.

303. Unit Stresses—Present specification

(b) Single or double butt welds, with complete penetration.
(c) double welded fillet joints.

Proposed

(b) Single or double welded butt joints, with complete penetration.
(c) Double welded lap joints.

304. Plate Thickness—Present specification

Lap welds ½ inch maximum
Field welds 1½ inch maximum

Proposed

Lap joints ½ inch maximum
Butt joints 1½ inch maximum

401. Definitions and Symbols—Present specification

Welding symbols shall be as shown in the latest edition of "Welding Symbols and Instructions for Their Use," issued by the American Welding Society.

Proposed

Welding symbols shall be as shown in the latest edition of "Standard Welding Symbols," issued by the American Welding Society.

403. Flat Tank Bottoms Resting Directly on Grade or Foundation—Present specification

Butt Welded Construction

Lap Welded Construction

Plates shall be reasonally rectangular, square-edged, of dimensions to provide laps at least 1¼ inches. Marginal sketch plates under the bottom ring shall have the outer end of joints "fitted" and butt welded to form a smooth bearing under the shell. Welding shall be on the top side only with a continuous full fillet weld on all seams.

Proposed

Butt Joint Construction

Lap Joint Construction

Plates shall be reasonably rectangular, square-edged, of dimensions to provide laps at least 1¼ inches. Marginal sketch plates under the bottom ring shall have the outer end of joints "fitted" and welded to form a smooth bearing under the shell. Welding shall be on the top side only with a continuous full fillet weld on all seams.

405. Butt Welded Joints—Present specification

Vertical joints in the side sheets of tanks and all joints in suspended bottoms and in riser pipes shall be double butt welded to insure complete penetration or single butt welded with suitable backing-up strip or equivalent means to insure complete penetration. Horizontal joints shall have not less than two-thirds penetration based on the thickness of the thinner plate, with the unwelded portion located substantially at the middle of the thinner plate.

Proposed

405. Butt Joints

Vertical joints in the side sheets of tanks and all joints in suspended bottoms and in riser pipes shall be double-welded butt joints to insure complete penetration or single welded butt joints with suitable backing-up strip or equivalent means to insure complete penetration. Horizontal joints shall have not less than two-thirds penetration based on the thickness of the thinner plate, with the unwelded portion located substantially at the middle of the thinner plate.

406. Lap Welded Joints—Present specification

Vertical joints in side sheets of tanks and all joints in suspended bottoms and in riser pipes shall have continuous full fillet welds both inside and outside with a lap not less than five times the thickness of the thinner plate. Horizontal joints shall have continuous welds both inside and outside which must develop a strength of at least two-thirds that of a double full fillet welded lap joint.

Proposed

406. Lap Joints

Vertical joints in side sheets of tanks and all joints in suspended bottoms and in riser pipes shall be continuous double-welded full fillet lap joints, with a lap not less than five times the thickness of the thinner plate. Horizontal joints shall be continuous double-welded lap joints which must develop a strength of at least two-thirds that of a double-welded full fillet lap joint.

407. Roof Wells—Present specification

Roof sheets shall be butt or full fillet lap welded on the top side only with a continuous weld on all seams.

Proposed

Joints in roof sheets shall be butt or full fillet lap joints, welded on the top side only with a continuous weld on all seams.

408. Intermittent Welds—Present specification

Intermittent butt welds shall not be used.

Intermitten lap welding shall not be used in tank shell plating. The length of any segment of intermittent lap welds shall be not less than four times the weld size with a minimum of 1½ inches. All seams of intermittent lap welding shall have continuous welds at each end of at least 6 inches.

Proposed

Intermittent groove welds shall not be used.

Intermittent fillet welds shall not be used in tank shell plating. The length of any segment of intermittent fillet welds shall be not less than four times the weld size with a minimum of 1½ inches. All seams of intermittent fillet welding shall have continuous welds at each end at least 6 inches long.

503. Inspection—Present specification

Tank joints shall be inspected by Sectioning Methods in accordance with Section VIII of the AWS Rules for Field Welding of Steel Storage Tanks.

Proposed

Tank joints shall be inspected by Sectioning Methods in accordance with Section VIII of the AWS Standard Rules for Field Welding of Steel Storage Tanks.

SPECIFICATIONS FOR SALT TO BE USED IN REGENERATION OF ZEOLITE WATER SOFTENING PLANTS

1949

Pages 13–55 and 56

202. Chemical Properties—Present specification

(a) The chemical properties of the salt sample shall be determined by standard methods of chemical analysis.

(b) Water softener salt shall conform to the following requirements as to chemical composition:

Sodium chloride—98.0 percent minimum

Proposed

After "Sodium chloride—98.0 percent minimum" add "and shall be free of grease, fats or oil."

302. Fineness—Present specification

All particles must be of such size as to pass through a U. S. Bureau of Standards No. 2 sieve which has an opening approximately 0.5 inch square, and not more than 10 percent shall be coarser than ⅜ inch. At least 90 percent must be retained on a U. S. Bureau of Standards No. 10 sieve which has openings approximately 0.0787 inch square, or not more than 10 percent finer than 1/16 inch.

Proposed

Rock salt shall be of grain size between 3 mesh and 50 mesh in accordance with Salt Producers trade practice, graded size not to be mixed; 95 percent to be retained on 60 mesh screen (U. S. Standard or Tyler screens). Evaporated salt (vacuum pan) preferably K. D. (Kiln Dried) shall produce 15 percent through 60 mesh screen.

Report on Assignment 2

Intercrystalline and Other Types of Corrosion of Steam Boilers

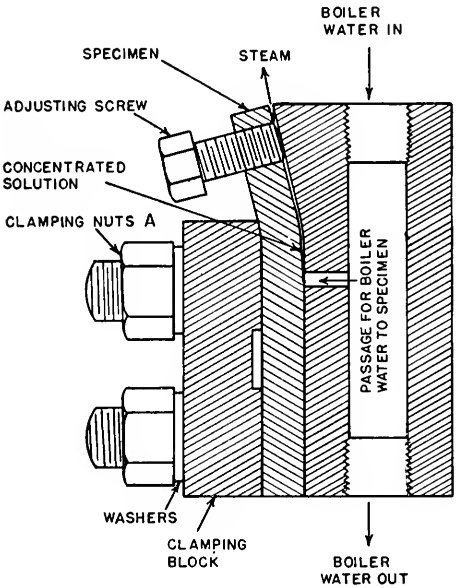
R. E. Coughlan (chairman, subcommittee), R. C. Bardwell, R. W. Chorley, B. W. DeGeer, M. A. Hanson, T. W. Hislop, Jr., H. M. Hoffmeister, Ray McBrian, Theodore Morris, S. E. Printz, R. W. Seniff, J. M. Short, R. M. Stimmel, J. E. Tiedt, J. W. Ussher.

This report is submitted as information.

During the past year, in the study of intercrystalline corrosion or embrittlement of boiler steel, special attention was paid by your committee to the excellent results obtained by means of sodium nitrate treatment on one of the eastern railroads. It was noted that water conditioning for locomotive boiler use by treatment to prevent scale and corrosion, without the addition of an inhibitor, was possibly one of the contributing causes of intercrystalline corrosion, due to the fact that clean boiler sheets and scale free seams appeared to be more susceptible to attack of intercrystalline corrosion than scale coated sheets and plugged seams.

Practically all Class 1 railroads have, in the past, experienced intercrystalline corrosion, or "caustic embrittlement" of boiler metal. Until comparatively recently, whenever intercrystalline corrosion or "caustic embrittlement" of boiler metal was under discussion, the complementary word sulfate-ratio was added. The acceptable way to avoid embrittlement or intercrystalline corrosion and one sanctioned by long usage, involved the addition of a sulfate, such as sodium sulfate to maintain a definite sulfate alkalinity ratio.

The railroad water chemists have never subscribed to this theory and, for this reason, the use of tannin compound, sulfite liquor and sodium nitrate were used as an inhibitor in the water when intercrystalline corrosion was encountered. Excellent results have been secured with tannin compounds, sulfite liquor, and recently sodium nitrate. The correlated data obtained by many authorities indicate the lack of value and, in fact, the misleading and false sense of security introduced through the maintenance of sulfate alkalinity ratios.



Embrittlement Detector

Prior to 1940 this eastern railroad used waste sulfite liquor treatment as an inhibitor, which treatment has resulted in satisfactory control of intercrystalline corrosion on other railroads. The difficulty of controlling this organic treatment was an important factor on this railroad in testing the effect of other inhibitors.

During the latter part of 1940, waste sulfite liquor treatment was replaced by sodium nitrate. This salt is inexpensive, has a definite chemical composition and is one of the most effective known inhibitors of intercrystalline corrosion which has been found for use in caustic solutions. Its concentration in water can be determined by standard chemical tests, which permit accurate control of the treatment. It is stable in dilute boiler water and apparently is not affected by sludge formation. In concentrated caustic solutions it tends to react with the steel to form an adherent iron oxide, which acts as an effective barrier between the steel and the caustic solution of the boiler water.

Bulletin No. 443 of the United States Bureau of Mines states, that the sodium nitrate content of the boiler water should be maintained at 40 percent of the alkalinity of the water expressed as sodium hydrate.

The embrittlement detector used in connection with the nitrate treatment is a simple device which may be attached to an operating boiler to test the embrittling or nonembrittling characteristics of the water while the boiler is in operation. The detector contains a test specimen which is bent by a clamping plate to the shape of a groove in a block through which the boiler water flows. A small opening brings the boiler water to the test surface of the specimen, where the dissolved solids in the water concentrate as the water evaporates to the atmosphere. The clamping plate keeps the test specimen under constant tension.

This embrittlement detector was found to be a very useful aid in determining that sufficient of the nitrate inhibitor was present in the water at all times to eliminate the embrittlement action of the water.

The marked decrease in embrittlement or intercrystalline cracking of the locomotive boilers on this railroad coincides perfectly with the use of sodium nitrate. It was also satisfactorily determined that the embrittlement detector used on the locomotives fulfilled the requirements of a handy instrument for checking the condition of the boiler water and for insuring the presence of proper amounts of the sodium nitrate inhibitor in the water at all times.

Report on Assignment 3

Federal and State Regulations Pertaining to Railway Sanitation

Collaborating with Joint Committee on Railway Sanitation, AAR

H. W. Van Hovenberg (chairman, subcommittee), R. C. Bardwell, R. E. Coughlan, B. W. DeGeer, R. H. George, F. L. Guy, S. H. Hailey, J. P. Hanley, K. P. Howe, A. W. Johnson, H. F. King, O. E. Mace, G. E. Martin, W. A. McGee, G. F. Metzdorf, L. R. Morgan, E. R. Morris, A. B. Pierce, D. C. Teal, T. A. Tennyson, Jr., R. E. Wachter.

This is a report of progress, presented as information.

Your representatives on the Joint Committee on Railway Sanitation under which the Sanitation Research Project of the AAR functions, have witnessed a marked transition during the last year in this investigation of the treatment and disposal of toilet wastes from railroad passenger cars. Instead of theoretical studies and laboratory investigations, this project has advanced through the stage of design and fabrication of operating devices to the conduct of practical field tests with a unit for so-called "complete" treatment. This consists of a grinding mechanism which discharges the ground toilet wastes into a retention tank, from which the wastes flow through a heat exchanger, where they are brought to a temperature of at least 160 deg. F. and thereafter released to the atmosphere through a discharge valve connected to a speed-control device which will not permit the unit to discharge in the station or when the train is traveling at low speed. Obviously such a device, should it be capable of mechanical perfection, would not have universal application. The present emphasis is on field testing of this unit, requiring observations over long periods of service. There is the possibility that simple grinding of the toilet wastes and their direct dispersal to the atmophere may prove satisfactory as a means of disposal for use in certain kinds of passenger traffic.

The research project is also giving detail study to devices for the retention of toilet wastes until their removal in terminals. These studies involve: (1) metal containers permanently installed and which can be regularly drained and cleaned; (2) removable metal containers which can be replaced regularly by clean containers; (3) disposable bags which retain all the wastes flushed from the hoppers; and (4) disposable containers which permit liquids to be leached away, thereby retaining only the solids to be disposed of at terminals.

Looking to the future of passenger car building, member railroads have been given some suggestions on the principles of water consumption, placement of toilet hoppers in sleeping cars, and the assignment of space under hoppers for possible future installations of a treating device.

Technical Report No. 5, on disinfection of toilet wastes by electrical heating is now in preparation. Plans are being made for a study of the extent to which intestinal organisms are killed when discharged to the air by dispersal methods. Information has been requested of the U. S. Public Health Service on the extent to which the general population is estimated to carry communicable intestinal diseases in an infectious state.

The Sanitation Research Project expects to complete its present assignment, with a final report, on or about September 30, 1949. Representatives from the Engineering Division on the Joint Committee on Railway Sanitation are R. C. Bardwell, A. B. Pierce and H. W. Van Hovenberg.

Report on Assignment 5

Sanitation Practices For Construction and Operation of Camp Car Outfits

D. C. Teal (chairman, subcommittee), R. H. George, K. P. Howe, H. F. King, H. L. McMullin, L. R. Morgan, A. R. Nichols, A. B. Pierce, H. M. Schudlich, H. M. Shepard, J. W. Ussher, H. W. Van Hovenberg, R. E. Wachter, C. L. Waterbury, E. L. E. Zahm.

Last year your subcommittee made an informative report in which past practices and current developments in sanitation as applied to raliway camp cars were reviewed in some detail. The general conclusions were that good sanitation depends on two things, the first being reasonably adequate equipment and the second, good housekeeping. It was further developed that but few roads now have a comprehensive sanitary control program that clearly establishes departmental supervisory responsibilities and instructs all concerned in fundamental sanitary practices.

This year's report, which is presented as information, gives specific recommended sanitation practices for (1) design and equipment and (2) maintenance and operation of camp car outfits. These recommendations were derived in part from study of past and present practices as developed in last year's report and from review of all the federal and state health service regulations pertaining to camp sanitation that could be found.

Acknowledgment.—Your committee hereby acknowledges with thanks, the assistance of the United States Public Health Service, District No. 2, which collected and furnished most of the public health service publications that were reviewed in this report.

(1) Recommended Sanitation Practices for Design and Equipment of Camp Car Outfits

Sleeping and Living Cars

Space Requirements.—The number of bunks in combination sleeping–living cars should be based on a space allowance of at least 50 sq. ft. per man, figured on the total inside area. Bunks should be separated as far as practical to restrict transmission of respiratory diseases.

Floors.—Floor surfaces should be smooth, water resistant and of such construction as to be easily cleaned.

Walls and Ceilings.—Walls and ceilings should have a smooth washable surface with as few cracks as possible to minimize harboring of insects. They should be insulated for warmth in winter and against excessive heat in summer. Walls and ceiling should be finished in light colors.

Heat.—Provide coal or oil-fired, arcola type heating units with hot water pipes so located as to furnish even heat throughout the car.

Ventilation.—Provide window openings totaling at least 12 percent of the floor area and so constructed that at least half of each window area can be opened. Locate windows to give maximum natural ventilation. Install roof or wall ventilators for bunks that are not adjacent to windows.

Screening.—Provide screens for windows and install self-closing screen doors. Use 16-mesh screening or better.

Lighting.—Wire cars for electric lights with at least one light socket installed for every 100 sq. ft. of floor area. Provide larger outfits with engine-driven generators.

Washing and Bathing.—Equip cars with water storage tanks, hand or engine-operating pumps to fill them, hot water heaters, porcelain wash basins and shower baths. One wash basin should be provided for every three users and one shower bath for every ten.

Lockers.—Each man should have a clothes locker of adequate size, preferably of steel construction. Provide cabinets for the storage of housekeeping equipment.

Drinking Water.—Install drinking water coolers with separate ice compartments and recessed spigot outlets, similar to the type accepted by the Public Health Services for use on passenger coaches.

Toilet Facilities.—Provide adequate toilet facilities for each camp car outfit to meet the requirements of the state health departments concerned. Portable privies or chemical toilets, properly constructed and maintained will comply with most current public health service regulations. The portable privies should be designed to be fly-proof when erected and the seat openings should be covered with tight fitting hinged lids.

Kitchen and Dining Cars

General.—The construction of kitchen and dining cars with regard to floors, walls and ceilings, screening and lighting, should be the same as recommended for sleeping and living cars.

Ventilation.—Provide metal hoods over stoves and exhaust fan ventilators.

Tables and Shelves.—Fixtures used in the preparation and serving of food or for the storage of cooking utensils, should have smooth, water resistant surfaces and be so constructed as to be easily cleaned.

Food Storage.—Provide clean, dry storage facilities for packaged and nonperishable foods, protected from insects, dust and other contaminating influences.

Refrigeration.—Install ice refrigerators of adequate size and designed to store perishable foods at temperatures below 50 deg. F., properly drained and constructed of materials and in such a manner that will permit thorough cleaning.

Dishwashing Equipment.—Kitchen cars should have two-compartment sinks of adequate size and depth, constructed of non-rust materials, and a water heating arrangement that will provide an ample supply of boiling hot water.

(2) Recommended Sanitation Practices for Maintenance and Operation of Camp Car Outfits

Responsibility

Foremen.—The foreman in charge should be made responsible for the enforcement of these rules in his own camp car outfit.

Division Engineer.—The division engineer on whose territory cars are located, or the general officer in charge, should exercise supervisory control over the sanitary condition of cars as well as over other matters.

The Chief Engineering Officer.—The chief engineering officer and his departmental heads who are ordinarily responsible for the provision of adequate sanitary facilities in new or reconsrtucted camp car outfits, should also assume supervisory control over their sanitary condition.

Sanitary Inspections

Official Sanitary Inspections.—Sanitary inspections should be made weekly by the foreman in charge, and by his superior officers whenever they visit the outfit.

Personnel For Sanitary Work

On Small Outfits.—In forces of 8 to 40 men, one man should be assigned on a part-time basis to do the cleaning work necessary for the maintenance of proper sanitation. The amount of time spent should be at the judgment of the foreman.

On Large Outfits.—In outfits of over 40 men, one or more men should be assigned to full-time housekeeping duties. These men should be capable and show interest in their work.

On Kitchen and Dining Cars.—Cooks and their helpers should maintain sanitation within their province.

Sanitary Supplies and Repairs

Supplies.—Supplies should be ordered through established channels.

Minor Repairs.—Repairs to screening, etc., whenever possible should be done by camp car men under the direction of the foreman.

Major Repairs.—Major repairs should be handled by the division engineer or the general officer in charge, who, if he is unable to have the work done on the division, should request aid from the chief engineering officer.

Sickness and Disease

Sick Employees.—Employees who become ill should be treated by a doctor as soon as possible, preferably by the nearest company doctor. In case of a communicable disease, the doctor will direct fumigation or quarantine procedure.

Cooks and Food Handlers

Physical Requirements.—Cooks and food handlers should be in good health, free of skin rashes, clean of person and wear clean clothing. They should keep fingernails cut short and hair trimmed.

Examination.—Cooks and food handlers should undergo a special physical examination by a company doctor on entering the service and at intervals of approximately six months thereafter. A written certificate of good health should be secured from the doctor and kept on file. No diseased person should be allowed to cook or serve food on camp cars.

Sanitation in Bunk Cars

Cleaning.—Living quarters should be maintained in a sanitary condition by daily cleaning of floors and by daily collection and disposal of trash.

Heating and Ventilation.—Sleeping and living quarters should be kept at a healthful temperature if possible by proper attention to heating and ventilation.

Beds.—Beds should be made up after each use by the occupant.

Bedding.—Blankets and comforts should be aired and sunned at least twice each month. Linen, when used should be changed at least twice each month.

Sanitation in Kitchen and Dining Cars

Cleaning.—Floors should be scrubbed daily, tables and shelves washed daily, lower part of walls washed weekly and food storage rooms and containers cleaned by appropriate methods at weekly intervals. These cars should be kept free of dirt, dust, rubbish, roaches, ants, mice and flying insects.

Dish Washing.—The minimum dishwashing procedure should be:

(a) Scrub with brushes in hot soapy water in one sink.

(b) Rinse and sterilize by submersion in extremely hot (180 deg. F. or more) water for at least two minutes in another sink. Use a wire basket for this purpose.

(c) Air dry.

(d) If necessary to use drying towels on glassware and cutlery, they should be clean. Change towels frequently. After use, the towels should be boiled in soapy water, then thoroughly rinsed and dried, preferably in the sun. Dish towels should be used for no other purpose.

Disposal of Kitchen Wastes

Garbage.—In general, kitchen wastes should be collected and disposed of in such a way as not to attract flies nor otherwise to create a nuisance or a health menace. Garbage should be kept in water tight metal cans with fly tight lids and disposed of daily. Arrangements for pick up by a public or private garbage collector should be made whenever possible. Otherwise, all garbage, including empty food cans, should be buried at an appropriate location (at least 100 ft. from kitchen or dining cars) on company owned property. Pits for this should be dug deep enough to allow two feet of backfill over the garbage. The backfilling must be done immediately after the garbage is placed in the pit, to minimize fly attraction and breeding.

Kitchen Waste Water.—Kitchen waste water should be directed into covered, water tight containers, set under the car. These should be emptied into a city sewer when possible, otherwise into the garbage pits as outlined above.

Rubbish.—Old papers, boxes and trash should be collected daily and burned or buried. They should be handled in such a manner as not to be unsightly or create a nuisance.

Garbage Cans.—Garbage cans should be of sufficient size and number, of sturdy construction, water tight and have well fitting, fly tight lids. Suitable cans should be ordered if needed. Cans in use should be kept clean on the outside at all times, and covered. They should be washed on the inside, every time they are emptied.

Drinking Water For Camp Outfits

Uses.—Bacteriologically pure water should be provided for drinking, cooking and dishwashing purposes.

Source.—In most cases drinking water is carried to the cars by hand from the nearest available source. Especial care should be exercised in choosing this source. Whenever possible, it should be from tested, pure water supplies, preferably from a city water system. If the only water available is of untested (hence questionable) bacteriological quality, arrangements should be made to have it chlorinated to a 0.5 ppm. residual 30 min. before it is used for drinking. If necessary to drill a new well for supplying camp cars, it should be so located, constructed, topped, and the pump so attached as to prevent pollution of the well water. Surface waters should be excluded by a concrete platform around top of well. Springs should not be considered a satisfactory source of drinking water unless amply protected against pollution and the water is tested for bacteriological quality according to an established routine, or the water is chlorinated before use.

Containers.—Containers used for collection, storage and distribution of drinking water, should be of rust proof materials and so designed as to protect the contents from contamination. In general, these containers should have large filling openings with tight overlapping lids and a covered spout or recessed spigot outlet, depending on usage. The dispensing containers should be constructed so that water can be drawn only from the spigot. All drinking water containers should be labeled "For Drinking Water Only."

Drinking Cups.—The use of paper cups should be encouraged when practical to supply them. If used, sanitary dispensers must be provided and arrangements made for the collection and disposal of old cups. The practice of dipping drinking water from containers should be prohibited.

Sanitary Care of Equipment.—The containers provided for the handling and storage of drinking water should be kept sterile by washing and rinsing in boiling hot water at weekly intervals.

Care in Handling.—Care should be taken to prevent contamination of drinking water in handling. The containers used for transporting it should be rinsed with pure water before each use and the lids kept closed.

Ice.—When ice is added directly to water for cooling, it should be washed with pure water and otherwise handled with clean hands and in a sanitary manner.

Toilets

Public Health Service Requirements.—All camp cars must have adequate facilities for the sanitary disposal of excreta that will comply with the rules of the various state health departments concerned. Either the pit privy or the waterless chemical toilet, properly constructed and maintained, will in most cases satisfy public health service regulations that apply.

Portable Privies.—Outfits not equipped with chemical toilets should carry along one or more portable privies. When cars are parked where there are no existing railway toilet facilities within practical walking distance, these privies should be set up over pits on company owned property. In general they should be located, constructed and maintained so that they will not cause contamination of any water supply, attract flies or vermin or produce unpleasant odors. They should be located at least 200 ft. from kitchen or dining cars, drinking water wells or streams. In erection, it is important that the pit be deep enough and that tight contact be made between the box and the ground to prevent entry of flies. Spray the inside of the pit and privy weekly with a residual DDT solution. Scrub latrine seats weekly with soap and water, then spray with a disinfectant that is nonirritating to the skin. When filled to within two feet of the top and/or when the outfit moves, the pits should be closed by filling with earth.

Chemical Toilets.—Chemical toilets should be operated and maintained in a sanitary manner and in accordance with the special instructions issued by the manufacturer (of the toilet) for this purpose. A copy of these instructions should be posted in each toilet room. Experiences of various railroads with this type toilet, to date, indicate a tendency of the responsible personnel to neglect the draining of retention tanks at proper intervals and to neglect the ordering of vital supplies such as the caustic soda chemical and toilet paper. The retention tanks are ordinarily drained by digging a pit and directing the contents into it through a hose, and then backfill. In general, the contents of the tank must be disposed so as not to create a nuisance or cause pollution of ground water or a stream. They should not be emptied directly into stream or pond, nor into drainage pits located within 100 ft. of drinking water well or stream.

Insect and Rodent Control

General.—Camp car outfits are rather commonly infested with insects and rodents of various kinds, the most common being bed bugs, roaches, mice, mosquitoes and that principal transmitting agent of intestinal diseases, the fly. In this connection, it should be emphasized that the neglect of routine measures of sanitary disposal of human waste, garbage and trash, will most assuredly present insect and rodent problems that cannot easily be controlled.

Control Methods.—To control insects and rodents requires unceasing activity. Simple cleanliness through frequent and abundant use of soap and water, and the careful sanitary disposal of wastes, are prerequisites. When, for one reason or another, insects become prevalent, the following additional control measures should be taken:

(a) Make special efforts to improve the basic sanitation in order to eliminate attraction and harboring of insects.
(b) See that screen doors and windows are in good repair and are kept closed.
(c) Spray the infested and affected quarters periodically (as required for effective control) with DDT and/or pyrethrum type insecticides.
(d) Provide a good insect repellent for the use of employees required to work in heavily infested outside areas.
(e) Set out poison bait and traps for rodents.

Supervision of Control Work.—The proper application of insecticides and rodent bait requires a certain know how and should be done by instructed personnel. Railroads having extensive insect control work to do should designate either system or division men to organize and supervise this work. The technique of spraying, description of equipment required, etc., are outlined in many trade and public health service publications. Probably the one best adapted to camp car service at present time is an 11-page circular entitled "Use of DDT—Interstate Carriers, Land and Air," issued by the U. S. Public Health Service, Sanitary Engineering Division, Washington, D. C., under date of May 1, 1947.

On Moving Camp Cars to Another Location

Sanitary Procedures.—The foreman should see that all latrine and garbage pits are backfilled properly, all trash and waste burned or buried and that the area that has been occupied is left in a clean and sanitary condition.

Summary

The basic rule of sanitation for camp car outfits should be so to construct, operate, and maintain them as to provide healthy living conditions for the occupants and not endanger the health of the public. Proper observance will require unceasing activity and vigilance.

Report on Assignment 6

New Developments in Water Conditioning for Diesel Locomotive Cooling Systems and Steam Generators

M. A. Hanson (chairman, subcommittee), I. C. Brown, B. W. DeGeer, R. S. Glynn, T. W. His'op, Jr., H. M. Hoffmeister, O. E. Mace, G. E. Martin, Ray McBrian, H. L. McMu'lin, H. M. Schudlich, R. M. Stimmel, T. A. Tennyson, Jr., J. E. Tiedt, R. E. Wachter, E. L. E. Zahm.

Your committee submits the following progress report as information.

Diesel Cooling Systems

During the past year there has been very little new development work beyond that reported by your committee in the Proceedings, Vol. 49, 1948, page 80.

The work done by Mears and Eldridge[1] shows that the chloride content of cooling water is very important when aluminum and copper are in contact. If the sodium chloride content of the cooling water is more than 10 ppm., the usual chromate type inhibitors will not completely stop the corrosion of the aluminum. This probably explains some of the rather erratic performance of aluminum in contact with cooling water.

This is not as important now as it was previously, since the use of aluminum in diesel cooling systems is being reduced. In some instances it may be more economical to replace the corroded parts than to completely prevent corrosion taking place. This is particularly true if the part is readily replaceable.

Steam Generators

A number of the new type of water wall steam generators, with forced circulation, are now in service. For these, the railroads are conditioning the water as it is done for the Clarkson type steam generators, namely, providing demineralized water with pH correction, lime-soda treated water, internal treatment with calcined potassium carbonate and conventional internal treatment with soda ash, tannins and phosphate. To date it appears the water behavior is somewhat similar to that which might be expected with a water wall stationary boiler except that the allowable concentration of soluble boiler salts without excessive carry over is higher. The use of internal treatment with calcined potassium carbonate without antifoam treatment concentrations of 400 gpg. has been carried successfully.

Several steam generators of this type have been in railway service for about a year. As far as can be ascertained none of them, as yet, has required tube renewal, consequently none of them has been given a thorough internal inspection to determine if any corrosion is occurring.

At the 1948 annual meeting of the Railway Fuel and Traveling Engineers Association it was reported[2] that a severely scaled Clarkson type steam generator wasted up to 29 percent of the fuel used for steam generation. With a unit fuel loss of $.09 per gal. this represents a fuel loss of $2.45 per 1000 gal. of feedwater used. Thus, it can be seen that water conditioning can be very easily justified economically on the basis of fuel conservation alone without taking into consideration reduced maintenance expense, or more satisfactory performance on the line of road.

Report on Assignment 7

Water Hammer: Its Effect on Pipe Lines and Methods of Control

C. E. Fisher (chairman, subcommittee), I. C. Brown, R. H. George, H. E. Graham, F. L. Guy, K. P. Howe, W. A. McGee, A. R. Nichols, H. M. Smith, C. L. Waterbury.

This report is submitted as information.

Water hammer is the hydraulic shock which occurs when a non-viscous liquid such as water flowing through a pipe undergoes a sudden change in velocity. The kinetic energy of the flowing liquid under this latter condition is converted into a dynamic pressure wave, which produces a series of shocks sometimes sounding like hammer blows

[1] Uhlig, Herbert H.—Corrosion Handbook, 1848, pages 915–916.
[2] Hanson, M. A.—Water Treatment for Diesel Locomotives from the Standpoint of Fuel Economy, presented at the annual meeting of the Railway Fuel & Traveling Engineers Association, 1948.

which may have sufficient magnitude to rupture the pipe or damage connecting equipment. The pressure wave due to water hammer travels back up stream from the quick closing valve towards the pump check or inlet pipe where it then reverses and surges back and forth through the pipe until friction head and gravity dampen out the surge. It is the sudden stoppage of flow which causes the water hammer. Since water is only slightly compressible, it can be compared to a solid column and its action on a disc of a check valve is the same as dropping the weight in a pile driver. The farther the weight falls, the greater the force exerted when stopped.

The velocity of these surge waves is that of an acoustic wave in an elastic medium, the elasticity of the medium in this case being a compromise between that of the liquid and the pipe. The excess pressure due to water hammer is additive to the normal hydrostatic pressure in the pipe and depends on the elastic properties of the liquid and pipe and on the magnitude and rapidity of change in velocity. Complete stoppage of flow is not necessary to produce water hammer, as any sudden change in velocity will create it to a greater or lesser degree.

Water hammer is produced to some extent in all sizes of pipe regardless of pressure, is transferred great distances, and effects piping and equipment far removed from the source. The surge pressure is governed by the rapidity of valve closure and the more rapidly an outflow valve is closed, the greater will be the hammer. Therefore, the most certain method of eliminating water hammer is to install valves which are designed to minimize this action. It is better engineering to select the proper outflow and check valves so that water hammer will not take place than to try and control it by dash-pots, air chambers, counterweights, etc.

Water hammer is generally set up by the following operating conditions:

1. In starting or stopping a pump or in an abrupt change in the pump's speed.
2. Sudden closure of an overflow valve.
3. Power failure.
4. Accumulation of air in the discharge lines.

To determine by calculation the magnitude of water hammer, four fundamental relations are essential.

1. Velocity of flow in the pipe line.
2. Length of pipe line.
3. Time of valve operation or closure t.
4. The pressure wave velocity a.

The water engineer ordinarily is concerned with water hammer due to the operation of a valve in a long conduit or distribution system. In addition, he is concerned with adverse conditions which may result from the improper adjustment or use of a quick operating valve, either in automatic or manual operation. The surges which result when motor-driven units are shut down, either as a routine operation or as a result of power failures are becoming more and more serious as flow line velocities increase.

The simplest and safest basis of allowing for water hammer conditions is to consider only the flow line velocity as a definite, easily determined factor and assume that the remaining three fundamentals are at their critical values.

In pursuing this line of reasoning, the formula is:

$$\left.\begin{array}{l} h=\dfrac{aV}{g} \\ \text{or} \\ p=\dfrac{aV}{2.3g} \end{array}\right\} \qquad (1)$$

where h or p is water hammer pressure in excess of normal pipe pressure in feet of water h or pounds per square inch p; a is velocity of pressure wave in ft. per sec; g is the familiar 32.2 ft. per sec. per sec., and V is the flow line velocity in ft. per sec. cut off by the valve or other action in the critical time 2L/a sec. or less. (2L/a sec. is the time for one wave cycle to travel up and down the pipe.)

If on distribution systems fed from reservoirs or elevated storage, there is assumed an effective cut-off time Te short enough to be equivalent to so-called instantaneous stoppage of flow, then formula (1) applies. The length and time factors are not then important, since the pressures computed from formula (1) are the maximums that could ordinarily result.

Since the flow line velocity is known or can be determined, and g is known (32.2 ft. per sec. per sec.), the only factor yet to arrive at is a and the formulas become:

$$\left.\begin{array}{l} h=\dfrac{aV}{32.2} \\ \text{or} \\ p=\dfrac{aV}{74} \end{array}\right\} \qquad (1a)$$

If some simple means of determining a (the pressure wave velocity) could be found for all the different types of pipe used in water supply lines, the problem would be one of referring to tables or charts rather than complex mathematical formulas.

Surge Wave Velocity A

The research and test work on water hammer carried out in the last half century has established a significant fact—the velocity of the water hammer or surge wave is the same as the velocity of sound in a fluid filled pipe. The elastic properties of the pipe are fairly well known and water is compressible on the order of 3-1/3 parts per million. Thus we have an elastic system where the relationship of the physical dimensions and elastic values can be established and hence the wave velocity calculated with a great degree of accuracy.

The formula is:

$$a=\frac{4660}{\sqrt{1+\dfrac{K}{E}\cdot\dfrac{d}{e}}}$$

where a is the wave velocity, (feet per second) K is the modulus of compression of water (pounds per square inch), E the modulus of elasticity of the pipe material (pounds per square inch) d the internal diameter in inches, and e the wall thickness in inches.

Examination of formula (2) will show that the wave velocity is 4660 ft. per sec. max. The relations between the modulus of elasticity of water and of the pipe walls as well as the ratio of diameter to thickness of the pipe may tend to reduce this velocity, but cannot increase it.

The value of K has been reported at 290,000 to 300,000 psi. The modulus of the pipe material E depends upon many factors and the values vary to some extent but Table 1 gives those usually accepted.

TABLE 1

Material	Modulus E psi.
Steel	28,000,000 to 31,000,000
Av.	30,000.000
Cast iron (pit cast)	10,000,000 to 15,000,000
Av.	11,000 000
Cast iron (centrifugally cast)	12,000,000
Av.	12,000,000
Asbestos cement	2,800,000 to 4,200,000
Av.	3,400,000

By using the average values of E, Table 2 gives the ratio of the modulus of elasticity of water to the pipe material.

TABLE 2

Material	(Mr) Modulus ratio (E/K)
Steel	100
Pit cast iron	37
Centrifugally cast iron	41
Asbestos cement	11 to 12

and formula (2) becomes:

$$a = \frac{4660}{\sqrt{1 + \frac{d}{e} \cdot \frac{1}{\mathrm{Mr}}}} \qquad (2a)$$

From the tables of standard pipe sizes, the ratio of internal diameter to wall thickness can be calculated and by the use of the chart in Fig. 1, the surge wave velocity can be obtained.

Comparative Surge Wave Velocities

Take the equivalent diameter and pressure specifications for steel pipe, asbestos cement pipe, and cast iron pipe for the same service utilizing this simplified analysis and again assuming practically instantaneous cut off of flow, the corresponding results would be as given in Table 3. Standard tables of published dimensions have been used throughout. The physical characteristics of the pipe walls are from published literature and the allowance for barrel thickness over machined end thickness has been obtained from published articles and from data supplied by manufacturers of asbestos cement pipe.

TABLE 3.—COMPARISON OF WAVE VELOCITIES FOR VARIOUS TYPES OF PIPE BASED ON TABLES OF STANDARD DIMENSIONS

4-in. pipe for 150-lb. service

Type of pipe	*Inside dia. in.*	*Wall Thickness*	*d/e*	*Modulus psi.* $\times 10^6$	*Wave velocity ft./sec.*	*Water hammer psi. per sec. of velocity wave cut off*
Steel std. wt.	4.026	0.237	17.8	30.0	4290	58
Pit cast iron	4.000	0.40	10.0	11.0	4120	56
Centr. cast iron	4.012	0.34	11.8	12.0	4090	55
Asbes. cement (ends)	3.950	0.45	8.8	3.4	3570	48
Asbes. cement (bbl.)	3.950	0.59	6.7	3.4	3780	51

A

4-in. pipe for 150-lb. service

Type of pipe	*Inside dia. in.*	*Wall Thickness*	*d/e*	*Modulus psi. × 10^6*	*Wave velocity ft./sec.*	*Water hammer psi. per sec. of velocity wave cut off*
Steel std. wt.	13.25	0.38	34.8	30.0	4010	54
Pit cast iron	14.39	0.63	22.8	11.0	3660	49
Centr. cast iron	14.20	0.55	25.8	12.0	3620	49
Asbes. cement (ends) ...	14.00	1.13	12.4	3.4	3270	44
Asbes. cement (bbl.) ...	14.00	1.27	11.0	3.4	3390	46

It will be noted from the above tables that the variation of wave velocity and water hammer for 4-in. pipe varies from 3570 to 4290 ft./sec. and from 48-lb. to 58-lb. respectively, per sec. of flow velocity reduction.

Many factors tend to reduce these surge pressures and the figures shown in Table 3 can be affected greatly if the flow is cut off at a much slower rate than the critical time, or if branch pipes are still flowing freely, in which case they act as points of relief for the surge pressures.

It is evident from an inspection of Table 3 that there is a difference in the surge pressures resulting from stopping any given flow in a pipe line, depending upon the diameter, thickness, and material of construction of the pipe. The setting up of arbitrary allowances for water hammer pressures without considering these additional factors would seem to impose a severe penalty in some cases and in others the arbitrary allowance might not be great enough.

Once the flow conditions and size recommendations have been set up for a given pipe line, the maximum instantaneous water hammer pressures above normal can be computed readily from the charts and tables in this article.

Particular attention should be paid to the valves installed for controlling the flow. It is usually possible to adjust the time of closure to a matter of minutes rather than seconds so that the effective time of closure will be long enough to avoid heavy pressure rise. Automatic operating valves should be carefully regulated and maintained to prevent rapid closing or opening, and special precautions should be taken to avoid the slamming shut of pump check valves. Many other factors must be considered such as the parting and rejoining of pipe lines, the effect of the pump and motor characteristics and the inertia of the pump rotating element, as well as the ratio of the length of pipe line to the head acting on it and the rate of reversal of flow as compared with the critical time of the line.

As the size of the pipe line increases it becomes more important to make careful analysis of surge conditions and pressures. Fig. 1 shows in graph form surge wave velocity for various type pipe. By substitution in formula $p = \frac{aV}{74}$ the water hammer pressure can be readily determined for each second of flow line velocity reduction.

Water Hammer Correctives

Relief from destructive water hammer may be accomplished by proper use of quick closing check valves, slow closing altitude valves properly maintained, and the use of surge suppressers at the check valves. Air chambers are generally impractical due to the difficulty of maintaining the proper amount of air space. Small pipe lines can be protected by several types of shock absorbers or arresters. Relief valves are sometimes used to control water hammer but they can be used only in special cases due largely to the spill of water which must be cared for and do not operate except under high surge pressure. Satisfactory service has been obtained from water hammer elimination on water column lines serving water columns in railway service. See Fig. 2 for detail.

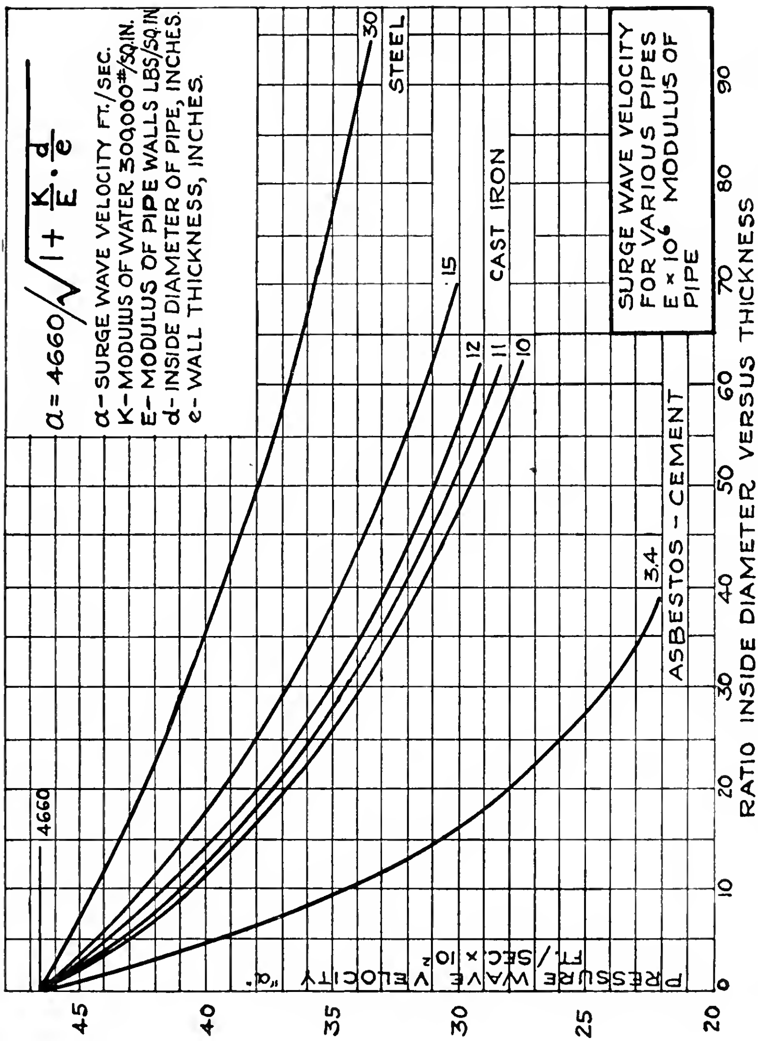
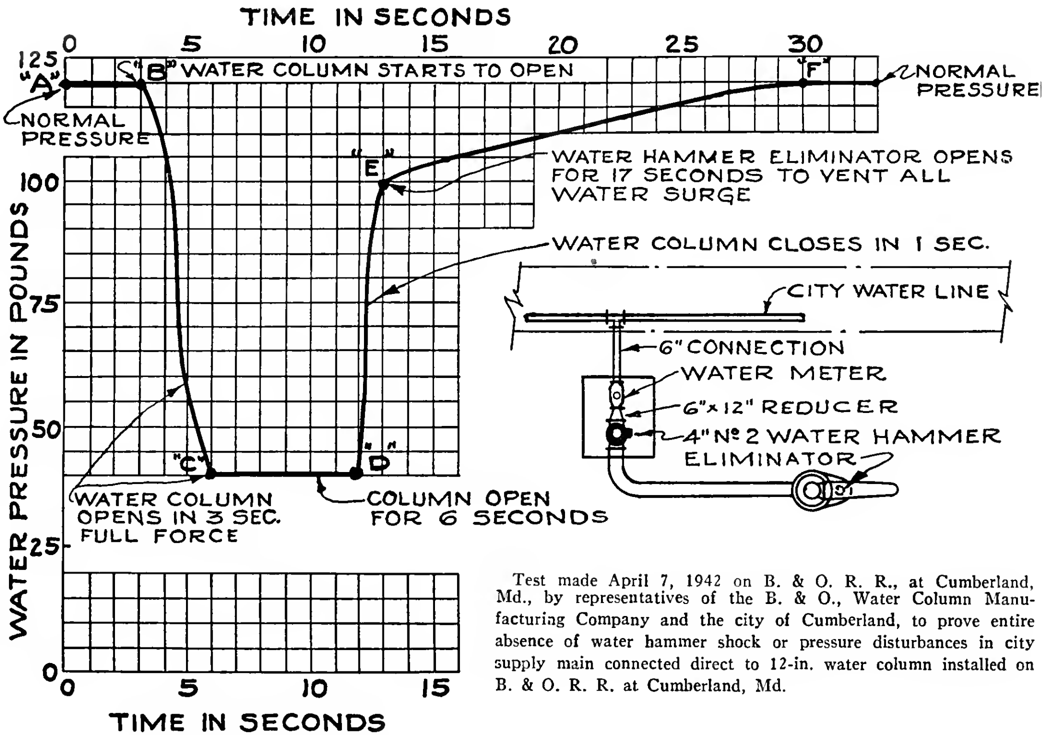


Fig. 1.—Surge Wave Velocity for Various Type Pipes. Reproduced from Practical Aspects of Water Hammer—Journal American Water Works Association, Vol. 40, June 1948.



Test made April 7, 1942 on B. & O. R. R., at Cumberland, Md., by representatives of the B. & O., Water Column Manufacturing Company and the city of Cumberland, to prove entire absence of water hammer shock or pressure disturbances in city supply main connected direct to 12-in. water column installed on B. & O. R. R. at Cumberland, Md.

Fig. 2.—Showing Effectiveness of Water Hammer Eliminator.

Check valves may be grouped into two general classes (a) slow closing and (b) quick closing.

Most slow closing check valves are impractical to use on pump discharge lines because of the resulting water hammer unless controlled to open and close.

A check valve should generally be of a type that closes before the pressure reverses from the immediate low to the quickly ensuing high. The quick closing check valve provides for eliminating surge shock at the valve seat and quickly returns the surge wave to the static pressure before any appreciable surge oscillation can be set up in the discharge line. All discharge lines, especially of the larger diameters, are to some degree elastic and will permit so-called harmonic surges to develop. When the discharge column of water is halted before a reversal of flow takes place, these surges will not generally cause a dangerous pressure rise. The use of a surge suppresser in conjunction with a quick closing type check valve and properly controlled altitude valve provides ample protection against damage due to water hammer.

In many cases of operating centrifugal pumps, surge and water hammer cannot be entirely eliminated by the installation of quick closing check valves and slow closing altitude valves. For these difficult locations one of the best pieces of equipment is the surge suppresser. This surge suppresser is a high class relief valve. It may be operated by water pressure, solenoid, or mechanical interconnection with the check valve. The surge suppresser *opens with a drop in pressure* following shutdowns, remaining open to relieve the surge which follows. It then automatically closes at an adjustable rate.

In actual operating practice it is seldom that any two cases of surge or water hammer are identical and therefore must be studied and corrected by different methods.

Reference.—S. Logan Kerr, Practical Aspects of Water Hammer, Jour. American Water Works Assoc. June 1948, Vol. 40, No. 6, pp. 599–605.

Report on Assignment 8

After-Precipitation from Treated Water; Cause and Prevention

H. L. McMullin (chairman, subcommittee), J. J. Dwyer, A. W. Johnson, O. E. Mace, H. M. Smith, R. M. Stimmel, E. L. E. Zahm.

This report is offered as information.

For the purpose of this report, after-precipitation is defined as that precipitation in water treatment which takes place after the treated water has passed from the treatment tank or chamber. After-precipitation occurs in two forms. In its most harmful form it is an incrustation which is deposited on all objects with which the water comes in contact. In its other form it is sludge in "milky" water. "Milky" water, particularly that from lime-soda treating plants, usually causes foaming in boilers using it. The severity of foaming from this cause depends to some degree upon the amount of sludge present. The most common constituents of after-precipitation are calcium carbonate, calcium phosphate and iron oxide. Under some conditions silicates of calcium and magnesium and calcium tannate may be formed.

As an incrustation, after-precipitation is found along the entire course of the water-use cycle from the treating tank outlet pipe to and inside boilers, on the walls of water lines and tanks, on filter media and strainers, in pump valves and impellers, in economizers, feedwater heaters, feed lines and injectors, and boiler checks. In water lines the deposits accumulate most rapidly at or near the entry of the treating tank outlet pipe, at points of restriction and agitation, and at points where heat is applied. These deposits reduce the openings in the pipe, valves and fittings, and the smoothness of the pipe walls, thereby reducing the capacity of the lines. This results in excessive pressures to maintain a required pumping rate and, consequently, in increased maintenance costs due to excessive wear of pump valves, packing, etc., and to eventual cleaning or renewing of the clogged lines. The incrustation interferes with the operation of valves, preventing their tight closure and causing automatic and water column valves to hang open or partially so.

Efficiency Is Reduced

After-precipitation deposits accumulate on the wood strands or shavings in excelsior filters and on the gravel and sand grains in sand filters. These deposits cause a clogging of excelsior filters and the "grcwth" of filter sand grain size. Both interfere with the efficient operation of the filters and eventually require the renewal of the filter bed. The principles involved in the formation of these deposits are the same as those utilized in a certain type of lime-soda water softener in which all the calcium is deposited as calcium carbonate on fine granules of the same material which serve as a catalyst to speed the reaction and as nuclei for the deposits. However, the deliberate application of these principles to clarification filters as a means of preventing after-precipitation at later points in the water-use cycle, is not recommended unless a thorough investigation of the matter indicates it to be the most efficient and economical method available and practicable.

In pumps, whether reciprocating, centrifugal or rotary, after-precipitation reduces capacity and efficiency, and cause excessive wear of parts. Increased maintenance costs for the removal of incrustation and the renewal of worn parts follow.

After-precipitation is particularly troublesome in injectors where frequently a very small deposit in certain areas will cause complete failure of the injector. Deposits in branch pipes and boiler checks require frequent cleaning or renewal of those parts. The efficiency of closed type feedwater heaters, particularly when internal water treating methods are employed, is soon reduced to a negligible figure by the rapid accumulation of after-precipitation incrustation. Such accumulations in feedwater heaters cause clogging and eventual stoppage, putting an unnecessary additional load on boiler feed pumps. An increased pressure is required to supply the boiler, resulting in excessive wear and often the failure of the feed pump.

The after-precipitation occurring in boilers normally forms sludge, the accumulation of which is determined by the amount of boiler blowing done in the control of foaming. It also causes an incrustation on the boiler flues and shell in the area of the boiler checks, very little, if any, reaching the hot zone of the firebox. Such deposits are relatively harmless as they form where overheating is unlikely and cover an area of such limited size that the fuel loss from their insulating effect is very small, perhaps not even measurable where suitable water treatment under adequate supervision is used. It has been found that boiler sludge absorbs or absorbs to some degree the active ingredient in the polyalkylene polyamide type antifoam compounds. To the extent that after-precipitation forms a part of the sludge it interferes with the effectiveness of antifoam compound.

When After-Precipitation Occurs

The methods of water treatment from which after-precipitation may be expected are those involving precipitation reactions. The external method using lime and soda ash, and the internal method with soda ash, caustic soda or mixtures containing either or both of these two and various other compounds such as the phosphates, tannins, etc., are such methods of water treatment, and they are responsible for most after-precipitation as defined in the opening paragraph of this report. In the former method and also generally in the latter the plant effluent is saturated with calcium carbonate. Since the solubility of calcium carbonate decreases with increase in temperature, any increase in temperature of the water results in a condition of supersaturation with respect to calcium carbonate and in its precipitation. In somewhat similar manner the less common constituents of after-precipitation are formed. Insufficient mixing of chemicals with the water being treated and inadequate retention time in the treatment tank contribute to conditions favorable to after-precipitation.

For the prevention or limiting of the amount of after-preciptation, first consideration should be given to efficient operation of treating plants, with a view to reducing the residual hardness to a minimum. In treating plants, particularly lime-soda plants, designed to provide ample mixing and reaction time and operated efficiently, the residual hardness of the water is reduced to a very low figure and there will be little trouble from after-precipitation. The use of coagulants such as sodium aluminate and iron sulfate in lime-soda ash treatment has been found beneficial in reducing the residual hardness to a minimum and relieving the saturation of calcium carbonate. A fairly recent development along this line is the lime-soda plant which utilizes the sludge blanket principle. Similar results are obtained by the recirculation of sludge. Efficiently operated plants, however, of the most favorable design cannot be expected to eliminate after-precipitation completely. This is particularly true with internal type treating plants using soda ash, caustic soda, etc.

How It May Be Controlled

After-precipitation may be controlled by the use of organic and inorganic surface active agents such as sodium hexametaphosphate and various tannin mixtures, and by the use of other chemical treatment. Of the surface active agents, sodium hexametaphosphate and tannin extracts have been found effective, the former in the ratio of 1 to 5 parts per million and the latter at the rate of 5 to 8 parts per million, depending upon the type and amount of tannin present in the extract. Recarbonation by the use of carbon dioxide gas or the use of sodium bicarbonate as a part of the soda ash treatment produces a more stable water. In lime-soda softened water, where the hardness is low, the addition of calcium sulfate[1] as an after treatment in an amount equal to the hardness of the treating plant effluent has been found effective in preventing incrustation of injectors, branch pipes and boiler checks. The use of acid to convert a part of the normal carbonate content of the water to bicarbonate form will produce results similar to those obtained by the use of sodium bicarbonate. However, this treatment is more or less hazardous, depending upon the quality of supervision and operation, and is not recommended where other methods are applicable. In the control of after-precipitation by the use of inhibiting agents, extreme care should be taken to prevent the retarding of precipitation until the water contacts the hot zone of the firebox. Otherwise, a light but very damaging scale will be formed which will increase staybolt leakage.

In many cases where after-precipitation is not particularly severe, chemical treatment for its control is not economical. Obviously it would be more economical to clean or renew a relatively short length of pipe periodically than to treat several million gallons of water monthly to prevent incrustation. Each case should be considered on its own merits.

It is frequently advantageous to be able to predict whether incrustation of pipes may be expected and the probable amount that will be formed, as it does not always follow water treatment. Also, it is advantageous to know whether the method adopted

[1] AREA Proceedings, Vol. 22, 1921, p. 419.

for its prevention is effective without having to wait for results. Langelier[2] and Ryznar[3] have developed methods by which it may, with fair accuracy, be determined in advance what is to be expected from the treatment of a given water and what results the treatment is giving. The Enslow stability indicator[4] is an apparatus with which water may be tested to determine whether it is incrusting or corrosive.

While the subject of this report confines the discussion of after-precipitation to that following water treatment where the principal difficulty is incrustation, it should not be assumed that all pipe line incrustation is the result of water treatment. Many cases of pipe line incrustation have been found where there was no water treatment. Nor should it be assumed that after-precipitation is entirely without advantage. The sludge formed by after-precipitation frequently serves to remove oil, particularly valve oil in condensate return, from the water and prevent its adherence to boiler metal with consequent serious damage.

Report on Assignment 9

Stream Polution from Sludges and Waste on Railway Property

T. A. Tennyson, Jr. (chairman, subcommittee), B. W. De Geer, H. E. Graham, T. W. Hislop, Jr., O. E. Mace, H. L. McMullin, L. R. Morgan, A. R. Nichols, H. M. Schudlich, H. M. Shepard, H. M. Smith, D. C. Teal, J. W. Ussher, C. L. Waterbury.

This report, presented as information, outlines the railway waste disposal problem and discusses briefly some of the operations involved in the items which seem to be of major importance at this time.

Since railroads haul and use the raw materials, semifinished, and finished products of practically every type of industry in the country, the wastes from railway operation may contain anything known to man and some combinations of known materials which may produce unknowns. It is easy to see how a train wreck, for instance, might create a serious hazard to plant and animal life in a community. The daily transportation of thousands of persons, the transportation of livestock and perishable produce and food products, and the feeding of thousands of employees creates a problem of waste disposal that assumes a national scope.

Considerable study and effort have gone into the problem of satisfactory industrial waste disposal and its regulation by both industry and government. This is evident from the extensive bibliography on chemical wastes which was recently published in Industrial and Engineering Chemistry[A] and in the fact that during the past 50 years more than 100 bills have been introduced into Congress relating to federal regulation and control of stream pollution.[B] Control is now mostly in the hands of the states and interpretation of the existing laws regarding this problem varies with the locality and the enforcing agency, but it is very likely that legislation will eventually lead to more uniform regulation of the disposal of industrial as well as domestic wastes. This is particularly true of wastes which contribute to stream and lake pollution and wastes, such as smoke, which cause pollution of the atmosphere.

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[2] Langelier, W. F.—The Analytical Control of Anti-Corrosion Water Treatment, Jour. A.W.W.A., 28: 1500 (1936).

[3] Ryznar, John W.—A New Index for Determining Amount of Calcium Carbonate Scale Formed by a Water, Jour. A.W.W.A., Vol. 36, No. 4, April 1944.

[4] Jour. W. W. & S., Vol. 86, No. 11, p. 450.

[A] Industrial and Engineering Chemistry, p. 557, Vol. 39, May 1947.

[B] R. W. Hess, Ibid. p. 676.

On railroads, as in industry in general, waste disposal involves some use of the unit processes of chemical engineering. Just what is necessary will depend upon the location and the type of material being handled as well as the conditions at the point of discharge of the waste materials. For instance, some streams are of such type as to permit disposal of many waste products just as they are without treatment. Some railway localities produce wastes which are not objectionable. In these cases wastes from railway property can be discharged directly to the stream. In other cases it is necessary to remove only oil and oily products before disposal of waste material into a receiving stream. Still other streams, and localities, require complete treatment of wastes and absolutely no discharge of raw wastes. The satisfactory disposal of many railway waste products can be carried on simultaneously, while some of them must be given individual attention. The solution of some part of the waste disposal problem usually involves operations which are part of everyday water treating practice such as flocculation sedimentation, filtration, etc.

Classification of Wastes

The study of an industrial waste disposal problem must begin with a classification of the waste material to be expected followed by a study of the individual materials involved and their point of origin. Wastes from railway operation can be classified generally in accordance with the method set up by W. B. Hart for the classification of petroleum refinery wastes.[c] This scheme groups the products in line with their principal objectionable characteristics. It is obvious that a given material may have some characteristics of several of the groups. Using similar procedure for railways the wastes fall generally into classes as follows:

1. Uncontaminated water waste
2. Storm water waste
3. Oil and oily waste, including emulsions
4. Wastes which affect pH, acidity, alkalinity
5. Wastes which cause taste and odor
6. Toxic wastes
7. Wastes which are highly concentrated solutions of mineral matter
8. Colored wastes
9. Wastes which absorb dissolved oxygen
10. Wastes which carry suspended matter
11. Semisolid or solid wastes
12. Miscellaneous waste products

Wastes from railway operation originate in various localities, under the control ot the various departments. as for example, fuel storage and handling areas, water storage and handling areas (including treating plants), mechanical department operations (including roundhouses, shops, powerhouses, car repair areas, cleaning areas, and servicing areas), laboratories, offices, stations, tie and timber treating areas, first-aid stations, yards and freight handling facilities, stores departments, restaurants, and right-of-way.

In the wastes from railway operation, some items can be readily recognized as having a definite bearing on the public health and these are as follows:

1. Sanitary wastes from all sources, such as toilets, washrooms, etc.
2. Floor sweepings and mopping residues

[c] W. B. Hart, Industrial Waste Disposal for Petroleum Refineries and Allied Plants, National Petroleum Publishing Co., Petroleum Processing, Cleveland, Ohio, 1946–1947.

3. Refuse from the cleaning of cuspidors
4. Food debris from lunches of employees and passengers
5. Garbage from all sources
6. Refuse from first aid stations
7. Grain and food products from cars and broken containers
8. Manure from stock cars
9. Bodies and dismembered parts of dead animals

These items directly affect the public health in that they constitute both food and litter for insects and rodents known to be carriers of diseases both human and animal.

In the entire list of railway waste products there is a large number of items which will be carried from railway property in solution, suspension, or emulsion to a receiving body of water. Depending upon the classification of the body of water, more or less treatment will be necessary to prevent pollution. The wastes which will most likely be involved in the pollution of streams are sanitary sewage, treating plant effluents (sludges and brines), oily wastes both with and without cleaning compounds, and certain toxic chemicals from tank car cleaning or leakage.

Sanitary Sewage Disposal

The methods of sanitary sewage disposal and reasons for their use are so well established by public health authorities that it would not seem necessary to include sewage disposal in this study. Any railroad officer charged with the disposition of sanitary sewage should contact the proper health agencies for information regarding satisfactory methods of disposal and the applicable regulations. Where connections to a municipal sanitary sewer system are available the problem is simple. Many other railway waste products can be placed in the city sewer system, with the exception of oily and toxic wastes, and this is the most convenient place of disposal if the city sewer system can stand the load. Local conditions will govern.

Treating Plant Effluents

Satisfactory disposal of sludge from lime soda ash water softening plants and of brines from zeolite plants and demineralizers may present a local problem from the standpoint of stream pollution or effect on the appearance of the surroundings. The latter is particularly true of the sludge.

Where small zeolite plants or demineralizers are in use the washings can be placed in the city sanitary or storm sewer if available. Methods of disposal in use at even large plants are:

1. Discharge to an open ditch, pond, or dry arroyo
2. Discharge to sanitary or storm sewer either with or without dilution
3. Discharge to ocean or other relatively large body of water
4. Discharge directly to large streams without dilution, or to small streams after dilution.

Railroad practice is to dispose of sludge from lime soda ash water softening plants in one of the following ways:

1. Discharge directly to streams
2. Discharge to storm or sanitary sewer systems
3. Discharge to ponds, pits, or ditches and finally moved to another location
4. Discharge into old wells or deep holes.

Where sludge is discharged directly to streams its pollution effect will depend upon the volume of water carried by the stream in relation to the amount of sludge to be disposed of and to the rate of flow of the stream. The effect of the sludge on stream turbidity is the main point to consider. The manner of putting the sludge into the stream will probably cause more concern than any actual stream pollution from the sludge itself. Sludge discharged on the bank or in a ditch for subsequent washing into the stream is unsightly. Where this condition exists sludge lines should be extended to the point of highest rate of flow in the stream and the sludge discharged into this area below the surface. In some cases provision for mixing will help. A change from intermittent to continuous removal of sludge from the plant will reduce the momentary load on the stream and in many cases might eliminate any objection to this method of disposal.

Where city storm sewers are available and can stand the load, continuous discharge of lime soda plant sludge to them should be satisfactory. A study of local conditions may reveal that the city sewer system is carrying acid industrial waste products and the addition of the alkaline sludge may be beneficial to the local sewage disposal plant. This is true on one railroad where the city gives credit for the amount of lime soda plant sludge put into the city sanitary sewer.

Ponds or sludge retaining basins to hold sludge and allow the clear water to drain off are in standard use on railroads and even at large municipal and industrial plants. As discharged from the plant the sludge contins from 2 percent to 10 percent of suspended matter which settles rapidly. The clear water either soaks into the ground, drains into streams or ditches, or is recovered for reuse. Large plants in relatively arid locations can recover considerable water from the sludge pits. The use of duplicate basins allows for periodic cleaning without interruption of plant operation. Sludge can be hauled from the basins and dumped in an out of the way location when necessary.

Although ponds and retaining basins temporarily solve the sludge disposal problem from lime soda ash plants, the sludge must eventually be moved. The amount of calcium carbonate available from the operation depends upon the hardness of the water, the amount of water used, and the amount of lime used in the softening operation. Where the total daily output of calcium carbonate exceeds five tons some investigators believe that it will be practicable to install equipment for the concentration and calcination of the sludge to lime. This is particularly true in locations where lime costs are high due to transportation or other factors. Equipment and processes are available for carrying this out and it is reported that a heat input of 8,000,000 Btu. is required per ton of lime recovered, starting with sludge which has been concentrated so that it contains 40 percent water and allowing for radiation and other heat losses in the process.[D] Several large industrial installations carry out this recovery process but it is not done on railroads.

Some large municipal plants concentrate the sludge, dry it, and sell the resulting powdered calcium carbonate either for use as agricultural lime or for industrial use. This is not done on the railroads due to cost of the operation and the limited amounts of sludge available. In some cases farmers will haul away the wet sludge for sweetening of land but generally they are either doubtful of its character or just do not want to handle it. Some years ago the News Edition of Industrial and Engineering Chemistry carried a notation that the railroads in England were finding a market for treating plant sludge in agriculture. Some work might be done in connection with county agricultural agents to develop local use of treating plant sludge for agricultural purposes.

[D] R. T. Sheen and H. B. Lammers, Recovery of Calcium Carbonate or Lime from Water Softening Sludges, Journal of A.W.W.A., Vol. 36, No. 11, p. 1145 (November 1944).

Oil and Oily Wastes

Oil and oily wastes, particularly on railroads which burn fuel oil, are a source of difficulty because of carelessness, incorrect useage, or faulty equipment and the problem can be reduced in intensity by a good conservation program. Oil lost through leaks, spills, overflows, and foaming in tanks represents a large part of the oil that reaches the ground and ditches around railroad property. The use of too much grease, so that considerable is thrown off or forced out of bearings, is a source of great expense as well as contamination. These oily materials are readily perceptible and come in for more attention from enforcement agencies than most of the other types of waste material. In addition they can constitute a serious fire hazard. They cannot be put into city sewer systems, and fire marshalls are constantly on the watch for them in bodies of water which are used for navigation. Fishermen and others who use the streams and bodies of water for recreational purposes readily detect and complain loudly about oil contamination. Most states are rather strict in their laws concerning pollution of bodies of water by oil. The earliest stream pollution regulations in this country involve oil.[C]

Diesel fuel oil, diesel lubricating oil, and the various oils used for lubrication around the railroad are lighter than water and can be separated to a great extent from water by the use of a well designed gravity trap of standard API dimensions. If the trap is followed by hay or sand filters. and possibly a biofilter, emulsions can usually be dealt with in a satisfactory manner. Mixing of emulsions and acid waste prior to arrival at the trap will assist in breaking many emulsions and facilitate the separation. Emulsions must be broken or separation will not be possible to the degree desired. At the present time the laws are not consistent about the amount of oil that may be discharged into streams. Concentrations of 60 ppm. or higher have been permitted, but the present tendency seems to be toward a maximum of 10 ppm. or less. A standard API trap, properly designed and operated, can be made to reduce oil content of water to as little as 5 ppm., provided the oil is above 18 gravity API and there is not much stable emulsion to be handled.[C] Unfortunately, from the standpoint of the use of standard API traps for the separation of oil from railway waste water, in recent years much of the locomotive fuel oil being purchased in certain regions of this country is heavier than water (below 10 gravity API) and will sink in water rather than rise to the surface. Operation of the conventional gravity trap must be changed when this type of oil is being handled. Around railroad shops the collection of various oily waste products results in mixing low gravity fuel oil with high gravity oils and the production of a mixture which is lighter than water and can be separated by the gravity trap. Fuel oil storage areas present the difficult problem. The presence of sanitary sewage, excessive silt. and sludge, and strong emulsifying agents in the waste water to the trap will interfere with its operation.

The standard API section gravity oil trap consists of a basin, with auxilliary equipment, which is 20 ft. wide and has 8 ft. of flow depth. The capacity of such a standard section in gallons per minute is not dependent upon the amount of oil present in the water—this controls the depth of the separation baffles—but is dependent upon the gravity of the oil being handled. If the rate of flow to be taken care of is greater that the amount which can be carried by a single standard section, then an additional section must be added. For flow rates less than that which can be handled by a standard section, consideration of a smaller separator is desirable from an economic standpoint, and the dimensions of the smaller separator are calculated from those of the standard section, being sure that the same ratio between width and flow depth, as in the standard section, is maintained. The length of the section depends upon the gravity of the oil being handled and upon its viscosity. Experience of the API in both laboratory and field tests has shown that the best complete separator will consist of a primary section in which emulsions are broken and most of the silt and free oil are removed, followed by a secondary section which is 140 percent as long as the primary section. The secondary section does the final "clean up" job. These work best with oils above 18 gravity API and can be followed by such operations as flocculation, filtration, or biofiltration to reduce the last traces of oil. In handling a disposal problem involving the separation of oil and water the following things must be known.

1. Most probable gravity of the oil to be handled at the handling temperature
2. Amount of sediment in the water
3. Rate of flow of the water being handled
4. Viscosity of the water at the handling temperature
5. Viscosity of the oil at the handling temperature.[c]

Since the capacity of a gravity trap is determined by the rate of flow of water through it, among other things, excessive rate of flow as from storm water will prevent the trap from functioning if this increased rate of flow has not been taken into account in the original design. In order to insure a minimum fire hazard, as well as to assist the operation of the trap, separated oil should be disposed of and not allowed to accumulate to any appreciable depth in the trap. Recovered oil can find a use as fuel in incinerators. The oil contained in the oily silt and sludge can be burned out in an incinerator and the resulting ash used for fill.

Storm Water

Storm water is most likely to be contaminated but a shop sewer system should be so designed that areas of greatest contamination can be discharged to traps or sedimentation basins, while relatively uncontaminated storm water can go directly to a city storm sewer system or to a receiving stream. With attention to design of the system and with conservation practices the average storm water drainage from railroad property should be no more contaminated than drainage from city streets. The best systems of waste water disposal consist of separate sanitary and storm sewer systems. By proper treatment after collection, in selective systems, storm water can be recovered for process use in locations where water supply is limited or very expensive.

Toxic Chemicals From Tank Car Cleaning

It is frequently necessary to drain tank cars which need repair, and improper disposal of their contents or some small residue of former contents may present a serious pollution problem. Tanks cars are used to transport acids, alkalis, toxic chemicals, materials which absorb dissolved oxygen, etc., as well as petroleum products and other oils. It is often difficult to determine the exact nature of the contents of a tank car from its billing and this is quite true of petroleum products. Disposal of waste drainage from rip tracks and car repair points should be given special study and possibly even a place of its own in the waste disposal scheme. In case of accidental loss of tank car contents which are toxic, special effort must be made to prevent entry of the material into a body of water or a stream, or special decontamination effort should be made if this is known to have happened. Each case will present its own particular problem. No rules can be set up except that someone who knows what to do should be informed immediately of loss of tank car contents on the line of road

Increasing Importance of This Problem

With increasing governmental activity toward the control of disposal of industrial and domestic wastes, particularly with reference to stream pollution, waste disposal costs must eventually become part of the operating cost of any industry including the railroads. The job will cost something but there can be some recovery of valuable materials, such as fuel, and considerable is to be gained from conservation practices which will naturally be the result of a critical study of the waste disposal problem. The job cannot be handled in a haphazard manner as has been discovered by industry. Trained personnel with well defined duties, responsibilities, and adequate authority as well as equipment, must be available if it is to be a success.

Report of Committee 14—Yards and Terminals

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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions or readoption of matter on LCL Freight Facilities of Chapter 14 (page 14–25) .... page 194

2. Classification yards, collaborating with Committee 16.

   No. report.

3. Scales used in railway service.

   Recommended revisions or readoption of portions of the Manual in which no changes or revisions have been made in the last ten years .... page 195

4. Bibliography on subjects pertaining to yards and terminals.

   Progress report presented as information .... page 196

5. Locomotive terminal facilities.

   Progress report on terminal facilities for electric locomotives, presented as information .... page 200

6. Facilities for expediting freight traffic through yards and terminals.

   Final report, presented as information .... page 203

7. Facilities for mechanical handling of l.c.l. freight, collaborating with Committee 6.

   No report.

8. Relative advantages and cost factors of flat, gravity and hump yards for handling various volumes of traffic, collaborating with Committee 16.

   No report.

AREA Bulletin 476, November 1948.

THE COMMITTEE ON YARDS AND TERMINALS,
G. F. HAND. *Chairman.*

Report on Assignment 1

Revision of Manual

L. L. Lyford (chairman, subcommittee), A E. Biermann, W. O. Boessneck, E. G. Brisbin, W. H. Giles, M. J. J. Harrison, G. F. Hand, E. M. Hastings, F. A. Hess, J. E. Hoving, C. E. Merriman, B. R. Meyers, W. B. Rudd.

Last year, the committee reviewed all portions of Chapter 14 of the Manual that were 10 or more years old, except section 34, page 14–25, "LCL Freight Facilities."

This year, the committee has reviewed section 34 and recommends the following action:

Readopt all paragraphs of section 341, page 14–25.

Readopt all paragraphs of section 342, page 14–25, except delete the word "minimal" in paragraph (c) and substitute the word "minimum."

Readopt all paragraphs of section 343, page 14–25, except paragraph (e). Delete paragraph (e). At the end of paragraph (c) add (Vol. 26, 1925, p. 677).

Readopt paragraphs (a), (b) and (d) of section 344, pages 14–25 and 14–26, except delete the word "minimal" in paragraph (a) and substitute the word "minimum." Delete the words "from 50 to 60 feet," from paragraph (c), and readopt the remaining portion of the paragraph, with the addition of the following words: "not less than 50 feet."

Readopt paragraphs (a), (b), (c) and (e) of section 345, page 14–26. Delete paragraph (d) and change paragraph (e) to paragraph (d). In the first line of newly designated paragraph (d) insert "hand" in front of "trucking." At the end of paragraph (a) add (Vol. 26, 1925, p. 668). At the end of paragraph (b) add (Vol. 26, 1925, p. 670). At the end of newly designated paragraph (d) add (Vol. 26, 1925, p. 672).

Readopt all paragraphs of section 346, page 14–26, except paragraph (g). Delete paragraph (g) and change paragraph (h) to paragraph (g).

Readopt all paragraphs of section 347, page 14–27, except delete the word "minimal" in paragraph (d) and substitute the word "minimum." At the end of paragraph (d) add (Vol. 26, 1925, p. 698).

Readopt all paragraphs of section 348, page 14–27.

Report on Assignment 3

Scales Used in Railway Service

M. J. J. Harrison (chairman, subcommittee), H. Austill, C. A. Beggs, E. D. Gordon, H. A. Hadley, G. F. Hand, E. M. Hastings, H. W. Hem, E. C. Jackson, V. C. Kennedy, E. K. Lawrence, L. J. Maguire, C. L. Richard, D. J. Strauch, J. N. Todd.

Your committee submits the follwoing proposed revisions of designated paragraphs and sections of Chapter 14 of the Manual, with the recommendation that the revised material be approved for publication in the Manual as a substitute for existing material.

Page 14–33: Amend Article 511–1–(d) by adding to the present wording the introductory paragraphs of present Article 511–3 on page 14–34, to make the amended Article 511–1–(d) read:

(d) *Whether cars are to be weighed spotted or in motion.* If cars are to be weighed in motion the scale must be on a gradient in the drill track at the head of the classification yard.

Attention is called to the following provision of the "National Code of Rules Governing the Weighing and Re-Weighing of Carload Freight." (ARA Circular 1433, May 29, 1914, approved by the ICC, June 9, 1914.)

"Rule 3–c—Cars may be weighed in motion only when uncoupled and free at both ends and alone upon scales properly designed for weighing in motion and in charge of a competent weighmaster."

Page 14–34: Delete from Article 511–3 the introductory paragraphs transferred to Article 511–1–(d).

Page 14–47: In line 2 of paragraph 1 of the "Introduction," substitute the word "revenue" for the present word "interchange."

Page 14–47: In line 1 of paragraph 2 of the "Introduction," substitute the word "specify" for the present word "stipulate."

Page 14–48: In line 1 of Article 103, and in the column heading of Table 1402, substitute the word "maximum" for the present word "maximal."

Page 14–48: Place an appropriate symbol at the figure "42" and "46", wherever these appear in column 1 of Table 1402, and add a new footnote below the table, reading, "These lengths of scale are included here as information only. They are less than the minimum specified by section IV hereof."

Page 14–51 and page 14–70: On both of these pages, Article 307 appears, with the same wording. In each case, amend the last three lines of the Article to read, "If the soil does not have a bearing capacity of at least 4000 pounds per square foot, and its bearing capacity cannot be increased by drainage, by stabilization, or by other means, pile foundations shall be provided."

Readopt all other material, not amended as above, on pages 14–33 to 14–83, incl., of the Manual, under the headings, "Rules for the Location, Maintenance, Operation and Testing of Railway Track Scales" (pages 14–33 to 14–46, incl.), "Specifications for the Manufacture and Installation of Four-Section, Knife-Edge Railway Track Scales" (pages 14–47 to 14–65, incl.), and "Specifications for the Manufacture and Installation of Two-Section, Knife-Edge Railway Track Scales" (pages 14–67 to 14–83, incl.).

Report on Assignment 4

Bibliography on Subjects Pertaining to Yards and Terminals In Recent Publications

W. C. Sadler (chairman, subcommittee), W. O. Boessneck, M. H. Dick, G. F. Hand, W. W. Hay, J. E. Hoving, L. L. Lyford, J. W. Seltzer.

Recent literature in book form relating more or less to this subject includes the following: (1) American Railroads by S. H. Holbrook; (2) New Chapter of Erie by H. S. Sturgis; (3) Next Station by Christian Barman; (4) Railroad Motive Power by P. W. Kiefer; (5) Railways of Britain by O. S. Nock; (6) South African Railways by W. M. Clark; (7) Transportation in America by Association of American Railroads; (8) World's Railways by Odhams Press Limited; (9) Economics of Transportation by Philip Locklin; (10) Briitsh Railway Stations by R. H. Clark; and (11) Rail and Platform Plans of British Stations by R. H. Clark.

Reference is made to the following literature appearing since the committee report, Proceedings, Vol. 49, 1948, page 103:

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Selecting storage tanks for pipe line service*—D. A. Leach—Petroleum Engineer 18: 49–51, June, 1947.
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Report on Assignment 5

Locomotive Terminal Facilities

J. E. Hoving (chairman, subcommittee), F. E. Austerman, H. Austill, A. E. Biermann, E. G. Brisbin, H. F. Burch, M. H. Dick, W. H. Giles, G. F. Hand, H. H. Harsh, J. S. Knight, A. S. Krefting, J. L. Loida, C. E. Merriman, B. R. Meyers.

Last year your committee reported on terminal facilities for diesel locomotives. This year the following report on terminal facilities for electric locomotives is submitted as information:

General

Electric locomotives are usually designed for multiple operation with 1, 2 and sometimes 3 units forming a complete locomotive. The terminal facilities should be adequate to handle the longest combination of units other than in a single stall, or on a pit. Where multiple-unit equipment is used, the motor cars may be handled in the same facilities as are provided for electric locomotives. The ordinary steam locomotive facilities are not as a rule adequate to accommodate the electric locomotives, which require supplementary or special terminal facilities especially designed to handle them. The steam, smoke and gases prevalent around steam locomotive facilities are injurious to electrical equipment and it is desirable, if possible, that there be a separation of the facilities if electric and steam locomotives are to be accommodated in the same general vicinity.

Location and General Layout

Location.—If a new location for a terminal is decided upon, it should be such that the movements of the locomotive to and from its train are held to a minimum. A study of the requirements of the new facility should be made so that adequate provisions can be made for handling the locomotives.

Site.—In deciding upon the site, consideration must be given to land values, preparation of the site, type of foundation, drainage, sewers, water supply, electricity, labor supply, fire protection, future expansion of the terminal and the relation to existing yard and terminal facilities.

* Illustrations.

Track layout.—The track arrangement should be such as to provide orderly movement of locomotives to and from the terminal, and there should be at least one run-around track to provide flexibility.

Facilities for Locomotives in Quick Turn-Around Service

At the ends of short electric locomotive runs where the operation requires quick turn-around service (more frequently required in passenger train operation where it is necessary to change power from steam or diesel locomotives to electric locomotives for entrance into passenger stations), facilities should be provided for standing locomotives, quick sanding, and for filling tanks with oil and water where locomotives have heating boilers installed. Inspection pits also are sometimes provided.

Shop Building—Facilities for Running and Heavy Repairs

Size of Building.—The size of the building is determined by the length of units and the number to be housed simultaneously. Generally, a rectangular structure will be found best to serve the requirements. The structure as a rule should be so designed that facilities will be provided for running repairs, heavy repairs, machine shop, store room, parts cleaning and parts conditioning, wheel supply and storage, lockers, washrooms, toilets and office.

Construction.—The construction employed should be fire resistant. Large panels of glass block windows with center pivoted window sash are coming into increasing use.

Tracks.—The number and length of tracks should be sufficient to accommodate the locomotives to be housed at any one time. All running repair tracks preferably should be through tracks, while the tracks for heavy repairs may be stub ended. The desirable distance between track centers is not less than 23 ft., which will allow for a 12-ft. width of working platform.

Heating.—Heating can be accomplished by means of a central heating plant or a separate plant for the particular building. At terminals a central heating plant usually can be utilized to advantage.

Lighting.—The building should be designed to give a maximum amount of daylight to the interior. Electric lighting should be provided throughout the shop building, utilizing fluorescent, incandescent or mercury lamps. Where a great intensity of light is desired, fluorescent lighting can be employed. The locomotive pits should be provided with lights within the pit section. Illumination should be provided both below and above the elevated platforms. Outlets should be provided at frequent intervals for lighting extensions and power tools.

Fire Protection.—Fire protection facilities should be provided and so arranged as to permit complete protection coverage of the shop and terminal structures.

Engine Pits.—All electric locomotive servicing tracks within the shop should have engine pits for inspection and repair purposes. Pits 4 ft. wide and 4 ft. to 4 ft. 6 in. deep from top of rail will be found satisfactory. Ledges half way up the pits for supporting planks for men working on the underframe may be of advantage.

The engine pits may be of concrete construction with the floor of the pit pitched for drainage. Ramps or stairs should be provided to permit easy entrance to the pits. A wall-less pit, with the running rails supported on short columns, is sometimes found desirable.

The pits should be of adequate length to accommodate the longest electric locomotive.

It is desirable to have the elevation of the shop floor between the pit tracks 30 in. below the top of the pit rails to allow shop men to work on the sides of the locomotive mechanism, running gear and brake rigging without unnecessary stooping.

Where required, facilities should be provided in pits for melting snow and ice on the running gear of the locomotives. These facilities may be of a type which is built into the pit or a portable type. The pits should be connected with the sewer system so that proper drainage is provided.

Jacking Pads.—In shops where screw or hydraulic locomotive jacks will be used to raise the body of the electric locomotive, jacking pads should be incorporated along the sides of the pit walls. These pads should be so located that they will be in the proper position for all types of locomotives.

Wheel and Track Replacement.—Means should be provided for the replacement of a complete truck or a single pair of wheels. Drop table, jacks or overhead cranes will accomplish the desired result.

Elevated Platforms Between Pits.—To permit repair work alongside the tracks in the shop, elevated platforms are provided with the surface of the platform at the approximate elevation of the floor of the locomotive body. This type of construction is applicable when the pit tracks are elevated to facilitate truck repairs. A clearance of 5 ft. 6 in. from center line of the track to the edge of the platform and a height of the platform floor above top of pit rail of 4 ft. 10 in. will provide good working space. If it is necessary to do repair work at the roof level of the locomtive it may be found desirable to provide a second tier of high platforms at roof level elevation.

Each of the repair tracks in the shop should be provided with elevated platforms. The platforms should be constructed of fire resistant material and of such length so as to accommodate the longest of the electric locomotives. A desirable minimum width of a platform serving two tracks is 12 ft. Removable railings should be provided as a safety measure.

Overhead Traveling Cranes.—To permit the handling of heavy machinery and parts, overhead traveling cranes should be provided to carry parts to and from the areas set aside for repair purposes. Underclearance below the crane bridge should be sufficient to move the parts to the desired location. The crane should be of sufficient capacity to handle the heaviest items likely to be encountered.

Machine and Electric Shop.—The shops, housing the necessary tools, equipment and machines for making the required repairs, should be located in or adjacent to the repair shop.

Wheel Supply and Storage.—Wheel supply and storage facilities should be provided adjacent to the shop.

Locker, Wash and Toilet Room.—Locker, wash and toilet room facilities should be provided at convenient locations.

Sanding Facilities

Sanding facilities should be provided. Due consideration must be given to keep clear of power conductors.

Fuel Oil

Facilities should be provided for servicing locomotives with fuel oil where required for train heating boilers. Suitable means should be provided to prevent spillage or overflow oil entering into the ground or sewers.

Water Facilities

Facilities will be required for servicing passenger locomotives with water of proper quality where necessary for train heating boilers.

Locomotive Washing Facilities

A locomotive washing facility located on the shop lead track will be found desirable. Brushes and spray pipes can be so arranged that the operation is automatic when the locomotive shunts the track rails at the washer. Some hand washing of the locomotive may be necessary. A washing platform with or without a pit to facilitate cleaning the underside of a locomotive may be found desirable.

Store Room for Electric Locomotive Parts

Facilities for storing parts for the electric locomotive should be provided at the terminal in close proximity to the shop. If there is an existing store room serving the terminal, it may be found that there is adequate space to accommodate the additional parts and if not an addition to the store room should be constructed.

Electric Trolley and High Tension Conductors

The electric trolley and high tension conductors should be terminated outside of the shop building.

Report on Assignment 6

Facilities For Expediting Freight Traffic Through Yards and Terminals

F. A. Hess (chairman, subcommittee). G. F. Alderdice, F. E. Austerman, A. E. Biermann, E. G. Brisbin, N. C. L. Brown, H. F. Burch, J. C. Bussey, M. H. Dick, H. C. Forman, W. H. Giles, G. F. Hand, F. M. Hawthorne, W. J. Hedley, W. H. Hobbs, J. L. Loida, C. E. Merriman, H. T. Roebuck, W. B. Rudd, H. F. Smith, J. N. Todd.

This is a final report submitted as information.

From time to time this committee has reported on the subject of Expediting Freight Traffic Through Yards and Terminals. Its latest report is contained in the Proceedings, Vol. 39, 1938, page 224, in which are listed all references to this subject appearing in the AREA Manual, Proceedings and Bulletins. The committee has reviewed this earlier material and desires to supplement with the following subject matter:

1. Revamping of Yard Facilities to Consolidate Operations and Avoid Extra Moves and Retrograde Movements

Fundamentally, the handling of a car through a terminal should be accomplished with the least number of moves and such moves should be made in the direction of destination.

Some large terminals are made up of a number of relatively small units or yards which have been added from time to time to supplement the original facility as the volume of traffic increased and/or the stepped up, on line, movement of trains caused a congested condition within the terminal.

Usually the several units are used to the best advantage possible. However, it may be found that tracks of sufficient length to receive or make up trains are not available; much reshuffling of cars is necessary; and extra moves are made from unit to unit (and in some cases returned) during the process of terminal handling.

Extra moves and retrograde movements result in terminal delays. Reduction in the number of such moves may be accomplished by the consolidation of yard units and rearrangement of facilities to provide tracks of proper length.

2. Improved Communication Systems

Great strides have been made in developing new systems of communications and in improving older types. Communication systems both on line and in yards and terminals will speed the operations on the railroad.

(a) *Radio and Inductive Train Communication Systems.*—The use of either of these systems provides a method of rapid communication between fixed points, between fixed points and railway vehicles, and between railway vehicles. In general, the communication systems provide contact between the following facilities:

Offices, yard buildings and stations.
Offices, yard buildings, stations and other points on the ground.
Offices, yard buildings, stations and locomotives, cabooses and other railway equipment, including marine equipment.
Locomotives, cabooses, marine and other railway equipment.

(a–1) *Radio Communication* (space radiation).—Radio or space radiation uses the air to carry the message. Space should be provided in the buildings and moving equipment for the sending and receiving sets and other equipment used in connection therewith. Also, provide room at the humps and other places in the yards and right-of-way for the aerial and for the standards on which are mounted the speakers and receivers. This system is described in the Proceedings of the 23rd Annual Session of the AAR Communications Section (Nov. 19, 20, 21, 1946), pages 460 to 481.

(a–2) *Inductive Train Communication.*—This system provides a method of communication using modulated carrier waves which are transmitted over a path made up of the tracks and existing line wires parallel to the tracks. Wayside stations are coupled to the track and to the line wires paralleling the track. Vehicles transmit and receive by induction. This system is described in the proceedings of the 23rd Annual Session of the AAR Communications Section, pages 549 to 570.

(b) *Walkie-Talkies.*—The "walkie-talkie" is a portable sending and receiving radio set which can be carried by an employee and used in communicating with the fixed stations or moving vehicles. It is used in connection with the radio communication system.

(c) *Carryphone.*—The carryphone is a portable inductive set which can be carried by an employee and used in conjunction with the inductive train communication system the same as the "walkie-talkie" is used in the radio system. Carryphones can be used satisfactorily up to about 100 ft. from pole lines.

(d) *Two-Way Loud Speakers Using Paging and Intercommunication Units.*—This provides rapid communication between the yardmaster, switch engine crews, switch tenders and car inspectors for the purpose of coordinating work and the elimination of delays to switch engines, making up of trains, movements out of yards and to and from the engine servicing facilities, repair tracks, ice house, etc.

The master control equipment is generally placed in a tower situated so the yardmaster, who uses the equipment, has an unobstructed view of all operations within the yard.

The two-way communication speakers are usually mounted on standards 5 ft. to 6 ft. above the ground and located along the yard leads and other points where instructions are to be given to men working about the yard.

The paging loud speakers are usually mounted on telegraph poles and directed at the area they are to cover. These speakers are normally used for issuing instructions or to page switching crews or others outside the range of the two-way speaker units.

(e) *Teletype.*—The use of teletype machines has been expanded by combining with modern punch-card machines. Teletype is used on many roads for the transmission of advance train consists to the "next" yard and the furnishing of passing report information to general offices. With the use of punch-card machines, punched cards are prepared for each car on the line containing all necessary information and from these cards teletype tapes are automatically prepared, producing switch lists, wheel reports and yard records. Likewise, information is automatically and promptly furnished to car service and traffic departments.

(f) *Voice Recorder for Car Lists.*—Another recently developed device substitutes a voice recorded list of car initials and numbers for the customary hand-written train check. Under this operation the yard clerk taking the check is located at a fixed point in the yard where the trains or drags of cars pass by at yard speed. As the cars pass by he calls into a telephone handset the car initials and numbers which are registered on a recorder at the general yard office or other convenient point. The recording is then played back by a clerk in the general yard office who arranges bills in outward train order. After being played back the recording may be filed. The advantages of this are that the check is in the office as soon as the last car of the drag has passed. The voice recorded check has proved advantageous as to accuracy, the hand-written train checks often being hard to read.

3. Mobile or Fixed Facilities for Servicing Locomotives at Various Locations in Yards and Terminals

Consideration should be given to having servicing facilities at various points in yards so as to eliminate lost time in moving locomotives from their points of operation to the point where they are to be serviced.

In general, locomotives working on the hump, in the classification, receiving, or departure yards, or at freight houses might have their efficiency increased by providing servicing facilities adjacent to their points of operation.

With the increasing use of locomotives capable of working 24 hours per day, a considerable amount of lost engine time can sometimes be eliminated by the installation of additional servicing facilities.

Fuel and water for coal burning steam locomotives and water requirements for oil burning steam locomotives, will, in general, require fixed facilities, while the sand for these locomotives and the fuel, sand and water requirements for the diesel-electric locomotive can be satisfied either with fixed or mobile units.

Additional fixed facilities for servicing steam locomotives may be obtained, with a minimum of cost, track space and yard area, by the use of mechanical or direct engine coaling plants, mechanical cinder conveyors, water columns directly connected to the main, and pneumatic sand plants. The number of engines it is proposed to service at each particular location will determine the type and capacities of the facilities to be installed.

Fixed facilities for the servicing of the diesel-electric locomotives can be obtained by the use of a fuel oil servicing station, consisting of a storage tank with necessary pumping units, a standard water service connection and a pneumatic sand plant. In some cases storage tanks could be so located that they could serve two or more fueling stations.

At locations where the sand requirements are light, the steam and diesel sanding facilities could be eliminated and the sand brought to these locations in containers from the main engine terminal sanding plant.

The elimination of the need of coaling facilities in diesel-electric locomotive operation permits locating the servicing facilities close to the points of operation.

Mobile units of the tank truck type can be so designed that complete servicing facilities for the diesel-electric locomotives will be available at any point in the yard or terminal where vehicular traffic is possible.

These units can handle the necessary fuel oil, lubricating oil and sand to service the locomotives and may be assigned to work out of the main engine terminal on a fixed schedule to service several locomotives at various locations in the terminal.

4. Operation of Main Line and Other Switches at Entrance and Departure Ends of Yard

Where switches cannot be left lined for yard movement or where the use of spring switches is not permitted, the movement of road trains into and out of the yard may be expedited by providing switch tenders or power operation of the main line and other switches on the route into the receiving yard or receiving tracks and the route out of the departure yard or departure tracks.

The method employed should be determined in the light of the circumstances and conditions in any particular location under consideration.

Report on Assignment 9

Rolling Resistances of Freight and Passenger Cars Equipped with Roller Bearings

B. R. Meyers (chairman, subcommittee), G. F. Hand. N. C. L. Brown, H. B. Christianson, H. J. Gordon, W. H. Hobbs, J. E. Hoving, W. B. Rudd, W. C. Sadler.

This is a final report submitted as information.

This assignment was limited to gathering and assembling existing information only.

Roller bearings were first applied to railroad cars in 1921. Their application to passenger cars has become standard practice on most roads; there are, now, approximately 9000 or 20 percent of all passenger cars so equipped.

Until recently the acceptance of roller bearings for freight cars has been slow. Now, there are approximately 3700 cars equipped with roller bearings in service or on order for freight and miscellaneous service. (See detailed list.)

Timken, Hyatt, Fafnir, and SKF are the principal suppliers of roller bearings for railroad cars; however, Timken is the only company having freight car applications up to this time. Claims that other companies had applications on freight cars were checked and found to be on box cars equipped with high speed trucks and assigned exclusively to head-end service on passenger trains.

Bearings

The friction bearing contacts about 30 percent of the journal area, and is lubricated by waste impregnated with oil which is packed in the lower part of the journal box and which rubs against the journal. When a car is standing, the brass is in direct contact with the steel journal, but, in motion, they are separated by a thin film of oil. The roller bearing completely surrounds the journal and operates in a bath of oil or grease.

Starting

Very little information is available on force required to start cars equipped with roller bearings. The average of 56 tests by the Timken Company in 1925, with a dynamometer on a 61-ton freight car, required 4.38 lb. per ton to start cars equipped with roller bearings; and 38.59 lb. per ton for cars with friction bearings—a ratio of 1 to 8.8. This would be equivalent to grades of 0.22 percent and 1.93 percent, respectively.

In tests by a Class I railroad in 1927, 5 passenger cars equipped with roller bearings required a starting force of 4.15 lb. per ton, and 4 similar cars equipped with friction bearings required 40.7 lb. per ton—a ratio of 1 to 9.8. Other tests have indicated starting forces for cars equipped with roller bearings as low as 1.5 lb. per ton, which seems exceeding low. The generally accepted figure for starting resistance of locomotives with friction bearings is 28 lb. per ton; and 4 lb. per ton with roller bearings—a ratio of 7 to 1.

Grade

From the tests indicated, it appears that the force required to start cars equipped with roller bearings is 3 to 4 lb. per ton. Considering gravity only, this is equivalent to a grade of 0.15 percent to 0.20 percent. However, the recorded test data in 1930 by a Class I railroad indicate that a 70-ton loaded freight car equipped with roller bearings started with a resistance of only 1.5 lb. per ton. This is equivalent to a grade of 0.075 percent and represents the lightest starting grade indicated in data available to the committee.

Rolling Resistance

The results of 1927 tests on passenger equipment on one Class I railroad are shown in Table 1.

TABLE 1.—ROLLING RESISTANCE OF PASSENGER EQUIPMENT—1927

Speed mph.	*Friction Bearings lb. per ton*	*Roller Bearings lb. per ton*
30	4.02	3.32
35	4.25	3.67
40	4.59	4.06
45	5.02	4.47
50	5.57	4.96
55	6.23	5.42
60	7.12	6.05
65	8.02	6.85

Similar data from a report on passenger equipment in 1942, are shown in Table 2.

TABLE 2.—ROLLING RESISTANCE OF PASSENGER EQUIPMENT—1942

Speed mph.	*Friction Bearings lb. per ton*	*Roller Bearings lb. per ton*
10	4.2	3.665
20	4.6	4.078
30	5.0	4.444
40	5.7	5.109
50	6.6	5.965

From the above data, in the 1942 tests it is evident that the rolling resistance of cars equipped with roller bearings is 10 percent to 17 percent less than cars equipped with friction bearings. Roller bearings only help reduce that part of train resistance caused by journal friction. It requires 20 lb. of tractive effort per ton to pull a train up a one percent grade without considering any force other than gravity. Considering grade and train resistance, a train ascending a 1 percent grade at 30 mph. would require approximately 25.0 lb. per ton with friction bearings; and 24.4 lb. per ton with roller bearings—a difference of only 2.5 percent.

Table 3.—Timken Freight Car Applications For Main Line Service

	Railroad	No. Cars	Total	Type of Car	Date in Service
1	AC&Y	25		70-ton covered hopper	5–1–46
	AC&Y	6	31	Caboose	10–21–46
2	AT&SF	25		50-ton box	9–13–44
	AT&SF	5		50-ton box	9–13–44
	AT&SF	1	31	50-ton box	11–16–44
3	C&O	10		50-ton aluminum box	1948
	C&O	5		50-ton corten steel hopper	1948
	C&O	5		50-ton aluminum hopper	1948
	C&O	1000	1020	70-ton hopper	To be built in 1948
4	C&NW	1	1	50-ton box	6–29–44
5	CMStP&P	5	5	50-ton box	1–26–44
6	CRI&P	5	5	50-ton box	8–8–44
7	Fruit Growers Exp.	1	1	refrigerator	
8	G.N.	50		50-ton box	(25) 9–12–44 (25) 1948
	G.N.	1		Caboose	1948
	G.N.	20	71	70-ton ore	To be placed in service in 1948
9	MoPac	25	25	50-ton box	10–29–45
10	Nat'l. Malleable	2	2	70-ton hopper	2–19–46
11	NYC&StL	10	10	50-ton aluminum box	1947
12	StLSW	5	5	50-ton box	11–23–45
13	StLSF	5	5	50-ton box	1948
14	T&P	5	5	50-ton box	10–27–45
15	UP	9		50-ton merchandise	10–39
	UP	300		50-ton livestock	1947–1948
	UP	500	809	50-ton livestock	1948
16	W&LE	12	12	70-ton covered hopper	1948
	Grand Total		2038		

Table 4.—Timken Freight Car Applications For Industrial and Mining Service

	Company	No. Cars	Total	Type of Car	Date in Service
1	Carnegie Illinois	16		Hot metal	9–17–45
	" "	6		Hot metal	1–8–46
	" "	16		Cinder cars	11–22–46
	" "	6		Hot metal	4–29–47
	" "	14		Cinder cars	8–11–47
	" "	4		Hot metal	8–25–47
	" "	16	78	Cinder cars	8–26–47
2	Chile Exploration Co.	50		70-ton ore	9–14–42
	" " "	32	82	70-ton ore	To be built in 1948
3	Mesta Machine	6	6	70-ton gondola	1934–1947
4	Michigan Limestone & Chemical	20		70-ton dump	11–24–44
	" " "	1		70-ton dump	6–22–45
	" " "	18	39	70-ton dump	To be built in 1948
5	National Tube	1	1	70-ton gondola	1–1931
6	Northwestern Steel & Wire	1	1	70-ton mill	To be in service in 1948
7	Oliver Iron Mining. Co.	8		Air dump	3–1940
	" " " "	50		40-yd. dump	2–27–43
	" " " "	50		40-yd. dump	11–19–43
	" " " "	50	158	40-yd. dump	To be built in 1948
8	Phelps Dodge	60		Ore dump	12–39
	" "	80		100-ton dump	4–41
	" "	140		90-ton ore	5–1–42
	" "	30		90-ton ore	8–2–46
	" "	10	320	90-ton ore	1–14–47
9	Philadelphia & Reading Coal & Iron Co.	10	10	35-ton dump	11–29
10	Phoenix Iron Co.	1	1	50-ton flat	1–36
11	Timken Roller Bearing Co.	125	125	70-ton gondola	1928–1947
12	U. S. Gypsum	15	15	40-ton ore	5–13–46
	Grand Total		836		

TABLE 5.—TIMKEN FREIGHT CAR APPLICATIONS FOR U. S. ARMY

Owner	No. Cars	Type of Car	Date in Service
U. S. Army	68	40-ton ammunition	7–41
U. S. Army	29	40-ton fire control	7–41
U. S. Army	29	Railway gun mount	11–41
U. S. Army	30	50-ton kitchen	3–42
U. S. Army	16	50-ton store	3–42
U. S. Army	3	20-ton tank	4–40
U. S. Army	23	20-ton tank	12–40
Total	198		

Express Refrigerator Cars

1 Railway Express Agcy.	500		1947–1948
2 Atlantic Coast Line	50		1947–1948
Total	550		

Descending the same grade at 30 mph. the available force for acceleration would be 15.0 lb. per ton with friction bearings; and 15.6 lb. per ton with roller bearings or an advantage of 4.0 percent.

A coasting test was conducted on a track with a starting grade of 0.25 percent. The roller bearing car started without assistance when brakes were released and the friction bearing car had to be bumped three times to get it started.

No information is available on humping cars equipped with roller bearings. The increase in acceleration over friction bearing cars would not be great; however, when classified in existing retarder hump yards, special handling may be required. When a friction bearing car reduces to slow speed, the oil film breaks down and the friction between metals stops the car. This condition is not present in roller bearings.

The journal friction in friction bearings increases as temperature drops. Available data indicates there is no increase in friction in roller bearings due to lower temperatures.

Most roads have found it necessary to issue special instructions for cars equipped with roller bearings to insure that brakes are properly set; and, in many cases, wheels are blocked to prevent starting by wind or vibration.

Report on Assignment 10

Advantages and Disadvantages of Low and Car Floor Level Passenger Platforms

A. S. Krefting (chairman, subcommittee), C. A. Beggs, H. B. Christianson, W. H. Goold, G. F. Hand, W. W. Hay, W. J. Hedley, J. L. Loida, C. H. Mottier, J. W. Seltzer.

This report is presented as information with the recommendation that the subject be discontinued.

The advantages and disadvantages resulting from the use of either low or car floor level passenger platforms depends largely on the volume and type of traffic handled; particularly, the need for loading and unloading passengers quickly during rush periods and the difficulties involved in transferring mail, express and baggage.

The low type of platform ordinarily is most favorable except at those stations which handle a heavy volume of traffic. The initial cost of providing this type of platform is less than for a car floor level platform, the encroachment on track clearance is held to a minimum and mail, express and baggage can be readily transferred by trucking across tracks to adjacent platforms.

The use of car floor level platforms has considerable advantage at stations where there is a heavy movement of passenger traffic that must be loaded and unloaded quickly. This is particularly true at stations where a large part of the traffic consists of commuters who carry no baggage and are familiar with the routine at that station. Through rapid handling of passengers, the length of time a train is held at a station will be reduced, thereby speeding up train schedules and making tracks and platforms more quickly available for succeeding trains. Some advantage will result in reducing the possibility of accidents to passengers by making it unnecessary for them to climb car steps or use a stepping box. There is also advantage in having car floor level platforms at stations in electrified territory where a third rail is used, as there is less likelihood of a passenger getting onto the track.

Car floor level platforms make it more difficult to inspect and service running gear, air conditioners, and other equipment located under the cars. In some states existing laws will not permit the construction of car floor level platforms placed at the usual distance from the track unless a special exemption is obtained from the state authority. At stations where car floor level platforms are used, it is more difficult and expensive to transfer mail, express and baggage, as transfer trucks must either be handled down and up ramps at the ends of the platform or up and down on elevators.

The question of whether low or car floor level platforms should be provided at a given station will depend on the operating conditions which prevail at that station. A factor which should be considered is whether passengers are to enter and leave the platforms by means of a subway or an overhead approach.

Examples of large terminals that have car floor level platforms are:

Grand Central Station, New York City
Pennsylvania Station, New York City
Canadian National Railways Station, Montreal, Canada

The following large terminals are examples of those with low level platforms:

South Station, Boston, Mass.
Union Station, Cincinnati, Ohio
Union Station, Kansas City, Mo.

Union Station, St. Louis, Mo.
Union Station, Chicago, Ill.
Union Depot, St. Paul, Minn.

It does not appear that the advantages which will result from the use of car floor level platforms are sufficient to warrant the use of this type of platform except at stations where the need of handling a heavy movement of passengers as quickly as possible is of extreme importance.

Report on Assignment 11

Recent Developments in Undercar Inspection of Passenger Cars

A. E. Biermann (chairman, subcommittee), W. O. Boessneck, H. B. Christianson, G. F. Hand, J. S. Knight, A. S. Krefting, L. L. Lyford, C. H. Mottier.

This report is presented as information, with the recommendation that the subject be discontinued.

The need for thorough and quick inspection of modern streamline passenger cars, which are used on the faster trains and the short layover time generally scheduled for these trains, have resulted in the increased use of the undercar inspection pit.

Although the majority of the inspection pits now in use were built primarily for streamline equipment, they are also being used for the older type of equipment. The addition of air conditioning machinery and other undercar items has made the pit inspections a desirable feature in order to detect defects which are not visible from the side of the car.

The pits now being used for inspection purposes can be divided into the following three types:

1. The full train length pit on which the cars are inspected, repaired and serviced.
2. The full train length pit on which the cars are only inspected.
3. The short pit, a car length or less, over which the cars are moved slowly during inspection operations.

In order to determine the number of each of the above mentioned types of pits now in use or contemplated, a questionnaire was submitted to 54 Class I railroads. Answers to this questionnaire were received from 42 railroads, and the number of each type of pit now in service or contemplated was derived from these replies.

Type 1 Pit

These answers show there are 28 pits of type 1, either in service or contemplated at various locations throughout the country. A recent installation of pits of this type is that of the Chicago & North Western Railway in its Chicago coach yard. Here 3 pits, on 21-ft. track centers, each 1330 ft. long and cross connected with 6 drop pits, are used for inspection, repair and servicing of modern streamline trains. The floors of these pits vary uniformly in depth from 1 ft. 4 in. to 1 ft. 9 in. below the base of rail, and they have an inside width of 4 ft. Paved areas between the pits are 11 in. below the top of rail. All undercar inspection is made while the cars are on these pits being serviced and repairs are then performed, if necessary, based on the inspector's reports. Built primarily for servicing and repairing cars, these pits have proved satisfactory, and a considerable reduction in the cost of their construction was made possible by using the shallow depths stated above.

The majority of the type 1 pits in service are, however, single pits built in existing coach yards, primarily for the inspection and servicing of streamline equipment. The average depth of these pits is from 3 ft. to 4 ft. below the top of rail. Where time in coach yards permits, all servicing operations are performed while the cars are on the pit; however, where time does not permit, the cars must be switched over to another track after the inspection and minor repairs are made, and the remainder of the servicing is then completed.

Type 2 Pit

Only one type 2 pit is in operation, possibly due to the congested conditions in the average railroad coach yard. One advantage of this type of pit is that, after the inspection is completed the cars can be set over to either the repair track or servicing track, as the case may be, with a minimum amount of switching interference with the car cleaning and servicing crews. Another advantage of the type 2 pit is a saving in the number of pits required in a coach yard if a type 2 pit rather than pits of type 1 are installed.

The type 2 pit, constructed by the Atchison, Topeka & Santa Fe Railway in its coach yard in Chicago, is 1050 ft. long, has an inside width of 3 ft. 11 in. and varies in depth from 3 ft. 7 in. to 3 ft. 11 in. below the top of rail. All trains entering the coach yard are set over this pit for inspection. After this is completed the train is switched off the pit to the proper servicing track and the bad order car or cars are switched out to the repair track. As in the case of the type 1 pit, the underside inspection is coupled with the conventional inspection from the outside.

In types 1 and 2, drainage is an important item and should be provided. A pit bottom crowned to the center with good drainage gutters will provide dry footing for the workmen. Adequate lighting is an essential item, and it appears desirable for inspection purposes to provide portable flood lights mounted on a small dolly to illuminate the underside of the cars. The portable flood lights can be attached to properly spaced outlets in the pit walls. Specially designed pit lights for mounting in the pit walls are obtainable from a number of sources. Flood lighting the underside of the cars will facilitate the inspections. It also appears desirable to provide entrance to these pits at intervals through the sides of the pits instead of only at the ends. On long pits, entrances to the pits through the sides will permit more than one or two men to work the inspections and will facilitate the reinspection of individual cars.

Reference to pits of types 1 and 2 can be found in the Manual in section 252–(i) page 14–18.02.

Type 3 Pit

Eight type 3 pits are in operation in this country, there being one each on the Pennsylvania Railroad in Philadelphia, on the Illinois Central Railroad in New Orleans and on the Missouri Pacific Railroad in St. Louis. At each of these installations the cars are moved slowly over the pit and are inspected on the underside by inspectors or carmen in the pit. At a speed of about 2 mph. it is possible to make an inspection of the underside of the cars and their running gear.

The Missouri Pacific uses a pit 50 ft. long, 3 ft. 10 in. wide and 4 ft. 3 in. deep below the top of rail. It has been found advisable to employ electricians and pipe fitters in the pit inspections in addition to the regular inspectors. In this way all items on the underside of the car are inspected. Portable fluorescent fixtures are used to illuminate the underside of the cars.

The Illinois Central pit is 20 ft. long, 4 ft. wide and 4 ft. 0 in. deep below the top of rail. It was placed in a position in advance of the car washing machine on the theory that the slow moving cars could be readily inspected from the underside. Operation of this pit has proved very satisfactory and, due to the fact that inspection reports are available while the switching crew still has the train, the time consumed in switching out cars for the repair track is kept at a minimum.

The pit in use on the Pennsylvania is an outgrowth of the pits built for freight car inspection, and, as in the case of the Illinois Central, it is located in advance of the car washing machine. The pit is 8 ft. long, 3 ft. 11 in. wide and 7 ft. 6⅝ in. deep below the base of rail. This depth is necessary, however, only because the car inspector is seated in an elevated chair while he makes the inspection.

Pits of type 3 appear to have certain distinct advantages over the pits of types 1 and 2. These advantages are (a) the minimum of space and track length required either in the coach yard or on the lead; (b) reduced initial investment; (c) reduced maintenance; (d) faster inspections, and (e) minimum amount of interference with other operations in the coach yard.

For all types of inspection pits the following items are essential in their operation: Good drainage, adequate lighting of the underside of the cars and sufficient depth to allow the inspectors to perform their duties properly.

Report on Assignment 12

Length of Freight Cars as the Basis for Determining the Capacity of Yard and Terminal Tracks

D. C. Hastings (chairman, subcommittee), F. E. Austerman, C. A. Beggs, A. E. Biermann, E. G. Brisbin, F. W. Creedle, G. F. Hand, H. H. Harsh, F. M. Hawthorne, B. R. Meyers, J. W. Seltzer.

The dimensions of freight equipment acquired in recent years have indicated that it is necessary to consider the length of this equipment in the design of yards and terminals or in rechecking the capacities of existing yards and terminals that were calculated on the basis of the lengths of equipment of former years. The report of this subcommittee is a compilation of current figures on coupled car lengths that have been secured from eight railroads and several private car companies. The dimensions of a total of 771,729 cars are included in the tabulations.

The various summaries in this report are based on weighted averages, and the information obtained in tabulated form follows. In each case, the number of cars checked on each road does not necessarily represent the total ownership of the road or private line reporting.

TABLE OF COUPLED LENGTHS OF FREIGHT CARS

AUTOMOBILE CARS

Railroad	Number Checked	Maximum Length Ft.	Maximum Length In.	Minimum Length Ft.	Minimum Length In.	Weighted Avg. Length Ft.	Weighted Avg. Length In.
NP	1, 600	54	8⅛	44	11½	52	3⅞
B&O	5, 553	55	8¾	37	11¾	49	7
PRR	2, 450	74	3	44	4⅛	47	4
NYNH&H	None	-----		-----		-----	
CMStP&P	2, 322	54	7	44	2	45	9
RF&P	None	-----		-----		-----	
C&NW	1, 631	54	3½	44	5½	48	6
NYC	19, 649	54	3½	40	6½	44	4½
Summary	33, 205	74	3	37	11¾	46	1 9/16

Table of Coupled Lengths of Freight Cars—Continued

Stock Cars

Railroad	*Number Checked*	*Maximum Length Ft. In.*	*Minimum Length Ft. In*	*Weighted Avg. Length Ft. In*
NP	883	45 7½	40 9¼	43 11¾
B&O	1,197	45 3	39 8	44 9
PRR	2,400	44 6	40 6	44 6
NYNH&H	None	-------	-------	-------
CMStP&P	3,810	44 8	39 10	41 2
RF&P	1	44 8	-------	44 8
C&NW	3,718	44 8	40 3½	42 6
NYC	1,700	44 9⅝	44 2¾	44 8¼
Summary	13,709	45 7½	39 8	43 0½

Tank Cars

Railroad	*Number Checked*	*Maximum Length Ft. In.*	*Minimum Length Ft. In*	*Weighted Avg. Length Ft. In*
NP	47	41 0¾	35 2¼	36 5¼
B&O	None	-------	-------	-------
PRR	None	-------	-------	-------
NYNH&H	None	-------	-------	-------
CMStP&P	None	-------	-------	-------
RF&P	None	-------	-------	-------
C&NW	175	43 3	34 0¼	38 7
Private Lines	55,445	46 8	31 1	38 6⅞
NYC	None	-------	-------	-------
Summary	55,667	46 8	31 1	38 7 1/32

Box Cars

Railroad	*Number Checked*	*Maximum Length Ft. In.*	*Minimum Length Ft. In*	*Weighted Avg. Length Ft. In*
NP	11,354	54 0¼	40 6¾	45 5⅜
B&O	27,184	55 2¼	37 11¾	45 5
PRR	53,700	64 3¾	38 7	43 6
NYNH&H	6,000	44 4	44 3½	44 3⅝
CMStP&P	23,318	54 7	43 5	45 4
RF&P	386	44 8	-------	44 8
C&NW	19,527	54 4⅛	44 2⅝	48 6
NYC	55,863	54 7	39 5	43 11½
Summary	202,332	64 3¾	37 11¾	44 9 3/32

Refrigerator Cars

Railroad	*Number Checked*	*Maximum Length Ft. In.*	*Minimum Length Ft. In*	*Weighted Avg. Length Ft. In*
NP	1,350	45 7½	44 9	45 5⅜
B&O	None	-------	-------	-------
PRR	550	44 9	40 5	44 6
NYNH&H	None	-------	-------	-------
CMStP&P	None	-------	-------	-------
RF&P	None	-------	-------	-------
C&NW	631	51 6	41 6	45 0
Private Line*	109,864	56 0	35 3	43 10
NYC	None	-------	-------	-------
Summary	112,395	56 0	35 3	43 10 11/32

*Includes 15,141 cars of Santa Fe Railroad.

Flat Cars

Railroad	*Number Checked*	*Maximum Length Ft. In.*	*Minimum Length Ft. In*	*Weighted Avg. Length Ft. In*
NP	4,720	56 8	43 10⅛	45 11⅞
B&O	716	56 9	40 1⅝	44 8
PRR	8,580	52 6	38 0	44 0
NYNH&H	172	60 10	38 0	50 2
CMStP&P	4,900	56 9	32 6	50 2
RF&P	None	-------	-------	-------
C&NW	3,867	56 8	44 1¼	48 6
NYC	3,153	60 10	32 7½	46 9½
Summary	26,108	60 10	32 6	46 2 3/16

Table of Coupled Lengths of Freight Cars—Continued

Railroad	Number Checked	Maximum Length Ft. In.	Minimum Length Ft In.	Weighted Avg. Length Ft. In.
Hopper Cars				
NP	1,930	44 2 1/4	34 5	40 7 5/8
B&O	50,220	45 4 7/8	31 5	37 2
PRR	93,200	57 11 1/2	34 2	39 6
NYNH&H	1,001	36 6	34 5	35 0
CMStP&P	4,035	44 9	36 6	40 3
RF&P	115	33 11	33 8	33 10
C&NW	4,552	42 10 3/8	36 3 7/8	39 6
NYC	42,497	43 2	33 2 3/4	35 4 1/2
Summary	197,550	57 11 1/2	31 5	38 1 15/32
Gondola Cars				
NP	2,100	46 3 1/2	44 6 1/2	45 4 7/8
B&O	14,426	70 10 1/4	41 8 1/4	54 7
PRR	60,087	70 3	41 11	46 5
NYNH&H	1,138	45 10 1/2	43 10 1/2	44 10 5/8
CMStP&P	7,752	70 9	43 11	49 3
RF&P	96	42 11 1/2	42 7 1/2	42 9 1/2
C&NW	4,676	69 10	44 1 1/4	48 0
NYC	40,488	70 1	34 5	46 9
Summary	130,763	70 9	34 5	47 7 11/32
Summary By Roads All Types of Cars Weighted Average Each Road				
NP	23,984	56 8	34 5	45 6 11/16
B&O	99,296	70 10 1/4	31 5	42 9 1/2
PRR	220,967	74 3	34 2	42 8 3/16
NYNH&H	8,311	60 10	34 5	43 4 13/32
CMStP&P	51,137	70 9	32 6	45 8 8/32
RF&P	598	44 8	33 8	42 3 3/8
C&NW	38,777	69 10	34 0 1/4	46 5 3/16
NYC	163,350	70 1	32 7 1/2	42 5 1/2
Private Lines (Tanks)	55,445	46 8	31 1	38 6 7/8
Private Lines* (Refrigerator)	109,864	56 0	35 3	43 10

*Includes 15,141 cars of Santa Fe Railroad.

Summary By Types of Cars

Automobile	33,205	74 3	37 11 3/4	46 1 9/16
Stock	13,709	45 7 1/2	39 8	43 0 1/2
Tank	55,667	46 8	31 1	38 7 1/32
Box	202,332	64 3 3/4	37 11 3/4	44 9 3/32
Refrigerator	112,395	56 0	35 3	43 10 11/32
Flat	26,108	60 10	32 6	46 2 3/16
Hopper	197,550	57 11 1/2	31 5	38 1 15/32
Gondola	130,763	70 9	34 5	47 7 11/32
SUMMARY	771,729	74 3	31 1	43 0 3/16

OVERALL WEIGHTED AVERAGE LENGTH OF ALL TYPES OF CARS 43 0 3/16
MAXIMUM LENGTH FOUND ALL TYPES 74 3
MINIMUM LENGTH FOUND ALL TYPES 31 1

Report of Committee 22—Economics of Railway Labor

J. S. McBride, *Chairman,*	J. P. Ensign	H. E. Kirby, *Vice-Chairman,*
Lem Adams	H. W. Flemming	G. M. O'Rourke
C. W. Baldridge	R. J. Gammie	W. C. Perkins
E. J. Bayer	R. L. Groover	W. G. Powrie
J. G. Begley	C. G. Grove	A. G. Reese
F. J. Bishop	C. T. Gunsallus	C. W. Reeve
W. H. Brameld	C. C. Haire	G. L. Sitton
E. J. Brown	K. H. Hanger	G. M. Strachan
F. G. Campbell	N. D. Howard	W. H. Vance
H. A. Cassil	W. M. Jaekle	E. C. Vandenburgh
G. E. Chambers	Roy Lumpkin	H. J. Weccheider
J. B. Clark	E. H. McIlheran	Edward Wise, Jr.
W. E. Cornell	W. H. Miesse	C. R. Wright
P. A. Cosgrove	H. L. Miller	*Committee*

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report including recommended revisions of the Manual .... page 217
2. Analysis of operations of railways that have substantially reduced the cost of labor required in maintenance of way work.
   Progress report, presented as information .... page 226
3. Organization of forces for track maintenance operations.
   No report.
4. Labor economies of various methods of tamping track.
   No report.
5. Organized training of supervisors.
   Progress report, presented as information .... page 228
6. Labor economies of different types of foundations under railroad crossings.
   No report.
7. Track maintenance in CTC territory.
   Final report, presented as information .... page 230

The Committee on Economics of Railway Labor,
J S McBride, *Chairman.*

Report of Assignment 1

Revision of Manual

C. C. Haire (chairman, subcommittee), Lem Adams, C. W. Baldridge, W. H. Brameld, E. J. Brown, F. G. Campbell, H. A. Cassil, R. J. Gammie, G. M O'Rourke, W. C. Perkins, W. G. Powrie, E. C. Vandenburgh, C. R. Wright.

Your committee submits the following recommendations for adoption and inclusion in the Manual.

1. Beginning on page 22–5 and ending on page 22–9 delete the entire section under the title "II Programming of Bridge and Building Work."
2. Adopt the following in lieu of the text deleted as described in 1 above.

AREA Bulletin 476, November 1948.

II—PROGRAMMING OF BRIDGE AND BUILDING WORK

The programming of bridge and building work is as essential to obtain economies in labor as it is in the case of other maintenance of way and structures work (see Manual, this chapter, Part I, Section G). Information necessary for the preparation of a program should be secured by careful field inspection and from reports made of such inspection. The programming function is an integral part of budgeting and the control of expenditures.

The inspection of bridges and buildings and the programming of repair and improvement work are two important functions of maintenance of way organizations, and to do this work they should function annually through the activities of system inspectors with the cooperation of the supervisor of bridges and buildings, the division engineer, and division or district inspectors. Secondary inspections by district and/or division inspectors should also be made periodically; not less frequently than semi-annually. For proper organization and records covering inspection and programming. it is necessary that all structures be appropriately numbered and that there be a register of structures to control and maintain a proper numbering system for all bridges and buildings.

Field Inspection to Develop Bridge and Building Work Program

Field inspection reports furnish a basis on which to plan the work program and should be properly designed to furnish information for the preparation of the current year's budget as well as a longer range budget for a number of subsequent years. The procedure to develop such programs may be described as follows:

1. Concurrently with the inspection of bridges and buildings to determine the physical conditions, it is necessary that all the facts be stated on the inspection form separately for each structure, to indicate the work needed for both the current and following years so that the budget in effect for the current year can be adjusted and/or the budgets be prepared for the following years.

2. Where repairs are needed, the basic field reports should show a bill of materials required, together with an estimate of the labor and other anticipated costs. However, if addition and betterment charges to capital account are involved, the report should likewise so state. The information should be set up so that ultimately an estimate can be prepared to show the amounts chargeable to capital account, operating expenses, accrued depreciation and other accounts.

3. The engineer of bridges and the engineer of buildings should check the field reports and prepare estimates for capital expenditure work involved, separately from the maintenance repair budget. (There should also be shown estimated amounts chargeable to operating expenses as developed in the capital expenditure budget.) AFE should then be secured for the work involving capital expenditures. These officers should also prepare the budget, separately for repairs and capital expenditures in such a manner that the work is listed in order of urgency and importance, and the less urgent work can be deferred if circumstances dictate. The budget should likewise show the estimated amounts to be borne by other companies and individuals in connection with any jointly owned property.

4. The engineering department should make arrangements with the accounting department to furnish monthly detailed statements of charges for the repair and AFE work separately by structures and show for each item the current month's capital expenditures, operating expenses and charges to other accounts in

connection with the AFE work for the proper control of the expenditures. The accounting department should also furnish concurrently a summary statement showing, separately for each project, the aggregate gross expenditures by ICC primary accounts, and the credits by accounts. This statement should show expenditures prior to current month and total to date.

5. Division forces (or system forces doing the work) should prepare a field report each month, and a progress report to show for each of the components of the project the percentage of the physical work performed during the current month and to date—both for repair work and AFE projects. The progress report should also show the estimated date of completion and remarks as to any delays. At the end of the year a carry-over report should be prepared to show all items of incomplete work and an estimate of expenditures remaining to be incurred, separately for repair work chargeable to operating expenses and for the AFE projects chargeable to capital account.

Form 2202 Rev.—Summary Report—
Programming of Bridge and Building Work

This form should be used to summarize the bridge and building inspections, to develop the work program and to recapitulate the results of the entire inspection, separately by districts and operating divisions. The summary should be prepared from the individual reports for each bridge and building as recorded on inspection reports.

Each entry from these forms should be listed in Column 1, Item No., in proper geographical order and by appropriate operating subdivisions for ready reference. Column 2, Bridge or Building No. should show the numbers as assigned. Column 3 should be a brief description of the type of structure. Column 4 should show the date inspected as reflected by individual inspection reports. Column 5 should be a brief résumé of the substance reported in the separate inspection reports. Column 6 shows whether the work comes in the class of AFE work, repairs, other companies and individuals, joint property and/or joint facilities, etc. In Columns 7, 8, 9 and 10 can be shown the estimated amounts recommended for the program.

Separate sheets of the report can be used to record the result of the inspection where immediate work is necessary during the current year, another set of sheets to show program of work recommended for the next year (or future years); also a separate set of sheets can be used to separate the AFE work from repair work when desired.

The development of estimated amounts for each project chargeable to Capital Account for which AFE will be required necessitates the use of a second summary to estimate the capital expenditures and other accounts. Other summaries are needed for separating major and minor repair projects in order of importance and/or urgency.

The summary involving capital expenditures should be prepared as follows:

	Capital Account			*Operating*			
Item No.	*Cost of New Work*	*Property Retired*	*Net Col. 2–3*	*Expenses Repairs and/or Remove*	*Salvage Col. 6*	*Accrued Depreciation Col. 3–6*	*Total Cols. 4 + 5 + 6 + 7*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*

Notes: Column 1 should be same item number as Column 1, Form 2202 Rev.
Column 3 Ledger value of any nondepreciable property should also be shown in Column 5
Column 8 should be same amount as Column 10, Form 2202 Rev.

Approval by Management and Control of Program

Field inspection forms and Summary Form 2202 Rev. provide for recommendations and development of the annual programs for repairs and/or improvements. After these recommendations are submitted, further classification and modification may be desired in the offices of the engineer of bridges, engineer of buildings, and engineer of maintenance of way, and a final budget should be prepared for approval of the management. After final approval it is necessary to establish control of the expenditures for the current year and give consideration to items to be carried over until next year (or future years) covering work which will not be done within the current year. The control of the expenditures can be accomplished by statements of detailed monthly maintenance expenditures for each repair item and each AFE. The results shown by the posting and accumulation of the charges for each of the projects must be coordinated with a progress report from the field showing the physical work performed and an estimate of the expected date of completion, as well as a statement of any conditions retarding or delaying the work, such as the shortage of labor, material, etc.

Copies of the revised budget or program prepared by the engineer of bridges, engineer of buildings, and engineer of maintenance of way, when approved by the management, should be furnished district and/or division officers. The final approved budget or program of work should include a list of the projects by classes and in order of importance insofar as possible. The accounting department should likewise be furnished a copy of the approved current year budget and progress report so as to furnish the monthly details and statements of expenditures according to AFE and by item numbers shown for the repair projects.

Inspection of Bridges and Buildings

The committee found it necessary to study the entire question of bridge and building inspection, and submits as information the following report and a recommended series of forms.

The inspection of bridges and buildings is required to ascertain, from field investigation, conditions as to safety and measures necessary to maintain safe and expeditious operation and also to secure necessary information for programming repairs and/or improvement work for the current year and in the future.

Bridge and building inspection has a dual purpose, the first being to ascertain if conditions are satisfactory as to safety and whether the facility is in proper repair to serve its purpose or what remedies are needed to give proper service. The second function is to program repair and/or improvement work for the current year as well as for future years. This requires a series of field inspection forms and methods to recapitulate the data on a summary form.

Competent representatives should periodically make a careful field inspection to secure first hand field information on the condition of structures. This information and the report thereon concurrently constitutes data for a recommendation for programming repairs and/or improvements. All other conditions at a bridge and building site should be examined, such as contiguous physical conditions other than those of the bridge proper, drainage, and other items that may have a bearing on the maintenance of uninterrupted traffic and the efficient use of the facility at all times. The fundamentals to be observed in inspection of each bridge and building are as follows:

1. Inspect each bridge or building for physical conditions that may require work to maintain the structure in a safe operating condition and for efficient service.

Form A

TIMBER

NORTH & SOUTH RAILWAY—BRIDGE INSPECTION REPORT

District__________ Division__________ Bridge No.__________

Kind of Structure__________Height__________

Date Built__________

Description

	Bents	Piles	Strg's	Caps	Braces	G'd Rail		
No.								
Size								
Kind								

Condition of Structure at Date of Inspection__________Date__________

Should Bridge be considered for renewal within two years?__________

Necessary repairs within one year__________

Supervisor of Bridges & Buildings Inspector

2. Report the inspection on a separate form for each structure. Describe the physical conditions actually found, and recommend work needed promptly for safety requirements and all other work in the nature of repairs that can be used in preparation of the annual programming of bridge and building work. If, however, immediate attention is required in the interest of safety or efficient functioning of the facility, the forms should show estimated costs for labor and material, but ordinary renewals and repairs can be described with a statement of materials required so that estimates can be compiled elsewhere (see Section 5 below). Individual inspection reports as made by system inspectors should be prepared in triplicate so that the engineer of bridges or engineer of buildings will have a copy for the departmental files. A copy (or copies) of each inspection report should be furnished the district and/or division engineer.

3. Engineers of bridges and of buildings should summarize the inspections on Summary Form 2202 Rev. separately for each structure and describe the phys

ical conditions actually found, report needed work, and show estimated costs to place the strucutres in a safe condition. Copies of the summary report of the system inspection should likewise be sent to the district and/or division engineer's office and the original retained in the office of the engineer of bridges or engineer of buildings.

4. The bridge and building inspection by division forces should be interim inspections, using the same methods prescribed for the system inspection.

5. Where an urgent need for corrective action exists in the judgment of the system inspector or the district or division inspection force, a special and independent report should be prepared and immediately filed with the district and/or division engineer's office, and a copy sent to the engineer of bridges so that proper corrective measures can be taken at once. Copies of the same report should be retained with the routine inspection files for the purpose of the record, but such copies should be clearly marked "Special" with the date any such report was forwarded; however, it may be necessary in extraordinary cases to arrange verbally for remedial action without delay.

Forms for Inspection of Bridges and Buildings and Programming of Work

The organization for the inspection and programming work requires that separate standard forms be used for each bridge and each building; also a uniform summary form to report the results. These forms are described as follows:

Form A—Timber Bridge Inspection Report.—This form should be prepared to record the data obtained from field inspection. The necessary facts to record conditions

Form B

NORTH & SOUTH RAILWAY—STEEL BRIDGE INSPECTION REPORT

District ______________ Division ______________ Bridge No. ______________

Number and Kind of Spans ______________________________

____

Kind of Substructure ______________________________

Is this report based on detailed inspection? ________ Date previous report ________

Year Painted ______ Kind of Paint, 1st Coat ______ 2nd Coat ______ Condition ______

Detailed description of conditions found and recommendations ______________

____

____

____

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____

Supervisor of Bridges & Buildings ______ Date of Inspection ______ Inspector

Form C

NORTH & SOUTH RAILWAY—CULVERT INSPECTION REPORT

District__________ Division__________ Date__________

Pipe Culverts, Wood & Other Boxes, Arches & Other Types

No.	Kind	Size	Length	Condition*	Remarks

Supervisor of Bridges & Buildings Inspector

*Condition—Use "G" for good, "F" for fair, and "P" for poor. For "P", explain under Remarks.

found at each bridge inspected should be recorded on the form. Whether or not immediate or future repairs are required should be stated, but the primary requisite is for the inspector to indicate the facts as to safety.

This form prescribes that a brief description of the structure and the component parts thereof be given. The following should be reported:

> Year built, length, height, condition of structure, date of inspection, whether renewal should be considered within the next two years, necessary repairs within one year (immediate or for future year's program).

The reports should be signed by the district or division bridge inspector and the supervisor of bridges and buildings. In case these inspections are made by system bridge inspectors the report should be so signed.

Form B—Steel Bridge Inspection Report.—This form can be used for steel bridges and other permanent structures. As required in Form A, the data recorded on the form should be obtained from field inspection. The facts as found from the inspection and any recommendation of immediate or future repairs should be recorded on the form, but the primary information should be to indicate that the structure is in satisfactory condition as regards safety or otherwise.

Form D

The North & South Railway

BUILDING AND STRUCTURES ANNUAL INSPECTION REPORT 19___

DIVISION__________ DISTRICT__________ BUILDING NO._____

Location and name__________

Description__________

Is this report based on detailed inspection?______Date previous report______

Year painted__________Condition__________

Detailed description of conditions found__________

Recommended repairs and/or improvements this year__________

Bill of Material and Estimated Cost

Description Or Items And Specifications (1)	Unit Name (2)	Unit Number (3)	Unit Cost (4)	TOTAL (5)

Supervisor of Bridges & Buildings — Date of Inspection — Inspector

FORM 2202 Rev.

North & South Railway

SUMMARY REPORT OF BRIDGE, BUILDING & OTHER STRUCTURES INSPECTION AND PROGRAM OF WORK

________________District ________________Division

Period: From____________to____________ Type of Structures____________________________

Note: This report is a recapitulation of Reports on Forms A, B and C. Bridges, Trestles, Culverts, Buildings, Etc.

Item No. (1)	Bridge or Bldg. No. (2)	Description (3)	Date Inspected (4)	Conditions Found, Description of Work Required and Recommendations (5)	Cost of Work				
					Class (6)	Labor (7)	Material (8)	Other (9)	Total (10)

Date______________ Signed________________________

This form prescribes a brief description of the structure divided between the substructure and superstructure. The condition of the painting for steel bridges should be carefully indicated.

In the space "Detailed description of conditions found and recommendations" should be shown the findings of the inspector as to general physical condition, any repairs needed and any recommendations. The reverse side of the form or separate sheets can be used for the preparation of any detailed report and estimate; however, in the case of improvement work involving capital expenditures, or where the projects involve heavy and/or extensive repairs, it is necessary to forward the recommendations to the engineer of bridges for detailed investigation and the preparation of the AFE or maintenance costs.

Form C—Culvert Inspection Report.—The use of this form should be confined to reports on the inspection of pipe culverts, wood and other boxes, small arches and other types in geographical order. One line can be used for each culvert, unless a detailed report requires the use of more space.

Where no bridge number is assigned to a culvert, the location should be fixed by mile post reference and the approximate chainage distance shown therefrom.

Form D—Building and Structures Annual Inspection Report.—This form should be prepared to record the results from field inspection of each building. As in bridge work, safety is of paramount importance and recommendations should be recorded.

This form prescribes that the building number be shown, location, name of building and a brief description. Particular emphasis should be given to the condition of the paint and the need of ordinary as distinguished from extraordinary repairs.

Under the heading "Bill of material and estimated cost," space is provided for an estimate. The material items should be shown first and then the labor item (or items). If more space is required, the reverse side of the form may be used or separate statements prepared.

Summary Report of Bridge and Building Inspection and Program of Work.—The results of bridge and building inspections should be summarized on Form 2202 Rev. for the dual purpose of reporting the facts regarding (a) safety and conditions found requiring immediate remedial measures and (b) the necessary facts and needed data for programming bridge and building work. (See II Programming of Bridge and Building Work, this chapter).

Report on Assignment 2

Analysis of Operations of Railways that Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work

W. E. Cornell (chairman, subcommittee), F. J. Bishop, E. J. Brown, F. G. Campbell, H. A. Cassil, J. P. Ensign, H. W. Flemming, R. J. Gammie, R. L. Groover, C. T. Gunsallus, C. C. Haire, N. D. Howard, H. E. Kirby, E. H. McIlheran, H. L. Miller, G. M. O'Rourke, Edward Wise, Jr.

This report is presented as information. It describes and gives cost figures on performance of certain major items of track work on the Delaware, Lackawanna & Western Railroad by large gangs with traffic detoured, as compared to performing similar work with smaller gangs under traffic with a 45-mph. slow order for first class trains and

20 mph. for extras. For convenience of discussion the work with the larger gang will be identified as the "Detour Method."

Under the detour method the track or a length of 5 miles between temporary or permanent crossovers is taken out of service and given over to the exclusive use of a track gang of some 140 to 150 men for the 8-hour work period. All work within a 5-mile stretch is completed before taking another section out of service.

The work performed during the detour operation includes renewing ties (three or more per rail), fork tamping (3-in. out-of-face lift), then machine tamping (1½-in. lift), spot tamping, gaging, third or hold down spiking, changing bars where necessary, welding rail ends, grinding, resetting rail anchors and unloading and dressing ballast.

The track structure is 131-lb. rail on treated cross ties and crushed stone ballast.

The traffic during the 8-hour working period consists of two passenger trains each way at 80 mph. speed and four and five freight trains each way at 50 mph.

The organization of the detour method gang is as follows:

9 Foremen (including one work-train foreman)
7 Assistant foremen
125 to 135 Laborers
5 Repairmen (welders)
2 Assistant repairmen (grinders)
1 Repairman helper

While the amount of each type of work varies greatly from section to section and even from day to day, a typical set-up of the gangs as furnished the committee by the railroad for the performance of the work is about as follows:

Work Performed	*Foreman*	*Assistant Foreman*	*Laborers*
Pulling spikes on ties to be removed; raising and tamping jacks ahead of tie renewal gang and pulling out old and putting in new ties	1	1	20
Spiking, spacing ties, fork tamping, applying anti-creepers	1	1	32
Surfacing track and tamping jacks ahead of machine tampers	1	1	6
Machine (pneumatic) tamping	1	1	28
Tighten bolts, grinding joints, oiling joints and lining track	1	..	14
Dressing	1	..	18
Follow-up tamping gang (crawler compressor)	1	..	7
Work train	1	..	6
Miscellaneous: Road crossings, station platforms, gaging and fill-in to other gangs	1	1	4
Timekeepers	..	2	..

Following is a tabulation showing the man-hours required for doing work on one mile of track by the detour method as compared with the use of the smaller gangs working under traffic.

The hours shown, at present wage rates, indicate a cost of approximately $3,459 per mile for the detour method as compared to $7,365 for the smaller gangs working under traffic, an indicated saving of approximately 53 percent.

	Detour Method Hours	*Smaller Gangs Under Traffic Hours*
Foremen	180	192
Asst. foremen	140	478
Laborers	2,500	6,220
Repairmen	100	70
Asst. repairmen	40	70
Repairmen helper	20	
Work train	26	24
Detour conductor	20	
Detour brakeman	20	
Proportion of crossovers		
Foreman	3	
Laborers	64	
Total	3,113	7,054

Conclusion

Substantial savings may be obtained by use of the detour method for doing certain major items of track work as compared to doing the work under traffic.

Report on Assignment 5

Organized Training of Supervisors

Edward Wise, Jr. (chairman, subcommittee), E. J. Bayer, F. J. Bishop, J. B. Clark, P. A. Cosgrove, R. L. Groover, C. G. Grove, C. C. Haire, K. H. Hanger, W. M. Jaekle, H. E. Kirby, Roy Lumpkin, G. M. O'Rourke, C. W. Reeve, G. L. Sitton, E. C. Vandenburgh, H. J. Weccheider.

This report is submitted as information.

Organized training of supervisors is most important to the railroads to insure a constant supply of an efficient class of supervisory officers who can effectively and economically conduct maintenance of way work to meet the desired standards, and to provide personnel from which officers of higher rank can be recruited for the engineering and operating branches of the railroads.

A questionnaire was sent to some 20 leading railroads of the United States and Canada, inquiring as to their practice in this respect. Three of the railroads replying had definite training courses. Three of them had partial training courses, six replied that they use no training courses, and eight railroads did not reply to the questionnaire. The three railroads that have a definite training course for supervisory officers conduct it about as follows:

One railroad has had its course of training in effect for a number of years. This course extends over a period of 30 months, and its purpose is to train engineering graduates for official positions in the maintenance of way department. When selecting young men, in addition to educational requirements, consideration is given to their personality, physique, evidence of initiative and desire to learn the railroad business.

Apprentices are given a thorough grounding in the fundamentals of all phases of railroad maintenance and related requirements of operation. On entering the service apprentices are placed under a supervisor of track, and they are actively engaged in repairing and renewal work with the gangs for the purpose of learning the use of track tools, machines, etc. Apprentices then spend one month with the telephone and signal inspector, and another month is spent with bridge inspector. After this they spend from 4 to 8 months with different track supervisors at different locations over the system.

Examinations on specific subjects are conducted at the end of certain periods, by interested officers. Semi-annual reports on the apprentices throughout this course are furnished to the chief engineer. After the trainee completes his training course and when a vacancy occurs, he is appointed assistant supervisor. The length of time spent as an assistant supervisor of track, supervisor of track and in the higher ranks varies, depending upon demonstrated ability and available vacancies due to men leaving the service, retirements, etc. This railroad is convinced that the course of training fits the man for the next job ahead and gives him a broad view of railroad maintenance and operation.

The same railroad also promotes nontechnical men, such as outstanding track foremen and other foremen to assistant supervisors, thence to supervisors and to higher positions.

Another railroad uses practically the same general training course as outlined above, except that it does not require written examinations, but gives consideration to definite papers written by the trainee on assigned subjects, and requires him to make a monthly report covering details of his acquired knowledge. Opinions as to the qualifications of trainees for promotion are obtained from supervisors and division engineers. Oral examinations are given on operating rules and motor car rules.

This railroad also uses track laborers, generally with high school education and who study correspondence courses in "Roadmaster" or "Railroad Engineering," as trainees; especially when engineering graduates are not available to fill vacancies, and from then on they are treated the same as engineering graduates, provided they complete their correspondence courses.

Another method of advancement is by direct promotion from the position of foreman to assistant supervisor, thence to supervisor.

It also promotes men from the ranks of junior engineers and assistant engineers who appear to be qualified for supervisory positions, placing them first as assistant supervisors, sometimes as supervisors, from which they work upward, depending upon demonstrated ability.

Such a course of training has been in use on this railroad for about 36 years.

The other railroad training program course was started in 1940. Engineering graduates are started on the engineer corps, advancing to assistant supervisors; the course as planned is of a two-year period, with certain time spent in the track, bridge and building, communication, signal and water service departments. These men are required to make written reports monthly regarding their activities in the first year, and thereafter quarterly until they are advanced to supervisors, and to make comments on any of the various phases of railroad work in which they are engaged. These trainees are the men in line for promotion later on to division engineers, superintendents and higher positions. When consistent to do so, it is the practice to promote a practical man and a technical man alternately to the position of supervisor. This railroad also promotes promising young men in the engineering corps who have not had the advantage of any college education nor received a degree for completing one, to general foreman in charge of work and from thence on to supervisor.

The three railroads that have a partial training course for supervisory officers conduct them about as follows:

Several years ago one railroad began a program of foremanship training, consisting of 10 two-hour sessions, the purpose being to develop better supervisors and to impress upon them that they are "Public Relations" men in their organization.

Another railroad has promoted young men after they have been in the engineering corps two or three years to bridge inspectors, immediately under the bridge and building supervisor. Most of these men are generally promoted to bridge and building supervisors as vacancies occur.

Another railroad has made it a practice to promote young engineering graduates from positions in the chief engineer's office to higher rated positions in the engineering corps on the division, then back into the chief engineer's office again, from which position they are promoted to assistant supervisor bridge and buildings, thence to assistant division engineer, division engineer, etc., depending on demonstrated ability.

Outstanding track and other foremen are advanced to assistant supervisor; thence to supervisors.

Large industries other than railroads have been very active in securing engineering graduates and training them for future supervisory officers. Your committee is of the opinion that the railroads should give serious consideration to competing for these young graduates and inaugurate a training plan to qualify them for responsible positions in the maintenance of way and operating departments. Such training is feasible and produced results for those railroads using such a plan.

Report on Assignment 7

Track Maintenance in CTC Territory

A. G. Reese (chairman, subcommittee), Lem Adams, C. W. Baldridge, E. J. Bayer, W. H. Brameld, J. B. Clark, W. E. Cornell, R. J. Gammie, K. H. Hanger, N. D. Howard, W. M. Jaekle, Roy Lumpkin, E. H. McIlheran, W. C. Perkins, W. G. Powrie, G. M. Strachan, E. C. Vandenburgh, Edward Wise, Jr., C. R. Wright.

This is a final report submitted as information.

General Maintenance

Replies from some 16 railroads in answer to a questionnaire submitted to roads having a considerable mileage of CTC installations, indicate that while maintenance of main tracks is not affected to any great extent by such installations, the maintenance of switches and sidings is affected to a considerable degree.

Since switches in CTC territory are usually at a distance from section headquarters and their method of operation requires strict adherence to standards of construction and maintenance, it is essential that inspection be frequent and painstaking. Close cooperation between track forces and signal maintainers in all phases of switch maintenance in CTC territory is imperative. Permissive train speed through these switches and passing sidings is usually higher than the speed through switches and sidings outside CTC territory, and requires additional anchorage to limit the movement of rail to the minimum. The general practice is to restrict the movement of rail to a maximum of not more than ½ in., to insure uninterrupted service at all times. Grade, alinement and volume of traffic in either direction govern the number and method of application of the anchors at switches. The practice of boxing every other switch tie, excepting those under the movable points, and every other cross tie for a distance in each direction from the switch on the main track and for an equal distance on the siding, has proved effective. This practice necessitates the use of from 200 to 500 additional anchors for each turnout.

Uniform tamping of switch ties on an adequate cushion of ballast insures a satisfactory riding switch and reduces the hazard of failures in the switch machines.

The physical condition of sidings is maintained at a standard which will allow operation of trains at the highest speed permitted by the switches at either end. The rail, tie and ballast condition should be comparable with that of the parallel main track, making allowance for the reduced speed permitted through the siding.

Rail Relay

Relay of rail in CTC territory must be handled in such a way as to minimize interference with traffic and yet permit maximum progress of the work. Fully mechanized gangs of from 85 to 110 men are generally used but in many instances it is economical to use smaller gangs. Careful distribution of material in advance of the relay, paying particular attention to switch and signal material, is of the utmost importance.

Although unrestricted use of the track is generally prearranged, flagmen are also on duty, and in most instances these flagmen are equipped with portable telephones to facilitate communication. CTC installations in multiple track territory can effect a material savings in delays to trains and expedite the progress of the work by providing a flexible movement of trains around the work in progress without the installation of temporary crossovers and the use of operators. This savings is applicable to both rail relay and surfacing operations.

The assignment of a trainmaster to a large mechanized gang to assist in coordinating the movement of trains and programming the work of relay has proved to be very effective in reducing delays to trains and expediting the progress of the work. Cooperation between trainmaster with the dispatcher, roadmaster, track supervisor and signal supervisor, will permit detouring or grouping of extra trains and programming of the relay to insure minimum delays.

In emergency rail relays, the procedure is the same as in any bonded track section. Cooperation between the dispatcher, roadmaster, track supervisor and signal maintainer provides for the necessary replacement under proper flag protection. The dispatcher, through his control of signals and switches, can and does facilitate the movement of replacement rail to the site of the work and provide protection to the work.

Surfacing

No unusual conditions are involved in surfacing operations in CTC territory as compared with the same work outside the limits of such installations. Mechanical equipment is generally used, the extent of such use depending upon the type of ballast, amount of the raise and the length of the surfacing item. Some railroads use large gangs, but the general practice is to use smaller gangs in order to limit the amount of track affected by the slow order. Work is handled under the protection of slow orders, slow flags and flagmen. As in any other location, the necessity for renewal of ties and ballast governs the time and site of surfacing, and correction of the condition of both is made in the same operation. However, on some railroads the renewal of ties is handled prior to the final surfacing by making a light raise on the old ballast, at which time the necessary renewals are made. Where clearances will permit, this method is efficient and also eliminates considerable expense incident to skeletonizing the track and disposing of the old material.

Winter Maintenance

Maintenance of track in CTC territory during the winter months is complicated by the necessity of providing protection during storms to insure uninterrupted operation of switches. Careful planning and allotment of forces is essential in order that equipment will be available and the personnel will know the assignment and duty of each individual. Since switches are usually at remote locations it is necessary to anticipate the possibility of a relief force in case of protracted storms, as well as to provide an adequate supply of fuel for switch heaters, if this equipment is used. Geographic and climatic conditions govern the use of switch heaters; their use is general throughout the northern part of the United States. Generally, one man is assigned to each controlled switch, but local conditions may dictate the assignment of additional men. Transportation of relief forces and supplies is by truck where possible; otherwise, by train or motor car.

Because power interruptions during storms are not unusual, it has been found practicable to charge storage batteries for the operation of CTC systems from generators of electric tie tampers, or other portable generators, and thereby keep the system from failing as a result of temporary discontinuance of commercial power. It is suggested that on lines where commercial power is subject to interruptions from electrical, sleet and wind storms, it may be of definite advantage in such emergencies to arrange for the temporary transfer of a number of these generators from their normal assignment to emergency use as battery chargers.

Maintenance Organization

Experience on several railroads has demonstrated that no material change in the track organization is necessary as the result of CTC installation. However, local conditions may require the employment of additional labor at times to insure adequate maintenance of switches, etc.

Operation of Motor Cars

Operation of motor cars in CTC territory must, of necessity, be in accordance with established rules.

Conclusions

Your committee is of the opinion that general maintenance of track in CTC territory offers no more difficulty than the same work in automatic block territory where traffic and speed are comparable.

The installation of additional anchors at switch locations will reduce track maintenance.

Since sidings in CTC territory are in reality second main tracks, it is imperative that their physical condition be maintained at a standard to allow the highest speed permitted by the switches at either end.

Winter maintenance does offer a challenge in CTC territory to meet which the individual railroad must carefully plan for the adequate forces and supplies necessary to afford uninterrupted service during storms.

The use of portable telephone by track forces facilitates track maintenance in CTC territory.

Report of Committee 9—Highways

W. J. Hedley, *Chairman,*	G. A. Heft	Bernard Blum, *Vice-Chairman,*
C. J. Astrue	Warren Henry	W. C. Pinschmidt
O. C. Benson	J. T. Hoelzer	T. M. Pittman
H. D. Blake	C. D. Horton	C. H. Reisinger
D. A. Bryan	W. H. Huffman	P. T. Simons
H. B. Christianson	T. J. Jaynes	F. A. Stone
J. A. Droege, Jr.	R. B. Kittredge	W. C. Swartout
W. R. Dunn	A. E. Korsell	C. V. Talley
P. W. Elmore	H. S. Loeffler	R. R. Thurston
E. D. Flad	F. T. Miller	V. R. Walling
L. W. Green	H. G. Morgan	R. E. Warden
A. S. Haigh	A. C. Palmer	Charles Weiss
C. I. Hartsell	G. P. Palmer	

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions .... page 234

2. Design and specifications for highway-railway grade crossings, collaborating with Committee 1, and American Transit Association.

   Revised specifications for Prefabricated treated timber crossings; Precast concrete slab crossings; Monolithic concrete crossings; are submitted for inclusion in the Manual .... page 237

3. Merits of various types of highway-railway grade crossing protection, collaborating with Signal Section, AAR, and Highway Research Board.

   No report.

4. Number and location of automatic signals, automatic gates and auxiliary signs for highway-railway grade crossing protection, collaborating with Signal Section, AAR, and AAR Joint Committee on Grade Crossing Protection.

   Two drawings of typical location plans for automatic highway crossing signals are presented for adoption and published in the Manual .... page 244

5. Method of classifying highway-railway crossings with respect to public safety.

   Progress report, submitted as information .... page 244

6. Principles for determining allocation of cost of public improvement projects affecting highway-railway crossings.

   No report.

The Committee on Highways,
W. J. Hedley, *Chairman.*

Bulletin 476, November 1948.

Report on Assignment 1

Revision of Manual

H. G. Morgan (chairman, subcommittee), H. D. Blake, Bernard Blum, H. B. Christianson, J. A. Droege, Jr., A. S. Haigh, W. J. Hedley, G. P. Palmer, W. C. Pinschmidt, R. E. Warden.

Your committee recommends the following revisions of the Manual:

Item 1

Substitute Requisites for Highway Grade Crossing Signals—1949 for the material on former pages 9–17, 9–18 and 9–18.1, which were deleted last year.

Item 2

Delete page 9–111 and substitute Requisites for Automatic Crossing Gates—1949.

The new requisites are identical with those recently approved by the Signal Section. AAR, except for figure and page references.

Other manual revisions are recommended in the reports on other assignments.

REQUISITES FOR HIGHWAY GRADE CROSSING SIGNALS

1949

1. Purpose

(a) The purpose of these requisites for highway grade crossing signals is to set forth the general requirements representing modern practices recommended for new installations and the replacement of existing installations when general renewal or replacement becomes desirable.

2. Aspect

(a) A signal used for the protection of traffic at a railroad highway grade crossing shall present an aspect toward approaching highway traffic conforming to Fig. 2, page 9–97; Fig. 3, page 9–98; Fig. 4, page 9–99; Fig. 5, page 9–100; Fig. 8, page 9–103 or Fig. 9, page 9–104. The operative part of the signal, when indicating the approach of a train, shall present the appearance of a horizontally swinging red light or swinging disc.

3. Mounting

(a) Either flashing light type or wig-wag type signals may be used, but both should not be used at the same crossing.

(b) One signal shall be placed on each side of the track, preferably to the right of approaching highway traffic.

4. Painting

(a) Discs and signs shall be painted as necessary to conform to Fig. 5, page 9–57; Fig. 6, page 9–58; Fig. 8, page 9–60; Fig. 9, page 9–61; Fig. 10, page 9–62; Fig. 6, page 9–101; Fig. 7, page 9–102; and Signal Section Drawing 1553.

(b) Parts which function as background for light signal indications shall be painted with non-reflecting black in accordance with Specification 214. Signal Section Manual Part 221.

(c) All other parts shall be painted white or aluminum.

5. Operating Time

(a) Signals indicating the approach of a train shall operate for such period of time before the arrival of any train operated over the crossing as is reasonably required to protect highway traffic.

(b) Where the distance from the most remote signal to the clearance of the farthest track on which trains operate at medium or higher speed as measured parallel to the center line of the highway, is 35 ft. or less, the signals shall operate for not less than 20 sec. before the arrival of any train on such track. Where this distance is more than 35 ft., the minimum time should be increased by 1 sec. for each additional 5 ft.

(c) For trains in either direction on main tracks over which trains normally operate in either direction, and for trains moving with the current of traffic on main tracks over which trains normally operate in one direction only, signals shall operate until the rear of the train clears the crossing.

(d) Where reverse running is frequent on main tracks, consideration shall be given to meeting the same requirement as specified where trains normally operate in either direction on main track.

6. Bell

(a) Bell, where required by public authority or special conditions, shall be in accordance with Specification 44, Signal Section Manual, Part 21.

1. Bell, when used, should be mounted preferably on the top of the mast supporting the crossing signal, with the face of the gong parallel to the highway.
2. Design of the bell mechanism shall, as far as practicable, be such as to insure proper operation during unfavorable weather conditions.
3. Size and range of bell shall be determined by local conditions.

Flashing Light Type

7. Electric Light Units

(a) Electric light units shall be in accordance with Specification 190, Signal Section Manual, Part 166 or Specification 232, Signal Section Manual, Part ...., and shall be arranged to shine in both directions along the highway. They shall be mounted horizontally 2 ft. 6 in. centers and preferably not less than 7 ft. nor more than 9 ft. above the surface of the highway.

8. Range and Spread

(a) Range shall be the distance at which the indications will be clear and distinct to a person with normal vision.

(b) Each electric light unit, when equipped with a roundel designed for 30 deg. horizontal spread, shall provide an indication having a beam candlepower of uniform intensity at any angle up to 10 deg. on either side of the axis and the range at any point within the 20-deg. angle under bright sunlight conditions, with the sun at or near the zenith, shall be not less than 1500 ft.

(c) Electric light units shall display a satisfactory close indication.

9. Flashes

(a) Electric lamps shall flash alternately. The number of flashes of each electric lamp per minute shall be 30 min., 45 max. Electric lamps shall each burn approximately the same length of time. Total burning time of both electric lamps shall be practically the entire operating time.

Wig-Wag Type

10. Electric Light Units

(a) Electric light units shall shine in both directions along the highway.

11. Lenses or Roundels

(a) Lenses or roundels shall be Highway Crossing Red 5-in. dia. min. and in accordance with Specification 69, Signal Section Manual, Part 136.

12. Range and Spread

(a) The electric light unit, when the disc is suspended vertically, shall have a range, at night, of 1500 ft. through a total angle of not less than 20 deg. when a 10-watt lamp rated at 1000 hours is burned at rated voltage.

13. Cycles

(a) Movement from one extreme to the other and back constitutes a cycle. The number of cycles per minute shall be 30 min., 45 max.

REQUISITES FOR AUTOMATIC CROSSING GATES

1949

1. Aspect

(a) An automatic gate used for the protection of highway traffic at a railway–highway grade crossing, when indicating the approach of a train, shall present toward approaching highway traffic the aspect of an arm equipped with red lights being lowered across the lane or lanes used by traffic approaching the crossing or at rest in the horizontal position across the lane or lanes.

2. Mounting

(a) An automatic gate, when installed, shall be mounted as shown in Fig. 4, page 9–116, as an adjunct to highway crossing signal as shown in Fig. 2, page 9–97.

(b) Automatic gate installation shall be in accordance with Specification 209, Signal Section Manual, Part 179.

(c) One gate shall be placed on each side of the track preferably to the right of approaching highway traffic.

3. Arm

(a) Gate arm shall conform to Fig. 5, page 9–117.

(b) Each gate arm shall be equipped with not less than three red lamps arranged to shine in both directions along the highway.

(c) The gate arm, when in the raised position, shall not obstruct or interfere with highway traffic.

4. Mechanism

(a) Mechanism shall be in accordance with Specification 199, Signal Section Manual. Part 194.

5. Operation

(a) The gate arm lights shall operate in conjunction with the highway grade crossing signal, as follows:

1. Lights shall operate at all times when the gate is in position to obstruct highway traffic.
2. Light nearest the tip of arm shall burn steadily.
3. The other two lights shall flash alternately and in unison with the lights on the signal.

(b) Gate arm shall start its downward motion not less than 3 sec. nor more than 5 sec. after the signal lights start to operate.

(c) Gate arm shall reach full horizontal position before the arrival of any train on a main track and shall remain in that position until the rear of the train has cleared the crossing.

6. Circuits

(a) Circuits shall be so arranged that a failure of the gate mechanism to operate as intended will not prevent the lights on gate arm and signal from operating on the approach of a train.

7. Bell

(a) Bell, where required by public authority or special conditions, shall be in accordance with Specification 44, Signal Section Manual, Part 21.

1. Bell, when used, should be mounted preferably on the top of the mast supporting the crossing signal. with the face of the gong parallel to the highway.
2. Design of the bell mechanism shall, as far as practicable, be such as to insure proper operation during unfavorable weather conditions.
3. Size and range of bell shall be determined by local conditions.

(b) Bell, if used, shall sound a warning from the time the signal lights start to operate at least until the gate arm has descended to within 10 deg. of the horizontal position.

8. Highway Marking

(a) The highway traffic lanes in the vicinity of the crossing should be distinctly marked.

Report on Assignment 2

Design and Specifications for Highway–Railway Grade Crossings

Collaborating with Committee 1, and American Transit Association

R. E. Warden (chairman, subcommittee), O. C. Benson, H. D. Blake, D. A. Bryan. H. B. Christianson, W. R. Dunn, L. W. Green, W. J. Hedley, J. T. Hoelzer, C. D. Horton, T. J. Jaynes, A. E. Korsell, H. S. Loeffler, T. M. Pittman, F. A. Stone, W. C. Swartout, R. R. Thurston, V. R. Walling, Charles Weiss.

Your committee submits the following revised specifications and recommends substitution of them for the similar specifications now on pages 9–12.01 to 9–12.7, incl., of the Manual:

Item 1

SPECIFICATIONS FOR THE CONSTRUCTION OF PREFABRICATED TREATED TIMBER CROSSINGS

1949

1. Scope

These specifications cover the fabrication and installation of sectional treated timber crossing for highway with railroad track. The completed crossing shall consist of prefabricated sections, which may be removed and reinstalled individually.

See the General Specifications for Highway Grade Crossings over Railroad Tracks to determine the size of crossing, the construction of crossing approaches and the preparation of track structure.

2. Ties

New treated sawed ties shall be used throughout the crossing area.

3. Materials

Crossing sections shall be made of a fine-grained hardwood timber, preferably of one of the following, stated in order of preference: (1) Black gum; (2) tupelo gum; (3) sweet gum. If shims are used they shall be of the same material.

4. Size of Sections

(a) *Length.*—The sections shall be made in lengths which are multiples of the tie spacing used in the track. An 8-ft. length is recommended.

(b) *Width.*—The center sections of the crossing shall be of such width that two of them will make up that portion between the running rails, allowing sufficient flangeway opening. A width of 25¼ in. is recommended for each center section. Outside of the rail, one section shall fit against the head of the rail and shall be of such width as to extend to the end of the ties, but shall not overhang the end of a tie of nominal length used by more than 3 in. Sections for use in the intertrack space shall have a minimum width of 20 in. In determining the width of intertrack sections, allowance should be made for a ½-in. space between sections.

(c) *Depth.*—Crossings may be of either of two types.

Type A crossings shall be full depth. The depth of the sections shall be such that the top surface of the crossing will lie in the plane of the tops of the rails with the bottom of the section resting directly on the cross ties. In determining this depth, allowance should be made for the depth of the tie plate and for the nominal depth of adzing of the ties.

Type B crossings are made with shims or furring strips between the bottom of the sections and the top of the ties. The combined depth of the sections and shims shall be such that the top surface of the crossing will lie in the plane of the tops of the rails. Proper allowance should be made for the depth of tie plate and for the nominal depth of adzing of the ties. Sections shall have a minimum depth of 5⅛ in., shims shall have a minimum thickness of 1⅝ in. and shall be made of material having a nominal width of 8 in.

5. Fabrication

The sections shall be made true to plan measurements in all three dimensions. The underside of one edge of the sections of Type A crossings and the ends of the shims of Type B crossings shall be shaped to allow for necessary clearance over tie plates and spike heads. The upper corner of the timber adjacent to the flangeway opening shall be given a ⅝-in. chamfer. The top surface of the timber which fits against the rail head on the outside shall be planed down a depth of ¼ in. below the top surface of the crossing for a distance of 3 in. from the edge of the timber. The ends of all sections shall be squared up. The outside ends of the end sections shall be beveled, the bevel having dimensions of 8 in. horizontally and 4 in. vertically. Each section shall have at least 4 holes for use in anchoring the section to the ties with lag screws. These holes shall be 13/16 in. in diameter and shall have a 2⅝-in. counter bore 1¼ in. deep in the top side. Each shim shall have two ¼-in. diameter holes for use in fastening it to the tie.

All timbers shall be so placed that when the section is in its normal position in the track, the heartwood of the timber will be on the bottom side. Timbers which are relatively thin shall be placed on the inside of the section. No timber having a dimension of less than 2 in. shall be used. The individual timbers of each section shall be permanently held together with a minimum of three steel bolts or twisted dowels, not less than ¾ in. in diameter, placed horizontally through the timbers, either at the center of their vertical dimension or staggered not more than 1 in. off center in either direction. When bolts are used a 1½-in. flat washer shall be placed under the head and a 1½-in. flat washer and a lock washer shall be placed under the nut. Toothed-ring timber connectors may be used between the individual timbers of the section. All fabrication of the individual timbers and shims shall be completed prior to treatment.

6. Fillers

Filler blocks of treated timber shall be placed below the head of the rail on the gage side between the web of the rail and the edge of the crossing section. The filler block shall be of such size and shape as to provide a snug fit and to provide flangeway width in accordance with the General Specifications.

7. Treatment

All timber shall be treated with preservative in accordance with the AREA specifications for the preservative treatment of wood with creosote.

8. Installation

Before the crossing sections are put in place, ties shall be accurately spaced so that when in place the ends of each section will be at the center of a tie. The shims of a Type B crossing shall be secured in place with 60-d spikes. After the sections have been properly located, holes shall be bored in the ties, and through the shims in Type B crossings, to receive the lag screws. In ties of oak or similar hardwoods these holes shall be 9/16-in. diameter; in ties of pine, fir or similar woods, they shall be 17/32-in. diameter. Holes shall be filled with creosote oil before the lag screws are placed. Each section shall be anchored in place with four ¾-in. diameter lag screws. In track where the rail is of 110-lb. section or lighter, the lag screws shall be 10 in. long. In track of heavier rail, lag screws shall be 12 in. long. Lag screws shall be screwed in place. After the lag screw is in place, the space in the counter bore shall be filled with a mastic material.

Item 2

SPECIFICATIONS FOR THE CONSTRUCTION OF PRECAST CONCRETE SLAB CROSSINGS

1949

1. Scope

These specifications cover design, manufacture and installation of precast concrete slabs for highway crossings with railroad tracks.

See General Specifications for Highway Grade Crossings over Railroad Tracks to determine the size of crossing, the construction of crossing approaches and the preparation of track structure.

2. Loading

Slabs shall be rated on the following loading basis:

(a) American Association of State Highway Officials H–15 loading for truck train with maximum axle load of 24,000 lb., or

(b) American Association of State Highway Officials H–20 loading for truck train with maximum axle load of 32,000 lb.

3. Depth—Crossings May be of Either of Two Types

Type A crossings shall be full depth. The depth of the sections shall be such that the top surface of the crossing will lie in the plane of the tops of the rails with the bottom of the section resting directly on the cross ties. In determining this depth, allowance should be made for the depth of the tie plate and for the nominal depth of adzing of the ties.

Type B crossings are made with shims or furring strips between the bottom of the sections and the top of the ties. The combined depth of the sections and shims shall be such that the top surface of the crossing will lie in the plane of the tops of the rails. Proper allowance should be made for the depth of tie plate and for the nominal depth of adzing of the ties. Shims shall have a minimum thickness of 1⅝ in. and shall be made of material having a nominal width of 8 in.

4. Design

The units shall be designed to sustain a concentrated wheel load of one-half of the above axle loading, placed so as to produce maximum stresses, with distribution in the direction of traffic equal to width of slab, but not in excess of 17 in., and no distribution at right angles to traffic; with 50 percent impact in both moment and shear at stresses not greater than 2/3 of the elastic limit of the reinforcement, and 2/3 of the ultimate strength of the concrete at 28 days. Slabs intended for support on more than two ties shall be designed to meet the above requirements with one of the intermediate ties not in bearing. Covering of reinforcement shall be not less than ¾ in. Clearance shall be provided for tie plates and spike heads.

5. Armor

When specified, all exposed edges of slabs shall be armored. Where armored slabs are used in track circuit territory they shall be insulated from the rail and rail fastenings.

6. Flangeways

Proper flangeways shall be provided by shaping the edge of the slab or by the use of filler blocks. Filler blocks shall be shaped to the contour of the rail section and of proper depth to fit securely under the rail head.

7. Outside of Rail Head

On the outside of the head of the running rail the top of the slab shall be not less than ¼ in. below the top of rail for a distance of 3 in.

Filler blocks may be used on the outside of the running rail. Filler blocks shall be 3 in. in width from the side of the rail head to the face of the slab, shaped to the contour of the rail section and the depth required, so that the top of filler will be not less than ¼ in. below the top of rail.

8. Anchorage

Each slab shall be fastened to the ties by two ⅝-in. countersunk lag screws, one in each end of the slab, and wood block spiked to the tie at the end of each end slab.

All slabs adjacent to the running rails shall bear against the rail or filler blocks shall be provided between the slab and the web of the rail.

9. Beveled end Slabs

Outer end of all end slabs shall be beveled not more than 45 deg. with the horizontal with an end thickness of 3 in., or, in lieu thereof, a beveled end timber shall be fastened to the ties.

10. Concrete

Concrete shall conform to AREA specifications for concrete, with a minimum compressive strength of 4250 psi. in 28 days. It shall be thoroughly compacted in the molds and around the reinforcement.

11. Steel

Steel for reinforcement shall conform to the AREA specifications for billet steel concrete reinforcement bars.

Bars shall be thoroughly cleaned and free from rust and shall be carefully placed and effectively secured so that specified covering will be provided.

12. Ties

New treated sawed ties shall be used throughout the crossing area, and shall be properly spaced to provide bearing of half the width of the tie for the adjacent ends of slabs.

13. Filler Blocks and Shims

Where wood filler blocks and shims are used, they shall be of treated hardwood suitable for the purpose, with treatment to conform to AREA specifications for the preservative treatment of wood with creosote.

Item 3

SPECIFICATIONS FOR THE CONSTRUCTION OF MONOLITHIC CONCRETE CROSSINGS

1949

1. Scope

These specifications cover the furnishing and placing of materials necessary to the installation of a monolithic concrete crossing for highway with railroad track.

See General Specifications for Highway Grade Crossings over Railroad Tracks to determine the size of crossing, the construction of crossing approaches and the preparation of track structure.

2. Use

Monolithic crossings are not recommended for main line crossings or for crossings at locations where frequent track surfacing is required.

3. Special Track Construction

Track structure shall be constructed in accordance with AREA recommended practice, except that ballast shall be placed only to an elevation 6 in. or more below the bottom of the tie. The track shall be supported by means of brick, stone or metal blocking placed underneath the ties and the track brought to proper grade and alinement prior to pouring concrete.

4. Design

The concrete shall completely encase the ties and shall extend 6 in. beyond the ends of the ties on each side. The concrete shall be brought to a surface in the plane of the tops of the rails for the full width of the crossing, except that concrete shall be poured against premoulded, bituminous rail fillers or against removable wood or metal forms placed on both sides of the rail.

Reinforcement of the crossing below the bottom of the tie shall consist of eight ¾-in. round bars, or equal, running longitudinally the full length of the crossing; and ¾-in. round bars transverse with the track, spaced at 6-in. intervals through its length. These bars shall be supported to provide a minimum distance of 2½ in. between bars and the top of the ballast.

Reinforcement of the concrete above the tie shall consist of eight ¾-in. round bars, running longitudinally for the full length of the crossing, these bars to be placed in pairs 3 in. apart, the center of each pair located one foot from the center of the rail. Bars shall be supported in a position half way between the top of the tie and the top surface of the finished crossing.

5. Rail Fillers

(a) *Premoulded Bituminous Fillers.*—If premoulded bituminous fillers are used, they shall be placed on each side of the rail. These fillers shall be moulded to conform to the contour of the rail, and the one located on the gage side shall provide a flangeway 2½ in. wide and 2 in. deep on tangent track and on curves of 8 deg. and under, and 2¾ in. wide on curves in excess of 8 deg. The filler shall be 4 in. wide at its maximum dimension. The material of the filler shall conform to the following requirements:

(a) Asphalt ....45 to 50 percent
(b) Mineral ....35 to 45 percent
(c) Fiber ....10 to 15 percent

The mineral shall consist of finely crushed slate, limestone, silica, or sand, or other similar mineral matter complying with the following gradation:

Passing No. 4 sieve ....100 percent
Passing No. 10 sieve—not less than .... 90 percent

(b) *Poured Bituminous Filler.*—If concrete is poured against removable wood or metal forms on each side of the rail, such forms shall be removed as soon as the concrete has set, and the space between the concrete and the rail filled with poured bituminous filler. On the outside of the rail, the filler shall be poured flush with the top of the concrete. On the gage side, the filler shall be poured to within 2 in. of the top of rail. The flangeway on the gage side shall conform to the requirements of the preceding paragraph.

Material used for poured bituminous filler shall be petroleum asphalt, free from water, and shall not foam when heated to a temperature of 392 deg. F. It shall conform to the following requirements:

	Min.	*Max.*
Softening point (ring and ball method) ..	167 deg. F. (75 deg. C.)	185 deg. F. (85 deg. C.)
Flash point (Cleveland open cup)	469 deg. F. (243 deg. C.)	......
Penetration:		
0 deg. C. (32 deg. F.) 200 g., 1 min. ..	15	......
25 deg. C. (77 deg. F.) 100 g., 5 sec. ..	30	40
46 deg. C. (115 deg. F.) 50 g., 5 sec. ..	......	80
Ductility at 25 deg. C. (77 deg. F.) (5 cm. per min.) cm.	3	......
Loss on heating at 163 deg. C. (325 deg. F.) 50 g., 5 hours percent	......	1.0
Total bitumen soluble in carbon disulfide, percent	99.0	......
Proportion of bitumen soluble in carbon tetrachloride, percent	99.0	......

The material shall be heated to a temperature between 300 deg. and 400 deg. F. with constant stirring to avoid local overheating, and at the time of pouring shall have a temperature of not less than 300 deg. F. Prior to pouring the filler, a layer of dry sand approximately ½ in. thick shall be placed and leveled over the bottom of the area to be filled. Care shall be taken to prevent foreign material from becoming mixed with the freshly poured filler.

6. End of Crossing

The end of the crossing shall be squared up with the track and shall be at the near face of a tie. It shall be beveled from the top surface of the concrete to the top of tie on a plane making an angle of 30 deg. with the horizontal.

7. Concrete

Concrete shall conform to AREA specifications for concrete, with a minimum compressive strength of 3300 psi. in 28 days. High-early-strength cement is recommended. All concrete materials shall conform to requirements of AREA specifications. The concrete shall be carefully placed under the ties and around the reinforcing so as to leave no voids in the finished slab. The top of the concrete shall be brought to a true surface and finished.

8. Steel

Steel for reinforcement shall conform to AREA specifications for billet steel concrete reinforcement bars. Bars shall be thoroughly cleaned and free from rust, and shall be carefully placed and effectively secured so that the specified covering shall be provided.

Report on Assignment 4

Number and Location of Automatic Signals, Automatic Gates and Auxiliary Signs for Highway–Railway Grade Crossing Protection

Collaborating with Signal Section, AAR, and AAR Joint Committee on Grade Crossing Protection

C. I. Hartsell (chairman, subcommittee), C. J. Astrue, H. D. Blake, A. S. Haigh, W. J. Hedley, H. S. Loeffler, A. C. Palmer, T. M. Pittman, C. V. Talley.

Your committee submits the following two drawings of typical location plans for automatic highway crossing signals, with the recommendation that they be approved for publication in the Manual.

Report on Assignment 5

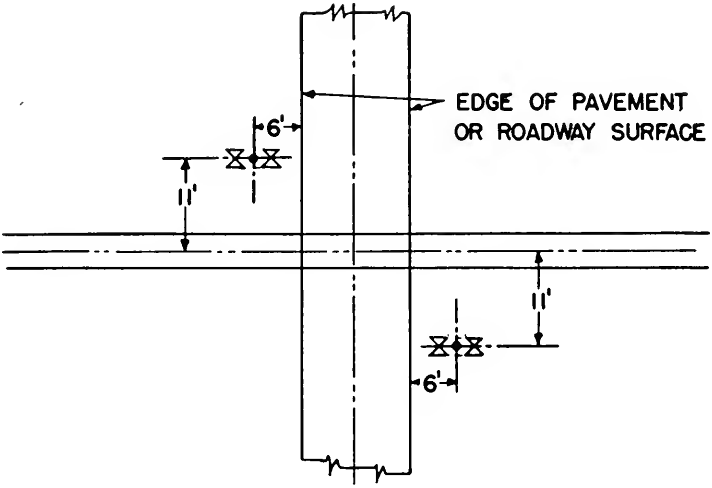
Method of Classifying Highway–Railway Crossings With Respect to Public Safety

H. B. Christianson (chairman, subcommittee), W. J. Hedley, C. J. Astrue, H. D. Blake, J. A. Droege, E. D. Flad, Warren Henry, W. H. Huffman, A. E. Korsell, W. C. Pinschmidt, C. H. Reisinger, P. T. Simons.

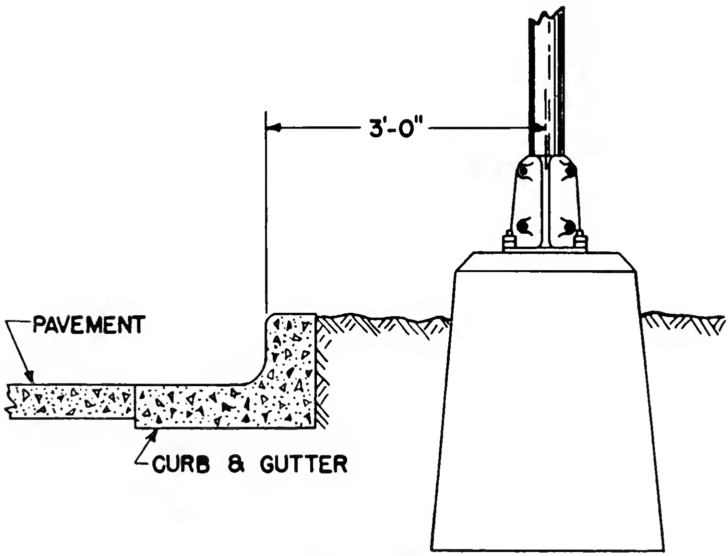
This is a progress report presented as information.

In the fall of 1946 your committee obtained information from the state highway departments concerning methods they used in determining priorities for grade crossing protection programs. It was learned that 18 states used formulas for this purpose, of which 4 had adopted the Bureau of Public Roads formula developed by L. E. Peabody and T. B. Dimmick and published in Public Roads, Vol. 22, No. 6, dated August 1, 1941. One state used that formula in conjunction with its own, and 13 used other formulas, all different except one which 2 states used in common. The remaining 29 states reporting did not use formulas, but 14 depended upon independent engineering judgment in each case.

All of the formulas made provision for the daily volumes of both vehicular and train traffic. Following is a list of other factors to which values were assigned in the various formulas. The figure opposite each item represents the number of formulas in which the factor appeared:

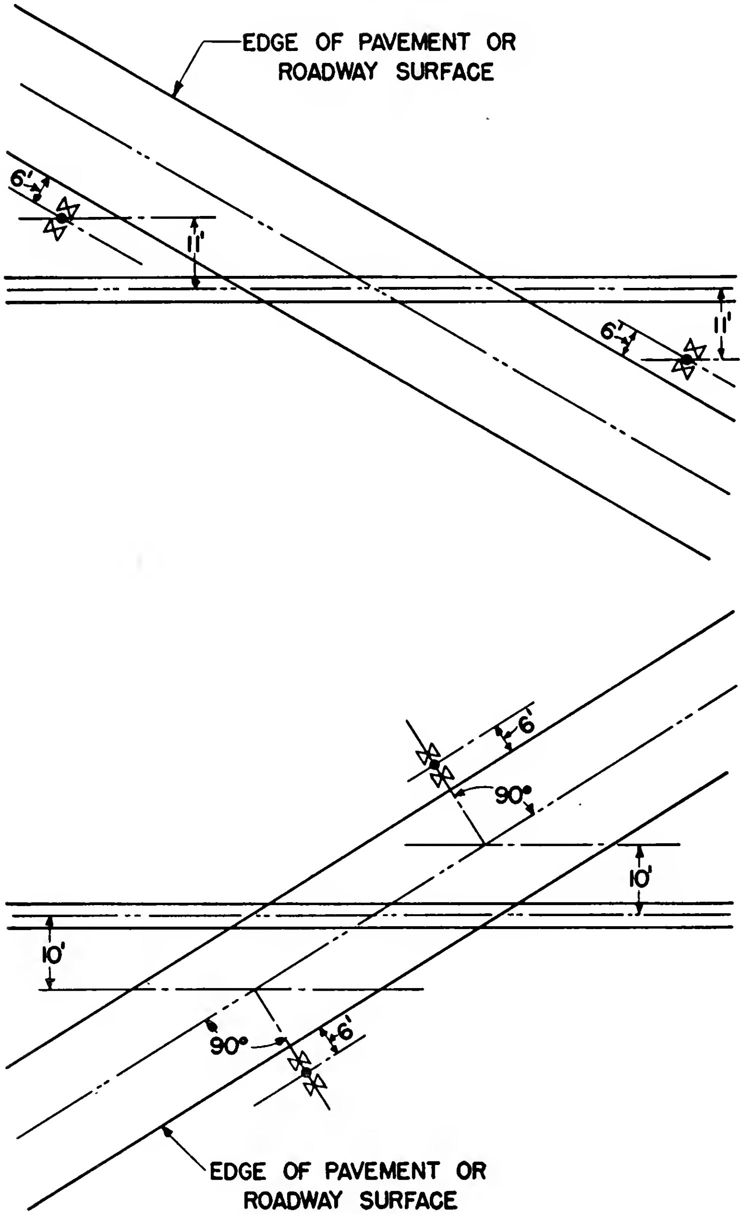


LOCATION PLAN



SPECIAL DETAIL FOR CURB AND GUTTER LOCATIONS

Typical Location Plans for Highway Crossing Signals.



Typical Location Plans for Highway Crossing Signals.

Vehicular speed	7
Approach grades and conditions	7
Angle of vision	5
Angle of crossing	2
Pedestrian hazard	3
Train speed	9
Number of tracks	8
Sight distances	10
Existing protection	8
Time crossing is blocked	1
Type of train	3
Night trains	2
Switching	1
Glare or fog	5
Number of delays	2
Accident record	3
Inherent hazard	4
Accident severity	2
Probability of train and vehicle meeting	1
Crossing of highways within 50 ft. of railroad crossings	2
Crossing of highways within 100 ft. of railroad crossing	1
Restrictive sight distances to railroad crossing	1
Average length of vehicles	1
Coincidence of vehicles and trains	1

Values assigned to the factors are based on the judgment of the various highway departments, and therefore the weights for similar factors in the formulas differ.

Several of the formulas follow the same general form as the one used by the state of Illinois which was developed by Warren Henry, chief engineer for the Illinois Commerce Commission, and a member of this subcommittee. The Henry formula is based on the principle that the hazards to the public arise from the physical conditions at the crossings, volume of traffic on the highway and on the railroad, and that for a given set of physical conditions the hazards to the public vary substantially in proportion to the number of train and highway movements per day over the crossing. The formula is

$$IH = V \times T \times (l + F_1 + F_2 + F_3) \quad \text{(A)}$$

IH = Index of hazard

V = Number varying from a minimum of 1 to a maximum of 10, depending on the volume of highway traffic in 24 hours.

T = Number varying from a minimum of 1 to a maximum of 10, depending on the volume of train traffic in 24 hours. Both V and T are obtained from tables which give relatively more weight to the lighter traffic. The values of l are given to vehicle traffic up to 250 per day and train traffic of 2 or less, and the number 10 to over 10,000 vehicles and 50 or more trains per day.

l = Represents value of inherent hazard.

F_1 = The view factor, varying in value from 0 to 1 in each quadrant depending on the distance that the fastest trains cover in 10 sec. (called railroad sight distance), the distance from crossing along the highway that the traveler will have view of the track throughout the railroad sight distance, and speed of highway traffic.

F_2 = The condition factor, which has values varying from 0 to 1 for each of the following four conditions:

(1) gradient, curvature and riding conditions of highway approaches and restrictions in width at the crossing;

(2) railroad layout, including multiple tracks, parallel or adjacent railroad, switching operations, etc.;
(3) angles of vision in each of the four quadrants corresponding to the sight distances established for F_1;
(4) Special conditions such as other intersecting highways, sun glare, and pedestrians using highway.

F_3 = The user factor, varying in value from 0 to 1, influenced by simultaneous or separated unusual peaks of traffic on highways and tracks and proportion of users unfamiliar with conditions at the crossing.

The index hazard theoretically can have a minimum value of 1 and a maximum of 1000, but as a practical thing the maximum value will seldom be over 400.

Two formulas resembling the Henry formula are shown below as (B), used by Idaho and Wyoming, and (C), by Montana:

$$IH = V \times T \times (F + \ldots\ldots + F_6) \quad \ldots\ldots (B)$$
$$IH = V \times T \times (F_1 + \ldots\ldots + F_{11}) \quad \ldots\ldots (C)$$

Tables giving values for V and T are identical for (B) and (C) and have the same limits from 1 to 10 as the Henry formula, (A), but the values applying to given traffic counts are not the same for (B) and (C) as for (A). One to 50 vehicles and 1 or 2 trains have values of 1, and over 5000 vehicles and over 80 trains per day have the maximum values of 10 in formulas (B) and (C). Following is an explanation of the F factors in (B) and (C):

F_1 = Represents inherent hazard which can vary from 1 to 5 in (B) and 0.5 to 4.0 in (C) depending on types and speeds of trains.

F_2 = The view factor which varies from 0 to 2 in each formula and is obtained from tables after sight distances are determined in same manner as described for F_1, formula (A).

F_3 = Angle of vision factor which varies from 0 to 0.5 in each.

F_4 = Track layout factor which varies from 0 to 0.7 in (B) and from 0.1 to 0.8 in (C).

F_5 = Highway alinement factor which varies from 0 to 0.5 in (B) and from 0 to 0.6 in (C).

F_6 = Special conditions factor in formula (B) which varies from 0 to 0.8 and can include sun glare, other highway intersections within 50 ft. of the crossing, and other conditions that might distract the driver's attention.

F_6 = In formula (C), varies from 0 to 0.5 for intersecting streets or highways within 50 ft.

F_7 = Sun glare factor which varies from 0 to 0.2.

F_8 = Approach gradients factor which varies from 0 to 0.2.

F_9 = Restricted sight distance to the crossing itself, which varies from 0 to 0.2.

F_{10} = Narrow crossings factor which varies from 0 to 0.2.

F_{11} = Special conditions that might distract motorist's attention, varies from 0 to 0.3.

An additional factor has been applied by Idaho, Wyoming and Montana called the accident severity factor, *FA*, and the product of it and the *IH* factor is considered to be a reasonable indication of the probable loss to society incident to the existence and use of an unprotected grade crossing. The value of *FA* is in proportion to the maximum train speed plus ½ the maximum normal vehicular speed until the total reaches 50, (corresponding to an *FA* value of 10) the maximum value being 10.

The formula used by Arkansas is the product of highway traffic points by rail traffic points and by local conditions ratings in points, with each having a minimum value of 1 and a maximum value of 5. Curves have been prepared from which the values are taken off. The highway traffic factor has a minimum value of 1 for 0 to 50 vehicles and maximum of 5 for 2600 and over per 24 hours. The railway traffic factor has four divisions, *A, B, C* and *D*. Division *A* represents the total number of trains. The value is in proportion to the number of trains per day up to 15 where the value is 2½. For the heavier traffic the increase in value of *A* grows less in proportion to the increase in trains and the maximum is 3.75 for 70 or more trains. Factor *B* is for average train speeds and has a maximum value of 0.25 for 70 mph., while *C* is for total time per day the crossing is blocked and has maximum value of 0.5 for 60 min. and longer. Factor *D* is for number of tracks, with 0.1 value for 1 main track only and a maximum value of 0.5. Local conditions are also separated into four divisions for rating. The ratings are good, fair, medium, bad and hazardous, and the values are in straight line progression in that order. *A* is for visibility with minimum value of 0.5 and maximum of 2.5; *B* is for grades of approaches with values from 0.05 to 0.25; *C* is for glare or fog, 0.05 to 0.25; and *D* is for accident history, 0.40 to 2.00. A hazard rating of 9 to 25 is considered to call for flashing signals, and 25 to 125 for grade separations.

The Vermont formula is

$$DI = \left(\frac{Tr \times T \times S}{3200} (SD + APG + N + TL) \right) P$$

$DI =$ Deficiency index
$Tr =$ Average daily highway traffic.
$T =$ Number trains per day.
$S =$ Train speed factor with minimum value of 0.1 and maximum of 0.9 for maximum train speed of 60 mph.
$SD =$ Sight distance factor, 0.2 to 3.0, the values taken from tables based on view from point 300 ft. from crossing.
$APG =$ Approach grade factor, 0 to 1.80 for grades totaling 8 percent and over for the two approaches.
$N =$ Night train factor, maximum value of 0.3.
$TL =$ Time loss factor with value 0.06 times number of times crossing is blocked.
$P =$ Protection factor, 0.2 for barriers, 0.3 for watchmen, gates, 0.5 for automatic flash signals, 0.7 for lights, and 1.0 for signs only.

The values given the factors are such as not to have a deficiency index higher than 25.0 for any crossing in the state.

The Connecticut formula consists of algebraically adding point ratings for train and highway traffic, physical features, type of protection and some restrictions. The following have positive values:

Train service ratings, which vary from 2 points for 1 or 2 trains to 45 points for 57 to 100 trains.
Highway traffic, which varies from 1 point for "infrequent," to 45 points for very heavy.
One point for each main track more than 1, and for each highway lane more than 2.
10 points for highway intersection on grade crossing.
5 points for highway intersection within 100 ft. of crossing.

The following have negative values:

4 points for highway grade level on one side.
10 points for highway grade level on both sides.
1 point for highway grade under 1 percent on one side.
2 points for highway grade under 2 percent both sides.
3 points for bell protection at crossing.
10 points for flagman on duty 24 hours.
16 points for gates operated 24 hours.
18 points for flashing light signals.

Where train speeds are limited to 10 mph., ½ the train charge is to be deducted, and where crew protects crossings and train stops, the entire train charge is to be deducted.

In California the rating is based on the accident probability factor obtained by multiplying the daily train traffic by highway traffic and dividing by 1000 and then applying judgment with respect to train speeds, sight distances, accident record, etc.

In Virginia crossings are all listed in the order which volume of rail times highway traffic places them, and then the ratings are modified by features such as number of tracks, speed of trains, sight distances and grade and curvature of highway.

The State of Oregon has made a thorough study with the aim to develop a formula containing all of the variables concerned and which will eliminate insofar as possible all personal judgment. The state authorities concluded that such factors as sight distances, angles of intersection, number of tracks, surface and alinement of highway approaches have no marked influence on the frequency of accidents at grade crossings in their state. The formula developed and used is

$$IH = vtdr\ (S_v + S_t)\ \frac{a}{a_1}$$

IH = Inherent hazard.
v = Vehicular volume.
t = Train movements.
d = Darkness factor.
r = Variable depending on value of vtd.
S_v = Vehicular speed factor.
S_t = Train speed factor.
a = Accident record of crossing in question.
a_1 = Variable depending on value of vtd.

The Oregon study brought out that the probability of accident at night was greater than by day. It was decided therefore to separate the 24 hour traffic figures into 4 equal periods and then multiply the number of trains by the number of vehicles for the same periods and apply the d factor to the two night periods. The factor d is given a value of 3.0 for urban locations, 2.5 for suburban, and 1.8 for rural. The r factor varies from a value of 1.0 for vtd of zero to 20,000 to 0.2 when greater than 760,000. S_v varies from 1 for vehicle speeds up to 14 mph. to 3.0 for speeds 45 mph. and over. S_t varies from 0 when all speeds are low to 1.0 where 10 percent or more are high speed trains. The value of a_1, which is the accident vtd relationship, varies from 0.5 for a vtd up to 3500 to a value of 26.0 for a vtd over 660,000. The minimum value of $\frac{a}{a_1}$ is made to be 1.

Kansas uses an empirical formula in which the "design hazard rating" equals

$$A\,\frac{(B+C+D)}{4}$$

where

$$A=\frac{[\text{Highway traffic}]\,[(2\times\text{No. of fast trains})+(\text{No. of slow trains})]}{400}$$

and

$$B=\sqrt{\frac{8000}{\text{Sum of sight dist. 4 ways}}}\ \text{(2000 ft. max. for one way)}$$

and

$$C=\sqrt{\frac{90}{\text{Angle of Intersection}}}$$

and

$D=$ 1.0 for one main track; 1.5 for two main tracks; 1.8 for three main tracks; or 2.0 for four main tracks.

Georgia uses a combination of the Public Roads formula and one of its own development, the latter being:

$HP=N+R+D+S+T+A+W$, in which
$HP=$ Hazard potential rating.
$N=$ Condition of highway approaches with values varying from 0 to 1
$R=$ Railroad and highway alinements, values 0 to 1.6.
$D=$ Angle of intersection, values 0 to 2.
$S=$ Sight distance, values 0 to 8.
$T=$ Train switching movements, value 0 to 2.
$A=$ Accident record (5 year period), 0.2 for one accident, 1.0 for 2 accidents, and 2 points added for each accident over 2.
$W=$ Number of main line tracks; value of zero for one main track and 2.0 for 2 or more main tracks.

The value of *HP* is multiplied by 1.28 and divided by the constant for type of protection used in the Public Roads formula for the crossing in question. The figure thus obtained is averaged with that obtained from the Public Roads formula.

The Utah formula is based on 8 factors which are added together, after which a percentage reduction is made on the basis of type of protection existing at the crossing, as follows:

1. Vehicle traffic divided by 1000 and multiplied by the sum of one-tenth the passenger trains, one-twentieth the freight trains, and one-thirtieth the switching trains.
2. Sight distance rating varying from 0 to 4 in each quadrant.
3. Number of tracks, 0 for one track, 10 for 2 to 4 tracks, and 12 for more than 4 tracks.
4. Road approach conditions varying from 0 to 2.
5. Crossing condition varying from 0 to 1.
6. Accident experience twice number accidents in previous 3 years.
7. Users rating, (the human factor), varying from 0 to 2.
8. Pedestrian train factor. Substitute pedestrians divided by 100,000 for vehicles divided by 1000 in (1) above.

The deduction for existing protection is 0.5 percent for advance warning, 2 percent for cross bucks, 2 percent for automatic bell, 25 percent for automatic flashing lights, and 60 percent for automatic gates, with smaller values for manually operated signals and gates and for lights on one side only.

The State of West Virginia measures the coincidence of train and vehicular traffic by multiplying the number of trains in each of the 24 hours by the number of vehicles during the same hours and then establishing what is called the index of coincidence of traffic by dividing the time in minutes the crossing is blocked by trains in each hour by the average number of cars that would reach the crossing in that time, and adding up these figures for each of the 24 hours.

Another formula used by West Virginia is the result of an attempt at mathematical analysis and determination of the probability of a train and car meeting on the crossing, calling this the exposure index E and multiplying by an impact index I to obtain the index of hazard called EI. This formula, however, is being further studied by its originator with the thought of revision.

The Public Roads formula, which is used by the states of Alabama, Maine, Nevada and Rhode Island, is based on data secured for 3563 rural crossings in 29 states covering railroad and highway traffic, physical characteristics, type of protection and complete 5-year accident history. The results of the study indicated that the factors of traffic and type of protection were the only ones that could be depended on to rate the crossings on an average accident basis. The formula that was developed is

$$I = 1.28 \frac{H^{0.170} \times T^{0.151} + K}{P^{0.171}}$$

$I =$ Probable number of accidents in a 5-year period (the hazard rating).
$H =$ Average daily number of highway vehicles.
$T =$ Number of trains per day.
$P =$ Protection type coefficient. . . .
$K =$ Additional parameter.

That report suggests that the formula be used in conjunction with the known peculiar local conditions and that the index rating which the formula develops is no more than an " . . . indication of the variation of the number of accidents in conjunction with the variation of the factors considered and other items must be weighed before any set of crossings can be assigned rating numbers." It also brings out that in July and August, during heaviest traffic, the frequency of accidents is at the low point, whereas in November and December, low traffic months, the high point is reached, and that as many accidents occur in the night hours when the traffic is relatively light as during the day. It points out that the traffic laws in the various states have an effect on the number of accidents. States having the poorer records have approximately 10 times more casualties per 10,000 registered vehicles than the states with the best records.

The Public Roads Administration report contains the suggestion that additional information be obtained; however, inquiry develops that additional information is not available at the present time.

The ratings of crossings by means of the various formulas give inconsistent results and there is no way of determining which formula is most nearly correct. It is evident to your committee that information which will take into consideration all of the conditions prevailing at the time of accidents concerning a large number of crossings is necessary before a comparison can be made of existing formulas and a satisfactory one can be developed.

Report of Committee 20—Uniform General Contract Forms

W. R. SWATOSH, *Chairman,*
E. H. BARNHART
H. F. BROCKETT
J. W. HAYES
C. J. HENRY
W. D. KIRKPATRICK
J. S. LILLIE
J. F. MARSH
C. E. MCCARTY
A. A. MILLER
W. L. MOGLE
A. B. MONTVILLE
O. K. MORGAN
F. L. NICHOLSON
C. B. NIEHAUS
W. G. NUSZ
G. K. DAVIS, *Vice-Chairman,*
L. A. OLSON
H. A. PALMER
G. W. PATTERSON
C. A. ROBERTS
BRUCE SHAFFNER
B. M. STEPHENS
J. L. WAY

Committee.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

THE COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS,
W. R. SWATOSH, *Chairman.*

Clark Dillenbeck

Clark Dillenbeck retired chief engineer of the Reading Company and a life member of the Association, died on October 9, 1948.

He was born June 24, 1866 at Palatine Bridge, Montgomery county, N. Y., and was educated at the Palatine Union Free School, Canajoharie Academy and Cornell University.

He joined the American Railway Engineering Association November 1, 1916, became a member of the Committee on Uniform General Contract Forms and served on it from 1921 to 1928 and again from 1938 to 1942. He was its vice-chairman during 1927–1928.

The Association, the railroad world, his friends and community in which he lived have lost, in his passing, a cultured gentleman of a very endearing personality and who had the faculty of making lasting friendships. His friends feel deeply the loss they have sustained.

AREA Bulletin 476, November 1948.

Report on Assignment 1

Revision of Manual

J. S. Lillie (chairman, subcommittee), E. H. Barnhart, G. K. Davis, A. A. Miller, O. K. Morgan, F. L. Nicholson, C. B. Niehaus, W. G. Nusz, L. A. Olson, H. A. Palmer, G. W. Patterson, W. R. Swatosh.

The committee recommends readoption of the Form of Agreement for Joint Use of Freight Terminal Facilities with changes as shown below (Manual pages 20–53 to 20–59).

The committee recommends readoption of the Form of Agreement for Crossing of Railways at Grade with changes as shown below. (Manual pages 20–81 to 20–86).

The committee recommends that Form of Agreement for Trackage Rights (Manual pages 20–67 to 20–72), Form of Agreement for Industrial Track (Manual pages 20–73 to 20–75), Form of Lease for Industrial Site (Manual pages 20–77 to 20–80). Form of License for Private Road Crossing (Manual pages 20–87 to 20–88) and Form of Agreement for Purchase of Water (Manual pages 20–89 to 20–90), be reaffirmed without change.

FORM OF AGREEMENT FOR JOINT USE OF FREIGHT TERMINAL FACILITIES

Page 20–55 6. *Payments,* clause (f). The words "based on ...." should be inserted. The clause would then read:

(f) The cost of switching including rental of engine, based on ...., wages of engine and train crews, engine repairs, fuel, water, supplies, engine house expenses and housing of engines.

Page 20–57 *For Use of Icing Station,* after clause (e) and before the paragraph beginning "Bills rendered hereunder ....," insert an additional heading in Italics *General.*

Page 20–58 12. *Liability.* Change next to the last paragraph to read:

Each party shall adjust the claims of its own employees. No settlement for which the other party is to be held wholly responsible, and no settlement in excess of .... Dollars for which the other party is to be held jointly responsible, shall be made without its concurrence.

Insert an explanatory note at the end of agreement reading as follows:

It is understood that the term "wages" includes such charges as taxes, insurance, and allowances at rates which are in effect at the time of the agreement.

FORM OF AGREEMENT FOR CROSSING OF RAILWAYS AT GRADE

Page 20–84 11. *Precedence.* In the last line the letter "A" should be inserted. This paragraph would then read:

In the use of said crossing, passenger, mail and express trains shall have precedence over freight or work trains and light engines, and freight or work trains shall have precedence over light engines. The trains and engines of the . . . "B" . . . Company shall have precedence over the trains and engines of like class of the . . . "A" . . . Company."

Report on Assignment 2

Form of Agreement to Permit Subsurface Exploration by State or Other Government Agencies, on Railway Right-of-Way

A. B. Montville (chairman, subcommittee), G. K. Davis, J. W. Hayes, C. J. Henry, W. D. Kirkpatrick, J. S. Lillie, J. F. Marsh, C. E. McCarty, L. A. Olson, H. A. Palmer, C. A. Roberts, Bruce Shaffner.

Last year your committee presented as information, a tentative draft of Form of Agreement to Permit Subsurface Exploration by State or Other Governmental Agencies, on Railway Right-of-Way (Proceedings, Vol. 49, 1948, pages 133 and 134), and requested comments and criticism thereon. This form of agreement with minor revisions is now submitted with the recommendation that it be adopted and published in the Manual.

FORM OF AGREEMENT TO PERMIT SUBSURFACE EXPLORATION BY STATE OR OTHER GOVERNMENTAL AGENCIES, ON RAILWAY RIGHT-OF-WAY

THIS AGREEMENT, made this .... day of ...., 19 ...., by and between the ...., a corporation of the State of ...., with its principal office at .... hereinafter referred to as the "Company" and the ...., hereinafter referred to as the "Agency":

WITNESSETH:

WHEREAS, the Company is the owner of certain lands in the Township of ...., County of ...., State of ...., and

WHEREAS, for the purpose of ascertaining subsoil conditions, the Agency is desirous of making certain borings on the property of the Company in the vicinity of mile post .... of the Company's railway, in the Township of ...., County of ...., and State of ....

NOW THEREFORE, in consideration of the covenants herein contained and the sum of One Dollar ($1.00) by each to the other in hand paid, the receipt of which is hereby acknowledged, the parties hereto mutually agree as follows:

1. The Company hereby grants authority to the Agency to enter upon its property in the vicinity of the above mile post and to drill and make such borings in such manner and at such locations as may be agreed upon between the Agency and the Chief Engineer of the Company.

2. The Agency shall exercise all reasonable care and shall take such precautions as the Chief Engineer may deem necessary to properly protect the Company's facilities and operation of its trains. The Company reserves the right to make inspections of all drilling and boring operations. The Agency shall reimburse the Company for all costs and expenses incurred by the Company in affording such protection during the progress of the work as, in the opinion of the Chief Engineer, may be necessary. The costs and expenses shall include the actual cost of labor and materials to which shall be added percentages for accounting, overhead, taxes, insurance, vacation allowances, etc., as follows: Labor .... percent. Material .... percent.

3. The Agency shall indemnify the Company and save it harmless from all loss, claims, damages, costs, or causes of action of whatsoever nature, arising from or growing out of injury to or death of any person or persons, or damage to or destruction of

property of any person whomsoever, in connection with the work herein contemplated, and operations adjacent or incident thereto, arising in any way out of the performance of the work for which the permission herein is granted. The Agency shall furnish to the Company's Chief Engineer such evidence of insurance coverage as he may require.

4. Upon completion of the work, the Agency shall restore the premises to their original condition, or a condition satisfactory to the Chief Engineer.

5. The covenants, terms and agreements herein contained shall be binding upon and inure to the benefit of the parties hereto and their respective successors and assigns.

IN WITNESS WHEREOF, the parties hereto have executed this agreement in .... on the day and year first above written.

Attest: .... Company

.... By ....

Secretary

Witness:

.... Agency

Report on Assignment 3

Form of Agreement for Maintenance and Operation of Flood Protection Works

C. J. Henry (chairman, subcommittee), W. R. Swatosh, E. H. Barnhart, H. F. Brockett, A. A. Miller, J. F. Marsh, O. K. Morgan, W. L. Mogle, F. L. Nicholson, W. G. Nusz, H. A. Palmer, G. W. Patterson, Bruce Shaffner, B. M. Stephens, J. L. Way.

Your committee submits the following tentative draft of agreement as information.

The Manual, at present, does not contain a form of agreement for the maintenance and operation of flood protection works located upon lands and right-of-way of a railway company. The committee has drafted a form of agreement which it believes will permit maintenance and operation of flood control works, so located, to be progressed under the control of the railway and assure minimum interference with the operation of trains. Each member of the Association who is interested in the tentative draft of the agreement is urged to give your committee the benefit of his criticisms and suggestions.

FORM OF AGREEMENT FOR MAINTENANCE AND OPERATION OF FLOOD PROTECTION WORKS

THIS AGREEMENT, made this .... day of .... 19 ...., by and between ...., hereinafter called the Public Authority and .... Railway Company, a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company.

WITNESSETH:

WHEREAS, by virtue of an Act of ...., approved the .... day of .... 19 ...., the Public Authority authorized and established the .... Flood Control District located ....; adopted official plans for the construction of facilities to control flood waters within said District; entered into agreements with the .... Government, and the Railway Company for the construction and financing of costs of said facilities; and

WHEREAS, said official plans contemplated the construction of earth levees, stop log closures, and other types of flood control works and also the reconstruction, rearrangement and alteration of tracks and appurtenant facilities of the Railway Company, all upon its lands and right-of-way; and

WHEREAS, the Railway Company has granted certain easements and rights to construct the flood control works upon its lands and right-of-way, and, in connection therewith, has permitted the alterations of its tracks and appurtenant facilities; and

WHEREAS, the Public Authority has agreed, upon completion of the project, to maintain and operate the flood control works in accordance with the regulations prescribed by the .... Government; and

WHEREAS, it is the intent and purpose of this agreement to set forth the conditions under which the flood control works constructed upon Railway Company lands and right-of-way will be maintained and operated.

NOW, THEREFORE, in consideration of the covenants herein contained, the parties hereto mutually agree as follows:

1. Plan No. ...., dated ...., is attached hereto and made a part of this agreement to show:

(a) The location of the flood control works to be operated and maintained under this agreement.

(b) The Railway right-of-way and lands upon which the flood control works are located.

2. The Railway Company hereby grants to the Public Authority, its servants, contractors, agents and assigns the right of entry upon Railway Company's lands to maintain, repair, operate, inspect, or in event of abandonment to remove said flood control works, with the understanding that:

(a) No entry will be made upon the Railway Company's property until its operating superintendent has been notified and arrangements for maintaining and protecting rail traffic have been agreed upon between the parties hereto, and put into effect.

(b) Equipment, tools and materials will not be used, stored, or placed closer than .... ft. from the near rail of the nearest track.

(c) The Public Authority will, at its sole expense, operate, maintain, repair, renew, or in event of abandonment remove the flood control works located upon properties of the Railway Company. If, in respect to any such work, the Railway Company renders any services or performs any work, the Public Authority shall reimburse the Railway Company promptly for the cost thereof. The inspection of the flood control works will not be the obligation or duty of the Railway Company; however, in the event the Railway Company should notify the Public Authority of any unsafe conditions requiring repairs or renewals, and such repairs or renewals are not effected promptly, after notice to the Public Authority so to do, the Railway Company may, if it so elects, make such repairs or renewals and the Public Authority shall reimburse the Railway Company for the cost thereof.

(d) The bills rendered by the Railway Company for work performed on the flood control works shall be paid promptly by the Public Authority and shall include wages, at the standard rate paid by the Railway Company for each class of labor furnished, vacation allowance, Public Liability and Property Damage Insurance, Workmen's Compensation Insurance, contributions measured by the wages of its employees required to be made under the Unemployment Compensation Insurance, Social Security and Retirement Laws or similar laws, State and

Federal, that may now or hereinafter be enacted, applicable to the work undertaken by the Railway Company, and .... percent on labor costs for supervision and administration. Said bills shall likewise include materials at cost plus .... percent for handling, supervision and administration.

3. The Public Authority shall indemnify the Railway Company, and save it harmless from, all loss, claims, damages, costs, or causes of action of whatsoever nature, arising from or growing out of injury to or death of any person or persons, or damage to or destruction of property of any person whomsoever, in connection with the maintenance and operation of the flood control works located upon the lands and right-of-way of the Railway Company.

In the event the Public Authority elects to perform any of the work of inspection, maintenance, operation, repair, renewal or removal of the flood control works by contract it shall require its contractor or contractors to provide Contractor's Public Liability and Property Damage Insurance, for and in behalf of the Railway Company, in amounts and with insurance companies satisfactory and acceptable to the Railway Company.

4. In operating the flood control works covered by this agreement, the Public Authority shall give notice to the operating superintendent of the Railway Company, or his authorized agent, when the water has reached an elevation of .... (Railway Company datum), being .... in. below the base of rail, of the Public Authority's intent to start operation of the stop-log closure structure when the water in the .... reaches an elevation of .... (Railway Company datum) .... in. below the base of rail, providing, however, that operations of said stop-log closure may be started before the water reaches an elevation of .... in. below base of rail only upon written agreement between the operating superintendent of the Railway Company .... and the Public Authority or its authorized agent.

IN WITNESS WHEREOF, the parties hereto have executed this agreement in ...., on the day and year first above written.

.... Railway Company

Witness: .... By ....

.... Public Authority

Witness: .... By ....

Report on Assignment 4

Form of Agreement for Railway Force Account Work on Flood Control Projects

H. F. Brockett (chairman, subcommittee), G. K. Davis, J. W. Hayes, W. D. Kirkpatrick, C. E. McCarty, J. F. Marsh, W. L. Mogle, A. B. Montville, O. K. Morgan, F. L. Nicholson, C. B. Niehaus, L. A. Olson, C. A. Roberts, B. M. Stephens, W. R. Swatosh, J. L. Way.

Your committee submits the following tentative draft of agreement as information.

At the present time the Manual does not contain a form of agreement for railway force account work on flood control projects. The Congress of the United States has passed legislation charging the army engineers with responsibility of flood control and protection and no doubt the railways will be called upon to participate where their lines are affected. The committee has drafted a form which it believes can be used as a satisfactory agreement with alterations made as needed to cover special conditions.

Members of the Association who are interested in the tentative draft of agreement are requested to give the committee their suggestions for its improvement.

FORM OF AGREEMENT FOR RAILWAY FORCE ACCOUNT WORK ON FLOOD CONTROL PROJECTS

THIS AGREEMENT, entered into this .... day of .... 19, ..., by and between the United States of America, hereinafter referred to as "Government" represented by the Contracting Officer executing this agreement and .... a corporation organized and existing under the laws of the State of ...., hereinafter referred to as "Railway" having its principal office at ....

WITNESSETH THAT:

WHEREAS, pursuant to Act No. .... of the ....th Congress of the United States of America approved .... 19 ...., which Act authorized construction of a flood control project located .... miles (direction) of (Town or City), ... County, State of ...., and all appurtenant works under certain plans entitled ....; and

WHEREAS, said plans contemplate certain changes of existing facilities of the Railway and its tenants, consisting of the following: ....; and

WHEREAS, it is advantageous and in the best interest of the Government to have the Railway or its agents, effect said changes; and

WHEREAS, the Railway, or its agents, for the consideration hereinafter stated, is agreeable to the changes in its track and facilities, all of which are specifically shown on Railway drawing, file ...., dated .... 19, ..., attached hereto and made a part hereof, hereinafter referred to as Exhibit "A."

NOW, THEREFORE, in consideration of the covenants herein contained, the parties hereto mutually agree as follows:

1. Scope of Work

(a) The items of work to be performed by the Government within the scope of this agreement are substantially as shown on plans and described in specifications approved by the Railway Chief Engineer and Contracting Officer.

(b) The items of work to be performed by the Railway within the scope of this agreement are substantially as shown on Exhibit "A," and include but are not limited to, the following:

....
....
....

2. Prosecution of Work

The Railway will begin work promptly after receipt of notice to proceed, will prosecute same in an expeditious manner, and will complete each phase of the work within the period of time agreed upon between the Government and the Railway.

3. Payment for Work

The Government shall reimburse the Railway for the cost of all work performed and materials furnished by the Railway. The costs shall include all items of expense properly chargeable to the work, including specifically the following:

(a) All costs of surveys and preparation of plans, estimates, and specifications and expenses of inspection during the progress of the work, including wages, salaries and traveling expenses paid Railway employees (exclusive of general supervisory personnel) directly engaged in survey work, plan preparation and progress inspection.

(b) All the costs arising under any subcontract for any portion of the work, provided said subcontract has been authorized by the Railway Chief Engineer with approval of the Contracting Officer.

(c) All costs of labor furnished directly by the Railway, including, all wages, salaries and traveling expenses paid by the Railway to its employees (exclusive of general supervisory personnel) engaged upon the work plus .... percent of all labor costs covered by this subparagraph for supervision and administration.

(d) All costs of materials furnished by the Railway plus stores expense at the rate of .... percent of the value of materials furnished by the Railway's stores department and purchase expense at the rate of .... percent on the cost of materials furnished through the Railway's Purchasing Agent, for handling, supervision and administration.

(e) All costs of Workmen's Compensation, Employers' Liability, Fire Insurance, Public Liability, Owners and Contractor's Contingent Liability and Property Damage Insurance.

(f) All applicable taxes levied on any materials purchased for the work.

(g) Rental on tools, equipment, and machinery (including locomotives), rolling stock and roadway machines furnished by the Railway at rental rates set up in General Manager's agreement.

(h) Cost of bond premiums and cost of fees for all permits and licenses.

(i) Vacation allowances and all taxes, Federal and State, based on compensation paid by the Railway to employees engaged upon the work.

(j) Expense of work train service at actual operating cost to the Railway.

(k) Cost of transportation of materials and equipment over the Railway's lines at .... mills per ton-mile and at actual cost for other methods of transportation.

(l) Such other items of expense as may be agreed upon by the Railway's Chief Engineer and the Contracting Officer.

The Government shall reimburse the Railway monthly upon receipt of properly certified invoices in (Number of copies) approved by the Contracting Officer.

Upon completion and final acceptance of all work performed by the Railway and within .... days following receipt of certified invoices, the Government shall make final payment to the Railway, provided the total amount paid by the Government to the Railway shall not exceed the sum of .... ($..............) dollars.

The Railway shall furnish such evidence as may be required of it and shall permit examination of its records from which invoices have been prepared.

4. Delays

Should the Railway fail to complete the work in the time allowed, plus any extensions thereof, the Government may, by written notice, terminate the right of the Railway to proceed with the work, provided that the right of the Railway to proceed shall not be terminated because of any delay due to causes beyond control, and without fault of the Railway including but not restricted to acts of God, or of the public enemy, acts of the Government or its agents, fires, strikes, labor stoppages, material shortages, floods, epidemics, quarantine restrictions, freight embargoes, or unusually severe weather. The Railway shall within ten (10) days from the beginning of any delay notify the Contracting Officer in writing of the causes thereof. Upon notification, the Contracting Officer shall verify the facts and probable period of delay, and extend the time for completing work, when the facts justify such extension, and the findings shall be final, subject only to appeal within thirty (30) days by the Railway to the Chief of Engineers, Department of the Army, whose decision on such appeal shall be final and conclusive upon the parties hereto.

5. Changes During Construction

Subject to the approval of the Railway's Chief Engineer, the Contracting Officer may, by written order, make changes in the plans and specifications of this agreement and within the general scope thereof. If such changes cause an increase or decrease in the amount due under this agreement, or in the time required for its performance, an equitable adjustment shall be made and this agreement shall be modified in writing accordingly.

6. Disputes

Except as otherwise provided, all disputes concerning questions of fact arising under this agreement shall be decided by the Contracting Officer subject to written appeal by the Railway within thirty (30) days to the Head of the Department or his duly authorized representative, whose decision shall be final and conclusive upon the parties hereto.

7. Licenses and Permits

The Railway shall obtain all required licenses or permits from the Interstate Commerce Commission or State and local authorities for prosecution of the work.

8. Insurance

Before performing any work the Railway shall arrange for and procure the following insurance coverage and shall keep the same in effect until the work is completed and accepted.

(a) Fire Insurance to cover structures, and structural materials and supplies on hand which may be subject to damage as a result of fire.

(b) Workmen's Compensation Insurance covering employees of the Railway, and its subcontractors, as required by the State in which the work is to be performed, so that the Railway shall be fully protected from any liability or claim for damages for personal injury, including death, which may arise while the Railway is engaged upon the work covered by this agreement.

(c) Public Liability Insurance in amounts of $........... $............, and Property Damage Insurance in amounts of $............ $............

(d) Contractor's Contingent Public Liability and Property Damage Insurance, if there are one or more subcontractors, in the same amounts as required in (c) above.

All the policies must be written by reliable and well rated companies, acceptable to the Contracting Officer. The policies shall be so written that they protect both the Railway and Government against any action which may be instituted against either or both of them. Certified copies of all policies shall be submitted to the Contracting Officer for approval and he shall also be notified when policies are cancelled.

9. Notification of Accidents

The Contracting Officer or his authorized representative shall be notified by the Railway in writing of all accidents in connection with the work.

10. Nonrebate of Wages

The Railway shall comply with the regulations of the Secretary of Labor pursuant to the Act of June 13, 1934, 48 Stat. 948 (U. S. Code, Title 40, Secs. 276b and 276c), and any amendments or modifications thereof, shall cause appropriate provisions to be inserted in subcontracts to insure compliance therewith by all subcontractors subject thereto, and shall be responsible for the submission of affidavits required of subcontractors thereunder, except as the Secretary of Labor may specifically provide for reasonable limitations, variations, tolerances, and exemptions from the requirements thereof.

11. Final Inspection

The Railway shall notify the Contracting Officer promptly upon completion of the work. The Contracting Officer or his authorized representative shall make final inspection within .... days from the receipt of notice of completion and the Contracting Officer, if the work is satisfactory, shall notify the Railway of his acceptance.

12. Right-of-Way

The Government shall convey or cause to be conveyed to the Railway, without cost to the Railway, good merchantable title, free and clear of liens and encumbrances, to such right-of-way, lands and property as may be required by the Railway for its new roadbed, slopes, berms, drainage, communication lines, and other facilities.

13. Covenant Against Contingent Fees

The Railway warrants that it has not employed any person to solicit or secure this agreement in consideration of a commission, percentage, brokerage, or contingent fee. This warranty shall not apply to commissions payable by the Railway upon contracts or sales secured or made through bona fide established commercial or selling agencies maintained by the Railway for the purpose of securing business.

14. Officials not to Benefit

No member of or delegate to Congress or resident commissioner shall be admitted to any share or part of this agreement or to any benefit that may arise therefrom, but this provision shall not be construed to extend to this agreement if made with a corporation for its general benefit.

15. Convict Labor

The Railway shall not employ any person undergoing sentence of imprisonment at hard labor. This provision shall not be construed to prevent the Railway or its subcontractors hereunder from obtaining any of the supplies, or any component parts or ingredients thereof, to be furnished under this agreement or any of the materials or supplies to be used in connection with the performance of this agreement, directly or indirectly, from any Federal, State or territorial prison or prison industry, provided, that such articles, materials or supplies are not produced pursuant to any contract or other arrangement under which prison labor is hired by or employed or used by any private person, firm, or corporation.

16. Definitions

(a) The term "Head of the Department" as used herein shall include the Under Secretary of the Army, and the term "his duly authorized representative" shall mean the Chief of Engineers, Department of the Army or an individual or board designated by him.

(b) Except for the original signing of this agreement and except as otherwise stated herein, the term "Contracting Officer" as used herein shall include his duly appointed successor or his authorized representative.

17. Approval

This agreement shall be subject to the written approval of the Chief of Engineers, Department of the Army, Washington, D. C., and shall not be binding until so approved.

In Witness Whereof, the parties hereto have executed this agreement in .... as of the day and year first above written.

The United States of America

.... By ....

Title ....

Witnesses:

.... Company

.... By ....

.... Title ....

Report of Committee 6—Buildings

A. G. Dorland, *Chairman,*
F. H. Alcott
C. M. Angel
G. A. Belden
C. E. Booth
C. M. Burgess
E. Christiansen
H. M. Church
C. E. Close
G. V. Coffey
D. W. Converse
C. O. Coverley
L. B. Curtiss
W. T. Dorrance
V. E. Elshoff
A. H. Exon
R. L. Fletcher
J. P. Gallagher
C. S. Graves
W. G. Harding
A. T. Hawk
J. W. Hayes
V. V. Holmberg
C. D. Horton
N. D. Howard
A. C. Hoyt
W. V. Kerns
L. P. Kimball
E. E. Kinzel
S. E. Kvenberg
L. H. Laffoley
H. C. Lorenz
J. B. Schaub, *Vice-Chairman,*
F. H. Lovell
I. A. Moore
B. M. Murdoch
G. P. Nagtegaal
W. C. Oest
C. A. Roberts
E. W. Scripture, Jr.
J. E. South
O. W. Stephens
W. R. Swatosh
S. G. Urban
W. E. Webb
J. W. Westwood
O. G. Wilbur

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions .... page 266

2. Specifications for railway buildings.
   Progress report, including specifications for hollow concrete masonry units, submitted as information .... page 282

3. Shop facilities for diesel locomotives.
   No report.

4. Servicing facilities for diesel locomotives.
   No report.

5. Fire retardant coatings, collaborating with Committee 17.
   Final report, presented as information .... page 284

6. Specifications for lumber for railway building purposes.
   No report.

7. Docks and wharves.
   No report.

8. Pile foundations for railway buildings.
   No report.

9. Modernization of station buildings.
   No report.

10. Station name signs, collaborating with Committees 1 and 14.
    No report.

The Committee on Buildings,
A. G. Dorland, *Chairman.*

AREA Bulletin 477, December 1948.

Report on Assignment 1

Revision of Manual

J. B. Schaub (chairman, subcommittee), H. M. Church, C. E. Close, D. W. Converse, C. O. Coverley, C. S. Graves, A. T. Hawk, A. C. Hoyt, H. C. Lorenz, F. H. Lovell, G. P. Nagtegaal, C. A. Roberts, O. W. Stephens

Your committee submits for adoption the following revisions of the Specifications for Buildings for Railway Purposes:

Pages 6–1 to 6–4, incl

I General Conditions

1927

Submitted for reapproval without change.

Pages 6–4 to 6–7, incl.

II Excavation, Filling and Backfilling

1937

Paragraph 214, in fourth line insert "off" between "cutting" and "of."

In sixth and eleventh lines insert "current" ahead of "specifications."

Pages 6–7 to 6–10, incl.

III Sewers and Drainage

Paragraph 307, in the second line, between sentences, insert the sentence, "The pipe shall comply with the current standard specifications for standard strength clay sewer pipe of the ASTM serial designation C 13, or extra strength clay pipe as per current ASTM Specification C 200, if required by loading conditions."

Paragraph 313, the word "current" should be inserted in each instance ahead of the word "specifications."

Page 6–10

IV Concrete

1939

Submitted for reapproval without change.

Pages 6–10 to 6–14, incl.

V Brickwork

1936

Paragraph 507, in second line, insert the word "current" between "Association's" and "specifications."

Paragraph 508, substitute "C 117" for "D 136."

Paragraph 509, in the first line and third line, insert "current" before "specifications." In the fourth line substitute "C 6" for "C 8."

Pages 6–14 to 6–16, incl.

VI Stone Masonry and Cut Stone Work

1936

Paragraph 607, in the second line, delete "Association for portland cement" and substitute "Association's current specification for portland cement. Cement that has hardened or partially set shall not be used." In line seven substitute "C 117" in place of "D 136." In lines fourteen and sixteen insert "current" before "specifications."

Pages 6–17 to 6–19, incl.

VII Clay Hollow Tile

1936

Paragraph 704, in the second line delete "Association for portland cement" and substitute "Association's current specification for portland cement. Cement that has hardened or partially set shall not be used. In line seven substitute "C 117" in place of "D 136." In lines fourteen and sixteen insert "current" before "specifications."

Pages 6–19 to 6–21, incl.

VIII Architectural Terra Cotta

1936

Paragraph 807, in the second line delete "Association for portland cement" and substitute "Association's current specification for portland cement. Cement that has hardened or partially set shall not be used." In line six substitute "C 117" in place of "D 136." In lines thirteen and fifteen insert "current" before "specifications."

Pages 6–22 to 6–24, incl.

IX Concrete Architectural Stone

1936

Paragraph 907, in the second line delete "Association for portland cement" and substitute "Association's current specification for portland cement. Cement that has hardened or partially set shall not be used." In line seven substitute "C 117" in place of "D 136." In lines fourteen and sixteen insert "current" before "specifications."

Pages 6–24 to 6–27, incl.

X Concrete Roofing Tile

1934

Submitted for reapproval without change.

Pages 6–27 to 6–28, incl.

X Clay Roofing Tile

1926

Submitted for reapproval without change.

Pages 6–28 to 6–29, incl.

X Slate Roofing

1927

Submitted for reapproval without change.

Pages 6–91 to 6–92, incl.

XVII Hardware

1926

Submitted for reapproval without change.

Pages 6–116 to 6–122, incl.

XXI

BRICK PAVEMENTS AND FLOORS

1949

2102—

Paragraph 2102 shall be changed to following:

The work shall consist of a subgrade, a concrete base and a vitrified paving brick wearing surface laid over a cushion of either bituminous mastic, cement-sand or sand. In special cases the base may consist of a properly compacted sand, chert, gravel, crushed stone, slag or macadam; and the cushion may consist of slag or stone screenings.

In designing a brick pavement from the specifications herein provided, the following combinations of brick, filler and cushion are recommended. When a rigid (concrete) base is used, the brick wearing surface may be either a flexible type with asphalt filler, or a rigid type with cement-grout filler. When a flexible (all other materials except concrete) base is used, a flexible type wearing surface is recommended.

In the flexible (asphalt filler) wearing surface, the following portions of the specifications should be used:

Brick—with lugs.
Cushion—either sand, bituminous mastic, slag or stone screenings.
Filler—asphalt.

In the rigid (cement grout) wearing surface, the following portions of the specifications shall be used:

Brick—any type or size with lugs.
Cushion—cement-sand, slag, sand or stone screenings.
Filler—cement-grout.

2103—

Paragraph 2103, together with its heading, shall be changed as follows:

2103. Grading, Subgrade and Concrete Base

The grading and subgrade shall be constructed in accordance with current AREA Specifications for Concrete Pavements, Section XXII. The concrete base shall be of a relatively lean mix using 7 gal. of water per sack of cement. The 28-day strength of the concrete shall be at least 2500 psi. Materials and workmanship shall be according to above specifications of Section XXII. Joints will be used only if so indicated on the plans. The concrete shall be finished to a smooth even surface exactly the depth below the finished pavement corresponding to the combined depth of the paving brick and its cushion.

2104—

Paragraph 2104, delete ". . . bituminous mastic, cement-sand or sand cushion" and substitute "cushion."

2106—

Paragraph 2106 shall be changed to the following:

Paving brick shall comply with the requirements of the current Standard Specifications for Paving Brick of the ASTM Serial Designation C 7.

Brick shall be subject to thorough inspection before and after rolling and all rejected material shall immediately be removed from the work.

The contractor must submit with his proposal a sample of the paving brick which he proposes to use, for the approval of the engineer. All brick must be equal to the approved sample.

Paragraph 2107 and its heading, shall be changed to the following:

2107. Cushion (Pavements and Floors)

Fine aggregate for cushion shall consist of a clean, hard, durable siliceous sand of approved quality from an approved source. The grains shall be uncoated particles, well graded from coarse to fine, with the coarse particles predominating, free from lumps of clay and all organic matter. It shall not contain more than 3 percent, by weight, of clay and silt as determined by decantation. The sand for the untreated cushion and for the cement sand cushion shall be graded to meet the following requirements:

Sieve Size (U.S. Standard)		*Percent Passing by Weight*
¼ in.		100
No. 16	not more than	40
No. 100	not more than	5

The sand for the bituminous mastic cushion shall be graded as follows:

Sieve Size (U.S. Standard)		*Percent Passing by Weight*
⅜ in.		100
No. 4		95–100
No. 8		70– 90
No. 16		45– 75
No. 30		20– 50
No. 50		5– 25
No. 100	not over	5

The sand for the bituminous cushion shall be of such quality that mortar composed of the sand and portland cement, 1 to 3 mix, shall show tensile and compressive strengths at the ages of 7 days and 28 days, not less than 90 percent of mortar composed of standard Ottawa sand and the same cement in same proportions.

The bituminous material for the mastic cushion shall be cut-back asphalt free from water, homogeneous and shall meet with the approval of the engineer. A grade of asphalt must be selected which will give the best results considering the character of the sand used and the prevailing weather conditions.

Cut-back Asphalt for Prime Coat and Mastic Cushion

Cut-back asphalt shall meet the following requirements as determined by the designated standard methods of tests of the ASTM.

	Minimum	Maximum	ASTM Test Designation
1. Viscosity, Furol at 122 deg. F.	Sec. 200	400	D 88
2. Distillation:			D 20
(a) Distillate by volume:			
To 437 deg. F.—percent	10	...	...
To 599 deg. F.—percent	20	...	...
To 680 deg. F.—percent	..	35	...
(b) The residue from the distillation to 680 deg. shall meet the following requirements:			
Penetration at 77 deg. F.	70	110	...
Ductility at 77 deg. F.—cm.	60	...	...
Total bitumen soluble in carbon disulfide, percent	99.0	...	...

2108—

Paragraph 2108 shall be revised as follows:

Unless otherwise specifically permitted in the contract, all filler shall be asphalt cement, which shall comply with the current specifications of the ASTM Serial Designation D 241, Grade A.

2109—

Paragraph 2109 shall be changed to the following:

When specifically permitted by the contract, cement grout filler may be used instead of the asphalt filler. The cement shall comply with the requirements of the Specifications for Portland Cement, ASTM Serial Designation C 150.

The sand shall consist of clean, hard, durable, uncoated particles, preferably of a siliceous nature, and limited in organic matter content to be suitable for use in high grade concrete as determined by test of ASTM, Serial Designation C 40. It shall contain not more than 3 percent, by weight, of clay and silt as determined by decantation. The sand shall be graded to meet the following sieve analysis:

Sieve Size (U.S. Standard)		*Percent Passing by Weight*
No. 4		100
No. 16	not less than	95
No. 100	not over	10

The tensile strength of cement sand mortar (1 to 3) shall be not less than 90 percent of standard when compared with standard Ottawa sand mortar.

2110—

Paragraph 2110, add the following:

The expansion joint may also be a premoulded strip of bituminous material extending the full depth of the joint. It shall be of approved quality and shall be of such composition and consistency as not to disintegrate but to remain pliable at any temperature to which a bituminous paving filler may be subjected.

2111—

Paragraph 2111, add same as given in above paragraph 2110.

2112—

Paragraph 2112 shall be changed to the following:

Unless otherwise specifically permitted in the contract, the cushion shall be of bituminous material.

(a) *Bituminous Mastic Cushion.*—Immediately prior to placing the mastic cushion, the concrete base course, which shall have been finished to within $\frac{3}{16}$ in. of the grade of the bottom of the brick and which shall have been thoroughly cleaned and dried, shall be given a prime coat of cut-back asphalt. The prime coat shall be applied by means of an approved air pressure method, using not less than 1 gal. for every 12 sq. yd. of pavement base surface. Application of this prime coat shall be made in the form of a finely divided spray. Cut-back asphalt for prime coat shall be as specified under 2107.

The mastic cushion shall be placed while the prime coat is still tacky.

Mastic cushion shall be composed of fine aggregate and cut-back asphalt mixed in the proportions, by weight, of 94 to 96 percent dry sand, and 6 to 4 percent cut-back asphalt. Within the above limits, the mixture shall contain the largest possible percentage of cut-back asphalt consistent with the requirements that the cushion shall screen easily, spread and compact properly, and retain its shape and bed during the rolling of the brick.

The sand shall be thoroughly dried and shall have a minimum temperature of 125 deg. F., before mixing. It shall have a maximum temperature of 175 deg. F. After mixing thoroughly in an approved batch mixer, the sand and cut-back asphalt shall be placed while its temperature is not less than 60 deg. F.

The cushion shall be shaped and molded to a true surface parallel to the finished pavement surface by means of an approved wooden template. The template shall be supported on a pair of compensating carriages and shall be adjustable so as to satisfactorily span pavement widths of 24 ft., or less. A properly designed, self-propelled finishing machine with adjustable strike may be used if contractor so desires. At intersections, catch basins and similar areas, rakes and lutes shall be used in shaping the cushion.

The mastic cushion shall be ¾ in. in depth. After finishing the surface of the mastic cushion, the surface shall not vary more than $\frac{3}{16}$ in. in 10 ft., and shall be corrected if necessary, by adjusting the cushion to meet this requirement before the bricks are laid.

The contractor shall so design his equipment and conduct his work that workmen, materials and equipment shall be kept off the cushion material after it has been placed in front of the template, and care shall be taken that the cushion is not otherwise disturbed or locally compacted prior to rolling of the brick.

The cushion shall be prepared at least 50 ft., in advance of laying of the brick. Cushion which is not covered with brick at the end of any continuous working period shall be removed from the site. Any areas that are injured or displaced shall be replaced in a manner satisfactory to the engineer.

The contractor shall provide sufficient waterproof covers to protect from rain, cushion which has been laid in advance of brick laying. In case the surface becomes wet enough to show the presence of free water, it shall be allowed to dry thoroughly before being covered with brick.

When specifically permitted by the contract, a cement-sand cushion may be used instead of the bituminous cushion.

(b) *Cement Sand Cushion.*—Upon the prepared base, which shall be thoroughly cleaned, shall be spread a cement-sand cushion to a uniform depth of ¾ in. The cushion shall be composed of 1 part of portland cement and 6 parts of sand. The sand shall meet the requirements as set forth in 2107.

The cement and sand shall be thoroughly mixed by machine in the proportions specified until it is a uniform color throughout. It shall be dry when mixed and shall be kept dry until the brick are placed, rolled and inspected. If necessary to use damp sand in order that the work shall not unreasonably be delayed, then only so much sand and cement shall be mixed and spread as can be covered with brick, inspected, and rolled within one hour of the commencement of the operation.

The cushion shall be shaped and molded to a true surface parallel to the finished pavement by use of satisfactory templates as described for the mastic cushion. At intersections, in the vicinity of catch basins and in similar areas, rakes and lutes shall be used to shape the cushion. The cushion shall not be disturbed after shaping and prior to the laying of the brick.

When specifically permitted by the contract, a sand cushion may be used instead of the bituminous cushion.

(c) *Sand Cushion.*—Upon the prepared base, which shall be thoroughly clean, shall be spread a ¾-in. layer of sand which shall meet requirements of 2107. The cushion shall be sufficiently dry to permit proper spreading, or if deemed necessary, shall be moistened to secure proper compaction. All cushion material shall be rehandled and respread by hand methods after being unloaded on the base, in order to avoid non-uniform compaction.

The cushion shall be shaped and molded to a true surface parallel to the finished pavement by use of satisfactory templates as described for the mastic cushion. At intersections, in the vicinity of catch basins and in similar areas, rakes and lutes shall be used in shaping the cushion.

If required by the engineer, the cushion, after it has been shaped, shall be rolled over its entire surface with a hand roller of suitable size and weight. The template shall then be used to complete the cushion surfacing. If so ordered, the sand shall be dampened before rolling.

Any irregularities shall be brought to the proper grade by the addition or removal of cushion material and the surface restruck with the template. This operation shall be repeated until a uniformly compacted cushion of required depth and surface is produced.

2113—

Paragraph 2113 shall be changed to the following:

The pavement shall be laid upon the specified cushion in a single layer of brick on edge, end to end and at right angles to the center line of the thoroughfare except at intersections where the courses shall be laid as the engineer directs. All bricklaying and conveying of brick shall take place over brick already laid. Brick shall not be piled or stored on sections of pavement that have not been rolled or filled. The better face or wire cut side shall be laid up and lugs, if any, shall be turned in one direction. The end lugs shall be in contact and the side lugs shall be in contact with the brick in the preceding course. Whole brick shall be used except where necessary to break joints at the start or at end of a course. Such alternate courses shall begin with one-half a brick and where necessary shall be completed at the ends with bats not less than 3 in. long, a portion of the adjoining brick being broken off if necessary to give the minimal 3-in. bat at the end of the course. The bricks in adjacent courses shall break joints at least 3 in. The alinement of each course shall be such that it will not deviate more than 1½ in. in 20 ft. At every 15 ft., for the full width of the pavement. this course shall be trued to a line at right angles to the curb, but in no case shall the brick be driven up to the extent expansion will be limited or interfered with. The brick shall be set perpendicular to the grade and to a height from ¼ to ¾ in., or such other height is the engineer may direct, above the finished grade of the pavement to provide for settlement in tamping and rolling.

On curves, the brick shall be laid with cross joints until the line of the brick on the outer edge of the curve shall have fallen back for a distance to be determined by the engineer in the field. At this point the line of the next course shall be moved ahead a distance which is also to be determined in the field, and the laying with cross joints continued as before. The resulting unpaved wedge shall be filled by laying as many whole brick as possible in courses parallel to the original alinement of courses. The remaining spaces between the courses shall be filled with brick laid longitudinally at right angles to one of the transverse courses at each successive closure. No portion of a brick less than 3 in., in length shall be used for batting such closure and the amount of space to be batted in, shall, by varying the length of the successive transverse courses, not exceed a whole brick. The general procedure, as herein described, is illustrated by layouts showns on the contract drawings.

Unless otherwise directed by the engineer, the brick courses shall be laid commencing at one curb of the roadway with closure at the other curb. The brick shall be laid as closely as possible to fill the distance between the concrete shoulders without wedging or "bridging in." Joints around manholes, lane marker units, etc., shall be ¼ in. in width.

2114—

Paragraph 2114 shall be changed to the following:

The laying of paving brick flooring shall conform to the procedure as indicated in 2113 except where specifically indicated otherwise by the engineer.

2115—

Revise the ninth sentence of the first paragraph as follows:

The rolling shall then begin at the edge of the pavement or at the curb at a very slow pace and continue longitudinally backward and forward until the center of the pavement is reached, then passing to the opposite edge or curb and working in a like manner until the center of the pavement is again reached.

Omit the twelfth sentence of the first paragraph and revise the thirteenth sentence as follows:

After rolling, all broken or injured brick shall be taken up and replaced with perfect brick. If a large percentage of the brick requires replacement, the entire surface of the pavement shall then finally be rolled, such rolling to be parallel to the center line of the pavement.

Revise the last paragraph of 2115 to read as follows:

After final rolling, the pavement shall be tested with a profile meter or a 10-ft. straight edge laid parallel to the curb and any deviation from the surface exceeding $\frac{3}{16}$ in. must be taken out. If necessary, the pavement shall be rolled again.

Add to paragraph 2115 the following alternate for rolling:

Alternate

As soon as possible after the brick in the pavement are inspected and rejected brick replaced by acceptable brick, the surface shall be swept free of spalls. The surface shall then be rolled by a self-propelled tandem roller weighing not less than 5 tons and not more than 10 tons. Rolling shall be done longitudinally on boards, not less than 10 in. wide and 12 ft. long, dressed on both sides to a uniform thickness of 13/16 in., laid longitudinally and in close contact. The roller shall not progress more than 10 in. transversely at each longitudinal roll. Sufficient boards shall be required for rolling longitudinally a distance of 24 ft. Boards that become split or broken shall be replaced.

The requirements for tamping, culling and smoothness shall be identical with the foregoing specification for rolling.

2116—

Omit the sixth sentence of the second paragraph and revise the seventh sentence as follows:

After rolling, all broken, injured and defective brick shall be replaced with acceptable ones which shall be brought to the true surface by tamping, or if necessary, by additional rolling.

In the last paragraph of 2116, substitute $\frac{3}{16}$ in. for $\frac{5}{16}$ in.

2117—

Revise to read as follows:

Soon after the pavement has been properly compacted and surfaced and before any dirt or any other foreign material has entered the joints they shall be filled with asphalt filler meeting the requirements as stated in 2108. Unless permission is received from the engineer to use the squeegee method, the surface removal method of bituminous filler application shall be used. Cement grout filler shall be used only when required by the plans.

At no time shall more than 200 lin. ft. of pavement be laid in advance of filling, and filling must follow the laying as closely as practicable. All brick laid shall be inspected, rolled and filled before the close of that day's operations.

(a) *Surface Removal Method*

Application of Separating Agent

Immediately prior to the application of the bituminous filler, the brick shall be treated with either a lime whitewash (screened) or a solution of calcium chloride (screened).

Whitewash shall be prepared by mixing finishing lime and water in the proportions of not less than 1½ sacks of lime to 50 gal. of water. The mixture shall be prepared at least one day in advance of using.

Calcium chloride shall be used in a solution composed of:

	Percent	
Calcium chloride	35	by weight
Laundry starch	1	do
Water	64	do

The separating agent shall be applied with an approved air pressure device manipulated so as to cause the material to settle vertically downward onto the exposed surfaces in the form of a fine mist of fog. The type of nozzle used, the amount of pressure and the manner of operation of the spraying equipment shall be subject to the approval of the engineer. If this method results in coating the surfaces of the brick in the joints, other approved methods of application shall be used. In no case shall brooms be used for applying. The application of separating agent shall precede that of the filler by the interval of time that is necessary for minimum foaming and for giving best results for removal of the surplus filler from the brick surface.

Other agents, methods and equipment which have demonstrated their ability to produce results equivalent to those described herein will be permitted upon the approval of the engineer.

Application and Removal of Asphalt Mastic Joint Filler

The asphalt must be heated, in heating kettles having sufficient capacity, to a temperature of 400 to 450 deg. F., before it is applied, and maintained at the temperature during its application. The kettle must be of approved design and be equipped with a stationary thermometer for accurately indicating the temperature of the asphalt at all times. For protection of pavement, kettles shall be provided with a swinging pan, so interposed between the kettle and the pavement as to provide a minimum of 2 in. of air space between the pan and the pavement at all times. The filler shall be stirred in the melting kettles to prevent injury by burning. While at the specified temperature, the filler shall be poured or flushed into the joints so as to penetrate fully to the bottom of the joint with a surplus retained on the brick surface of at least ⅛ in. The filler shall be emptied directly onto the brick with buckets or containers without the use of squeegee bugies, nozzles or similar devices. The use of wheelbarrows is prohibited. The filler shall not be manipulated over the surface by the use of squeegees or lutes. Partially filled areas or patches where foaming occurs shall receive a second application of hot filler. Lutes will be permitted only for the prevention of waste over the curb or adjacent construction.

The engineer will have the right to limit the area of pavement laid in advance of filling.

When the filler has cooled to the leathery state, the surplus mat of filler shall be removed from the brick in transverse strips not more than four brick wide by means of approved sharp-edged, hand sidewalk cleaners, spading tools or similar devices. The entire operation, especially the handling of the bituminous mat after being cut loose, shall be such as will have no tendency to pull or loosen the asphalt in the joints. Rolling the mat into a tight roll and thus exerting a direct pull while cutting will not be permitted. Any joints found to be unfilled after the above operation shall be refilled with a hand pot. The final result shall be a clean brick surface with the joints filled flush with the tops of the brick, and all surplus filler entirely removed from the brick, curbs and adjacent construction. If directed by the engineer, the surfaces shall be cleaned with gasoline. Asphalt will not be permitted to lie on the brick surface.

Surplus filler may be reheated and reused with new material, but the proportion of reheated asphalt shall be such as will cause a minimum of foaming.

(b) *Squeegee Method*

Applying Filler

The asphalt filler must be heated in heating kettles having sufficient capacity, to a temperature between 400 and 450 deg. F. before it is applied and maintained at this temperature during application. The kettle must be of approved design and equipped with a stationary thermometer for accurately indicating the temperature of the asphalt at all times.

For protection of the pavement, kettles shall be provided with a swinging pan, so interposed between kettle and pavement as to provide a minimum of 2 in. of air space between the pan and the pavement at all times. The filler shall be agitated in the kettles to prevent injury by burning. While the filler is at the specified temperature it shall be applied to the brick surface with a squeegee machine operated slowly backward and forward at an angle with the joints so as to penetrate fully to the bottom of the brick and entirely fill the joints to within ⅛ in. of the top. Should the top of the filler in any joints be more than ¼ in. from the top of the brick, the joints shall be refilled by pouring from a hand pot. After completion of the filling operations the asphalt remaining on the surface of the brick shall not exceed 1/32 in. in thickness.

The temperature of the brick should be at least 80 deg. F. immediately before applying the filler.

Asphalt may be applied with truck pressure distributors on special permission of the engineer.

Surface Dressing

Immediately after the joints are filled as above specified, and the asphalt is still soft and pliable, a dressing of dry, clean silica pebbles of sizes varying from ⅛ in. to 3/16 in. or No. 9 limestone chips shall be distributed over the asphalt, using not less than 9 lb. to 1 sq. yd. Mechanical spreaders should be used to distribute the aggregates uniformly over the asphalt so as to form a mat over the entire surface of the brick. This work may be done by hand if uniform distribution is obtained. The dressing material shall be thoroughly rolled into the asphalt while it is still pliable with a tandem roller of the same weight as used in rolling the brick. All brick shall be filled and the surface dressing applied on the day of the laying.

Cleaning and Testing Finished Pavement

As soon as all work in connection with the construction has been completed, the contractor shall thoroughly clean the pavement throughout. The pavement will then be tested again for smoothness by means of a straight edge or surface testing machine on one or more longitudinal lines as determined by the engineer, and all deviations from a straight line of more than 3/16 in. in 10 ft. shall be corrected by adjusting the cushion and relaying the brick.

2118—

Paragraph 2118, first sentence, substitute 3 parts, for, 1½ parts.

2119—

The first paragraph of 2119 shall be revised as follows:

When cement grout filler is used, poured expansion joints are constructed by placing two strips of wedge-shaped siding or other approved material, of dimensions required and extending the full depth of the brick between the rows of brick at the locations required. Soon after the grouting is completed and the cement filler has set and the pavement is in all respects finished, these strips shall be removed. Care shall be taken in removing strips so that bond existing between existing brick is not broken or the curbing injured. When the strips have been removed, the space shall be filled with the bituminous cement composed of the ingredients specified hereinbefore and mixed and prepared as follows:

Pages 6–128 to 6–135 incl.

XXIII

2301 Creosoted Wood Block Pavements

1928

2302 Wood Block Floors

1929

Delete the two specifications and substitute the following:

XXIII

2301. WOOD BLOCK FLOORING AND PAVING

1949

1. General

The contractor shall furnish all labor, materials, tools and equipment, except as otherwise noted, necessary to complete entirely the wood block floors (or pavements) as hereinafter specified and as indicated on the drawings.

2. Description

The floor or pavement shall consist of a subgrade, a concrete foundation and a wearing course of wood blocks laid over either a bituminous paint coat or a bituminous mastic cushion, applied to such foundation.

3. Subgrade and Foundation

The subgrade, if one be needed, and foundation shall be designed of sufficient strength to carry the loading to be encountered and shall be constructed in accordance with the current specification of the AREA for concrete for railway buildings as given in Section IV of these specifications, except that the concrete shall be finished to a smooth even surface, with no projections of any kind parallel to the contour of and to the depth below the finished floor level, corresponding to the combined depth of the block and the thickness of the bitumen, or mastic cushion specified.

4. Kind of Timber

The wood blocks which are to be pressure-creosoted shall be manufactured from air-seasoned or kiln-dried Douglas fir, Norway pine, oak, southern pine, tamarack, western larch, or other suitable wood approved by the engineer. Only one species shall be used in any one contract or order.

5. Curb and Gutter for Paving

The curb or the curb and gutter shall be built in the location and to the elevation, sizes and cross section shown on drawings.

All cement and concrete materials and workmanship shall comply with the specifications for concrete as given in Section IV of these specifications.

6. Quality of Blocks

The blocks shall be sound; shall be well manufactured, square butted and square edged, and shall be free from unsound, loose or hollow knots, knot holes, worm holes and other defects such as shakes, checks, etc., that would be detrimental.

Douglas fir or southern pine blocks shall average not less than 6 annual rings per inch, and in addition one-third or more distinctly contrasted summer wood measured along the 3-in. portion of a radial line representative of average growth, provided however that blocks averaging less than 6 rings per inch shall be accepted if they contain 50 percent or more summer wood.

7. Size of Blocks

Blocks may vary in length from 5 in. to 9 in., the maximal length not to exceed 2½ times their depth for pavements, 3 times their depth for floors. They shall be 2½ in. to 4 in. in depth (parallel to grain) according to condition of traffic; they shall be

2½ in. to 4¼ in. in width, but in any one job all blocks shall be of uniform width and depth, with a variation of 1/16 in. allowed in depth and ⅛ in. in width, provided the width shall be greater than the depth by at least ¼ in.

8. Preservatives and Preservative Treatment

The preservatives used shall be either creosote–coal tar solution, or Grade 1 creosote, as conforming to AREA specifications.

Blocks shall be treated in air-tight cylinders in accordance with any standard empty-cell (Lowry or Reuping) process, Tentative 19c as adopted by American Wood-Preservers Association—1947. The net retention in any charge shall be not less than 90 percent of the quantity of preservative specified; for contract or orders comprising less than five charges the average retention shall be not less than 95 percent; the average retention by the wood blocks treated under contract or orders of five or more charges and the average retention of any five consecutive charges shall be not less than 100 percent of the quantity specified, except when the character of the wood in any charge makes these requirements impracticable, despite treatment to refusal, in which latter case allowance shall be made for the difference between the quantities of the preservative specified to be retained and as actually obtained.

The amount of preservative retained shall be calculated from readings of working-tank gages or scales, or from weights before and after treatment of loaded trams or suitable truck scales with necessary corrections for changes in moisture content.

The volume of preservative shall be calculated on the basis of 100 deg. F. Calculations of volume or weight shall be made by the use of temperature or specific gravity factors contained in the volume correction tables in Chapter 17—Wood Preservation, of the AREA Manual.

9. Required Retention

The amount of preservative per cubic foot of wood in the charge, depending on the use requirements and as stipulated in the purchaser's order and in accordance with Section 8 above, shall be as follows:

(1) Blocks for floors within buildings, under normally dry conditions of use, 6 lb. of creosote–coal tar solution or creosote,

(2) Blocks for interior floors under humid conditions, 8 lb. of creosote–coal tar solution or creosote,

(3) Blocks for exterior or exposed floors, platforms or paving, 8 lb., 10 lb. or 12 lb. creosote–coal tar solution depending on severity of exposure, with preference for higher retention for the more severe and wet exposures.

10. Penetration of Preservative

The blocks after treatment shall show satisfactory penetration of the preservative, and in all cases the oil shall be diffused throughout the sapwood. To determine this, at least 25 blocks shall be selected from various parts of each charge and sawed in half perpendicular to the grain through the center, and if more than one of these blocks show untreated sapwood, the charge shall be retreated. After retreating, the charge shall be again subjected to a similar inspection.

11. Handling Blocks after Treatment

The blocks shall be shipped in closed cars and be stored under cover upon arrival on the work and protected from the weather at all times, both before and after being laid and until the finished work is accepted.

12. Inspection at Plant

All materials prescribed in these specifications and processes used in the manufacture of the blocks therefrom shall be subject to inspection, acceptance, or rejection at the plant of the manufacturer, which shall be equipped with all the necessary gages, appliances, and facilities to enable the inspector to satisfy himself that the requirements of the specifications are being fulfilled. Such plant inspection shall be as to kind and quality of timber, uniformity and size of blocks, preservatives and treatment, retention and satisfactory penetration.

13. Inspection at Site of Work

The engineer shall have the further right to inspect the blocks after delivery at the site of the work, for the purpose of rejecting any blocks that do not conform to these specifications or fail to meet the requirements for the subgrade foundation, base-coat or cushion, workmanship in laying, filler, binding and finishing as covered by these specifications and as shown in the accompanying drawings.

14. Base Coats for Laying Blocks

(a) *Bituminous Paint Coat.*—On the thoroughly cleaned, dried and uniformly surfaced concrete foundation shall be spread a thin, uniform hot bitumen paint coat, of which the melting point shall be not less than 135 deg. F. nor more than 155 deg. F. It shall be heated to a temperature of not less than 250 deg. F. nor more than 300 deg. F. and be mopped or squeegeed to a uniform thickness not exceeding ⅛ in.

(b) *Bituminous Mastic Base.*—Where required before laying wood block paving, the thoroughly cleaned concrete foundation shall be covered with a layer of mastic not exceeding ¾ in. in thickness consisting of 10 percent by volume of coal-tar pitch and 90 percent clean, dry, screened sand, thoroughly mixed to uniform density and screeded by template to a surface parallel to the grade and contour of the finished pavement as shown on the accompanying drawings. This cushion, spread the day before laying blocks, shall be allowed to cure for 24 hours.

15. Laying Blocks

(a) The contractor shall furnish and lay the wood blocks under the direct supervision of the manufacturer and shall arrange for such supervision. The base coat shall be specified for respective interior normally dry floors, floors subject to water or humidity, exposed shipping platforms, loading pavements, driveways and paving outdoors as required.

(b) All blocks shall be laid with the grain of the wood vertical and the length of the blocks to line in straight, parallel courses which wherever practicable shall be at right angles to the course of maximum traffic, with all joints bonded by a lap of at least 1½ in. Except for half and three-quarter blocks for closures and bonded coursing, nothing but full length blocks shall be laid. A uniform space for expansion joints 1 in. in width shall be set back from all walls, curbs, abutments, piers and columns, manholes and other obstructions and in wide expanse of floors, additional space for expansion joints may be required.

(c) Wood blocks laid in normally dry interiors shall be driven up by ramming every four courses and longitudinally so as to minimize bed and cross joints.

Where wet floors or humid conditions are likely the joints in both directions shall be uniformly spaced as specified and shall not be tightly driven up for any purpose.

For roadways, paving, and exposed or alternately exposed locations wood blocks shall be laid with uniform jointing and no ramming to straighten the line of courses shall permit any tight joints or spaced joints in excess of 3/16 in.

(d) All wood blocks when laid shall be rolled and surfaced to the finished contour specified and irregularities shall be tamped and rolled to a smooth, level surface as required by the drawings. Paving blocks shall be rolled parallel to the line of traffic and diagonally by a tandem roller of approximately 6 tons until the surface becomes smooth and is brought truly to the grade and contour of the finished pavement.

16. Expansion Joints and Binder

After tamping and rolling have been completed and the wearing faces of the blocks have all been brought to a smooth even surface at the grade required, all expansion joint strips at all walls, curbs, piers, columns and other obstructions shall be removed. These uniform 1-in. spaces and every joint between blocks and between courses shall then be filled by flushing and surfacing with two successive coats of extremely hot bitumen filler carefully heated and regulated by temperature controls to prevent injuring its consistency. After the first filling the second or binder coat of the same hot bitumen shall be worked into all joints and spaces with rubber-bladed squeegees so as to leave all joints completely filled and a minimum of the coal-tar binder on the block surface. Where not detrimental fine sharp sand may be strewn over the surface and remain under traffic for a week or more. For spark-proof floors no sanded or gritted surfacing shall be permitted.

17. Bituminous Bases and Binder

The bitumen used for the bituminous paint coat, mastic, expansion joints and filler and binder surfacing shall be coal-tar pitch derived from the distillation of coal tar, complying with the following requirements:

(a) Specific gravity at 77 deg. F. (25 deg. C.) shall not be less than 1.22 nor more than 1.54.
(b) Free carbon shall not be less than 16 percent nor more than 37 percent.
(c) Melting point shall not be less than 135 deg. F. nor higher than 155 deg. F. when determined by the half-inch cube method.
(d) When 100 grams of pitch are distilled to 670 deg. F (355 deg. C.) in an 8-oz. retort, the specific gravity of the distillate shall not be less than 1.07 at 100 deg. F. (37.7 deg. C.).

18. Melting Point Test

Coal-Tar Pitch.—A clean shaped ½-in. cube of the pitch to be formed in a mold, placed on a hook on No. 12 copper wire and suspended in a 600-c.c. beaker, so that the bottom of the pitch is 1 in. above the bottom of the beaker. (A sheet of paper placed on the bottom of the beaker and conveniently weighted will prevent pitch from sticking to the beaker when it drops off.) The pitch to remain 5 min. in 400 c.c. of water at a temperature of 60 deg. F. (15.5 deg. C.) before heat is applied, heat to be applied in such manner that the temperature of the water is raised 9 deg. F. (5 deg. C.) each minute, the temperature recorded by the thermometer at the instant the pitch touches bottom of the beaker is to be considered the melting point.

19. Guarantee

It is hereby understood and agreed that the contractor shall guarantee the material furnished and used and the workmanship employed in the construction of said work to be of such quality and character as to insure the same to be free from all defects and to remain in continuous good order and condition satisfactory to the engineer as above set forth for a period of 2 years. The guarantee shall include all repairs to be made or, if necessary, the entire reconstruction of the work as the engineer may direct without additional charge or cost to the railroad company.

In case the paving or any part thereof is on public property where city ordinance or other ruling requires a maintenance bond, the contractor shall furnish, within 10 days after the contract is let, a good and satisfactory bond to the amount as stated in the general contract to maintain that portion of the work on said public property as covered by this contract at the finished line and grade for a period of years as required by ordinance or ruling.

20. General Conditions

All materials entering into the work and all methods used by the contractor shall be subject to the approval of the engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this specification.

Pages 6–144 to 6–146, incl.

XXV

2501. Asphalt Block Pavements

1929

Delete the entire specification

Pages 6–146 to 6–148. incl.

XXV

2502. Asphalt Block Floors

1929

Delete the entire specification

Pages 6–149 to 6–151, incl.

XXVI

2601. Macadam Pavements

1929

Paragraph 4, in line five substitute "5 gallons" in place of "7 gallons."

Pages 6–151 to 6–153, incl.

XXVI

2602. Asphalt Macadam Pavements

1929

Paragraph 4, in line five substitute "5 gallons" in place of "7 gallons."

Pages 6–153.6 to 6–157, incl.

XXVII

Sprinkler System

1930

Dry Pipe, Wet Pipe or Deluge System

Paragraph 2721, add the following paragraph:

The guarantee shall be for not less than one year of time after acceptance of the work by the engineer. The contractor shall furnish and reinstall without cost to the owner, any part or parts of the work which may prove during that time to have been faulty or defective.

Your committee also submits for approval the following revisions of Recommended Practice Governing the Design of Inbound and Outbound Freight Houses:

Pages 6–217 to 6–221, incl.

Freight Houses

1948

Section 3, add the following paragraph at the end of the section:

In order to accommodate the increasing tendency to handle commodities on pallets and fork lift trucks, clearances at doors and inside the inbound and outbound freight houses and on transfer platforms should be increased to permit this method of handling.

Section 6, delete the paragraph and substitute the following:

On the driveway side of all freight houses and along platforms for delivery of freight, suitable longitudinal wooden fenders, protected by steel plates, should be provided to protect the walls from damage by trucks.

Both the wooden fenders and steel plates should be designed so that they can be readily renewed, and fenders should preferably be kept about 2 in. from the walls of the buildings by separators.

Report on Assignment 2

Specifications for Railway Buildings

O. G. Wilbur (chairman, subcommittee), F. H. Alcott, C. M. Angel, G. A. Belden, C. E. Booth, E. Christiansen, H. M. Church, C. O. Coverley, A. H. Exon, R. L. Fletcher, B. M. Murdoch, G. P. Nagtegaal, J. B. Schaub, E. W. Scripture, Jr., S. G. Urban, W. E. Webb.

Under the assignment of specifications for railway buildings your committee submits Specifications for Hollow Concrete Masonry Units, which are offered as information with a request for comment and criticisms with a view to resubmission in another year for adoption and publication in the Manual.

SPECIFICATIONS FOR HOLLOW CONCRETE MASONRY UNITS

(These specifications closely follow both federal and ASTM specifications for hollow concrete masonry units.)

General

The concrete block manufacturer shall furnish all labor, materials, and plant necessary to manufacture the hollow concrete masonry units as shown or called for on the drawings in accordance with these specifications.

Material

The units shall be made from portland cement or other hydraulic cement, subject to approval. Suitable aggregates such as sand, gravel, crushed stone, bituminous or anthracite cinders, burned clay or shale and blast furnace slag shall be used in such proportions and with such a process of manufacture that units meeting the requirements of these specifications shall be produced. The bidder shall state in his bid the nature and composition of the cement that he proposes to use. When cinder aggregates are called for on the plans, or otherwise specified, the combustible material in the cinder aggregate shall not exceed 35 percent of the weight of the aggregate.

Workmanship

At the time of delivery to the site of the work, the units shall be sound and free from cracks or other defects that would interfere with the proper placing of the units or impair the strength or permanence of the construction. When used as a base for plaster or stucco the units shall have a sufficiency rough surface to afford good bond. No overall dimension shall vary more than 3 percent over or under the specified dimension for any form of unit.

Types

The units shall be of either load-bearing or non-load-bearing type as shown on the plans and specifications.

Where load-bearing units are specified, they shall conform to the requirements of Table 1.

TABLE 1

Minimum Face Shell Thickness, in.	*Compressive Strength Minimum psi. (Over average gross area)* Average of 5 units	*Individual unit*	*Water Absorption Maximum lb. per cu. ft. Average of 5 units*	*Moisture Content Maximum percent Average of 5 units*
¾ to 1¼	1000	800	15	40
1¼ or more	700	600	15	40

When non-bearing units are shown or specified they shall conform to the requirements of Table 2.

TABLE 2

Compressive Strength Minimum psi. (Over average gross area) Average of 5 units	*Individual Unit*	*Moisture Content Maximum percent of total absorption Average of 5 units*
350	300	40

Minimum face thickness shall be not less than ¾ in.

Sampling and Testing

Test samples may be taken before shipment or after delivery at the discretion of the purchaser or his authorized representative.

Units shall be sampled and tested in accordance with ASTM method Serial Designation C 140.

Before units are taken for test, individual units shall be rejected for failure to meet the requirements for size or workmanship and finish. All units so rejected shall be replaced immediately without cost to the purchaser. In case of failure to meet the absorption and/or strength requirements shown in the tables, the manufacturer may sort the shipment and new samples shall be taken by the purchaser from the remaining lot and tested at the expense of the manufacturer. In case the second samples fail to meet the requirements of this specification, the entire shipment shall be rejected.

Except as herein specified or otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

Markings

All units shall bear a distinctive mark of the manufacturer or shall be otherwise readily identified as to origin.

Each shipment of units shall be clearly marked as to contents and as to the order of which they are a part.

General Conditions

All material entering into the work and all methods used by the manufacturer shall be subject to the approval of the engineer and no part of the work will be considered as finally accepted until delivery and acceptance have been made.

The "General Conditions" as given in Section 1 of these specifications shall be considered to apply with equal force to this section of the specifications.

Report on Assignment 5

Fire Retardant Coatings

Collaborating with Committee 17

H. M. Church (chairman, subcommittee), F. H. Alcott, C. M. Angel, C. E. Close, C. S. Graves, W. G. Harding, J. W. Hayes, N. D. Howard, S. E. Kvenberg, E. W. Scripture, Jr., J. E. South, O. W. Stephens, J. W. Westwood.

This is a final report, presented as information.

The use of fire retardant coatings for railway structures, since the survey made in 1945, has progressed to a point where it has become an established practice. The classification of materials as recommended by Committee 1 of ASA Project A51, on which final acceptance is now pending, comprises the following.

Class I (incombustible)	0– 15
Class II (fire retardant)	16– 30
Class III (slow burning)	31– 75
Class IV (combustible)	76–200
Class V (highly combustible)	Over 200

Flame Spread Classifications of Building Materials

The following flame spread classifications of building materials have been developed by the tunnel type test method described in Underwriters' Laboratories, Inc., Bulletin of Research No. 32, dated September 1944. Those marked by an asterisk have been formally listed and classified by Underwriters' Laboratories, Inc., (see List of Inspected Fire Protection Equipment and Materials); those not so marked do not necessarily apply specifically to the products of a particular manufacturer and in all cases may not apply to commercial products now on the market. The values given are factors and are comparable, but do not express percentages.

Material	*Flame Spread Classification*
Asbestos-cement board*	0
Foamglass*	8
Flame resistant treated wall fabric	
On unpainted plaster	0–10
On painted plaster	20–30
Asbestos protected metal*	20–45
Mineral wool batt insulation*	
Without exposed vapor seal	10–20
With exposed special vapor seal	30–40
With exposed ordinary vapor seal	270
Flame resistant treated lumber, impregnated*	25–60
Yellow pine	
Ponderosa pine	
Southern yellow pine	
Maple	
Birch	
Red oak	
Douglas fir	
Flame resistant treated lumber, coated*	30–65
White pine	
Yellow pine	
Red oak	
Douglas fir	
Flame resistant treated canvas	30–40
Flame resistant treated hair felt	35
Flame resistant treated plywood*	35
Flame resistant treated cellulose board	50
Red oak lumber	100
Douglas fir lumber	100
White pine lumber	130
Yellow pine lumber	130
Plywood	100–180
Plastic wall tile	170
Pitchy pine lumber	180
Cellulose board	225
Hair felt	240
Veneered wood	515
Canvas—in folds	640
Cotton fabric—in folds	1600–2500

The following fire hazard classification for fire retardant coatings is based on the coverage per gallon for coating material, for application with spray or brush, to reduce the combustibility of white pine, yellow pine, and Douglas fir surfaces on interiors of buildings, and is applicable when the coating is maintained.

	Fire Hazard Classification† Coverage per gal.	
	50 sq. ft.	*70 sq. ft.*
Flame spread	30–40	40–50
Fuel contribution	10	15
Smoke developed	Approximately same as uncoated wood	

† In comparison with uncoated red oak as 100.

Fire Retardant Paints

Particulars regarding a fire resistant paint (Formula A) developed and applied for exterior use by one railroad and a fire retardant paint produced by a leading manufacturer (Formula B) are given in the table.

	Formula A percent	*Formula B*[1] *percent*
Pigment—by weight	75[2]	70
Vehicle—by weight	25	30
Composition of pigment by weight		
Titanium dioxide	8.3	5
Leaded zinc oxide 35/65	35.7	27
Lead carbonate	...	16
Antimony oxide	8.3	..
Magnesium silicate	8.1	18[3]
Calcium carbonate (whiting)	19.8	..
Borax	...	34
Chlorinated paraffin 70 percent Grade	19.8	..
Composition of vehicle by weight		
Linseed oil, alkali refined	48.5	65[4]
Linseed oil, viscosity X	12.8	15[5]
Drier A	1.3	..
Mineral spirits	37.4	21[6]
Pigment—by volume	37.4	Not given
Weight per gal.	16 lb.	Not given

[1] A variation of ± 2 percent from percentages given is permissible.
[2] Including chlorinated paraffin ground with pigment.
[3] Described as silica and silicates.
[4] Described as raw linseed oil.
[5] Described as heat-treated linseed oil.
[6] Includes drier.

Methods of Test

In addition to the tunnel type test method used by the Underwriters' Laboratories, Inc., to develop the flame spread classifications of building materials, one railroad has used the modified Schlyter test and another railroad uses five other test methods.

A report of tests on three types of wall materials, coated with the two foregoing fire retardant coatings and two others, made by the modified Schlyter test by the laboratory of one railroad is summarized as follows:

Object: Conduct modified Schlyter test on the following paints, using Wolmanized pine,[1] Temlock wallboard,[2] and Careystone[3] panels:

1. Formula A.
2. Formula B.
3. Formula C (white)
4. Formula C primer plus Formula C (gray)

Reference: Report of chemical corporation on Formula B.

General Procedure: Panels cut 12 in. by 31 in.—2 coats of paint applied by brush —24 hours between coats. Panels were seasoned for 30 days prior to fire test.

[1] Wolmanized Pine—Pine wood treated with fire retardant salts (chromated zinc chloride).
[2] Temlock—Combustible compressed wood fiber wallboard.
[3] Careystone—Cement asbestos wallboard.

Results:

	Formula A			Formula B		
	Wolm. Pine in.	*Tem-lock in.*	*Carey-stone in.*	*Wolm. Pine in.*	*Tem-lock in.*	*Carey-stone in.*
Height of char	7½	7½	5¼	7½	8	4¾
Maximum flame height	7	6½	5½	7	8½	7
Original flame height	5	5	5	5	5	5½
Maximum flame spread	2	1½	½	2	2½	1½
Flame duration after removal of burner, sec.	120	glow 95	....	....	....	....
Moisture, percent	8.01	7.39	5.40	8.01	7.39	5.40
Sq. ft. per gal.	80.04	69.07	91.63	89.1	84.0	94.76

	Formula C (White)			Formula C Primer + Formula C (Gray)		
	Wolm. Pine in.	*Tem-lock in.*	*Carey-stone in.*	*Wolm. Pine in.*	*Tem-lock in.*	*Carey-stone in.*
Height of char	10⅜	9⅜	9¼	10½	9	4¾
Maximum flame height	10	9	6½	12	9	5½
Original flame height	5	5	5	5	5	5
Maximum flame spread	5	4	1½	7	4	½
Flame duration after removal of burner, sec.	110	.....	.....	50	.....	.....
Moisture, percent	8.01	7.39	5.40	8.01	7.39	5.40
Sq. ft. per gal.	140.2	132.41	147.8	285.0	27.4	288

Description of five other methods of test used by the laboratory of another railroad are:

Test No. 1

Fire retardant properties were determined with ASTM test Serial Designation E 160 modified equipment, using untreated dry Georgia pine wood strips, ½ in. by ½ in. by 3 in., moisture as received 9.80 percent as controls. Georgia pine strips ½ in. by ½ in. by 3 in. were suspended by strings tied around tacks in ends, dipped into test paint, allowed to drain several minutes, then dried a minimum of 72 hours before testing. Twelve of above specimens, weighed to nearest 0.01 g., were placed in crib, flame shield lowered, burner adjusted, and test conducted in accordance with ASTM method Serial Designation E 160. The residue was weighed and percentage loss calculated.

Test No. 2

A further modification of method E 160, in which 3 specimens (prepared as in Test No. 1) were placed side by side on bottom of wire crib, shield lowered, and Meker burner flame adjusted to 600 deg. F. at point closest to 3 specimens. Flame was removed when specimens were afire, time of exposure to flame before burning recorded, flame duration and glow duration after removal of burner also recorded. Any specimens which resisted the 600-deg. F. flame for 30 min. were scraped and the condition of the underlying wood noted.

Test No. 3

One uniform coat of test paint was brushed on a section of regular pine car siding, 12 in. long, by 5½ in. wide by 13/16 in. thick, an untreated section being used as a control. After allowing a minimum drying time of 72 hours, fire resistance of sections was tested by exposure to the flame of a blowtorch, adjusted to a constant temperautre of 1100 deg. F., for exactly 2 min. at a distance of 3 in. from metal end of torch. Duration of burning, if any, was recorded after removal of flame. After testing, part of charred exterior was scraped to reveal effect on underlying wood.

Test No. 4

The most practical and indicative test was conducted with pine strips 12 in. long, 1 in. wide, and 13/16 in. thick, sawed from standard car siding and dried in an electric oven for 8 hours at 250 deg. F. Two coats of test paint were brushed on 48 hours apart, allowed to dry a minimum of 48 hours, then the specimens were placed in a ¼-pint can, containing 10 g. of cotton wiping waste and 75 g. of denatured alcohol. These specimens included an untreated strip as control. Specimens were fastened in a perpendicular position and the alcohol in each can ignited simultaneously and allowed to burn for 22 min. The time required for the specimens to be burned to the point of collapsing was recorded, along with the progress of the burning, noting such details as whether the coating contributed to the fire.

Test No. 5

(Fire, Glow and Charcoal Point Determination)

This test was developed to simulate conditions arising from a spark or live coal, by employing an electric heating element with which a surface temperature of around 740 deg. F. could be maintained. At this temperature the heating elements were a very bright red. One control and several coated specimens prepared as for Test No. 1 were placed 1 in. above these electric coils at 600 deg. F. for 12 min. The fire, glow and charcoal points were recorded.

Report of Committee 8—Masonry

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Maurice Coburn
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W. Wilbur
W. R. Wilson
E. P. Wright

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

No report.

2. Principles of design of masonry structures, collaborating with Committees 1, 5, 6, 7, 13, 15, 28, 29 and 30.

Report on crib walls presented for adoption and publication in the Manual . page 290

Report on design of plain and reinforced concrete members presented as information .... page 291

3. Foundations for masonry structures, collaborating with Committees 1, 6, 7, 15 and 30.

Report on pile foundations presented for adoption and publication in the Manual .... page 311

4. Earth pressure as related to masonry structures.

No report.

5. Methods of designing, constructing and maintaining tunnels, collaborating with Committees 1, 5, 28 and 29.

Report on lining railway tunnels with timber presented for adoption and publication in the Manual .... page 314

6. Methods of repairing masonry, including internal pressure grouting.

Report on repairing and solidifying masonry structures presented as information .... page 314

AREA Bulletin 477, December 1948.

7. Methods for improving the quality of concrete and mortars, collaborating with Committee 6.

   Report on proportioning concrete mixes for field use presented as information .... page 320

8. Specifications for the construction and maintenance of masonry structures.

   No report.

THE COMMITTEE ON MASONRY,
F. R. SMITH, *Chairman.*

George Eugene Boyd

The members of Committee 8 record with sorrow the death on May 14, 1948, of a valued and esteemed associate, George Eugene Boyd. They take this occasion to endorse the sentiments expressed in the memoir prepared on behalf of the Committee on Maintenance of Way Work Equipment which appears on page 324.

Report on Assignment 2

Principles of Design of Masonry Structures

Collaborating with Committees 1, 5, 6, 7, 13, 15, 28, 29 and 30

R. L. Mays (chairman, subcommittee), A. J. Boase, Meyer Hirschthal, J. E. Kalinka, A. P. Kouba, A. N. Laird, B. J. Ornburn, W. R. Prass, Everett Scroggie, J. H. Shieber.

Part 1—Crib Walls

Last year your committee presented as information, tentative specifications for reinforced concrete cribbing, metal cribbing, and timber cribbing, so that the Association would have an opportunity to review and criticise them before they were offered for adoption and publication in the Manual. During the past year, no comments or suggestions have been received, and accordingly, they are recommended this year for adoption and publication in the Manual as new material in Chapter 8 identically as they appear in the Proceedings, Vol. 49, 1948, pages 244–250, incl.

Part 2—Design

Tentative specifications for design were submitted as information in 1947. They appear in the Proceedings, Vol. 48, 1947, pages 418–449, incl. The specifications were submitted with an invitation and request for critical review, comments, and criticisms, so that they could be constructively amended before offering them for adoption and publication in the Manual. Your committee has received much advice pertaining to these specifications, and there has been a great amount of controversy over certain issues within the committee. The following Design Specifications have resulted from much concerted effort, collaboration, and debate. Recognizing the importance of this issue, and the difficulty involved in preparing design specifications understandingly, after careful consideration and utilizing the best thinking of authorities on the subject, your committee offers the following specifications for adoption and publication in the Manual to replace the material now included on pages 8–35 to 8–52.5, incl.

SPECIFICATIONS FOR DESIGN OF PLAIN AND REINFORCED CONCRETE MEMBERS

A. GENERAL

1. Scope

These specifications shall govern the design of plain and reinforced concrete members of railway structures supporting or protecting tracks.

2. Highway Bridges

Unless otherwise specified by highway authority, all highway bridges shall be designed in accordance with the latest Standard Specifications for Highway Bridges adopted by the American Association of State Highway Officials.

3. Buildings

Unless otherwise specified by city ordinance or state code, all railway buildings shall be designed in accordance with the latest Building Code Requirements for Reinforced Concrete of the American Concrete Institute, subject to design loads conforming to railway requirements, and the unit stresses hereinafter specified.

B. ASSUMPTIONS

1. Basic Assumptions

The design of reinforced concrete members under these specifications shall be based on the following assumptions:

Calculations shall be made using allowable unit stresses and safe loads rather than ultimate strength and ultimate loads.

Plane sections normal to the axis remain plane after bending, shearing distortions being neglected.

Tensile strength of concrete is negligible in resisting bending.

The ratio of the modulus of elasticity of steel to that of concrete, for concrete of a given strength, is constant in flexural members within the range of allowable unit stresses. The ratio, however, is not considered as fixed in the case of columns or in the case of compression reinforcement in flexure where, due to plastic flow, the reinforcement will be more highly stressed than indicated by a constant value of the modular ratio.

2. Temperature Change

In railway structures such as elastic frame bridges, and similar types where temperature change is an important factor in the resultant stresses, it is assumed that the temperature change is uniformly distributed throughout the member affected. For design purposes the linear coefficient for temperature change shall be taken as 0.000006 per deg. F. Location, mass, and exposure conditions shall determine the temperature range.

3. Volume Change

Where shrinkage is considered a factor in design, the linear coefficient of the volume change shall be assumed to range from 0.00015 to 0.00045, depending upon the size of the member, the moisture conditions, cement, type of aggregates, water content, and amount of curing.

C. DESIGN LOADS

1. General

The following loads and forces shall be used in the design of railway masonry structures supporting tracks:

Dead load
Live load
Impact
Centrifugal force
Other lateral forces
Longitudinal forces

Each member of the structure shall be designed for that combination of such loads and forces that can occur simultaneously to produce the maximum stress.

2. Dead Load

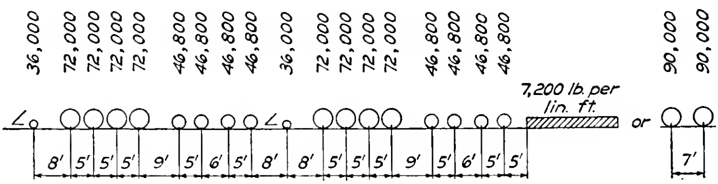
The dead load shall consist of the estimated weight of the structural member, plus that of the track, ballast, fill and other portions of the structure supported thereby.

The unit weight of materials comprising the dead load, except in special cases involving unusual conditions or materials, shall be assumed as follows:

Track rails, inside guard rails and fastenings
200 lb. per lin. ft. of track
Ballast, including track ties—120 lb. per cu. ft.
Reinforced concrete—150 lb. per cu. ft.
Earth filling materials—120 lb. per cu. ft.
Waterproofing and protective covering—estimated weight.

3. Live Load

The recommended live load for each track of main line structures is Cooper E 72 loading with axle loads and axle spacing as shown in the diagram. On branch lines and in other locations where the loading is limited to the use of light equipment, or cars only, the live load may be reduced, as directed by the engineer.



Cooper E 72 Wheel Load Diagram.

The axle loads on structures may be assumed as uniformly distributed longitudinally over a length of 3 ft., plus the depth of ballast under the tie, plus twice the effective depth of slab, limited, however, by the axle spacing.

The live load for each track of structures with ballasted deck or structures under shallow fills, shall be assumed as uniformly distributed over a width of 14 ft., unless further restricted by the distance between centers of adjacent tracks or structural conditions.

The lateral distribution of the live load from a single track for structures under deep fills where there is little likelihood of any future additional tracks, shall be assumed as uniform over a width equal to the length of track tie, plus the depth of ballast and fill below the bottom of tie, unless limited by the extent of the structure.

The lateral distribution of the live load for structures under deep fills carrying multiple tracks, shall be assumed as uniform between centers of outside tracks, and the loads beyond these points shall be distributed as specified for single track. Widely separated tracks shall not be included in the multiple track group.

In calculating the maximum live load stresses in a structural member due to simultaneous loading on two or more tracks, the following proportions of the specified live load shall be used:

For two tracks—full live load.

For three tracks—full live load on 2 tracks and ½ on the other track.

For four tracks—full live load on two tracks, ½ on one track, and ¼ on the remaining track.

The tracks selected for full live load in accordance with the listed limitations shall be those tracks, which, when fully loaded, will produce the maximum stress in the member under consideration.

4. Impact Load

To the axle loads specified, there shall be added impact forces, applied at the top of rail, distributed the same as outlined for the axle loads, and equal to the following percentage of the live load:

$$I = \frac{100\,L}{L + D} \qquad (1)$$

where I is the percentage of the live load for impact. D is the dead load applicable to the member for which computations are being made.

L is the total live load on the member for which computations are being made.

Where, by reason of the mass of the structure or other features, the effect of impact may be dissipated, the engineer may use his judgment in reducing the percentage produced by the above formula.

5. Centrifugal Force

On curves, a centrifugal force corresponding to each axle load shall be applied horizontally through a point 6 ft. above the top of rail measured along a line perpendicular to the line joining the tops of the rails and equidistant from them. This force shall be the percentage of the live load taken from the table.

On curves, each axle load on each track shall be applied vertically through the point defined in the first paragraph of this article.

The greater of loads on high and low sides of a superelevated track shall be used for the design of supports under both sides.

The table following gives the permissible speeds and the corresponding centrifugal force percentages for curves with the amounts of superelevation shown. It is based on a maximum speed of 120 mph. and a maximum superelevation of 7 in., resulting in a maximum centrifugal force of 17.5 percent.

If the conditions at the site restrict the permissible speeds to less than those shown in the table, the centrifugal force shall be taken for the greatest speed expected.

D	E	S	C	D	E	S	C
0°–10′		120	2.81	2°–30′	7	77	17.5
0°–20′	0.16	120	5.62	3°–00′	7	71	17.5
0°–30′	1.75	120	8.42	3°–30′	7	65	17.5
0°–40′	3.33	120	11.23	4°	7	61	17.5
0°–50′	4.92	120	14.04	5°	7	55	17.5
1°–00′	6.50	120	16.85	6°	7	50	17.5
1°–15′	6.80	109	17.5	8°	7	43	17.5
1°–30′	7	100	17.5	10°	7	39	17.5
1°–45′	7	93	17.5	15°	7	32	17.5
2°–00′	7	87	17.5	20°	7	27	17.5
2°–15′	7	82	17.5				

D = Degree of curve.
E = Superelevation in inches.
S = Permissible speed in miles per hour.
C = Centrifugal force in percentage of the live load.

$$C = 0.00117\, S^2 D = 1.755\,(E + 3)$$

$$E = \frac{S^2 D}{1500} - 3 = \frac{C - 5.265}{1.755}$$

$$S^2 = \frac{1500}{D}\,(E + 3)$$

6. Other Lateral Forces

The wind force shall be assumed as 30 lb. per sq. ft. on the vertical projection of the structure, applied at the center of gravity of the vertical projection; plus a moving load of 300 lb. per lin. ft. on the train, applied 8 ft. above the top of rail. The wind force shall be assumed to act horizontally, in a direction perpendicular to the center line of the track.

7. Longitudinal Force

The longitudinal force resulting from the stopping and starting of trains shall be either the force due to braking, equivalent to 15 percent of the total live load without impact; or the force due to traction, equivalent to 25 percent of the weight on the driving wheels on said structure without impact, whichever is the greater.

The longitudinal force shall be taken on one track only and shall be assumed to act 6 ft. above the top of the rail.

For bridges where, by reason of continuity of members or frictional resistance, much of the longitudinal force will be carried directly to the abutments (such as continuous or ballasted deck bridges of only 3 or 4 spans) only ½ of the longitudinal force shall be considered.

The longitudinal force shall be distributed to the supporting members of the substructure, such as piers and abutments, taking into account their relative stiffness, and the types of bearings.

D. ALLOWABLE UNIT STRESSES

1. Modular Ratio *n*

The ratio of the modulus of elasticity of steel to that of concrete, E_s/E_c equals n, shall be based upon the compressive strength of the concrete as follows:

f'_c	n
2000–2400	15
2500–2900	12
3000–3900	10
4000 and over	8

For lightweight concrete the values of n shall be determined by the engineer.

f'_c is the ultimate compressive strength of the concrete at the age of 28 days, based upon tests of 6-in. by 12-in., or 8-in. by 16-in. cylinders made and tested in accordance with ASTM Specifications Serial Designations C 31 and C 39.

2. Concrete

f_c is the unit compressive stress in the concrete.
v is the unit shearing stress.
u is the unit bond stress.
f_s is the unit tensile stress in the longitudinal reinforcement.
f_w is the unit tensile stress in the web reinforcement.
f'_s is the unit compressive stress in the longitudinal reinforcement.
d is the depth from compression surface of beam or slab to the center of gravity of longitudinal reinforcement.

Flexure f_c

Extreme fiber stress in compression .... 0.40 f'_c
Extreme fiber stress in compression in continuous beams adjoining supports .... 0.45 f'_c

Bearing f_c

Full area loaded .... 0.25 f'_c
Load on one-third of area with minimum edge distance of 6 in., f_c variable maximum .... 0.35 f'_c
But not more than 1050 psi.
When the loaded area is greater than one-third but less than the full area, the allowable bearing stress shall be interpolated, but the minimum edge distance shall be 6 in.

Axial compression f_c

In pedestals .... 0.25 f'_c
In columns see paragraphs H 2, H 3, H 4.

Tension—extreme fiber stress (plain concrete footings only) .... 0.025f'_c

Shear v

Beams without web reinforcement and without special anchorage of longitudinal steel .... .0.02 f'_c
Beams without web reinforcement but with special anchorage of longitudinal steel .... 0.03 f'_c
Beams with properly designed web reinforcements, but without special anchorage of longitudinal steel .... 0.06 f'_c
Beams with properly designed web reinforcement, and with special anchorage of longitudinal steel .... 0.075f'_c
Flat slabs at distance d from edge of column capital, or dropped panel 0.03 f'_c
Footings with longitudinal bars having no special anchorage .... 0.02 f'_c
Footings with longitudinal bars having special anchorage .... 0.03 f'_c
Combined footings and foundations designed as beam elements with properly designed web reinforcement and special anchorage .... 0.06 f'_c

Bond u

In beams, slabs and one-way footings:

Plain bars	0.04 f'_c	but not over	160 psi.
Deformed bars	0.05 f'_c	" " "	200 "

In multiple-way footings:

Plain bars	0.03 f'_c	" " "	120 "
Deformed bars	0.0375 f'_c	" " "	150 "

When special anchorage is provided, 1½ times these values may be used, but in no case to exceed 180 psi. for plain bars or 225 psi. for deformed bars.

3. Reinforcement

Flexure f_s (with or without axial loads)

Structural grade billet steel bars	18,000 psi.
Intermediate grade and hard-grade billet steel	20,000 "
Wire mesh not exceeding ½ in. in dia. when used in one-way solid slabs slabs only—50 percent of minimum yield point but not to exceed	24,000 "
Cold drawn steel wire	24,000 "
Tension f_w in web reinforcement, all grades of steel	16,000 "
Compression f'_s in column verticals:	
Structural grade billet steel bars	13,200 "
Hard-grade	16,000 "
Intermediate grade billet steel bars	16,000 "

Compressive reinforcement in flexural members—See E 4.
Compression in composite and combination columns—See H 4, H 5.

4. Maximum Combined Stresses

Members subject to stresses produced by a combination of dead load, live load, impact, and centrifugal force, with other lateral forces and with longitudinal force, may be proportioned for unit stresses 25 percent greater than those specified; but the section of any member shall not be less than that required for the combination of dead load, live load, impact, and centrifugal force at the specified unit stresses.

E. DESIGN OF BEAMS, SLABS, AND FRAMES

1. Span Lengths

The effective span of continuous beams and slabs or elastic frames shall be taken as the center-to-center distance between supports.

The effective span of freely supported beams or slabs may be taken as the center-to-center distance between supports, but shall not be less than the clear span plus the distances to centers of the required bearing areas.

The effective span of slabs built integrally with supports capable of fully restraining the slab, shall be taken as the clear distance between supports.

2. Computed Stresses

The bending moments and shears produced in frames and continuous beams by the various applied loads shall be computed in accordance with the elastic frame theory by any of the recognized methods of analysis, such as moment distribution, slope deflection, theorem of three moments, virtual work, etc.

Rigorous methods of analysis are recommended for continuous girder bridges or other statically indeterminate structures carrying moving railway loading. The objective in any case is to recognize that moments in one member due to applied loads will produce moments, and consequently stresses in adjoining rigidly connected members in proportion to the stiffness of the various members.

Approximate methods of analysis may be used for less important or simpler structures.

3. Stiffness

The stiffness, K, of a member is defined as SEI divided by l or h, where S is a coefficient depending upon the variation in the moment of inertia throughout a member, E is the modulus of elasticity of the material, I is the moment of inertia of the minimum cross section of the member, l is the span length, and h is the height of columns.

Where deflections or displacements are not involved, K is SI divided by l or h.

For beams with a constant moment of inertia S equals 4. For beams having a variable moment of inertia S shall be calculated or may be taken from standard text-books on statically indeterminate structures. When each member of a frame or continuous beam has a constant moment of inertia throughout its length S may be omitted.

The moment of inertia of flexural and compression members, for purposes of computing the relative stiffness, may be that of the gross cross sectional area of the member, making reasonable allowance for the effect of flange width in T-beams as outlined in E 4.

4. General Limitations for Beams

Lateral Support

If the distance between lateral supports for the compression face of a beam exceeds 24 times the least width of the compression face, the allowable unit stress shall be reduced. In no case shall the distance between lateral supports be more than 36 times the least width, at which limit the reduction in allowable unit stress shall be 50 percent. Proportionate reduction shall be made for intermediate ratios of distance between lateral supports to width of beam.

Compressive Reinforcement in Beams.

Compressive reinforcement in girders or beams shall be secured against buckling by ties or stirrups adequately anchored in the concrete and spaced not more than 16 bar diameters or 48 tie or stirrup diameters. Where compression reinforcement is used, the value of "n" for calculating the amount of compressive reinforcement required, shall be taken as twice the value given in paragraph D 1. However, in no case shall a stress in compressive reinforcement greater than 16,000 psi. be allowed.

T-beams and L-beams.

In T-beam and L-beam design, provision shall be made for constructing the slab and beam integrally.

The effective flange width used in the design of T-beams shall not exceed ¼ of the span length of the beam, nor shall the overhanging width on either side of the web exceed eight times the thickness of the slab, or ½ the clear distance to the next beam.

For beams having a flange on one side only (L-beams), the effective overhanging flange width shall not exceed 1/12 of the span length of the beam, nor 6 times the thickness of the slab, nor ½ the clear distance to the next beam.

When the principal slab reinforcement is parallel to the beam, transverse reinforcement shall be provided in the top of the slab. This reinforcement may be designed to carry the load on that portion of the slab which is assumed to act as the flange of the T-beam or L-beam. The spacing of the reinforcement shall not exceed twice the effective thickness of the slab, nor in any case 18 in.

Provision shall be made for the compressive stress at the support in continuous T-beam or L-beam construction, considering the web section as a rectangular beam with both tensile and compressive reinforcement.

The overhanging portion of the flange of the beam shall not be considered as effective in computing the shear and diagonal tension resistance of T-beams and L-beams.

F. SHEAR AND DIAGONAL TENSION

1. Notation

A_v is the total normal cross-sectional area of web reinforcement in any one plane.
α is the angle between inclined web bars and axis of beam.
b is the width of rectangular flexural member or web of T, L or I sections.
d is the depth from compression face of beam or slab to centroid of longitudinal tensile reinforcement.
f'_c is the compressive strength of concrete at age of 28 days.
f_w is the tensile unit stress in web reinforcement.
j is the ratio of distance between centroid of compression and centroid of tension to the depth d.
s is the spacing of stirrups or of bent bars in a direction parallel to that of the main reinforcement.
v is the shearing unit stress.
V is the total shear.
V' is the excess of the total shear over that permitted on the concrete, with the exception that when v is greater than $0.06f'_c$ V' is the total shear.

2. Shearing Unit Stress

The shearing unit stress v, as a measure of diagonal tension, in reinforced concrete flexural members shall be computed by the formula:

$$v = \frac{V}{bjd} \qquad (2)$$

When the value of the shearing unit stress computed by formula (2) exceeds the shearing unit stress permitted for the unreinforced concrete section, web reinforcement shall be provided to carry the excess.

When the shearing unit stress exceeds $0.06f'_c$ the web reinforcement shall be provided to carry the entire shear.

3. Types of Web Reinforcement

Web reinforcement shall consist of:

Stirrups or web reinforcement bars perpendicular to the longitudinal steel.

Stirrups or web reinforcement bars rigidly attached to the longitudinal steel and making an angle of 30 deg. or more with the longitudinal steel.

Longitudinal bars bent so that the axis of the inclined portion of the bar makes an angle of 15 deg. or more with the axis of the longitudinal portion of the bar.

Stirrups or other bars to be considered effective as web reinforcement shall be anchored at both ends, according to the provisions of G 5.

4. Stirrups

The area of steel required in stirrups placed perpendicular to the longitudinal reinforcement shall be computed by the formula:

$$A_v = \frac{V's}{f_w jd} \qquad (3)$$

Inclined stirrups shall be proportioned by formula (5).

Stirrups placed perpendicular to the longitudinal reinforcement shall not be used alone as web reinforcement when the shearing unit stress (v) exceeds $0.06f'_c$.

5. Bent Bars

When the web reinforcement consists of a single bent bar or of a group of bars bent in one plane, the required area of such bars shall be computed by the formula:

$$A_v = \frac{V'}{f_w \sin \alpha} \qquad (4)$$

In formula (4) V' shall not exceed $0.04f'_c\, bjd$.

The length of beam over which a single bent bar or a group of bars bent in one plane may be considered effective, shall be measured one-half each way from the bar at the mid-depth of the beam, and shall not exceed ¾ of the effective depth.

Where there is a series of parallel bent bars, the required area shall be determined by the formula:

$$A_v = \frac{V's}{f_w jd\ (\sin \alpha + \cos \alpha)} \qquad (5)$$

6. Combined Web Reinforcement

Where more than one type of reinforcement is used to reinforce the same portion of the web, the total shearing resistance of this portion of the web shall be assumed as the sum of the shearing resistances computed for the various types separately. In such computations the allowable shearing resistance of the concrete shall be included only once, and no one type of reinforcement shall be assumed to resist more than $2/3\ V'$.

7. Spacing of Web Reinforcement

Where web reinforcement is required it shall be so spaced that every 45 deg. line (representing a potential crack) extending from the mid-depth of the beam (downward and towards the nearest support) to the longitudinal tension bars shall be crossed by at least one line of web reinforcement. If a shearing unit stress in excess of $0.06f'_c$ is used, every such line shall be crossed by at least two lines of reinforcement.

8. Critical Sections

The critical section for shear or diagonal tension in beams with two or more supports shall be taken at the face of the supports.

For the critical sections in footings see Article I.

G. BOND AND ANCHORAGE

1. Notation

d is the depth from compression face of beam or slab to centroid of longitudinal tensile reinforcement.

f'_c is the compressive strength of concrete at age of 28 days.

j is the ratio of distance between centroid of compression and centroid of tension to the depth d.

Σo is the sum of perimeters of bars in one set.

u is the bond stress per unit of surface area of bar.

V is the total shear.

2. Computation of Bond Stress in Beams

In flexural members in which the tensile reinforcement is parallel to the compression face, the bond stress at any cross section shall be computed by the formula:

$$u = \frac{V}{\Sigma ojd} \qquad (6)$$

in which V is the shear at that section.

Adequate end anchorage shall be provided for the tensile reinforcement in all flexural members to which formula (6) does not apply, such as sloped, stepped or tapered footings, brackets or beams in which the tensile reinforcement is not parallel to the compression face.

3. Ordinary Anchorage Requirements

Tensile negative reinforcement in any span of a continuous, restrained or cantilever beam, or in any member of a rigid frame shall be adequately anchored by bond, hooks or mechanical anchors in or through the supporting member. Within any such span every reinforcing bar, whether required for positive or negative reinforcement, shall be extended at least 12 diameters beyond the point at which it is no longer needed to resist stress. In cases where the length from the point of maximum tensile stress in the bar to the end of the bar is not sufficient to develop this maximum stress by bond alone, the bar shall be extended to such a point that with the addition of a standard hook (See G 7) the maximum tensile unit stress can be developed. If preferred, the bar may be bent across the web at an angle of not less than 15 deg. with the longitudinal portion of the bar and made continuous with the reinforcement which resists moment of opposite sign.

Of the positive reinforcement in continuous beams not less than ¼ the area shall extend along the same face of the beam into the support a distance of ten or more bar diameters. Where extension of the reinforcement into the support a distance of 10 or more bar diameters is impracticable the bars shall be extended as far as possible into the support and terminated in standard hooks or other adequate anchorage.

In simple beams, or at the outer or freely supported ends of end spans of continuous beams, at least ½ the positive reinforcement shall extend along the same face of the beam into the support a distance of 12 or more bar diameters, or shall be extended as far as possible into the support and terminated in standard hooks.

4. Special Anchorage Requirements

Where increased shearing or bond stresses are permitted because of the use of special anchorage (See D 2), every bar except those specifically mentioned in G 3, second paragraph, shall be terminated in a standard hook in a region of compression, or shall be bent across the web at an angle of not less than 15 deg. with the longitudinal portion of the bar and made continuous with the reinforcement resisting moment of opposite sign.

5. Anchorage of Web Reinforcement

Single separate bars used as web reinforcement shall be anchored at each end by one of the following methods:

(a) Welding to longitudinal reinforcement.
(b) Hooking tightly around the longitudinal reinforcement through 180 deg.
(c) Embedment above or below the mid-depth of the beam on the compression side, a distance sufficient to develop the stress to which the bar will be subjected at a bond stress of not to exceed 0.04 f'_c on plain bars nor 0.05 f'_c on deformed bars.

(d) Standard hook (See G 7), considered as developing 10,000 psi, plus embedment sufficient to develop by bond the remainder of the stress to which the bar is subjected. The unit bond stress shall not exceed that specified in D 2. The effective embedded length shall not be assumed to exceed the distance between the mid-depth of the beam and the point of tangency of the hook.

The extreme ends of bars forming simple U or multiple stirrups shall be anchored by one of the methods outlined for single separate bars or shall be bent through an angle of at least 90 deg. tightly around a longitudinal reinforcing bar not less in diameter than the stirrup bar, and shall project beyond the bend at least twelve diameters of the stirrup bar.

The loops or closed ends of such stirrups shall be anchored by bending around the longitudinal reinforcement through an angle of at least 90 deg. or by being welded or otherwise rigidly attached thereto.

Hooking or bending stirrups or separate web reinforcement bars around the longitudinal reinforcement shall be considered effective only when these bars are substantially perpendicular to the longitudinal reinforcement.

Longitudinal bars bent to act as web reinforcement in a region of tension shall be continuous with the longitudinal reinforcement where this is possible. The tensile stress in each bar shall be fully developed in both the upper and the lower half of the beam by one of the following methods:

Methods (c) and (d) given for single separate bars.

By bond, at a unit bond stress not exceeding $0.04 f'_c$ on plain bars nor $0.05 f'_c$ on deformed bars, plus a bend of radius not less than twice the diameter of the bar, plus an extension of the bar, parallel to the upper or lower surface of the beam, of not less than 12 diameters of the bar terminating in a standard hook. This short radius bend extension and hook shall together not be counted upon to develop a tensile unit stress in the bar of more than 10,000 psi.

By bond, at a unit bond stress not exceeding $0.04 f'_c$ on plain bars nor $0.05 f'_c$ on deformed bars, plus a bend of radius not less than twice the diameter of the bar, and a continuation of the bar parallel to the upper or lower surface of the beam as longitudinal reinforcement. The short radius bend and continuity shall together not be counted upon to develop a tensile unit stress in the bar of more than 10.000 psi.

The tensile unit stress at the beginning of a bend may be increased from 10,000 psi. when the radius, of bend is two bar diameters, at the rate of 1000 psi. tension for each increase of 1½ bar diameters in the radius of bend, provided that the length of the bar in the bend and extension is sufficient to develop this increased tensile stress by bond at the unit stresses of $0.04 f'_c$ and $0.05 f'_c$ respectively for plain and deformed bars.

In all cases web reinforcement shall be carried as close to the compressive surface of the beam as weathering protection, fire protection or proximity of other steel will permit.

6. Anchorage of Bars in Footing Slabs

All bars in footing slabs shall be anchored by means of standard hooks. The outer faces of these hooks shall be not less than three inches nor more than six inches from the face of the footing.

7. Hooks

The terms "hook" or "standard hook" as used herein shall mean either:

A complete semicircular turn with a radius of bend on the axis of the bar of not less than three and not more than six bar diameters, plus an extension of at least four bar diameters at the free end of the bar, or

A 90-deg. bend having a radius of not less than 4 bar diameters plus an extension of 12 bar diameters.

Hooks having a radius of bend of more than six bar diameters shall be considered merely as extensions to the bars.

No hook shall be assumed to carry a load which would produce a tensile stress in the bar greater than 10,000 psi.

Hooks shall not be considered effective in adding to the compressive resistance of bars.

Any mechanical device capable of developing the strength of the bar without damage to the concrete may be used in lieu of a hook. Tests must be presented to show the adequacy of such devices.

H. DESIGN OF COLUMNS

1. General

Reinforced concrete or composite columns designed to carry the permissible maximum load shall have an unsupported length preferably not greater than 10 times the least lateral dimension.

However when the conditions require an unsupported length greater than 10 times the least lateral dimension, the maximum allowable load shall be reduced in accordance with the provisions of H 9.

Columns shall preferably have a minimum diameter or thickness of 12 in.

The unsupported length of a column is the clear distance between members which resist lateral movement of the column in at least two directions.

In columns restrained laterally by struts, the unsupported length shall be the clear distance between consecutive struts in each vertical plane; provided that to be an adequate support, two such struts shall meet the column at approximately the same level, and the angle between vertical planes through the struts shall not vary more than 15 deg. from a right angle. Such struts shall be of adequate dimensions and anchorage to restrain the column against lateral deflection.

In columns restrained laterally by struts or beams, with brackets used at the junction, the unsupported length shall be the clear distance between the edges of the brackets, provided that the bracket width equals that of the beam or strut and is at least half that of the column, and provided further that the face of the bracket makes an angle with the face of the column of at least 45 deg.

For rectangular columns, the unsupported length shall be that length which produces the greatest ratio of length to depth of section.

2. Spirally Reinforced Columns

ALLOWABLE LOAD.

The maximum allowable axial load P on columns reinforced with longitudinal bars and closely spaced spirals enclosing a circular core is given by the following formula:

$$P = 0.225\, f'_c A_g + A_s f'_s \qquad (7)$$

wherein A_g is the overall or gross area of the column.

f'_c is the compressive strength of the concrete at the age of 28 days.

f'_s is the nominal working stress in vertical column reinforcement, to be taken at 40 percent of the minimum specification value of the yield point, except for hard-grade steel

viz. 13,200 psi. for structural grade,
16,000 psi. for intermediate grade and hard-grade steel.

A_s is $p_g A_g$

p_g is the ratio of the effective cross-sectional area of vertical reinforcement to the gross area A_g.

LONGITUDINAL REINFORCEMENT.

The ratio p_g shall be not less than 0.01 nor more than 0.08. The minimum number of bars shall be six, and the minimum diameter of bar shall be 5/8 of an inch. The center-to-center spacing of bars within the periphery of the column core shall be not less than 2½ times the diameter for round bars or 3 times the side dimension for square bars. The clear spacing between individual bars or between pairs of bars at lapped splices shall be not less than two inches or twice the maximum size of the coarse aggregate used.

SPLICES IN LONGITUDINAL REINFORCEMENT.

The minimum length of lap for deformed bars with concrete having a compressive strength of 3000 psi. or higher, shall be 20 diameters for bars for structural grade steel and 24 diameters for bars of intermediate and hard grade steel. When the concrete strength is less than 3000 psi., the length of lap shall be 1/3 greater than the values just given.

The minimum length of lap for plain bars shall be 25 percent greater than that specified for deformed bars.

If approved by the engineer welded splices or other positive connections may be used instead of lapped splices. Welded splices shall preferably be used in cases where the bar size equals or exceeds 1⅛ in. An approved welded splice shall be defined as one in which the bars are butted and welded and that will develop in tension at least the yield point stress of the reinforcing steel used.

Where changes in the cross section of a column occur, the longitudinal bars shall either be sloped for the full length of the column, or offset in a region where lateral support is provided. When bars are offset, the slope of the inclined portion from the axis of the column shall not exceed 1 in 6 and the bars on each side of the offset shall be parallel to the axis of the column.

SPIRAL REINFORCEMENT.

The ratio of spiral reinforcement p' shall be not less than the value given by the following formula:

$$p' = 0.45\left[\frac{A_g}{A_c} - 1\right]\frac{f_c'}{f''_s} \qquad (8)$$

wherein p' is the ratio of volume of spiral reinforcement to the volume of the concrete core (out to out of spirals).

A_g/A_c is the ratio of gross area to core area of column.

f''_s is the useful limit stress of spiral reinforcement to be taken as 40,000 psi. for hot rolled rods of intermediate grade, and 60,000 psi. for cold drawn wire.

Spiral reinforcement shall consist of evenly spaced continuous spirals held firmly in place and true to line by at least three vertical spacer bars. For columns up to 18 in. core diameter, the minimum diameter of spiral bars shall be ¼ in. For columns larger than 18 in. core diameter, the minimum diameter of spiral bars shall be ⅜ in. Anchorage of spiral reinforcement shall be provided by 1½ extra turns of spiral rod or wire at each end of the spiral unit. Splices, where necessary, shall be made in spiral rod or wire by a lap of 1½ turns. The center-to-center spacing of the spirals shall not exceed 1/6 of the core diameter. The clear spacing between spirals shall not exceed 3 in., nor be less than 1½ in. or twice the maximum size of coarse aggregate used. The spiral reinforcement shall be protected everywhere by a covering of concrete cast monolithically with the core and having a minimum thickness of 1½ in. or 1½ times the maximum size of the coarse aggregate.

LIMITS OF COLUMN SECTION.

For columns built monolithically with concrete walls or piers, or columns of unusual section, the outer boundaries of the column section shall be taken as a circle 1½ in. outside the column spiral or as a square the sides of which are 1½ in. outside the spiral. In case two or more spirals are used in such a column the outer boundary shall be taken as a rectangle the sides of which are at any point at least 1½ in. outside of the spirals. For these types of spirally reinforced columns the value of A_g thus defined shall be used in both formulas (7) and (8).

3. Tied Columns

ALLOWABLE LOAD.

The maximum allowable axial load on columns reinforced with longitudinal bars and separate lateral ties shall be 80 percent of that given by formula (7).

LONGITUDINAL REINFORCEMENT.

The ratio p_g shall be not less than 0.01 nor more than 0.04. The minimum number of bars shall be four, and the minimum diameter shall be ⅝ in. The bars shall be placed with a clear distance from the column face of not less than 2 in.

SPLICES IN LONGITUDINAL REINFORCEMENT.

Splices in longitudinal reinforcement shall be made as outlined for spirally reinforced columns.

LATERAL TIES.

Lateral ties shall be at least ¼ in. in diameter and shall be spaced not over 16 bar diameters. 48 tie diameters, or the least dimension of the column. When there are more than four vertical bars, additional ties shall be provided so that all longitudinal bars are held firmly in their designed position.

LIMITS OF COLUMN SECTION.

In a tie column which, for architectural reasons, has a larger cross section than required by considerations of loading, a reduced effective area A_g not less than ½ of the total area may be used in applying the provisions of Section H 3.

4. Composite Columns

ALLOWABLE LOAD.

The allowable load on a composite column consisting of a structural steel column thoroughly encased in concrete reinforced with both longitudinal and spiral reinforcement, shall not exceed that given by the following formula:

$$P = 0.225\, A_c f'_c + f'_s A_s + f_r A_r \quad \text{.......} \quad (9)$$

wherein A_c is the net area of concrete section $= A_g - A_s - A_r$

A_s is the cross-sectional area of longitudinal bar reinforcement

A_r is the cross-sectional area of the steel core

f_r is the allowable unit stress in the steel column not to exceed 16,000 psi.

The remaining notation is that previously used.

DETAILS OF METAL CORE AND REINFORCEMENT.

The cross-sectional area of the metal core shall not exceed 20 percent of the gross area of the column. If a hollow metal core is used, it shall be filled with concrete. The amounts of longitudinal and spiral reinforcement and the requirements as to spacing of bars, details of splices, and thickness of protective shell outside the spiral shall conform to the limiting values specified for spirally reinforced columns. A clearance of at least 3 in. shall be maintained between the spiral and the metal core at all points except that when the core consists of a structural steel H-column, the minimum clearance may be reduced to 2 in.

SPLICES AND CONNECTIONS

Metal cores in composite columns shall be accurately milled at splices and positive provision shall be made for alinement of one core above another. Transfer of loads to the metal core shall be provided for by the use of bearing members such as billets, brackets or other positive connections. These shall be provided at the top of the metal core and at intermediate points where required. Ample section of concrete and continuity of reinforcement shall be provided at the junction with beams and girders. At the column base, provision shall be made to transfer the load to the footing at safe unit stresses in accordance with I 8. The base of the metal core shall be designed to transfer the load from the entire composite column to the footing, or it may be designed to transfer the load from the metal section only, provided it is so placed as to leave ample section of concrete above the base for the transfer of load from the reinforced concrete section of the column by means of bond on the vertical reinforcement and by direct compression on the concrete.

ALLOWABLE LOAD ON METAL CORE DURING CONSTRUCTION.

The metal cores of composite columns shall be designed to carry safely any construction or other loads to be placed upon them prior to their encasement in concrete.

5. Combination Columns

ALLOWABLE LOAD ON COMBINATION COLUMNS.

The allowable load on a structural steel column which is encased in concrete at least 2½ in. thick over all metal (except rivet heads), and reinforced as hereinafter required shall be computed by the following formula:

$$P = A_r f'_r \left[1 + \frac{A_c}{100 A_r}\right] \qquad (10)$$

wherein A_r is the cross-sectional area of the steel column.
f'_r is the allowable unit stress for the unencased steel column.
A_c is the total area of concrete section, $= A_g - A_r$

The concrete used shall develop a compressive strength of at least 2500 psi. at the age of 28 days. It shall be reinforced with welded wire mesh having wire not smaller than No. 10 gage, spaced in the vertical direction not more than 4 in. and in the horizontal direction not more than 8 in. This mesh shall extend entirely around the column at a distance of 1 in. inside the outer concrete surface, and shall be lap-spliced at least 40 wire diameters and wired at the splice.

Special billets or brackets shall be provided to transfer the loads from beams or girders to the steel columns.

The steel column shall be designed to safely carry any construction or other loads to be placed upon it prior to its encasement in concrete.

6. Pipe Columns

Allowable Load on Pipe Columns.

The allowable load on columns consisting of steel pipe filled with concrete shall not exceed that given by the following formula:

$$P = 0.225\, f'_c\, A_c + f''_r\, A_r \quad \ldots\ldots (11)$$

The value of f''_r shall be that given by the following formula:

$$f''_r = \left[18{,}000 - 70\frac{h}{R}\right] F \quad \ldots\ldots (12)$$

wherein f''_r is the allowable unit stress in the steel pipe section.
h is the unsupported length of the column.
R is the radius of gyration of the steel pipe section.

$$F = \frac{\text{tensile yield point of pipe material}}{45{,}000}$$

If the yield point is not known, the factor F shall be taken as 0.5. If the concrete strength is not known, it shall be assumed as 2500 psi.

7. Bending Moments in Columns

The bending moments in the columns of all reinforced concrete structures shall be determined on the basis of loading conditions and restraint and shall be provided for in the design. When the stiffness and strength of the columns are utilized to reduce moments in beams, girders, or slabs, as in the case of rigid frames in general, the need of recognizing column moments is obvious; in other forms of continuous construction where column moments are unavoidable, they shall also be provided for in the design.

8. Determination of Combined Axial and Bending Stresses

In a reinforced concrete column which is (1) symmetrical about two perpendicular planes through its axis and (2) subject to an axial load N, combined with bending in one or both of the planes of symmetry (but with the ratio of eccentricity to depth, e/t. no greater than 0.5 in either plane), the combined fiber stress in compression may be computed on the basis of recognized theory applying to uncracked sections, using formula (13).

$$f_c = \frac{N}{A_g}\left[\frac{1 + \dfrac{De}{t}}{1 + (n-1)\, p_g}\right] \quad \ldots\ldots (13)$$

wherein N is the axial load applied to the column.
A_g is the overall or gross area of the column.
t is the overall depth of column section.
D is $\frac{t^2}{2R^2}$ a factor usually varying from 3 to 9.
R is the radius of gyration of the entire column section.
e is the eccentricity of the resultant load on a column, measured from the gravity axis.

Equating this calculated stress, f_c to the allowable stress, f_p in formula (15) it follows that the column can be designed for an equivalent axial load P as given by formula (14).

$$P = N\left[1 + \frac{CDe}{t}\right] \quad \text{.......... (14)}$$

When bending exists on both axis of symmetry, the quantity De/t is to be computed as the numerical sum of the De/t quantities in the two directions.

For columns in which the load, N, has an eccentricity e greater than ½ the column depth t or for sections at construction joints, or for beams subject to small axial loads the determination of the fiber stress f_c shall be made by use of recognized theory for cracked sections, based on the assumption that no tension exists in the concrete. For such cases the tensile steel stress shall also be investigated.

9. Allowable Combined Axial and Bending Stress

For spiral and tied columns, eccentrically loaded or otherwise subjected to combined axial compression and flexural stress, the maximum allowable compressive stress f_p is given by formula (15).

$$f_p = f_a\left[\frac{1 + \frac{De}{t}}{1 + \frac{CDe}{t}}\right] = f_a\left[\frac{t + DE}{t + CDe}\right] \quad \text{.......... (15)}$$

wherein f_a is the average allowable stress in the concrete of an axially loaded reinforced concrete column, as given in formula (16) for spirally reinforced columns. For tied columns the value of f_a is 80 percent of that given for spirally reinforced columns.

$$f_a = \frac{0.225\, f'_c + f_s\, p_g}{1 + (n - 1)\, p_g} \quad \text{.......... (16)}$$

C is given by formula (17)

$$C = \frac{f_a}{0.40\, f'_c} \quad \text{.......... (17)}$$

For tied columns which are designed to withstand combined axial and bending stresses, the limiting total steel ratio of 0.04 may be increased to 0.08, provided that the amount of steel spliced by lapping shall not exceed a steel ratio of 0.04 in any 3-ft. length of column. The size of the column designed under this provision shall in no case be less than that required to withstand axial load alone.

10. Long Columns

Allowable Load on Long Columns.

The maximum allowable load P' on axially loaded reinforced concrete or composite columns having an unsupported length h greater than 10 times the least lateral dimension d is given by the following formula:

$$P' = P\left[1.3 - 0.03\frac{h}{d}\right] \quad \text{.......... (18)}$$

wherein P is the allowable axial load on a short column.

ALLOWABLE LOAD ON ECCENTRICALLY LOADED COLUMNS.

The maximum allowable load P' on eccentrically loaded columns having an unsupported length greater than 10 times the least lateral dimension is also given by formula (18) in which P is the allowable eccentrically applied load on a short column of the same cross section.

In long columns subjected to definite bending stresses, the unsupported length h shall not exceed 20 times the least lateral dimension.

11. Reinforced Concrete Bearing Walls

The allowable stresses in reinforced concrete bearing walls with minimum reinforcement as specified later, shall be $0.25 f'_c$ for walls having a ratio of height to thickness of 10 or less, and shall be reduced proportionally to $0.15 f'_c$ for walls having a ratio of height to thickness of 25. When the reinforcement in bearing walls is designed, placed and anchored in position as for tied columns, the allowable stresses shall be the same as for tied columns, (see H 3). In the case of concentrated loads, the length of the wall to be considered as effective for each shall not exceed the center-to-center distance between loads, nor shall it exceed the width of the bearing plus four times the wall thickness. The ratio P_g shall not exceed 0.04.

Walls shall be designed for any lateral or other pressure to which they are subjected. Proper provision shall be made for eccentric loads and wind stresses. In such designs the allowable stresses shall be as given in Section D.

Reinforced concrete bearing walls shall have a thickness of at least 1/25 of the unsupported height; provided however, that approved buttresses, built-in columns, or piers designed to carry all the vertical loads, may be used in lieu of increased thickness.

Reinforced concrete walls shall be properly anchored to footings, columns, pilasters, buttresses and intersecting walls.

Reinforced concrete walls shall be reinforced with an area of steel in each direction, both vertical and horizontal, at least equal to 0.0025 times the cross-sectional area of the wall, if of bars, and 0.0018 times the area if electrically welded wire fabric. The wire of the welded fabric shall be of not less than No. 10 USS wire gage. Walls more than 10 in. in thickness shall have the reinforcement for each direction placed in two layers parallel with the faces of the wall. One layer consisting of not less than ½ and not more than 2/3 the total required shall be placed not less than two in. nor more than 1/3 the thickness of the wall from the exposed surface. The other layer, comprising the balance of the required reinforcement, shall be placed not less than two in. and not more than 1/3 the thickness of the wall from the unexposed surface. If both faces are exposed, ½ the reinforcement shall be placed not less than two in. and not more than 1/3 the thickness of the wall from both surfaces. Bars, if used, shall be not less than the equivalent of ½-in. round bars, nor shall they be spaced more than 15 in. on centers. Welded wire reinforcement for walls shall be in flat sheet form.

I. DESIGN OF FOOTINGS

1. General

For purposes of design, footings may be divided into simple, continuous or cantilever beams, or a combination thereof, and proportioned accordingly.

2. Loads on Foundations

The load per unit of area on soil foundations shall be computed by dividing the total load by the area of the footing and correcting for any eccentricity.

The load on pile foundations shall be computed in the same manner, except that the pile reactions shall be considered as concentrated at the pile centers.

3. Critical Sections

The critical section for bending in a concrete footing which supports a rectangular or square concrete column, pedestal, or wall, shall be taken at the face of the column, pedestal or wall.

The critical section for bending in a concrete footing which supports a column other than square or rectangular, shall be taken at the side of a concentric square of equivalent area.

The critical section for bending in a concrete footing beneath a masonry wall where bond with the footing is negligible, shall be taken midway between the middle and the edge of the wall.

The critical section for bending in a concrete footing which supports a metallic column base, shall be taken midway between the face of the column and the edge of the metallic base.

The critical sections for bond shall be taken at the same planes as those for bending, and the shear used for computing bond shall be based on the same loading as for bending. Bond shall also be investigated at planes where changes in section or in reinforcement occur.

The critical section for diagonal tension in isolated footings on soil foundations shall be taken on the concentric vertical planes through the footing at a distance equal to the effective depth from each face of the column, pedestal or wall.

The critical section for diagonal tension in isolated footings on piles shall be taken on the concentric vertical planes through the footing at a distance equal to ½ the effective depth from each face of the column, pedestal or wall, and piles whose centers are at or outside this section shall be included in computing the shear.

In sloped or stepped footings, analyses shall be made of stresses at sections where the slope or depth changes, outside the critical sections as defined.

4. Calculation of Stresses

Bending, shearing and bond stresses in isolated or combined footings shall be determined for the critical sections as defined. For the projecting portion of any footing the bending moment shall be taken as the statical moment of all the forces outside the critical section. In two-way isolated footings, tensile reinforcement shall be determined by using 85 percent of the moment thus computed. In one-way footings, such as wall footings, the full moment shall be used.

For isolated footings cast monolithically, the section resisting bending in any direction shall be the full critical section cut, except as noted for sloped or stepped footings.

In sloped footings the section resisting bending shall be as defined above provided the slope of the top is not such as to require special treatment of the projecting cantilever as a wedge-shaped beam. A slope of 1 vertical to 2 horizontal shall be considered as a satisfactory limit. The slope of the footing top need not be uniform, provided the limit of 1 on 2 is not exceeded at any point.

For stepped footings cast monolithically, the section resisting bending shall be limited to the lower step, or to the area falling within the boundaries of an imaginary sloped footing which meets the requirements of the previous paragraph and lies entirely within the stepped footing.

The reinforcement shall be distributed over the entire width of the section.

In case the reinforcement does not cross a section at which bending moment is computed, at right angles, only the component of the sectional area of the reinforcement normal to the section shall be considered effective.

5. Combined Footings

The critical sections for transverse bending shall be as outlined in I 3.

The longitudinal reinforcement shall be distributed over the entire width.

The transverse reinforcement at each column shall be proportioned to the column load and shall be placed uniformly in a band having a width not greater than the width of the column plus twice the effective depth of the footing.

The critical sections for diagonal tension in combined footings shall be taken at the faces of the supported members for all beam elements and for all projecting cantilevers.

6. Plain Concrete Footings

The design of plain concrete footings shall conform to the requirements of paragraphs I 3 and I 4 and the section shall be computed as a monolithic section of the entire width and depth measured from a plane two inches above the bottom of the footing.

7. Pedestals Without Reinforcement

The depth of a pedestal or pedestal footing shall be not greater than 3 times its least width and the projection on any side from the face of the supported member shall be not greater than ½ the depth.

When the sides of a pedestal are sloped or stepped, the depth shall not exceed 3 times the least width or diameter of the section midway between the top and bottom.

A pedestal footing supported directly on piles shall have a mat of reinforcing bars having a cross-sectional area of not less than 0.2 sq.in. per ft. in each direction, placed approximately 3 in. above the top of the piles.

8. Transfer of Stress at Base of Column

The compressive stress in the vertical reinforcement at the base of a column shall be transferred to a footing or pedestal by extending the bars into the footing or pedestal, by the use of dowels, or by means of metal bases.

When dowels are used there shall be at least one dowel for each column bar, and the total sectional area of the dowels shall be not less than the sectional area of the vertical steel in the column.

Dowels or column bars shall extend into the column, and into the footing or pedestal the distance required to transfer to the concrete at allowable bond stresses, their full working strength. Hooks shall not be considered as adding to bond resistance in compression.

The compressive stress in the concrete at the base of a column or pedestal shall be considered as being transferred by bearing to the top of the supporting pedestal or footing. The unit compressive stress on the loaded area shall not exceed the bearing stress allowable for the quality of the concrete in the supporting member as limited by the ratio of the loaded area to the supporting area.

The minimum distance from the edge of the column base to the edge of the top of the footing shall be 6 in., and the area of the top of a pedestal shall be at least twice the area of the column base.

9. Depth of Adjoining Footings

For soil foundations the difference in elevation of the bottoms of any two footings shall be such that a line drawn between the lower adjacent edges preferably shall not incline at an angle more than one half the angle of repose of the soil, nor greater than 45 deg. with the horizontal, unless adequate provisions are made to retain the soil. Local soil conditions should be given special consideration.

Report on Assignment 3

Foundations for Masonry Structures

Collaborating with Committees 1, 6, 7, 15 and 30

M. Nearing (chairman, subcommittee), J. R. Burkey, G. H. Dayett, Roscoe Owen, L. Spalding, Jamison Vawter, K. J. Wagoner, E. P. Wright.

Pile Foundations

A report embracing specifications for various types of pile foundations was submitted last year as information for review by Association members before offering it for adoption and publication in the Manual. In view of comments received during the year, and further thinking on the part of your committee, several revisions have been recommended. Your committee recommends for adoption and publication in the Manual the Specifications for Pile Foundations as they appear in the Proceedings, Vol. 49, 1948, pages 254–263, incl., revised in accordance with the following recommendations which will replace specifications now included on pages 8–87 to 8–89, and 8–117 to 8–122, incl.

Article A., Change Paragraph 1 Scope to read as follows:

These specifications cover the investigation, design and construction of pile foundation, under substructures located below the surface of the ground.

Article C., Change to read as follows:

C. ALLOWABLE LOAD ON PILES

1. Soil Investigation

Test borings or soundings shall be made at enough locations and to a sufficient depth below the ends of the piles to determine adequately the character of the material through which the piles are to be driven and of the materials underlying the points of the piles. The results of the borings, soundings and soil tests, taken into consideration with the function of the piles in service, will determine the type, spacing and length of piles that should be used and whether the piles will be end bearings, friction bearing or a combination of both types.

Sufficient borings or soundings should be made to determine the thickness of any material that may provide end bearings. If the bearing stratum is of doubtful thickness, the exploration should be extended below it to determine the capacity of the underlying material to support the load transmitted to it.

The borings or soundings should be of such a character as to disclose the looseness or denseness of cohesionless soils and the strength and compressibility of cohesive soils. The latter shall preferably be determined on the basis of laboratory tests for the moisture content, liquid limit, plastic limit and unconfined compressive strength.

2. Allowable Load on End Bearing Piles

A pile may considered end bearing when driven to an impenetrable material such as rock or hard shale or into a material that offers rapidly increasing resistance to driving when the tip reaches the end bearing stratum. The capacity of end bearing piles depends on the structural strength of the piles, crushing strength of the pile points, crushing strength of the materials supporting the piles at the point and the supporting strength of the stratum that affords end bearing. The structural and crushing strength of the pile depends upon the type of pile and shall be in accordance with the values provided by AREA specifications. If the end bearing strength of the stratum is ample, the capacity of a pile in a group is equal to the capacity of a single pile. When end bearing piles penetrate unconsolidated material such as new embankment, above the firm stratum, consideration should be given in design to the additional load that may be imposed on the pile as the material consolidates above the pile point. The design load where the end bearing stratum is sand, gravel, clay, soft rock or shale shall preferably be determined by loading test piles. Where end bearing capacity is not determined by test piles, the allowable load at the tip of the pile shall not exceed the value of the material supporting the pile as determined by test borings.

3. Allowable Load on Friction Piles

Any pile in silt or clay that does not derive its support from end bearing shall be considered a friction pile. A single row of piles shall not be considered as a group provided the piles are spaced not less than 2½ times their nominal butt diameter.

Where piles are driven in groups, consideration should be given not only to the allowable load per pile but also to the load that can be assigned safely to the group. On the average job and under normal soil conditions, the allowable load per group can usually be determined on the basis of the result of the soil exploration. In cohesive soils, the shearing strength may be taken as ½ the unconfined compressive strength. On large projects or where soil conditions are unusual, it is recommended that the soil information be supplemented by loading a group of test piles.

The loading tests shall be made to failure in accordance with the provisions of Article D, Paragraph 9, Class B Test. The average shearing stress in the soil at failure may be determined on the assumption that the total load is distributed on planes through the perimeter bounding the group and extending downward to the tips of the piles. The results of the test are directly applicable only when the piles of the design group are of the same type and have the same penetration, size and spacing as those of the test group and the probable effect of a variation in any of these items shall be reflected in the design. The ultimate capacity of the test group having thus been determined, the working load per pile can be selected using safety factors depending on the nature of the service load and character of the supported structure. Larger safety factors should be used where the entire load is dead load than are required for loads due to a combination of dead, live, wind and horizontal loads. A great deal more settlement (See Note 1) can be expected in a group of a larger number of piles than in the test group with the same load per pile in each group, and safety factors should be chosen which take this relationship into account.

4. Compaction Piles

Piles driven into loose granular material for the purpose of compacting the soil are considered to be compaction piles. The piles should be driven to a specified resistance and will generally have differing lengths. The allowable load may be determined by load test on a single pile after all piles in a group have been driven.

5. Combination End and Friction Bearing Piles

Where the pile penetrates material having substantial friction value and has its point driven on or into end bearing stratum, the pile may be designed for a combination of friction and end bearing. The allowable load per pile can usually be selected on the basis of the soil exploration. If the information is inadequate, it may be supplemented by a load test of a group of piles having their points several feet above the end bearing stratum and a second group driven to bearing in the stratum. The soil exploration shall also include an investigation of the material underlying an end bearing stratum that is limited in depth. For the purpose of structural analysis of a pile, the dead and permanent load may be considered as carried by end bearing if the pile reaches a firm stratum, and either all, or that part of live load up to the working value of the skin friction for the soil and pile, may be considered to be carried by friction bearing.

6. Lateral Support

A pile shall be considered fully supported laterally except that portion which is or may be, as a result of scour, in air or water, or which may be in muck, peat, thin mud or fluid material. Where a portion of the pile is not supported laterally as a short column, that portion shall be considered as a long column and proper allowance made in the design.

7. Pile Formula

When the cost of load tests or laboratory analyses is excessive in comparison with the cost of the project, the pile capacity may be determined by the Engineering News formula, but in any event the value of the material supporting the pile, as disclosed by the test borings, shall be adequate. Under no circumstances shall a pile formula be used to determine the capacity of a pile driven to rock, or of a friction pile in silt or clay.

> *Note 1.*—Settlement may be calculated approximately on the basis of the results of the soil tests by assuming that the load on each pile of a group is transferred to the ground at the lower third point of the pile. The settlement computation is then made as if the piles were not present and as if the material above the lower third point of the piles were incompressible.

H. CAST-IN-PLACE CONCRETE PILES

Metal Casings

Where gages are listed, the first, mentioned should read No. 18 Manufacturer's Standard Gage, and the two following notations should be No. 7 MSG and No. 9 MSG.

K. H-SECTION STEEL PILES

Capping

The first sentence in line four should read as follows:

The bearing plate shall be of such size that the pressure on the footing concrete shall not exceed 1050 psi.

Report on Assignment 5

Methods of Designing, Constructing and Maintaining Tunnels

Collaborating with Committees 1, 5, 28 and 29

C. B. Porter (chairman, subcommittee), G. F. Eberly, W. P. Geiser, G. A. McRoberts, R. V. Proctor, E. T. Rucker, D. H. Shoemaker, Neil Van Eenam.

Lining Railway Tunnels with Timber

Your committee prepared a report last year on the subject of lining railway tunnels with timber. This report was submitted as information in the form of a tentative specification. A critical review was invited from the Association so that the specification could be constructively amended before offering it for adoption and publication in the Manual as a new section in Chapter 8. During the past year several comments were received pertaining to the type of timber treatment that should be recommended. None of these, however, was of sufficient consequence to amend the provisions for treatment contained in the tentative report. Your committee now recommends as new material for adoption and publication in the Manual, the Specifications for Lining Railway Tunnels with Timber as they appear in the Proceedings, Vol. 49, 1948, pages 264–268, revised in accordance with the following recommendations:

Paragraph 17, page 268—after the first sentence, add—"When treated timber lining is used, packing timber shall be treated as outlined in Paragraph 4."

Paragraph 18, page 268—change Paragraph 203 to Paragraph 7.

Report on Assignment 6

Methods of Repairing Masonry, Including Internal Pressure Grouting

C. P. Schantz (chairman, subcommittee), L. T. Casson, R. W. Gilmore, J. S. Hancock, R. Hayes, L. H. Needham, W. M. Ray, G. E. Robinson.

This report is submitted as information with the view of offering it next year for adoption and publication in the Manual, at which time it will replace specifications now included on pages 8–141 to 8–142.

REPAIRING AND SOLIDIFYING MASONRY STRUCTURES

A. GENERAL

1. Scope

These specifications apply to restoration of deteriorated masonry by patching, encasement and pressure grouting.

Engineering plans should be made when strengthening of the structure is involved.

2. Preliminary Work

Conditions causing or contributing to deterioration, including faulty drainage, shall be corrected where practicable. Existing drains shall be cleaned and otherwise put in working order. New drains shall be installed when required.

If impracticable to correct inadequate drainage and thus prevent saturation, the part of the structure so exposed shall be made watertight by replacing honeycombed and unusually porous portions and/or by filling cracks and pores with pressure grout or waterproofing materials, all of which are subject to the approval of the engineer.

The effectiveness of existing expansion joints in any structure repaired or encased shall not be impaired.

3. Materials

The materials used shall conform in physical properties to the AREA Specifications for Concrete and Reinforced Concrete, except as hereinafter specified. Air entraining cement may be used if approved by the engineer.

The color of the aggregate and cement for patching or partial encasement shall be selected to produce a color as nearly the same as practicable as that of the old concrete.

Sand used in hand-patched concrete shall preferably have a "fineness modulus" between 2.80 and 3.0.

Sand used for pressure grout shall be plaster sand, fine mason sand or engine sand; the fineness modulus shall not be more than 2.00.

Wire mesh shall be composed of cold drawn steel wire, electrically welded and galvanized.

Any bonding, waterproofing or counter shrinkage material used shall be approved by the engineer.

All special equipment for placing of concrete or grout shall be an approved type.

B. SURFACE REPAIR

1. Scope

Repairs shall consist of the removal of soft, disintegrated or honeycombed concrete or stone, cleaning and preparing of the bonding surface, placing of anchor bolts and reinforcing, the placing of concrete by shotcreting, hand-patching, or pouring, or as specified, and the finishing of such concrete to true lines and surface and proper curing.

2. Preparation

All loose, soft, honeycombed and disintegrated concrete or stone shall be removed from the areas to be repaired by means of power and hand tools, to expose a bending surface of sound material. The bonding surface shall be not less than 1½ in. from the finished surface. The engineer may disregard the minimum limit for depth of bonding surface in the case of hand-patch work.

Thin or feather edges shall be avoided and the boundaries of the areas to be repaired shall be square cut or slightly undercut to a depth of not less than one inch.

Abrupt changes in the thickness of concrete patches shall be avoided.

All defective construction joints and cracks shall be chipped out to a minimum of four inches in width by two inches in depth. Where movement occurs in the crack, an approved metal or composition joint shall be provided.

On concrete masonry, removal shall not exceed eight inches in depth, except as specified or directed by the engineer.

The bonding surface should be rough, clean, sound concrete or stone. Oil or film of any sort that may reduce the bond shall not be permitted. Loose particles of dust and dirt shall be removed by wire brushes, sand blast, or air, followed, finally, by water blast.

3. Anchorage

Where new concrete less than 4 in. thick is to be placed, ¼-in. dia. anchor bolts shall be spaced 18 in. center-to-center on vertical surfaces and 12 in. center-to-center on overhead surfaces. Each bolt shall have sufficient engagement in the sound masonry to resist a pull of 150 lb. When pried from the wall with a bar inserted under the bond of the bolt, the bond shall straighten without pulling the bolt.

Specified spacing of anchors is based on supporting three times the total weight of suspended concrete and two times the weight of concrete on vertical surfaces. Facilities shall be provided for testing the supporting value of anchors. Each anchor shall be set in sound masonry as specified in the table below and shall be capable of supporting, without loosening, the suspended load indicated.

Diameter of Bolt—In.	*Size of Drilled Hole—In.*	*Minimum Embedment—In.*	*Load in Lb.*
¼	⅝	1½	150
⅜	15/16	2⅜	400
½	1	2⅝	750
⅝	1⅛	3¼	1,200
¾	1⅜	4	1,750

Any anchor failing to support such load shall be reset.

When concrete four inches or more in thickness is to be placed, approved anchors shall be set where shown on the plans, and in accordance with the following table:

SIZE AND SPACING OF ANCHOR BOLTS

Thickness of Concrete In.	*Suspended Concrete In. dia. at Ft.-In.*	*Vertical Surfaces In. dia. at Ft.-In.*	*Top Surfaces In. dia. at Ft.-In.*	*Minimum Embedment In.*
4	⅜ @ 1—8	⅜ @ 2— 0	⅜ @ 3—0	2⅜
5	" @ 1—5	" @ 1— 9	" @ 3—0	2⅜
6	" @ 1—4	" @ 1— 8	" @ 3—0	2⅜
7	" @ 1—2	" @ 1— 6	" @ 3—0	2⅜
8	½ @ 1—7	½ @ 1—11	½ @ 3—0	2⅝
9	" @ 1—6	" @ 1—10	" @ 3—0	2⅝
10	" @ 1—5	" @ 1— 9	....	2⅝
11	" @ 1—4	" @ 1— 8	....	2⅝
12	" @ 1—3	" @ 1— 6	....	2⅝

Top surface concrete over 9 in. in depth shall be anchored with ¾-in. dia. dowels spaced 2 ft.—0 in. centers.

When concrete exceeding 12 in. in thickness is to be supported, the size, spacing and embedment of anchors shall be determined by the engineer.

The exposed end of each anchor shall have a right angle, or greater, bend for engaging reinforcement.

No isolated area greater than two square feet shall have fewer than three anchors.

Where only a single line of anchors is required, the maximum spacing shall be 24 deg. and the size shall be determined in accordance with second paragraph under Anchorage.

If sound masonry has not been exposed at a depth of 8 in., long dowels shall be used for anchorage. The size and length shall be determined by the engineer.

Dowels shall be made of deformed bars, shall be grouted in and shall be long enough to engage a mass of masonry sufficient to support the load. Horizontal dowel holes shall be drilled downward on a slope of approximately one inch per foot.

4. Reinforcement

Where new concrete 4 in. or less in thickness is to be placed, one layer of 3 in. by 3 in. by No. 10 or 2 in. by 2 in. by No. 12 gage wire mesh shall be secured to the anchor bolts.

Vertical and Top Surfaces. Where new concrete over four inches in thickness is to be placed, one layer of wire mesh shall be used for each four-inch thickness, or fraction thereof, secured to the anchors.

Suspended Surfaces. Where new concrete three inches thick or more is to be suspended, one additional layer of wire mesh shall be used for each three-inch thickness, or fraction thereof. Each layer of mesh shall be wired to each anchor.

A two-way system of ¼ in. dia. reinforcing bars securely wired to anchors shall be provided for vertical and suspended surfaces. The last layer of mesh shall be continuous and shall be secured by wiring to the reinforcing bars.

Corner Reinforcement. At the corners, the layers of mesh from the two intersecting planes shall be securely wired together. For each layer of mesh, an additional layer made from a strip of mesh 12 in. wide shall be preformed symmetrically around its center line and securely wired to the mesh.

All reinforcement involved in the repair work shall be completely embedded in the new concrete and shall be not less than 1½ in. from the finished surface of the concrete. Each layer of mesh must be completely encased before the succeeding layer of mesh is applied. The succeeding layer of mesh shall not be applied until the previous layer of encasement has set.

Reinforcement shall be held away from the surface of the old concrete. Reinforcement extending around corners or re-entrant angles shall be bent to templet before securing to anchorage and not sprung or forced into position. Where splices of wire mesh are necessary, a lap of one mesh in each direction shall be required, wired together at intervals of not more than 18 in.

Splice bars shall lap at least 40 dia. of the bar, with laps securely wired together. Where special reinforcement is required for structural strength, engineering plans will be furnished.

Reinforcement in the old structure shall be thoroughly cleaned and any deficiency in area shall be supplied with additional reinforcement.

5. Placement

After the bonding surfaces of the old masonry have been prepared as outlined in paragraph No. 4, and when new concrete is to be placed by hand-patch methods, and without the use of pneumatic pressure or forms, the bonding surface shall be kept constantly wet for a minimum of one hour immediately prior to application of the bonding or waterproofing coat. In no case shall fresh materials be applied to a dry surface. The bonding or waterproofing coat shall be applied to the damp bonding surface and shall be vigorously brushed on to completely fill all surface pores immediately prior to placing the body of the new concrete. The bonding coat shall be composed of one part cement to one part fine sand and sufficient water to make a creamy mixture. If required by the engineer, an approved waterproofing or countershrinkage material shall be added. The bonding coat shall not be troweled, screened or disturbed before the next layer of new concrete is applied.

Immediately after the bonding coat has been applied, the entire cavity shall be filled to finished lines with concrete of plastic consistency, composed of 1 part cement to 2½ parts of sand. The concrete shall be thoroughly impacted. In the case of overhead, steep, or vertical surfaces, the concrete shall be placed in successive layers, but while preceeding concrete is still green. In any case, where it is necessary to permit any concrete to harden, any new applications of concrete shall be applied over a new bonding coat.

Each morning all concrete placed the previous day shall be sounded for adhesion and soundness. All areas which fail to meet the test shall be cut out and replaced.

Each inside layer of concrete shall be tamped until set, i.e., the moment when plasticity disappears, and the final layer shall have the finished surface worked until set in the concrete is developed. Retempered mortar may be used for hand-patched concrete, if approved by the engineer.

Where restoration or encasement is accomplished by ramming the new concrete in between forms and the old surface, the forms shall have sufficient strength to withstand the pressure of the new concrete without yielding appreciably. If possible, the new concrete shall be placed in layers, each rammed solidly into place while the preceding layer is plastic. In any case, the new concrete shall completely fill the space provided and present a surface identical with the original. Vibration of the forms in lieu of ramming is subject to approval of the engineer. Vibrators, if used, shall preferably deliver not less than 3000 impulses per min.

Surface shall be finished as directed by the engineer.

6. Curing and Protection

The surface of all new concrete shall be kept thoroughly wet for a period of at least seven days, beginning immediately after placement.

An approved curing compound may be used in lieu of the above.

Repair work shall not be done in freezing weather unless properly protected, nor until the old structure is free from frost. The new concrete shall have a temperature when placed of not less than 50 deg. F., nor more than 120 deg. F., and shall be kept at a temperature not lower than 50 deg. F. for not less than 72 hours after placing, or until the concrete has thoroughly hardened.

C. INTERNAL CONSOLIDATION

1. Scope

Internal consolidation by pressure grouting consists of filling voids, seams and cracks in masonry, with grout containing cement and water, and, if required by the engineer, other ingredients such as fine sand, waterproofing agents, countershrinkage materials and admixtures to improve penetration.

2. Preparation

Before the grouting operation is started, all defective materials are to be removed and the entire surface of the masonry shall be thoroughly inspected for points of leakage and indications of voids. Inserts for grouting shall be so located and set that the pressure grout will reach all voids and paths of leakage.

All exposed joints and cracks shall be chipped out with power tools, then thoroughly cleaned of all foreign material by means of high-pressure air or water blast. In chipping joints, care shall be taken to obtain square joints.

The joints and cracks shall be restored to the original surface with hand painting or shotcrete, consisting of one part of cement, three parts of sand and, if required by the engineer, an approved type of countershrinkage material.

3. Grout Holes—Drilling

Before drilling of grout holes is started, test drillings shall be made through the masonry to the back of the same and to the bottom of the footings in order to determine the thickness of the masonry. From these test drillings, the proper depth of grout holes shall be determined in order that grout holes shall not be drilled completely through the masonry.

Grout holes shall be drilled at substantially regular intervals, e.g., at 10-ft. spacing horizontally and 2½-ft. spacing vertically, staggered to include approximately 25 sq. ft. of surface area per hole or at such other locations as may be specified. Holes shall be 1½ in. min. dia. and shall be drilled to such a depth, and in such manner, as necessary to intercept joints and internal voids, so that complete consolidation of the structure is assured. No holes which have been drilled completely through the masonry shall be used for pressure grouting and these holes must be completely plugged before grouting begins.

In cases of arch rings, the holes shall be drilled diagonally to intercept the longitudinal joints (parallel to the barrel) and staggered at such intervals as to include approximately 12 sq. ft. of surface area per hole.

On structures, or parts of structures, of one stone thickness, the grout holes shall be drilled in such a manner as to intercept the horizontal joints where possible; however, if, due to insufficient clearance, these holes cannot be drilled through the horizontal joints, they shall then be drilled so as to intercept the vertical joints.

The holes in the courses of masonry below ground line shall be drilled diagonally downward at various angles, but not into the foundation below the masonry, so that consolidation of the bottom courses is assured.

In case of masonry which is founded on timber grillage which it is desired to consolidate, diagonal holes at various angles should be drilled through the timber to the natural foundation so that consolidation of the timber grillage is assured.

4. Material

Generally, the pressure grout mixture shall consist of 1 part of cement, ½ part of sand (see paragraph A 3) and, if required by the engineer, an approved type of countershrinkage material.

The amount of sand to be used in the grouting mixture shall be determined by starting the grouting operation with neat cement grout and adding sand in gradually increasing proportions until the optimum ratio of sand to cement has been reached which will give a free flowing grout. If it is found through application of the above that the addition of sand retards the free flow of the grouting material, the sand shall be omitted.

5. Grouting

Grout shall be applied by pneumatic, pump, or gravity pressure.

Grout inserts shall be set in drilled holes and the interior voids washed clean with water, prior to the application of the pressure grout.

The grout shall be forced into the internal voids and joints of the structure by means of pneumatic or hydraulic pressure to completely fill all internal voids and consolidate the masonry.

Grouting shall be started at the lowest row of holes and at the hole nearest the center line of structure.

If grout appears in adjacent holes at the same elevation, these holes shall be temporarily plugged and grouting continued in the original hole until grout appears at the next adjacent hole at the same elevation or at the next line of holes above the one being grouted. When this condition occurs, grouting of the original hole shall be discontinued and the grout line moved to the last hole at the lowest elevation at which grout appeared, and the same procedure followed until all holes in the lowest line have been grouted, at which time grouting shall proceed in a like manner along the next line of holes above, etc., until the entire structure has been completely filled.

During the course of all grouting operations, extreme care shall be given to observing the surrounding ground fill, track subgrade, ballast and stream bed for the breaking out of grout, and when such breaking out occurs, the grout line shall be moved to some other part of structure. Grouting may be resumed in the original location after the elapse of 24 hours.

In grouting foundations pressure grout should be applied to the various holes in rotation, keeping a careful watch for the surrounding ground, including the water in the stream.

When grout breaks out in either the ground or stream, all operations should be suspended until the next day at which time new holes are drilled and the same procedure followed until the grout again breaks out, which will usually be at a higher level than on the preceding day.

The above program should be followed until the grout is brought up into the masonry.

6. Cleaning

On completion of, and during progress of, the pressure grout operations, all excess deposits occurring over the exposed stone face shall be cleaned off. Sandblasting of the exposed stone surface shall then be applied if required by the engineer.

The work shall be conducted in such a manner that, when the job is completed, it will have a workmanlike appearance.

Report on Assignment 7

Methods for Improving the Quality of Concrete and Mortars

Collaborating with Committee 6

L. M. Morris (chairman, subcommittee), M. W. Bruns, Maurice Coburn, W. J. Galloway, J. A. Lahmer, C. P. Marsh, M. S. Norris, G. H. Paris, J. L. Rippey.

Proportioning Concrete Mixes for Field Use

Your committee presents as information a procedure entitled Proportioning Concrete Mixes for Field Use.

In 1945 a report was presented to the Association on the design of concrete mixes, as noted in Vol. 46, 1945, pages 438–460, incl. This report was a rather complete exposition of the principles and procedures involved in the design of concrete mixes. Since

Proportioning Concrete Mixes For Field Use

The following procedure is recommended by AREA Committee 8—Masonry as a guide for the manufacture of concrete on small jobs where

4. A workable mix.
5. Proper placing.
6. Adequate curing.

Use Good Materials.—Sand, gravel, crushed stone or other aggregates for concrete work must be clean and free from clay, loam and dirt. Usually, washed and screened materials assure best results. Mixing water should be clean enough to drink, unless tests or previous experience show it to be suitable.

Materials should be kept in separate piles. Cement should be kept in a dry place as in a building or on a raised platform and covered with tarpaulins.

surface brings water and fine material to the top, which upon hardening has a tendency to check and crack. Best results are secured by allowing the concrete to stand until it is quite stiff before finishing.

Cure New Concrete.—For continued improvement concrete must be kept moist. When the water used in mixing is lost by evaporation, the chemical reactions cease. Concrete should be protected from early drying by leaving forms in place, or by covering exposed surfaces with wet sand, burlap or other materials, and by keeping wet. This wet "curing" should be started as soon as possible without marring the surfaces and should be continued as long as possible—at least 7 days when normal portland cement is used and 3 days when high early strength portland cement or concrete is used.

Table 4.—Suggested Trial Mixes for Concrete of Medium Consistency (3-in. Slump)

With Medium Sand (Moisture content 4% by weight. Bulking due to moisture 20%)

Mix No.	Max. size of coarse agg., in. from Table 3	Total water, gal. per sack cement from Table 1	Assumed minimum compressive strength at 28 days, psi.	Water, gal. per sack cement, to be added at mixer	Using Rounded Coarse Aggregate						Using Angular Coarse Aggregate					
					Per sack cement				Yield, cu. ft. conc. per sack cement	Cement, sacks per cu. yd.	Per sack cement				Yield, cu. ft. conc. per sack cement	Cement, sacks per cu. yd.
					sand, lb.	gravel, lb.	sand, cu. ft.	gravel, cu. ft.			sand, lb.	stone, lb.	sand, cu. ft.	stone, cu. ft.		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Proportioning Concrete Mixes For Field Use

The following procedure is recommended by AREA Committee 8—Masonry as a guide for the manufacture of concrete on small jobs where detailed analysis is not practicable. See instructions for use of tables.

Table 1—Gallons of Water Per Sack of Cement for Various Types of Construction and Exposure Conditions

Type or location of structure	Severe or moderate climate, wide range of temperature, rain, and long freezing spells or frequent freezing and thawing					Mild climate, rain or semiarid; rarely snow or frost				
	Thin sections, gal. per sack		Moderate sections, gal. per sack		Heavy and mass sections, gal. per sack	Thin sections, gal. per sack		Moderate sections, gal. per sack		Heavy and mass sections, gal. per sack
	Reinf.	Plain	Reinf.	Plain		Reinf.	Plain	Reinf.	Plain	
A. At the water line in hydraulic or waterfront structures or portions of such structures where complete saturation or intermittent saturation is possible, but not where the structure is continuously submerged:										
In sea water	5	5½	5½	6	6	5	5½	5½	6	6
In fresh water	5½	6	6	6½	6½	5½	6	6	6½	6½
B. Portions of hydraulic or waterfront structures some distance from the water line, but subject to frequent wetting:										
By sea water	5½	6	6	6	6	5½	6½	6½	7	7
By fresh water	6	6½	6½	6½	6½	6	7	7	7½	7½
C. Ordinary exposed structures, buildings and portions of bridges not coming under above groups	6	6½	6½	7	7	6	7	7	7½	7½
D. Complete continuous submergence:										
In sea water	6	6½	6½	7	7	6	6½	6½	7	7
In fresh water	6½	7	7	7½	7½	6½	7	7	7½	7½
E. Concrete deposited through water	*	*	5½	5½	5½	*	*	5½	5½	5½
F. Pavement slabs directly on ground:										
Wearing slabs	5½	6	*	*	*	6	6½	*	*	*
Base slabs	6½	7	*	*	*	7	7½	*	*	*

G. Special cases: For concrete not exposed to the weather, such as interiors of buildings and portions of structures entirely below ground, no exposure hazard is involved, and the water-cement ratio should be selected on the basis of the strength and workability requirements.
For concrete exposed to strong sulfate ground waters, or other corrosive liquids or salts, the maximum water content should not exceed 5 gal. per sack.
*These sections not practicable for the purpose indicated.

Table 2—Recommended Slumps for Various Types of Construction

Type of construction	Slump, in.*	
	Maximum	Minimum
Reinforced foundation walls and footings, and thin plain walls	5	2
Plain footings, caissons, and substructure walls	4	1
Slabs, beams, and reinforced walls	6	3
Building columns	6	3
Pavements	3	2
Heavy mass construction	3	1

*When high-frequency vibrators are used, the values given should be reduced about one-third.

Table 3—Maximum Sizes of Aggregate Recommended for Various Types of Construction

Minimum dimension of section, in.	Maximum size of aggregate*, in in., for:			
	Reinforced walls, beams and columns	Unreinforced walls	Heavily reinforced slabs	Lightly reinforced or unreinforced slabs
2½ to 5	½ to ¾	¾	¾ to 1	¾ to 1½
6 to 11	¾ to 1½	1½	1½	1½ to 3
12 to 29	1½ to 3	3	1½ to 3	3

*Based on square screen openings. Maximum size should not exceed ⅕ minimum clear distance between reinforcement. Range in maximum sizes should be in proportion to range of sectional dimensions.

Instruction For Selection of Trial Mix

When the mix is not specified, use the following steps.

Step 1.—Select gallons of water per sack of cement recommended in Table 1 for type of construction and exposure conditions involved.

Step 2.—Select maximum size of coarse aggregate recommended in Table 3 for type of construction involved.

Step 3.—Select mix proportions from Table 4 corresponding to water content and size of aggregate obtained in Steps 1 and 2. Do not use more water than specified. If mix is too stiff, reduce amount of aggregate.

Adjustment in Table 4 For Other Conditions

Table 4 is based on concrete with 3-in. slump. For each 1 in. increase in slump, reduce amount of sand by 10 lb. per sack and amount of coarse aggregate 20 lb per sack. For each 1 in. decrease in slump, reverse process.

For stone sand, increase amount of sand shown in Table 4 about 5 percent and reduce coarse aggregate shown in Table by same amount.

When air-entrained concrete is used, reduce the amount of fine aggregate given in Table 4 by an amount equal to about 3 percent of the combined weight of the fine and coarse aggregate and use the water necessary for required consistency. This should be about ¼ gal per sack of cement less than shown in Table 4.

For slag coarse aggregate reduce weight of coarse aggregate shown in Table 4 by 15 percent.

Fundamentals of Concrete Making

The procedure for proportioning concrete mixes is based on observing certain fundamental principles of making concrete. They include:

1. Suitable materials.
2. Accurate measurement of materials.
3. Thorough mixing.
4. A workable mix.
5. Proper placing.
6. Adequate curing.

Use Good Materials.—Sand, gravel, crushed stone or other aggregates for concrete work must be clean and free from clay, loam and dirt. Usually, washed and screened materials assure best results. Mixing water should be clean enough to drink, unless tests or previous experience show it to be suitable.

Materials should be kept in separate piles. Cement should be kept in a dry place as in a building or on a raised platform and covered with tarpaulins.

Measure Materials Accurately.—Each of the ingredients should be accurately measured.

Mix Thoroughly.—Mix concrete thoroughly and until the color is uniform and there is a uniform distribution of the material. Do not overload mixers or operate them at speeds higher than recommended by the manufacturer. Continue mixing for at least 1 min after all materials are in the mixer. Longer mixing gives more uniform results.

Use a Workable Mixture.—Should the proportions of sand and coarse aggregate selected give a mixture which is not workable, they should be adjusted to produce a mixture suitable for the job but without exceeding the selected amount of mixing water.

Place Concrete Carefully.—Handle and place concrete carefully to prevent the materials from separating. In general it should not be allowed to drop freely into place more than 3 or 4 ft. Place it in the forms where it is to stay, and in horizontal layers, usually not over 1 to 2 ft thick. Do not allow the concrete to flow over long distances in the forms as this causes the materials to separate. Spade each layer to settle the concrete, remove stone pockets and provide smooth surfaces along the forms.

Do not trowel or float concrete while it is soft. Such working of the surface brings water and fine material to the top, which upon hardening has a tendency to check and crack. Best results are secured by allowing the concrete to stand until it is quite stiff before finishing.

Cure New Concrete.—For continued improvement concrete must be kept moist. When the water used in mixing is lost by evaporation, the chemical reactions cease. Concrete should be protected from early drying by leaving forms in place, or by covering exposed surfaces with wet sand, burlap or other materials, and by keeping wet. This wet "curing" should be started as soon as possible without marring the surfaces and should be continued as long as possible—at least 7 days when normal portland cement is used and 3 days when high early strength portland cement or concrete is used.

TABLE 4.—SUGGESTED TRIAL MIXES FOR CONCRETE OF MEDIUM CONSISTENCY (3-in. Slump)

With Medium Sand (Moisture content 4% by weight. Bulking due to moisture ...)

Mix No.	Max. size of coarse agg., in. from Table 3	Total water, gal. per sack cement from Table 1	Assumed minimum compressive strength at 28 days, psi.	Water, gal. per sack cement, to be added at mixer	Using Rounded Coarse Aggregate: Per sack cement: sand, lb.	gravel, lb.	sand, cu. ft.	gravel, cu. ft.	Yield, cu. ft. conc. per sack cement	Cement, sacks per cu. yd.	Using Angular Coarse Aggregate: Per sack cement: sand, lb.	stone, lb.	sand, cu. ft.	stone, cu. ft.	Yield, cu. ft. conc. per sack cement	Cement, sacks per cu. yd.
1	¾	5	4250	4	185	235	2.0	2.4	3.65	7.4	180	190	1.9	2.1	3.38	8.0
2	1	5		4¼	170	270	1.8	2.7	3.75	7.2	170	220	1.8	2.4	3.46	7.8
3	1½	5		4¼	165	310	1.7	3.1	3.97	6.8	165	250	1.7	2.8	3.65	7.4
4	2	5		4¼	165	350	1.7	3.5	4.22	6.4	165	290	1.7	3.2	3.86	7.0
5	3	5		4¼	160	400	1.7	4.0	4.50	6.0	165	325	1.7	3.6	4.10	6.6
6	¾	5½	3700	4½	215	260	2.2	2.6	4.03	6.7	210	210	2.2	2.3	3.70	7.3
7	1	5½		4½	200	300	2.1	3.0	4.15	6.5	200	240	2.1	2.7	3.80	7.1
8	1½	5½		4½	185	340	2.0	3.4	4.36	6.2	190	280	2.0	3.1	4.03	6.7
9	2	5½		4½	185	390	2.0	3.9	4.68	5.8	190	315	2.0	3.5	4.22	6.4
10	3	5½		4½	185	435	2.0	4.1	5.00	5.4	190	360	2.0	4.0	4.50	6.0
11	¾	6	3300	5	240	280	2.5	2.8	4.36	6.2	240	230	2.5	2.5	4.07	6.7
12	1	6		5	225	320	2.3	3.2	4.50	6.0	225	260	2.3	2.9	4.15	6.5
13	1½	6		5	215	365	2.2	3.7	4.74	5.7	220	300	2.3	3.3	4.36	6.2
14	2	6		5	220	425	2.3	4.3	5.10	5.3	220	345	2.3	3.8	4.66	5.8
15	3	6		5	210	475	2.2	4.7	5.40	5.0	220	390	2.3	4.3	4.90	5.5
16	¾	6½	3000	5¼	270	305	2.8	3.1	4.74	5.7	270	245	2.8	2.7	4.36	6.2
17	1	6½		5½	250	350	2.6	3.5	4.91	5.5	255	280	2.6	3.1	4.50	6.0
18	1½	6½		5½	245	400	2.6	4.0	5.19	5.2	245	325	2.6	3.6	4.71	5.7
19	2	6½		5½	245	455	2.6	4.6	5.51	4.9	245	370	2.6	4.1	5.09	5.4
20	3	6½		5½	240	515	2.5	5.2	5.87	4.6	245	415	2.6	4.7	5.40	5.1
21	¾	7	2750	5½	300	325	3.1	3.3	5.10	5.3	300	265	3.1	2.9	4.47	5.7
22	1	7		5½	280	370	3.0	3.7	5.30	5.1	280	300	2.9	3.3	4.82	5.6
23	1½	7		5¾	279	420	2.8	4.2	5.51	4.9	270	350	2.8	3.9	5.13	5.3
24	2	7		5¾	279	480	2.8	4.8	5.87	4.6	280	395	2.9	4.4	5.40	5.0
25	3	7		5¾	265	545	2.8	5.4	6.28	4.3	275	450	2.8	5.0	5.75	4.7
26	¾	7½	2500	6	335	350	3.5	3.5	5.51	4.9	330	280	3.4	3.1	5.10	5.3
27	1	7½		6	310	390	3.2	3.9	5.63	4.8	310	320	3.2	3.6	5.19	5.2
28	1½	7½		6	300	455	3.1	4.6	6.00	4.5	310	370	3.2	4.1	5.51	4.9
29	2	7½		6	300	510	3.1	5.1	6.28	4.3	300	415	3.1	4.6	5.75	4.7
30	3	7½		6	300	580	3.1	5.9	6.75	4.0	300	480	3.1	5.3	6.13	4.4

1	¾	5	4250	4	185	235	2.0	2.4	3.65	7.4	180	190	1.9	2.1	3.35	8.0
2	1	5		4¼	170	270	1.8	2.7	3.75	7.2	170	220	1.8	2.4	3.46	7.8
3	1½	5		4¼	165	310	1.7	3.1	3.97	6.8	165	250	1.7	2.8	3.65	7.4
4	2	5		4¼	165	350	1.7	3.5	4.22	6.4	165	290	1.7	3.2	3.86	7.0
5	3	5		4¼	160	400	1.7	4.0	4.50	6.0	165	325	1.7	3.6	4.10	6.6
6	¾	5½	3700	4½	215	260	2.2	2.6	4.03	6.7	210	210	2.2	2.3	3.70	7.3
7	1	5½		4½	200	300	2.1	3.0	4.15	6.5	200	240	2.1	2.7	3.80	7.1
8	1½	5½		4½	185	340	2.0	3.4	4.36	6.2	190	280	2.0	3.1	4.03	6.7
9	2	5½		4½	185	390	2.0	3.9	4.66	5.8	190	315	2.0	3.5	4.22	6.4
10	3	5½		4½	185	435	2.0	4.4	5.00	5.4	190	360	2.0	4.0	4.50	6.0
11	¾	6	3300	5	240	280	2.5	2.8	4.36	6.2	240	230	2.5	2.5	4.03	6.7
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20	3	6½		5½	240	515	2.5	5.2	5.87	4.6	245	415	2.6	4.7	5.40	5.1
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23	1½	7		5¾	270	420	2.8	4.2	5.51	4.9	270	350	2.8	3.9	5.10	5.3
24	2	7		5¾	270	480	2.8	4.8	5.87	4.6	280	395	2.9	4.4	5.40	5.0
25	3	7		5¾	265	545	2.8	5.4	6.28	4.3	275	450	2.8	5.0	5.75	4.7
26	¾	7½	2500	6	335	350	3.5	3.5	5.51	4.9	330	280	3.4	3.1	5.10	5.3
27	1	7½		6	310	390	3.2	3.9	5.63	4.8	310	320	3.2	3.6	5.19	5.2
28	1½	7½		6	300	455	3.1	4.6	6.00	4.5	310	370	3.2	4.1	5.51	4.9
29	2	7½		6	300	510	3.1	5.1	6.28	4.3	300	415	3.1	4.6	5.75	4.7
30	3	7½		6	300	580	3.1	5.9	6.75	4.0	300	480	3.1	5.3	6.13	4.4

the publication of this report your committee has felt the need for an abbreviated sheet which could be used by division supervisors or foremen on small jobs where detailed analysis of all the factors involved is not practicable. It is arranged particularly to give trial mixes, but with the procedures given it should be comparatively easy to make the necessary corrections for proper final mixes.

The quantities given are based on data published by the U. S. Bureau of Reclamation, as averaged from many tests. This sheet is now presented as information, and it is hoped that railroad construction forces will give it a fair trial and let your committee have the benefit of their comments. These data, or an improved version thereof, are expected to be included in a concrete manual for field use which your committee hopes to present to the Association next year.

Report of Committee 27—Maintenance of Way Work Equipment

EDGAR BENNETT, *Chairman,*
E. L. ANDERSON
C. M. ANGEL
R. M. BALDOCK
R. E. BERGGREN
W. R. BJORKLUND
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J. R. RUSHMER
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E. G. WALL
G. R. WESTCOTT
A. H. WHISLER
F. E. YOCKEY
F. F. ZAVATKAY
Committee

* Died August 5, 1948.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Motor cars, trailer and push cars.
   No report.

3. Portable conveyors.
   Final report, submitted as information .... page 325

4. Power ballasting machines.
   Final report, submitted as information .... page 329

5. Equipment for oiling rail and track fixtures in the track.
   Final report, presented as information .... page 333

6. Power cribbing machines.
   Final report, presented as information .... page 338

7. Portable power units and power tools for roadway terminal gangs.
   Final report, presented as information .... page 341

8. Diesel engines.
   Final report, presented as information .... page 345

9. Portable power units and power tools for bridge and building gangs.
   Final report, presented as information .... page 347

10. New developments in maintenance of way equipment.
    Final report, submitted as information .... page 350

THE COMMITTEE ON MAINTENANCE OF WAY WORK EQUIPMENT,
EDGAR BENNETT, *Chairman.*

AREA Bulletin 477, December 1948.

Clarence Richard Knowles

The Committee on Maintenance of Way Work Equipment records with sorrow the death on August 5, 1948, of a member and former chairman, Clarence Richard Knowles. An appropriate memoir of him appears elsewhere in this volume.

George Eugene Boyd

George Eugene Boyd, retired associate editor of Railway Engineering and Maintenance and the Railway Age, died on May 14, 1948.

Mr. Boyd was born at Roseville, Ill., on February 26, 1874, and was graduated by the University of Illinois in 1896 with the degree of Bachelor of Science in Civil Engineering.

His 49 years' association with the railroads covered two periods. For 26 years, from 1897 to 1923, he was employed directly in railway engineering, beginning as a track apprentice on the Illinois Central Railroad and ending as division engineer on the Delaware, Lackawanna & Western Railroad. This period included service in construction and maintenance of both tracks and structures, and admirably fitted him for the second period as engineering editor of railway publications.

After three years' service with the Railway Review and two years as associate editor of the Railway Engineering and Maintenance Cyclopedia, Mr. Boyd became associate editor of Railway Engineering and Maintenance and the Railway Age, which position he held until his retirement on January 1, 1947. During his service with Railway Engineering and Maintenance, he conducted the "What's the Answer?" department, a widely read and exceedingly practical exchange of ideas among railroad maintenance men.

Mr. Boyd's activities extended far beyond the demands of his editorial position. He was for many years a member of the American Railway Bridge and Building Association and of the Roadmasters' and Maintenance of Way Association. He served on many of the standing committees of these associations, giving generously of his time and abilities. For 14 years, also, he edited the Annual Proceedings of the American Wood-Preservers' Association.

In 1908, he became a member of the American Railway Engineering Association, and from that time until prevented by failing health, he rendered valuable service on several of the Association's standing committees, serving the Committee on Masonry 34 years, the Committee on Waterproofing 16 years, and the Committee on Maintenance of Way Work Equipment 14 years. His work on these committees was in no sense limited to editorial counsel; as his practical suggestions pertaining to the subjects being studied impressed his fellow committeemen with the breadth of his knowledge of railroad maintenance matters. He also represented the Association on the Joint Committee on Specifications for Concrete and Reinforced Concrete.

For many years, Mr. Boyd was a member of the Woodlawn Methodist Church of Chicago, and for long periods served on the official board, and the board of trustees of that church.

By all with whom he was associated he was held in highest esteem not alone for his knowledge of railway maintenance and his ability as a writer and editor, but for his genial personality and stability of character as well.

The younger men who had the privilege of being associated with Mr. Boyd will miss him particularly. He had the happy faculty of unobtrusively tempering their ideas with his judgment and experience while conveying at the same time, the impression that those ideas were valuable contributions to the discussion at hand.

The committees with which he worked join in recording here their appreciation of his most valuable service, and their profound sorrow at his passing.

Report on Assignment 3

Portable Conveyors

F. F. Zavatkay (chairman, subcommittee), C. M. Angel, R. E. Berggren, C. L. Fero, E. B. Harris, Jack Largent, W. B. Lee, Francis Martin, R. A. Morrison, A. W. Munt, M. M. Stansbury, J. L. Starkie, E. G. Wall, F. E. Yockey.

This is a final report presented as information.

Your committee submitted a report to the Association two years ago, published in Proceedings, Vol. 48, 1947, page 341, covering power-operated portable conveyors for use in the maintenance of way department and this is to be considered a continuation of that report.

Because there are a number of makes of portable power operated conveyors now on the market, and other types are being considered, it is difficult to submit a complete, comprehensive report covering all portable conveyors that would produce economies in handling materials commonly used by the maintenance of way departments on the various railroads. It is sufficient to state that portable power-operated conveyors are now available in such a variety of types, lengths and capacities that they will fit any kind of work in which quantities of materials are to be handled. This equipment can be supplied with either gasoline engine power units or electric motors.

Following are some of the more widely used conveyors for handling bulk material in connection with railroad work:

Fig. 1 shows a power-operated creeper-mounted bucket loader and discharge conveyor with a rated capacity from 2½ to 3 cu. yd. per min., driven by a 46-hp. multicylinder gasoline motor. This creeper-mounted loader has treads 13 in. wide by 7 ft. long, center to center. It has smooth faced, overlapping, manganese steel tread plates, and electric steel sprockets, idlers and track rollers (7 lower—2 upper) with 3-point suspension. The elevator is raised and lowered by hand wheel operating worm-driven jack-knife levers which are controlled at the operator's platform. This loader is well adapted for loading coal or other bulk material from ground storage into hopper-bottom cars or other equipment.

Fig. 2 shows another type of power-operated conveyor with a power-operated loader being used for loading and unloading coal to and from ground storage with the aid of a bulldozer. This equipment can easily be used to good advantage in handling other bulk material such as sand, gravel, crushed stone, etc., in construction work or storage. These conveyor units are furnished in lengths from 20 to 40 ft. and capacities up to 90 tons per hour. The loader is powered by a 1-cylinder 7½-hp. gasoline engine and the conveyor with a 4-cylinder 15-hp. gasoline engine. These conveyors are also useful for coaling engines at outlying points.

Fig. 3 shows a fixed type of conveyor being used as a locomotive coaler and can also be used in transferring cars where bulk material is involved. Capacities usually range from 60 to 90 tons of coal per hour.

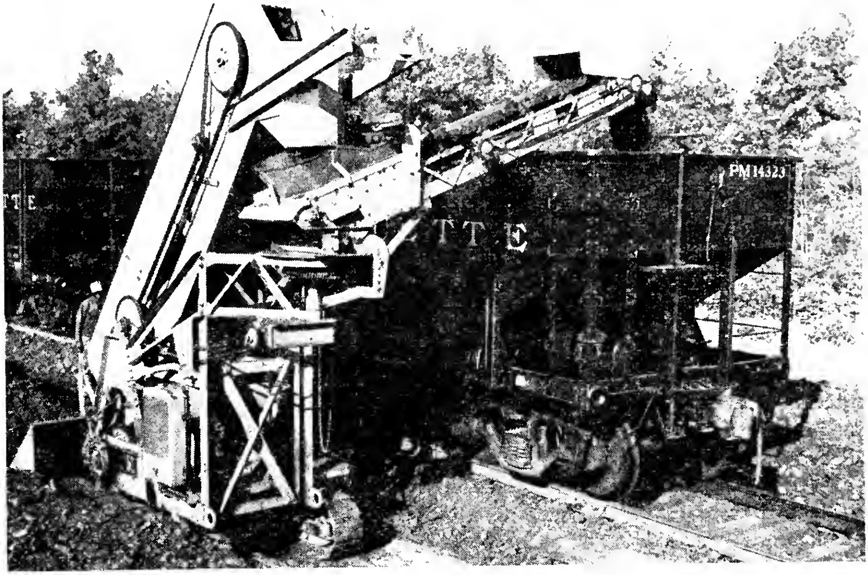

Fig. 1.—Power-Operated Loader and Conveyor.

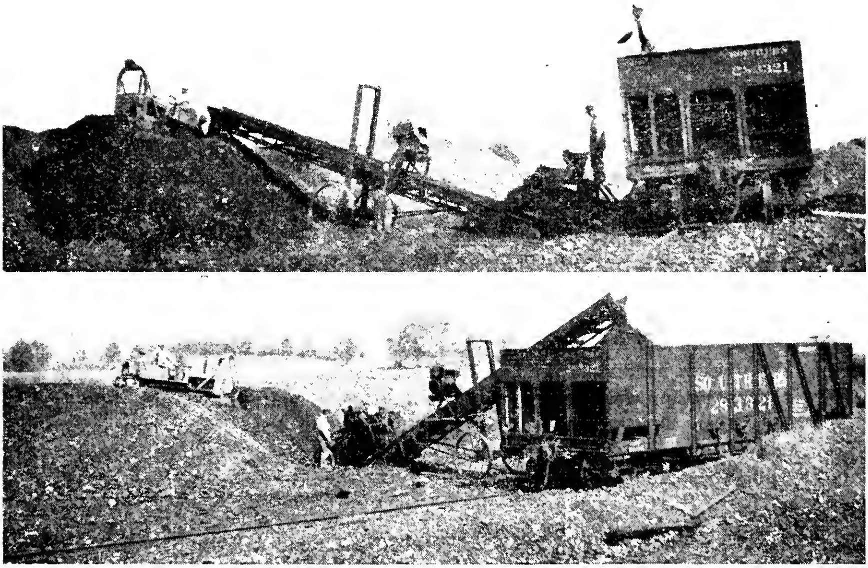

Fig. 2.—Views Showing Loading and Unloading Operations.

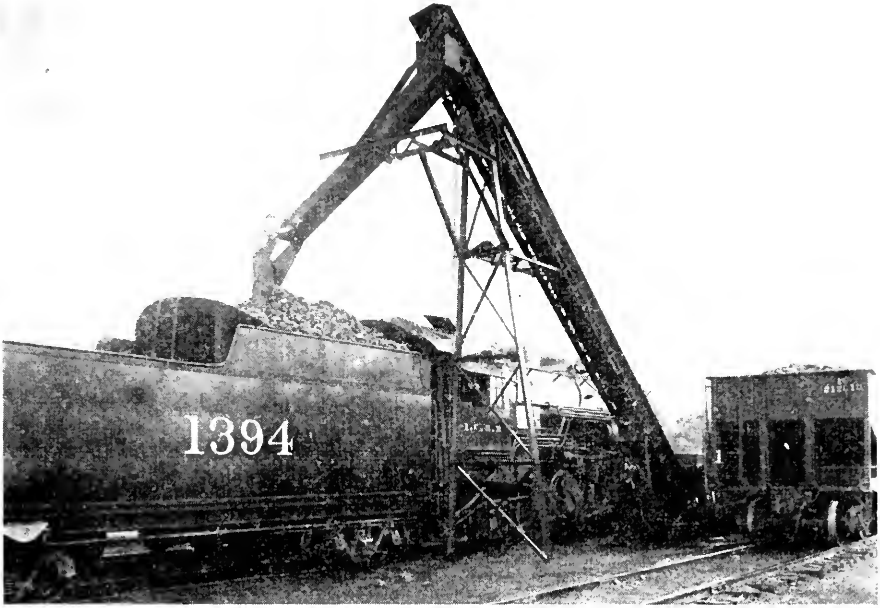

Fig. 3.—Fixed Type Conveyor as a Locomotive Coaler.

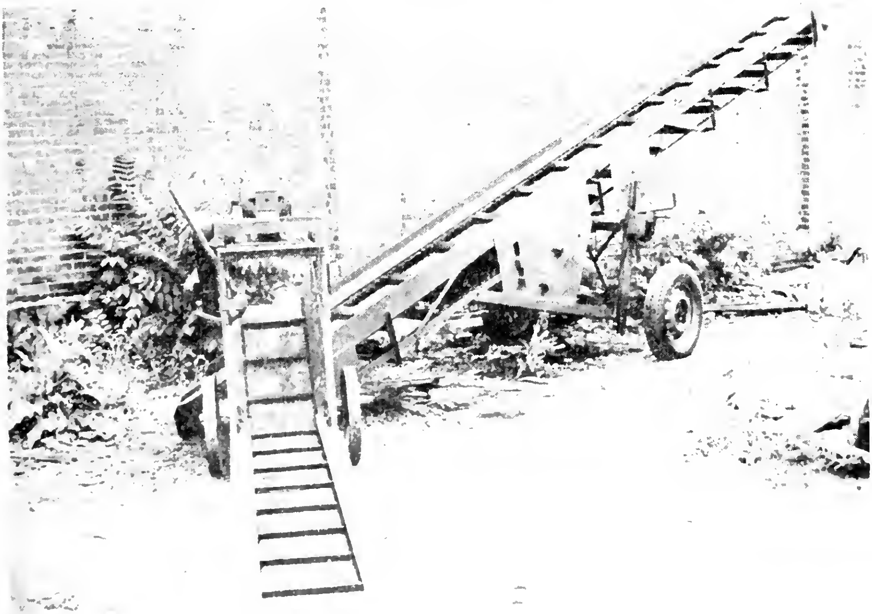

Fig. 4.—A Portable Trough Belt Conveyor.

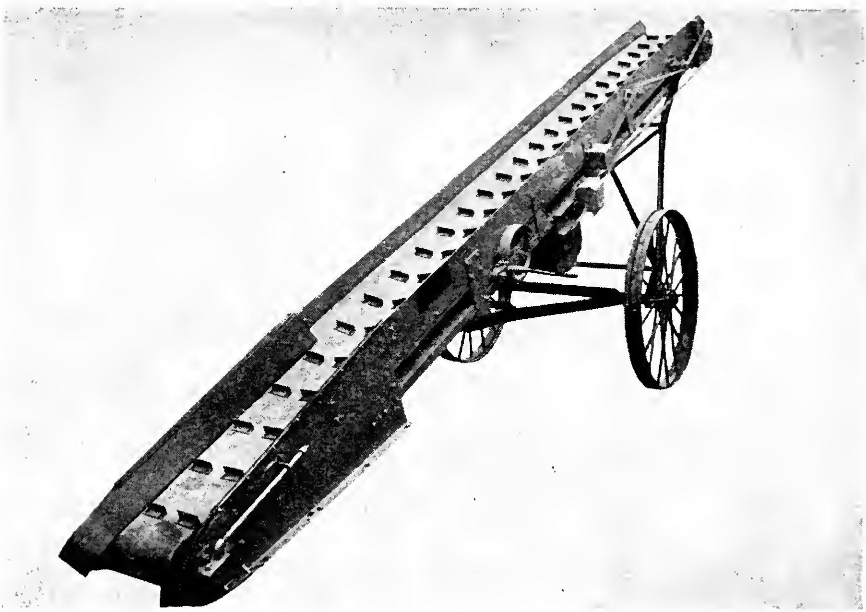

Fig. 5.—Another Portable Conveyor.

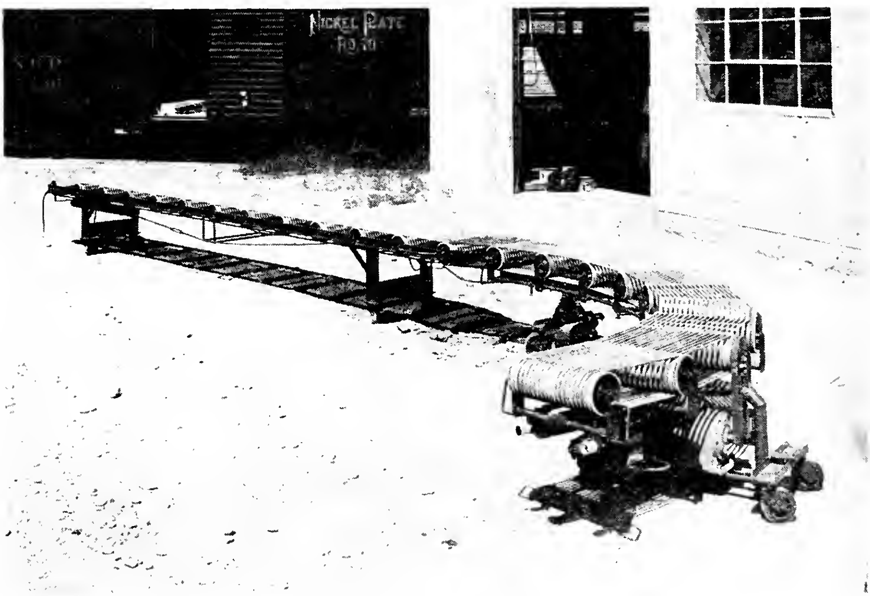

Fig. 6.—Conveyor Designed to Provide Changes in Direction.

Fig. 4 shows another type of car unloader and yard conveyor, ruggedly built and of simple design with drag chain on pressed steel rollers with bronze bearings. A $\frac{3}{16}$-in. steel plate conveyor trough insures long life in handling rough material.

Fig. 5 shows another type of portable trough belt conveyor. It is one of a number of different designs for various applications such as stone, gravel, sand, brick, coal, boxes, etc. The manufacturer also builds horizontal freight conveyors as well as large heavy-duty conveyors, 50 ft. long with 36-in. belt for handling miscellaneous freight and maintenance material.

Fig. 6 shows conveyors mounted on swivel casters, making them completely portable. Each conveyor can be furnished in rigid or flexible lengths. Rigid conveyors are made in standard lengths of 5, 10, 15 and 20 ft. Flexible conveyors are only made in 15-ft. lengths and are capable of a 90-deg. turn in either direction. The standard width is 20 in., although units 24 in. wide can be furnished. Several sections, both rigid and flexible, can be coupled together to form a continuous conveyor and can be placed in any circuitous route in freight or warehouses in handling materials to and from cars. These 15-ft. conveyors are powered by a 1-hp. motor, operating at 125 rpm. on 220 or 440 volts, 3-phase, 60-cycle current. Conveyors can be operated on any speed from 85 to 200 ft. per min. and are reversible. Each section of conveyor is equipped with electric cable with connector plug at each end. This type of conveyor is well adapted to handling material in bags, cartons, boxes, and bales. There are a number of makes of sectional type conveyors available, as well as light-weight sectional roller gravity units.

Report on Assignment 4

Power Ballasting Machines

F. H. Rothe (chairman, subcommittee), R. E. Buss, E. L. Cloutier, A. J. Flanagan, R. K. Johnson, A. A. Keever, W. F. Kohl, C. E. Morgan, T. M. Pittman, J. C. Ryan, R. S. Sabins, G. M. Strachan, M. C. Taylor, E. G. Wall.

This is a final report, presented as information.

Your committee has previously reported on power ballasting machines in the Proceedings Vol. 45, 1944, page 100; and Vol. 49, 1948, page 151.

The electric vibratory type of power ballaster has been giving a good account of itself where the lift is high enough and the type of ballast is suitable.

The following is a description of the electric vibratory power ballasters:

Machine

Weight	6500 lb.
Length	12 ft.
Width	11 ft. 6 in.
Height	5 ft. 2 in.
Wheelbase	58¾ in.
Wheels	16 in. cast steel. All wheels insulated
Brakes	4-wheel brakes. Cast iron brake shoes

Hand operated by powerful toggle lever action.

A

Fig. 1.—The Electric Vibratory Ballaster.

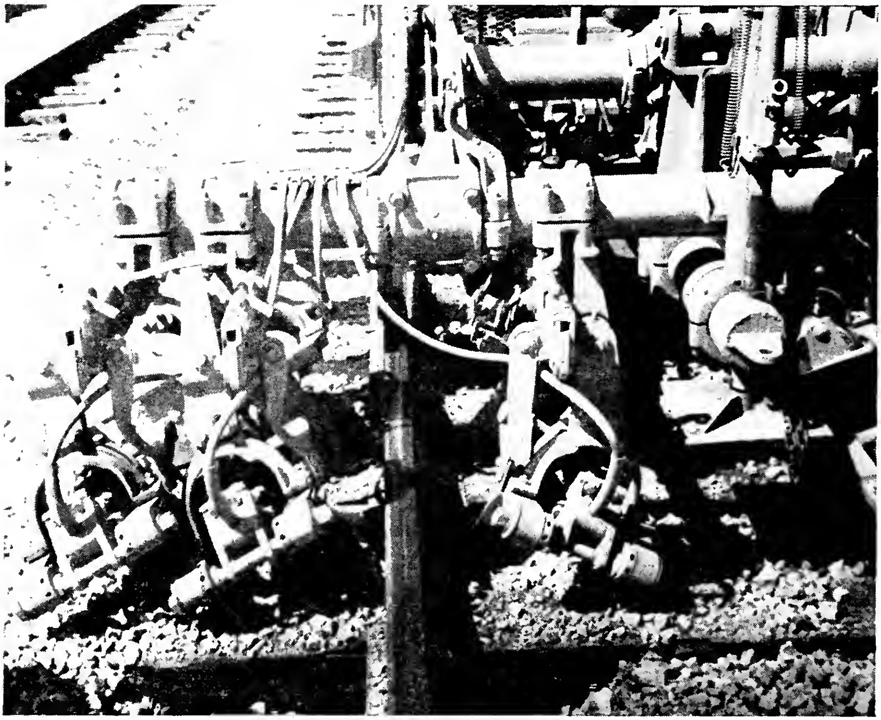

Fig. 2.—Close-Up Showing Mounting of the Vibratory Tampers.

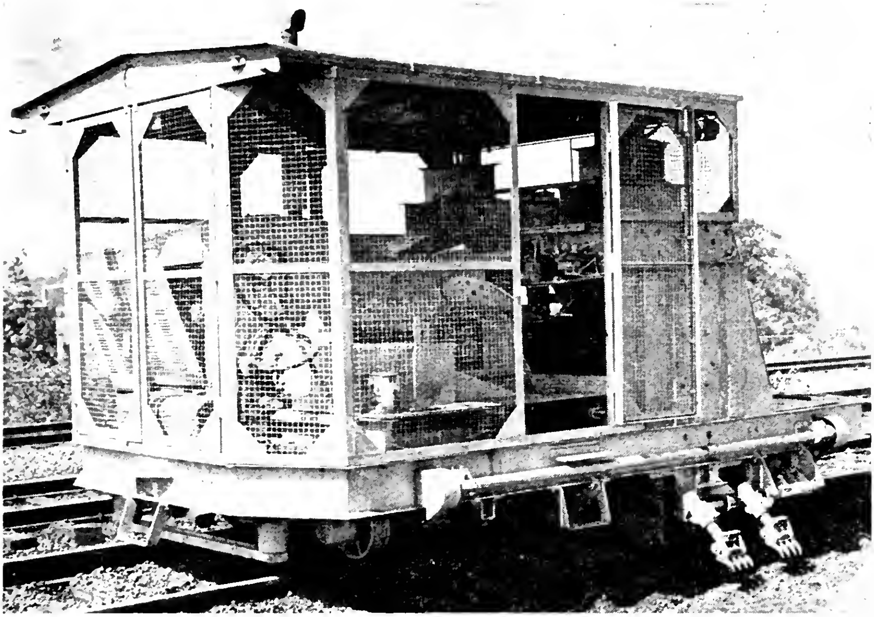

Fig. 3.—General View of the Impact Type Ballaster.

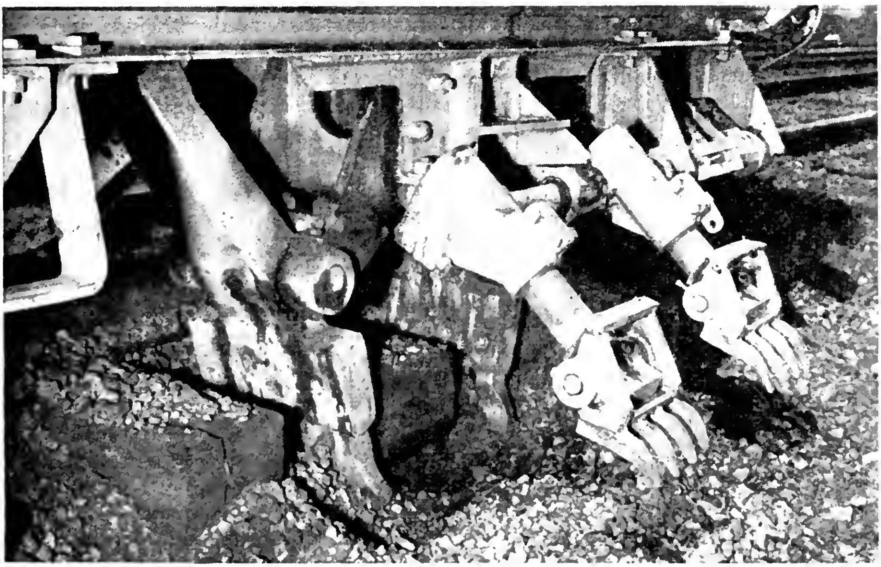

Fig. 4.—Showing the Ballast "Kickers."

ENGINE

Type	4-cylinder, air-cooled, gasoline powered
Horsepower	25 at 2400 rpm.
Bore	3¼ in.
Stroke	3¼ in.
Piston displacement	107.7 cu. in.

TRANSMISSION

Type	selective sliding gear
Speeds forward	2
Speeds reverse	2
Drive	from transmission to rear axle by roller chain

CLUTCH

Type	automotive dry plate
Drive	3 No. B-51 V belts

GENERATOR

Type	permanent magnet (no brushes)
Voltage	110 volts at 60 cycles at 1800 rpm.
Capacity	5 kv.a.—3 phase—25 amperes/phase
Drive	3 No. B-51 V belts

The electric vibratory machine consists of a four-wheel car arranged to operate on the track on flanged wheels. It is equipped with transverse wheels and a hydraulic jack for detracking it; about five minutes are required to remove the machine from the track.

The power plant mounted on the rear of the machine consists of a gasoline engine driving the electric generator and hydraulic pump through V belts.

On the front end of the car is a transverse cylinder which is used as a carrying beam for the 12 vibratory tampers, which are suspended from it in pairs, each pair being attached to the carrying beam with a suitable yoke. One pair of tampers is mounted on the gage side of each rail and two pairs on the outside of each rail. The tampers are resiliently mounted in the yokes and provision is made for necessary adjustment. The raising and lowering of the cylindrical beam carrying the tampers is accomplished by hydraulic power.

When tamping ties the ballaster is moved from tie to tie by a geared hand wheel which is conveniently located. The power plant can be used to propell the machine when traveling any appreciable distance at speeds up to 20 mph. Figs. 1 and 2 show the equipment.

One man can operate the machine but additional men are required for holding up loose ties and throwing in ballast; this force varies according to the speed of operation.

The rate of tamping has been reported as varying from 180 ft. per hour in stone ballast and 200 ft. per hour in gravel ballast on one railroad, and up to ⅝ of a mile per day in gravel ballast on another railroad. The rate of tamping with either machine varies with the force available and the amount of track work to be done in connection with the tamping, as the ballasters frequently have a greater capacity for tamping than the gang has for preparatory and other work associated with track raising.

The impact type of power ballaster was previously reported in considerable detail. One notable addition this year is a "ballast kicker," which is operated pneumatically. It is adjusted and timed to go into action only when additional ballast is needed. This device materially reduces the amount of hand labor required to keep this type of power ballaster properly supplied with ballast. Figs. 3 and 4 show the equipment.

Both types of power ballasters now on the market are considered excellent labor saving machines that will, when properly applied to the work they are suitable for and given intelligent supervision, make a substantial saving for the user.

Report on Assignment 5

Equipment for Oiling Rail and Track Fixtures in the Track

F. L. Etchison (chairman, subcommittee), E. L. Anderson, R. E. Buss, W. M. Dunn, C. H. R. Howe, A. A. Keever, W. B. Lee, F. H. McKenney, C. E. Morgan, J. R. Rushmer, J. L. Starkie, G. M. Strachan, A. H. Whisler, F. E. Yockey.

This is a progress report, presented as information.

As a part of a general assignment this subject was reported on in Proceedings, Vol. 33, 1932, Appendix F, and in the Proceedings, Vol. 42, 1941, page 177. It was recognized then, and more so today, that cost of replacing rail and fixtures is the most important item of maintenance expense. Any successful method that prolongs the useful life of these materials must receive serious consideration.

Deterioration of rail and track fixtures is due to their location and the natural processes that create dust, friction and corrosion. The causes of corrosion of rail are in general:

1. Refrigerator car brine drippings.
2. Locomotive exhaust gases combined with moisture.
3. Fumes from nearby manufacturing plants.
4. Drippings from locomotives and coal cars.
5. Salt water and salt air.
6. Electrolysis.

Separately they affect the steel in proportion to their presence, but collectively in any group or quantity they cause rapid deterioration. To control or limit these destructive agencies, it is simply necessary to place a protective coating on the surface of the metal, and renew it thereafter as conditions warrant. There are many oils and preventives available today; however, the most commonly used material is an asphalt base oil or grease usually containing 45 to 60 percent asphalt. Viscosity or density of the material is often varied by the addition of light solvents or by heating to make it more adaptable to the method of application.

Methods for applying these materials are divided into two general classifications: Namely, hand and pressure spraying. In 1932, 12 of 17 reporting railroads used pressure spray equipment. In 1948 15 of the same 17 reporting railroads are using pressure spray equipment, while the other two are using hand methods.

The hand method may be subdivided into two groups: (a) Brushing or painting, and (b) Application of joint packing.

(a) The method of applying preservatives by brushing or painting is generally understood and requires no description.

(b) The application of joint packing is described in the Proceedings, Vol. 42, 1941, pages 177 through 179.

Pressure spraying may be divided Into four groups.

(a) Hand-operated portable pressure spray outfits.
(b) Small power spray outfits, mounted on push car.
(c) On-track self-propelled spray cars.
(d) Train-operated spray cars.

(a) Various makes and types of hand sprayers are available. They consist mainly of welded tanks of 3, 4, or 5-gal. capacities to which pressure is applied by means of a hand-operated air pump. They are equipped with a pressure gage, a special oil resisting hose, and a brass or bronze spray attachment. These are generally of tubular design with a squeeze grip control valve for spraying behind angle bars or to which a spray type nozzle is attached. The outside of joints, as well as the inner side can be sprayed with the tubular type, although more oil is used and the application is not as uniform as by the spray type nozzle. In general the tubular or finger type is used to spray behind angle bars, whereas the spray type nozzle is used for the outer surfaces. It is necessary to use oil of low viscosity, or add light solvent, or heat the oil, to get satisfactory performance from spray type nozzles, due to the small orifice as well as weather conditions. This type of sprayer gives economical performance on application of preservatives to rail and track fixtures of turnouts, yards, spot treatments of main tracks, as well as angle bars. Its use is flexible and does not entail heavy expenditures to accomplish small cures.

Roads reporting the use of this type sprayer state that in joint application from 3 to 30 gal. of oil per mile are used. This variation depends on the size of the rail and the degree of coverage desired.

(b) Several developments have been made in small power sprayers mounted on push cars. These were developed primarily for the hand spraying of angle bars, spot segments of rail and turnouts. These cars were pushed along by hand while working, but could be towed to and from locations used by motor car. The cars, as developed both by railroads and manufacturers, are of the same general design.

One large southern railroad has developed a car which has a 1200-gal. tank with 100-gpm. rotary pump which is driven by a 4-hp. gasoline engine. The oil is not heated and is sprayed out under 40 lb. pressure. This machine is towed at 20 to 30 mph., spraying approximately 40 gal. to the mile for complete coverage. It weighs 23,000 lb. when loaded. It is shown in Fig. 1.

A manufacturer has developed an oil sprayer mounted on push car that has a tank of 70 gal. capacity and is equipped with a 1-cylinder 4-cycle engine to drive a rotary gear type pump delivering 5 gpm., and an oil heater of the exhaust type. It is claimed that heated materials are delivered at the discharge end of spray nozzles up to a maxi-

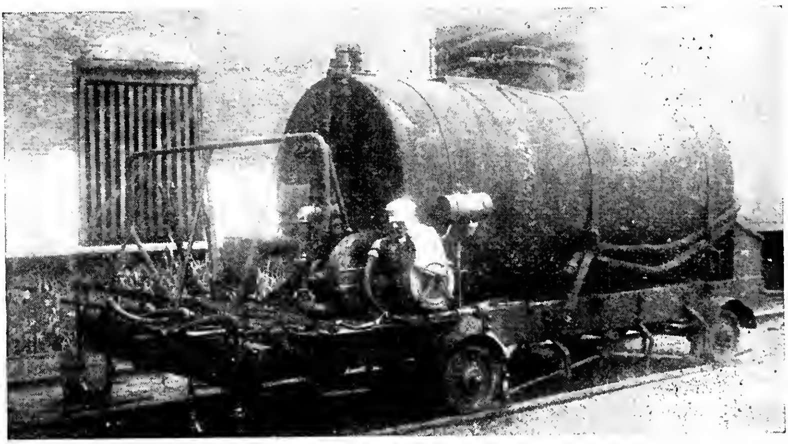

Fig. 1.—Oiler Developed by a Southern Railroad.

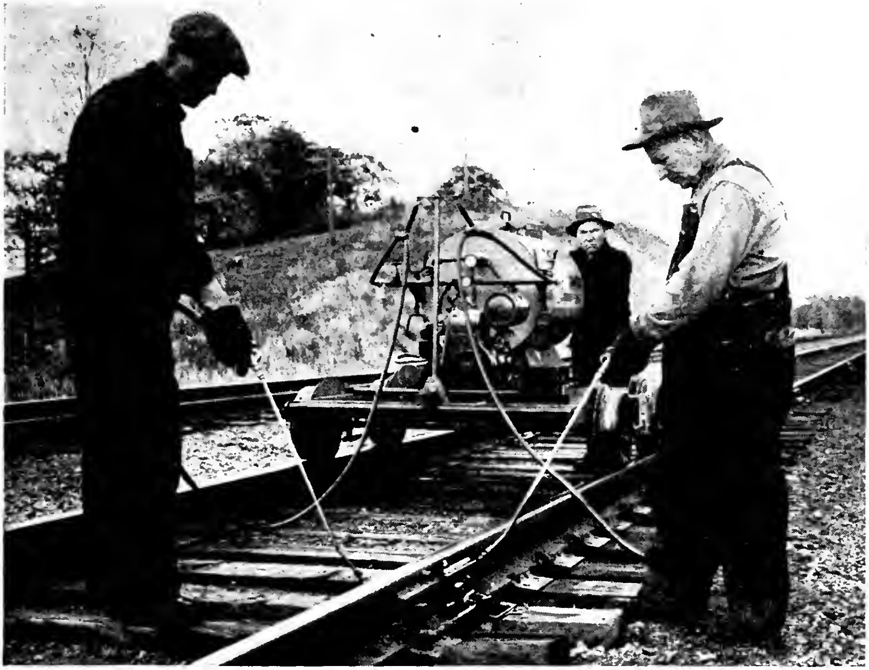

Fig. 2.—Oiler Equipped With Two Hand Sprays.

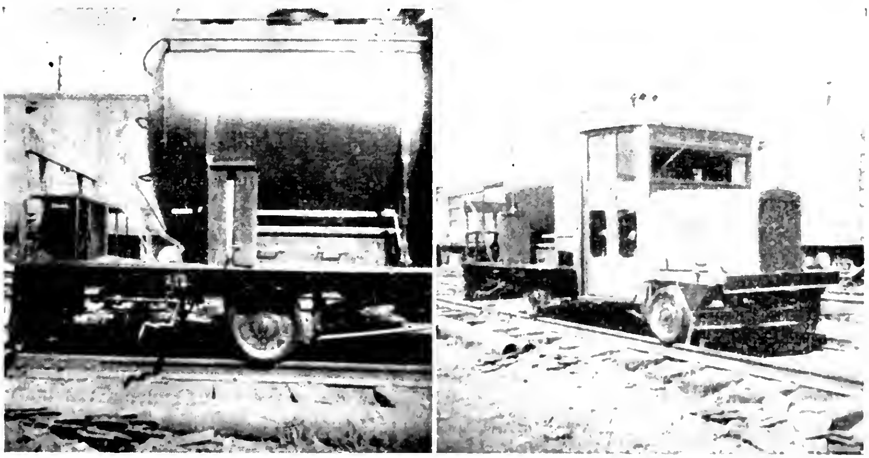

Fig. 3.—Self-Propelled Spray Car Made from Inspection Motor Car.

mum pressure of 225 lb. This machine comes equipped with two hand sprays, which can be increased to four if desired. Three men with this sprayer, equipped with two hand sprays, can cover one mile of track per hour, spraying joints, which will consume ten gallons of oil. For this class of work the car is pushed by hand. By placing a fixed nozzle on the front of this car, with control valves so that the spray will be directed to the full contour of the rail below the top of the ball, arranging for additional oil to be carried on a tow car, the outfit can be pulled by a motor car for continuous spraying. The light weight of this machine is 850 lb. Fig. 2 shows manufacturer's outfit spraying joints.

(c) One manufactured self-propelled track oiler is briefly described in Proceedings, Vol. 42, 1941, page 180.

Several roads have developed their own self-propelled spray cars. One has been made from an inspection motor car (Fig. 3), which has proved to be most successful. The tank of 1250 gal. capacity is mounted on wooden saddles with 2-in. pipe leading through a 2-in. type GV meter to a 2-in. rotary pump driven by a power take-off from the main transmission. Oil is pumped under pressure to four spray nozzles arranged in pairs to spray both sides of rail. A lever from the deck can raise or lower each pair of nozzles to avoid obstructions, the levers being connected to a cut-off valve so as to stop the flow when nozzles are raised. The light weight of this machine is 11,000 lb. It is operated by three men. On a full application over 1004 miles of track it used 44,254 gal. of asphalt metal preservative.

For extensive mileage coverage the above described self-propelled track spray outfits would require convenient access to oil supplies. Unless this is worked out in advance the outfits must either be moved over additional mileage to the supply source, or lose time while waiting for tank cars to arrive. For short segments of main line or yard coverages these machines are excellent.

(d) Spray cars designed for movement in trains also are described in the Proceedings Vol. 42, 1941, pages 180 and 181. They are essentially the same today as when previously described, except that certain improvements have been made in the equipment. One road operates a rail oiling train consisting of a locomotive pushing one or more 10,000-gal. tank cars, with spray car ahead. This car has a gasoline engine-driven 200 gpm. pump. The intake line in this car is a heating manifold consisting of a 6-in. pipe about 20 ft. long, extending from the rear end of the car to the pump, inside of which there are twelve ¾-in. steam pipes, approximately 19 ft. long, connected to the steam line.

Air pressure from the train line to two large air reservoirs in the car is piped to the rear and connected to the tank car dome by means of ¾-in. air hose. Air at about 20 lb. pressure is admitted to the top of the tank car through an air regulation valve to assist the pump in handling the oil. Oil pumped from the tank car is passed around the coils, which heat it to about 175 to 190 deg. F., and the 3-in. discharge pipe from the pump to the front end of car is also steam coiled, to keep the oil hot during train delays. A remote control thermometer is connected to the discharge pipe at the pump; there is also a thermometer just inside the car on the forward end, which permits close temperature control at all times. The spraying mechanism consists of two spray heads mounted above and centered over each rail on the forward end of the car. A hollow cone type spraying nozzle with a 7/32-in. orifice is adjusted to cover the rail from just under the head to the edge of tie plates. The spray heads are raised and lowered independently or together by a small air cylinder and piston connected to each head. When raised the spray valves automatically close, and likewise open when lowered. Three men operate the car. Train operated spray cars cover from 12 to 20 mph.

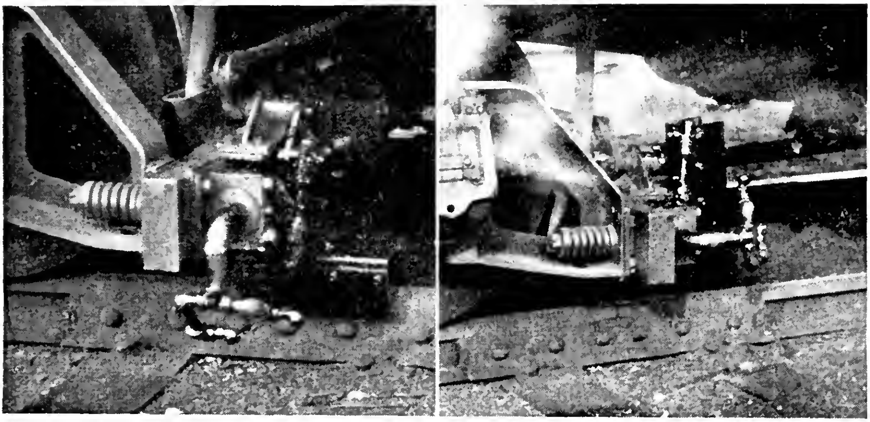

Fig. 4.—Spray Nozzle on Car Designed for Movement in Trains.

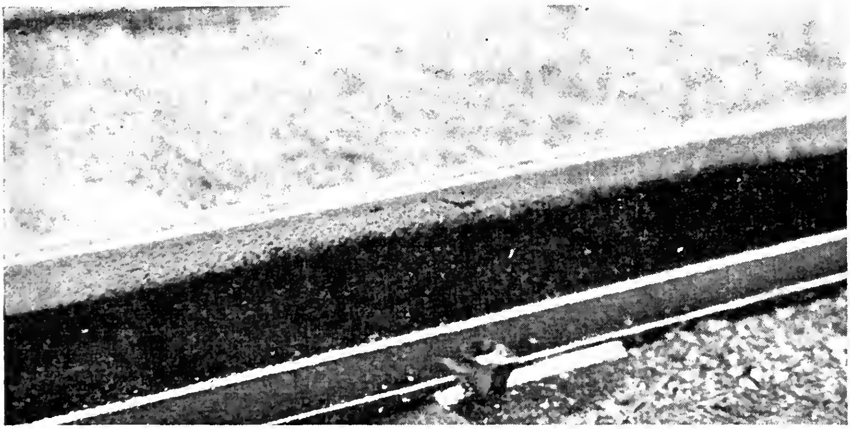

Fig. 5.—An Example of Oil Application.

Fig. 4 shows train spray car nozzles in both the up and down positions. Fig. 5 shows close view of rail after oil application.

The roads reporting the use of train operated spray cars apply from 65 to 200 gal. of hot oil per mile for full application. In most all cases the oil has a 45 to 60-percent asphalt content.

General: Some roads use air compressors equipped with hose and spray nozzles for spot spraying. Portable off-track units are now being developed by one manufacturer which are intended to be used for weed spraying, grass and weed burning, and spot spraying of rail and fixtures, with a view to providing all year use for this type equipment. Another manufacturer is investigating the possibility of modifying a large self-propelled track weed spraying car so as to deliver heated oil for spraying rail and fixtures. Unusual interest is being shown in improving equipment for oiling rail and track fixtures, with the object of reducing the loss of metal due to corrosion. While the conditions which bring about corrosion cannot be eliminated, they can be controlled and damage reduced to a minimum by the proper application of oil or preservatives to the metal track structure.

Report on Assignment 6

Power Cribbing Machines

A. A. Keever (chairman, subcommittee), R. M. Baldock, W. M. Dunn, C. W. Engle, F. L. Etchison, A. J. Flanagan, N. W. Hutchison, R. A. Morrison, E. H. Ness, F. H. Rothe, J. R. Rushmer, J. C. Ryan, M. M. Stansbury, F. F. Zavatkay.

This is a final report, presented as information. A preliminary report was presented last year and appears in the Proceedings, Vol. 49, 1948, pages 158–161.

Of the various types of machines which have been developed to clean cribs, this report will cover only those machines capable of cleaning any type ballast from the crib without preliminary loosening of the ballast ahead of cribbing operation with auxiliary equipment.

One type of cribber removes the ballast from half the crib and deposits the material beyond the ends of the ties by a pivoted digger boom equipped with an endless roller chain on which are mounted digger flights. This on-track machine is supported by a four-wheel carriage on which the power unit and the excavating mechanism are mounted. The endless chain is mounted on a boom which is in the form of a "U." The pivot point is at one leg of the U, while the other leg is the nose of the digger. When in the maximum down position, the U is on its side with the open end towards center of track.

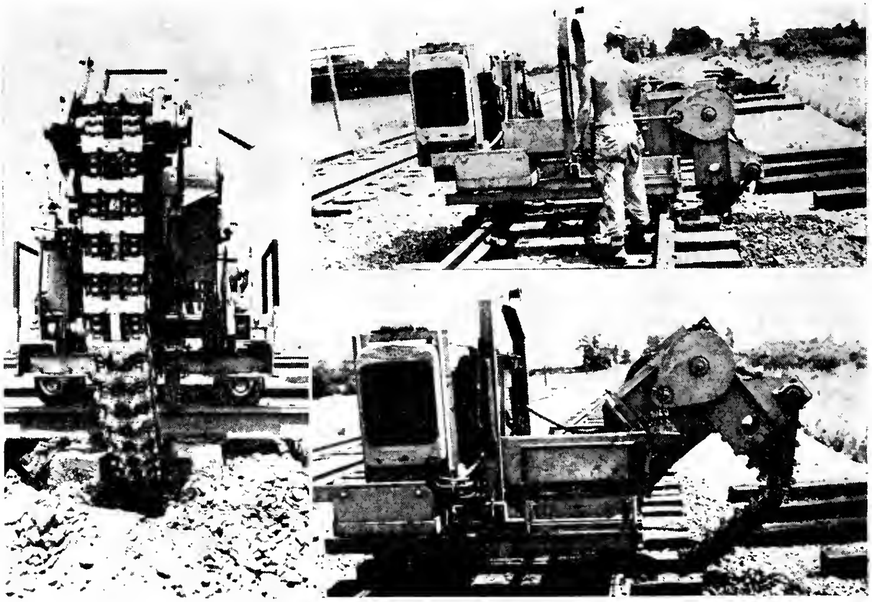

Fig. 1.—Endless Chain Type of Cribber.

The endless chain on which is mounted the digger flight travels around this U. The travel of these digger flights on the bottom is away from the center of track. When the digging boom is lowered to enter the crib, the digging nose contacts the ballast at a point just outside the rail base. As the boom is lowered, the ballast is pulled to ends

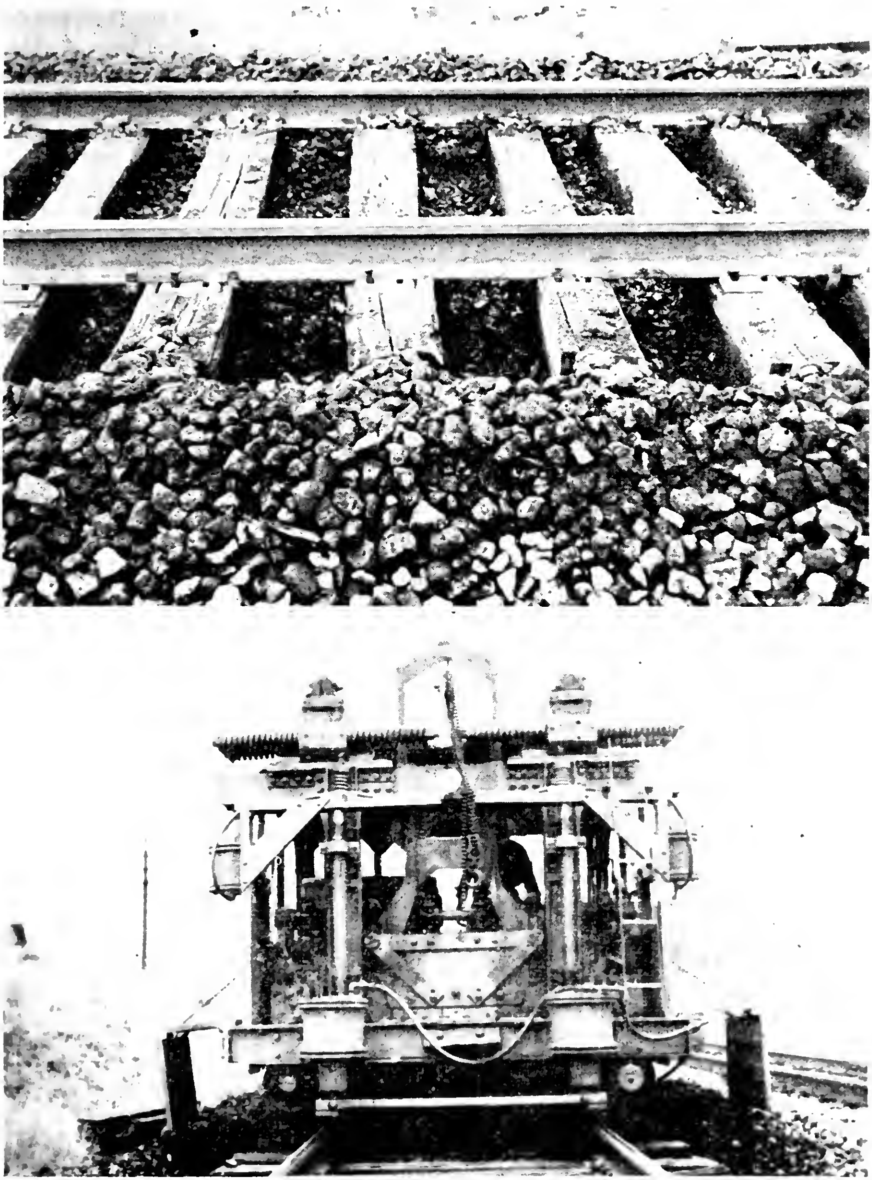

Fig. 2.—This Cribber Employs Digger Bars on a Crosshead. Above—An Example of the Work Done.

of ties and as soon as boom is in plane with the base of rail, the nose is moved under the rail and on towards center of track, cleaning out the crib as the boom moves towards center of track. The digger boom requires a 7½-in. space between ties for insertion in the crib. After a 7½-in. space has been cleaned, the machine is moved back and forth on its carriage in order to clean the entire space between adjacent ties. Power is provided by a four-cylinder gasoline motor mounted on the carriage. The controls are hydraulic. An operator and one man are required to manipulate the machine. The carriage is not self-propelled and must be moved to and from the job by motor car. An hydraulic set-off device is provided to remove the machine from the track, which operation can be done in from three to four minutes. Since one machine cleans the crib from the center of the track to the end of the tie, a companion machine is used on the opposite side to follow up and clean out the other end of the crib. This machine has successfully demonstrated its ability to completely clean a half crib of solidified ballast of the most extreme kind at rate of 60 cribs per hour. See Fig. 1.

Another on-track cribber employs a heavy crosshead which extends across the track for the full length of the tie crib, and transversely acting digging bars are mounted on this crosshead. This crosshead is raised by a continuous chain drive and falls freely after reaching the peak height. There are eight transversely operating digger bars, four working from the center of the track out to the ends of the tie. The mounting of these digger bars is such that there is a force transverse to track which tends to break the ballast loose. After the digger teeth have worked down to the bottom of the tie there is a cam action which increases the transverse action of the digger bars, enabling them to move all ballast to beyond the ends of the tie. The digger bars are equipped with renewable teeth of abrasion resisting material. The digging action is accomplished through

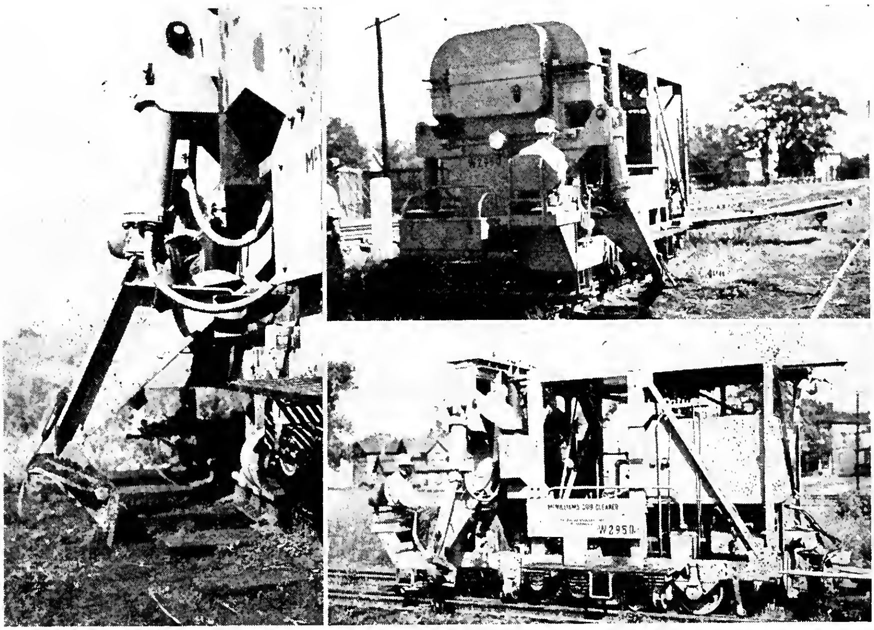

Fig. 3.—Cribber With Bucket Type Conveyor.

impact of the falling crosshead, which enables this machine to break up and remove to beyond the end of the tie, ballast of any degree of solidification, and has demonstrated its ability to clean 60 cribs per hour when working in the most resistant type of ballast. A minimum space of five inches is required between ties for the insertion of the digger bars. The machine is equipped with power-operated transverse set-off wheels and a power lift so it can be removed from the track or replaced on it in from three to five minutes. Air controls are used in operation. The unit is self-propelled, and has a traveling speed of about 25 mph. The construction of this machine is such that it has proved very dependable and reasonably free from mechanical delays. It is operated by one man, with two trackmen to assist in removing it from track. See Fig. 2.

A crib cleaning machine is now in service, which is an on-track unit and employs a bucket type conveyor which picks up the ballast from the crib within the area between the rails, and delivers it to vibrating shaker screens, where it is cleaned and redeposited on the track, while the dirt is delivered to the shoulder by a belt conveyor so mounted that it can be swung to either side of track on which the cleaner is working. The ballast from the end of the tie to the inside of the rail is shoved inside the gage by hydraulically operated rams so the bucket conveyor can pick it up. The machine is self-propelled and has set-off wheels for removal from the track. It has hydraulic controls, the power being supplied by a gasoline motor. As the rams and buckets are nine inches wide, uniform spacing of the ties is necessary for the operation of this machine. The rams are not always completely effective in shoving solidified ballast inside the rail for the bucket conveyor to pick up. In wet ballast the shaker screen cannot successfully remove all the fine material. This machine will clean 40 cribs per hour in partially solidified ballast. An operator and one man handle this machine. See Fig. 3.

Report on Assignment 7

Portable Power Units and Power Tools for Roadway Terminal Gangs

R. E. Buss (chairman, subcommittee), E. L. Cloutier, Jack Largent, W. B. Lee, F. H. McKenney, Francis Martin, P. G. Petri, T. M. Pittman, J. R. Rushmer, F. E. Yockey.

This is a final report, presented as information.

Roadway terminal gangs are naturally subjected to more frequent delays from train movements than outlying divisional gangs. As a result of these additional delays it is obvious that productive work time is lost. To offset this loss of productive time, portable power units and power tools offer some relief.

There are many power units and power tools on the market today, ranging in sizes and capacities to fit most requirements. In the selection of such power units and tools various factors must be considered. For example, density of traffic might preclude the use of on-track machines. Another consideration is the size of gang. A small gang might use unit tampers to a good advantage, while for large gangs multiple tool outfits would be more desirable. Following is a list and brief description of some of the equipment commonly used by roadway terminal gangs:

1. Air compressors are available wheel type tractor mounted, track wheel mounted, skid mounted, wheelbarrow mounted or pneumatic or steel two-wheel mounted. The air compressor capacity for this type of service is usually 110 cu. ft. per min. on the wheel type tractor mounted, 60 cu. ft. per min. on the skid or two-wheel type mounted, and 30 cu. ft. per min. on the wheelbarrow type. Track maintenance forces customarily use the following pneumatic tools with these compressors: Tampers, wood drills and impact wrenches. These drills and impact wrenches are used primarily for the application or removal of screw spikes around switches, turnouts and on curves.

2. Electric generators for operating electric tampers are in common use, and these generating plants also may be used to operate electric wood drills and impact wrenches for the application or removal of screw spikes. Occasionally floodlights are operated from these generating plants in emergencies.

3. Gasoline-driven portable power bolt tighteners are used for the application, removal or maintenance tightening of rail joints and frogs. (Fig. 1)

4. Portable gasoline-driven power rail saws are being extensively used in place of the old method of cutting rails by the nick and break process; as well as the oxyacetylene torch.

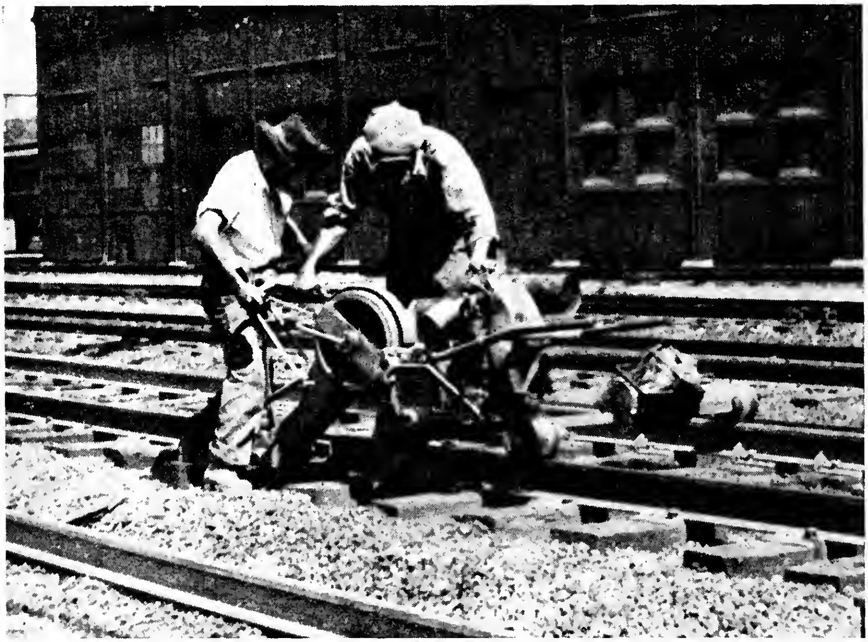

Fig. 1.—Power Bolt Tightener.

5. Portable power rail drills are used extensively for drilling rails and other track fittings and show great economy over the old hand powered drills formerly used.

6. Electric welding generators are used primarily for building up manganese crossings and frogs. They are also used for building up battered rail joints. These welding

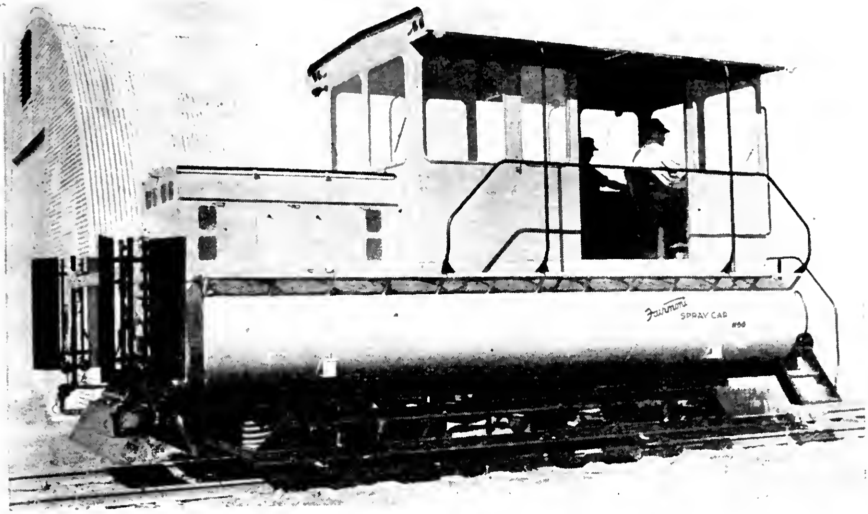

Fig. 2.—A Small Chemical Weed Spray Outfit.

Fig. 3.—Two Types of Weed Mower.

generators may be mounted on a highway truck, a track push car, a crawler tractor, or a rubber-tired trailer mounting to be towed by a truck or moved short distances by hand.

7. Small chemical spraying machines with a tank capacity ranging from 1500 to 2500 gal., self-propelled or towed by a heavy duty motor car, are used for the control of vegetation. Up to the present time the majority of spraying outfits of this type have been constructed by the various railroads according to their own ideas. One manufac-

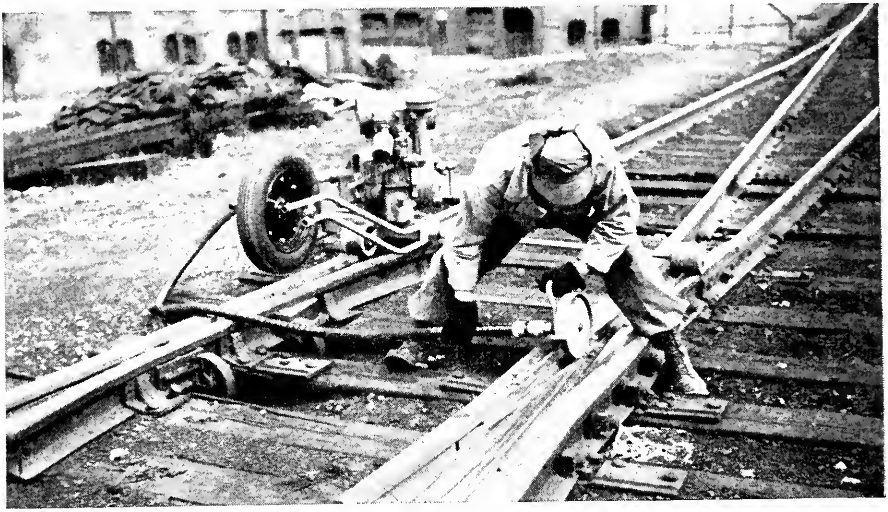

Fig. 4.—A Portable Power Grinder.

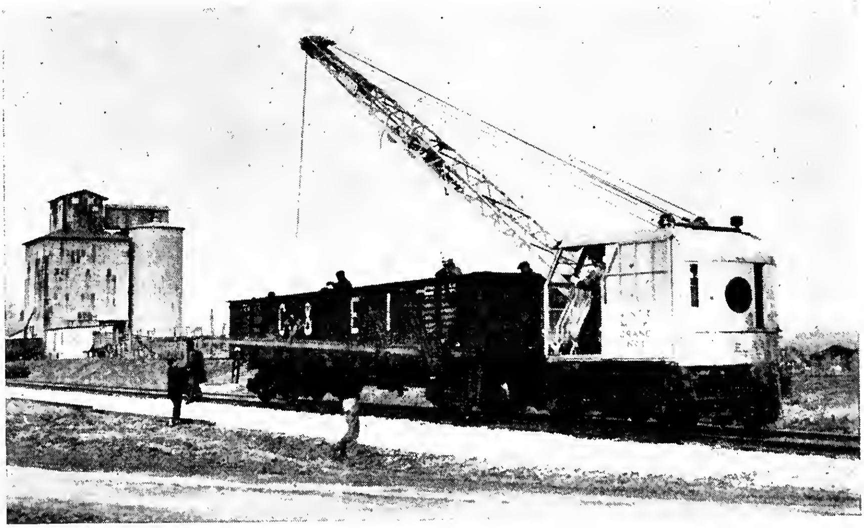

Fig. 5.—Power Cranes Are Widely Used.

turer of railroad equipment has recently developed a small machine of this type with perhaps greater refinement in design than those constructed by the railroads. It is reasonable to assume that with the wider use of chemical weed control, other manufacturers will build similar machines. (Fig. 2.)

8. Weed burners of various sizes are used for weed control in areas such as switching and storage yards that are free from fire hazards. These burners are either of the self-propelled type or rubber tired wheel mounted, the latter pulled or pushed by hand. These burners are also used effectively for melting snow and ice in switches and cars retarders.

9. Weed mowers wheel type tractor mounted, sickle bar self propelled and hand pushed or self-propelled rotary models play an important part in the control of vegetation. (Fig. 3.)

10. Portable power grinders are in common use and these machines are either track or wheelbarrow mounted. They are used principally by track maintenance men for the following purposes: Slotting rail joints to prevent chipping by overlapping of end flow and for removing side flow on switch points and stock rails or in flangeways. (Fig. 4.)

11. Power cranes are commonly used under the direction of the track supervisor for loading and unloading track materials of all kinds, removing worn-out ballast between tracks in preparation for reballasting. (Fig. 5.)

12. Heavy duty motor cars capable of handling several trailer cars are used in lieu of work trains on some terminals. Hydraulic dump bodies are provided for placement on these trailer cars and they are used frequently for the removal or distribution of ballast.

13. Portable oiling machines are used by track forces for oiling track and fastenings in terminals where it is impracticable to use the large track-mounted oil spraying machines.

Real economies are derived from the intelligent and regular use of the above-described power units and tools. Their use not only results in savings in manhours, but also takes the drudgery out of tasks formerly done by hand methods.

Report on Assignment 8

Diesel Engines—Part II

J. N. Todd (chairman, subcommittee), C. M. Angel, R. M. Baldock, R. E. Berggren, C. L. Fero, N. W. Hutchison, E. C. Jackson, W. F. Kohl, Jack Largent, E. H. Ness, P. G. Petri, R. S. Sabins, S. E. Tracy.

This is a final report presented as information:

The assigned subject, diesel engines, was last reported by this committee in Proceedings, Vol. 47, 1946, page 196, giving some historical details and describing fundamentals of the diesel principle, fuel injection, etc. The report was entitled "Diesel Engines —Part I." This report will carry forward the general treatment of the subject as begun in the first report.

Historical

The year 1948 has been observed as the 50th anniversary of the diesel engine, as it was in 1898 that Dr. Rudolph Diesel presented it to the public at the Munich Exposition. In that year it was given its first industrial use, although Dr. Diesel had invented it in 1892. Because of its weight and slow speed the use of the new engine was confined at first to fixed installations such as power plants and for marine power. For many years the diesel was considered a heavy, slow moving engine suited principally to the aforementioned uses.

Engineering developments of recent years, however, have resulted in the design of diesel engines of lighter weight and greater speed. The horse-power-weight ratio has changed greatly in the past 10 to 15 years, resulting in greater use of diesel power in a variety of portable machines. The volume of production of diesel engines has greatly expanded and while the last war added impetus to this expansion, it should be pointed out that the expansion was well under way before the war began.

American Developments

American manufacturers of diesel engines are alert and aggressive, and now number approximately 50, and they offer about 10 times that many models, including portable, stationary and marine models. While the great majority of models are over 100 hp., there are a considerable number in the smaller sizes. Nearly a dozen makers offer engines of less than 10 hp. One of the American made, air-cooled, small diesels has the following specifications:

Cylinders	1
Bore	3 in.
Stroke	4 in.
Compression ratio	18:1
Continuous horsepower at 1800 rpm.	3.75
Weight fully equipped	415 lb.

A tabulation of makes and models by size groups, as of early 1948, reveals the following with respect to diesels in this country (marine models are included, and in many cases are duplicates of other models except for marine modifications):

	Under 10 hp.	*10–100 hp.*	*100–1000 hp.*	*Over 1000 hp.*
Makers	12	30	42	16
Models	18	155	426	99

Foreign Developments

The foreign use of diesel engines has shown a greater trend toward smaller sizes than has been true in this country and that trend began earlier. In some of the South American countries where gasoline is scarce and expensive, diesel engines were used for automotive power years ago. In Europe today a number of small diesel generating sets are on the market. Several English manufacturers are offering diesel-powered generating sets of less than 10 kw., one as low as 1.75 kw. Typical of the small English diesels is that offered by one manufacturer in single or twin cylinder, air-cooled models. Starting is by hand crank on the camshaft and a decompressing device is used. Following is a brief description:

	Single	*Twin*
Bore	85 mm.	280 lb.
Stroke	100 mm.	85 mm.
Compression ratio	19.5:1	100 mm.
Dry weight	200 lb.	19.5:1
Speed range, rpm.	1200 to 1800	1200 to 1800
Brake horsepower 12-hour rating at 1500 rpm.	5.1	11.7

A novel application of diesel power is found in a pile hammer brought out of Germany after the war by our armed forces. It has a single cylinder and works about as gasoline hammers and unit tampers do, except that the diesel principle is utilized. It is still in the hands of the government and is being tested. The size in use at present is relatively small, its weight being about 2000 lb., including the piston, which weighs 1100 lb., but the stroke is 6½ ft. giving about 6600 ft.-lb. of energy.

Without going into detail, which is not practical here, the following description of the operation is offered. The fall of the piston compresses the fuel mixture to the heat of combustion and the resulting explosion drives the pile downward. The energy of the falling piston also serves to break the skin friction of the pile, thereby overcoming inertia and giving the effect of greater force to the explosion by starting the pile immediately before the explosion occurs. A mechanism to inject fuel at low pressure into the combustion chamber is operated by the movement of the piston. Exhaust ports in the cylinder wall are closed by the fall of the piston. The rate of operation is 50 strokes per minute, fuel consumption 0.8 gal. per hour and thermal efficiency of 17 percent is claimed. A multiple-drum hand winch is used for hoisting and for raising the ram for its first stroke, after which the action is automatic.

Railroad Use

Railroad use of diesel engines has been principally in the diesel electric locomotives. Aside from that, however, diesels have been used in work equipment for 12 years or more. On some roads diesel power is used generally in crawler shovels, crawler cranes, tractor bulldozers, locomotive cranes and air compressors. The question of when to assume the extra cost of diesel power is an economic one and has no place in this committee's report, but the greater efficiency of fuel and lower fuel cost of the diesel as against the greater initial cost, measured by the time used, are the principal factors which determine the answer.

Some roads find that with ordinary care diesel engines have a long life, probably greater than that of gasoline engines. Engines having renewable cylinder liners present no serious problem of overhaul. Proper lubrication is the principal item of care and close attention to filters and crankcase oil will add many trouble-free years of service. Without these simple precautions the life of a diesel engine, as well as any other type, may be very short indeed, but there are many who believe that lubrication is more critical in diesels than in others. The care and attention to filters should include fuel and air filters as well as oil. Clean fuel reaching the injectors means long life to the injectors. Otherwise they will be a constant source of trouble and failure.

Report on Assignment 9

Portable Power Units and Power Tools for Bridge and Building Gangs

F. H. McKenney (chairman, subcommittee), C. M. Angel, R. M. Baldock, R. E. Berggren, W. R. Bjorklund, F. L. Etchison, C. L. Fero, E. B. Harris, E. C. Jackson, Francis Martin, E. H. Ness, T. M. Pittman, J. N. Todd.

This is a final report submitted as information.

Due to ever changing conditions it is necessary from time to time to bring up to date, information pertaining to various power units and tools available for construction and maintenance gangs.

Portable bridge and building power units and tools in common use are in three general classes:

1. Direct driven gas engine tools such as table saws, chain saws, paving breakers, concrete vibrators, and several kinds of flexible shaft driven tools.
2. Electric generators and tools.
3. Air compressors and air driven tools.

Air compressors and electric generators have long been used on the larger gangs doing heavy construction work but with increased cost of labor and scarcity of skilled men there has arisen a need of smaller, highly portable units for use in maintenance gangs. Portable electric generators are now available in almost any size from the large self-propelled track-mounted machines down to small one-kilowatt machines which can be carried by one man and will operate a one-horsepower tool. Air compressors, while generally much heavier constructed, can now be obtained in very small units for paint spray operation.

To be of maximum value for the small gangs, an electric generator must be small enough to be really portable and many gangs are now being equipped with generators of from 1.5 to 5 kv.a., any of which can be handled by two to four men. The cost of operation over a period of years of a small gas engine-driven generator will probably be greater than larger and heavier machines, but the savings due to size and portability more than make up for any excess operating and repair cost. Some of these small plants have run two or three years without repairs. Most electric tools also stand up well and require very little shop work.

Portable electric power units may be direct current, or single-phase, or three-phase alternating current. Some think that the 2.5 or 3-kv.a. and 5-kv.a. three-phase 110/220 volt 60-cycle units with 110 volt single-phase outlets for portable saws, drills, hammers, flood lights, etc., are ideal portable power plants and are preferred over single-phase and direct current power plants because they do not have commutators and brushes and have a minimum number of internal connections and moving parts. The three-phase generator will operate the occasional three-phase tool and also will operate single-phase tools with universal a.c.–d.c. motors up to the rated capacity of each circuit which is approximately 1/3 the total rated capacity of the unit.

A recent development in portable electric power units is the 180-cycle generator and tools. These are not in very general use as yet although some roads report very satisfactory results. So far there is only one manufacturer producing these tools and units. The generator produces 180-cycle three-phase current at 230 volts. The advantages claimed for 180-cycle tools is that much greater horsepower is developed from a smaller lighter weight tool. As an example, a 24-in. chain saw with 180-cycle 230-volt three-phase motor weighs only 33 lb., compared to 45 lb. or more for a similar 60-cycle tool. Other high cycle tools include wrenches, grinders and drills, all of which are smaller and lighter weigh than corresponding 60-cycle tools. In addition to operation of high-cycle 230-volt tools the generators will operate 110-volt universal a.c.–d.c. tools of conventional design from a 110-volt direct current outlet provided on the generator. An engine generator set of 5000 watt capacity weighs only 175 lb. The high cycle tools will fill a need for tools requiring considerable power that are used in close quarters or in hazardous or difficult positions where light weight and small size are important.

Electric tools are mostly single-phase 110/220 volt 60-cycle a.c.–d.c. universal and are available for a large number of uses. For safety reasons, it is important to use grounded cables on all tools equipped with ground wire to prevent possible serious injury from electric shock in case the tool or wiring is short circuited or grounded. Serious shock or even death can occur when working on wet ground or in water with tools not properly equipped with ground wires. Tools usually assigned to bridge and building gangs for use with portable electric generators include circular saws up to 12 in., electric drills from ¼ in. up to ⅞ in., electric nut runners, electric grinders, flood lights, and a number of special tools and attachments. A small electric impact wrench has been developed but there is need for the development of a heavy duty electric impact wrench for use in place of the nut runners. Most small electric tools have universal motors which operate on either 110-volt 60-cycle a.c. or d.c. current. Some bridge departments prefer 220-volt tools especially for saws and larger tools requiring considerable power but for small tools the 110–125 volt rating is more common, as it can be plugged into any 110–125 volt lighting circuit as well as into a portable plant. Where 220-volt tools are in use the generator must be 220 volt and if 110-volt tools are operated from it a two-to-one transformer may be used to provide 110-volt current for 110-volt tools or for lighting.

Portable air compressors are used in bridge and building gangs in sizes ranging from 60 to 315 cu. ft. per min. The usual sizes are 60, 85, 105, 210 and 315 cu. ft. The 210 and 315-cu. ft. sizes are usually mounted on a 4-wheel truck for either on-track or off-track transport. Some are tractor or truck mounted. These are quite large machines weighing three tons or more and cannot be classed really as portable units for the purpose of this discussion. They may be mounted on pneumatic tired trucks if desired. The larger units are used more often with large construction gangs which do not move often and where large amounts of air are required and portability is not so necessary.

The three smaller sizes (60, 85 and 105-cu. ft.) compressors are available mounted on two-wheeled pneumatic tired frames for ready transportation. The two smaller sizes are available on narrow tread pneumatic tired frames for use along track shoulder and can be moved along by hand in rather close quarters. The 60-ft. compressor so mounted weighs about 1300 lb. It can be hauled on a trailer or push car. The smaller compressors can be readily moved and placed near the work to be done, avoiding the construction of long pipe lines. Some roads prefer to couple two or more compressors together rather than use the larger, more cumbersome machines, where the occasional job requires more than the capacity of one machine. The 105-cu. ft. compressors similarly mounted weigh around 4000 lb. and while readily portable, require the use of a tractor or truck to move them about. They are usually equipped for towing behind a tractor or truck.

Recently, several small compressors have been developed to compete for portability with electric power units, but the volume of air produced is small and therefore their use is limited to jobs requiring compressed air in small quantities. One of these has a wheelbarrow type of mounting with single pneumatic tire. It has a horizontally mounted radial type four-cycle, three-cylinder gas engine, with three air compressor cylinders alternated between the engine cylinders, all connected to a single crank. It weighs about 250 lb. and can be carried on a motor car. It will produce about 35 cu. ft. of air per minute.

There is a wide choice of air-operated tools to be had for almost any purpose and some special purpose tools. One recent tool development is a 150-watt electric generator consuming about 10 cu. ft. of air at 90 lb. pressure which will furnish light for emergency jobs where air is being used and electric current is not available.

The more common air tools furnished to maintenance bridge and building gangs are: Circle saws up to 12 in., chain saw, drills and wood boring machines with bits up to 52 in. long, with twist length of 48 in., wrenches for bolting and unbolting, impact wrench, and air operated hoist. Some of the heavier equipment like various kinds of jack hammers, riveting equipment, etc., are usually furnished only to special gangs doing that kind of work, but a stock of such tools may be maintained at some central point for use of small maintenance gangs when called for.

The development of light portable power units has made a great many power tools available to the small maintenance gang to increase efficiency of the gang. The lighter weight and more portable nature of electric power units, together with the low maintenance and dependability of electric tools and use of such tools on most electric lighting circuits, has caused many departments to consider greater use of electric units.

Report on Assignment 10

New Developments in Maintenance of Way Equipment

N. W. Hutchison (chairman, subcommittee), W. R. Bjorklund, W. M. Dunn, C. W. Engle, E. B. Harris, C. H. R. Howe, E. C. Jackson, F. H. Rothe, M. M. Stansbury, J. L. Starkie, S. E. Tracy, E. G. Wall, G. R. Westcott, F. F. Zavatkay.

This is a final report, presented as information.

This assignment is the result of an ever-present demand on the part of railroad maintenance officers for machines to perform as many of the maintenance tasks as is possible, and a desire on the part of the work equipment manufacturers to satisfy this demand.

The initial report on this assignment was submitted to the Association in March 1942, in which an historical outline is presented to show the evolution from hand labor to machine work, and its underlying causes. That report emphasized the fact that the early machines were crude and inefficient, and some at least, apparently were designed by persons who had only a hazy knowledge of railroad requirements. The use of work equipment on railroads has assumed large proportions and consequently it has been of interest to the manufacturers to develop machines of new types and to improve their existing machines continually. It is also of interest to the Association not only to keep its membership informed of the new machines that are available, but also to inform the manufacturers of machines that should be developed.

This current report is confined to a brief description of new machines that have been made available for purchase since the last report of this subcommittee in 1944, but does not include any machines that have been described in reports of other subcommittees. It also includes reference to changes in design of existing machines but only where the revised design permits the use of the machines for work other than that for which they were originally designed. In addition, the report brings to the attention of the Association and the manufacturers, the need for machines to perform work for which equipment is now not available.

New Machines

Tractor-Spreader

A crawler-mounted tractor, equipped with spreader wings, has been developed and is in use on one or more railroads. This machine operates on top of the rails and, in addition to the crawler treads with lugs which keep it on the track, it is equipped with small, flanged wheels which help support the front of the machine and assist in keeping it on the track. The spreader wings are controlled by cables actuated by rear power take-offs and within certain limits, can cut ballast away from the heads of the ties, spread dirt and perform other work of a similar nature. It is claimed that the crawler shoes are so constructed that they do not damage the rails.

Soil Compactor

There are two machines referred to as soil compactors, one of which is powered by a gasoline engine mounted in the machine, similar to a gasoline paving breaker; the other being an electrically driven vibratory machine.

The first-named machine operates on a modification of the rocket principle, in which the machine is forced upwards and falls back by gravity, tamping as it strikes. The weight of the machine is approximately 200 lb. and the drop is said to be sufficient to produce the desired soil compaction.

The electrical soil compactor consists of a vibratory motor mounted in a metal frame, and is operated by a 3-phase, 60-cycle, 110-volt squirrel-cage induction motor. When in operation, it propels itself at a speed of 5 to 6 ft. per min. and is guided by the operator. When used for compacting granular materials, the frame has a corrugated base; by substituting a smooth base, the machine can be used for compacting and smoothing asphalt-type paving mixtures at highway crossings and station platforms.

30-Cubic Foot Air Compressor

A small, portable air compressor, weighing approximately 200 lb. is now being manufactured and marketed. It is equipped with a carrying bar and is also furnished with a detachable rubber-tired wheelbarrow frame.

The machine consists of six radial cylinders, alternately air and power, arranged in a horizontal plane surrounding a vertical, single throw crankshaft. The power cylinders operate on the four-stroke cycle principle, with magneto ignition and the entire unit is air-cooled.

The appeal claimed for this machine is its small size, light weight, ready portability and low maintenance costs.

Prime Mover

A machine known as a "prime mover" is essentially a gasoline-powered wheelbarrow with two front and one rear pneumatic-tired wheels, and a tilting bucket. The bucket is dumped by pressure on a foot pedal which, when the load is dumped, returns to normal position automatically. The bucket may be replaced by a platform body for use in hauling, a variety of materials, and a snow plow attachment is optional.

The unit, with a 10-cu. ft. bucket, weighs 440 lb. and is of 1000 lb. capacity. It is powered by a 3-hp., two-cycle, air-cooled engine, with impulse starter magneto and is equipped with a kick-starter.

Crane Carrier Car

One of the crane manufacturers has developed a carrier car for one of its crawler-mounted cranes, which permits the crane to be operated on railroad track under power supplied by the crane's engine.

The carrier car has a well-type frame, suspended between two pairs of flanged wheels, one pair of which is provided with a gear mechanism for transmission of power from the crane. The opposite end of the car is provided with a storage space, and the car is equipped with a lifting bail by which it may be placed on, or removed from, the track by the crane.

The handling of the crane to and from the carrier car is accomplished with the aid of two ramps that are carried in the storage space as standard equipment. When in position on the carrier car, the crane crawler tracks are at right angles to the track and suitable means are provided for locking them securely in that position.

The manufacturer advertises that the crane, in conjunction with the carrier car, can be used for all work for which both on and off-track cranes are adaptable.

Truck-Mounted Shovel With Rotating Telescopic Boom

There is on the market a truck-mounted excavating outfit which, instead of the conventional boom and dipper, is equipped with a hydraulically controlled, telescopic boom. The boom will rotate through 45 deg. above or below its normal horizontal position and the boom length ranges from 12 to 24 ft. It has a boom angle ranging from 22 deg. above to 44 deg. below the horizontal, and its maximum digging depth is 10 feet below the ground surface. The rotating range of the unit is 360 deg.

Equipped with a variety of attachments, this machine is advertised as being capable of working up against curbs and walls, around poles and trees, under low hanging wires and in other close quarters, doing such work as trench digging, highway widening, basement excavating, ripping and loading old pavement, ditch cleaning, sloping and grading, back filling and removing snow.

Ballast Cribbers

Two manufacturers are producing machines designed for lowering ballast in tie cribs during rail laying operations, the purpose being to prevent the ballast from fouling the adzing machines. One of the machines may be used also for removing ballast from the cribs over the entire length of the ties, but this must also be done while the rail is removed during rail laying operations.

Each of these machines is operated by a gasoline engine and consists essentially of a belt driven digging wheel of from 40 in. to 48 in. in diameter equipped with 12 evenly spaced digging teeth. One of the machines has a rotating brush attachment for removing ballast from the tops of the ties.

Ballast Plow and Track Dresser

A machine known as a "Ballast Plow and Track Dresser" has been developed for use in plowing dumped ballast from between the rails and shaping the ballast shoulder. It is a track-bound machine but is equipped with a turntable for removing it from the track.

This unit is powered by a 100 hp. gasoline engine, and is equipped with a V-shaped plow and dressing wings with scarifying teeth, all of which are hydraulically controlled.

The manufacturer states that this machine will plow out, regulate, shape and scarify ballast. It is also said that, by removing the attachments, the power unit may be used as a motor car.

High Cycle Generators and Electric Tools

Most of the electrical tools used for railroad maintenance work are those which operate from a current frequency of 60 cycles. Just recently certain manufacturers have made available for purchase, electrical tools which operate from a current frequency of 180 cycles and the tools of this type are referred to as "high cycle" tools.

A partial list of the high cycle electrical tools available includes drills, screw drivers, nut runners, grinders, buffers, sanders, polishers, impact wrenches, paving breakers and chain saws.

In order to operate these high cycle tools, a high cycle alternating current generator is essential and such generators are also available. One manufacturer has on the market a "dual-purpose" generator which, in addition to producing 230-volt, 180-cycle, 3-phase alternating current for operation of high cycle tools, also produces 110-volt direct current to operate floodlights and standard universal electric tools.

It is said that the most outstanding advantage of high cycle tools is that they maintain their speed and power under load, thereby permitting faster work, with uniform results and less fatigue to the operator. A particularly important feature of this type tool is the increased power-per-pound-of-weight; thus being lighter and more easily handled.

Improvements to Existing Machines

Ballast Excavator

One of the manufacturers of off-track ballast cleaning equipment has made an improvement to one of the cleaning machines whereby the ballast and dirt may be excavated from the center ditch, and from the shoulder if desired, and disposed of by means of a belt conveyor. This is accomplished through a solid, metal vibrating chute which replaced the vibrating shaker screen normally used to clean the ballast; otherwise, there is no difference in the construction or operation of the machine. It is claimed that the shaker screen and the chute are readily interchangeable and that considerable economy can be effected in the stripping of center ditch and shoulder ballast. In conjunction with a ballast cribbing machine, entire tracks may be completely stripped of ballast except under the ties, by mechanical means, within certain limits of depth.

In the 1942 report on this assignment, the following machines were suggested for development:

1. Electrically-operated impact wrench.
2. High-cycle electrical tools.
3. Self-contained, gasoline operated spike driver.
4. Crib ballast cleaner.
5. Portable rail saw.
6. One-man inspection motor car weighing less than 400 pounds.
7. Signal to warn track and bridge gangs of the approach of trains.

As an indication of the interest displayed by the manufacturers in the machines suggested for development, all but the last two items mentioned above, have been developed and are in use on various railroads. These two items are still an unfulfilled requirement.

The following suggestions have been made by railroad representatives, for machines that. in their opinion, should be made available:

Suggested Developments

1. A machine to crop and redrill rail in the field during rail relaying.
2. Heavy duty electric impact wrench.
3. Multiple drill for boring ties in the field, to fit various tie plate punchings.
4. Magazine-fed spike driver in which spikes are fed into a tube and held in position automatically; this to eliminate spike setting by hand drivers.
5. A drainage car or scarifier so constructed that it can perform its work while moving both forward and backward.
6. A machine for preparing tie beds for installation of ties.

Report of Committee 29—Waterproofing

G. E. Robinson *Chairman,*	W. G. Harding	R. L. Mays, *Vice-Chairman,*
Lyle Bristow	E. A. Johnson	F. J. Pitcher
L. J. Deno	M. L. Johnson	W. E. Robey
L. P. Drew	J. A. Lahmer	A. L. Sparks
P. R. Eastes	J. F. Marsh	T. M. von Sprecken
E. T. Franzen	M. S. Norris	J. P. Walton
Nelson Handsaker	B. J. Ornburn	C. A. Whipple
	H. A. Pasman	*Committee*

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Waterproofing of railway structures in collaboration with Committees 8 and 15.
   No report.

3. Waterproofing protection to prevent concrete deterioration.
   Progress report, presented as information below.

The Committee on Waterproofing,
G. E. Robinson, *Chairman.*

Report on Assignment 3

Waterproofing Protection to Prevent Concrete Deterioration

The research staff of the Engineering Division, AAR, has completed a test for Committee 29 on the waterproofing properties of various proprietary waterproofing membranes. This test was an attempt to compare the various membranes as to their ability to perform the protective job necessary to prevent entrance of water and subsequent concrete deterioration. This test will be reported in a later bulletin.

Another test is now planned to try various surface coatings on concrete for use in above-grade waterproofing. This test will consist of two sections; the first will be a laboratory test using all of the available surface coatings proposed by the suppliers; the second will be a field service test of those coatings performing best in the laboratory.

The laboratory experiments will subject small concrete blocks treated with the coatings to alternate cycles of freezing and thawing and periods of exposure in a weatherometer. The length of time that a coated block lasts before deteriorating will be compared to the length of time that an uncoated control block lasts. In this manner, a comparative performance record will be obtained on each coating.

Coatings which the laboratory test indicates to be suitable will then be applied on existing railway structures so that field service ratings may be obtained, and a correlation established between service performance and the accelerated laboratory tests. These coated structures will be compared with nearby uncoated structures of the same age and built of concrete with the same characteristics and composition. Thus, finally, the efficiency of any coating in preventing concrete deterioration can be evaluated.

AREA Bulletin 477, December 1948.

Report of Committee 3—Ties

C. D. Turley, *Chairman,*
M. L. Bardill
R. S. Belcher
H. J. Bogardus
W. C. Bolin
W. H. Brameld
P. D. Brentlinger
W. J. Burton
R. E. Butler
F. G. Campbell
G. B. Campbell
B. S. Converse
R. L. Cook
R. W. Cook
W. T. Donoho
L. P. Drew
H. R. Duncan
T. H. Friedlin
L. E. Gingerich
E. A. Humphreys
C. E. Jackman
R. H. Jordan
C. M. Long
Roy Lumpkin
R. B. Midkiff
B. D. Howe, *Vice-Chairman,*
L. E. Peterson
Arthur Price
W. W. Rohrbough
E. F. Salisbury
T. D. Saunders
W. D. Simpson
J. G. Sutherland
S. Thorvaldson
W. H. Vance
A. W. White

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of the Manual.
   No report.

2. Extent of adherence to specifications.
   Progress report, presented as information .... page 356

3. Substitutes for wood ties.
   No report.

4. Tie renewals and costs per mile of maintained track.
   Progress report, presented as information .... page 357

5. Cause and control of splitting in track ties.
   No report.

6. Methods for reducing mechanical wear of track ties, including stabilization of wood, collaborating with the NLMA.
   Progress report, presented as information .... page 357

7. Causes leading to the removal of ties.
   No report.

8. Dimensions of ties.
   No report.

The Committee on Ties,
C. D. Turley, *Chairman.*

AREA Bulletin 477, December 1948.

Report on Assignment 2

Extent of Adherence to Specifications

P. D. Brentlinger (chairman, subcommittee), M. L. Bardill, W. J. Burton, G. B. Campbell, R. L. Cook. R. W. Cook, W. T. Donoho, L. P. Drew, H. R. Duncan, T. H. Friedlin. L. E. Gingerich, C. E. Jackman, C. M. Long, E. F. Salisbury, W. D. Simpson, J. G. Sutherland, S. Thorvaldson, A. W. White.

Committee 3 continued field inspection of cross ties stored for seasoning by the railroads at various wood preserving plants during 1948. Observations showed that cross ties are being manufactured and inspected in accordance with the current AREA specifications. Enough standard ties were in stock to prove conclusively that when the railroads require sound full-sized ties, the manufacturer will produce such ties. Similarly railroads that disregard wane, decay and full-body dimensions and inspect ties on that basis are being offered ties of an inferior quality.

The committee, as a whole, is in agreement that the majority of railroads purchase and inspect ties according to approved specifications and, aside from the expected failure of the inspector to catch every defect, and wane, the sizing of ties compared favorably with any visual inspection.

Total disregard of standard acceptance practices was noted in a few cases. In one case ties were sized up as much as two sizes—entirely too much to be ascribed to an error on the part of the inspector. Ties obviously sized up and many ties too thin or too narrow for the size class branded were in evidence. Such practice is one way to increase the price of ties, but, such ties laid in track do not give the service life expected of a tie so branded.

With the high cost of cross ties laid in track today, strict vigilance is necessary to guarantee the maintenance of way departments the quality of product that will perform satisfactorily with a long service life.

Committee members completed two field trips in 1948, and observed 1,500,000 railroad ties in six wood preserving plants located in five states. The ties were produced in 17 states and were stored for 8 eastern railroads.

Generally the wood preserving plants were well maintained but in a few, scattered debris and weeds created a fire-hazard as well as a breeding place for wood destroying fungi. Sound, treated sill ties were the rule rather than the exception, although some old sill ties too crushed or shattered for holding the weight of cross ties were observed. Treating companies had done a reasonably good job of stacking ties. Where ties were crowded together, it was noticed those ties were usually over-sized hewed ties, and the treating company had only complied with the instructions of the railroad in placing a given number of ties in each layer. Mechanical stacking was usually better than manual placement of ties. Lift trucks or cranes usually did an exceptionally good job of spacing the ties. Proper spacing is important to insure an adequate circulation of air currents to season the ties properly.

Railroad representatives charged with the responsibility for railroad material in treating plants should exercise close supervision over spacing and ironing of ties, and insist that the storage yard be kept free of weeds or debris.

Table A

Table 4

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I STEAM RAILWAYS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1947

Road	Cross ties laid in replacement: New wooden ties untreated (U): Number	New wooden ties untreated (U): Average cost	New wooden ties treated (T): Number	New wooden ties treated (T): Average cost	Total all new wooden ties laid: Number	Total all new wooden ties laid: Average cost	Ties other than wood(S) & second-hand (*) reapplied ties	Total ties applied	Miles of maintained tracks (item 25)	Estimated total cross ties in all maintained tracks (item 24)	Average number of cross ties per mile of maintained track	Number of equated gross ton-miles a (thousands)	Number of equated gross ton-miles per mile of maintained track (thous.)	New wooden cross tie replacement averages: Per cent renewal to all ties in track	Number laid per mile of maintained track	Renewal cost per mile of maintained track	Renewal cost per 1000 equated gross ton-miles
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NEW ENGLAND REGION:																	(cents)
Bangor & Aroostook	70 123	$1.57	65 287	$2.96	135 410	$2.24	-	135 410	829.04	2 382 831	2 874	2 110 537	2 546	5.7	163	$365	14.36
Boston & Maine	296	1.00	179 537	2.96	179 833	2.96	-	179 833	2 884.88	8 510 400	2 950	17 010 123	5 896	2.1	62	185	3.13
Canadian Nat.Lines in New Eng.	1 527	0.83	24 209	1.99	25 736	1.92	-	25 736	237.61	751 871	3 164	613 939	2 584	3.4	108	208	8.04
Canadian Pacific (lines in Me.)	1 007	1.60	20 565	2.17	21 572	2.14	-	21 572	216.07	671 715	3 109	2 138 699	9 898	3.2	100	214	2.16
Canadian Pacific (lines in Vt.)	394	1.50	8 130	2.15	8 524	2.12	-	8 524	125.08	377 644	3 019	723 411	5 784	2.3	68	145	2.50
Central Vermont	-	-	25 695	2.43	25 695	2.43	* 599	26 294	495.02	1 463 000	2 955	2 354 734	4 757	1.8	52	126	2.66
Maine Central	47 647	1.50	101 738	3.15	149 385	2.62	-	149 385	1 210.23	3 619 900	2 991	4 737 555	3 915	4.1	123	324	8.27
New York Connecting	-	-	3 242	3.45	3 242	3.45	-	3 242	25.90	81 641	3 152	371 474	14 343	4.0	125	431	3.01
New York,New Haven & Hartford	-	-	315 566	2.72	315 566	2.72	-	315 566	3 809.61	11 919 330	3 129	27 277 064	7 160	2.6	83	225	3.14
Rutland	-	-	18 891	2.49	18 891	2.49	* 1 619	20 510	486.13	1 511 300	3 109	1 711 614	3 521	1.2	39	97	2.75
Total	120 994	1.53	762 860	2.80	883 854	2.62	2 218	886 072	10 319.57	31 289 632	3 032	59 049 150	5 722	2.8	86	225	3.93
GREAT LAKES REGION:																	
Ann Arbor	-	-	40 364	2.75	40 364	2.75	-	40 364	402.78	1 221 484	3 033	1 865 813	4 632	3.3	100	275	5.94
Cambria & Indiana	-	-	4 610	2.88	4 610	2.88	-	4 610	56.43	162 501	2 880	152 031	2 694	2.8	82	235	8.74
Delaware & Hudson	26	1.27	166 701	3.00	166 727	2.99	(S) 274	167 001	1 355.40	4 244 880	3 132	15 328 908	11 310	3.9	123	368	3.26
Delaware,Lack.& Western	-	-	188 567	2.78	188 567	2.78	* 6 391	194 958	2 181.86	6 327 854	2 900	18 519 052	8 488	3.0	86	241	2.84
Detroit & Mackinac	16 730	1.54	19 369	2.22	36 099	1.91	-	36 099	275.78	826 009	2 995	313 778	1 138	4.4	131	249	21.93
Detroit & Toledo Shore Line	-	-	10 084	3.08	10 084	3.08	* 151	10 235	149.26	450 321	3 017	812 199	5 442	2.2	68	208	3.82
Erie	86	1.03	290 278	2.85	290 364	2.85	-	290 364	4 709.09	13 885 890	2 949	43 346 084	9 205	2.1	62	176	1.91
Grand Trunk Western	-	-	214 100	2.34	214 100	2.34	-	214 100	1 850.02	5 867 717	3 172	11 139 152	6 021	3.6	116	271	4.51
Lehigh & Hudson River	511	1.70	10 498	3.40	11 009	3.32	* 1 616	12 625	111.72	300 300	2 688	921 229	8 246	3.7	99	328	3.97
Lehigh & New England	-	-	18 477	3.16	18 477	3.16	-	18 477	245.14	742 836	3 030	1 070 525	4 367	2.5	75	238	5.46
Lehigh Valley	-	-	241 310	3.07	241 310	3.07	-	241 310	2 590.18	7 726 409	2 983	16 981 254	6 556	3.1	93	286	4.36
Monongahela	-	-	18 223	2.88	18 223	2.88	-	18 223	238.41	694 714	2 914	1 531 416	6 423	2.6	76	220	3.43
Montour	1 526	2.29	4 820	3.58	6 346	3.27	* 89	6 435	72.88	209 895	2 880	334 975	4 596	3.0	87	285	6.19
New York Central	172	1.84	1 532 914	2.81	1 533 086	2.81	* 899	1 533 985	20 964.62	64 588 333	3 081	193 740 173	9 241	2.4	73	206	2.22
New York,Chicago & St.Louis	-	-	341 696	2.85	341 696	2.85	-	341 696	2 539.96	8 000 874	3 150	26 960 855	10 615	4.3	135	384	3.61
New York,Ontario & Western	-	-	-	-	-	-	* 11 942	11 942	703.31	1 995 516	2 837	2 253 446	3 204	-	-	-	-
New York,Susq.& Western	-	-	8 670	2.67	8 670	2.67	-	8 670	212.73	617 804	2 904	369 661	1 738	1.4	41	109	6.27
Pittsburgh & Lake Erie	-	-	81 809	2.60	81 809	2.60	-	81 809	824.13	2 490 364	3 022	5 577 543	6 768	3.3	99	258	3.82
Pittsburg & Shawmut	-	-	17 887	3.10	17 887	3.10	* 8	17 895	116.57	329 471	2 826	407 752	3 498	5.4	153	476	13.60
Pittsburgh & West Virginia	-	-	14 509	3.24	14 509	3.24	* 3 308	17 817	180.93	550 571	3 043	1 334 063	7 373	2.6	80	260	3.53
Wabash	-	-	315 430	2.70	315 430	2.70	-	315 430	3 166.09	9 858 302	3 114	26 652 604	8 418	3.2	100	269	3.20
Total b	19 051	1.60	3 540 322	2.81	3 559 373	2.80	24 678	3 584 051	42 957.91	131 734 118	3 067	369 620 049	8 604	2.7	83	232	2.70
CENTRAL EASTERN REGION:																	
Akron,Canton & Youngstown	37 870	2.27	1 210	1.93	39 080	2.26	-	39 080	214.89	620 342	2 887	933 618	4 345	6.3	182	411	9.46
Baltimore & Ohio	-	-	1 036 970	2.54	1 036 970	2.54	-	1 036 970	10 346.64	29 505 868	2 852	101 286 718	9 789	3.5	100	255	2.60
Bessemer & Lake Erie	-	-	13 773	3.41	13 773	3.41	-	13 773	485.83	1 511 785	3 112	5 028 590	10 351	0.9	28	97	0.94
Central R.R.of New Jersey	-	-	76 507	2.57	76 507	2.57	-	76 507	930.49	2 615 670	2 811	5 806 552	6 240	2.9	82	212	3.39
Central R.R.of Pennsylvania	-	-	53 009	3.04	53 009	3.04	-	53 009	470.13	1 321 709	2 811	3 666 144	7 798	4.0	113	343	4.40
Chicago & Eastern Illinois	-	-	80 068	2.39	80 068	2.39	-	80 068	1 325.24	4 031 716	3 042	7 880 846	5 947	2.0	60	145	2.43
Chicago & Illinois Midland	-	-	19 340	3.14	19 340	3.14	-	19 340	170.14	496 967	2 921	1 503 627	8 838	3.9	114	357	4.04
Chicago,Indpls.& Louisville	-	-	90 928	2.41	90 928	2.41	-	90 928	731.88	2 272 032	3 104	3 797 277	5 188	4.0	124	299	5.77
Detroit,Toledo & Ironton	1 298	0.74	41 742	2.55	43 040	2.49	-	43 040	601.85	1 733 328	2 880	2 183 162	3 627	2.5	72	178	4.91
Elgin,Joliet & Eastern	-	-	52 257	2.38	52 257	2.38	* 8 905	61 162	850.30	2 630 617	3 094	4 156 116	4 888	2.0	61	146	2.99
Illinois Terminal Co.	225	1.01	46 186	2.18	46 411	2.17	* 231	46 642	633.85	1 901 550	3 000	1 360 577	2 147	2.4	73	159	7.41
Long Island	-	-	91 525	3.47	91 525	3.47	-	91 525	791.88	2 255 146	2 848	4 710 508	5 949	4.1	116	401	6.74
Missouri-Illinois	-	-	47 255	2.26	47 255	2.26	-	47 255	215.36	675 281	3 136	467 331	2 170	7.0	219	496	22.84
Pennsylvania	-	-	1 905 974	2.87	1 905 974	2.87	-	1 905 974	21 422.24	61 139 853	2 854	237 487 880	11 086	3.1	89	256	2.31
Penna.-Reading Seashore Lines	-	-	68 356	3.51	68 356	3.51	-	68 356	634.21	1 723 334	2 717	1 929 149	3 042	4.0	108	379	12.45
Reading	-	-	364 925	2.73	364 925	2.73	-	364 925	2 848.23	7 919 351	2 780	22 184 414	7 789	4.6	128	350	4.49
Staten Island Rapid Transit	-	-	6 978	2.72	6 978	2.72	-	6 978	92.43	236 624	2 560	191 890	2 076	2.9	75	206	9.90
Western Maryland	397	1.93	89 417	2.76	89 814	2.75	-	89 814	1 161.08	3 368 172	2 901	10 814 962	9 315	2.7	77	213	2.29
Wheeling & Lake Erie	-	-	84 325	2.52	84 325	2.52	* 1 474	85 799	843.38	2 533 202	3 004	5 885 866	6 979	3.3	100	252	3.60
Total	39 790	2.21	4 170 745	2.75	4 210 535	2.74	10 610	4 221 145	44 770.05	128 492 547	2 870	421 275 227	9 410	3.3	94	258	2.74
POCAHONTAS REGION:																	
Chesapeake & Ohio (Incl.P.M.)	-	-	684 676	2.64	684 676	2.64	-	684 676	7 772.26	23 621 218	3 039	98 119 309	12 624	2.9	88	233	1.85
Norfolk & Western	-	-	488 740	2.40	488 740	2.40	* 2 737	491 477	4 297.16	13 321 196	3 100	54 050 881	12 578	3.7	114	273	2.17
Richmond,Fred.& Potomac	-	-	21 178	2.54	21 178	2.54	* 1 930	23 108	408.00	1 191 400	2 920	6 624 602	16 237	1.8	52	132	0.81
Virginian	-	-	92 488	2.05	92 488	2.05	-	92 488	926.39	2 847 544	3 074	11 482 752	12 395	3.2	100	205	1.65
Total	-	-	1 287 082	2.51	1 287 082	2.51	4 667	1 291 749	13 403.81	40 981 358	3 057	170 277 544	12 704	3.1	96	241	1.89
SOUTHERN REGION:																	
Alabama Great Southern	-	-	120 135	2.77	120 135	2.77	-	120 135	548.13	1 658 590	3 026	4 795 080	8 748	7.2	219	608	6.95
Atlanta & St.Andrews Bay	-	-	10 913	2.95	10 913	2.95	-	10 913	106.41	323 689	3 042	431 108	4 051	3.4	103	303	7.47
Atlanta & West Point	280	0.84	18 431	2.59	18 711	2.57	-	18 711	141.22	436 508	3 091	939 457	6 652	4.3	132	340	5.11
Atlantic Coast Line (inc.AB&C)	204 863	1.71	1 671 245	2.52	1 876 108	2.43	-	1 876 108	7 393.35	22 446 621	3 036	40 834 019	5 523	8.4	254	617	11.17
Central of Georgia	906	[illegible]	355 513	2.05	356 419	2.04	-	356 419	2 390.47	6 698 700	2 802	10 342 843	4 327	5.3	149	305	7.04
Charleston & Western Carolina	[illegible]	1.96	79 160	[illegible]	79 961	2.29	-	79 961	426.91	1 233 527	2 889	1 143 223	2 678	6.5	187	430	16.05
Cin.,New Orleans & Tex.Pac.	44	1.77	73 451	2.77	73 495	2.77	-	73 495	769.06	2 246 918	2 922	9 970 761	12 965	3.3	96	265	2.04
Clinchfield	43 620	1.42	44 193	2.66	87 813	2.04	-	87 813	414.70	1 260 690	3 040	5 010 519	12 082	7.0	212	433	3.58
Columbus & Greenville	-	-	37 140	2.29	37 140	2.29	-	37 140	205.44	692 018	3 368	301 543	1 468	5.4	181	414	28.21
Florida East Coast	34 128	1.67	189 955	2.74	224 083	2.58	* 6 676	230 759	1 148.03	3 344 383	2 913	7 484 126	6 519	6.7	195	503	7.72
Georgia	5 878	1.88	43 314	2.52	49 192	2.45	-	49 192	437.33	1 338 976	3 062	2 220 982	5 079	3.7	112	275	5.42
Georgia & Florida	92 561	1.53	-	-	92 561	1.53	-	92 561	460.35	1 241 838	2 698	659 697	1 433	7.5	201	307	21.41
Georgia,Southern & Florida	85 374	1.74	11 985	2.83	97 359	1.87	-	97 359	464.73	1 462 677	3 147	1 991 042	4 284	6.7	209	393	9.17
Gulf,Mobile & Ohio (Incl.Alton)	42 026	1.52	787 028	2.43	829 054	2.39	* 6 576	835 630	3 540.53	10 990 418	3 104	19 395 285	5 478	7.5	234	559	10.20
Illinois Cent.(inc.G&SI & Y&MV)	-	-	1 947 147	2.39	1 947 147	2.39	(S) 282	1 947 429	9 851.78	30 038 435	3 049	67 917 548	6 894	6.5	198	471	6.84
Louisville & Nashville	325	0.96	900 824	2.49	901 149	2.49	-	901 149	6 718.46	19 236 929	2 863	55 072 176	8 197	4.7	134	334	4.07
Mississippi Central	-	-	27 951	2.63	27 951	2.63	-	27 951	173.25	550 873	3 180	282 726	1 632	5.1	161	424	25.96
Nashville Chatt.& St.Louis	-	-	123 440	2.13	123 440	2.13	-	123 440	1 447.36	3 967 214	2 741	9 218 693	6 369	3.1	85	182	2.85
New Orleans & Northeastern	-	-	67 933	3.03	67 933	3.03	-	67 933	289.83	830 073	2 864	3 016 874	10 409	8.2	234	710	6.82
Norfolk Southern	99 082	1.57	94 064	2.57	193 146	2.06	-	193 146	844.96	2 470 215	2 923	1 935 678	2 291	7.8	229	471	20.55
Seaboard Air Line	6 065	1.64	908 944	2.44	915 009	2.43	-	915 009	5 345.38	16 150 786	3 021	36 894 085	6 902	5.7	171	417	6.03
Southern Ry.	10 805	1.80	1 098 301	2.95	1 109 106	2.94	-	1 109 106	8 612.02	26 633 634	3 093	59 918 417	6 958	4.2	129	379	5.44
Tennessee Central	27 379	1.46	24 536	2.53	51 915	1.96	-	51 915	342.00	1 035 576	3 028	1 040 617	3 043	5.0	152	298	9.80
Western Ry.of Alabama	253	0.88	22 732	2.60	22 985	2.58	-	22 985	184.83	562 900	3 046	1 075 173	5 817	4.1	124	321	5.51
Total	654 390	1.62	8 658 335	2.51	9 312 725	2.45	13 534	9 326 259	52 256.53	156 852 188	3 002	341 891 672	6 543	5.9	178	437	6.68

Table A

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I STEAM RAILWAYS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1947

Road	Cross ties laid in replacement: New wooden ties untreated (U): Number	New wooden ties untreated (U): Average cost	New wooden ties treated (T): Number	New wooden ties treated (T): Average cost	Total all new wooden ties laid: Number	Total all new wooden ties laid: Average cost	Ties other than wood (S) & second-hand (*) reapplied ties	Total ties applied	Miles of maintained tracks (item 25)	Estimated total cross ties in all maintained tracks (item 24)	Average number of cross ties per mile of maintained track	Number of equated gross ton-miles (thousands)	Number of equated gross ton-miles per mile of maintained track (thous.)	New wooden cross tie replacement averages: Per cent renewal to all ties in track	Number laid per mile of maintained track	Renewal cost per mile of maintained track	Renewal cost per 1000 equated gross ton-miles
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NORTHWESTERN REGION:																	(cents)
Chicago & North Western	28 578	$1.35	1 155 650	$2.27	1 184 228	$2.25	-	1 184 228	11 181.75	33 160 975	2 966	49 536 783	4 430	3.6	106	238	5.37
Chicago Great Western	93 111	2.06	157 441	2.70	250 552	2.46	-	250 552	1 872.53	5 553 011	2 966	10 831 643	5 784	4.5	134	329	5.69
Chicago, Milwaukee, St.Paul & Pac.	51 593	0.55	1 917 826	2.27	1 969 419	2.22	-	1 969 419	13 542.45	41 902 764	3 094	66 772 423	4 931	4.7	145	323	6.56
Chicago, St.Paul, Minpls.& Omaha	1 361	1.07	247 795	2.43	249 156	2.42	-	249 156	2 147.43	6 367 237	2 965	8 416 588	3 919	3.9	116	281	7.17
Duluth, Missabe & Iron Range	6 930	1.47	55 056	2.21	61 986	2.12	-	61 986	1 098.65	3 272 880	2 979	7 322 296	6 665	1.9	56	120	1.80
Duluth, South Shore & Atlantic	12 907	1.49	58 015	2.27	70 922	2.13	-	70 922	514.88	1 518 268	2 949	1 433 932	2 785	4.7	138	293	10.52
Duluth, Winnipeg & Pacific	7 888	1.32	46 615	2.10	54 503	1.98	-	54 503	207.00	607 993	2 937	937 863	4 531	9.0	263	523	11.53
Great Northern	24 448	1.02	1 240 834	2.20	1 265 282	2.18	* 30 104	1 295 386	10 236.82	31 541 085	3 081	56 507 469	5 520	4.0	124	269	4.88
Green Bay & Western	12 210	1.37	18 039	2.71	30 249	2.17	-	30 249	274.24	843 763	3 077	681 863	2 486	3.6	110	240	9.64
Lake Superior & Ishpeming	25 878	1.49	9 697	2.69	35 575	1.82	-	35 575	238.78	716 340	3 000	219 605	920	5.0	149	271	29.48
Minneapolis & St.Louis	49 498	1.33	185 981	2.49	235 479	2.24	-	235 479	1 564.21	4 723 985	3 020	4 265 950	2 727	5.0	151	338	12.39
Minneapolis, St.Paul & SS Marie	18 432	1.13	517 021	2.14	535 453	2.11	-	535 453	4 810.54	14 397 757	2 993	16 236 399	3 375	3.7	111	234	6.94
Northern Pacific	1 347	1.08	606 409	1.99	607 756	1.99	-	607 756	9 266.38	26 896 203	2 903	45 085 433	4 865	2.3	66	131	2.69
Spokane International	54 670	1.48	-	-	54 670	1.48	-	54 670	177.30	515 147	2 906	352 611	1 989	10.6	308	456	22.94
Spokane, Portland & Seattle	2 532	0.20	188 837	2.57	191 369	2.54	-	191 369	1 130.07	3 442 968	3 047	6 623 584	5 861	5.6	169	430	7.33
Wisconsin Central							Included in report of Minneapolis, St.Paul & SS Marie										
Total	391 383	1.41	6 405 216	2.25	6 796 599	2.20	30 104	6 826 703	58 263.03	175 460 376	3 012	275 224 442	4 724	3.9	117	257	5.44
CENTRAL WESTERN REGION:																	
Atchison, Topeka & Santa Fe	35	1.91	1 699 395	1.94	1 699 430	1.94	-	1 699 430	19 230.74	58 403 757	3 037	156 000 466	8 112	2.9	88	172	2.12
Chicago, Burlington & Quincy	-	-	886 012	2.16	886 012	2.16	* 56 653	942 665	11 854.49	36 606 665	3 088	70 555 349	5 952	2.4	75	161	2.71
Chicago, Rock Island & Pacific	-	-	683 918	2.21	683 918	2.21	-	683 918	9 522.59	28 446 365	2 987	56 312 797	5 914	2.4	72	159	2.69
Colorado & Southern	-	-	77 364	2.25	77 364	2.25	* 4 170	81 534	827.04	2 481 120	3 000	4 010 032	4 849	3.1	94	210	4.33
Colorado & Wyoming	-	-	2 990	2.81	2 990	2.81	-	2 990	106.05	308 200	2 906	29 239	276	1.0	28	79	28.72
Denver & Rio Grande West. (inc.D&SL)	-	-	136 235	2.64	136 235	2.64	* 39 540	175 775	3 451.79	10 772 600	3 121	18 553 317	5 375	1.3	39	104	1.94
Fort Worth & Denver City	-	-	126 956	2.28	126 956	2.28	* 946	127 902	1 032.43	3 073 031	2 977	4 270 020	4 136	4.1	123	280	6.77
Northwestern Pacific	21 239	2.39	27 054	2.86	48 293	2.66	-	48 293	420.40	1 218 839	2 899	1 403 977	3 340	4.0	115	305	9.13
Southern Pacific Co.- Pac.Lines	23 399	1.71	1 083 944	2.55	1 107 343	2.53	* 1 608	1 108 951	11 804.36	36 730 345	3 112	126 359 801	10 705	3.0	94	237	2.22
Toledo, Peoria & Western	-	-	8 371	1.91	8 371	1.91	-	8 371	277.96	877 631	3 157	411 828	1 482	1.0	30	58	3.88
Union Pacific	4 266	1.27	982 397	2.03	986 663	2.03	-	986 663	13 168.62	37 181 346	2 823	135 115 420	10 260	2.7	75	152	1.48
Utah	3 983	1.83	7 560	2.77	11 543	2.45	* 286	11 829	71.39	200 394	2 807	511 613	7 166	5.8	162	396	5.52
Western Pacific	440 607	2.05	92 148	3.10	532 755	2.23	* 2 249	535 004	1 531.50	4 582 745	2 992	12 798 891	8 357	11.6	348	777	9.30
Total	493 529	2.04	5 814 344	2.19	6 307 873	2.18	105 452	6 413 325	73 299.36	220 883 038	3 013	586 332 750	7 999	2.9	86	187	2.34
SOUTHWESTERN REGION:																	
Beaumont, Sour Lake & Western	-	-	23 860	2.28	23 860	2.28	-	23 860	148.34	441 700	2 978	1 838 594	12 394	5.4	161	367	2.96
Burlington-Rock Island	-	-	30 114	2.30	30 114	2.30	-	30 114	178.27	557 985	3 130	1 008 055	5 655	5.4	169	388	6.87
International-Great Northern	-	-	196 122	2.16	196 122	2.16	-	196 122	1 420.97	4 258 600	2 997	8 812 003	6 201	4.6	138	298	4.81
Kansas City Southern	-	-	89 997	2.19	89 997	2.19	-	89 997	1 276.58	4 041 290	3 166	10 313 902	8 079	2.2	70	154	1.91
Kansas, Oklahoma & Gulf	-	-	24 904	2.33	24 904	2.33	-	24 904	350.11	1 036 325	2 960	1 521 184	4 345	2.4	71	166	3.82
Louisiana & Arkansas	-	-	113 484	2.09	113 484	2.09	-	113 484	875.39	2 848 336	3 254	3 806 178	4 348	4.0	130	272	6.25
Midland Valley	49	0.47	22 806	2.26	22 855	2.25	-	22 855	355.93	1 053 550	2 960	413 654	1 162	2.2	64	145	12.45
Missouri & Arkansas c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Missouri-Kansas-Texas Lines	-	-	425 370	2.36	425 370	2.36	-	425 370	3 902.13	12 276 900	3 146	20 626 389	5 286	3.5	109	258	4.88
Missouri Pacific	7 772	1.09	1 408 705	2.34	1 416 477	2.34	-	1 416 477	8 914.80	27 509 555	3 086	66 125 541	7 418	5.1	159	371	5.00
New Orleans, Texas & Mexico	-	-	32 209	2.26	32 209	2.26	-	32 209	227.62	696 300	3 059	1 538 197	6 758	4.6	142	320	4.73
Oklahoma City-Ada-Atoka	319	1.34	25 687	2.12	26 006	2.11	-	26 006	136.99	394 530	2 880	108 701	793	6.6	190	401	50.49
St.Louis, Brownsville & Mexico	-	-	111 935	2.25	111 935	2.25	-	111 935	763.63	2 310 000	3 025	4 411 380	5 777	4.8	147	329	5.70
St.Louis-San Francisco	69 836	1.58	731 194	2.15	801 030	2.10	-	801 030	6 229.33	19 617 689	3 149	32 763 045	5 259	4.1	129	270	5.13
St.Louis, San Francisco & Texas	461	1.59	16 967	2.12	17 428	2.10	-	17 428	148.39	464 729	3 132	827 956	5 580	3.8	117	247	4.43
St.Louis Southwestern	-	-	344 919	2.30	344 919	2.30	* 396	345 315	1 873.05	5 807 698	3 101	15 086 118	8 054	5.9	184	423	5.25
San Antonio, Uvalde & Gulf	-	-	43 887	2.30	43 887	2.30	-	43 887	355.15	1 024 300	2 884	741 884	2 089	4.3	124	285	13.63
Texas & New Orleans	-	-	611 717	2.09	611 717	2.09	-	611 717	5 442.58	15 309 754	2 813	32 115 884	5 901	4.0	112	235	3.98
Texas & Pacific	-	-	390 721	2.14	390 721	2.14	-	390 721	2 271.27	6 639 850	2 923	21 225 062	9 345	5.9	172	367	3.93
Texas Mexican	636	0.47	16 301	2.23	16 937	2.16	-	16 937	210.16	665 787	3 168	266 065	1 266	2.5	81	174	13.77
Total	79 073	1.52	4 660 899	2.24	4 739 972	2.22	396	4 740 368	35 080.69	106 954 878	3 049	223 549 792	6 372	4.4	135	301	4.72
Grand Total - United States b	1 798 210	1.69	35 299 803	2.44	37 098 013	2.40	191 659	37 289 672	330 350.95	992 648 135	3 005	2 447 220 626	7 408	3.7	112	270	3.64
CANADIAN ROADS:																	
Canadian National	1 052 214	1.21	2 807 613	1.91	3 859 827	1.72	-	3 859 827	26 899.00	78 859 271	2 932	d	d	4.9	143	247	d
Canadian Pacific	729 659	1.13	2 354 165	2.04	3 083 824	1.82	-	3 083 824	21 111.00	60 818 599	2 881	99 973 317	4 736	5.1	146	267	5.63
Ontario Northland	93 419	1.18	19 826	2.25	113 245	1.37	-	113 245	693.60	1 970 550	2 841	1 516 574	2 187	5.7	163	223	1.02

a Gross ton-miles of cars and contents, plus two times gross ton-miles of locomotives and tenders in freight service, plus three times gross ton-miles of locomotives and tenders in passenger service.
b Totals for Great Lakes Region and United States include figures for Pittsburg, Shawmut & Northern for three months ended March 31, 1947. Road abandoned as of that date.
c Ceased operations.
d Not reported.

Note: "Average Cost" as shown in Columns 3, 5 and 7, represents storekeepers average cost of ties charged out and used. They are not the actual costs or the prices paid for the ties purchased during the period.

Compiled by
Association of American Railroads, Bureau of Railway Economics, Washington, D.C.
from Annual Reports of Class I Railways to the Interstate Commerce Commission.
June 23, 1948.

Table B

NUMBER AND AGGREGATE COST OF [illegible]

Table B

NUMBER AND AGGREGATE COST OF NEW WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOODEN CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1943 to 1947, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wooden cross tie renewals per mile of maintained track						Aggregate cost of new wooden cross tie renewals per mile of maintained track						Per cent new wooden cross tie renewals to all ties in tracks					
	1943	1944	1945	1946	1947	5 year average	1943	1944	1945	1946	1947	5 year average	1943	1944	1945	1946	1947	5 year average
NEW ENGLAND REGION:																		
Bangor & Aroostook	114	109	110	201	163	139	$84	$195	$231	$449	$365	$265	4.0	3.8	3.8	7.0	5.7	4.9
Boston & Maine	66	72	42	47	62	58	131	157	101	124	185	140	2.2	2.4	1.4	1.6	2.1	1.9
Canadian Nat. Lines in New England	80	112	126	88	108	103	104	174	211	157	208	171	2.6	3.6	4.0	2.8	3.4	3.3
Canadian Pacific (lines in Me.)	71	63	82	80	100	79	91	108	154	172	214	149	2.4	2.0	2.6	2.6	3.2	2.6
Canadian Pacific (lines in Vt.)	74	116	66	93	68	87	96	230	168	184	145	165	2.5	3.9	2.3	3.1	2.3	2.9
Central Vermont	29	23	21	41	52	33	44	40	42	92	126	69	1.0	0.8	0.7	1.4	1.8	1.1
Maine Central	119	126	124	84	123	115	208	246	299	205	324	256	3.9	4.1	4.1	2.8	4.1	3.9
New York Connecting	154	127	132	39	125	115	430	365	400	123	431	350	4.9	4.0	4.2	1.2	4.0	3.7
New York, New Haven & Hartford	67	87	77	100	83	83	146	196	190	261	245	204	2.1	2.8	2.5	3.2	2.6	2.6
Rutland	45	45	39	51	39	44	63	81	83	120	97	89	1.5	1.4	1.2	1.6	1.2	1.4
Total	74	84	72	85	86	80	133	177	169	211	225	183	2.4	2.8	2.4	2.8	2.8	2.6
GREAT LAKES REGION:																		
Ann Arbor	90	94	97	104	100	97	154	198	213	249	275	218	3.0	3.1	3.2	3.4	3.3	3.2
Cambria & Indiana	326	211	177	110	82	181	842	563	416	333	235	472	11.9	7.4	6.2	3.8	2.8	6.4
Delaware & Hudson	109	152	110	134	123	126	239	387	294	386	368	335	3.5	4.9	3.5	4.3	3.9	4.0
Delaware, Lackawanna & Western	65	81	71	77	86	76	145	190	171	202	241	190	2.2	2.8	2.5	2.7	3.0	2.6
Detroit & Mackinac	109	104	93	88	131	105	98	106	101	124	249	136	3.7	3.5	3.1	2.9	4.4	3.5
Detroit & Toledo Shore Line	92	43	72	53	68	66	205	96	170	138	205	163	3.0	1.4	2.4	1.7	2.2	2.1
Erie	79	88	71	62	62	72	158	218	177	160	176	178	2.6	3.0	2.4	2.1	2.1	2.4
Grand Trunk Western	148	146	142	140	116	138	275	317	327	365	271	311	4.7	4.6	4.5	4.4	3.6	4.4
Lehigh & Hudson River	164	92	98	99	99	110	458	273	288	303	328	330	6.1	3.4	3.7	3.7	3.7	4.1
Lehigh & New England	54	48	59	60	75	59	113	121	159	172	238	160	1.8	1.6	1.9	2.0	2.5	2.0
Lehigh Valley	74	109	74	89	93	88	166	266	189	251	286	232	2.5	3.7	2.5	3.0	3.1	3.0
Monongahela	147	130	96	91	76	108	337	313	220	237	220	265	5.0	4.4	3.3	3.1	2.6	3.7
Montour	70	81	100	78	87	83	129	169	213	172	285	194	2.4	2.8	3.5	2.7	3.0	2.9
New York Central	131	150	118	100	73	114	268	352	288	262	206	275	4.2	4.9	3.9	3.2	2.4	3.7
New York, Chicago & St. Louis	132	176	156	151	135	150	265	427	359	409	384	369	4.2	5.6	4.9	4.8	4.3	4.8
New York, Ontario & Western	8	6	2	-	-	3	18	14	4	1	-	7	0.3	0.2	0.1	-	-	0.1
New York, Susquehanna & Western	54	46	32	33	41	41	62	78	62	79	109	78	1.8	1.6	1.1	1.1	1.4	1.4
Pittsburgh & Lake Erie	98	101	92	102	99	99	239	239	233	234	258	241	3.3	3.4	3.1	3.4	3.3	3.3
Pittsburg & Shawmut	181	206	164	175	153	176	454	586	507	524	476	509	6.4	7.3	5.8	6.2	5.4	6.2
Pittsburgh & West Virginia	171	123	105	110	80	118	382	338	325	343	260	330	5.6	4.0	3.5	3.6	2.6	3.9
Wabash	126	113	111	103	100	112	211	236	235	252	269	241	4.1	3.8	3.6	3.3	3.2	3.6
Total a	114	130	106	97	83	106	231	255	255	252	232	245	3.7	3.5	3.2	3.2	2.7	3.3
CENTRAL EASTERN REGION:																		
Akron, Canton & Youngstown	226	218	221	269	182	223	406	376	420	563	411	441	7.8	7.6	7.7	9.3	6.3	7.7
Baltimore & Ohio	200	191	144	123	100	152	428	422	312	277	255	339	7.0	6.7	5.1	4.3	3.5	5.3
Bessemer & Lake Erie	57	40	30	30	28	37	147	114	92	97	97	109	1.8	1.3	1.0	1.0	0.9	1.2
Central R.R. of New Jersey	77	104	84	132	82	96	175	250	204	323	212	233	2.7	3.7	3.0	4.7	2.9	3.4
Central R.R. of Pennsylvania b	-	-	-	68	113	•	-	-	-	176	343	•	-	-	-	2.4	4.0	•
Chicago & Eastern Illinois	118	128	116	142	60	113	208	220	256	324	145	231	3.8	4.1	3.7	4.6	2.0	3.6
Chicago & Illinois Midland	156	150	329	34	114	157	410	431	1070	34	357	472	5.2	5.0	11.1	1.2	3.9	5.3
Chicago, Indpls. & Louisville	58	66	51	72	124	74	76	105	94	156	299	146	1.9	2.1	1.6	2.3	4.0	2.4
Detroit, Toledo & Ironton	55	47	47	60	72	56	80	77	40	127	178	110	1.9	1.6	1.6	2.1	2.5	1.9
Elgin, Joliet & Eastern	83	146	90	99	61	96	153	290	192	218	146	200	2.7	4.7	2.9	3.2	2.0	3.1
Illinois Terminal	80	87	89	81	73	82	109	137	159	158	159	144	2.7	2.9	3.0	2.7	2.4	2.7
Long Island	146	210	143	87	116	136	356	604	361	270	401	398	5.1	7.4	4.3	3.0	4.1	4.8
Missouri-Illinois	211	219	175	191	219	203	335	411	310	393	496	389	6.7	7.0	5.6	6.1	7.0	6.5
Pennsylvania	97	101	109	92	89	98	180	233	252	229	256	230	3.4	3.5	3.8	3.2	3.1	3.4
Penna.-Reading Seashore Lines	74	83	78	92	108	87	185	216	222	276	379	256	2.7	3.0	2.9	3.4	4.0	3.2
Reading Co.	104	145	122	111	128	122	227	345	292	289	350	301	3.8	4.7	4.4	4.0	4.6	4.3
Staten Island Rapid Transit	70	61	65	108	75	76	160	155	182	270	206	195	2.6	2.3	2.7	4.2	2.9	2.9
Western Maryland	102	109	75	72	77	87	202	248	171	183	213	203	3.5	3.8	2.6	2.5	2.7	3.0
Wheeling & Lake Erie	121	94	94	93	100	100	211	214	223	220	252	224	4.0	3.1	3.1	3.1	3.3	3.3
Total	121	127	115	102	94	112	243	287	261	245	258	259	4.2	4.4	4.0	3.5	3.3	3.9
POCAHONTAS REGION:																		
Chesapeake & Ohio (Inc. P.M.)	121	118	108	93	88	106	195	233	235	226	233	224	3.9	3.9	3.6	3.0	2.9	3.5
Norfolk & Western	69	66	68	86	114	81	112	124	144	191	273	169	[illegible]	2.1	2.2	2.8	3.7	2.6
Richmond, Fred. & Potomac	294	183	215	98	52	168	588	400	469	231	132	364	10.3	6.4	7.4	3.4	1.8	5.9
Virginian	101	107	89	81	100	96	166	186	158	152	205	173	3.3	3.5	2.9	2.6	3.2	3.1
Total	108	102	97	90	96	99	178	199	208	210	241	207	3.5	3.3	2.9	3.0	3.1	3.2
SOUTHERN REGION:																		
Alabama Great Southern	97	132	214	227	219	178	207	316	545	594	608	450	3.2	4.4	7.1	7.5	7.2	5.9
Atlanta & St. Andrews Bay c	-	-	-	-	103	•	-	-	-	-	303	•	-	-	-	-	3.4	•
Atlanta & West Point	202	201	278	214	132	205	363	408	611	506	340	446	6.5	6.5	9.0	6.9	4.3	6.6
Atlantic Coast Line (Inc. AB&C)	172	182	271	288	254	233	321	361	588	701	617	518	5.9	6.2	9.3	9.6	8.4	7.9
Central of Georgia	147	147	144	154	149	148	214	241	240	298	305	260	5.0	5.0	4.9	5.2	5.3	5.1
Charleston & Western Carolina	184	182	270	197	187	204	278	364	600	539	430	442	6.4	6.3	9.3	6.8	6.5	7.1
Cincinnati, New Orleans & Tex.-Pac.	44	56	74	93	96	73	65	143	180	241	265	183	1.4	1.9	2.5	3.2	3.3	2.5
Clinchfield	172	130	151	173	212	168	296	211	277	340	433	311	5.7	4.3	5.0	5.7	7.0	5.5
Columbus & Greenville	179	167	174	154	181	171	318	345	364	344	414	357	5.7	5.3	5.5	4.9	5.4	5.4
Florida East Coast	154	183	156	178	195	173	293	414	383	450	503	409	5.3	6.4	5.4	6.2	6.7	6.0
Georgia R.R.	270	212	200	128	112	184	392	412	400	287	275	353	8.8	6.9	6.5	4.2	3.7	6.0
Georgia & Florida	285	317	195	253	201	250	253	331	258	396	307	309	10.5	11.8	7.2	9.4	7.5	9.3
Georgia, Southern & Florida	141	113	143	195	209	160	207	180	238	334	393	270	4.5	3.6	4.6	6.2	6.7	5.1
Gulf, Mobile & Ohio (Inc. Alton)	235	246	238	228	234	236	407	497	505	545	559	503	7.6	7.9	7.7	7.4	7.5	7.6
Illinois Central (Inc. C&SI and Y&MV)	202	241	203	208	198	210	331	453	424	472	471	430	6.6	7.9	6.6	6.8	6.5	6.9
Louisville & Nashville	189	130	134	130	134	143	306	246	272	287	334	289	6.6	4.5	4.7	4.5	4.7	5.0
Mississippi Central	160	122	136	98	161	135	247	252	297	211	424	286	5.1	3.9	4.3	3.1	5.1	4.3
Nashville, Chattanooga & St. Louis	230	208	178	123	85	165	382	425	383	288	182	332	8.4	7.6	6.5	4.5	3.1	6.0
New Orleans & Northeastern	147	207	250	239	234	215	304	519	680	651	710	573	4.8	7.1	8.7	8.3	8.2	7.4
Norfolk Southern	320	272	224	255	229	260	387	439	419	511	471	445	10.6	9.3	7.7	8.8	7.8	8.8
Seaboard Air Line	191	207	186	175	171	186	336	430	388	404	417	395	6.3	6.9	6.1	5.8	5.7	6.2
Southern Ry.	158	154	136	136	129	143	304	350	327	380	379	348	5.1	5.0	4.4	4.4	4.2	4.6
Tennessee Central	213	151	139	137	152	158	344	287	257	275	298	292	7.0	5.0	4.6	4.5	5.0	5.2
Western Ry. of Alabama	242	250	235	183	124	207	403	480	485	416	321	421	7.9	8.2	7.7	6.0	4.1	6.8
Total	186	187	187	187	178	185	317	371	398	443	437	393	6.2	6.3	6.2	6.2	5.9	6.2

Table B

Table B

NUMBER AND AGGREGATE COST OF NEW WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOODEN TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1943 to 1947, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wooden cross tie renewals per mile of maintained track						Aggregate cost of new wooden cross tie renewals per mile of maintained track						Per cent new wooden cross tie renewals to all ties in tracks					
	1943	1944	1945	1946	1947	5 year average	1943	1944	1945	1946	1947	5 year average	1943	1944	1945	1946	1947	5 year average
NORTHWESTERN REGION:																		
Chicago & North Western	99	108	143	121	106	113	$121	$192	$267	$240	$238	$212	3.0	3.6	4.8	4.1	3.6	3.8
Chicago Great Western	120	180	127	155	134	143	188	341	266	370	329	299	4.0	6.1	4.3	5.2	4.5	4.8
Chicago, Milwaukee, St. Paul & Pac.	145	161	157	109	145	143	226	279	297	213	323	268	4.7	5.2	5.1	3.5	4.7	4.6
Chicago, St. Paul, Minpls. & Omaha	114	133	142	112	116	123	187	256	307	253	281	257	3.8	4.5	4.8	3.8	3.9	4.2
Duluth, Missabe & Iron Range	127	89	66	64	56	80	225	185	134	133	120	159	4.2	3.0	2.2	2.2	1.9	2.7
Duluth, South Shore & Atlantic	145	147	148	142	138	144	157	224	258	273	293	241	5.1	5.0	4.6	4.7	4.7	4.8
Duluth, Winnipeg & Pacific	356	342	347	295	263	321	520	682	609	521	523	571	12.1	11.6	11.8	10.0	9.0	10.9
Great Northern	156	169	149	96	124	139	279	330	286	177	269	268	5.1	5.5	4.8	3.1	4.0	4.5
Green Bay & Western	212	392	225	142	110	216	368	793	490	318	240	442	7.4	13.6	7.2	4.9	3.6	7.3
Lake Superior & Ishpeming	77	134	171	151	149	136	100	213	293	310	271	237	2.6	4.5	5.7	5.0	5.0	4.6
Minneapolis & St. Louis	117	135	144	111	151	132	152	221	256	209	338	235	3.9	4.5	4.8	3.7	5.0	4.4
Minpls., St. Paul & SS Marie (Inc. Wis. C.)	86	84	92	104	111	95	120	147	178	201	234	176	2.9	2.9	3.1	3.5	3.7	3.2
Northern Pacific	119	107	90	61	66	89	178	17.	154	109	131	149	4.1	3.7	3.1	2.1	2.3	3.1
Spokane International	387	435	342	294	308	353	370	506	405	358	456	419	13.3	15.0	11.8	10.1	10.6	12.2
Spokane, Portland & Seattle	225	492	233	119	169	248	348	932	438	253	430	480	7.4	16.2	7.7	3.8	5.6	8.1
Total	127	144	136	104	117	126	197	258	257	203	257	234	4.2	4.8	4.5	3.4	3.9	4.2
CENTRAL WESTERN REGION:																		
Atchison, Topeka & Santa Fe	80	78	100	80	88	85	102	116	173	147	172	142	2.6	2.6	3.3	2.6	2.9	2.8
Chicago, Burlington & Quincy	185	182	169	126	75	147	278	336	319	258	161	270	6.0	5.9	5.5	4.1	2.4	4.8
Chicago, Rock Island & Pacific	117	165	140	109	72	121	140	331	292	236	159	232	3.9	5.5	4.7	3.6	2.4	4.0
Colorado & Southern	111	99	103	103	94	102	190	188	205	222	210	203	3.7	3.3	3.4	3.4	3.1	3.4
Colorado & Wyoming	64	69	56	40	28	51	178	195	169	117	79	148	2.2	2.4	2.0	1.4	1.0	1.8
Denver & Rio Grande West. (Inc. D&SL)	29	40	40	35	39	37	49	74	83	77	104	77	0.9	1.3	1.3	1.1	1.3	1.2
Fort Worth & Denver City	99	117	114	153	123	121	163	174	235	329	280	236	3.3	3.9	3.8	5.1	4.1	4.0
Northwestern Pacific	231	297	237	142	115	204	384	516	413	251	305	374	6.0	10.2	8.2	4.9	4.0	7.1
Southern Pacific Co.- Pac. Lines	115	150	160	77	94	119	17-	256	283	141	237	218	3.7	4.8	5.1	2.5	3.0	3.8
Toledo, Peoria & Western	95	61	*	*	30	*	135	107	*	*	58	*	3.0	1.9	*	*	1.0	*
Union Pacific	164	160	140	70	75	122	223	246	232	123	152	195	5.8	5.7	4.9	2.5	2.7	4.3
Utah Ry.	69	52	66	85	1..	87	168	12.	157	214	396	211	2.4	1.8	2.3	3.0	5.8	3.1
Western Pacific	164	293	264	123	348	238	238	517	468	247	777	449	5.5	9.8	8.8	4.1	11.6	8.0
Total	124	138	135	90	86	115	174	239	246	175	187	204	4.1	4.6	4.5	3.0	2.9	3.8
SOUTHWESTERN REGION:																		
Beaumont, Sour Lake & Western	192	255	157	182	161	189	317	484	309	395	367	374	6.4	8.6	5.3	6.1	5.4	6.4
Burlington-Rock Island	73	95	84	137	169	112	65	117	133	292	388	199	2.3	3.0	2.7	4.4	5.4	3.6
International-Great Northern	112	102	123	142	138	123	169	190	247	315	278	244	3.7	3.4	4.1	4.7	4.6	4.1
Kansas City Southern	409	251	83	50	70	174	650	439	161	113	154	303	14.9	7.9	2.6	1.8	2.2	5.5
Kansas, Oklahoma & Gulf	48	60	36	55	71	54	72	104	67	116	166	105	1.6	2.0	1.6	1.9	2.4	1.8
Louisiana & Arkansas	718	448	130	25	130	290	1180	832	255	51	272	518	22.1	13.7	4.0	0.8	4.0	8.9
Midland Valley	61	68	34	61	64	58	88	99	52	126	145	104	2.1	2.3	1.2	2.1	2.2	2.0
Missouri & Arkansas d	355	384	344	97	*	236	353	573	454	145	*	305	11.4	12.3	11.0	3.2	*	7.6
Missouri-Kansas-Texas Lines	324	325	157	92	109	201	549	630	343	196	258	391	10.3	10.3	5.0	2.9	3.5	6.4
Missouri Pacific	105	95	90	110	159	112	147	160	159	226	371	213	3.4	3.1	2.9	3.6	5.1	3.6
New Orleans, Texas & Mexico	301	168	113	137	142	172	242	330	222	300	320	284	9.8	5.5	3.7	4.5	4.6	5.6
Oklahoma City-Ada-Atoka	158	287	233	248	190	223	256	248	433	522	411	372	5.5	10.0	8.1	8.6	6.6	7.8
St. Louis, Brownsville & Mexico	153	186	146	157	147	158	249	354	276	334	329	308	5.1	6.2	4.8	5.2	4.8	5.2
St. Louis-San Francisco	132	13.	107	111	129	122	186	208	17.	212	270	210	4..	4.2	3.4	3.5	4.1	3.9
St. Louis, San Fran. & Texas	104	91	61	122	117	99	135	139	97	226	247	169	3.3	2.9	2.0	3.9	3.8	3.2
St. Louis Southwestern Lines	168	206	196	158	184	182	274	350	389	338	423	361	5.3	6.5	6.2	5.1	5.9	5.8
San Antonio, Uvalde & Gulf	113	172	114	145	124	134	159	194	210	319	285	233	3.9	6.0	4.0	5.2	4.3	4.7
Texas & New Orleans	110	128	122	115	112	117	130	201	197	221	235	197	4.0	4.7	4.4	4.1	4.0	4.2
Texas & Pacific	262	232	192	181	172	208	365	411	370	325	367	368	9.0	7.9	6.6	6.2	5.9	7.1
Texas Mexican	104	104	144	79	81	102	178	187	266	170	174	195	3.3	3.3	4.5	2.5	2.5	3.2
Total	179	169	124	115	135	144	265	293	224	230	301	263	5.9	5.5	4.1	3.8	4.4	4.7
Grand Total, United States a	136	144	132	113	112	127	226	280	269	251	270	254	4.5	4.8	4.4	3.8	3.7	4.2
CANADIAN ROADS:																		
Canadian National	170	165	159	154	143	158	187	217	240	246	247	227	5.8	5.6	5.4	5.3	4.9	5.4
Canadian Pacific	141	145	149	149	146	146	168	306	228	251	267	224	4.9	5.1	5.2	5.2	5.1	5.1
Ontario Northland	176	200	200	205	163	189	144	180	294	252	223	219	6.1	6.9	6.6	7.1	5.7	6.5

*Not reported.
a See note b, Table A.
b The Central Railroad of Pennsylvania started operations August 5, 1946; formerly part of Central R.R. of New Jersey.
c The Atlanta and Saint Andrews Bay became a Class I road January 1, 1947, formerly a Class II road.
d Ceased operations.

Compiled by
Association of American Railroads, Bureau of Railway Economics, Washington, D.C.
from annual reports of Class I railways to the Interstate Commerce Commission.
June 23, 1948.

Report on Assignment 4

Tie Renewals and Costs Per Mile of Maintained Track

C. D. Turley (chairman, subcommittee), M. L. Bardill, W. C. Bolin, W. H. Brameld, Roy Lumpkin, R. B. Midkiff, L. E. Peterson, S. Thorvaldson, W. H. Vance.

Information reported annually to the Interstate Commerce Commission by Class I steam railroads in the United States, and to this Association by large railroads in Canada, regarding the number and cost of cross ties laid in replacement, is supplied for the year 1947 in Tables A and B. In order to make the information available as promptly as possible, these tables were published in Bulletin 474, June–July 1948.

The rise in the cost of ties began in 1941, extended through 1942, 1943, 1944, 1945 and 1946, and continued through 1947. The cost per tie was approximately 18 cents more than in 1946, but the total ties applied was more than 624 thousand ties less.

A thorough knowledge of general practices, kind and volume of traffic, and general maintenance conditions is necessary before comparisons of tie renewals records on individual railroads can be made.

Report on Assignment 6

Methods for Reducing Mechanical Wear of Track Ties, Including Stabilization of Wood, Collaborating with the NLMA

F. G. Campbell (chairman, subcommittee), L. P. Drew, L. E. Gingerich, E. A. Humphreys, R. H. Jordan, C. M. Long, C. E. Peterson, Arthur Price, W. W. Rohrbough.

Methods and devices for reducing and retarding splitting and mechanical wear of railroad ties have been covered in previous reports, ending with a thorough over-all report published in the Proceedings, Vol. 47, 1946. The subcommittee recommended laboratory research for further development of the subject.

The Association of American Railroads, and the National Lumber Manufacturers Association, have entered into a joint research project to determine ways and means of improving and lengthening the service life of cross ties. Active work was started early in 1948, and progress reports will be presented as soon as new information becomes available.

Report of Committee 17—Wood Preservation

C. S. Burt, *Chairman,*
W. P. Arnold
R. S. Belcher
P. D. Brentlinger
Walter Buehler
C. M. Burpee
G. B. Campbell
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H. R. Duncan
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F. W. Gottschalk
F. A. Hartman
F. W. Hillman
H. L. Holderman
B. D. Howe
M. S. Hudson
R. P. Hughes
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J. N. Roche
Henry Schmitz
L. B. Shipley
T. H. Strate
J. E. Tiedt
Hermann von Schrenk
C. H. Wakefield
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

Bulletin 478, January 1949.

THE COMMITTEE ON WOOD PRESERVATION,
C. S. BURT, *Chairman.*

Report on Assignment 2

Service Test Records of Treated Wood

A. J. Loom (chairman, subcommittee), T. H. Friedlin, W. R. Goodwin, H. L. Holderman, R. P. Hughes, J. W. Reed, W. C. Reichow, T. H. Strate.

The following report of test records and analysis of creosote used in treatment of ties is submitted as information:

A. T. & S. F. Ry.—System records of creosote analysis 1926–1927.

C. & N. W. Ry.—Record of analysis of the creosote used in treatment of test ties in 1914, last reported in the Proceedings, Vol. 40, 1939, page 482.

Great Northern Railway—Service record of test ties treated with 50–50 creosote–petroleum solution and analysis of creosote and specific gravity of petroleum used in 1924.

Northern Pacific Railway—Analysis of creosote and specific gravity of petroleum used in treatment of test ties in 1922.

CHICAGO & NORTH WESTERN RAILWAY

Record of analysis of creosotes used in treatment of test ties placed in track in 1914. Service record last reported on page 482 of the 1939 AREA Proceedings.

	1 *Percent*	*2* *Percent*	*3* *Percent*	*Average* *Percent*
Special Gravity @ 38 deg. C.	1.065	1.064	1.060	1.063
Water	0.75	1.00	0.50	0.75
200 deg. C.	.86	1.01	0.10	0.69
210 deg. C.	1.36	1.81	0.90	1.36
235 deg. C.	18.91	17.07	17.39	17.79
355 deg. C.	81.94	75.35	77.69	78.33
Residue (soft)	18.94	24.65	22.31	21.97

GREAT NORTHERN RAILWAY

Service Record—2316 white birch ties. Stone Arch Bridge, Minneapolis, Minn.
Treated with 8 lb. per cu. ft. 50–50 creosote-petroleum solution.
Placed in track in October 1924. Results of 1948 annual inspection.
Total number removed 437 or 18.9 percent after 24 years' service.
Average Life of Ties Removed—20.7 years.
Estimated Average Life all Ties (FPL Curve)—32 years.
(Earlier reports of this test published in AREA Proceedings 1940 and 1948.)
Analysis of creosote used was as follows:

(continued on page 374)

Atchison, Topeka and Santa Fe Railway

Analyses of Creosote Received at Galveston & Somerville, Reduced to a Weighted Average for Each Year, also Showing Minimum and Maximum for Each Year, 1905 - 1947 Incl.

	1905			1906			1907			1908			1909		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.037	1.079	1.061	1.032	1.079	1.055	1.028	1.076	1.062	1.025	1.071	1.054	1.032	1.070	1.059
Distillation:															
Up to 210°C	2.6%	16.7%	7.95%	1.4%	9.5%	5.60%	2.2%	9.7%	3.80%	1.0%	7.0%	2.87%	1.4%	3.7%	2.55%
210 - 235	9.1	37.6	24.53	7.7	32.7	21.58	8.3	35.6	16.73	5.5	37.4	17.08	10.3	35.8	17.22
235 - 315	30.1	57.1	44.19	41.7	58.0	47.78	38.7	57.4	47.12	33.4	61.0	48.67	42.9	58.4	50.05
Residue	15.0	30.9	22.38	11.4	39.8	24.83	15.2	48.3	32.79	14.5	43.1	31.45	17.0	41.5	30.09
Water Content %	0.1	1.2	.48	0.0	1.5	.36	0.0	2.0	.73	0.0	2.75	.73	0.0	2.20	.71
Tar Acids %															

	1910			1911			1912			1913			1914		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.034	1.071	1.061	1.064	1.071	1.070	1.064	1.071	1.067	1.064	1.076	1.069	1.038	1.074	1.070
Distillation:															
Up to 200°C	0.3%	2.7%	1.11%	0.2%	1.5%	.69%	0.2%	1.6%	.71%	0.4%	1.9%	.88%	0.0%	1.9%	.28%
200 - 210	0.6	4.2	1.39	0.3	2.0	.91	0.4	1.8	.75	0.3	0.8	.49	0.3	4.2	1.57
210 - 235	8.2	33.8	14.92	7.6	13.0	11.09	3.7	13.2	7.58	5.0	8.0	6.86	5.3	22.8	9.21
235 - 270	22.6	28.8	25.57	20.3	28.3	23.14	21.0	23.4	22.37	21.3	24.6	22.86	18.0	25.4	20.54
270 - 315	16.9	36.6	24.96	22.3	25.4	23.20	22.9	28.1	25.72	24.3	26.6	25.39	16.4	22.7	21.02
315 - 355	12.0	24.0	17.66	21.0	26.9	25.05	22.0	28.3	26.00	24.2	25.5	24.94	17.1	26.8	25.28
Residue	7.3	18.4	13.49	14.0	17.1	15.92	14.7	17.5	16.20	16.6	19.3	17.75	11.1	24.8	21.47
Water Content %	0.0	1.60	.21	0.0	0.1	.02	0.0	0.8	.42	0.0	1.3	.79	.4	2.8	.58
Tar Acids %										3.0	8.0	5.72	5.0	9.5	5.94

Galveston & Somerville 2 of 5.

	1915			1916			1917			1919			1920		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.020	1.054	1.043	1.032	1.053	1.045	1.032	1.032	1.032	1.030	1.030	1.030	1.075	1.075	1.075
Distillation:															
Up to 200°C	.3%	2.3%	.95%	1.2%	2.7%	1.92%	2.7%	2.7%	2.74%	1.3%	1.3%	1.25%	.5%	.5%	.46%
200 - 210	.8	2.0	1.19	2.3	4.7	3.31	2.2	2.2	2.16	2.7	2.7	2.70	.4	.4	.40
210 - 235	11.0	22.6	14.75	13.8	21.5	18.59	24.0	24.0	24.04	20.0	20.0	20.04	2.5	2.5	2.47
235 - 270	30.7	33.0	31.52	25.2	50.2	29.47	26.2	26.2	26.20	30.3	30.3	30.25	23.7	23.7	23.68
270 - 315	16.1	23.7	21.24	14.2	20.4	18.89	19.5	19.5	19.52	20.9	20.9	20.91	30.9	30.9	30.85
315 - 355	13.5	17.4	16.14	5.6	16.4	14.39	12.5	12.5	12.46	11.8	11.8	11.75	25.6	25.6	25.59
Residue	8.5	13.4	11.81	8.6	12.5	10.34	10.8	10.8	10.79	9.5	9.5	9.54	16.5	16.5	16.49
Water Content %	1.8	2.8	1.87	.5	4.3	1.76	2.1	2.1	2.10	3.6	3.6	3.56	.1	.1	.06
Tar Acids %	5.5	10.5	9.21	5.1	10.1	6.56	4.7	4.7	4.70	4.3	4.3	4.30	5.9	5.9	5.85

	1921			1922			1923			1924			1925		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.044	1.069	1.056	1.008	1.075	1.061	1.024	1.055	1.043	1.020	1.079	1.045	1.028	1.070	1.043
Distillation:															
Up to 200°C	1.4%	2.3%	1.80%	.1%	6.3%	1.50%	0.2%	3.3%	2.20%						
200 - 210	.9	1.6	1.24	.4	9.5	2.13	1.0	6.4	2.14						
Up to 210										0.0%	3.6%	1.64%	.4%	4.5%	2.90%
210 - 235	9.8	20.4	15.14	2.0	27.6	8.30	7.4	25.0	15.70	2.5	21.2	10.72	3.9	20.6	14.76
235 - 270	25.8	28.6	26.16	20.8	25.4	23.17	21.4	33.0	27.37	18.6	34.5	30.32	24.6	33.8	29.63
270 - 315	18.8	24.8	21.92	14.8	34.8	27.94	19.5	29.9	22.68	14.7	29.1	22.32	17.4	24.4	20.23
315 - 355	17.7	25.1	21.47	14.1	26.3	22.73	11.7	21.3	17.38	15.5	25.8	18.55	15.0	28.1	18.52
Residue	11.2	12.2	33.46	6.6	16.2	14.12	10.1	16.6	13.12	14.2	23.3	15.81	10.5	21.9	13.68
Water Content %	1.3	3.4	2.19	.1	2.6	1.05	.2	4.0	2.08	.1	2.8	1.63	.7	2.6	1.42
Tar Acids %	6.75	7.80	6.99	5.1	19.4	8.15	6.5	23.0	11.64	5.9	12.5	9.03	7.6	12.8	9.95
Float Test Sec. at 70°C	30.0	92.0	61.47				25.2	55.0	43.42	22.0	39.5	28.95	24.0	45.0	33.89
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.030	1.040	1.037	1.005	1.042	1.033	1.011	1.034	1.026	1.012	1.036	1.024	1.019	1.032	1.023
315 - 355°C at 38/15.5°C	1.100	1.102	1.091	1.051	1.111	1.097	1.073	1.122	1.032	1.051	1.094	1.073	1.091	1.101	1.094
Coke Residue %						1.53	.98	2.09	1.47	.64	1.96	1.35	1.27	4.41	1.79
Benzol Insoluble %						.28	.02	.48	.28	.16	1.62	.40	.29	.61	.35

Note.—See correction on page 374.

Galveston & Somerville 3 of 5.

	1926			1927			1928			1929			1930		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.037	1.055	1.040	1.039	1.072	1.053	1.036	1.045	1.039	1.035	1.067	1.048	1.056	1.083	1.066
Distillation:															
Up to 210°C	1.0%	3.2%	2.48%	.2%	6.8%	2.86%	2.2%	4.8%	3.38%	.8%	4.7%	2.36%	.1%	2.5%	1.62%
210 - 235	9.8	21.7	17.83	2.9	18.5	11.52	10.9	17.6	14.62	5.8	15.5	10.58	6.2	18.0	11.16
235 - 270	28.1	30.0	29.46	23.1	30.6	27.18	26.7	32.0	28.76	26.6	31.0	28.13	20.7	27.4	25.73
270 - 315	18.2	24.4	20.35	16.0	33.5	20.75	17.2	20.7	18.87	18.8	24.0	21.22	15.3	24.0	18.92
315 - 355	14.2	21.9	16.78	17.0	26.7	21.15	15.6	20.4	17.81	18.0	24.3	20.69	16.0	24.9	19.92
Residue	12.1	14.4	13.21	12.5	19.9	16.65	14.4	17.0	15.81	16.0	17.9	16.89	17.5	34.7	22.46
Water Content %	.5	1.9	.96	.6	3.5	1.74	1.0	2.3	1.45	.2	1.8	.88	.4	2.0	.98
Tar Acids %	7.5	11.5	10.24	4.7	10.8	6.46	5.8	12.8	8.08	5.0	9.5	6.28	3.5	7.8	4.90
Float Test - Sec. at 70°C	19.5	40.0	24.66	12.0	44.0	27.14	15.0	34.0	21.24	19.0	49.0	25.14	7.0	26.0	18.77
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.012	1.027	1.022	1.018	1.039	1.026	1.004	1.022	1.013	1.013	1.032	1.020	1.024	1.035	1.030
315 - 355°C at 38/15.5°C	1.075	1.097	1.096	1.080	1.161	1.093	1.079	1.088	1.084	1.081	1.099	1.088	1.091	1.140	1.105
Flash Point (P.M.C.C.) °F										170	205	190	183	204	192
Coke Residue %	1.11	1.53	.77	.67	1.50	1.10	.09	2.48	.77	.58	1.30	.85	.68	2.00	1.12
Benzol Insoluble %	.13	.35	.15	.10	.36	.21	.12	.49	.23	.00	.34	.19	.04	.50	.21

	1931			1932			1933			1934			1935		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.057	1.063	1.060	1.054	1.068	1.067	1.053	1.075	1.064	1.055	1.078	1.066	1.058	1.076	1.069
Distillation:															
Up to 210°C	.0%	5.0%	1.83%	2.0%	2.8%	2.13%	1.8%	1.8%	1.80%	.0%	2.6%	.57%	.0%	1.7%	.61%
210 - 235	9.1	24.6	16.52	16.7	18.3	16.79	13.9	17.3	15.61	2.6	18.4	9.93	6.4	16.9	10.68
235 - 270	22.9	30.7	27.56	24.2	30.2	24.62	24.3	26.9	25.61	21.2	31.2	26.96	25.5	32.0	27.78
270 - 315	11.7	22.1	16.72	16.4	21.9	16.91	17.4	21.7	19.55	15.3	27.6	20.83	17.1	23.6	19.31
315 - 355	[illegible]	22.0	19.01	16.0	20.0	19.04	18.3	22.1	20.50	17.7	27.3	23.41	17.5	24.6	22.12
Residue	17.3	20.0	18.09	12.3	20.1	19.40	12.8	19.9	16.34	13.6	20.0	17.61	17.6	19.8	18.86
Water Content %	.1	2.0	.80	.4	1.2	.40	.45	.45	.45	.0	2.5	.89	.0	2.0	.84
Tar Acids %	[illegible]	9.8	5.15												
Float Test - Sec. at 70°C	20.0	35.0	27.22	28.0	33.0	28.35	25.4	47.0	36.20	9.0	61.0	27.00	15.5	49.0	33.89
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.022	1.035	1.027	1.028	1.029	1.029	1.024	1.039	1.031	1.027	1.040	1.035	1.028	1.042	1.036
315 - 355°C at 38/15.5°C	1.094	1.110	1.102	1.095	1.098	1.095	1.098	1.098	1.098	1.089	1.114	1.098	1.098	1.123	1.110
Flash Point (P.M.C.C.) °F	189	224	200	190	192	192	194	196	195	186	208	199	190	208	201
Coke Residue %	.57	1.77	1.20	1.03	1.35	1.32	.72	1.10	.91	.63	1.55	1.04	.55	1.93	1.08
Benzol Insoluble %	[illegible]	.26	.24	.16	.24	.24	.09	.09	.09	.11	.49	.30	.15	.47	.26

Galveston & Somerville 4 of 5.

	1936			1937			1938			1939			1940		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.059	1.074	1.068	1.062	1.072	1.068	1.060	1.065	1.062	1.060	1.075	1.068	1.052	1.082	1.065
Distillation:															
Up to 210°C	.0%	2.0%	.77%	.0%	1.2%	.58%	.0%	2.1%	.71%	.0%	1.2%	.41%	.0%	1.0%	.50%
210 - 235	5.9	13.2	10.44	6.6	12.5	9.14	6.9	12.7	8.90	3.5	14.4	9.69	4.3	12.1	7.81
235 - 270	25.5	31.2	28.12	24.8	33.3	29.29	26.2	35.4	31.39	24.1	34.3	27.93	20.9	33.0	27.74
270 - 315	18.0	22.4	19.49	17.3	21.0	19.80	19.5	22.2	20.60	15.2	26.0	20.28	19.0	26.5	21.90
315 - 355	18.9	25.1	22.49	18.4	24.9	21.99	18.0	24.0	19.56	16.4	24.9	22.33	18.4	29.4	23.01
Residue	16.5	20.0	18.05	16.7	20.6	18.53	16.8	22.4	18.65	17.7	19.3	18.72	17.8	19.5	18.48
Water Content %	.7	3.3	1.74	.2	2.3	.93	1.6	5.3	3.15	.8	2.5	1.44	1.7	2.5	1.93
Tar Acids %				.5	3.8	1.73				1.4	4.8	3.36	2.0	3.3	2.68
Float Test - Sec. at 70°C	16.5	68.0	38.00												
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.025	1.040	1.034	1.027	1.044	1.033	1.025	1.034	1.030	1.031	1.043	1.037	1.018	1.046	1.033
315 - 355°C at 38/15.5°C	1.098	1.120	1.113	1.109	1.122	1.112	1.089	1.107	1.098	1.096	1.114	1.106	1.095	1.118	1.106
Flash Point (P.M.C.C.) °F	190	205	199	190	215	199	190	210	199	192	204	199	192	206	199
Coke Residue %	.63	1.76	.80	.39	1.36	.99	.61	1.93	1.42	.70	1.72	1.15	1.01	1.61	1.34
Benzol Insoluble %	.18	.35	.27	.10	.25	.17	.26	.38	.33	.19	.24	.22	.20	.33	.27

	1941			1942			1943			1944			1945		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.061	1.079	1.073	1.059	1.089	1.077	1.069	1.089	1.083	1.065	1.069	1.067	1.076	1.081	1.078
Distillation:															
Up to 210°C	.0%	.3%	.12%	.0%	1.3%	.10%	.0%	.0%	.00%	.0%	.0%	.00%	.0%	1.0%	.48%
210 - 235	3.7	11.2	5.01	3.9	14.9	7.22	3.7	11.5	6.70	6.9	7.5	7.20	4.2	10.3	8.10
235 - 270	23.9	32.5	26.96	19.4	37.7	26.14	20.1	28.7	23.78	27.5	27.6	27.55	23.1	28.5	25.57
270 - 315	19.4	26.0	24.63	13.6	23.7	19.93	17.8	23.8	19.43	22.0	22.5	22.25	17.9	24.8	20.43
315 - 355	19.4	27.7	25.06	14.2	28.9	22.47	20.5	28.1	23.83	23.3	24.6	23.95	26.3	27.6	26.77
Residue	17.2	19.9	17.78	15.9	29.0	23.76	17.8	29.4	25.85	17.8	18.9	18.35	17.3	20.0	18.53
Water Content %	.6	1.7	1.16	.0	5.5	1.36	.1	1.8	.87	.4	2.1	1.25	.1	.9	.56
Tar Acids %										.8	1.0	.90			
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.028	1.041	1.034	1.029	1.041	1.035	1.031	1.044	1.038	1.027	1.031	1.029	1.032	1.046	1.040
315 - 355°C at 38/15.5°C	1.094	1.119	1.112	1.091	1.162	1.114	1.093	1.125	1.112	1.106	1.110	1.108	1.101	1.126	1.109
Flash Point (P.M.C.C.)°F	196	210	205	186	206	199	194	210	200	198	210	204	200	204	201
Coke Residue%	.19	1.98	1.18	.21	1.65	.89	.24	1.44	.86	1.11	1.51	1.31	.22	1.10	.50
Benzol Insoluble %	.18	.36	.29	.06	.45	.19	.03	.46	.21	.11	.33	.22	.01	.34	.10

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	1946*			1947		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.062	1.093	1.078	1.032	1.083	1.055
Distillation:						
Up to 210°C	.0%	2.4%	.95%	.4%	8.1%	2.18%
210 - 235	1.8	15.7	6.48	2.6	20.1	9.69
235 - 270	14.3	25.6	22.18	13.9	28.5	25.05
270 - 315	14.7	28.3	21.33	11.7	26.7	20.17
315 - 355	17.7	28.0	24.59	18.2	25.7	21.73
Residue	16.6	30.2	23.55	17.8	34.2	20.82
Water Content %	.4	3.0	1.74	.1	2.8	1.22
Tar Acids %						
Specific Gravity Fractions:						
235 - 315°C at 38/15.5°C	1.033	1.049	1.037	1.028	1.044	1.032
315 - 355°C at 38/15.5°C	1.101	1.133	1.117	1.101	1.128	1.108
Flash Point (P.M.C. C.) °F	188	240	206	176	224	196
Coke Residue %	.12	1.70	1.10	.19	1.18	.89
Benzol Insoluble %	.01	.68	.25	.02	.50	.14

* Average analysis for 1946 is for 89% of creosote received. Analyses of 11% of creosote incomplete.

Atchison, Topeka and Santa Fe Railway

Analyses of Creosote Received at Wellington, Reduced to a Weighted Average for Each Year, also Showing Minimum and Maximum for Each Year, 1931 - 1947 Incl.

	1931			1932			1933			1934			1935		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.065	1.070	1.068	1.052	1.077	1.056	1.073	1.075	1.075	1.055	1.082	1.068	1.060	1.070	1.064
Distillation:															
Up to 210°C	.1	1.9	.93	1.0	3.6	2.27	.0	.5	.11	.1	1.7	.87	.0	2.7	1.29
210 - 235	7.8	12.1	9.78	5.2	21.4	15.50	4.8	7.6	5.36	2.6	15.3	10.25	7.8	22.2	13.83
235 - 270	26.2	30.1	27.92	16.7	31.9	28.36	27.7	28.0	27.93	21.2	28.6	25.82	22.0	30.4	26.30
270 - 315	20.3	22.8	21.28	18.5	24.6	20.59	20.7	24.3	23.53	19.1	27.6	21.11	13.7	22.5	18.48
315 - 355	20.6	22.6	22.04	13.7	30.6	17.71	24.7	24.7	24.70	18.5	28.6	22.97	16.7	25.3	20.74
Residue	16.5	18.3	17.35	11.7	20.1	14.92	17.7	18.0	17.77	17.1	19.9	18.61	17.8	19.6	18.78
Water Content %	.0	.0	.00	1.0	1.6	1.24	.0	.0	.00	.0	2.9	.58	.0	3.8	1.99
Tar Acids %	1.6	10.7	5.68												
Float Test - Sec. at 70°C	20.0	43.0	34.5	24.0	45.0	32.9	36.0	41.0	39.9	14.0	30.0	25.2	24.0	39.0	29.4
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.033	1.042	1.038	1.024	1.034	1.029	1.040	1.043	1.042	1.027	1.042	1.034	1.028	1.037	1.033
315 - 355°C at 38/15.5°C	1.100	1.110	1.109	1.087	1.097	1.094	1.100	1.122	1.105	1.087	1.113	1.103	1.105	1.113	1.108
Flash Point (P.M.C.C.) °F	190	205	195	190	202	197	204	206	206	194	214	202	186	204	195
Coke Residue %	.17	.24	.21	.36	1.64	1.12	.41	.60	.45	.00	.97	.76	.36	1.09	.69
Benzol Insoluble %	.01	.05	.03	.06	.30	.18	.01	.14	.11	.11	.42	.26	.02	.39	.21

Wellington 2 of 2.

	1936			1937			1938			1939			1940		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.057	1.076	1.069	1.064	1.072	1.070	1.051	1.052	1.051	1.063	1.074	1.069	1.058	1.078	1.072
Distillation:															
Up to 210°C	.0	1.7	.49	.0	1.3	.48	2.7	2.9	2.84	.0	1.6	.75	.0	1.4	.47
210 - 235	5.3	19.8	10.77	8.6	11.6	10.35	17.0	21.5	18.51	9.2	15.2	11.40	9.0	15.2	11.70
235 - 270	25.1	32.4	28.62	26.4	35.7	28.28	21.7	23.6	22.34	23.9	28.2	26.78	25.6	28.1	27.06
270 - 315	16.3	23.7	19.87	19.2	22.1	20.59	16.4	19.4	18.40	17.4	20.6	19.50	17.6	21.0	18.83
315 - 355	15.4	25.5	21.65	15.3	24.4	23.15	18.6	19.8	19.39	21.5	25.6	23.80	19.6	25.1	23.47
Residue	16.4	19.6	18.00	15.3	18.1	16.43	16.6	18.3	17.73	14.8	19.1	17.61	15.0	19.7	17.78
Water Content %	.0	4.7	1.25	.0	1.8	.27	.5	1.8	1.37	.1	1.7	.68	.3	1.8	.84
Float Test - Sec. at 70°C	17.0	49.0	35.1												
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.031	1.042	1.039	1.027	1.042	1.039	1.029	1.030	1.029	1.034	1.045	1.039	1.026	1.044	1.038
315 - 355°C at 38/15.5°C	1.103	1.123	1.117	1.112	1.120	1.118	1.094	1.101	1.096	1.092	1.127	1.114	1.101	1.128	1.119
Flash Point (P.M.C.C.) °F	190	204	198	192	200	198	186	190	187	192	206	196	190	202	196
Coke Residue %	.38	1.38	.54	.33	.56	.40	.37	.65	.46	.19	.67	.42	.19	.58	.33
Benzol Insoluble %	.01	.38	.15	.01	.11	.04	.18	.19	.19	.01	.43	.12	.01	.19	.06

	1941			1942			1943			1945			1947*		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.063	1.074	1.069	1.062	1.075	1.071	1.068	1.073	1.070	1.075	1.077	1.076	1.072	1.073	1.073
Distillation:															
Up to 210°C	.0	1.1	.54	.0	1.3	.67	.0	.3	.05	.2	.3	.24	.8	2.3	1.39
210 - 235	6.8	14.0	11.38	8.5	14.5	11.33	8.3	12.9	9.76	9.5	12.6	10.99	12.5	14.1	13.12
235 - 270	26.3	32.4	28.05	24.8	36.3	27.30	25.6	29.1	27.45	27.0	28.8	27.93	26.2	27.2	26.21
270 - 315	17.4	24.8	20.14	17.3	22.9	18.61	18.0	20.2	19.29	17.9	18.6	18.26	14.0	15.5	14.54
315 - 355	21.5	26.1	23.79	18.2	25.5	23.47	24.7	25.7	25.26	25.1	25.3	25.20	23.2	25.0	24.19
Residue	9.8	18.0	15.30	8.2	19.4	18.07	18.1	19.1	17.51	17.0	17.2	17.10	18.1	20.4	19.94
Water Content %	.2	1.7	1.03	.4	1.8	.96	.5	1.8	1.00	.4	.5	.45	.3	1.3	.54
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.032	1.044	1.041	1.029	1.047	1.041	1.035	1.045	1.041	1.044	1.046	1.047	1.043	1.051	1.044
315 - 355°C at 38/15.5°C	1.096	1.126	1.118	1.094	1.139	1.110	1.102	1.121	1.114	1.105	1.123	1.114	1.111	1.180	1.126
Flash Point (P.M.C.C.) °F	190	202	200	190	202	196	198	202	200	198	198	198	170	192	183
Coke Residue %	.24	.70	.37	.26	.67	.41	.26	.34	.31	.28	.36	.32	.42	.51	.48
Benzol Insoluble %	.01	.19	.12	.02	.15	.05	.01	.02	.02	.02	.03	.01	.02	.05	.03

Note: No Creosote received in 1944.
Note: Analyses of all shipments of creosote received in 1946 were incomplete to extent that average analysis could not be figured.
* Average analysis for 1947 is for 52% of creosote received. Analyses of 48% of creosote incomplete.

Correction.—For 1945, average specific gravity, 235–315 deg. C. fraction should read 1.045; average benzol insoluble, 0.02 percent.

Atchison, Topeka and **Santa Fe Railway**

Analyses of Creosote Received at Albuquerque, Reduced to a Weighted Average for Each Year, also Showing Minimum and Maximum for Each Year, 1926 - 1947 Incl.

	1926			1927			1928			1929			1930		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.058	1.065	1.061	1.064	1.077	1.071	1.069	1.077	1.072	1.072	1.078	1.076	1.065	1.076	1.074
Distillation:															
Up to 210°C	.0	1.9	.69	1.5	3.5	2.65	1.4	3.6	2.53	.3	3.8	1.91	.5	3.5	1.64
210 - 235	12.7	21.1	17.36	13.3	21.8	17.24	11.8	17.3	14.21	7.4	13.5	10.69	8.6	12.0	10.20
235 - 270	29.5	38.0	31.75	19.4	23.4	21.38	18.9	25.7	22.23	22.4	25.4	24.21	22.0	27.9	23.47
270 - 315	17.1	24.4	20.36	14.9	17.5	15.87	14.7	18.8	16.42	15.6	19.4	17.40	16.5	21.9	18.10
315 - 355	19.0	23.5	21.14	18.0	22.6	20.46	16.6	21.5	19.39	17.8	21.7	19.04	17.2	20.3	18.79
Residue	6.0	10.9	8.16	17.8	27.3	22.45	20.2	27.3	25.36	22.9	29.3	26.67	15.8	29.0	27.32
Water Content %	.0	.0	.00	.0	.4	.10	.1	.2	.11	.1	.1	.10	.0	1.0	.10
Tar Acids %	1.4	2.0	1.8	.9	6.0	3.2	4.5	6.4	5.5	4.0	5.7	4.6	4.8	10.0	7.0
Float Test - Sec. at 70°C	49.0	58.0	52.0	36.0	60.0	46.9	19.0	51.0	43.1	35.0	50.0	41.8	33.0	40.0	35.4
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.031	1.041	1.037	1.038	1.054	1.044	1.018	1.044	1.041	1.037	1.042	1.040	1.034	1.039	1.036
315 - 355°C at 38/15.5°C	1.110	1.126	1.117	1.110	1.160	1.116	1.110	1.120	1.112	1.105	1.120	1.111	1.110	1.110	1.110
Flash Point (P.M.C.C.) °F													175	198	182
Coke Residue %	.35	.47	.41	.20	.47	.30	.25	.43	.35	.27	.72	.45	.25	.57	.40
Benzol Insoluble %	.05	.37	.20	.00	.21	.06	.02	.10	.04	.02	.17	.04	.01	.07	.04

Albuquerque 2 of 3.

	1931			1932			1933			1934			1935		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.055	1.070	1.060	1.052	1.070	1.058	1.062	1.073	1.066	1.065	1.072	1.067	1.065	1.074	1.070
Distillation:															
Up to 210°C	.0	2.5	1.66	.9	2.9	2.08	.2	1.9	.83	.3	.6	.37	.0	1.3	.25
210 - 235	7.8	17.1	14.73	9.5	21.4	16.80	7.6	21.2	14.01	2.6	17.0	13.11	6.4	14.4	8.63
235 - 270	18.0	29.8	23.46	26.6	31.9	29.37	26.0	27.9	26.92	21.2	28.6	26.04	28.3	29.4	28.86
270 - 315	17.2	27.0	20.57	18.5	22.5	20.46	17.8	21.8	19.68	18.5	27.6	20.75	17.7	22.5	21.28
315 - 355	19.2	22.0	20.67	13.7	22.5	16.69	14.5	24.7	19.83	20.1	28.6	21.95	19.6	25.1	22.93
Residue	16.6	19.2	18.21	9.6	18.2	14.29	17.8	19.6	18.25	16.8	19.2	17.37	16.6	20.4	17.55
Water Content %	.0	.8	.24	.5	1.6	.94	.0	3.0	.59	.0	2.9	.92	.0	2.1	.60
Tar Acids %															
Float Test - Sec. at 70°C	28.0	47.0	43.2	26.0	45.0	37.5	28.5	44.0	35.5	14.0	30.0	26.1	20.0	45.0	28.7
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.023	1.041	1.030	1.024	1.030	1.027	1.029	1.040	1.031	1.035	1.038	1.036	1.034	1.037	1.035
315 - 355°C at 38/15.5°C	1.089	1.110	1.096	1.087	1.100	1.095	1.099	1.122	1.104	1.087	1.105	1.102	1.099	1.112	1.107
Flash Point (P.M.C.C.) °F	190	210	199	190	200	193	193	204	200	194	214	199	192	202	200
Coke Residue %	.17	1.79	1.10	.77	1.64	1.16	.60	1.73	1.29	.73	1.56	1.32	.39	1.11	.58
Benzol Insoluble %	.01	.11	.05	.18	.40	.28	.13	.30	.21	.19	.37	.33	.04	.43	.16

	1936			1937			1939			1940			1941		
	Minumum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.060	1.073	1.068	1.052	1.061	1.056	1.073	1.073	1.073	1.062	1.077	1.070	1.059	1.078	1.066
Distillation:															
Up to 210°C	.0	1.7	.85	.4	1.1	.69	.5	.5	.50	.1	1.3	.65	.1	2.1	1.18
210 - 235	7.6	15.3	10.75	14.7	18.1	15.92	10.8	10.8	10.80	4.7	13.8	10.32	6.3	19.1	12.82
235 - 270	25.5	32.4	28.11	24.5	26.4	25.77	27.5	27.5	27.50	24.0	31.0	27.04	16.9	33.8	24.74
270 - 315	16.7	22.3	19.44	17.7	18.7	17.98	19.1	19.1	19.10	18.0	24.7	21.14	15.7	30.3	20.33
315 - 355	18.4	23.5	21.79	20.0	20.3	20.25	24.6	24.6	24.60	15.8	23.5	21.30	19.3	25.1	22.22
Residue	17.4	19.6	18.43	17.5	19.4	18.64	16.5	16.5	16.50	17.1	19.5	18.94	9.4	20.0	18.00
Water Content %	.0	3.4	.74	.0	.0	.00	.7	.7	.70	.5	3.0	1.53	.2	1.8	.79
Tar Acids %															
Float Test - Sec. at 70°C	17.0	47.0	32.9												
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.031	1.042	1.037	1.022	1.032	1.025	1.042	1.042	1.042	1.032	1.043	1.038	1.029	1.048	1.035
315 - 355°C at 38/15.5°C	1.103	1.125	1.114	1.086	1.101	1.093	1.120	1.120	1.120	1.098	1.185	1.124	1.097	1.139	1.112
Flash Point (P.M.C.C.) °F	189	204	196	190	198	194	192	192	192	192	200	196	184	202	194
Coke Residue %	.52	1.74	.98	1.76	2.01	1.85	.32	.32	.32	.08	.70	.35	.28	.83	.54
Benzol Insoluble %	.01	.38	.13	.04	.06	.05	.02	.02	.02	.02	.26	.10	.01	.15	.07

Note: No. Creosote Received in 1938.

Albuquerque 3 of 3.

	1942 Minimum	1942 Maximum	1942 Average	1943 Minimum	1943 Maximum	1943 Average	1945 Minimum	1945 Maximum	1945 Average	1946 Minimum	1946 Maximum	1946 Average	1947 Minimum	1947 Maximum	1947 Average
Specific Gravity at 100°F	1.062	1.086	1.069	1.065	1.070	1.068	1.077	1.079	1.078	1.072	1.085	1.079	1.071	1.102	1.083
Distillation															
Up to 210°C	.0	.9	.24	.0	.8	.38	.0	.2	.07	.0	1.6	.53	.0	.9	.27
210 - 235	5.7	16.6	11.43	10.0	16.7	12.49	9.5	10.0	9.82	3.6	16.4	10.01	.0	14.5	7.97
235 - 270	23.6	37.9	29.83	27.2	28.8	28.30	26.8	28.8	27.52	20.4	28.1	25.38	9.8	29.5	25.04
270 - 315	17.1	21.8	18.90	16.9	19.4	17.79	18.6	18.8	18.73	9.9	19.1	17.20	14.4	31.0	17.54
315 - 355	14.4	24.7	19.65	20.3	23.4	21.78	25.3	27.0	26.39	17.7	25.8	23.12	15.7	26.3	21.56
Residue	9.3	27.6	19.48	17.8	19.4	18.80	17.0	17.2	17.07	17.7	28.4	23.36	19.4	35.8	27.00
Water Content %	.2	3.2	.53	.2	1.8	.79	.3	.5	.37	.0	.5	.23	.0	1.3	.28
Tar Acids %															
Float Test - Sec. at 70°C															
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.028	1.044	1.034	1.032	1.041	1.036	1.045	1.046	1.045	1.025	1.043	1.038	1.024	1.059	1.040
315 - 355°C at 38/15.5°C	1.101	1.125	1.112	1.098	1.112	1.105	1.105	1.127	1.119	1.095	1.174	1.115	1.100	1.136	1.116
Flash Point (P.M.C.C.) °F	193	210	199	193	201	196	198	204	202	190	215	197	180	246	203
Coke Residue %	.40	1.29	.61	.24	.62	.43	.28	.41	.36	.23	1.06	.55	.21	1.62	.68
Benzol Insoluble %	.03	.48	.10	.03	.06	.04	.02	.03	.03	.02	.30	.05	.02	.58	.12

Note: No Creosote Received in 1944.

Atchison, Topeka and Santa Fe Railway

Analyses of Creosote Received at National City, Reduced to a Weighted Average for Each Year, also Showing Minimum and Maximum for Each Year, 1924 - 1947 Incl.

	1924			1925			1926			1927			1928		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.030	1.030	1.030	1.040	1.069	1.055	1.040	1.040	1.040	1.032	1.052	1.040	1.040	1.043	1.041
Distillation:															
Up to 210°C	10.8	10.8	10.80	.1	1.7	.89	4.0	4.0	4.00	.7	3.5	2.37	2.5	4.4	3.11
210 - 235	24.8	24.8	24.80	10.1	18.4	14.19	14.3	14.3	14.30	10.5	17.6	15.90	16.5	17.8	17.38
235 - 270	21.0	21.0	21.00	23.2	26.2	24.73	24.6	24.6	24.60	28.9	30.7	29.90	26.9	28.2	27.32
270 - 315	20.0	20.0	20.00	21.0	24.1	22.57	21.5	21.5	21.50	18.3	21.2	19.89	19.9	20.7	20.44
315 - 355	13.9	13.9	13.90	22.2	23.2	22.70	20.6	20.6	20.60	16.6	23.9	17.91	17.9	19.7	19.13
Residue	9.4	9.4	9.40	13.5	16.3	14.92	14.2	14.2	14.20	12.6	15.0	13.77	12.2	12.9	12.42
Water Content %	1.9	1.9	1.90	.4	.6	.50	1.3	1.3	1.30	1.0	1.8	1.69	1.4	4.0	3.17
Tar Acids %	9.0	9.0	9.00	8.5	8.7	8.59	9.2	9.2	9.20	7.8	8.5	7.90	7.4	8.2	7.65
Float Test - Sec. at 70°C				32.0	43.0	38.6									
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.036	1.036	1.036	1.019	1.019	1.019	1.033	1.033	1.033	1.027	1.029	1.028	1.023	1.033	1.030
315 - 355°C at 38/15.5°C	1.100	1.100	1.100	1.061	1.090	1.075	1.090	1.090	1.090	1.080	1.100	1.091	1.079	1.095	1.090
Flash Point (P.M.C.C.) °F															
Coke Residue %	.57	.57	.57	.57	.57	.57	.15	.15	.15	1.12	1.30	1.19	.90	1.40	1.25
Benzol Insoluble %	.50	.50	.50	.20	.50	.35	.39	.39	.39	.11	.25	.15	.20	.24	.22

National City 2 of 3.

	1929			1930			1931			1933			1936		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.045	1.048	1.047	1.060	1.062	1.061	1.064	1.064	1.064	1.071	1.071	1.071	1.054	1.054	1.054
Distillation:															
Up to 210°C	1.6	2.4	2.00	.6	2.3	1.41	1.5	1.5	1.50	1.5	1.5	1.50	.9	.9	.90
210 - 235	13.0	13.5	13.25	9.4	10.9	10.19	7.2	7.2	7.20	8.2	8.2	8.20	12.6	12.6	12.60
235 - 270	27.5	28.4	27.95	25.1	29.4	17.37	26.6	26.6	26.60	26.0	26.0	26.00	29.5	29.5	29.50
270 - 315	20.8	22.3	21.55	20.8	22.6	21.74	21.9	21.9	21.90	21.5	21.5	21.50	21.0	21.0	21.00
315 - 355	20.5	21.3	20.90	22.5	22.7	22.59	22.9	22.9	22.90	22.5	22.5	22.50	20.0	20.0	20.00
Residue	14.2	14.3	14.25	14.0	19.3	16.51	19.1	19.1	19.10	19.7	19.7	19.70	16.0	16.0	16.00
Water Content %	.7	1.3	1.00	.8	2.8	1.86	1.0	1.0	1.00	7	.7	.70	.7	.7	.70
Tar Acids %	9.2	10.0	9.60	6.7	6.9	6.81	7.2	7.2	7.2						
Float Test - Sec. at 70°C	19.0	25.0	22.0	32.0	36.0	33.9	25.0	25.0	25.0	20.0	20.0	20.0	20.5	20.5	20.5
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.024	1.028	1.026	1.031	1.035	1.033	1.031	1.031	1.031	1.031	1.031	1.031	1.030	1.030	1.030
315 - 355°C at 38/15.5°C	1.082	1.096	1.089	1.086	1.109	1.097	1.100	1.100	1.100	1.103	1.103	1.103	1.104	1.104	1.104
Flash Point (P.M.C.C.) °F	208	220	214	190	190	190	194	194	194	196	196	196	188	188	188
Coke Residue %	.54	1.15	.85	.53	.56	.55	.57	.57	.57	1.54	1.54	1.54	.80	.80	.80
Benzol Insoluble %	.12	.18	.15	.06	.23	.15	.27	.27	.27	.40	.40	.40	.14	.14	.14

	1937			1938			1939			1940			1941		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.072	1.072	1.072	1.071	1.071	1.071	1.072	1.072	1.072	1.055	1.055	1.055	1.062	1.087	1.067
Distillation:															
Up to 210°C	.3	.3	.30	.0	.0	.00	.2	.2	.20	2.5	2.5	2.50	.0	1.4	.68
210 - 235	5.6	5.6	5.60	8.3	8.3	8.30	7.8	7.8	7.80	13.8	13.8	13.80	6.6	15.2	11.14
235 - 270	27.4	27.4	27.40	29.1	29.1	29.10	28.0	28.0	28.00	25.6	25.6	25.60	20.7	31.9	26.22
270 - 315	22.2	22.2	22.20	19.3	19.3	19.30	19.2	19.2	19.20	20.1	20.1	20.10	16.8	24.6	19.37
315 - 355	24.7	24.7	24.70	24.0	24.0	24.00	23.3	23.3	23.30	20.1	20.1	20.10	19.0	25.9	22.89
Residue	18.8	18.8	18.80	19.3	19.3	19.30	21.0	21.0	21.00	17.4	17.4	17.40	11.4	27.5	19.41
Water Content %	1.5	1.5	1.50	.8	.8	.80	.9	.9	.90	1.1	1.1	1.10	.2	1.5	.57
Tar Acids %															
Specific Gravity Fractions:															
235 - 315°C at 38/15.5°C	1.037	1.037	1.037	1.036	1.036	1.036	1.036	1.036	1.036	1.028	1.028	1.028	1.024	1.049	1.034
315 - 355°C at 38/15.5°C	1.110	1.110	1.110	1.111	1.111	1.111	1.107	1.107	1.107	1.094	1.094	1.094	1.093	1.144	1.108
Flash Point (P.M.C.C.) °F	202	202	202	202	202	202	203	203	203	186	186	186	192	204	198
Coke Residue %	.49	.49	.49	.42	.42	.42	.53	.53	.53	.32	.32	.32	.15	.70	.48
Benzol Insoluble %	.14	.14	.14	.12	.12	.12	.05	.05	.05	.10	.10	.10	.01	.31	.10

Note - No Creosote Received in 1932, 1934 and 1935.

Correction.—For 1930, average distillation, third fraction, should read 27.37 percent.

	1942			1943			1947		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Specific Gravity at 100°F	1.052	1.080	1.068	1.065	1.072	1.068	1.033	1.041	1.035
Distillation:									
Up to 210°C	.0	2.7	.57	.0	.8	.14	.8	3.8	3.05
210 - 235	7.2	17.7	12.10	4.1	13.2	7.66	13.8	16.3	15.68
235 - 270	22.9	34.9	26.94	28.3	34.5	31.38	24.6	26.9	25.19
270 - 315	16.1	22.3	18.90	16.7	24.2	21.63	18.3	18.7	18.40
315 - 355	20.2	25.9	22.71	17.2	25.3	20.69	18.1	21.4	18.43
Residue	8.6	25.6	18.47	17.2	20.2	18.20	17.7	18.3	18.15
Water Content %	.5	3.2	1.46	.9	1.8	1.50	1.1	1.3	1.25
Tar Acids %									
Specific Gravity Fractions:									
235 - 315°C at 38/15.5°C	1.025	1.048	1.035	1.032	1.038	1.036	1.006	1.012	1.008
315 - 355°C at 38/15.5°C	1.100	1.140	1.111	1.100	1.115	1.109	1.074	1.080	1.076
Flash Point (P.M.C.C.) °F	176	210	196	190	198	194	176	192	180
Coke Residue %	.23	1.29	.59	.58	.95	.71	.82	.98	.94
Benzol Insoluble %	.01	.48	.14	.06	.38	.26	.05	.15	.13

Note - No Creosote Received in 1944, 1945 and 1946.

(continued from page 360)

	deg. C	*Percent*
Distillation to	210	2.74
	235	12.41
	270	19.25
	300	10.42
	315	4.04
	355	17.37
Residue above	355	33.70
Loss		.07
Specific gravity @ 38 deg. C. Whole oil		1.078
Fraction 235 deg. C. to 315 deg. C.		1.033
Fraction 315 deg. C. to 355 deg. C.		1.108
Water content		Trace
Benzol insolubles		0.18

The petroleum oil analysis consisted of the specific gravity which was 0.98 with an asphaltic content of approximately 50 percent.

Northern Pacific Railway

Report of analysis of creosote used straight and in 50–50 solution with petroleum for treatment of 1473 cross ties treated at Brainerd, Minn., October 17, 1922 and placed in tie record test tracks near Duluth, Minn., and Plateau, Mont., as last reported on page 185 of the 1948 AREA Proceedings.

	Percent
Specific Gravity @ 38 deg. C.	1.06
Water	Trace
210 deg. C.	4.5
235	22.5
270	24.5
315	16.4
355	14.0
Residue above 355 deg. C.	17.0
Loss	1.1

Petroleum from Bakersfield, Calif., specific gravity at 38 deg. C. was 0.98.

Note: Following are corrected values for figures appearing in the table on page 362.

Distillation	*Averages, percent*		
	1917	*1919*	*1920*
Up to 200° C.	2.70	1.30	0.50
200–210	2.20	2.70	0.40
210–235	24.00	20.00	2.50
235–270	26.20	30.30	23.70
270–315	19.50	20.90	30.90
315–355	12.50	11.80	25.60
Residue	10.80	9.50	16.50

1921—The Average Specific Gravity Fraction for 315–355 Deg. C. should read 1.101

Report on Assignment 3

Destruction by Marine Organisms; Methods of Prevention

W. F. Clapp (chairman, subcommittee). W. P. Arnold, Walter Buehler, C. M. Burpee, F. W. Gottschalk, B. D. Howe, M. F. Jaeger, R. R. Poux, J. N. Roche, Hermann von Schrenk.

The report of the inspections of the tropical timber tests made by James Zetek in September 1943, was included in the Proceedings, Vol. 45, 1944, pages 284–288. No further information regarding these tests has been received.

Test Piles

Dr. Hermann von Schrenk has reported that the Tiburon pile tests have been lost. The only ones remaining in this series are the piles at Long Wharf, Oakland, Calif. The results of recent inspections of these piles have not been made available to the committee.

Chemical Warfare Service Specimens—Series No. 2

This series of tests originally consisted of two duplicate sets of treated timbers 2 ft. in length and 5 in. to 6 in. in diameter. At the time of the last inspection on August 10, 1943, only four treated and one untreated control remained in this series, and no later report has been received.

Testing Station, Almirante, Panama

Because of conditions brought about the war, this station was abandoned and as a result all test pieces were lost. Five-foot lengths of southern yellow pine treated with high and low residue creosotes showed no attack by marine borers from October 1940, to September 1943. For detailed description of tests see Proceedings of the American Wood-Preservers' Association, 1942, pages 386–399. Untreated controls showed extremely heavy attack.

Testing Station, Newport, R. I.

A duplicate set of five-foot pile sections, the same as those reported above as lost from Almirante, were submerged at Newport on April 1, 1940. An inspection in October 1947, showed no evidence of marine borer attack. A few samples have been lost due to storms, but a representative number of each treatment remains on test. Tests of 30 pile sections, 10 treated to refusal with creosote, 10 with 50/50 coal tar creosote solution, and 10 with coal tar were submerged at Newport on May 29, 1936. None of these samples showed marine borer attack in October 1947.

Testing Station, Woods Hole, Mass.

Twelve pile sections of Douglas fir with a 12-lb. creosote retention were submerged at this station on June 1, 1942. Subsequently nine were lost. The three remaining on test showed no attack in October 1947.

A series of 20 southern pine sections treated to refusal with various solutions of coal tar and creosote were submerged on June 1, 1942. None of this series showed evidence of marine borer attack in October 1947.

Marine Borer Test Boards

The New England Marine Piling Investigation has continued in operation under the direction of T. G. Sughrue, chief engineer of the Boston & Maine Railroad. Test boards are being maintained and examined monthly from 60 locations along the New England coast. One change of importance in marine borer activity has been recorded from the North Atlantic coast, as described below:

> The New York Marine Piling Investigation has been continued under the direction of W. P. Hedden, Port Authority of New York. At the present time there are 41 locations in and about New York harbor being investigated with regular test boards.
>
> In 1947 a survey of several harbors adjacent to New York was made in an attempt to correlate the effect of sewage plant effluent on the activity of boring marine organisms. The results indicated that sewage treating plants in the areas examined had no measurable effect on marine borers.
>
> Under sponsorship of the Office of Naval Research standard marine borer test boards are being operated at 132 locations, from Newfoundland to Brazil in the Atlantic, and from the Aleutians and Alaska to Panama in the Pacific. Standard test boards are also operated regularly in the harbors of 20 of the Pacific Islands. In addition, 20 special test boards are submerged in harbors in the Caribbean and northern South America.
>
> There are also being operated 48 other miscellaneous test boards at various locations. All of the above mentioned test boards are those which are regularly operated. In addition, there are also approximately an equal number of special tests of various types operated at more or less regular intervals for special purposes.
>
> In 1935 and 1936 the piling supporting a small wharf at Beverly, Mass., was destroyed by teredo *dilatata*. During those years many lobster pot buoys and spar buoys along the coast of Massachusetts from Beverly south to Plymouth were riddled by this species of teredo. The planking of several boats in this area was found to have been badly damaged by the same species. Previously teredo *dilatata* has been found in destructive numbers in the more northern waters of Nova Scotia and Newfoundland. Since 1936 no trace of this teredo has been found in any of the thousands of test boards and piles which have been examined in the New England area, until the summer of 1948.
>
> Specimens 18 in. in length were found in tests which had been submerged for 3 months at Salem, Mass. The 2-in. by 4-in. timbers of a test float at Duxbury, Mass., were found to have been completely riddled by this teredo during the same period of time. Many of the organisms were two feet in length. Test boards at Chatham, Mass., also contained specimens of this species.
>
> The sudden reappearance in large numbers of this very destructive species at several locations in New England is very remarkable. In the past it has only been found in more or less open waters of normal salinity.
>
> It is possible that some timber structures in more or less open harbors may have been damaged during the summer of 1948.

Report on Assignment 4

Specifications for Creosote–Petroleum Solutions

R. S. Belcher (chairman, subcommittee), Walter Buehler, G. B. Campbell, H. B. Carpenter, W. R. Goodwin, R. P. Hughes, M. F. Jaeger, A. L. Kammerer, L. W. Kistler, A. J. Loom, W. C. Reichow, J. N. Roche, L. B. Shipley, T. H. Strate, J. E. Tiedt.

This report is presented as information but includes, with the recommendation for adoption and publication in the Manual, a footnote addition to the Specification for Petroleum for Blending with Creosote.

It is a continuation of reports presented in 1943, 1944, and 1945, which appear in the Proceedings, Vol. 44, 1943, page 642, Vol. 45, 1944, page 291, and Vol. 46, 1945, page 487, respectively.

To facilitate study your committee divided the assignment into seven phases as follows:

1. Effect of preservative treatment by use of creosote-petroleum.
2. Reasons for and extent of use of creosote–petroleum solutions.
3. Specifications for creosote–petroleum treatment.
4. Specifications for petroleum for blending with creosote.
5. Specifications for creosote for blending with petroleum.
6. Specifications for various creosote–petroleum solutions that may be used for preservative treatment.
7. Methods of analysis of creosote–petroleum solutions that may be used for preservative treatment.

Phases 1, 2, and 3 were covered in the 1943 report, Proceedings Vol. 44, 1943, pages 642 to 644, and these phases of the assignment have been considered complete. Your committee is still studying phases 4, 5, 6, and 7.

4. *Specifications for petroleum for blending with creosote.*—Specifications were adopted at the 1944 annual meeting and appear on page 17–23 of the Manual. However, your committee has found a considerable proportion of the petroleum used in creosote–petroleum solutions is of lower specific gravity than that given as the minimum in the specifications. Such petroleums, in general, have been reported compatible with creosote meeting the specifications of this Association, and otherwise generally satisfactory. It is recommended, therefore, that the following footnote be shown in the Manual following the specifications:

Petroleum of lower specific gravity may be used provided experience or test shows the oil to be satisfactory.

5. *Specifications for creosote for blending with petroleum.*—Your committee is of the opinion that creosote supplies have passed the critical stage and quantities approaching prewar requirements are now available. Consideration is now being given specifications covering creosote having characteristics which are particularly desirable in creosote for blending with petroleum.

6. *Specifications for various creosote–petroleum solutions that may be used for preservative treatment.*—The present specification which was approved by the Association in 1945, and appears on page 17–23 of the Manual, limits the percentage of creosote in the solution to not less than 50 percent. Creosote–petroleum solutions containing less than 50 percent creosote are in use by some roads. Wood treated with such solutions has shown favorable results to date, but even though some of this material

has been in service 20 years or more, both solutions containing 50 percent creosote and solutions containing less than 50 percent creosote have made excellent records, and it is at this time difficult to show definitely superior results from either one or the other. Your committee is of the opinion that this phase of the subject should receive further study and more data should be collected.

7. *Methods of analysis of creosote–petroleum solutions that may be used for preservative treatment.*—Study of this phase of the subject continues but as yet no entirely satisfactory methods of analysis have been developed.

STANDARD VOLUME CORRECTION TABLE FOR CREOSOTE–PETROLEUM SOLUTIONS

Factors to be used for determining the volume at 100 deg. F., occupied by unit volume at temperatures ranging from 60 deg. F. to 220 deg. F. on solutions containing from 30 percent to 70 percent Group 0 or Group 1 petroleum. When both Group 0 and Group 1 petroleum are used in making up a solution, the gravity of the mixture of the two oils will be used to determine the group in which the mixture falls and thus the factors to use. Group 0 oils are those whose specific gravities at 60 deg. F./60 deg. F. are not less than 0.9665. Group 1 oils are those whose specific gravities at 60 deg. F./60 deg. F. are not less than 0.8504 and not over 0.9664. The observed volume is to be multiplied by the factor corresponding to the observed temperature.

Observed Temp. deg. F	Factors		Observed Temp. deg. F	Factors	
	Creosote—Group 0 Petroleum Solutions	Creosote—Group 1 Petroleum Solutions		Creosote—Group 0 Petroleum Solutions	Creosote—Group 1 Petroleum Solutions
220	.9558	.9530	183	.9693	.9674
219	.9562	.9534	182	.9697	.9677
218	.9565	.9538	181	.9700	.9681
217	.9569	.9542	180	.9704	.9685
216	.9573	.9546	179	.9707	.9689
215	.9577	.9550	178	.9711	.9693
214	.9580	.9554	177	.9715	.9696
213	.9584	.9557	176	.9718	.9700
212	.9588	.9561	175	.9722	.9704
211	.9591	.9564	174	.9726	.9708
210	.9594	.9568	173	.9730	.9712
209	.9598	.9572	172	.9733	.9716
208	.9602	.9576	171	.9737	.9720
207	.9605	.9580	170	.9741	.9724
206	.9609	.9584	169	.9745	.9728
205	.9613	.9588	168	.9748	.9732
204	.9616	.9592	167	.9752	.9736
203	.9620	.9596	166	.9756	.9740
202	.9624	.9600	165	.9759	.9744
201	.9627	.9604	164	.9763	.9748
200	.9631	.9608	163	.9767	.9752
199	.9635	.9612	162	.9770	.9755
198	.9638	.9615	161	.9774	.9759
197	.9641	.9619	160	.9777	.9763
196	.9645	.9623	159	.9781	.9767
195	.9648	.9627	158	.9785	.9771
194	.9653	.9631	157	.9788	.9775
193	.9656	.9634	156	.9792	.9779
192	.9660	.9638	155	.9796	.9783
191	.9664	.9642	154	.9799	.9787
190	.9667	.9646	153	.9803	.9791
189	.9671	.9650	152	.9807	.9795
188	.9675	.9654	151	.9811	.9799
187	.9678	.9658	150	.9815	.9803
186	.9682	.9662	149	.9818	.9807
185	.9686	.9666	148	.9822	.9811
184	.9689	.9670	147	.9826	.9815

Observed Temp. deg. F	Factors		Observed Temp. deg. F	Factors	
	Creosote—Group 0 Petroleum Solutions	Creosote—Group 1 Petroleum Solutions		Creosote—Group 0 Petroleum Solutions	Creosote—Group 1 Petroleum Solutions
146	.9829	.9819	102	.9993	.9992
145	.9833	.9823	101	.9996	.9996
144	.9837	.9827	100	1.0000	1.0000
143	.9840	.9831	99	1.0004	1.0004
142	.9844	.9834	98	1.0008	1.0008
141	.9848	.9838	97	1.0011	1.0012
140	.9851	.9842	96	1.0015	1.0016
139	.9855	.9847	95	1.0019	1.0020
138	.9859	.9851	94	1.0022	1.0024
137	.9862	.9854	93	1.0026	1.0028
136	.9866	.9858	92	1.0030	1.0033
135	.9869	.9862	91	1.0033	1.0037
134	.9873	.9866	90	1.0037	1.0041
133	.9877	.9870	89	1.0041	1.0044
132	.9880	.9873	88	1.0045	1.0048
131	.9885	.9877	87	1.0049	1.0052
130	.9888	.9881	86	1.0052	1.0056
129	.9892	.9885	85	1.0056	1.0060
128	.9896	.9889	84	1.0060	1.0064
127	.9899	.9893	83	1.0063	1.0068
126	.9903	.9897	82	1.0067	1.0072
125	.9907	.9901	81	1.0071	1.0076
124	.9911	.9905	80	1.0075	1.0080
123	.9914	.9910	79	1.0078	1.0084
122	.9918	.9913	78	1.0082	1.0088
121	.9922	.9917	77	1.0086	1.0092
120	.9925	.9921	76	1.0089	1.0096
119	.9929	.9925	75	1.0093	1.0100
118	.9933	.9929	74	1.0097	1.0104
117	.9936	.9933	73	1.0101	1.0108
116	.9940	.9937	72	1.0104	1.0112
115	.9943	.9941	71	1.0108	1.0116
114	.9947	.9945	70	1.0111	1.0120
113	.9951	.9949	69	1.0115	1.0124
112	.9955	.9953	68	1.0119	1.0128
111	.9958	.9957	67	1.0123	1.0132
110	.9963	.9961	66	1.0127	1.0136
109	.9967	.9965	65	1.0130	1.0140
108	.9970	.9969	64	1.0134	1.0144
107	.9974	.9973	63	1.0138	1.0148
106	.9978	.9977	62	1.0142	1.0152
105	.9981	.9981	61	1.0146	1.0156
104	.9985	.9985	60	1.0149	1.0160
103	.9989	.9989			

Report on Assignment 5

Destruction by Termites; Methods of Prevention

Hermann von Schrenk (chairman, subcommittee), W. F. Clapp, F. W. Gottschalk, B. D. Howe, M. F. Jaeger.

This is a progress report submitted as information, dealing with the investigations which have been conducted during the past year concerning termites and the destruction which they cause, with special reference to railroad structures.

In the last report, which will be found in the Proceedings, Vol. 47, 1946, page 142, a progress report was presented dealing with the termite experimental tests at Florissant, Mo. During the past year very little has been done except to keep track of experiments, because the tests are still under way and it was not thought necessary to make another inspection until two or three additional years hence.

Your committee has thought it advisable this year to summarize some of the points which should be called to the attention of the members of the Association, particularly those who were not present when the previous reports were submitted. In the following a brief statement is given which will bring the subject up to date.

1. Termites are still active on American railroads. They are found in practically every state in the Union. Continued studies have shown that creosoted ties and timbers, including piles, when in contact with the ground or water, are generally immune from termite attacks. The only exceptions are where pieces of wood are sawed after treatment and the untreated heartwood is in contact with the ground, in which case almost universally termites will attack the heartwood and cause considerable destruction to the whole structure.

2. Railroad architects and engineers have learned that by using proper engineering practices and designs 100 percent protection from termites can be obtained. The committee has briefly summarized the points which should be considered, most of which it is believed will be desirable to emphasize again. The following notes apply particularly to the following structures:

A. *Foundation Walls.*—Coat all surfaces of foundation walls with a cement coating made up of sand and cement so as to close all holes through which the termites might get in below ground. It is particularly emphasized that the most important part of foundation walls are the tops because the insects come up through the insides of the holes from openings below ground. Accordingly, the upper or top surface of all foundation walls built of concrete should be coated with a layer about two inches in thickness of very rich mixture of cement and sand, which should be carefully trowelled on top so there is no possibility of any holes or cracks being left unprotected on the top of the wall.

B. *Cellars.*—In cellars all pieces of wood, such as are used for stair risers, posts, etc. should rest on well trowelled cement bases. It has been found best to have the bottom of posts rest on small concrete posts.

C. *Window Frames.*—Basement window frames, particularly those that are near the ground, should be set in a concrete window opening, the surface of which should be carefully trowelled, as in the case of the walls, so as to cut off all possibly entry from the concrete frame into the window frame.

D. *Bridges.*—In the case of bridges constructed of wooden piles and timbers only heavily creosoted materials should be used. Cut-offs of piles at the top should be protected with creosote and coal tar pitch and on top of this material metal caps which overhang at least 1 in. and then bent at a 45-deg. angle for at least 2 in., should be placed. For details, including drawing, see previous committee reports.

E. *Wood Culverts.*—Wood culverts should all be heavily creosoted and care taken not to expose any cut-off end of the plank. One of the most frequent causes of destruction in railroad tracks is due to the fact that workmen do not appreciate that the planks should be the exact length that are to be used and no cut-offs made after the planks are put in place.

3. Chemical Protection.—

A. Coal tar creosote or creosote-coal tar solutions, using at least 12 lb. or more per cu. ft., are the safest guarantee when properly applied to wood structures.

B. Within recent years some new compounds have been highly recommended by their manufacturers. Of these pentachlorophenol, trichlorbenzene, copper naphthenate, chromated zinc chloride, Celcure, Scafoil, and Ascu have so far given promise of effective protection. The committee, however, is unable to say definitely to what extent these newer compounds will give as effective protection as will timbers treated with coal-tar creosote and creosote-coal tar solutions.

4. Where stone, brick or concrete walls are placed as foundations for buildings, the rich cement-sand mixture mentioned above should protect the top surface, followed by termite shields, as described in previous reports of the committee.

Report on Assignment 6

New Impregnants and Procedures for Increasing the Life and Serviceability of Forest Products

F. W. Gottschalk (chairman, subcommittee), W. P. Arnold, R. S. Belcher, P. D. Brentlinger, H. B. Carpenter, W. F. Clapp, W. H. Fulweiler, F. A. Hartman, M. S. Hudson, L. W. Kistler, N. E. Kittell, L. A. Olson, R. R. Poux, J. W. Reed, Henry Schmitz, Hermann von Schrenk.

This report is presented as information, but it includes drafts of specifications for some of the newer impregnants, two of which are submitted for adoption and publication in the Manual.

The preservative zinc chloride which was once extensively used has been replaced by other preservatives. The use of zinc chloride now represents only one percent of its application in the peak year—1921. For the past six years, two other toxic-salt preservatives have been widely accepted by wood preservers; these are chromated zinc chloride and tanalith. Results of use for 1946 and 1947, which are typical for the general trends, are as follows:

	Ft. b.m. Treated	
	1946	*1947*
Zinc chloride	7,775,000	11,672,000
Chromated zinc chloride	45,249,000	52,270,000
Tanalith	69,386,000	43,935,000

For the year 1947, these three preservatives accounted for 97.5 percent of the toxic-salt treated material.

The committee submits the two specifications below for adoption and publication in the Manual.

SPECIFICATION FOR CHROMATED ZINC CHLORIDE

Chromated zinc chloride in the dry form shall have the following properties:

It shall contain not less than 77.5 percent of zinc chloride ($ZnCl_2$) calculated from the total soluble zinc content.

It shall contain hexavalent chromium equivalent to not less than 17.5 percent sodium dichromate dihydrate ($Na_2Cr_2O_7.2H_2O$). This may include chromium hydroxide sufficient to produce in a 3-percent solution of chromated zinc chloride a PH no lower than 3.0.

Chromated zinc chloride in concentrated solution or fresh working solution shall contain zinc calculated as zinc chloride and chromium calculated as sodium dichromate dihydrate in the proportion stated.

Samples of chromated zinc chloride treating solution taken from working tanks or treating cylinder may show a change in composition as a result of treating operations. Such changes shall not serve to cause rejection of the preservative if they do not raise the ratio of zinc chloride to sodium dichromate dihydrate to more than 8 to 1 and if it can be shown that the original fresh preservative was of the specified composition.

SPECIFICATION FOR TANALITH

Tanalith shall be composed of the following ingredients in the proportions given:

	Percents
Fluoride, calculated as sodium fluoride (NaF)	25
Arsenate, calculated as disodium hydrogen arsenate (Na_2HAsO_4)	25
Chromate, calculated as sodium chromate (Na_2CRO_4)	37½
Dinitrophenol	12½

Subject to the following tolerances:

The minimum proportions may be respectively 22, 22, 34 and 5, but the preservative shall contain at least 95 percent of these active materials.

The pH of the treating solution shall be not less than 7.2 or more than 7.8.

The foregoing specifications for chromated zinc chloride and tanalith were taken from the manual of the American Wood–Preservers' Association; the preservatives have been AWPA standards since 1942. Details for the two toxic-salt preservatives will be found in the 1941 and 1942 reports of the AWPA Preservatives committee.

New Oil-Soluble Preservatives

Two new oil-soluble wood preservatives have been in use by the industry for several years. These are pentachlorphenol and copper naphthenate. Information on these chemicals appears in the last several proceedings of the American Wood–Preservers' Association. The most informative data are in the 1948 report of the AWPA Preservatives committee; the report on pentachlorophenol, in part, reads:

> Last year the committee reported on the amount of pentachlorphenol solutions being used and also presented data on the effectiveness of such solutions as shown by laboratory and field tests. The tests reported were: (1) Post tests at Gulfport, Miss., by the Bell Telephone Laboratories, (2) post tests by the Santa Fe Railway at Cleveland, Tex., and tie tests at Cleburne, Tex. and at Cleveland, Tex., (3) stake tests by the Koppers Company at Charleston, S. C. and Montgomery, Ala., (4) stake tests by the Bell Telephone Laboratories at Gulfport, Miss., (5) stake tests by the U. S. Forest Products Laboratory at Saucier, Miss., (6) stake tests by the Chapman Chemical Co. at Bogalusa, La.. and at Jacksonville, Fla. Reference was made to tests reported elsewhere, namely, (1) post tests near Florissant, Mo., reported by the AREA, (2) post tests by the U. S. Forest Products Laboratory at Saucier, Miss., (3) laboratory block tests reported by the Bell Telephone Laboratories, (4) laboratory block tests reported by the U. S. Forest Products Laboratory. Since the results of these tests were consistently favorable and since petroleum solutions of toxic chemicals appear to fill a definite need in wood preservation, the committee recommends that the following specification for pentachlorophenol be adopted as a tentative standard. It is recommended that treating solutions be required to contain at least 5-percent pentachlorophenol and that the use of solutions in which pentachlorophenol is the principal ingredient be excluded from the treatment of piles. It is known that the performance of

pentachlorophenol as a wood preservative is influenced by the character of the petroleum oil in which it is dissolved. Best results are obtained with fairly heavy oils of low volatility. However, no specifications for oils to be used as solvents for pentachlorophenol will be offered at this time. The committee calls attention to some general information on the subject which was published in its 1947 report, and also to an opinion offered therein, as follows: "The use of as high a boiling petroleum as is consistent with penetration and cleanliness requirements for the treated wood is considered the practice involving the least risk."

SPECIFICATION FOR PENTACHLOROPHENOL

1. Pentachlorophenol shall contain not less than 95 percent of chlorinated phenols as determined by titration of hydroxyl and calculated as pentachlorophenol.

2. It shall contain not more than 1 percent of matter insoluble in N/1 aqueous sodium hydroxide solution.

3. It shall have a freezing point of not less than 174 deg. C.

4. The foregoing tests shall be made in accordance with the standard methods of the American Wood-Preservers' Association.

The AWPA and other groups are studying specifications for satisfactory oils and methods of treatment.

Copper Naphthenate

The 1948 report of the AWPA Preservatives committee on copper naphthenate, in part, reads:

> Last year the committee reported on the amount of copper naphthenate solutions being used and also presented data on the effectiveness of such solutions as shown by laboratory and field tests. The tests reported were: (1) Stake tests by the Koppers Company at Charleston, S. C., and at Montgomery, Ala., (2) stake tests by the U. S. Forest Producst Laboratory at Saucier, Miss. Reference was made to post tests reported by the AREA, and to laboratory block tests reported by the U. S. Forest Products Laboratory.
>
> In some tests reported by the Australian Forest Products Laboratory on poles treated with Cuprinol (a proprietary preservative containing copper naphthenate as the active ingredient) no failures were found and all poles were in excellent condition after 11 to 12 years' service. Of the untreated controls, 27 percent had failed and an additional 23 percent were badly attacked.
>
> In some accelerated laboratory tests by the Canadian Forest Products Laboratory, some blocks treated with copper naphthenate solutions and exposed to severe heating and leaching cycles showed little loss of chemical. When fuel oil had been used as a solvent, the weathered blocks were highly resistant to attack by *Coniophora cerebella;* when petroleum spirits had been used as a solvent the blocks were less resistant to attack. The concentrations of the treating solutions were higher than is commonly used in commercial treatments.
>
> Some unpublished data by the Bell Telephone Laboratories show that in a series of commercial treatments at one plant there was no progressive decrease in the concentration of copper naphthenate in the treating solution. Analyses of ¼-in. rings cut from disks out of treated poles showed little or no evidence of selective absorption of copper in the outer layers of the wood.
>
> Since the results of these tests have been consistently favorable, the committee recommends that the following specification for copper naphthenate be adopted.

It is recommended that the concentration of copper naphthenate in treating solutions be not less than that equivalent to 0.75 percent metallic copper.

Furthermore, it is recommended that pending the accumulation of more extensive service data, the use of solutions in which copper naphthenate is the principal ingredient be excluded from the treatment of piles.

As in the case of pentachlorophenol, the performance of copper naphthenate seems to be affected by the nature of the petroleum oil in which it is dissolved. No specification for such oils will be offered at this time but the general recommendations that have been offered regarding solvents for pentachlorophenol are believed to apply also to solvents for copper naphthenate, with the exception that adequate solvency may be assumed for all petroleum oils.

SPECIFICATION FOR COPPER NAPHTHENATE

1. The naphthenic acid used in the manufacture of copper naphthenate shall be of the group of cyclopentane carboxylic acids occurring in petroleum and shall have an acid number of not less than 180, on an oil-free basis.

2. The copper naphthenate concentrate used to prepare wood-preserving solutions shall contain not less than 6 percent nor more than 8 percent copper naphthenate calculated as metallic copper.

3. All of the copper present in the concentrate shall be combined as copper naphthenate.

4. The copper naphthenate concentrate shall not contain more than 0.5 percent water.

5. The foregoing tests shall be made in accordance with the standard methods of the American Wood-Preservers' Association.

Tentative Methods of Treatment for Copper Naphthenate

The AWPA and other groups are studying specifications for satisfactory oils and methods of treatment.

According to the report, Wood Preserving Statistics, prepared by the AWPA and the U. S. Forest Service, quantities of oil used in preservation were as follows:

	1946 *gal.*	*1947* *gal.*
Creosote and creosote-coal tar	173,310,920	214,000,745
Petroleum for creosote blending	38,787,288	42,363,468
Pentachlorophenol solution	13,968,011	16,853,069
Copper naphthenate solution	4,409,762	4,959,646

The committee offer no information on zinc meta arsenite in view of the fact that this preservative is not in commercial application today. It is of the opinion that the Specification for Zinc Chloride should be continued in the Manual.

Report on Assignment 7

Incising Forest Products

W. P. Arnold (chairman, subcommittee), F. W. Gottschalk, F. W. Hillman, B. D. Howe, R. P. Hughes, A. J. Loom, T. H. Strate, C. H. Wakefield.

Your committee submits as information, study of incising forest products:

To determine effect of incising cross ties on treatment and subsequent checking after installation, the following test was conducted:

Effect of Incising on Checks and Splits in Mixed Hardwood Ties

The effect of incising on the checking and splitting of mixed hardwoods other than oak was determined on a test group of 324 ties. All were received in a very green condition. Every second tie was incised as they were unloaded from the boxcars, so that one-half of the test ties represented each condition.

The ties were weighed in groups, keeping incised and unincised ties separate, before being stacked in 1 by 9 piles, on January 16, 1941. Thus, comparative loss in weight by seasoning was determined when these ties were weighed again just before treatment, 8½ months after stacking. Photographs were taken during the course of seasoning. After treatment, the ties were weighed a third time to determine comparative retention of oil. Borings were made in the heart face of each tie to determine penetration. The ties were then installed out of face in a tangent section of the Wheeling & Lake Erie Railroad track near Orrville, Ohio. Periodic observations were made to determine behaviour in service, but the first official inspection was in 1948, by a party including two experienced tie inspectors and two representatives of the Koppers Company Technical Department. Ties were placed in one of three rating groups, according to the following conditions:

Group 1—Checks less than ⅛ in. or no checks
2—Checks and splits approx. ⅛ in to ⅜ in.
3—Checks and splits over ⅜ in.

The ties had previously been rated on a similar basis by two experienced tie inspectors just prior to treatment and installation. At that time, four out of five ties in Group 3 were unincised. Incising did not appear to accelerate seasoning nor increase penetration, but did increase the retention of preservative by ½ lb. per cu. ft. of wood. The 1948 inspection showed five out of six ties in Group 3 to be unincised.

Treatment Data

Charge report No. C 647	Koppers Company, Wood Pres. Div. Orville, Ohio
Date treated	10/2/21
Initial air	90 lb.
Pressure period	2½ hours
Temperature of oil	210 deg. F.
Final vacuum	45 min.
Preservative	50/50 creosote–coal tar solution

	Number of Ties	*Total Cu. Ft.*	*Wt./Cu. Ft. When stacked*	*Wt./Cu. Ft. When treated*	*Retention in Lb./Ft.³*
Incised	162	587	60.6	40.0	8.1
Unincised	162	587	62.6	39.7	7.6

Photographs were taken as part of the 1948 inspection of the test ties, for comparison with the photographs of the original installation.

Results of Inspection—May 11, 1948

Incised

Species	*Total Number*		*GROUP No. 1 (Checks less than 1/8 in or no checks)*			*GROUP No. 2 (Checks and/or splits between 1/8 in. and 3/8 in.)*			*GROUP No. 3 (Checks and/or splits 3/8 in. and over)*		
				Percentages of			*Percentages of*			*Percentages of*	
	Actual	*Per-cent*	*No*	*Species*	*Group*	*No*	*Species*	*Group*	*No*	*Species*	*Group*
Maple	89	55.0	64	71.9	57.2	24	27.0	52.2	1	1.2	25.0
Elm	36	22.2	13	36.1	11.6	20	55.6	43.4	3	8.3	75.0
Gum	24	14.8	24	100.0	21.4	----	--------	--------	----	--------	--------
Cherry	7	4.3	7	100.0	6.2	----	--------	--------	----	--------	--------
Ash	4	2.5	3	75.0	2.7	1	25.0	2.2	----	--------	--------
Sassafras	1	0.6	1	100.0	0.9	----	100.0	--------	----	--------	--------
Hickory	1	0.6	----	--------	--------	1	--------	2.2	----	--------	--------
Totals	162	100.0	112			46			4		
Percents	100		69.1			28.4			2.5		

Unincised

Species	*Total Number*		*GROUP No 1 (Checks less than 1/8 in. or no checks)*			*GROUP No. 2 (Checks and/or splits between 1/8 in. and 3/8 in.)*			*GROUP No. 3 (Checks and/or splits 3/8 in. and over)*		
				Percentages of			*Percentages of*			*Percentages of*	
	Actual	*Per-cent*	*No*	*Species*	*Group*	*No.*	*Species*	*Group*	*No.*	*Species*	*Group*
Maple	83	51.2	36	43.4	48.7	39	47.0	61.9	8	9.6	32.0
Elm	45	27.8	12	26.7	16.1	17	37.8	27.0	16	35.5	64.0
Gum	24	14.9	22	91.7	29.7	2	8.3	3.2	----	--------	--------
Cherry	5	3.1	2	40.0	2.7	3	60.0	4.7	----	--------	--------
Ash	2	1.2	1	50.0	1.4	----	--------	--------	1	50.0	4.0
Sassafras	2	1.2	1	50.0	1.4	1	50.0	1.6	----	--------	--------
Hickory	1	0.6	----	--------	--------	1	100.0	1.6	----	--------	--------
Totals	162	100.0	74			63			25		
Percents	100		45.7			38.9			15.4		

Report on Assignment 8

Use of Straight Coal Tar for Tie Treatment and Results Obtained

Hermann von Schrenk (chairman, subcommittee), R. S. Belcher, Walter Buehler, C. M. Burpee, G. B. Campbell, H. B. Carpenter, H. R. Duncan, T. H. Friedlin, W. H. Fulweiler, W. R. Goodwin, H. L. Holderman, A. L. Kammerer, Henry Schmitz, L. B. Shipley, J. E. Tiedt.

As a report on the assignment your committee presents below a monograph by the chairman of the subcommittee for which he assumes full responsibility.

An Historical Statement on the Use of Straight Coal Tar for Tie Treatment

By Dr. Hermann von Schrenk
Consulting Timber Engineer, St. Louis, Mo.

Coal tar by itself, i.e., without any addition of any other compounds, has been used for tie treatment in the United States for only a comparatively short time. This practice was started in 1935 and was used on a number of the large eastern railway systems. This practice had to be discontinued during the early years of the late war due to the scarcity of acceptable coal tars. The use of straight coal tar has not been resumed as yet, as far as is known to the committee. One of the principal reasons for the scarcity of coal tar during the late war was the fact that the federal government issued instructions that no coal tar should be used except tar that had been topped. Such tar could not be used in the treatment of ties, consequently the use of straight coal tar had to be discontinued.

There was a long period of researcb preceding the recommendation made by the writer to a number of railroads that they use straight coal tar. This included studies, not only in connection with coal tar and other timber preservatives, but experimental work to enable one to answer the various questions which naturally arose.

It should be pointed out at the outset that coal tar is not a new product when it comes to dealing with its use for the preservation of wood. Its application to wood preservation dates back many years. One of the first references to the subject of coal tar was made by John Bethell, who took out letters-patent in 1838 in England. The following quotation from a paper by S. R. Church, published in Railway Engineering and Maintenance, July 1926, is of interest in this connection:

> When John Bethell took out his letters-patent in England in 1838 for "rendering wood, cork and other articles more durable," he laid, as historians have agreed, the foundation of the wood preserving industry that exists today. Whether Bethell was wiser than his generation, or for some other reason, he nevertheless indicated, in that patent, his belief that coal tar itself was a preservative, and he claimed its use, blended only with sufficient of the oils distilled therefrom so that the mixture would enter the woods. His own words are:
>
> "Coal tar obtained from gas works, thinned with from one-third to one-half of its quantity with the essential oil or spirit obtained by the distillation of coal tar. That which I use is the common spirit left after the naphtha is obtained and commonly called in the trade 'dead oil'."

On one of his trips to England the writer learned that coal tar was used to a very large degree with distillate creosote for various reasons. One of which was of particular interest, namely that the English people, when they ordered creosoted lumber, wanted it to look black, and in order to get a black looking creosote Mr. Bethell and his successors mixed distillate creosote, which was brown in color, with a sufficient amount of coal tar to make it look black.

First Use Here in 1908

In the United States the railroads began the use of coal tar in 1908 when the writer recommended its addition to creosote to several of the western railroads. The reason for this recommendation was that it came at a time when coal tar creosote was very expensive and difficult to obtain. A request was made by a number of the large railroad systems to find something which could reduce the cost of distillate creosote and at the same time be an efficient preservative. At that time a great many tests were carried on with creosote–coal tar solutions to determine whether there was any risk in adding coal tar to creosote from the standpoint of preventing decay, and among other things whether the coal tar addition to creosote would in any way retard the penetration of these solutions. The conclusion was reached that use of coal tar with a creosote would be advantageous, that the cost of the solution would be materially below that of straight distillate creosote. There was a great uproar and claims were made that we were recommending an adulteration of the well known coal tar creosote. However, in an incredibly short time one railroad after another in the United States adopted the use of coal tar with creosote because they were satisfied that our recommendation had proved correct.

In a preliminary report of this character it will hardly be possible to give all the reasons why we found the addition of the coal tar to creosote was a safe procedure. It is sufficient to state that one of the chief reasons why coal tar was accepted as an addition to creosote is that coal tar creosote is made by distilling coal tar, i.e., coal tar is the "mother liquor" from which creosote is derived. Furthermore, coal tar itself has a high toxic value.

Without going into detail, it was found that coal tars produced in the United States yielded high percentages of creosote when distilled to coke. As a result of many distillations of coal tar it was found that the amount of creosote obtainable amounted to 50–65 percent. It was furthermore discovered by an examination of many hundreds of railroad ties, telephone poles, piles, etc., which had originally been treated with distillate creosote, as we understand it, both in this country and abroad, particularly England, Germany and France, that in a comparatively short number of years the creosote contained in these timbers, as obtained by extraction, irrespective of whether the pieces were exposed to water, soil or air, had lost a major part of the low boiling compounds so that the composition at the end of various periods of time became approximately the same as that of original coal tar. This was, of course, not true in all cases, but in a sufficient number to show that after exposure distillate creosote, because of evaporation of the low boiling compounds, possibly also because of the dissolving out of the low boiling compounds, oxidation, etc., changed so that it consisted eventually of the very heavy constituents which approximated those found in coal tar.

Increase in Percentage Used in Mixtures

While the solution of creosote and coal tar started with 80 percent creosote and 20 percent coal tar, in an incredibly short time many railroads began using 70 percent creosote and 30 percent coal tar, and the relative proportion of coal tar has increased from year to year until it is common practice for many railroads to use 60/40 creosote–

coal tar solution and 50/50 creosote–coal tar solution. It is proposed, within the next year, to give full details of the periods when these changes took place, this to include the use of 100 percent coal tar, together with the reasons given by the various railroads for these changes.

A study of the annual statement of the practices of the various railroads in the United States of the preservatives they are using at the present time, as published in reports of Committee 17 and, particularly, a study of this same report issued before the last war, will at once show to what extent creosote–coal tar solutions have become standard. There are now, as far as the committee knows, only a very few large American railroads who still use distillate creosote in the treatment of ties.

A great many papers have been published from time to time by the U. S. Forest Products Laboratory and a good many other authors dealing with the question of what happens to creosote and creosote–coal tar solutions during periods of exposure in actual use in the shape of railroad ties. Those interested in the subject should read the report printed in the Proceedings, Vol. 15, 1914, page 625, which is a monograph by Hermann von Schrenk and A. L. Kammerer on the Use Of Refined Coal Tar In The Creosote Industry. This gives an account of extensive investigations carried on in the United States up to that time and gives reasons why the coal tar factor should be considered. From 1908 to the publication of this monograph, approximately 24,500,000 ties were treated with a combination of 80/20 creosote–coal tar solution, and practically all paving blocks since 1907 had been treated with such a combination.

Test on Chesapeake & Ohio

The last publication, which was initiated by the writer, covered an investigation in connection with a test on the Chesapeake & Ohio Railway. Red oak ties were treated in 1935, some with 60/40 creosote–coal tar solution and some with straight coal tar. A fundamental plan was developed, in cooperation with Dr. Henry Schmitz of the University of Minnesota, which involved getting full details as to the treatment to which these ties were subjected, namely, the preservative used, number of pounds of preservative injected, physical and chemical characteristics, character of the wood treated, etc. All ties were marked with copper labels and were laid in a track near Russell, Ky. It was proposed, in the original outline, that every few years some of these ties would be removed and carefully examined as to changes, if any. They were to be sawed and photographed and the preservative remaining in the ties was to be extracted, taking care to make such extracts from the bottom, middle and top of these ties. The preservatives, after chemical examination, were then used to determine the toxicity of the oil after a certain period of exposure as compared to the toxicity of the preservative at the time of original injection, this to find out what happened to the preservative after a number of years of service. Blocks of wood were to be cut from these ties and in addition to the Petri dish method of determining toxicity, these blocks were cut and exposed to laboratory conditions to determine the extent to which fungus would attack the blocks. An account of this investigation is given in AWPA Proceedings, Vol. 37, 1941, pages 248–298. After describing the outline under which this track test was made, the results of the first exposure examination are given in detail.

Four ties were selected in September 1938, three years after the original placing of these ties in track. This investigation is too long for more than a brief reference here and those interested are referred to the AWPA Proceedings mentioned. The report not only gives results of toxicity and changes in the preservatives, etc., but also contains photographs and diagrams which will prove of interest.

A second set of ties were removed from the C. & O. tracks in 1941, i.e., these ties had been in track five years. A report concerning these ties was printed in AWPA Proceedings, Volume 41, 1945, pages 153–179. This paper is entitled Changes in the Character and Amount of 60/40 Creosote–Coal Tar Solution and Coal Tar and the Decay Resistance of the Wood of Red Oak Crossties after Five Years' Service, by Henry Schmitz, Hermann von Schrenk and A. L. Kammerer. This report covers the same type of research as was given in the first report. The general results indicated practically the same trends in the changes of the creosote and the coal tar as was the case after three years. Anyone interested in this second report will find it worthwhile to read it. Without going into details the following conclusions are of interest in this connection. At the end of five years' service there seems to be no significant differences between the toxicity of 60/40 creosote–coal tar solution and 100 percent coal tar. All significant differences in the initial toxicity of these preservatives disappeared after five years' service.

It was anticipated that this year a third set of ties would be taken out in time to present detailed information to the AREA, but due to circumstances it was impossible to accomplish this. I anticipate that at the next meeting of the AREA we will be in a position to give full details about these ties after 13 years' service. While we are not prophets we feel that the results of these 13 years' service will prove rather surprising, judging by the results after 3 and 5-year service periods.

Use of 100-Percent Coal Tar Treatment

In the foregoing, the history of the use of coal tar in a mixture with creosote has been largely the subject of this report. To be sure, some references have been made in the last few paragraphs dealing with the experiments in which a comparison was made between ties treated with 60/40 creosote–coal tar solution and 100 percent coal tar. This brings us to the last part of this discussion, namely the treatment of ties with 100-percent coal tar, not only experimentally but on a large scale as standard treatment of ties on various railroads.

The first tests were made on the New York Central. These were carried out at the Rome plant of the New York Central in 1931. Several points were involved in these investigations, namely:

1. To what extent could we get suitable penetration with 100-percent tar.
2. Whether we could get the standard retentions in pounds or gallons per tie as prescribed by the specifications of the railroad.

A good many people were dubious as to whether the treatment with tar would be a practical scheme, some of which dealt with the question that ties would be so dirty that they would be objectionable on the part of the track forces. That we found was due to the type of tars and insoluble matter they contained and that objection was rapidly surmounted.

The penetration question was studied at Rome and at Indianapolis on the Big Four when it was found that tar treatment was practicable.

In the New York Central test at Rome, referred to above, 1351 red oak ties and 1511 hardwood ties, all grade 5, 8½ ft., were treated with 100-percent coal tar with an average retention of 3½ gal. per tie. This treatment was done in December 1931. All of these test ties were carefully marked with metal, numbered tags and were laid in the following locations on the St. Lawrence division:

Between M.P. 38 and 42, Rome, Rome branch;
Between M.P. 27 and 29, McConnellsville, Rome branch;
Eastbound main track in the vicinity of M.P. 41, Richland, Watertown branch.

The results of the last inspection in 1947 were as follows:

	Oak	*Hardwoods*
Installed in 1933	354	7
Installed in 1934	148	543
Total installed	502	550
Ties removed to date:		
Life of 7 years	0	9
Life of 8 years	1	9
Life of 12 years	1	41
Life of 13 years	18	163
Total	20	222
Percent removed to date	3.98	40.36
Number ties still in track	482	382
Actual average years' life to date	13.69	12.75

At the Rome installation, there were 17 ties missing due to the removal of the track in which they were installed.

The ties shown above were the actual renewals up to October 1, 1947.

McConnellsville

	Oak	*Hardwoods*
Installed in 1933	457	505
Ties removed to date:		
Life of 11 years	6	0
Percent removed to date	1.31	0
Number ties still in track	451	505
Actual average years' life to date	13.96	14.00

At McConnellsville, we were unable to locate one test tie.

Richland

	Oak	*Hardwoods*
Installed in 1932	0	333
Installed in 1933	379	110
Total installed	379	443
Ties removed to date	0	0
Percent removed to date	0	0
Number ties still in track	379	443
Actual average years' life to date	14.00	14.75

At both McConnellsville and Richmond the above figures reflect the conditions as of October 1, 1947.

Adirondack Hardwoods

In discussing the high removals of the Rome test hardwoods it should be noted that these hardwood ties consisted approximately of 60 percent beech, 20–25 percent maple and the balance birch. These ties were cut in the Adirondacks. The beech ties were largely heartwood and the maple mostly boxed hearts with a large percentage of heartwood. These treated hardwoods were largely removed on account of decay. The decay started where the ties had opened up on exposure to the weather. The resulting cracks and splits permitted the spores of wood destroying fungi to reach the untreated heartwood in the interior of the ties and start decay. It has been the general experience on the New York Central that the Adirondack hardwood ties are very refractory to treatment, irrespective of the type of preservative used. This is due to the larger percentage of impenetrable heartwood which is usually present in ties from this source. Furthermore the Adirondack hardwoods are subject to excessive splitting and checking. The unsatisfactory service of the hardwood ties produced in the Adirondacks was realized many years ago when the New York Central stopped getting these ties, except as a war emergency. These ties have been in track only 13–15 years, so it is still early to draw any definite conclusions as to their ultimate life, but there is a good indication that the 100-percent tar treatment has a high degree of efficiency.

As a result of the experimental work above referred to and the treating results of the experimental charges at Rome, it was decided by the New York Central to adopt 100-percent tar treatment as standard on the system. This was done in 1935.

Early in 1936 similar experiments and investigations were carried out on the Chesapeake & Ohio, using 100-percent coal tar and 60/40 creosote–coal tar solution. Suffice it to say that the results obtained from these ties were identical with those obtained from the New York Central. Because of these findings the C. & O. followed the New York Central and adopted the 100-percent coal tar treatment as standard in November 1936. This practice was continued until October 1939. The other railroads that adopted the 100-percent coal tar treatment at about the same time as the New York Central were the Erie, the Lehigh Valley, the New Haven, the Lackawanna and the Nickel Plate.

It should be emphasized that one of the important points that must be considered is the *type* of coal tar used in tie treatment with 100-percent tar. The railroads that have been using coal tar are always very specific in their specification requirements.

The writer believes that it would be of interest to know how many ties and other material have been treated with straight coal tar since it was first used on the New York Central. The table provides a summarized statement.

Ties and Other Material Treated with 100-Percent Coal Tar

Plant	*Year*	*Ties No.*	*Switch Ties Ft. B.M*	*Lumber Ft. B.M*	*Piles Cu. Ft.*
New York Central					
Indianapolis, Ind.	1935–1943	4,949,055	15,679,708	1,658,292	2,346
Toledo, Ohio	1935–1943	4,313,131	15,624,166	4,811,357	....
Rome, N. Y.	1936–1943	4,181,125	10,220,456	3,791,605	....
Total		13,443,311	41,524,330	10,261,254	2,346
Nickel Plate (N.Y.C. & St. L.)					
Edwardsville, Ill.	1936–1939	491,594	2,463,092	...	85
New York, New Haven & Hartford					
New Haven, Conn.	1936–1942	1,932,151	1,863,417	107,455	....
Chesapeake & Ohio					
Russell, Ky.	1935–1939	2,642,723	9,674,359	41,891	2,014
Erie					
Russell, Ky. & Patterson, N. J.	1936–1943	810,506	7,406,361	111,535	1,616
Delaware, Lackawanna & Western					
Patterson, N. J.	1936–1943	1,123,962	3,466,833	224,038	53,203
Lehigh Valley					
Manville, N. J.	1935–1942	448,415	962,606	40,377	....
Grand total		20,892,662	67,360,998	10,786,550	59,264

The second point which should be stressed is the question of penetration which it is possible to obtain with 100-percent coal tar treatment. There seems to be a general opinion on the part of many railroads that refined coal tar has a viscosity so high that one cannot get the proper amount of preservative into ties, and what is more important, one cannot get sufficient penetration. Needless to say, the railroads which adopted 100-percent tar treatment were very much alive to the question as to penetration and retention. Many ties were weighed before and after treatment at various points, specifically on the New York Central and C. & O. and photographs taken, not by individual ties, but taking low, average and high absorption ties and sectioning them at the rail base and center. It would take volumes to print all of these photographs but the committee believes that some representative photographs should be of interest.

Photographs

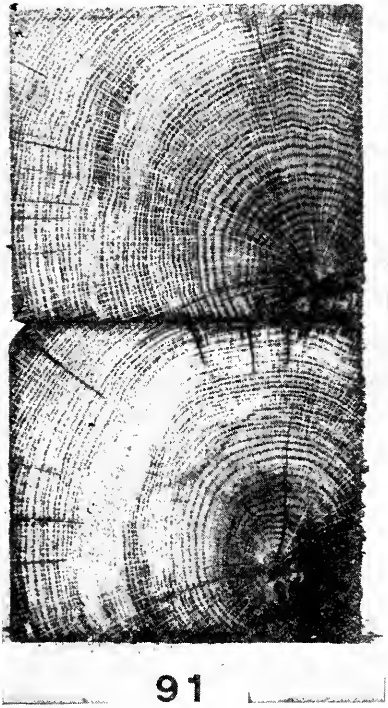
Each photograph shows the number of pounds of coal tar retained by the tie. The upper part of the photograph in each of the plates represents a section at the rail base, as will be evident from the indication of the greater penetration at the bored holes. The lower plates are photographs of the sections taken at the center of the ties. It should be noted that the ties which were cut and photographed were taken to illustrate some ties with minimum, average and maximum retentions. The following photographs are taken from ties representative of these three groups. Two sets are taken from each one of the New York Central and C. & O. tests, i.e., two ties typical of minimum, average and maximum retentions. It should be understood that there might be differences of opinion as to the representative ties of the sections shown in the photographs. There were a great many photographs to choose from and where there was a choice between two ties the clearest photograph was selected so as to get the best reproduction. All photographs were taken immediately after the sections had been planed so that there would be no chance of any flowing of the preservative over the surface after sawing.

The following facts should be taken into consideration in connection with the two largest tests made, namely on the C. & O. and the New York Central. On the New York Central the total weighed ties consisted of mixed white oak and red oaks. The total number of test ties weighed were 580, of which 87.1 percent were red oak and 12.9 percent were white oak. These ties were treated in twelve charges. In nine charges the ties were largely red oak. The white oak percentage was less than 1 percent in these charges. In the other three charges the percent of white oak was in the neighborhood of 50 percent in each charge. The reason for the treatment of the mixed ties was that the oak ties available to the New York Central were obtained from various sections of the east and south where oak ties are generally mixed as to species.

The ties treated in the C. & O. test were treated in nine charges. The total number of ties weighed before and after treatment was 602. In these nine charges the weighed ties varied in the various charges from 41 ties to 90 ties per charge. These were all red oak ties.

It should be understood that full details cannot be given in this preliminary statement as to type of tar used, method of treatment, i.e., pressure time, etc., because it would occupy too much space. It is anticipated, however, that the writer will, in a very short time, write a comprehensive monograph on the use of tar treatment.

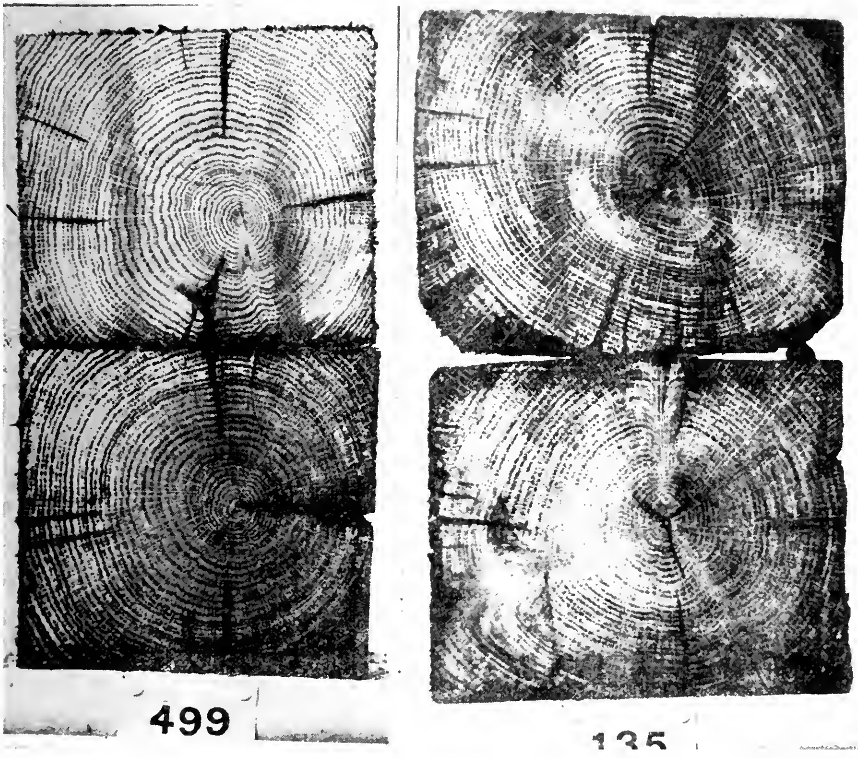
Suffice it to say that properly seasoned oak ties can be treated (by the empty-cell process) with as much success and good penetration with coal tar as creosote and solutions of creosote-coal tar, provided that a suitable coal tar is used.



Tie No. 91
20.5 lb.

Tie No. 612
19.0 lb.

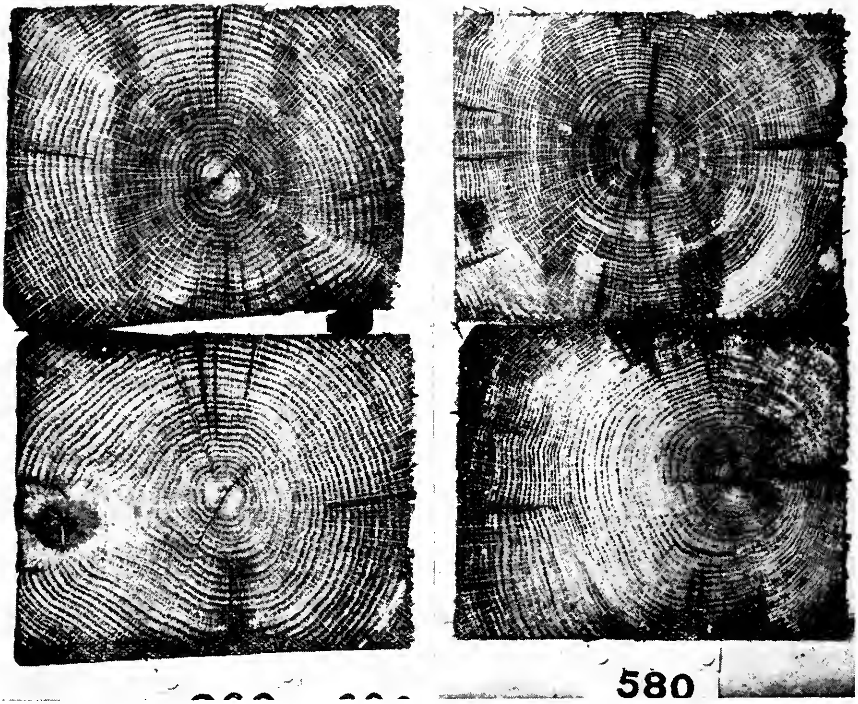
Fig. 1.



Tie No. 499
25.0 lb.

Tie No. 135
23.5 lb.

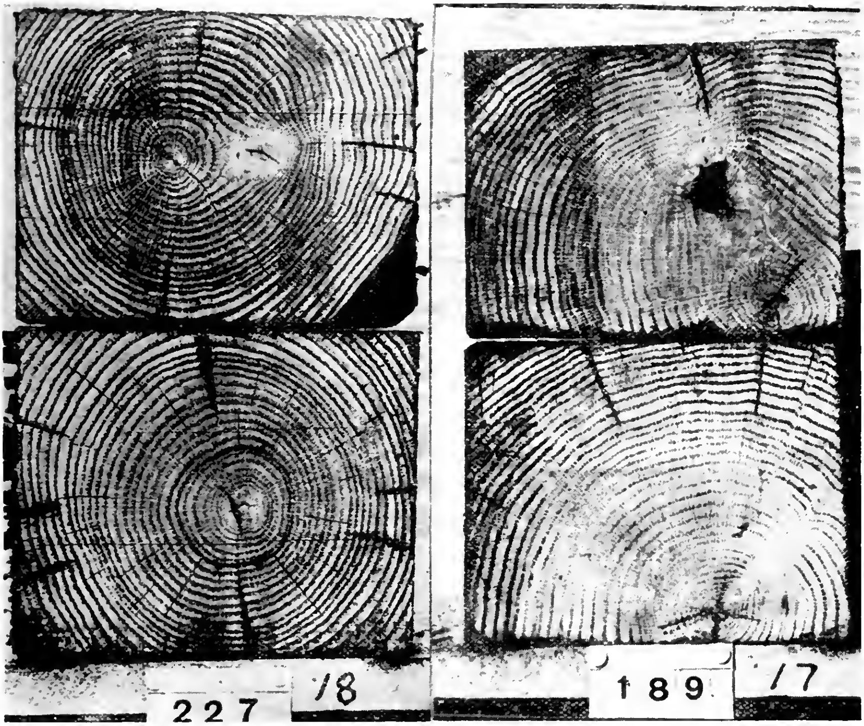
Fig. 2.



Tie No. 200
30.0 lb.

Tie No. 580
29.5 lb.

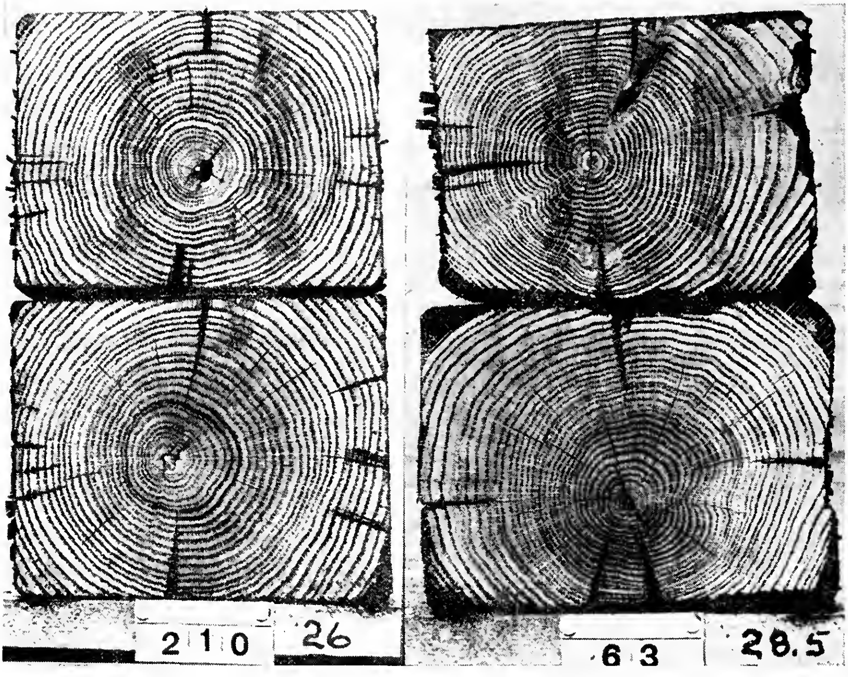
Fig. 3.



Tie No. 227
18.0 lb.

Tie No. 189
17.0 lb.

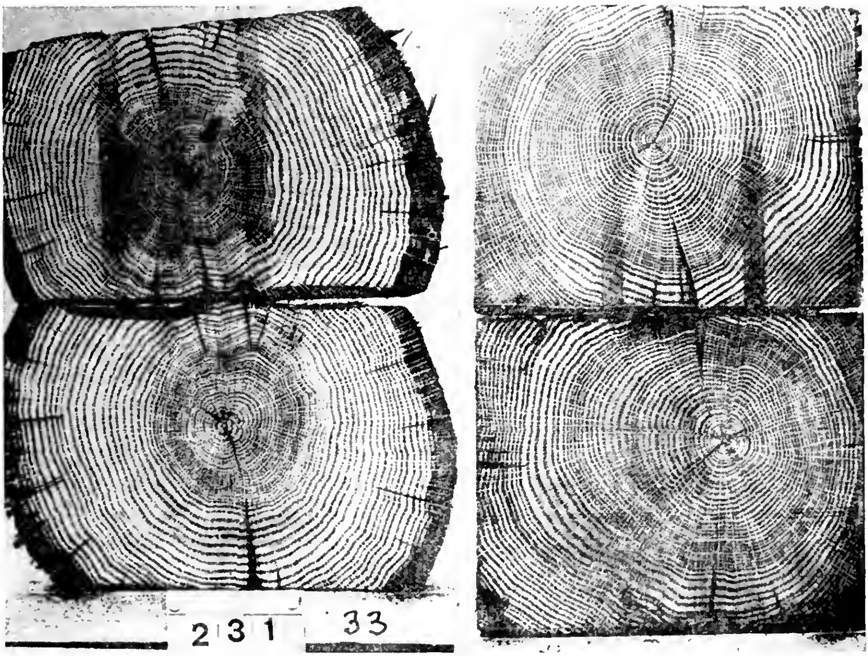
Fig. 4.



Tie No. 210
26.0 lb.

Tie No. 63
28.5 lb.

Fig. 5.



Tie No. 231
33.0 lb.

Tie No. 15
45.0 lb.

Fig. 6.

In the meantime we are going to collect whatever service data we find available. The remarkable results of treatment with the tar are already very evident on many lines where heavy traffic prevails. One can walk along the tracks and see at a glance the tar treated ties because they present a solid surface and show no indication whatever of any excessive splitting or checking or rail wear, such as we have been accustomed to in ties treated with distillate creosote. What physical principles are involved in connection with the tar treatment we do not as yet know. We wish to assure the association that this is a subject for research that is being vigorously prosecuted.

Report on Assignment 10

Treatment of Wood to Make It Fire Resistant

Hermann von Schrenk (chairman, subcommittee), W. P. Arnold, R. S. Belcher, P. D. Brentlinger, T. H. Friedlin, W. H. Fulweiler, F. W. Gottschalk, F. A. Hartman, M. S. Hudson, N. E. Kittell, L. A. Olson, R. R. Poux, Henry Schmitz, T. H. Strate, C. H. Wakefield.

This is a progress report, submitted as information pertaining to fire resistive treatment of wood. The committee has been active in observing the results of treatments made by several railroads, and by the various departments of the U. S. government. It also has followed closely the results of many tests made by manufacturers and users for determining whether fire resistive treatments give a high degree of fire protection.

In the absence of anything more effective to date, the committee still recommends the methods of testing fire resistance as printed in its previous report, namely the use of either the crib or the tube test.

There have, to be sure, been differences of opinion as to the method of taking samples for fire resistive tests. These differences have arisen largely because of uncertainty as to where these samples should be taken, particularly in the case of large timbers used for bridges and buildings. One of the bureaus of the federal government has suggested that where large pieces are ordered to be treated with fire resistive chemicals, extra pieces of the same size should be included for test purposes, using either the crib or the tube test or some other method such as that recommended by the Underwriters' Laboratories. Your committee has taken no stand, either for or against these suggestions, because it believes that a great deal more work will have to be done in order to determine the degree of fire resistance obtained.

One of the principal difficulties with treatments heretofore recommended has been the fact that the chemicals used are generally water soluble. This has made it necessary to restrict the use of fire resistant wood to structures which are roofed so that no rain can reach the treated wood. Recently a number of processes have been suggested whereby the leaching of the fire-resistive chemicals can be reduced by the application of suitable paints or sealers, but no definite conclusions can as yet be drawn.

Report on Assignment 11

Artificial Seasoning of Forest Products Prior to Treatment

W. P. Arnold (chairman, subcommittee), R. S. Belcher, P. D. Brentlinger, C. M. Burpee. R. F. Dreitzler, H. R. Duncan, F. W. Gottschalk, B. D. Howe, M. S. Hudson, L. A. Olson, R. R. Poux, L. B. Shipley, Herman von Schrenk.

Your committee submits as information, the following report of progress on its study of preliminary conditioning:

Studies in the Improvement of Air Seasoning

Last year your committee reported on tests conducted by the Atchison, Topeka & Santa Fe Railway of impregnation with urea solutions for retarding checks in seasoning of red oak and southern pine. This same railroad has also conducted tests on three other materials for the purpose of determining the effect on reducing checking and retardation of decay during air seasoning. Materials used were:

(1) Phenyl–mercury–oleate
(2) Urea and borax—boric acid
(3) Borax—boric acid

Reports of tests and results on these materials follow:

1. Phenyl–Mercury–Oleate—Final Report

Three stacks of green southern pine lumber, 6 by 6, 6 by 8, 8 by 8 and 8 by 10 in. in size, were treated with various amounts of phenyl–mercury–oleate. One stack was treated with 1.28 lb. urea and 0.026 lb. phenyl–mercury–oleate per cu. ft. using a solution containing 20-percent urea and 0.4-percent phenyl–mercury–oleate. The second stack of lumber was treated with 0.019 lb. phenyl–mercury–oleate, using a 0.2-percent solution. The third stack was treated with 0.029 lb. phenyl–mercury–oleate, using a 0.23-percent solution. The absorptions of phenyl–mercury–oleate are in pounds of 10-percent phenyl–mercury–oleate emulsion per cu. ft.

All of the lumber treated with phenyl–mercury–oleate alone and part of the lumber treated with both urea and phenyl–mercury–oleate was given final treatment with 50/50 creosote–petroleum solution after approximately 18 months' seasoning. There was no indication of decay in this lumber.

The balance of the lumber treated with both urea and phenyl–mercury–oleate was given final treatment with 50/50 creosote–petroleum solution after 28 months' seasoning. This lumber consisted of 24 pieces of 8 by 10 in.–16 ft. Four pieces were slightly decayed, having small decayed spots approximately ½ in. deep.

The indications are that small amounts of phenyl–mercury–oleate will lengthen the permissible maximum seasoning period of southern pine lumber to 18 months and possibly a little longer without damage to the lumber by decay, and to 24 months or longer without extensive damage by decay.

2. Urea and Borax-Boric Acid-Treated Material—Progress Report

Twenty-five pieces of 6 by 10 ft. green southern pine lumber were cut in halves, making 50 pieces 5 ft. long. Twenty-five of these pieces, representing one piece from each 6 by 10–10 ft., were treated with 0.503 lb. urea per cu. ft., using a 7.5 percent solution. The 25 treated and 25 untreated pieces were stacked in one stack, with the treated and untreated pieces from the same 6 by 10–10 stacked side by side.

Twenty-five more pieces of 6 by 10–10 were handled as above, but were treated with 0.545 lb. of borax–boric acid, using a solution of 1.6-percent borax and 1.6-percent boric acid.

The purpose of this test is to check the value of urea and borax–boric acid as agents to retard checking of lumber during seasoning period and to compare the two treatments for the same purpose.

This test was started July 27, 1947. After four months' seasoning, both the urea and the borax–boric acid-treated lumber show slightly less checking than do the matched pieces of untreated lumber.

3. Borax-Boric Acid-Treated Oak Ties—Progress Report

Two hundred fifty-one green hewn oak cross ties and 251 green sawn oak cross ties were treated with 0.556 lb. borax–boric acid per cu. ft., using a solution containing 1.6 percent borax and 1.6 percent boric acid.

The purpose of this test is to check the value of borax–boric acid as a pretreatment to inhibit decay during seasoning period, minimize checking, and increase penetration and distribution of preservative in final treatment of oak cross ties.

After six months' seasoning, there is slightly less checking in the pretreated material than in similar untreated material of the same age.

Vapor Drying

Your committee submits as information a report on more recently completed studies by M. S. Hudson of the Taylor–Colquitt Co., which appears on the next page as an appendix.

Report on Assignment 12

Preservative Survey

M. F. Jaeger, Chairman

This is a progress report submitted as information, and brings up to date the survey of treating practices, dated March 1938, which accompanied the report of your committee in the Proceedings, Vol. 41, 1940, page 517.

Under this assignment, efforts were directed toward assembling information pertaining to present treating practices of the railroads of the United States, Canada and Mexico in the preservation of cross ties, switch timbers, bridge ties, lumber and piles. Due to shortage of creosote oil during the World War years, some railroads were compelled to depart from their standard treating solutions in order to extend their available supply of creosote oil. This resulted in increasing petroleum content of creosote–petroleum mixtures or in reducing the net retention of preservatives per cubic foot of timber. In some instances the solution was fortified with such toxics as pentachlorophenol and copper naphthenate.

However, data reflected in the March 1948 tabulation represents, substantially, a return to normal or standard timber treatment practices by the railroads contributing the information. The changes that have taken place during the past decade can be determined by comparing this report with the March 1938 survey. Although a detailed list of the changes would be too voluminous to serve any useful purpose, a comparison of the two reports shows the following indicated trends:

PRESERVATIVE SURVEY - MARCH 1948

Railroad	Cross ties Percentage				Switch timber Percentage				Absorption*	Process	Remarks	Bridge ties and lumber Percentage				Absorption*	Piling Percentage				[illegible]	Process	Remarks
	Creo.	Pet.	Creo.	Tar	Creo.	Pet.	Creo.	Tar				Creo.	Pet.	Creo.	Tar		Creo.	Pet.	Creo.	Tar			
Atchison, Topeka & Santa Fe	30	70			30	70			10 lb.	Rueping		10 45 50	70 55 50			10 lb. Rueping - bridge ties. Other to refusal	45 50	55 50			Refusal	Full cell	Treat poles straight creo. 8 lb. Rueping. Treat car lumber straight creo. 6 lb. Rueping.
Atlantic Coast Line	100				100				8 lb.	Open cell		100				14 lb.	100				18 lb.	Open cell	
Baltimore & Ohio			80	20			80	20	7 lb.	Boulton & Rueping		100				10 lb.	100				10 to 14 lb. Refusal	Boulton & Rueping	
Bessemer & Lake Erie			80	20			80	20	8 lb.	Rueping				80	20	8 lb.							Also use bridge & lumber treated with 1/6 lbs. Chromated Zinc Chloride.
Boston & Maine	50	50			50	50			9 lb.	Rueping		50	50			12 lb.			50	40	1[illegible] lb. Dry locations. Refusal - marine. 10 lb. inland ties. [illegible] lb. coastal piles	Rueping & Full cell	Lumber treated Rueping and piles by full cell process.
Canadian National	50	50			50	50			8 lb. Hardwood. 7 lb. Softwood.	Rueping		100				10 lb.	100					Rueping	
Canadian Pacific	50	50			50	50			8 lb.	Rueping							[illegible]				[illegible] lb. inland, 12 lb. marine	Rueping	Do not treat bridge ties. Small quantity of lumber given 8 lb. Rueping treatment.
Central of Georgia			80	20			80	20	7 lb.	Rueping		100		80	20	7 lb. bridge ties and guard timber. 8 to 16 lb. other lumber.					16 lb.	Full cell & Rueping	7 lb. 80-20 creo. tar mixture for bridge ties and guard timber. All other timber and lumber 8 to 16 lb. straight creosote.
Central of New Jersey	40	60			40	60			8 lb. cross ties. 9 to 10 lb. switch timber.	Rueping & Lowry		100				10 to 14 lb.	100				1[illegible] to 14 lb. inland, Refusal marine.	Rueping & Full cell	Small percentage of bridge ties & lumber treated with 40-60 mixture.
Chesapeake & Ohio			60	40			80	40	7 to 8 lb.	Rueping & Lowry		100				10 to 16 lb.	100				10 to 20 lb.	Lowry & Full cell	Marine & F.P.A. - Pine Lumber Rueping.
Chicago, Burlington, & Quincy	50	50			50	50			8 lb.	Full cell, Lowry or Rueping		50 100	50			8 lb. Bridge ties. 8 to 10 lb. Lumber	100				14 lb.	Rueping	Bridge ties treated with 50-50 creosote petroleum mixture. Lumber treated with straight creosote oil. Lowry, Full cell or Rueping. Forced to treat some with 50-50 creosote petroleum.
Chicago & Eastern Illinois			60	40			60	40	0.86 gal. per cu. ft.	Lowry	Some with 50-50 creosote petroleum.	100				1.3 gal	100				1.3 to 1.72 gal.	Lowry	
Chicago Great Western			80	70			80	20	6 lb.	Rueping		100				14 to 16 lb.	100				16 lb.		
Chicago, Milwaukee, St. Paul, & Pacific	50	50			50	50			8 lb.	Empty cell		100				10 to [illegible] lb.	100				12 lb. inland, 14 lb. marine	Empty cell, bridge ties & lumber. Boulton & Rueping.	
Chicago Rapid Transit			80	20			80	20	6 lb.	Rueping	When 80-20 creo. tar not available, 50-50 creo. pet. is used.	100				6 lb. for deck ties & guard rail. 8 to 12 lb. heavier timber.	100				14 lb. for oak, 16 lb. for pine	Rueping - Lumber, Full Cell - Piling	
Chicago & North Western	40	60			40	60			8 lb.	Lowry & Rueping		40	60			9 lb. or refusal	100				10 lb.	Lowry, Rueping and Boulton	Bridge ties & lumber treated under vacuum followed by Lowry.
Chicago, Rock Island, & Pacific			70	30			70	30	8 lb.	Lowry & Rueping	60% creo. 40 tar used at [illegible].			70	30	8 lb. for bridge ties & small timber. 10 to 16 lb. for large timber.			70	30	16 lb.	Lowry	
Delaware & Hudson			80	70			80	20	Variable	Lowry		100				10 lb.					10 lb. maximum	Lowry	
Delaware, Lackawanna & Western			40	10			40	10	3 gal. per tie		50% of mixture is water gas tar.	100				10 lb.							No piles treated.
Denver, Rio Grande Western	50	50			50	50			7 lb.	Rueping		50	50			10 lb.	50	50			12 lb.	Rueping	
Duluth, Missabe & Iron Range	50	50			50	50			7 lb.	Rueping													No bridge, lumber or piles treated.
Elgin, Joliet & Eastern	100				100				5 lb. for oak	Rueping		100				[illegible] lb. for oak, 8 lb. for pine	100				9 lb. for oak, 12 lb. for pine	Rueping	
Erie			60	40			60	40	7 1/2 lb.	Lowry & Rueping	10% of cross ties treated with straight creo., approximately 5% with 40% creo. 10% coal tar & 50% water gas tar. Balance with 60-40 creo. coal tar.			60	40	10 lb.			50	40	10 lb.	Hot Bath, Lowry, Rueping	60% bridge & lumber treated with straight creo. Balance with 60-40 creo. coal tar mix. 5% piles treated with 60-40 creo. to coal tar mixture. Balance with straight creo.
Florida East Coast			50	50			50	50	9.5 lb.	Empty cell				70	30	9.5 lb. ties. 16 lb. other lumber			70	30	Infested waters - refusal. Others 16 lb.	Empty cell, ties & lbr. Full cell, piles.	
Great Northern	50	50			50	50			7 lb.	Lowry & Rueping		50	50			8 lb.	100				10 lb.	Lowry	
Gulf, Mobile & Ohio			80	20			80	20	8 lb.	Full cell		100		80	20	14 lb. Lumber. 8 lb. Bridge ties	100				14 lb.	Full cell & Rueping	Piles & lumber treated full cell with straight creosote oil. Bridge ties treated Rueping with 80-20 creo. tar.
Illinois Central			60 70 100	40 30			60 70 100	40 30	8 lb. 7 lb. 7 lb.	Empty cell	Pine-mix. 60-40. Oak " 70-30. Gum-Straight distillate.	100				6 lb. Bridge ties, Hand Rail & Crossing Plank. 6 lb. Pine & Gum Platform lbr. 16 lb. All other lbr.	100				8 lb. Highway bridge piles. 18 lb. Others.	Empty & Full cell	
Kansas City Southern			70	30			70	30	8 lb. Oak cross & switch ties. 12 1/2 lb. gum cross ties.	Lowry & Rueping	Lowry for oak. Rueping for gum.			70	30	10 to 20 lbs.			70	30	16 lb. land use, 24 lb. marine	Rueping, Lowry, Bethel	14 lb. or refusal for fir piles & lumber.
Lehigh & New England			50	50			50	50	8 lb.	Lowry & Rueping	Cross ties & sw. timber also treated with 25% creo. 25% coal tar & 50% water gas tar.	100				10 lb.						Lowry	No piles used.
Lake Superior & Ishpeming	50	50			50	50			8 lb.	Lowry													No lumber, bridge or piles treated.
Lehigh Valley			40	10			40	10	7" ties 3 gal. per tie min. 6" ties 2 gal. per tie min. Sw. Tbr. 8 lb. min.	Lowry	50% water gas tar used in addition to 40% creo. and 10% coal tar.	100				8 lb. min. for oak. 12 lb. min. for pine	100				9 lb. min. oak	Lowry	[illegible] pine piling used.
Louisiana & Arkansas			70	30			70	30	8 lb. oak cross & sw. ties. 12 1/2 gum cross ties.	Lowry & Rueping	Lowry for oak. Rueping for gum			70	30	10 to 16 lb.			70	30	16 lb. land use, 24 lb. marine	Rueping, Lowry & other	12 lb. to refusal for fir piles and lumber.
Louisville & Nashville	100				100				6 1/2 lb.	Rueping		100				12 lb.	100				14 to 16 lb. inland, 20 to 22 lb. marine	Full cell	
Maine Central	50	50			50	50			9 lb.	Rueping		50	50			9 lb.			50	50	15 lb. inland. Refusal - salt water	Rueping & Full cell	Portion of lumber treated with chromated zinc chloride. 3/4 lb. per cu. ft.
Minneapolis, St. Paul & Sault Ste. Marie	50	50			50	50			7 lb.	Rueping		100				8 lb.	100				12 lb.	Full cell	Timber treated Rueping.
Missouri, Kansas & Texas			80	20			80	20	6 lb.	Rueping		100				6 lb.	100				16 lb.	Rueping Lbr. & ties. Bethel - piles	
Missouri Pacific			70	30			70	30	1/4 gal. per cu. ft.	Rueping		100				8 lb. bridge ties. 16 lb. other lumber	100				16 lb.	Rueping & Full cell	
National Railways of Mexico	40	60			40	60			7 lb.	Rueping	Shortage of creo. necessitated curtailed absorptions & reduced quantity of ties & tbr. trtd.	100				9 lb.	40	60			7 to 10 lb.	Rueping, Lowry & Full cell	Some piles treated with 50-50 creo. petroleum, and in special cases with straight creosote. Study of treatments with "pentachlorphenol & copper naphthenate" being made.
Nashville, Chattanooga & St. Louis			80	20			80	20	7 lb. red oak. 9 lb. gum	Rueping		100				16 lb.	100				16 lb.	Rueping	
New York Central			60	40			60	40	2.5 to 3.0 gal. per tie, pine. 2.5 to 3.5 gal. per tie, oak & other hardwoods**	Lowry	The tar used is either coal tar, water gas tar or a mixture of both in varying proportions	100				8 to 16 lb.	100				10 to 24 lb.	Lowry or Full cell	
New York, Chicago & St. Louis			60	40			60	40	8 lb. or refusal	Lowry		100				Depends on mat'l.	100				Depends on mat'l.	Rueping	
New York, New Haven & Hartford			50	50			50	50		Empty cell		100				10 lb.	100				8 lb.	Empty cell	
New York, Ontario & Western												50				8 lb.							50% water gas tar and 50% creosote used in treatment bridge ties & lbr. No cross ties or switch tbr. purchased during or since World War II.
Norfolk & Western	100				100				6 1/2 lb.	Rueping		100				6-8 lb. bridge ties. 10-14 lb. lumber	100				12 lb. land piles. 18 lb. marine	Rueping & Full cell	
Norfolk Southern	100				100				8 lb.	Empty cell							100				16 lb.	Empty cell	No bridge ties or lumber treated.
Northern Pacific	50	50			50	50			8 lb.	Lowry & Boulton		50	50			10 lb.	50 100	50			10-14 lb. inland. 16 lb. salt water	Boulton	Boulton process for green material and Lowry for air seasoned material.
Pennsylvania			60	40			60	40	6 lb.	Rueping				60	40	8 lb. bridge ties. 6-10 lb. lumber			60	40	12 lb. to refusal	Full cell	Fir and oak to refusal. Pine 12 lbs. to refusal.
Pere Marquette			50	50			50	50	7 to 8 lb.	Rueping & Lowry		100				8 to 12 lb.	100				16 to 20 lb.	Rueping, Lowry & Full cell.	
Reading	40	60			40	60			8 lb. cross ties. 9-10 lb. sw. tbr.	Rueping & Lowry		100				10 to 14 lb.	100				12-14 lb. inland. Refusal marine	Rueping & Full cell	Small percentage of bridge ties and lumber treated with 40-60 mixture.
Richmond, Fredericksburg & Potomac			80	20			80	20	6 lb.	Full cell				80	20	12 lb. - pine. 6 lb. - oak							Small quantity pine lumber treated with 12 lb. per cu. ft.
Seaboard Air Line			70	30			70	30	8 lb.	Rueping	Company owned plant uses 70-30 creo., tar. Outside treating plants 80-20 creo., tar	100				16 lb.	100				16 lb. inland. 19-24 lb. marine	Rueping. Full cell	Bridge ties & lumber treated Rueping process.
St. Louis & Southwestern			70	30			70	30	2.5 gal. per #3 tie	Lowry & Rueping	Lowry for oak. Rueping for pine	100				9 to 12 lb.	100				12 to 14 lb.	Rueping	
St. Louis & San Francisco	50	50	50	50	50	50	50	50	8 lb. sw. ties. 7 to 8 lb.	Lowry & Rueping		100				8 lb. bridge ties. 8-12 lb. other lbr.	100				16 lb.	Lowry, Rueping	
Southern			80 60	20 40			80	20	8 lb.	Rueping	It is specified whether 80-20 or 60-40 creo. coal tar solution is to be used in treatment of cross ties			80	20	10 to 12 lb.			80	20	15 lb. min. inland. 18 lb. min. marine	Empty or full cell	
Southern Pacific	25 50	75 50			25 50	75 50			9 1/2 lb. fir. 8 1/2 lb. pine, gum and oak	Rueping or Lowry	Douglas Fir ties & sw. trtd. with 25-75 and others trtd. with 50-50 creo. pet. mix.	100				8 to 12 lb.	100				12 to 15 lb.	Full cell	Bridge ties treated with [illegible] at Commercial Plants. Small amount also, lumber treated with 1 lb. [illegible] per cu. ft.
Southern Pacific Lines in Texas & Louisiana	70	30			70	30			11 lb.	Full cell-oak. Rueping-others		70	30			12 lb.	70	30			16 lb. inland	Rueping & Full cell	Marine piles-Full cell-treated with straight creo. oil. Full [illegible] to refusal.
Tennessee, Coal, Iron & RR Co.			50	50			50	50	6 lb. pine. 8 lb. oak	Rueping. Full cell		100				6 lb.	100				6 to 8 lb.	Rueping	
Texas & Pacific	50 100	50			50	50			9 1/2 lb. pine. 12 1/2 lb. gum. 7 lb. oak	Rueping & Lowry	Oak cross ties trtd. with straight distillate by Lowry process. No oak sw. tbr. purchased.	100				12 to 16 lb.	100				16 lb.	Rueping	
The Minneapolis & St. Louis	50	50			50	50			7 lb.	Rueping							100				10 lb.	Rueping	
Union Pacific	50	50			50	50			8 lb.	Lowry & Rueping	Variety of species	50	50			8 lb.	100				12 lb.	Lowry & Rueping	Variety of species.
Virginian			80	20			80	20	6 lb.	Empty cell	Oak to refusal	100				8 lb.	100				12 to 16 lb.	Empty & Full cell	
Wabash			50	50			50	50	2.5 gal. #3 tie	Rueping & Lowry		100				16 lb.	100				16 lb.	Rueping & Lowry	
Wheeling & Lake Erie			60	40			50	40	6 lb. minimum	Rueping				80	[illegible]	8 lb. minimum			80	40	10 lb. minimum	Rueping	
Western Maryland			50	50			50	50	6 lb. cross ties. 7 lb. sw. tbr.	Rueping				50	70	7 lb.						Rueping	Have no records on piles.

*Lb. per cu. ft. unless otherwise noted

** Switch Timber 10 lb. Cu. Ft.

1. Elimination of straight coal tar for treatment of cross ties and switch timbers.
2. Some increases in petroleum content of creosote–petroleum solution, with slight increases in absorption per cubic foot.
3. Some increases in coal tar content of creosote–coal tar solutions. with slight increases in absorption per cubic foot.
4. Increased use of water gas tar in mixture with creosote and coal tar.
5. Although experimental treatments with pentachlorophenol–petroleum and copper naphthenate–petroleum solutions were made in recent years, the survey did not disclose the extent of these experiments

Appendix A

Vapor-Drying of Oak Cross Ties

By M. S. Hudson

Resear.h Chemist, Taylor-Colquitt Co., Spartanburg, S. C.

The new process for artificially seasoning wood known as vapor-drying which was placed in commercial production in 1945 at the Spartanburg, S. C., plant of the Taylor–Colquitt Co. has been in regular production for about a year after a period of testing and improvement. In the table below are listed the totals for timber vapor dried and treated during this period.

	Species	*Number of Units*	*Volume Cu. Ft.*
Cross ties	Oak	54,345	180,848
	Gum	26,231	82,533
	Mixed hardwood	3,578	12,069
	Pine	802	2,914
		84,956	278,364
Switch ties	Oak	13,070	70,104
	Pine	2,272	13,805
	Mixed hardwood	456	2,555
		15,798	86,464
Bridge ties	Oak	2,322	13,339
Bridge stringers	Pine	252	2,971
	Douglas fir	391	6,645
	Gum	539	1,644
		1,182	11,260
Lumber	Salt treated pine		
	Vapor dried only	1,025	2,112
Poles	Pine	22,807	399,897

Experience gained in the operation of this process has resulted in a number of improvements which have materially simplified the equipment required for the conversion of creosoting cylinders to perform the additional duty of vapor-drying. These improvements have been incorporated in the design of six additional vapor-drying units in process of construction at the present time. They will be installed on creosoting cylinders within the next few months.

General Description

The vapor-drying process consists essentially in subjecting wood in a closed vessel to the action of vapor produced by boiling any of a large number of organic chemicals. These chemicals which are usually distillates of coal tar or petroleum having narrow boiling ranges, with initial boiling points that vary from 212 deg. F. to 400 deg. F., are placed in a boiler or evaporator where they are distilled to produce vapor which is passed into the vessel containing the wood to be dried. The high temperature vapor condenses on contacting the wood, giving up its latent heat of vaporization which causes the contained water to vaporize. This water vapor or steam is conveyed by excess organic vapor that does not condense in the drying vessel, to a condenser in which the mixed vapor is cooled to produce the two liquids, water and the organic drying agent. Since the drying agent is usually of an oily nature the water will not remain mixed with it, so that when the condensate is led to a separator, two liquid layers are formed. The water layer is discharged from the separator and the drying agent is returned to the evaporator where it is again distilled to produce vapor for further drying of the wood. After sufficient water has been removed from the wood, as determined by weighing or measuring as it discharges from the separator, the vapor flow to the vessel containing the wood is

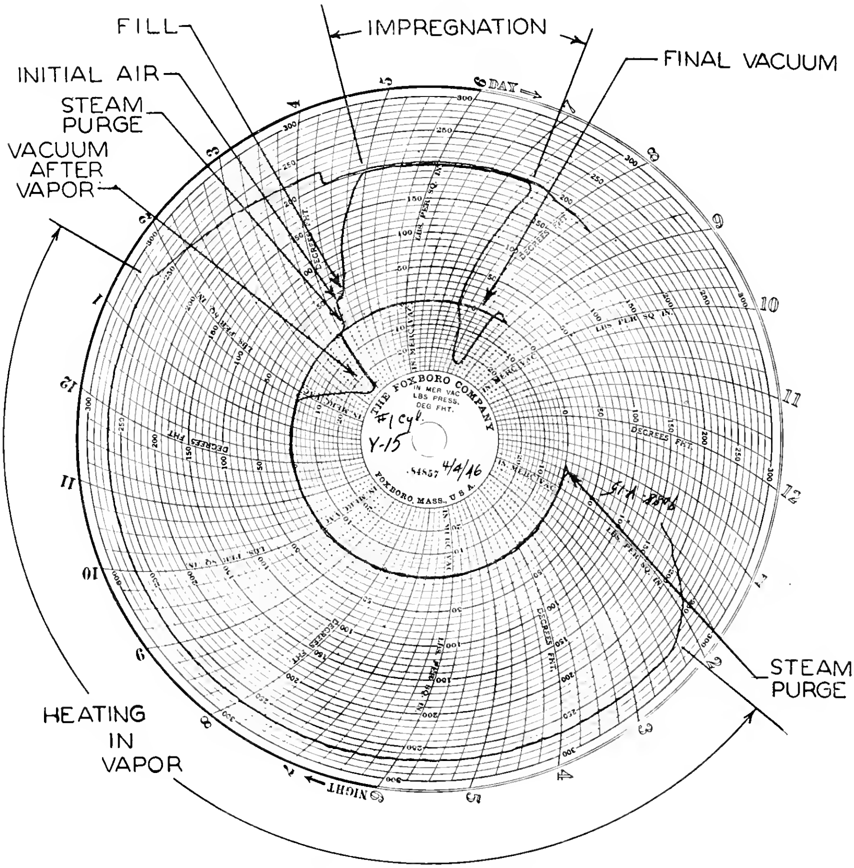


Fig. 1.—Various Steps in Drying Operation.

stopped and a vacuum is impressed to remove the condensed drying agent that has been absorbed by the wood while heating in vapor.

The vapor-dried wood may then be subjected to any of the conventional processes of preservative impregnation in the same vessel in which it was dried. More detailed descriptions of the operation of the process may be found in the list of literature references[1 2 3 4 5] cited at the end of this paper.

A Typical Example

A typical example of the processing conditions employed in vapor-drying oak cross ties is shown on the accompanying recording chart, Fig. 1. The various steps of the drying operation shown on this chart are as follows:

1. Immediately after the charge was placed in the cylinder, steam at atmospheric pressure was introduced for a period of 5 to 10 min. to blanket the charge in order to extinguish any possible source of ignition such as sparks that might have been thrown on the charge by the locomotive handling it, or chips that might have been brought to the ignition point by friction between locked tram wheels and the rail. This step is indicated on the chart by the initial steam purge.

2. As soon as the steam purge was completed vapor from the boiling organic drying agent was introduced to the cylinder. The drying agent used in this case was one designated as S–280 (Xylol) which boils at about 280 F. at atmospheric pressure. This vapor, which is several times heavier than either air or steam, rapidly displaces the air from the system through the condenser which is vented to the atmosphere. Steam produced by vaporization of water from the wood is displaced to the condenser almost as quickly as it is formed, so that within a short time after the start of flow of vapor to the cylinder the charge is blanketed in an atmosphere that is inert with respect to any detrimental chemical attack of the wood.

   This action of the drying agent in displacing air and steam accounts for the fact that the wood can be heated to very high temperatures in vapor-drying without incurring the serious damage that would be experienced from oxidation by air or hydrolysis by steam if the wood were exposed to these substances at such elevated temperatures. The possibility that the wood might undergo hydrolysis from the water contained in it has been advanced, but from studies of internal temperatures of the wood during vapor drying it has been found that the wood temperature is kept depressed by the vaporization of water as long as any appreciable amount of water remains in it, even though the wood is enveloped in vapor at temperatures as high as 350 deg. F. The reason for this is that the water is free to evaporate at approximately its boiling point at atmospheric pressure, since the system is open to the atmosphere, as shown by the fact that the pressure pen on the recording chart remained at zero psi. throughout the period of heating in vapor.

   The flow of vapor through the drying equipment is dependent on temperature differences that represent potential pressure differences rather than by pressure differentials set up by mechanical means such as blowers or fans which are required in processes employing heated fixed gases. The mechanism whereby temperature differences in the system induce flow is governed by the fact that a saturated vapor generated from a chemical at its boiling point when introduced to an open vessel will tend to flow toward any accessible part of the vessel, which is at a temperature lower than the boiling point of the chemical, under a pressure head amounting to the difference between the partial pressure of the chemical at its boiling point and its partial pressure at the lower temperature.

For example, the vapor from a chemical boiling at 300 deg. F. under atmospheric pressure (760 mm. of mercury) will, if its vapor pressure at 200 deg. F. is 200 mm. of mercury, be transported to any part of the vessel that is at 200 deg. F. by a pressure difference amounting to 560 mm. of mercury (10.8 psi.). This factor acts to give very uniform distribution of vapor throughout the charge during vapor-drying. However, in drying flat surfaced timbers such as sawed cross ties or lumber it is necessary that separation strips be used so that these surfaces can be reached by the vapor and so that the steam produced by vaporizing water from the wood, may escape. It has been found that spacing strips of ¼ to ½ in. in thickness give adequate voids to provide proper circulation of vapor through the charge.

3. At the end of 12 hours' heating in vapor a vacuum of 2 hours' duration was employed to remove the condensed drying agent that had been absorbed by the wood. This vacuum also removes a considerable quantity of water from the wood, which usually amounts to 15 or 20 percent of the total removed during the drying cycle.

4. At the end of 2 hours the vacuum was broken with steam and 5 psi. steam pressure was applied, followed immediately by 40 psi. initial air in preparation for the empty-cell preservative treatment. Application of the steam before introduction of the Rueping air is a precautionary step taken to dampen the incoming high pressure air to avoid the usual hazards involved in bringing organic substances into contact with high concentrations of oxygen at elevated temperatures. This simple precaution is one that would be well worthwhile employing when applying initial air in all creosoting operations since it would eliminate many of the cylinder fires that occur during the application of initial air.

Advantages

From this point on the procedure followed is that of conventional preservative treating practice, except that the duration of pressure impregnation required to obtain satisfactory penetration is much shorter than is usually necessary in treating air seasoned oak ties. Pressure periods of from 6 to 8 hours' duration are normally used when treating the latter, while impregnation of vapor-dried ties is accomplished in 2 to 4 hours. Difference in temperature of the ties at the start of impregnation accounts for this difference in rate of penetration of the preservative. Although the temperature of the preservative when introduced to the cylinder is about 200 deg. F. in both instances, in the case of the air seasoned ties it undergoes a rapid drop as the preservative penetrates the wood, since the ties are at atmospheric temperature. This increases the viscosity so that the rate of penetration is retarded.

Injection of the preservative into the vapor-dried ties is not retarded in this manner since the internal temperature is as high or higher than that of the preservative. The higher fluidity of the preservative in the vapor-dried ties not only makes it possible to obtain the required penetration in a shorter time but also allows more of the excess preservative to be expelled from the ties when equal amounts are injected. Whereas a preservative injection of about 10 to 12 lb. per cu. ft. into air seasoned ties will result in a final retention of about 8 lb. per cu. ft., about 12 to 14 lb. per cu. ft. can be injected into the vapor-dried ties to obtain the same retention.

In Table 1 are shown the charge makeup data, moisture removal, and gross injection, and net retention of preservative for the charge represented by the above mentioned recording chart.

TABLE 1.—DATA FOR TYPICAL CHARGE OF OAK CROSS TIES SEASONED BY THE VAPOR-DRYING PROCESS

Charge Make-Up:

Number of Ties	*Grade*	*Nominal Volume Cu. ft.*
187	3	529
139	4	460
488	5	1817
814		2804

Water Removed, Cumulative

Time hours	*Gal.*	*Lb.*	*Lb. per cu. ft.*	*Moisture Content Percent of Oven Dry Weight*
		Heating in Vapor		
0				77.6
1	87	729	0.26	76.9
2	377	3140	1.12	74.5
3	695	5973	2.13	71.7
4	1050	8748	3.12	69.0
5	1332	11104	3.86	66.7
6	1635	13627	4.86	64.2
7	1888	15730	5.61	62.1
8	2160	18002	6.42	59.9
9	2419	20161	7.19	57.8
10	2668	22236	7.93	55.8
11	2863	23862	8.51	54.2
12	3075	25629	9.14	52.5
	Vacuum After Heating in Vapor			
2	3870	32246	11.50	46.0
	Final Vacuum			
1	4166	34714	12.38	43.6

	lb. per cu. ft.
Retention of drying agent	0.48
Retention of 60–40 creosote–coal tar solution	7.37
Total retention	7.85
Gross injection 60–40 creosote–coal tar solution	12.00

The moisture content data of Table 1 have been plotted on semilogarithmic coordinates against time on the upper line in Fig. 2 to show the linear relationship between the logarithm of moisture content and drying time that has been found to express mathematically the rate of drying by means of the vapor process. The lower line in this figure has been included to show something of the effect of temperature on the rate of drying. This line represents data obtained in drying oak cross ties with a drying agent boiling at 320 deg. F. When the initial moisture content of a charge of ties is known, the equations of Fig. 1 can be used to determine the time that will be required to reduce the moisture content to any desired value. As an example, assume that ties having an initial moisture content of 75 percent are to be dried to a final moisture content of 40 percent. The calculation, using the equations of Fig. 2, is as follows:

If drying agent is S–280
$\text{Log } C = -0.0158\ t + \text{Log } I$
$0.0158t = 0.273$
$t = 17.3$ hours

If drying agent is K–4
$\text{Log } C = -0.0304\ t + \text{Log } I$
$0.0304t = 0.273$
$t = 9.0$ hours

An additional hour must be added to the above figures to obtain the total elapsed time, since a period of about an hour is required to heat up the system, during which no water is received at the condenser.

Since about 6.5 percent of water is removed during a hot vacuum of 2 hours following cycles of heating in vapor with either of the drying agents, the final moisture content at the end of the complete drying operation would be 33.5 percent. To obtain a moisture content of 40 percent after both the heating in vapor and vacuum steps, a value of 46.5 percent should be used for C in the above equations. The time required for heating in vapor in this case would be 14.1 hours when using S–280 and 7.8 hours when using K–4. The total drying time for heating in vapor and hot vacuum would be 16.1 hours with S–280 and 9.8 hours with K–4.

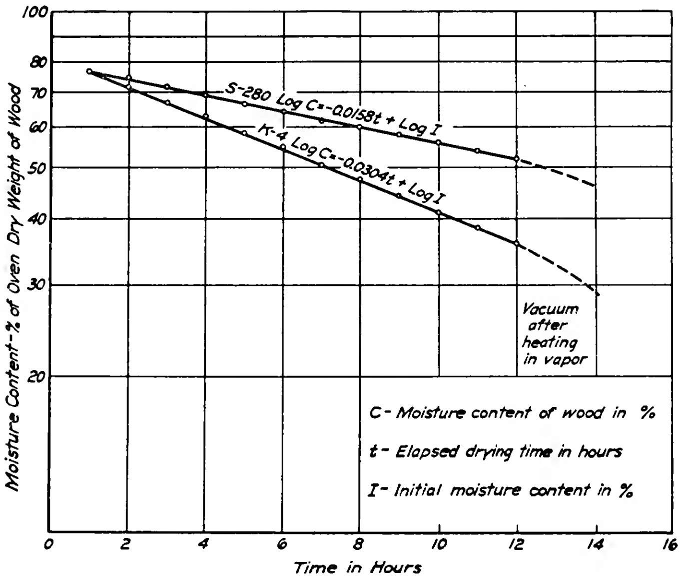


Fig. 2.—Relation of Moisture Content to Drying Time.

Use of the Charts

Even though the initial moisture content of the charge is not known, it is possible to estimate this with a fair degree of accuracy by means of charts on which the cumulative water removal, expressed in percent, is plotted against percent initial moisture content with lines representing drying time in hours drawn in. In using such a chart the operator of the vapor-drying unit determines the quantity of water removed from the charge as shown by the water meter or other measuring device connected to the water drain line from the water-drying agent separator. Then, knowing the elapsed drying time, he selects the proper chart for the given species and size of timber in process of drying with the drying agent being used, and beneath the intersection of the cumulative moisture removal value with the proper elapsed drying time line, he finds the initial moisture content of the charge. This value is then substituted in the drying rate equation along with the value for the desired final moisture content to calculate the drying time required. All of these operations can, of course, be resolved into simple nomographs so that the operator can obtain the desired information without resorting to mathematical calculations.

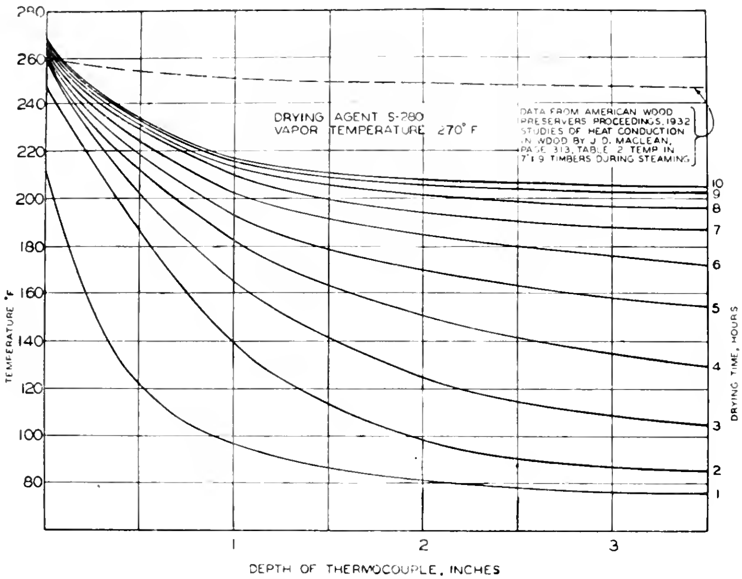


Fig. 3.—Temperature Gradient in Red Oak Ties.

The data of Fig. 3 showing the internal temperature of 7-in. by 9-in. red oak cross ties at hourly intervals during vapor-drying with S–280 at 270 deg. F. are presented in support of the statement that the temperature of the wood remains near that of the boiling point of water, as long as the water content of the wood is high, in spite of the fact that the temperature of the vapor surrounding the wood is much higher than 212 deg. F. In this figure is shown also the temperature reached in steaming 7-in. by 9-in. timbers at 260 deg. F. for 10 hours as reported by MacLean,[6] the heavy broken line in the figure. The substantial difference in temperature of the wood when heated by the two methods accounts in part for the fact that vapor-dried specimens show greater strength than those that are steamed.

Appearance of Treated Ties

Examination of the photographs of the ends of one of the trams of ties processed in the charge shown in Table 1, before and after vapor-drying and creosoting, will reveal that some opening up of the end checks present in the green ties occurred during drying and treatment. These ties had been exposed to atmospheric drying for a period of a month to six weeks before they were loaded to be processed. Lengthwise views of the ties from this tram are also shown. The white numerals on the ties as laid out

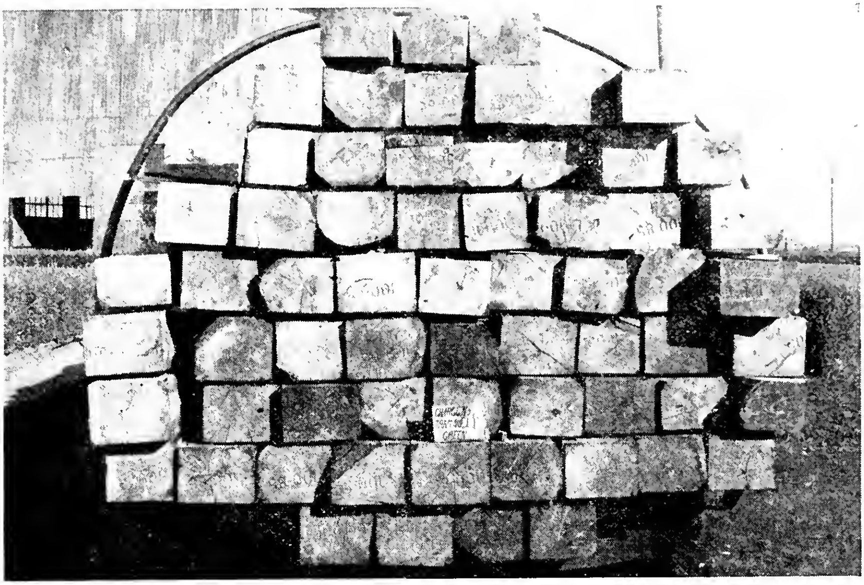


Fig. 4.—End View of Ties Before Vapor-Drying.

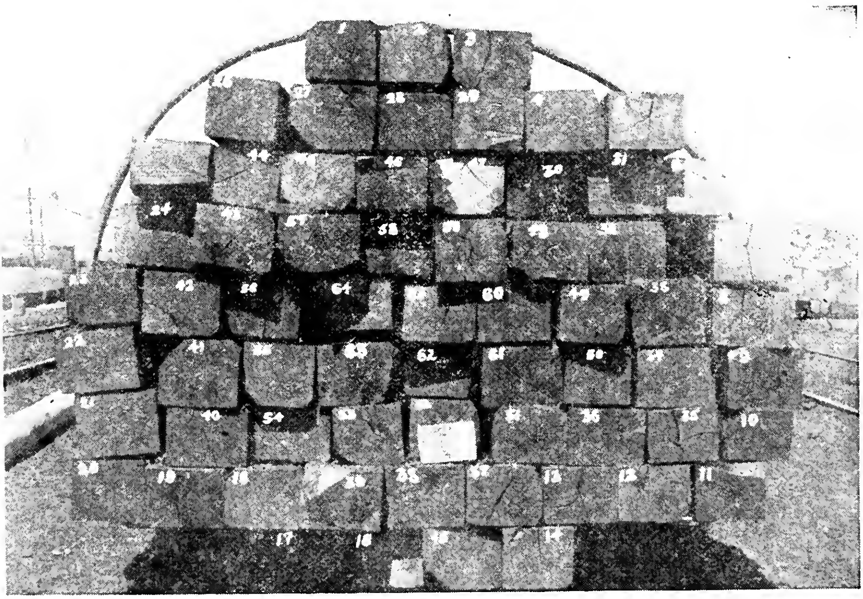


Fig. 5.—End View of Ties After Vapor-Drying and Creosoting.

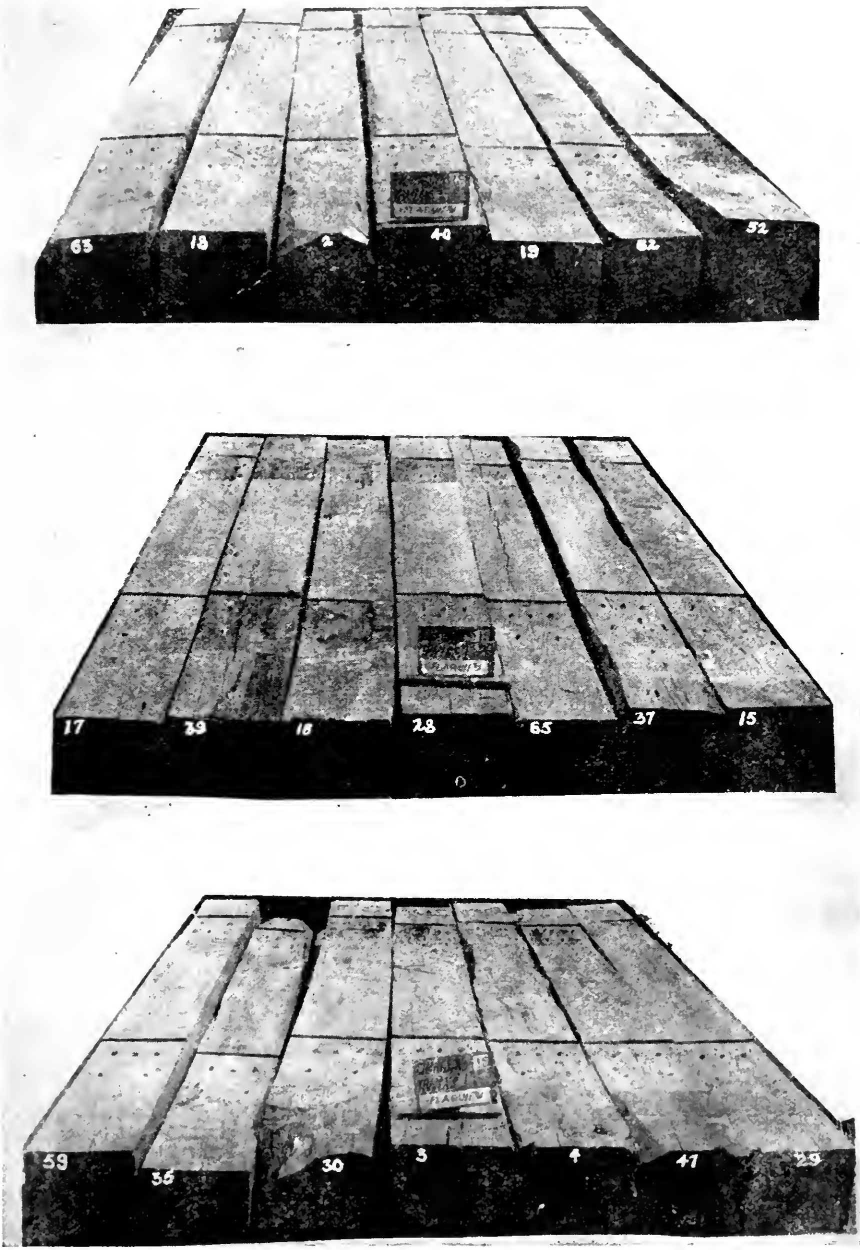


Fig. 6.—Lengthwise View of Ties After Vapor-Drying and Creosoting.

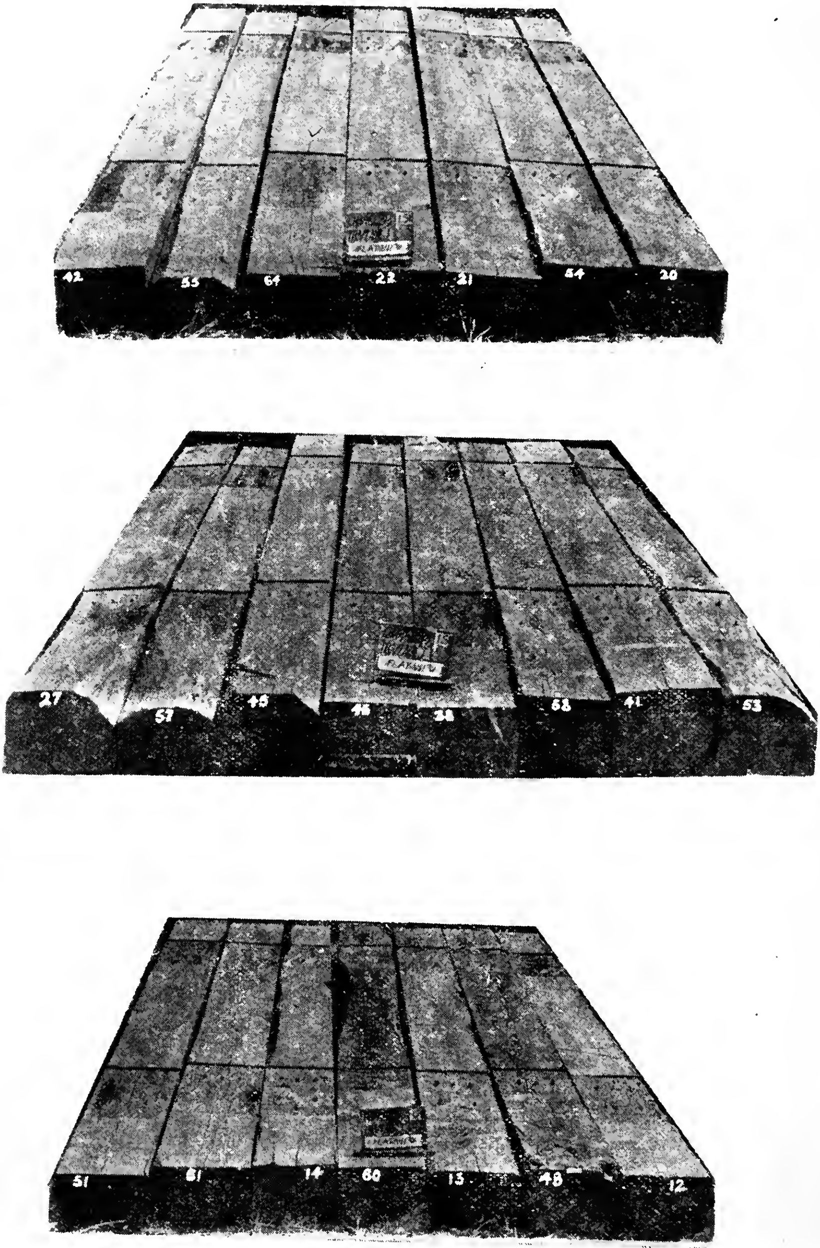


Fig. 7.—Lengthwise View of Ties After Vapor-Drying and Creosoting.

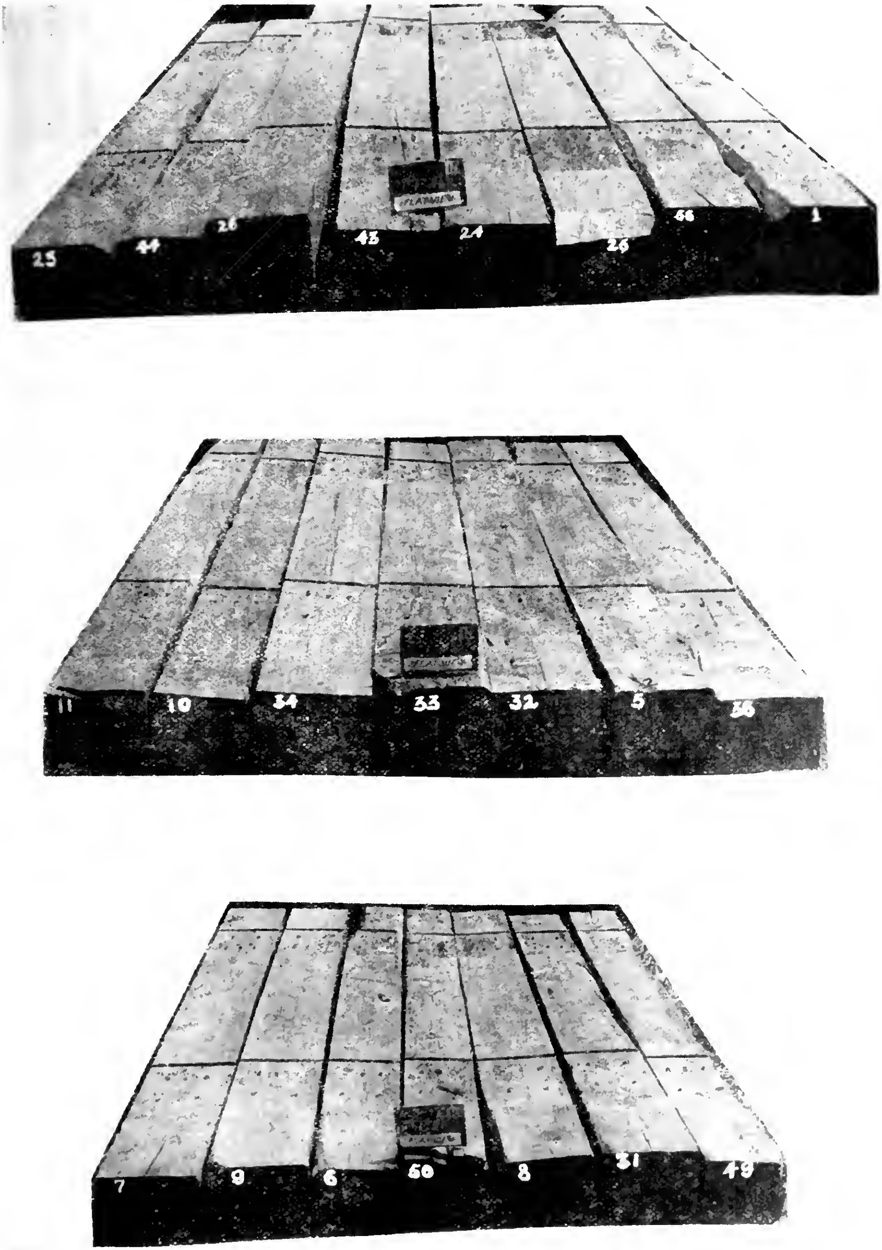


Fig. 8.—Lengthwise View of Ties After Vapor-Drying and Creosoting.

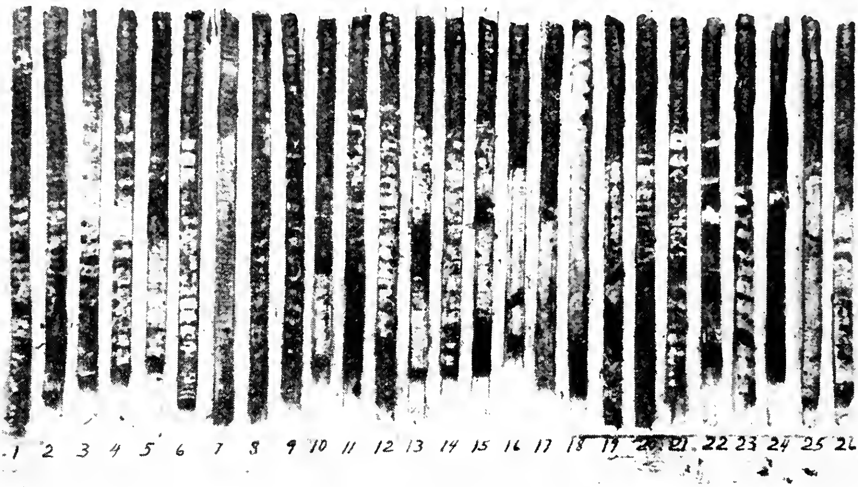


Fig. 9.—Borings from Tram of Vapor-Dried White Oak Ties.
Layer No. 1 Ties 7, 16, 17, 18 and 25.

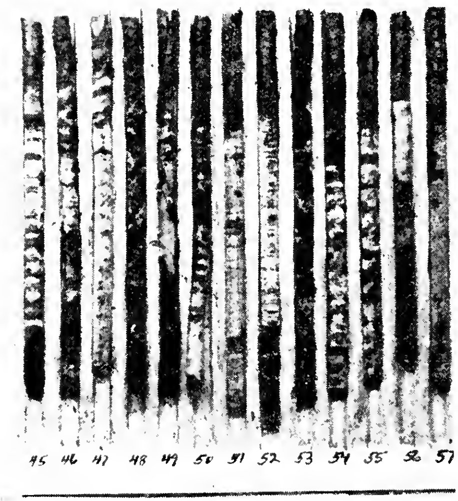
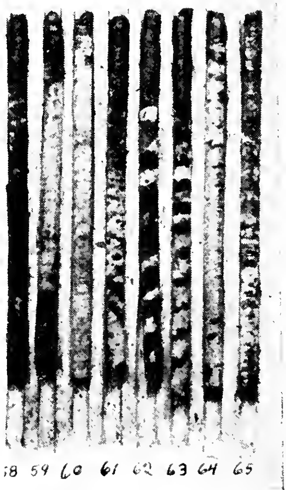


Fig. 10.—Layer No. 3, Ties 46, 47, 51, 52 and 57.



Layer No. 4. Ties 59, 60 and 64.

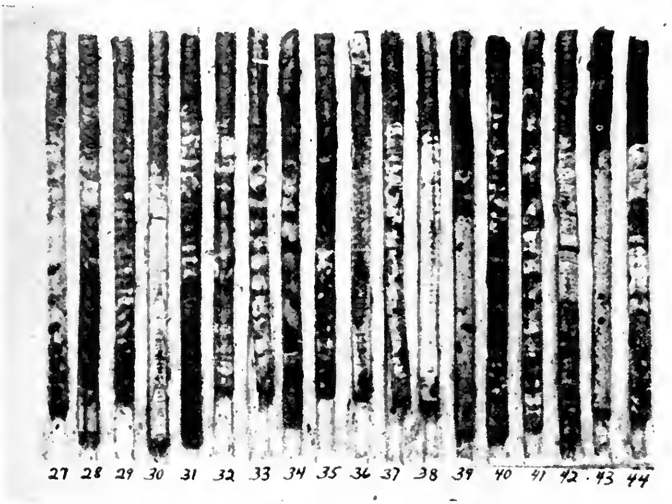


Fig. 11.—Layer No. 2. Ties 27, 30, 36, 37, 38, 39 and 43.

correspond to those shown in the end views so that direct comparisons can be made. From these photographs it will be seen that although end checks already present in the green ties tend to open up to some extent in vapor-drying, the lengthwise progress of the checks is confined to a very short distance. Observation of such checks in ties in test track over a period of five years has shown very little indication of further change either in width or length.

The borings shown in one of the photographs were taken from a tram of ties in the charge discussed above. The preservative used in impregnation was 60/40 creosote-coal tar solution. The four groups of borings shown indicate the position of the ties on the tram. Borings 1 through 26 were taken from ties in the outer layer around the tram, the tie numbers following the sequence shown in the photograph of the ends of the ties after treatment. Borings 27 through 44 were taken from the next layer, and so on. The borings listed as white oak group on the photograph were identified by means of a hand lens.

The penetration in white oak heartwood which usually averages about 1 to 1½ in. is obtained as a result of the numerous small internal checks developed in vapor-drying by straight cycles, that is, continuous heating in vapor for the entire drying period as was described in the Proceedings, Vol. 47, 1946, page 126. Although this internal checking has been found to cause some reduction in compressive strength perpendicular to the grain, these checks serve to relieve shrinkage and swelling stresses developed in the ties when they are exposed to varying weather conditions in service, preventing development of injurious localized checks and splits. For this reason the straight cycle procedure of vapor-drying as illustrated by the recording chart in Fig. 1 is employed in commercial practice.

Oak ties vapor-dried by means of straight cycles have been in service for a period of five years in test track of the Southern Railway. Recent photographs of this group of ties along with photographs of air seasoned ties installed at the same time are included for purposes of comparison.

Fig. 12.—Vapor-Dried Ties After Five Years.

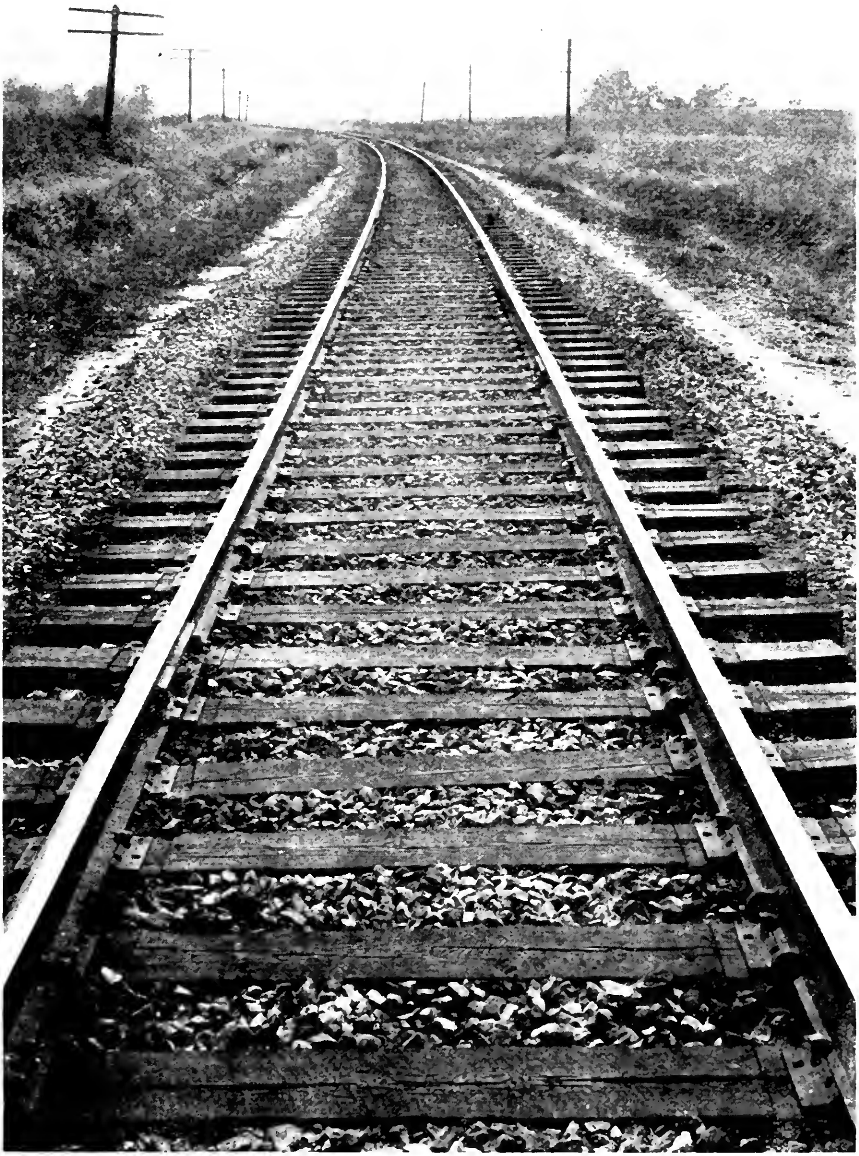


Fig. 13.—Air Seasoned Ties After Five Years.

TABLE 2.—TABULATION OF COMPARATIVE COST ITEMS FOR CREOSOTED CROSS-TIES MANUFACTURED BY THE VAPOR-DRYING AND AIR SEASONING METHODS

	Air Seasoned	*Vapor-Dried*
1. Cost of green ties	x	x
2. Cost of anti-checking irons and applying them	x	None used
3. Unloading and stacking on seasoning yard	x	None
4. Interest on investment in ties while seasoning 12 to 16 months	x	None
5. Insurance on ties in storage	x	None
6. Cullage caused by development of seasoning defects	x	Far less than in air seasoned stock
7. Loading for treatment	x	x
8. Adzing and boring	x	x
9. Cylinder time consumed in vapor-drying	None	8 hours—K–4 12 hours—S–280
10. Steam consumption	None	About 30 lb. of steam used per cu. ft. of wood dried from 75% to 40% Moisture content
11. Drying agent used	None	0.25 to 0.50 lb. per cu. ft. of wood
12. Cylinder time consumed in impregnation	8 hours	4 hours
13. Creosote required to obtain complete penetration	x	Less creosote required to obtain complete penetration than in air seasoned ties

x—Symbol repeated in vapor dried column indicates cost is same as for air seasoned.

Hardwood species other than oak have also been successfully seasoned by means of the vapor-drying process. These include the gums, beech, birch, maple and hickory. In addition to the advantages of the use of this process in preventing checking and splitting in seasoning these species, the fact that timber can be seasoned and preservatively treated within a very short time after cutting eliminates the serious risk of injury from decay that is involved in air seasoning it. The rate of drying of these species is approximately the same as that of oak and the internal temperatures attained during the drying period are of the same order as shown in Fig. 3, so that complete sterilization of the ties is assured.

The information in Table 2 is presented as a means of evaluating comparative costs of vapor-dried ties and of ties prepared for treatment by air seasoning. The cost of the vapor-drying operation will depend to some extent on the drying agent used. In cases where sufficient heat is available to boil drying agents such as K–4, a substantial reduction in drying time can be effected over that required where drying agents having lower boiling points must be used. In most instances, however, it will be found that the overall cost of processing the ties by air seasoning or vapor-drying is about the same.

LITERATURE CITED

[1] The Vapor-Drying Process for Conditioning Wood AREA Proceedings, Vol. 47, 1946, page 126.
[2] New Process Seasons Ties Overnight—Railway Age, March 1946.
[3] Poles Seasoned Quickly in Hydrocarbon Atmosphere—Electrical World, September 1946.
[4] The Vapor-Drying Process—Northeastern Wood Utilization Council Bulletin No. 18, June 1947.
[5] Vapor-Drying: The Artificial Seasoning of Wood in Vapor of Organic Chemicals.
[6] Studies of Heat Conduction in Wood—by J. D. MacLean, AWPA Proceedings, 1932, page 313.

Report of Committee 30—Impact and Bridge Stresses

A. B. CHAPMAN, *Chairman,*
E. S. BIRKENWALD
F. H. CRAMER
J. A. ERSKINE
S. F. GREAR
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C. H. SANDBERG
J. P. WALTON, *Vice-Chairman,*
J. H. SHIEBER
C. E. SLOAN
R. L. STEVENS
F. E. TURNEAURE
W. M. WILSON
L. T. WYLY
Committee

* Died August 1, 1948.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Viaduct columns, collaborating with Committee 15.
   Progress report, presented as information .... page 420

2. Steel girder spans with open decks and with ballasted decks.
   Progress report, presented as information .... page 420

3. Dynamic shear in girder and truss spans.
   Progress report, presented as information .... page 420

4. Impact and bending stresses in columns and hangers of truss spans.
   Progress report, presented as information .... page 421

5. Concrete structures, collaborating with Committee 8.
   Progress report, presented as information .... page 421

6. Determination of braking and traction forces in bridge structures, collaborating with Committees 7, 8 and 15.
   Progress report, presented as information .... page 421

7. Stresses and impacts in timber stringer bridges, collaborating with Committee 7.
   Progress report, presented as information .... page 422

8. Steel truss spans with open decks and with ballasted decks.
   Progress report, presented as information .... page 422

9. Distribution of live load in transverse floors and longitudinal stringers.
   No report.

10. Stresses in lateral bracing of bridges.
    Progress report, presented as information .... page 422

THE COMMITTEE ON IMPACT AND BRIDGE STRESSES,
A. B. CHAPMAN, *Chairman.*

Bulletin 478, January 1949.

Harold Todd Livingston

The Committee on Impact and Bridge Stresses records with sorrow the death on August 1, 1948, of a valued member, Harold Todd Livingston. An appropriate memoir to him appears elsewhere in this volume.

Report on Assignment 1

Viaduct Columns

Collaborating with Committee 15

A report of the investigation of impacts and bending stresses in the viaduct columns of a structure on the Detroit, Toledo & Ironton Railroad was presented in AREA Bulletin 475, September–October 1948. The stresses and impacts were measured in the columns supporting a 150-ft. truss span, 45-ft. girder span and a 30-ft. girder span; these data were presented as information.

Your committee will continue to assemble data on this assignment.

Report on Assignment 2

Steel Girder Spans with Open Decks and with Ballasted Decks

During the past season tests have been made on several more girder spans as part of this assignment. The AAR research staff now has complete data on 24 girder spans. Data will be secured on six more spans next year and then a final report will be presented on this subject.

The relation of impact to speed in several girder spans can be found in the diagrams presented this year in the annual report of Committee 15—Iron and Steel Structures.

Report on Assignment 3

Dynamic Shear in Girder and Truss Spans

Tests were made during 1947 on the web members of the following length truss spans:

(a) 102-ft. through pony span
(b) 124-ft. 6-in. through span
(c) 129-ft. 6-in. through span
(d) 175-ft. through span
(e) 194-ft. through span
(f) 200-ft. through span
(g) 400-ft. through span

A report of the investigation of the impacts and bending stresses in the web members of two truss spans on the Detroit, Toledo & Ironton Railroad was presented in AREA Bulletin 475, September–October 1948.

The dynamic shears have been measured in the web plates of all the girder spans tested under Assignment 2 and progress is reported in the analysis of the assembled data. Your committee will continue to assemble data on the dynamic shear in truss spans in connection with future tests conducted for Assignment 8.

Report on Assignment 4

Impact and Bending Stresses in Columns and Hangers of Truss Spans

The research staff of the AAR collaborated with Purdue University during the past year in measuring the static and dynamic stresses in the floorbeam hangers of a 200-ft. through Warren type truss span on the Missouri–Kansas–Texas Railroad near Erie, Kans., and of a 400-ft. through Warren type truss span on the Texas & New Orleans Railroad (Southern Pacific) near Morgan City, La.

A report of the investigation of impacts and bending stresses in the floorbeam hangers of a 136-ft. 9-in. through truss span and in the floorbeam posts of a 150-ft. deck truss span on the Detroit, Toledo & Ironton Railroad was presented in AREA Bulletin 475, September–October 1948.

Progress is reported in assembling and analyzing accumulated data on this subject and your committee will continue to collect data on this assignment.

Report on Assignment 5

Concrete Structures, Collaborating with Committee 8

Tests were made during 1947 to determine the vertical impact effects in a concrete pier 65-ft. in height, supporting 100-ft. girder spans. The static and dynamic stresses were measured in the concrete on sections at the top of the pier, the mid-height of the pier and close to the bottom of the pier. Progress is being made in the analysis of the data obtained on this pier.

The research staff of the AAR has arranged to conduct tests on a four-span continuous reinforced concrete subway at Flint, Mich., on the Grand Trunk Western Railroad and on a precast reinforced concrete trestle slab on the Chicago & North Western Railway. The stresses will be measured in both the concrete and reinforcing steel.

Report on Assignment 6

Determination of Braking and Traction Forces in Bridge Structures

Collaborating with Committees 7, 8 and 15

A report of the effect of braking and traction forces on the longitudinal bracing of the Detroit, Toledo & Ironton Railroad viaduct, the effect on the piles of the Missouri–Kansas–Texas Railroad timber trestle and the effect on the Chicago, Burlington & Quincy Railroad concrete pier was presented in AREA Bulletin 475, September–October 1948.

The effect of the braking and traction forces has been determined in connection with the tests made on the high concrete pier reported under Assignment 5.

The research staff of the AAR will conduct further tests on this assignment in an effort to determine the distributions of these forces between the rail and the structure.

Report on Assignment 7

Stresses and Impacts in Timber Stringer Bridges

Collaborating with Committee 7

A report of the investigation of stresses and impacts in the stringers. piles and bracing of an open floor wood pile trestle on the Missouri–Kansas–Texas Railroad, in the stringers of an open floor timber trestle on the Southern Railway System and in the stringers of a ballasted floor wood pile trestle on the Southern Railway System was presented in AREA Bulletin 475, September–October 1948.

A report on the stresses and the longitudinal distribution of axle loads to the bridge ties of open floor bridges and to the floor timbers of ballasted floor bridges was presented in AREA Bulletin 475, September–October 1948.

It is planned to conduct further tests on open and ballasted deck timber bridges and correlate the field data with the laboratory test data obtained by the Forests Product Laboratory at Madison, Wis.

Report on Assignment 8

Steel Truss Spans with Open Decks and with Ballasted Decks

The static and dynamic stresses were measured in the chord members of the truss spans in connection with the tests made under Assignment 3.

A report of the investigation of impacts and bending stresses in the members of two truss spans on the Detroit, Toledo & Ironton Railroad was presented in AREA Bulletin 475, September–October 1948.

Most of the tests of truss spans to date have been made at the request and expense of the individual railroads. Your committee reports progress in analyzing the assembled data and will continue to collect data on this assignment.

The magnitude of the impact values at reduced speeds in three truss spans can be found in Fig. 9 of the diagrams presented this year in the annual report of Committee 15 —Iron and Steel Structures.

Report on Assignment 10

Stresses in Lateral Bracing of Bridges

The stresses recorded in the lateral bracing angles of a 40-ft. deck girder span having a ballasted poured-in-place concrete deck on the Illinois Central Railroad and in the bracing agles of a 71-ft. 10-in. deck girder span having an open timber floor on the Chicago & North Western Railway were presented in AREA Bulletin 475, September–October 1948.

The stresses have been measured in the lateral bracing angles of most of the girder spans reported under Assignment 2 and progress is reported in the analysis of the assembled data.

The research staff of the AAR will measure the stresses in the lateral bracing of girder spans on curves as soon as the tests for Assignment 2 are completed.

Report of Committee 15—Iron and Steel Structures

E. S. Birkenwald, *Chairman,*	T. H. Jenkins	R. W. Mabe, *Vice-Chairman,*
P. E. Adams	M. L. Johnson	W. S. Ray
H. A. Balke	Jonathan Jones	G. E. Robinson
J. L. Beckel	R. L. Kennedy	M. A. Roose
J. E. Bernhardt	W. B. Kuersteiner	J. F. Salmon
R. T. Blewitt	M. B. Lagaard	C. H. Sandberg
M. Block	H. T. Livingston**	T. C. Shedd
F. H. Boulton, Jr.	C. T. G. Looney	C. E. Sloan
R. N. Brodie	F. M. Masters	G. L. Staley
A. W. Carpenter*	E. A. McLeod	H. C. Tammen
R. P. Davis	D. V. Messman	R. A. Van Ness
W. E. Dowling	N. W. Morgan	A. A. Visintainer***
W. N. Downey	C. T. Morris	J. P. Walton
C. E. Ekberg	Cornelius Neufeld	C. E. Webb
G. V. Guerin, Jr.	N. W. Newmark	W. M. Wilson
O. E. Hager	B. J. Ornburn	L. T. Wyly
Shortridge Hardesty	O. K. Peck	J. E. Yewell
A. R. Harris	R. E. Peck	R. W. Young
S. C. Hollister	F. J. Pitcher	W. L. Young
	A. G. Rankin	

Committee

* Died April 9, 1948.
** Died August 1,1948.
*** Died September 27, 1948.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Revisions of Specifications for Steel Railway Bridges and other parts of Chapter 15, submitted for adoption and publication in the Manual .... page 425

2. Fatigue in high strength steels; its effect on the current Specifications for Steel Railway Bridges.

   No report.

3. Design of expansion joints involving iron and steel structures, collaborating with Committee 29.

   No report.

4. Stress distribution in bridge frames–floorbeam stringers.

   Progress report, presented as information .... page 443

5. Design of steel bridge details.

   Progress report, presented as information .... page 445

6. Preparation of steel surfaces before painting.

   No report.

7. Specifications for cold riveted construction.

   No report.

AREA Bulletin 478, January 1949.

8. Design of metal culverts of 60-in. diameter and larger, including corrugated metal arches.

Progress report, presented as information .... page 449

THE COMMITTEE ON IRON AND STEEL STRUCTURES,

E. S. BIRKENWALD, *Chairman.*

Allen Wadsworth Carpenter

Allen Wadsworth Carpenter, a member of the Association since 1912, died at Yonkers, N. Y. on April 9, 1948, at the age of 75. His home was in Johnstown, N. Y.

A graduate of Case School of Applied Science, B.S. in 1895 and C.E. in 1899, Mr. Carpenter was with the Osborn Company, Civil Engineers, Cleveland. Ohio from 1895 to 1900, when he joined the New York Central. Until his retirement in 1943, he served the railroad as assistant engineer of bridges, division supervisor of bridges and buildings, division engineer, engineer of structures, assistant valuation engineer and finally engineer of bridges. He was at one time a member of the Interstate Commerce Commission's Railroad Carriers Valuation Committee on Bridge Cost Data. He became a member of the American Society of Civil Engineers in 1908.

Mr. Carpenter was primarily identified with the work of the Committee on Iron and Steel Structures of which he was a member from 1913 until his death. He served on the Committee on Conservation of Natural Resources from 1913 to 1915, of which he was vice-chairman in 1914.

Harold Todd Livingston

Harold Todd Livingston was born on November 10, 1888, at Golden City, Mo. He was graduated from the University of Missouri in 1908, receiving the degree of bachelor of science in civil engineering. While at the university, he worked during the summer months in various capacities with the St. Louis–San Francisco Railway, the Chicago, Rock Island & Pacific Railway, the Kansas City Southern Railway and the Southern Pacific Company.

In 1909, he entered the service of the Chicago, Rock Island & Pacific Railway as instrumentman, being promoted to assistant engineer in 1910 and to assistant engineer and master carpenter in 1915. From May 13, 1917 to June 1, 1919, he served as first lieutenant and captain, Corps of Engineers, U. S. Army, seeing overseas service in France. He returned to the Rock Island as division engineer, in which capacity he served until 1936, except for two years during 1930 and 1931, when he was engineer of construction. He was then successively appointed district maintenance engineer, superintendent and, in 1939, engineer of bridges. In January 1948, he was made chief engineer, maintenance of way and structures, in which capacity he was serving when he died suddenly at St. Luke's Hospital in Chicago on August 1, 1948.

Mr. Livingston was active in the committee work of the Association, being a member of the Committee on Economics of Railway Operation from 1927 to 1931, the Committee on Economics of Railway Labor from 1938 to 1939, the Committee on Wood Bridges and Trestles from 1941, the Committee on Iron and Steel Structures from 1942 and the Committee on Impact and Bridge Stresses from 1943. His principal interest of late years was with the latter two committees in which through his common sense, good judgment and knowledge he materially assisted their work.

He was also a member of the Roadmasters and Maintenance of Way Association, the American Bridge and Building Association, the American Society of Civil Engineers and the Society of American Military Engineers.

Alfred Alexander Visintainer

The committee directs attention to the memoir to Mr. Visintainer appearing in the annual report of the Committee on Wood Bridges and Trestles.

Report on Assignment 1

Revision of Manual

C. E. Webb (chairman, subcommittee), E. S. Birkenwald, J. L. Beckel, R. P. Davis, O. E. Hager, Jonathan Jones, C. T. Morris, C. H. Sandberg, G. L. Staley, R. A. Van Ness, J. P. Walton.

The committee recommends for adoption the following revisions of the Specifications for Steel Railway Bridges:

211—page 15–9

Revise paragraph to read:

For bracing systems or for longitudinal members entirely without a bracing system, the lateral force to provide for the effect of the nosing of locomotives (in addition to the other lateral forces specified) shall be a single moving force of 20,000 lb. applied at the top of the rail, in either lateral direction, at any point of the span. The resulting vertical forces shall be disregarded.

516—page 15–25

Add the word "current" before "requirements of" in first sentence.

Delete reference to year "1937" at end of first sentence.

1810—page 15–48.6

The following should be substituted for the second sentence:

Flame-cut edges shall be machined to a depth of ¼ in. except that machine-flame-cut edges of silicon steel may be used without removal of metal if they are softened by post-heating in a manner satisfactory to the engineer.

Page 15–115

Instructions for the Mill Inspection of Structural Steel.

Submitted for reapproval without change.

Pages 15–116 to 15–118

Instructions for the Inspection of the Fabrication of Steel Bridges.

Submitted for reapproval without change.

Pages 15–118 to 15–118.3

Instructions for the Inspection of Bridge Erection.

Submitted for reapproval with the following changes:

1 (a)—page 15–118

Add words "General and" at the beginning of sentence making same read:

General and special specifications apply to the work.

2—page 15–118

Delete paragraph and substitute the following:

Become fully acquainted with the terms of the contract, specifications and method of procedure as approved, or agreed upon.

4—page 15–118

Add new paragraph number 4 before present paragraph 4 as follows:

Make the acquaintance of the principal men engaged upon the work and of local residents whose interest may be affected thereby, and railway officers and employees whose cooperation will expedite the work.

Present paragraph 4 becomes paragraph 5.

5—page 15–118

Present paragraph 5 becomes paragraph 6.

6—page 15–118

Present paragraph 6 becomes paragraph 8. Add new paragraph 7 as follows:

Thoroughly check the contractor's provisions for safety with respect to wires, gas lines, and other utilities; adjacent waterways, highways, or railroads, with the object of anticipating possible hazards and adopting appropriate safety measures. See that all necessary arrangements have been made for the removal, or protection, of the above mentioned utilities.

Pages 15–118 to 15–118.1

Renumber current paragraphs 7 to 12 incl., as 9 to 14 incl.

Insert the following sentence before the last sentence in present paragraph 10:

Check over the contractor's scheme of operation, and for each phase of operation requiring a break in traffic, see that he has all necessary equipment handy and all preliminary work finished.

13—page 15–118.1

Present paragraph 13 becomes paragraph 15. Add the following sentence at end of paragraph:

Keep constantly on the alert to see that the contractor does not foul any live tracks at any time when the fouling will introduce the slightest risk.

14—page 15–118.1

Present paragraph 14 becomes paragraph 16.

15—page 15–118.1

Present paragraph 15 becomes paragraph 17.

16—page 15–118.1

Delete present paragraph 16 and substitute the following as paragraph 18:

Obtain a match-marking diagram of any existing structure that is to be removed and re-erected. See that the various parts of the structure are legibly marked in accordance with the match-marking diagram. Make a record of the manner of dismantling, of the nature and extent of damage to any part, and indicate by sketches, or by description, any repairs or replacements that will be required for re-erection.

17—page 15–118.1

Present paragraph 17 becomes paragraph 19.

18—page 15–118.1

Present paragraph 18 becomes paragraph 20. Add phrase at end of first sentence as follows:

"including a running record in the diary of all equipment which is on the job." At end of present third sentence, change the word "use" to the words "used daily."

19—15–118.1

Present paragraph 19 becomes paragraph 21.

Change word "class" in (b) to words "bid item."

20 and 21—page 15–118.1

Present paragraphs 20 and 21 become paragraphs 22 and 23.

22 and 23—page 15–118.2

Present paragraphs 22 and 23 become paragraphs 24 and 25.

24—page 15–118.2

Present paragraph 24 becomes paragraph 26. Add a third sentence reading as follows:

If you fail to obtain the full cooperation of the contractor, make a full report of the conditions and circumstances to your superior with your recommendations for the proper remedies to bring the job up to schedule.

25—page 15–118.2

Present paragraph 25 becomes paragraph 27.

26—page 15–118.2

Present paragraph 26 becomes paragraph 28.

Delete present paragraph and substitute the following:

Be constantly on hand when work is in progress. Observe and record any special difficulty in assembling.

27, 28, 29—page 15–118.2

Present paragraphs 27, 28, and 29 become paragraphs 29, 30 and 31.

30—page 15–118.2

Present paragraph 30 becomes paragraph 32. Add a sentence reading as follows:

The fact that all holes are filled with bolts or pins does not, in itself, assure proper alinement.

31, 32, 33, 34 and 35—page 15–118.2

Present paragraphs 31, 32, 33, 34 and 35 become paragraphs 33, 34, 35, 36 and 37.

36—page 15–118.2

Present paragraph 36 becomes paragraph 38.

Move the word "otherwise" after the word "would," making the second sentence read as follows:

Have the shanks drilled out if excessive force would otherwise be required for their removal.

37—page 15–118.2

38, 39 and 40—page 15–118.3

Present paragraphs 37, 38, 39 and 40 become paragraphs 39, 40, 41 and 42.

41—page 15–118.3

Delete entire paragraph.

42—page 15–118.3

Present paragraph 42 becomes paragraph 43.

Delete second sentence and substitute the following:

Inspect all moving machined contact surfaces to make sure that their temporary protective coverings have been removed, and that they are clean and properly lubricated.

43 and 44—page 15–118.3

Present paragraphs 43 and 44 become paragraphs 44 and 45.

45—page 15–118.3

Present paragraph 45 becomes paragraph 46.

Make the first two lines before the semicolon read as follows:

Determine whether power line, cables, or other construction, whether by railroad company or others, is likely to be completed in the time set for operating the bridge;

46—page 15–118.3

Present paragraph 46 becomes paragraph 47.

Change the first sentence to read:

Check, as often as necessary, the weight per cubic foot of the counterweight material to determine whether it agrees with the weight used in the calculations.

47—page 15–118.3

Present paragraph 47 becomes paragraph 48.

48—page 15–118.3

Present paragraph 48 becomes paragraph 49.
Delete the words "Section 9 of."

49 and 50—page 15–118.3

Present paragraphs 49 and 50 become paragraphs 50 and 51.

52—page 15–118.3

Add new paragraph 52 to read as follows:

If practicable, make a final report showing the cost of labor of erection per ton of material erected; the cost of labor per rivet in riveting; the cost, separately, of correcting errors in design and fabrication. Comment on the design and details, and give such other information as may be useful in planning similar work.

Pages 15–121 to 15–127

The following redraft of Rules for Rating Existing Iron and Steel Bridges is presented as information.

RULES FOR RATING EXISTING IRON AND STEEL BRIDGES

1949

I GENERAL

Except as otherwise provided in these rules, the Specifications for Steel Railway Bridges, Specifications for Movable Railway Bridges or Specifications for the Design of Rigid Frame Steel Bridges, as the case may be, shall govern.

101. Carrying Capacity

The carrying capacity of a bridge shall be determined by the computation of stresses based on authentic records of the design, details, materials, workmanship, and physical condition, including data obtained by inspection (and tests if the records are not complete). If deemed advisable, field determination of stresses shall be made and the results given due consideration in the final assignment of the carrying capacity. For a specific service the location and behavior under load shall be taken into account.

102. Inspection

Same as current rating rules.

103. Computation of Stresses

Same as current rating rules.

104. Loads and Forces

Same as current rating rules.

105. Dead Load

Same as current rating rules.

106. Live Load

The live load shall be one of the Cooper E series or a load consisting of a specific locomotive or other equipment, depending on the purpose for which the rating is desired.

If the live load is to be a specific locomotive and cars (or other equipment), complete data shall be obtained, including the spacing of axles and the static load on each axle.

107. Impact

(A) The impact shall be determined by the rules for impact in the current AREA Specifications for Steel Railway Bridges.

(B) Reduction of impact from direct vertical effect but not from roll will be allowed under the following conditions:

1. For all length and type of spans, except truss spans, carrying locomotives with hammer blow, and for all length and type of spans carrying rolling equipment without hammer blow, the vertical effect for speeds less than 40 mph. shall reduce in a straight line variation from full impact at 40 mph. to 0.2 of the full effect at 10 mph.
2. For all length of truss spans carrying locomotives with hammer blow, the vertical effect for speeds less than synchronous speed shall reduce in a straight line variation from full effect as synchronous speed to 0.2 of the full effect at 10 mph. Synchronism occurs when the locomotive speed in revolutions per second of drivers equals the natural frequency of the span, in vibrations per second, which is approximately

$$\sqrt{\frac{12}{d+D}}$$

in which d and D are the central deflections in inches, respectively, for dead load and placed in the position for maximum moment.

108. Centrifugal Force

Centrifugal force shall be determined by Article 208 of the current AREA Specifications for Steel Railway Bridges.

109. Wind

The wind force shall be considered as a moving load acting in any horizontal direction. On the train, it shall be taken at 200 lb. per lin. ft. on one track applied 8 ft. above the top of rail. On the bridge, it shall be taken at 20 lb. per sq. ft. of the following surfaces:

(a) For girder spans, ½ times the vertical projection of the span.
(b) For truss spans, the vertical projection of the span plus any portion of the leeward trusses not shielded by the floor system.
(c) For viaduct towers and bents in addition to the foregoing, the vertical projections of all columns and tower bracing.

This loading is predicated on the reasoning that a train will operate at reduced speed if the wind velocity exceeds 70 mph., if it operates at all.

If considered justifiable by the engineer, the wind forces on a bridge and the train may be reduced to not less than ½ of those required above.

110. Nosing of Locomotives

For bracing systems or for longitudinal members entirely without a bracing system, the lateral force to provide for the effect of the nosing of the locomotive shall be a single moving force equal to 1/16 of the weight of one locomotive without tender applied at the top of the rail in either lateral direction at the center of either the leading or trailing truck. The resulting vertical effect shall be neglected.

111. Longitudinal Force

The longitudinal force resulting from the starting and stopping of trains, taken on one track only and assumed to act 6 ft. above the top of rail, shall be the larger of:

(a) Force due to traction
Twenty-five percent of the total weight on the driving wheels, without impact.
(b) Force due to braking
Fifteen percent of the static live load.

For spans supported on sliding bearings, the longitudinal force shall be considered as being divided equally between the two ends. For spans that have roller or rocker bearings at one end, the whole of the longitudinal force shall be considered to act through the fixed end.

For bridges where, by reason of continuity of members or frictional resistance, much of the longitudinal force will be carried directly to the abutments (such as ballasted deck bridges of only three or four spans), only ½ of the longitudinal force shall be considered effective.

112. Live Load and Impact on Multiple Track Bridges

Same as Article 114 of the current rating rules.

113. Permissible Stresses

The permissible unit stresses resulting from the loads and forces described in the preceding articles are the following, in which

$k = 0.8$ of the yield point for open-hearth steel
$= 0.8$ of the yield point for wrought iron
$= 0.7$ of the yield point for bessemer steel
$= 0.7$ of the yield point for silicon steel
$= 0.65$ of the yield point for nickel steel

The yield point shall be taken at not more than 0.55 of the ultimate strength. In the absence of records, the yield point shall be taken as 30,000 psi. for open hearth or bessemer steel, 25,000 psi. for wrought iron, 45,000 psi. for silicon steel and 50,000 psi. for nickel steel.

Axial tension, net section in pounds per square inch and tension in extreme fibers of rolled shapes, girders and built sections, net section, in pounds per square inch, except for floorbeam hangers.
Open-hearth or bessemer steel
wrought iron, silicon steel
and nickel steel .... k
For floor beam hangers, value of 0.75 k shall not be exceeded.

Axial compression, gross section in pounds per square inch. (For compression members centrally loaded and with values of l/r not greater than 140 for open-hearth or bessemer steel and wrought iron; not greater than 130 for silicon steel; and not greater than 120 for nickel steel

	Riveted end	Pin end
Open-hearth or bessemer steel	$\frac{k}{18{,}000}\left(15{,}000 - \frac{1}{4}\frac{l^2}{r^2}\right)$	$\frac{k}{18{,}000}\left(15{,}000 - \frac{1}{3}\frac{l^2}{r^2}\right)$
Wrought iron	$\frac{k}{15{,}000}\left(12{,}500 - 0.21\frac{l^2}{r^2}\right)$	$\frac{k}{15{,}000}\left(12{,}500 - 0.28\frac{l^2}{r^2}\right)$
Silicon steel	$\frac{k}{24{,}000}\left(20{,}000 - 0.46\frac{l^2}{r^2}\right)$	$\frac{k}{24{,}000}\left(20{,}000 - 0.61\frac{l^2}{r^2}\right)$
Nickel steel	$\frac{k}{30{,}000}\left(24{,}000 - 0.66\frac{l^2}{r^2}\right)$	$\frac{k}{30{,}000}\left(24{,}000 - 0.86\frac{l^2}{r^2}\right)$

l = length of member in inches
r = least radius of gyration of the member in inches

For comparison members with l/r greater than designated above and for those of known eccentricity, see Appendix on formulas for compression members of the AREA Specifications for Steel Railway Bridges, using appropriate values of y and E and f as follows:

f = 1.20 for open-hearth steel and wrought iron
= 1.37 for bessemer steel and silicon steel
= 1.54 for nickel steel

Compression in extreme fibers of rolled shapes, girders and built sections, subject to bending, gross section, in pounds per square inch:

Open-hearth or bessemer steel	$\frac{k}{18{,}000}\left(18{,}000 - 5\frac{l^2}{b^2}\right)$
Wrought iron	$\frac{k}{15{,}000}\left(15{,}000 - 4\frac{l^2}{b^2}\right)$
Silicon steel	$\frac{k}{24{,}000}\left(24{,}000 - 6.67\frac{l^2}{b^2}\right)$
Nickel steel	$\frac{k}{30{,}000}\left(30{,}000 - 8.33\frac{l^2}{b^2}\right)$

l = length, in inches, of the unsupported flange between lateral connections or knee braces
b = flange width, in inches.

Tension in extreme fibers of pins in pounds per square inch, assuming loads concentrated at centers of bearing

Open-hearth or bessemer steel,
wrought iron, silicon steel
and nickel steel .... $2k$

If the members are packed close together on the pin, the bending stress may be disregarded unless the tension in the extreme fiber exceeds 60,000 psi. for open-hearth steel, 50,000 psi. for wrought iron or bessemer steel, 80,000 psi. for silicon steel or 90,000 psi. for nickel steel.

Shear in plate girder webs and rolled beams, gross section, in psi.

Open-hearth or bessemer steel, wrought iron, silicon steel and nickel steel ..$0.75\,k$

Shear in rivets and pins, in pounds per square inch

Open-hearth or bessemer steel, wrought iron, silicon steel and nickel steel ..$0.9\,k$

The permissible values for shear shall be reduced 20 percent for countersunk rivets, floor connection rivets and turned bolts.

Bearing on rivets, pins, outstanding legs of stiffeners, and other steel parts in contact, may be disregarded unless there is visible deformation of the parts in contact.

114. Action To Be Taken

If the stresses exceed those permissible under these rules, the speed or the loading shall be restricted so that the permissible stresses will not be exceeded; otherwise, the bridge shall be placed on falsework until it is strengthened or renewed. When the permissible stresses are closely approached, or when the physical condition of the main members or the details is not good, the bridge shall be kept under frequent inspection as long as it is continued in service.

Test Results on Relation of Impact to Speed

Your committee offers the following statement in support of the proposed Article 107 of the Rules for Rating Existing Iron and Steel Bridges presented on page 429.

In the Proceedings, Vol. 48, 1947, page 393, the committee presented as information a proposed change in the impact allowance for rating existing bridges which provided ordinarily for the use of the impact as determined from the design specifications of steel railway bridges with a reduction in total impact for speeds less than 40 mph., or less than synchronous speed for various types of spans.

As a result of having more available data in 1948, it developed that the magnitude of the roll effect was approximately the same at all speeds. Consequently, it was decided to apply a reduction of impact only to the direct vertical effect. This is reflected in Figs. 1 to 9, incl., prepared by the research staff of the Engineering Division, AAR.

A study of Figs. 1 to 8, incl., covering short span steel bridges 20 to 40 ft. long, and through and deck plate girder spans 40 to 130 ft. long subjected to live loads with or without hammer blow, indicates that the reduction of impact as a result of speed should occur at 40 mph. or less, rather than synchronous speed or less, as was proposed in 1947 for spans longer than 50 ft.

Since rolling equipment without hammer blow has no synchronous speed as defined in the proposed Article 107, the value of 40 mph. was selected as the maximum practical speed where allowable reduction in impact might be permitted.

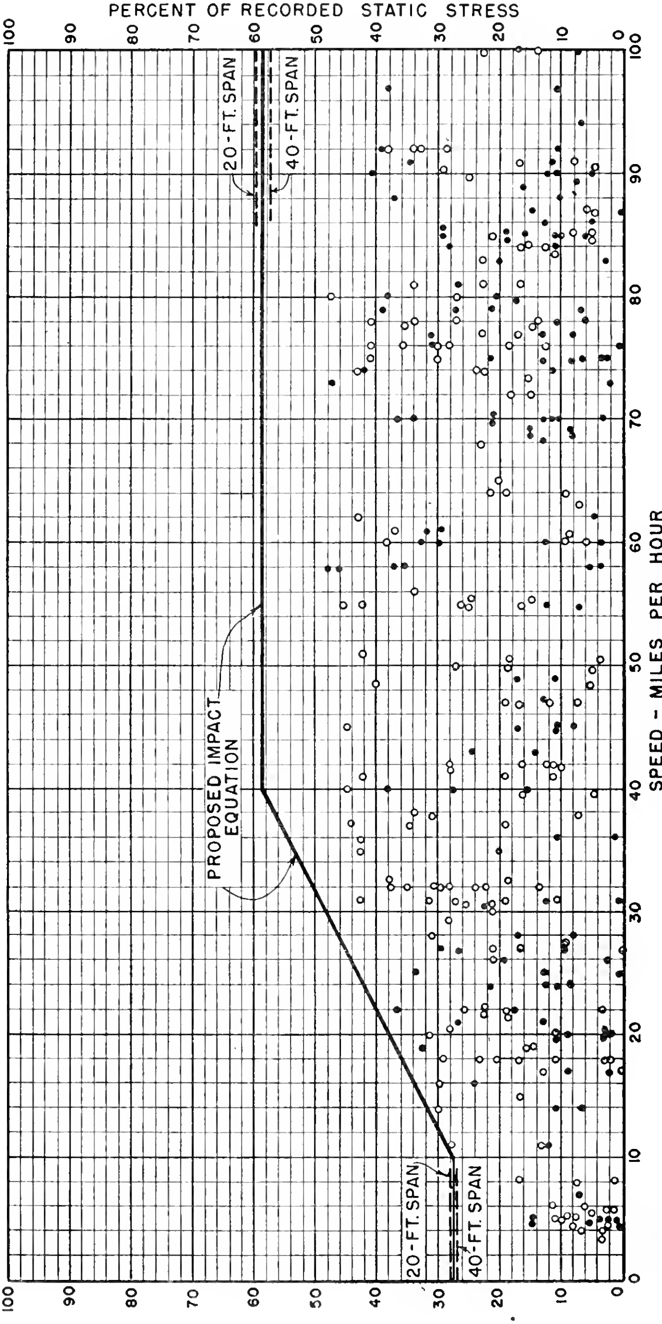
(text continued on page 443)

Table 1.—Total Impact in Relation to Speed as Obtained from Test Bridges Listed and Shown in Figs. 1 to 9

SPAN NUMBER	FIGURE NUMBER	RAILROAD	SPAN C.TO C. BEARINGS	TYPE OF SPAN	TYPE OF FLOOR	C.TO C. OF STEEL	NUMBER OF BEAMS PER TRACK
1[3)]	1 & 5	A.T. & S.F. RY.	19'-0	I-BEAMS	OPEN TIMBER	4'-10½	4-BEAMS
2[3)]	1 & 5	A.T & S.F. RY.	21'-0	I-BEAMS	BALLASTED TIMBER	4'-11½	6-BEAMS
3[3)]	5	C.B. & Q. R.R.	23'-0	D.P.G.	BALLASTED TIMBER	7'-0	2-GIRDERS
4[3)]	1 & 5	C. & N.W. RY.	25'-2	D.P.G.	OPEN TIMBER	5'-0	4-GIRDERS
5[3)]	5	C.B & Q. R.R.	28'-8	D.P.G.	BALLASTED TIMBER	7'-0	2-GIRDERS
6[5)]	5	D.T. & I.R.R.	30'-0	D.P.G.	OPEN TIMBER	6'-6	2-GIRDERS
7[3)]	1 & 5	C. & N.W. RY.	31'-8	D.P.G.	BALLASTED CONCRETE	5'-0	4-GIRDERS
8[3)]	1 & 5	I.C.R.R.	33'-0	W.F. BEAMS	OPEN TIMBER	5'-0	4-BEAMS
9	1 & 5	I.C.R.R.	38'-2½	D.P.G.	BALLASTED CONCRETE	7'-0	2-GIRDERS
10[5)]	6	D.T. & I.R.R.	45'-0	D.P.G.	OPEN TIMBER	6'-6	2-GIRDERS
11	6	C.M.ST.P. & P.R.R.	45'-8¾	D.P.G.	BALLASTED TIMBER	8'-0	2-GIRDERS
12[1)]	2 & 6	P.R.R.	54'-0	D.P.G.	OPEN TIMBER	5'-0	2-GIRDERS
13	2 & 6	I.C.R.R.	58'-2	D.P.G.	OPEN TIMBER	8'-0	2-GIRDERS
14	2 & 6	I.C.R.R.	58'-4	D.P.G.	OPEN TIMBER	7'-0	2-GIRDERS
15	3 & 7	C. & N.W. RY.	68'-5¼	D.P.G.	OPEN TIMBER	8'-0	2-GIRDERS
16	3 & 7	C. & N.W. RY.	70'-10	D.P.G.	OPEN TIMBER	6'-6	2-GIRDERS
17[2)]	3 & 7	P.R.R.	81'-0	D.P.G.	BALLASTED CONCRETE	7'-0	2-GIRDERS
18	8	C.M.ST.P. & P.R.R.	108'-0	T.P.G.	BALLASTED TIMBER	19'-2	2-GIRDERS
19[1)]	4 & 8	P.R.R.	119'-0	D.P.G.	OPEN TIMBER	8'-0	2-GIRDERS
20[5)]	9	D.T. & I.R.R.	136'-9	T.T.	OPEN TIMBER	16'-2	2-TRUSSES
21[4)]	9	T.T.R.R.	142'-0	D.T.	OPEN TIMBER	15'-0	2-TRUSSES
22[5)]	9	D.T. & I.R.R.	150'-0	D.T.	OPEN TIMBER	17'-0	2-TRUSSES

The results of these tests published in AREA Proceedings as follows:

[1] Vol. 42, 1941.
[2] Vol. 45, 1944.
[3] Vol. 46, 1945.
[4] Vol. 49, 1948.
[5] **Vol. 50, 1949.**



TOTAL IMPACT

SYMBOL:
- o OPEN FLOOR BRIDGES
- • BALLASTED FLOOR BRIDGES

PROPOSED IMPACT EQUATION AT REDUCED SPEEDS:
ROLL EFFECT AT ALL SPEEDS - SAME AS ART. 206, *a*.

VERTICAL EFFECT AT 40 MPH. AND OVER (ART. 206, b) = $40 - \frac{3L^2}{1600}$

VERTICAL EFFECT AT 10 MPH. AND UNDER = $0.2\left(40 - \frac{3L^2}{1600}\right)$

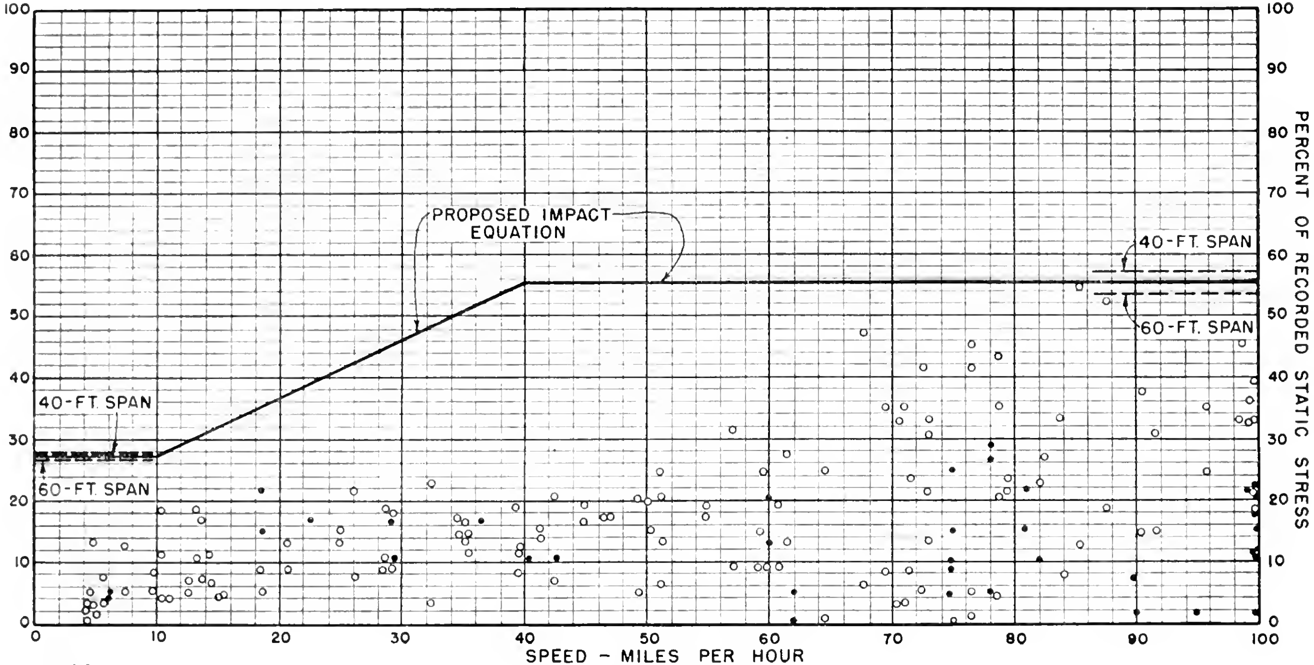
NOTE: PROPOSED IMPACT EQUATION IS SHOWN FOR SPAN LENGTH OF 30 FT. WITH GIRDERS AT 5-FT. CENTERS

FIG. 1

SHORT SPAN STEEL BRIDGES
20 TO 40-FT. SPANS

TOTAL IMPACTS

ROLLING EQUIPMENT WITHOUT HAMMER BLOW



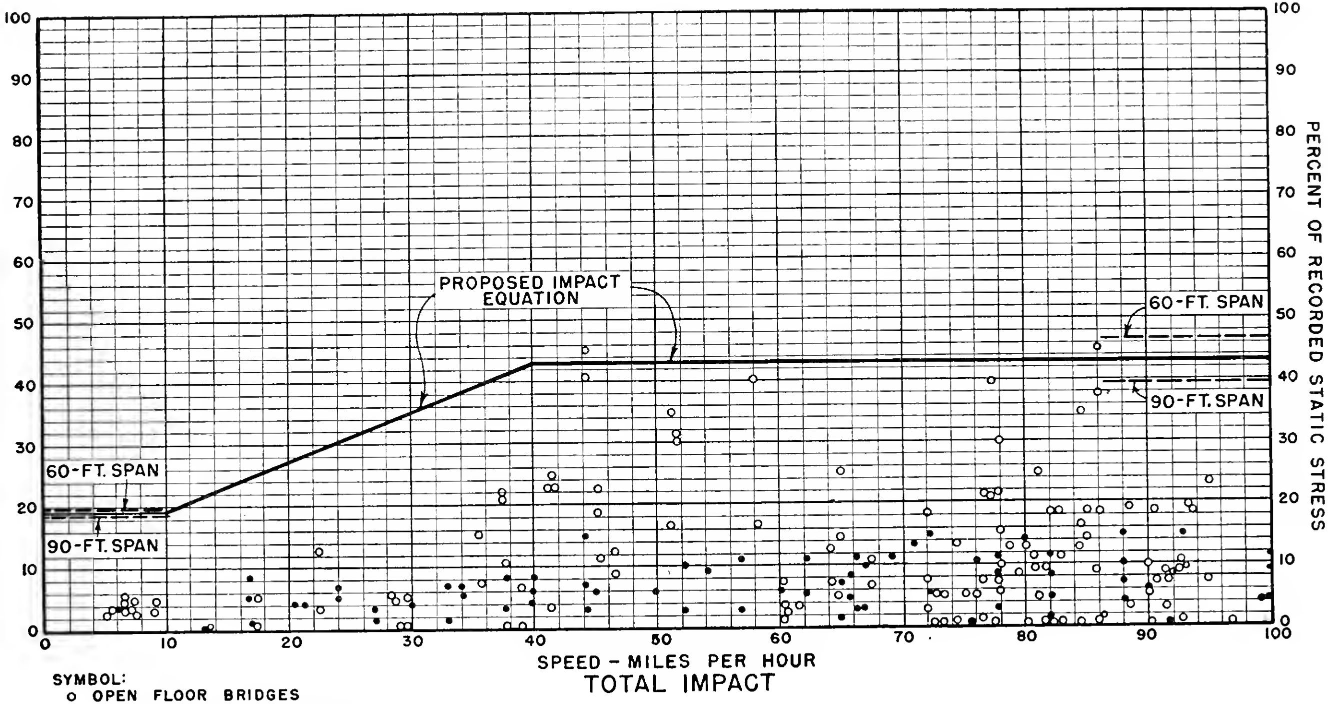
TOTAL IMPACT

SYMBOL:
○ OPEN FLOOR BRIDGES
• BALLASTED FLOOR BRIDGES

PROPOSED IMPACT EQUATION AT REDUCED SPEEDS:
ROLL EFFECT AT ALL SPEEDS - SAME AS ART. 206, a.
VERTICAL EFFECT AT 40 MPH. AND OVER (ART. 206, b) $= 40 - \frac{3L^2}{1600}$
VERTICAL EFFECT AT 10 MPH. AND UNDER $= 0.2\left(40 - \frac{3L^2}{1600}\right)$

NOTE: PROPOSED IMPACT EQUATION IS SHOWN FOR SPAN LENGTH OF 50 FT. WITH GIRDERS AT 5-FT. CENTERS

FIG. 2
THROUGH AND DECK PLATE GIRDERS
40 TO 60-FT. SPANS
TOTAL IMPACTS
ROLLING EQUIPMENT WITHOUT HAMMER BLOW



SYMBOL:
○ OPEN FLOOR BRIDGES
● BALLASTED FLOOR BRIDGES

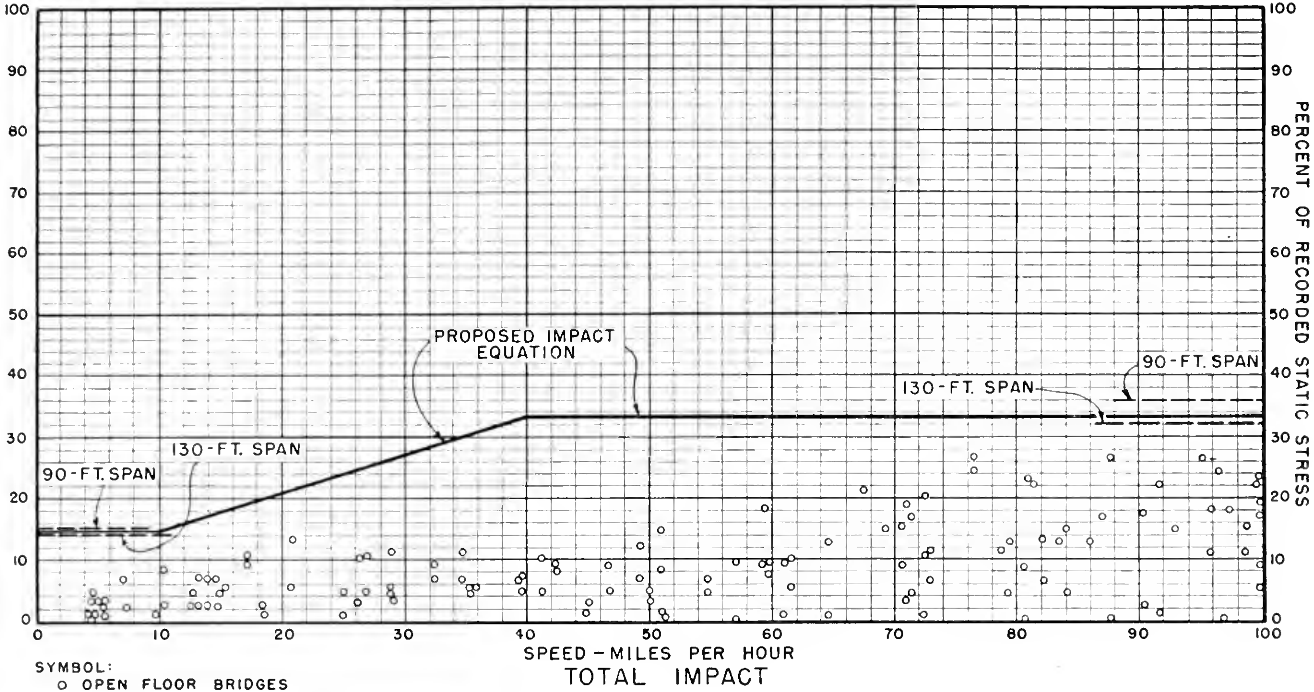
PROPOSED IMPACT EQUATION AT REDUCED SPEEDS:
ROLL EFFECT AT ALL SPEEDS – SAME AS ART. 206, a.

VERTICAL EFFECT AT 40 MPH. AND OVER (ART. 206, b) $= 40 - \frac{3L^2}{1600}$ { FOR SPANS 80-FT. AND UNDER

VERTICAL EFFECT AT 10 MPH. AND UNDER $= 0.2\left(40 - \frac{3L^2}{1600}\right)$

NOTE: PROPOSED IMPACT EQUATION IS SHOWN FOR SPAN LENGTH OF 75 FT. WITH GIRDERS AT 7-FT. 6-IN. CENTERS

FIG. 3
THROUGH AND DECK PLATE GIRDERS
60 TO 90-FT. SPANS
TOTAL IMPACTS
ROLLING EQUIPMENT WITHOUT HAMMER BLOW



SYMBOL:
- o OPEN FLOOR BRIDGES
- • BALLASTED FLOOR BRIDGES

PROPOSED IMPACT EQUATION AT REDUCED SPEEDS:

ROLL EFFECT AT ALL SPEEDS - SAME AS ART. 206, a.

VERTICAL EFFECT AT 40 MPH. AND OVER (ART. 206, b) $= \frac{600}{L-30} + 16$

VERTICAL EFFECT AT 10 MPH. AND UNDER $= 0.2 \left(\frac{600}{L-30} + 16\right)$

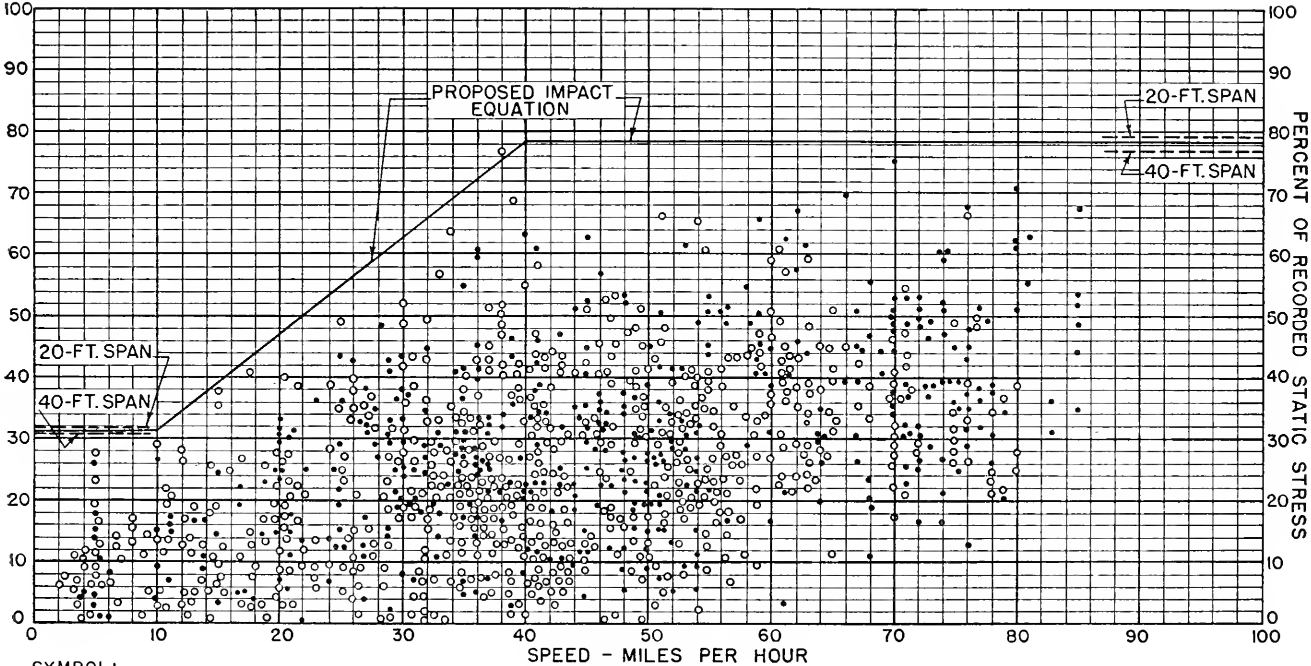
NOTE: PROPOSED IMPACT EQUATION IS SHOWN FOR SPAN LENGTH OF 110 FT. WITH GIRDERS AT 10-FT. CENTERS

FIG. 4

THROUGH AND DECK PLATE GIRDERS
90 TO 130-FT. SPANS

TOTAL IMPACTS

ROLLING EQUIPMENT WITHOUT HAMMER BLOW



TOTAL IMPACT

SYMBOL:
O OPEN FLOOR BRIDGES
• BALLASTED FLOOR BRIDGES

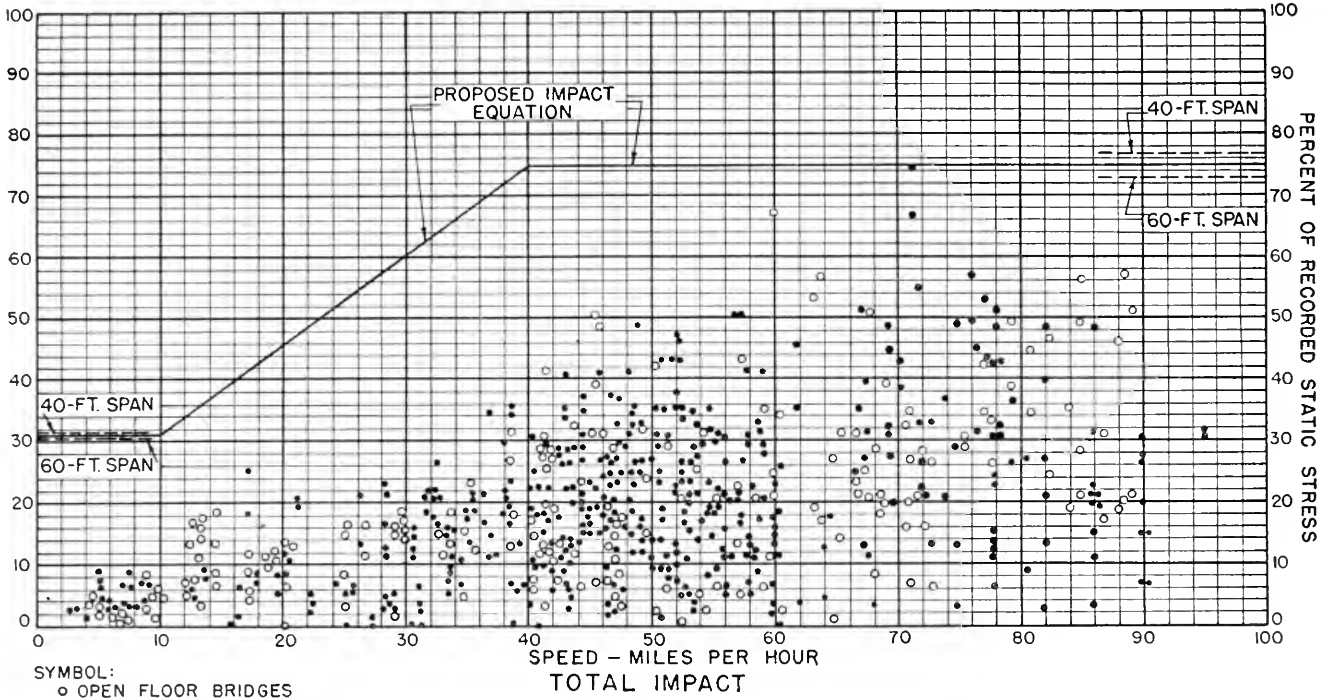
PROPOSED IMPACT EQUATION AT REDUCED SPEED:
ROLL EFFECT AT ALL SPEEDS – SAME AS ART. 206, a

VERTICAL EFFECT AT 40 MPH. AND OVER (ART. 206, b) $= 60 - \frac{L^2}{500}$

VERTICAL EFFECT AT 10 MPH. AND UNDER $= 0.2\left(60 - \frac{L^2}{500}\right)$

NOTE: PROPOSED IMPACT EQUATION IS SHOWN FOR SPAN LENGTH OF 30-FT. WITH GIRDERS AT 5-FT. CENTERS

FIG. 5
SHORT SPAN STEEL BRIDGES
20 TO 40-FT. SPANS
TOTAL IMPACTS
ROLLING EQUIPMENT HAVING HAMMER BLOW



SYMBOL:
- o OPEN FLOOR BRIDGES
- • BALLASTED FLOOR BRIDGES

PROPOSED IMPACT EQUATION AT REDUCED SPEEDS:

ROLL EFFECT AT ALL SPEEDS - SAME AS ART. 206, a

VERTICAL EFFECT AT 40 MPH. AND OVER (ART. 206, b) $= 60 - \frac{L^2}{500}$

VERTICAL EFFECT AT 10 MPH. AND UNDER $= 0.2\left(60 - \frac{L^2}{500}\right)$

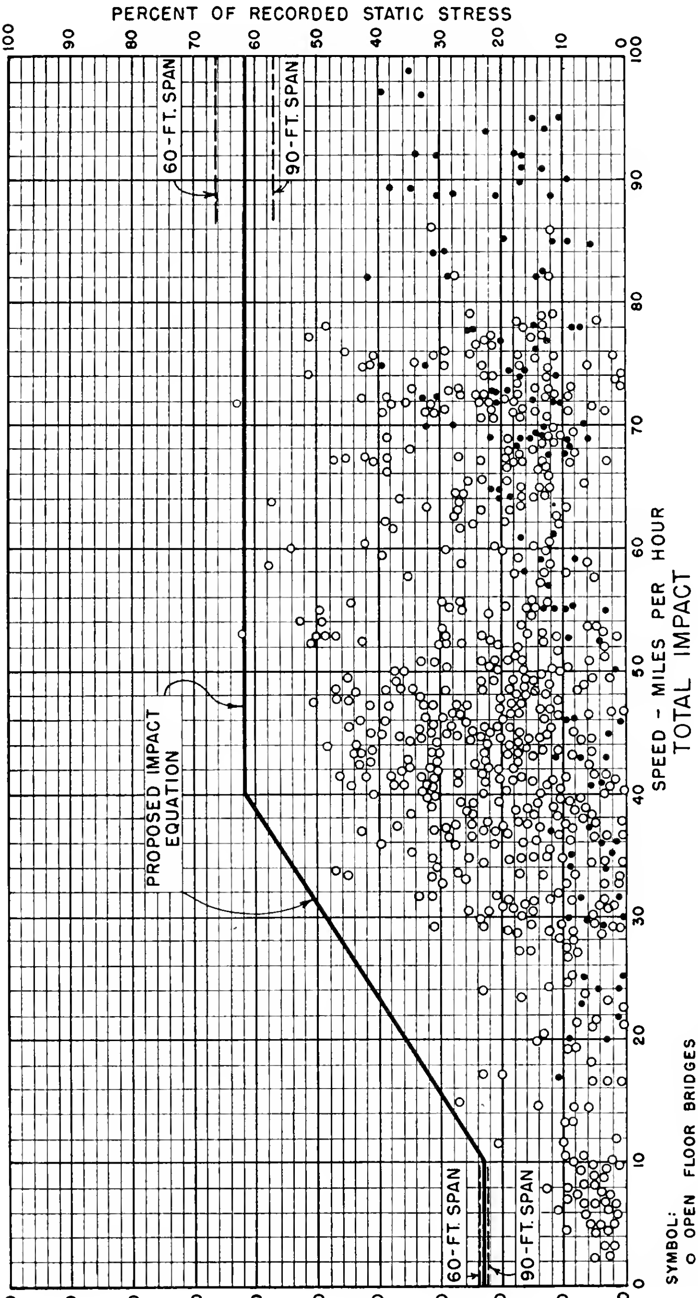
NOTE: PROPOSED IMPACT EQUATION IS SHOWN FOR SPAN LENGTH OF 50 FT. WITH GIRDERS AT 5-FT. CENTERS.

FIG. 6

THROUGH AND DECK PLATE GIRDERS
40 TO 60-FT. SPANS

TOTAL IMPACTS

ROLLING EQUIPMENT HAVING HAMMER BLOW



SYMBOL:
○ OPEN FLOOR BRIDGES
● BALLASTED FLOOR BRIDGES

PROPOSED IMPACT EQUATION AT REDUCED SPEEDS:

ROLL EFFECT AT ALL SPEEDS - SAME AS ART. 206, a

VERTICAL EFFECT AT 40 MPH. AND OVER (ART. 206, b) = $60 - \frac{L^2}{500}$

VERTICAL EFFECT AT 10 MPH. AND UNDER = $0.2\left(60 - \frac{L^2}{500}\right)$

NOTE: PROPOSED IMPACT EQUATION IS SHOWN FOR SPAN LENGTH OF 75 FT. WITH GIRDERS AT 7-FT. 6-IN. CENTERS

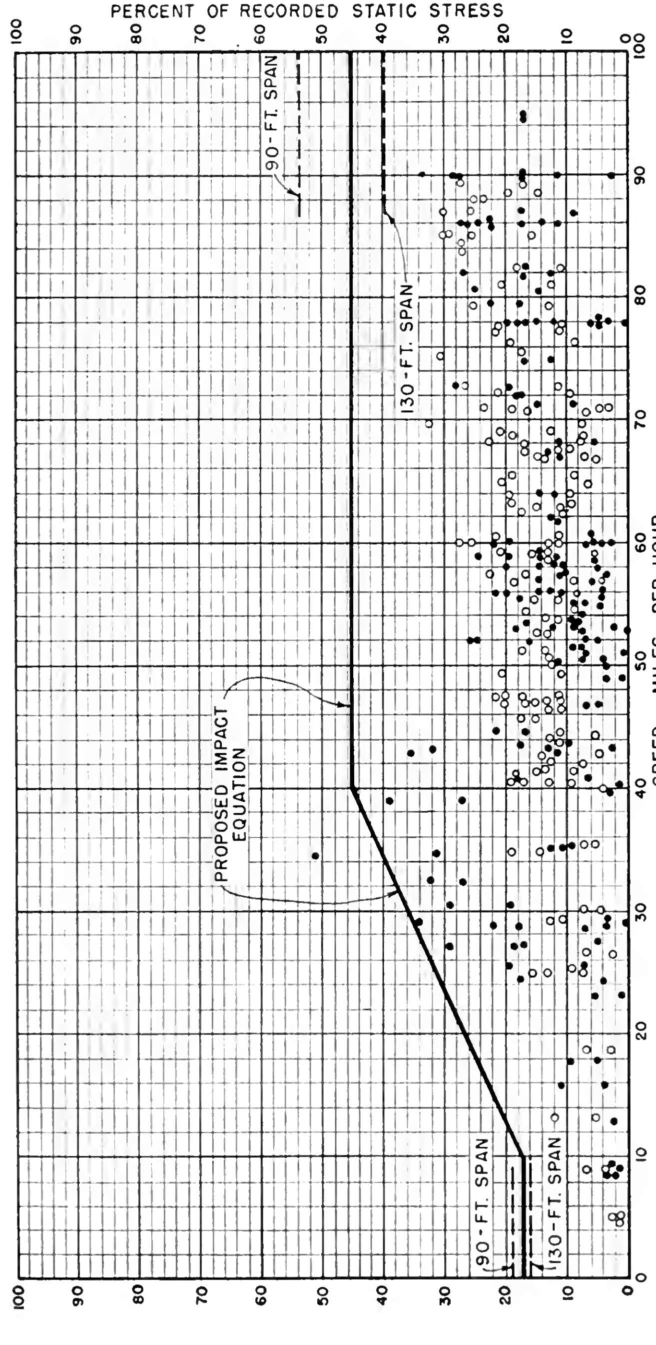
FIG. 7

THROUGH AND DECK PLATE GIRDERS

60 TO 90-FT. SPANS

TOTAL IMPACTS

ROLLING EQUIPMENT HAVING HAMMER BLOW



TOTAL IMPACT

SYMBOL
o OPEN FLOOR BRIDGES
• BALLASTED FLOOR BRIDGES

PROPOSED IMPACT EQUATION AT REDUCED SPEEDS
ROLL EFFECT AT ALL SPEEDS - SAME AS ART. 206, a.

VERTICAL EFFECT AT 40 MPH. AND OVER (ART. 206, b) = $\frac{1800}{L-40}+10$ {FOR 100-FT. SPAN OR MORE

VERTICAL EFFECT AT 10 MPH. AND UNDER = $0.2\left(\frac{1800}{L-40}+10\right)$ {FOR 100-FT. SPAN OR MORE

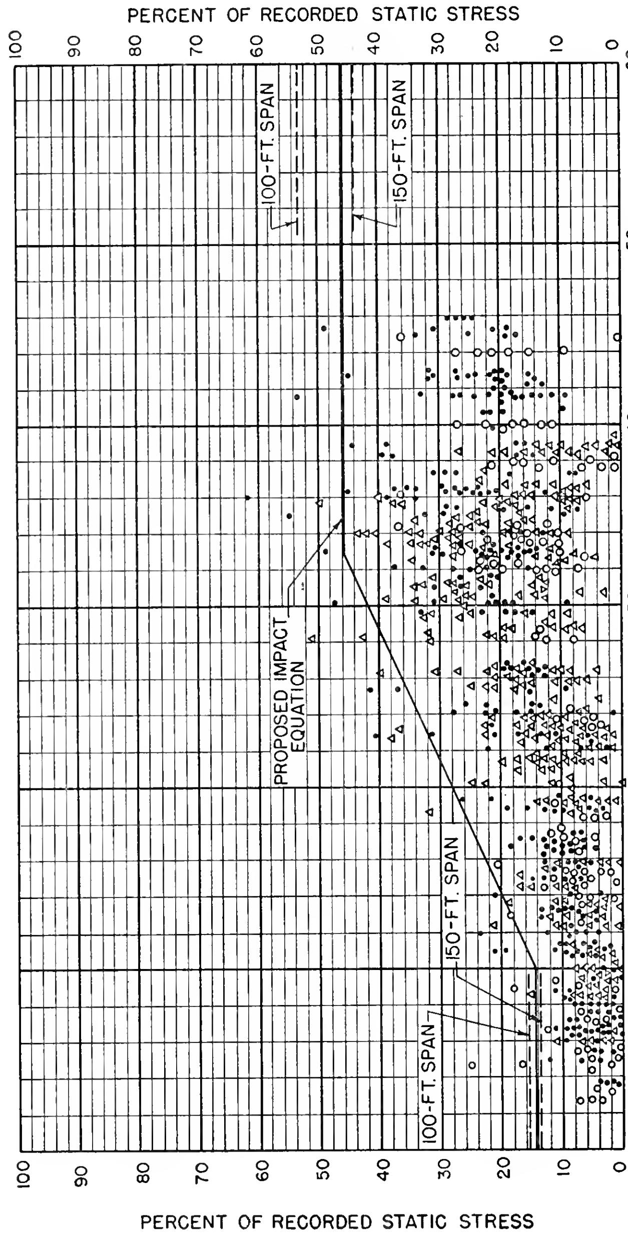
NOTE: PROPOSED IMPACT EQUATION IS SHOWN FOR SPAN LENGTH OF 100 FT. WITH GIRDERS AT 10-FT. CENTERS

FIG. 8

THROUGH AND DECK PLATE GIRDERS
90 TO 130-FT. SPANS

TOTAL IMPACTS

ROLLING EQUIPMENT HAVING HAMMER BLOW



SPEED - MILES PER HOUR

TOTAL IMPACTS

OPEN FLOOR BRIDGES, SYMBOL:-
• D.T.& I.R.R., 136'-9 THRU TRUSS SPAN
o D.T.& I.R.R., 150'-0 DECK " "
Δ T.T.R.R., 142'-0 DECK TRUSS SPAN

PROPOSED IMPACT EQUATION AT REDUCED SPEEDS
ROLL EFFECT AT ALL SPEEDS SAME AS ART. 206, a.
VERTICAL EFFECT AT SYNCHRONOUS SPEED AND OVER (ART. 206, b) $\Big\} = \frac{4000}{L+25} + 15$

VERTICAL EFFECT AT 10 MPH. AND UNDER $= 0.2\left[\frac{4000}{L+25}+15\right]$

NOTE: PROPOSED IMPACT EQUATION IS SHOWN FOR D.T.& I.R.R. 136'-9 THROUGH TRUSS SPAN WITH TRUSSES AT 16'-2 CENTERS AND SYNCHRONOUS SPEED OF 33.6 MPH.

FIG. 9
THROUGH AND DECK TRUSSES
100 TO 150-FT. SPANS
TOTAL IMPACTS
ROLLING EQUIPMENT HAVING HAMMER BLOW

(text continued from page 432)

Fig. 9 shows some values of total impact on truss spans somewhat greater than proposed by Article 107. This is directly attributable to the fact that truss spans approximately 120 to 150 ft. long, subjected to equipment with hammer blow, receive more impact than is provided by Article 206 of the Specifications for Steel Railway Bridges. This was indirectly pointed out in the Proceedings, Vol. 49, 1948, page 207. The character of the reduction equation for truss spans subjected to rolling equipment with hammer blow is consistent with the data and for this reason this has been proposed by the committee.

Report on Assignment 4

Stress Distribution in Bridge Frames—Floorbeam Hangers

C. H. Sandberg (chairman, subcommittee), J. E. Bèrnhardt, S. C. Hollister, H. T. Livingston, F. M. Masters, N. M. Newmark, C. E. Webb, L. T. Wyly.

Your committee submits the following report on stresses in bridge frames and floorbeams hangers as information. In recent years a considerable number of failures in floorbeam hangers have occurred on several railroads. Consequently, a study of floorbeam hanger failures was recommended by Committee 15 and arrangements made with Purdue University whereby Professor L. T. Wyly and his staff would conduct field and laboratory tests, including theroetical analysis.

Survey of Failures

A fact-finding questionnaire regarding floorbeam hanger failures was sent to all Class I railroads in 1947. Fifty roads replied reporting failures as follows:

Span		*No. of Failures*	*No. of Spans*	*No. of Railroads*
Riveted trusses	Square	64	33	7
	Skew	10	10	
Pin-connected trusses	Square	45	18	6
	Skew	6	4	
Totals		125	65	13

The location of failures in riveted spans and the type of hanger sections are shown in Table 1.

All failures were by brittle progressive fracture which is typical of fatigue failures. It is considered that rigid frame bending is the major factor in the failure of hangers near the floorbeams while stress concentrations at rivet holes is the major factor in failures at the upper gussets.

Stress Analysis

A stress analysis study has been carried on of floorbeam hangers which have failed. The total calculated stress consisting of live load, impact and bending stresses in the hangers at the gussets of the riveted spans amounted to 19 to 23 ksi. on the net section.

Field Studies

Stress measurements have been carried on in the field on modern design bridges as shown in Table 2.

TABLE 1.—LOCATION OF FAILURES IN HANGERS

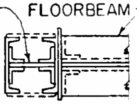
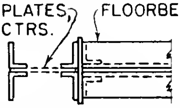
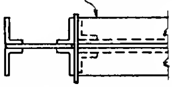
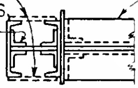
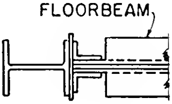
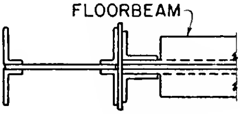
TYPE OF SECTION	NUMBER OF FAILURES	
	NEAR FLOORBEAM	AT UPPER GUSSET
DIAPHRAGM, DEPTH OF FL. BEAM; FLOORBEAM  2-CHANNELS, LACED	1	
TIE PLATES, 4' CTRS.; FLOORBEAM  4-ANGLES, TIE PLATES	2	
FLOORBEAM  4-ANGLES & WEB PLATE	9	62
TOTALS	12	62

TABLE 2.—DETAILS OF HANGERS IN MODERN BRIDGES

YEAR	BRIDGE	HANGER SECTION	TYPE OF TRUSS	STRESS MEASUREMENTS	
				STATIC	DYNAMIC
1947	GALENA	TIE PLATES, ABT. 4' CTRS.; DIAPRAGM, DEPTH OF FL. BEAM; FLOORBEAM  2-CHANNELS & TIE PLATES	PRATT	PURDUE UNIVERSITY	AAR RESEARCH STAFF
1948	ERIE	FLOORBEAM  W.F. BEAM	WARREN	PURDUE UNIVERSITY	AAR RESEARCH STAFF
1948	WAX LAKE	FLOORBEAM  4-ANGLES & WEB PLATE	WARREN	AAR RESEARCH STAFF	AAR RESEARCH STAFF

For the Galena tests all the static and dynamic readings have been tabulated and analyzed, and diagrams partially prepared for the report, which is 90 percent complete.

For the Erie tests the tabulation and analysis of the static and dynamic readings are about 30 percent complete.

For the Wax Lake test all the static and dynamic readings have been secured but the analysis has not been started.

Preliminary conclusions based on the data partially completed are as follows:

1. Tie plates alone as used on the hangers of the Galena bridge do not form a sufficient bracing system for a tension member.
2. Rigid frame bending may be severe and produce heavier stresses than are computed by conventional methods of analysis.
3. Impact stresses analyzed so far are found to be within the 1948 impact allowances.

Laboratory Studies

Pilot tests of stress concentrations at rivet holes and fatigue strength of riveted joints have been made in the laboratory at Purdue University to study the causes of the failures. Preliminary conclusions from work thus far are:

1. The increase in stress concentration at the sides of the rivet holes due to rivet bearing is often quite large and may easily be the major factor in the fatigue failures at the gussets.
2. Fatigue tests of plates connected by rivets to gussets on one side only produce progressive fracture through the plate at the rivet holes at relatively low unit stresses.
3. Loss of clamping force in the rivets reduces the fatigue strength of such riveted joints.

Future Work

Present studies are being continued and extended with a view to ascertaining the cause of these failures and to finding a proper remedy.

Inspection by Railroads

The extent of the hanger failures that have occurred on some railroads indicates the desirability of all railroads keeping a close inspection of floorbeam hangers. In a number of cases close examination has disclosed a number of progressive fractures where none had been suspected. It will be of assistance in this work if the railroads will send details of any such failures to the subcommittee, to Mr. Magee, or to Professor Wyly.

Report on Assignment 5

Design of Steel Bridge Details

G. L. Staley (chairman, subcommittee), P. E. Adams, H. A. Balke, R. P. Davis, W. E. Dowling, G. V. Guerin, Jr., Shortridge Hardesty, W. B. Kuersteiner, M. B. Lagaard, R. W. Mabe, D. V. Messman, N. M. Newmark, A. G. Rankin, J. F. Salmon, R. A. Van Ness, J. E. Yewell, W. L. Young.

Your committee submits as information the following progress report on (1) faulty details in modern design of railway bridges and (2) details of deck fastening for steel railway bridges.

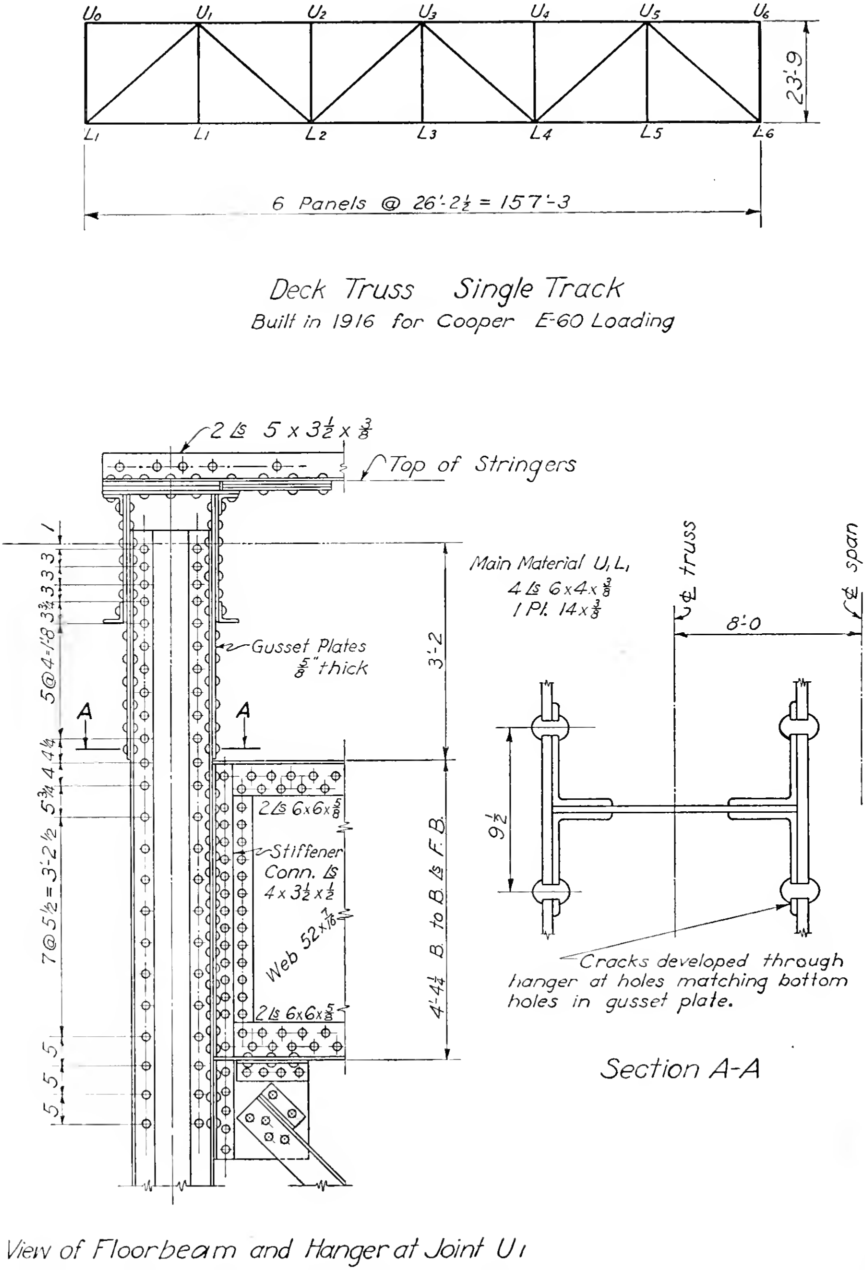
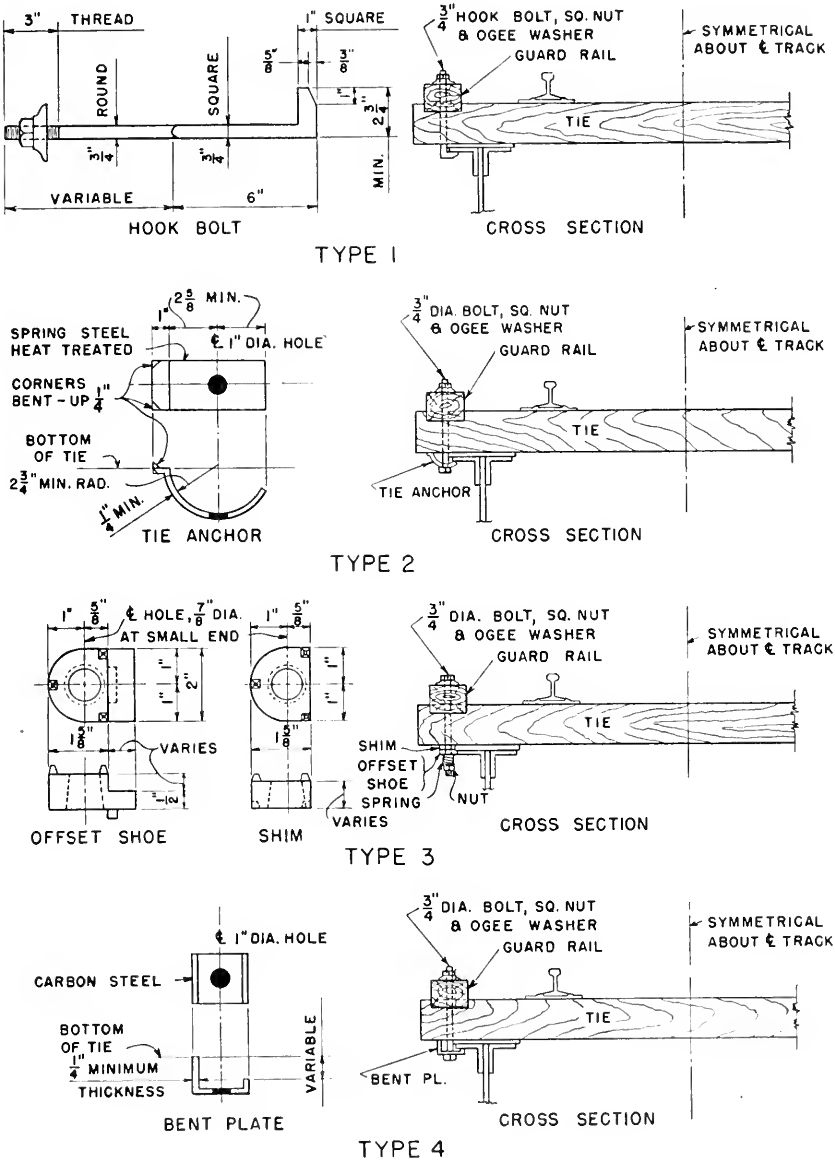


Fig. 1.—Detail of Floorbeam Connection in a Deck Truss Span.



NOTE:
TIMBER DECK FASTENINGS SHALL BE SPACED NOT LESS THAN EVERY FOURTH TIE.

FIG. 2

TYPES OF TIMBER DECK FASTENINGS USED BY AMERICAN RAILROADS

Faulty Details

In 1946, a questionnaire was sent to 58 bridge engineers of Class I railroads to determine if any riveted steel bridge detail, used later than 1911, had developed trouble or failure. Some 16 railroads reported several faulty details which had been included in the Proceedings, Vol. 41, 1940, pages 412 to 444, with one exception. Fig. 1 illustrates a detail which would result in a lack of uniform stress distribution in floorbeam hangers of deck truss spans, resulting from the transfer of load from the floorbeam to the hanger at a point where the hanger has insufficient length to distribute the load uniformly throughout its cross section. Tests now in progress by Purdue University on floorbeam hangers will shed light on this matter.

The committee is not planning to investigate further faulty details in existing bridges.

Deck Fastenings

With the view of furnishing information to prospective purchasers of steel railway bridges regarding suitable deck fastenings called for in the Specifications for Steel Railway Bridges, Fig. 2 has been prepared to illustrate four types of deck fastenings in general use on American railroads.

Type 1, showing hook bolts, is commonly used in every second, third, or fourth tie. The square section is driven in a ¾ in. or 13/16 in. round hole to prevent the turning of the bolt. Ties may be dapped over the flanges of stringers or girders and the side of the bolt is ordinarily placed against the edge of the flange. The length of the hooked portion of the bolt may be varied to fit special conditions, but is usually a standard length. Ogee or malleable iron washers are generally used at the upper end of the bolt, but a combination nut and washer is available.

Boat spikes, washer-head drive spikes or lag screws are used, driven through the guard timber into the ties at points between hook bolts. When the spacing of stringers or girders prevents placing hook bolts through the tie and the guard timber, shorter hook bolts are used through the tie and the guard timber is spiked or lagged at each tie.

Type 2 utilizes tie anchors with standard bridge bolts at every third or fourth tie. Tie anchors are made of a good grade of spring steel which permits this device to remain tight, even with lumber shrinkage. The bent up corners of the anchor cut into the ties and assist in preventing turning of the anchor. The placing of bolts through the tie and guard timber is governed by the stringer or girder spacing, and boat spikes, washer-head drive spike or lag screws are used as described for Type 1.

Type 3 utilizes a cast iron device designed to fit tight against the edges of stringers or girder flanges with a standard bridge bolt, set back from the flanges. The variable thicknesses shown permit making the device fit any distance between bottom of tie and underside of stringer or girder flange. The short lugs on the upper surface of the upper casting cut into the ties to prevent turning. The springs near the ends of the bolts keep the bolts tight. The locations used and other hardware necessary are ordinarily the same as for Type 2.

Type 4 is a simple device which can be made of any suitable steel available in any small shop. Both the vertical and horizontal dimensions are varied to fit individual jobs. The thickness of metal shown is minimum. The bolts are standard bridge bolts. These devices are generally placed as are hook bolts with boat spikes, washer-head drive spikes or lag screws used at intermediate points. The bent plate cuts into the tie slightly when first installed but may turn on the bolt as the lumber shrinks. However, due to its shape, the bent plate cannot entirely disengage itself from contact with the underside of the stringer or girder flanges.

Report on Assignment 8

Design of Metal Culverts of 60-Inch Diameter and Larger, Including Corrugated Metal Arches

H. T. Livingston (chairman, subcommittee), F. H. Boulton, Jr., R. N. Brodie, C. E. Ekberg, E. A. McLeod, D. V. Messman, C. Neufeld, O. K. Peck, C. E. Sloan, G. L. Staley, W. L. Young.

Your committee submits the following as information.

It has confined its work to a study of the design data (gage tables for pipe) in the Specification for Corrugated Structural Plate Pipe and Arches adopted by Committee 1—Roadway and Ballast in 1944, which was deleted from the Manual in 1948.

The most logical approach was to determine whether the metal in structures designed in accordance with the above specification would be stressed beyond reasonable limits. The late A. N. Talbot in 1908 had verified rational moment equations for elastic rings[1] under three conditions of loading. Case III loading with vertical and horizontal pressure uniformly distributed, the latter being any ratio of the former, seemed applicable to flexible pipe conduits where passive lateral pressure is an important factor. The amount at the top, bottom or either side is:

$$M = 1/16\ (l\text{–}q)\ Wd$$

where W is the total vertical load, d the mean diameter of the ring, and q is the ratio of the horizontal to the vertical intensity of pressure.

Working values of two factors in the above equation, W and q, had to be established. The results of the AREA investigation of the loads acting upon culverts of various types[2–3] and the research work at Iowa Engineering Experiment Station,[4] define the load on flexible conduits within rather broad limits, but many factors such as "settlement projection ratio," type of bedding, soil, etc.. are involved, and have not been accurately determined. The value of q, the ratio of lateral to vertical pressure is even more elusive. According to Rankine, horizontal earth pressure may vary from less than 1/3 the vertical for active pressure to many times the vertical for maximum passive pressure.

Coupled with the uncertainty of choosing proper values of W and q in the moment equation is the question of maximum working stress in the flexure equation permitted in cold formed metal where the elastic limit has been exceeded twice in corrugating and forming the structure from flat sheets or plates. In a statically determinate structure above ground, the usual practice is to limit the stress to a definite maximum to prevent excessive deflection of the member or structure. This is necessary because the gravity load continues to exert its effect. On the other hand, in an underground conduit it is conceivable that the restraining and equalizing effect of the earth around the structure may permit safe use of stresses approximating the yield point of cold formed material. With such restraints, the design stress in a corrugated metal conduit may well vary within wide limits.

One producer of flexible pipe claims[5] to have recognized as early as 1926 that the structural failure of flexible pipe was due to excessive change in shape (deflection) instead

[1] Bulletin No. 22—Ill. Engineering Experiment Station, Tests of Cast Iron and Reinforced Concrete Culvert Pipe by A. N. Talbot.

[2] AREA Proceedings, Vol. 27, 1926—Culvert Load Determination.

[3] AREA Proceedings, Vol. 29, 1928—Theory of Culvert Loads.

[4] Underground Conduits—An Appraisal of Modern Research by M. G. Spangler, ASCE Proceedings, June 1947.

[5] Proceedings ASCE February 1947, page 268.

of excessive stress. This has since been confirmed by M. G. Spangler in his bulletin[6] on the Structural Design of Flexible Pipe Culverts, who states that the whole action of structural failure of flexible underground conduits "is one of deflection change unaccompanied by rupture or buckling of the metal ring, although the material in certain parts of the ring may be stressed well beyond its elastic limit."

Whether failure is a result of stress or change in shape, Spangler's method of design[6] should be considered, and if possible used to check the design data referred to at the beginning of this report. Spangler's equation is:

$$\text{Deflection} = D_l \frac{KW_c r^3}{EI + 0.061\, er^4}$$

where K = a constant depending on width of bedding,
W_c = load on the pipe per unit of length
r = the mean radius of the pipe
EI = the effective product of the moment of inertia of the pipe wall and the modulus of elasticity of the metal.
e = modulus of passive pressure of the sidefill, and
D_l = the deflection lag factor, suggested value of 1.25 to 1.50.

Again in this equation there are certain unknowns; those previously mentioned factors affecting load plus the proper value of e, the modulus of passive resistance of the soil, which is similar to q in Talbot's equation, and may vary within wide limits. Those values of e proposed by Spangler were based on tests using unstrutted riveted pipe in diameters from 36 in. to 60 in. E. F. Kelley of the Bureau of Public Roads in his discussion[7] of Spangler's ASCE paper[4] brings out the inadvisability of using Spangler's equation based on present knowledge. If the reliability of the equation is questioned within the range of shop riveted pipe size tested, it would seem unwise to use the equation on field erected pipe of much larger sizes installed by either the unstrutted or strutted method.

The evidence so far presented is that flexible pipe fails structurally due to excessive deflection. The problem then is to determine first, how much deflection should be permitted and second, with that permitted deflection, will the structure safely continue to carry the load with a reasonable factor of safety. Considering the design deflection first; G. E. Shafer of the Armco Drainage & Metal Products, Inc., in his discussion[6] of Spangler's paper[4] states that the common practice is to use 5-percent deflection for design because deflections in riveted pipe of as much as 22 percent have been recorded, with the pipe still carrying the load.

Accepting the 5-percent deflection as a reasonable design criterion, the committee chose to analyze the upper half of a deflected pipe as an arch with fixed ends. The vertical load was considered uniformly distributed over the horizontal projection with an intensity equal to 100 lb. per sq. ft. per ft. of fill height. The horizontal pressure was considered to be distributed parabolically with the maximum intensity equal to the vertical pressure. This means that the total horizontal force would be 2/3 the total vertical force.

The maximum total stress (combined bending and direct) is shown in Table 1 as it varies with diameters and fill heights for typical examples from the gage table under investigation.

[6] Iowa Engineering Experiment Station Bulletin No. 153.
[7] Proceedings ASCE March, 1947.

TABLE 1.—MAXIMUM STRESS IN POUNDS PER SQUARE INCH
UNSTRUTTED PIPE—E-70 LOADING

Diam. In.	*3-10-ft. fill*	*20-30-ft. fill*	*50 ft. fill*
90	11,300	16,850	24,800
120	15,800	24,460	

These computations show a certain consistency in the gage tables.

The committee also considered stress data based on Talbot's equation for moment, which was mentioned earlier in this report. In this case, the flexural stress was assumed equal to 20,000 psi. and the value of q was determined by the moment equation M—1/16 $(l-q)$ Wd. The values of q for various diameters and fill heights are shown in Table 2.

TABLE 2.—RATIO OF HORIZONTAL TO VERTICAL PRESSURE

Unstrutted Pipe—E-70 Loading Using a Stress of 20,000 psi. and $M. = 1/6\ (l-q)\ Wd$

Diam. In.	*3-5-ft. fill*	*11-15-ft. fill*	*36-40-ft. fill*	*56-60-ft. fill*
60	0.735	0.721	0.792	0.838
84	0.832	0.818	0.861	0.893
108	0.880	0.865	0.899	0.922

Here again as in the stress values shown in Table 1, there is an increase in q with diameter and fill height, which indicates greater side pressure on the larger pipe under heavier loads. This study, like the previous one, affirms the consistency of the gages used in the deleted AREA table. Performance of existing installations, based on this gage table, has been generally satisfactory. Those cases of excessive deflection, which have occurred, were due to improper bedding or backfilling. The committee has been informed that a producer of structural plate pipe made an inspection of selected pipe structures that have been in service from 4 to 13 years, in which over 200 structures under highways and railroads, conforming to the gage table in question, showed an average deflection of 2.3 percent of the pipe diameter.

Since the gage table used in the deleted AREA Specifications for Corrugated Structural Plate Pipe and Arches was based on average conditions, it is apparent that further study should be made to evaluate the degree of passive resistance and other pertinent data for various types of soil.

Analysis, made so far by your committee, has been confined exclusively to pipe culverts. It is felt that any specification for structural plate arches should not be combined with specifications for corrugated structural plate pipe, and therefore the study of structural plate arches should be treated separately.

It is the recommendation of the committee that the Association formally ratify the action of the Board Committee on Manual in deleting the Specification for Corrugated Plate Pipe and Arches from the Manual.

It is the opinion of your committee that the preparation of a new specification for the design of structural plate pipe culvert must be deferred, pending the development of a research program to evaluate the degree of passive resistance and other pertinent data on various soils for the determination of the proper gage of metal pipe under varying conditions, as well as to investigate the efficiency of the various types of joints and connections used in metal pipe culverts.

Report of Committee 7—Wood Bridges and Trestles

C. V. Lund, *Chairman,*
H. Austill
W. W. Boyer
H. M. Church
F. H. Cramer
E. F. Croxson
J. P. Dunnagan
N. L. Fleckenstine
E. L. Haberle
Nelson Handsaker
R. P. Hart
R. E. Jacobus
B. E. Jacocks
C. S. Johnson
J. V. Johnston
C. T. Kaier
W. D. Keeney
L. P. Keith
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H. S. Rimmington
W. C. Schakel
A. H. Schmidt
F. E. Schneider
F. W. Small
R. L. Stevens
A. A. Visintainer*
A. M. Westenhoff
W. C. Wilder

Committee

* Deceased Sept. 27, 1948.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revision, reapproval, and deletion of Manual material .... page 454

2. Grading rules and classification of lumber for railway uses; specifications for structural timber, collaborating with other organizations interested.

   Progress report, presented as information .... page 455

3. Specifications for design of wood bridges and trestles.

   Report of special subcommittee on bridge stresses and impact tests, presented as information .... page 455

4. Improved design of timber trestles, collaborating with Committee 17.

   No report.

5. Instructions for inspection of wood bridges and trestles.

   No report.

6. Methods of fireproofing wood bridges and trestles including fire-retardant paints, collaborating with Committee 17.

   No report.

The Committee on Wood Bridges and Trestles,
C. V. Lund, *Chairman.*

AREA Bulletin 478, January 1949.

Alfred Alexander Visintainer

It is with sorrow that Committee 7—Wood Bridges and Trestles, records the death of Alfred Alexander Visintainer, engineer of structures of the Erie Railroad, on September 27, 1948. He was born October 11, 1903, at Mount Carmel, Pa., and was graduated from Lehigh University in 1926 with the degree of Civil Engineer. He immediately entered railway service in the engineering department of the Erie and was successively employed as levelman, transitman; and inspector. On January 1, 1939, he was advanced to construction inspector, then to assistant engineer February 1, 1943. He was appointed assistant engineer of structures in December 1944 and promoted to engineer of structures April 1, 1947.

Mr. Visintainer became a member of this Association in February 1945, being appointed to serve on Committee 7—Wood Bridges and Trestles, the same year. He was a subcommittee chairman at the time of his death. He served also as a member of Committee 15—Iron and Steel Structures, from 1947.

The members of Committee 7 express their sincere appreciation of his whole-hearted cooperation and valuable service, and regret the loss of an admirable friend and associate.

Report on Assignment 1

Revision of Manual

Nelson Handsaker (chairman, subcommittee), H. Austill, W. W. Boyer, H. M. Church, R. P. Hart, C. S. Johnson, L. J. Markwardt, W. O. Nelson, W. A. Oliver, W. L. Peoples.

Your committee recommends the following changes in text now appearing in the Manual:

Page 7–64

Relative Economy of Repairs and Renewals of Wood Bridges and Trestles

Delete the entire item.

Page 7–69

Standardization and Simplification of Store Stock and the Disposition of Material Reaching Obsolescence

Revise paragraphs 4 and 5 to read as follows:

4. Treated pile butts should be used where suitable for foundations of buildings, and other purposes, reducing stocks of timber carried for such use.

5. Suitable bridge timber of obsolete sizes, or surplus timber of odd sizes, should be used for mudblocks for framed trestles, also for platforms, buildings, crib walls, and other purposes; in some cases it may be necessary and advisable to resaw such timber into smaller dimension material.

Insert words "and piling" following "timber" in paragraph 8 to make sentence read:

8. Emergency stocks of timber and piling carried at points other than general supply yards should be treated.

Readopt other paragraphs as now printed in the Manual.

Report on Assignment 2

Grading Rules and Classification of Lumber for Railway Uses; Specifications for Structural Timber

Collaborating with Other Organizations Interested

H. Austill (chairman, subcommittee), H. M. Church, L. P. Keith, A. L. Leach, T. K. May, C. H. Newlin, W. H. O'Brien, A. H. Schmidt, J. R. Showalter, R. L. Stevens, A. M. Westenhoff.

This is a progress report submitted as information.

Specifications for structural timbers and stress-grades now in the Manual conform to the principles of strength-grading as presented in U. S. Department of Agriculture Miscellaneous Publication No. 185 and the stress-grades are based on Table 8 of that publication.

After an exhaustive study of the subject, the Forest Products Laboratory, Madison, Wis., has made a reappraisal of working stresses for timber and has published Supplement No. 2 to U. S. Department of Agriculture Miscellaneous Publication 185 in which is recommended a table of "Basic stresses for clear material under long-time service at maximum design load" to be submitted for Table 8 of Miscellaneous Publication No. 185.

The principal effect of the adoption of the recommendation of the laboratory by this Association will be the increase of working stresses, now in the Manual, by about 10 percent in bending and in horizontal shear, and of about 20 percent in compression perpendicular to grain for seasoned material used under continuously dry conditions.

The committee plans a study of the subject matter now in the Manual with a view to recommending certain changes in substance and form at the next convention.

Report on Assignment 3

Specifications for Design of Wood Bridges and Trestles

(Foreword: A special subcommittee was assigned during the year to collaborate with Committee 30 on the subject of tests of timber structures. The following is report presented as information of this subcommittee, which consisted of R. L. Stevens, chairman, F. H. Cramer, and F. E. Schneider.)

Tests of Stresses and Impact in Timber Structures

The results of stress and impact tests of timber structures conducted by the research staff of the Engineering Division, AAR, are reported by the Committee on Impact and Bridge Stresses in Bulletin 475, September–October 1948. These reports are of importance because they present the first published data on stress measurements of timber structures in actual railroad service.

Trestles tested include an open floor pile trestle on the Missouri–Kansas–Texas Railroad and one on the Southern Railway, also a ballasted deck pile trestle on the Southern Railway. Tests of timber bridge ties on open deck steel spans and floor timbers of ballasted deck steel spans include long bridge ties supported on the chords of a through truss span on the Nashville, Chattanooga & St. Louis Railway, ordinary bridge ties on a deck girder span on the Chicago & North Western Railway, and floor timbers of a ballasted deck through girder span and a deck girder span on the Chicago, Milwaukee, St. Paul & Pacific Railroad. All tests were made under steam locomotives.

The tests were in part exploratory, in preparation of more extensive tests being planned. The results are too few to permit any definite conclusions, but certain behaviour and observations may be remarked upon:

1. The division of load carried by stringers of an open deck trestle may vary considerably; the maximum at midspan in one test at crawl speed exceeded the average by about 50 percent. The average measured stresses at midspan were less than those calculated for simple spans, but greater than those calculated for fully continuous spans, indicating partial continuity where stringers are of two-span length with staggered joints. Stresses measured in the continuous stringers over bents varied widely; in one test the average agreed fairly well with the computed.

2. In the ballasted floor trestle tested, distribution of load between floor timbers (stringers) showed extreme variation, both at midspan and over the bent; timbers under the rails showed maximum loading while those at the center and toward ends of ties showed low values, indicating that the track ties were well tamped under the rails. As in the case of stringers on open deck trestles tested, floor timbers of two-span length with staggered joints show partly continuous action at midspan and continuous action over bents.

3. Stresses measured in piles of a six-pile bent showed the outer piles as carrying much less load than the inner piles, both at crawl speed and at speeds up to 40 mph.

4. Dynamic stresses were measured in connection with the tests of trestles at speeds up to 45 mph. Some high total impact ratios in stringers were found, but these occurred in connection with very low static stresses; impact ratios in stringers at midspan otherwise appear to approximate those found in short steel spans.

5. Low bending stresses at all speeds, in the order of 100 to 140 psi. were found in piles near the ground line. Severe braking and acceleration tests failed to show increased bending stresses.

6. Oscillograph recordings furnished some original data on duration of stress, which is an important factor in consideration of working stresses for timber.

7. Open floor timber bridge ties on steel spans showed very irregular maximum stress values, even on ties of 16-ft. span. Some ties showed stresses in excess of 50 percent of the average and others very low stresses.

8. Floor timbers of ballasted deck steel spans tested showed more uniform maximum loading than the open deck ties; however, an individual timber was found to carry twice the average.

Report of Committee 11—Records and Accounts

F. B. Baldwin, *Chairman,*
S. H. Barnhart
B. A. Bertenshaw
W. C. Bolin
H. T. Bradley
P. D. Coons
Spencer Danby
V. H. Doyle
Benjamin Elkind
J. P. Ferris
D. E. Field
C. C. Haire
H. N. Halper
A. T. Hopkins
C. Jacoby
E. M. Killough
F. C. Knight
C. A. Knowles
W. M. Ludolph
D. O. Lyle
M. F. Mannion
A. H. Meyers
O. M. Miles
J. B. Mitchell
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H. D. Barnes, *Vice-Chairman,*
A. T. Powell
H. L. Restall
J. H. Roach
S. M. Rodgers
H. B. Sampson
H. A. Shinkle
D. C. Teal
J. R. Traylor
H. C. Wertenberger
J. L. Willcox
Louis Wolf

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Bibliography on subjects pertaining to records and accounts.
   Progress report presented as information ________________ page 458

3. Office and drafting room practices:
   (a) Organization; duties and nature of assignments.
   No report.
   (b) Modern mechanical, drafting aids.
   Progress report, submitted as information ________________ page 461

4. Use of statistics in railway engineering.
   Progress report, submitted as information ________________ page 461

5. Construction reports and property records; their relation to current problems.
   Progress report, submitted as information ________________ page 472

6. Valuation and depreciation:
   (a) Current developments in connection with regulatory bodies and courts;
   (b) ICC valuation orders and reports;
   (c) Development of depreciation data.
   Progress report on (a), presented as information ________________ page 472

7. Revisions and interpretations of ICC accounting classifications.
   Progress report, presented as information ________________ page 476

The Committee on Records and Accounts,
F. B. Baldwin, *Chairman.*

AREA Bulletin 478, January 1949.

Report on Assignment 2

Bibliography on Subjects Pertaining to Records and Accounts

V. H. Doyle (chairman, subcommittee), F. C. Knight, B. H. Moore, H. L. Restall, Louis Wolf.

This report is submitted as information.

The committee presents the following bibliography of subjects pertaining to railroad records and accounts for the period November 1947 to October 1948.

Books

1. Railway Accounting Rules. Mandatory and recommendatory accounting rules and forms and rules of order effective September 1, 1947, except as otherwise indicated. Published by Association of American Railroads, Accounting Division in 1947, 341 pp. Members $1, others $2.

2. Railway Accounting Officers 61st Report, Miami Beach, Fla., meeting May 21–23, 1947. Published by Association of American Railroads—Accounting Division. 47. 467 pp. Ill., tables, $2.

3. A Directory of Engineering Data Source. Includes names of federal government agencies issuing engineering data and technical publications, publications of universities and state agencies, publications of scientific and trade associations and publishers of technical books, also a classified list of publications. Published by the Southeastern Research Institute, 5009 Peachtree Road, Atlanta, Ga. $2.

4. Filing Systems for Engineering Offices. Bibliography on reference to books and articles on systems for filing of notes, correspondence, abstracts, reprints, drawings, maps, catalogues, etc., issued by the Engineering Societies Library, 29 W. 39th St. New York 18, N. Y. $2.

Pamphlets

1. National Association of Tax Administrators—Preliminary report of the committee on railroad allocation presented at the 15th annual meeting of the association at Cincinnati, June 23–25, 1947, mimeograph. Federation of Tax Administrators $0.75.

2. List of American Standards—List of all national standards giving prices approved by the American Standards Association includes dimensions for machine tools and parts, rating and testing of electrical equipment, dimensions and identification of pipes and piping, chemical, civil engineering and construction and other standards. American Standards Association, 70 E. 45th St., New York, 17, N. Y. 24 pp. free.

Articles

1. Public Utilities—Depreciation—Use of judgment in estimating life characteristics of depreciable property. G. T. Logan and C. T. Dwight. Edison Electric Institute Bul. Vol. 16, No. 5, May 1948, pp. 153–8. Review of 5 main causes of depreciation, deterioration, inadequacy, obsolescence, casualty and requirements of public authorities; functional vs. physical causes; examples of changing functional depreciation; effect of maintenance expenditures; small samples of recent experience vs. larger samples of older experience: future: life span or forecast method of estimating service life: estimation of remaining life.

2. Valuation and depreciation of public utility property. M. R. Scharff. American Society of Civil Engineers Proc. Vol. 74, No. 6, June 1948, pp. 825–43. Review of status of "fair value" and depreciation problems as they have been left by decisions of U. S.

Supreme Court in cases arising under Natural Gas Act (315 U. S. 575: 320 U. S. 636) solution is suggested based on conceptions that "fair value" and "service value" are identical.

3. Current problems in depreciation accounting. J. V. Toner. Edison Electric Institute Bul. 16, January 1948, pp. 7–10. Address before Controllers Institute of America, Boston, Mass. November 18, 1947, also in Commercial and Financial Chronicle Vol. 166, December 4, 1947, p. 2269 +. Three important current problems in accounting for depreciation with specific proposals for their solution and suggestions for clarifying the treatment of depreciation accounts in financial statements.

4. Depreciation under review. H. E. Hansen and F. R. Lusardi. Conference Board Business Record Vol. 4, August 1947, pp. 231–9. A review of the different policies now in use on account of high replacement costs; a survey of business practices from questionnaire sent out to various industries.

5. Depreciation and the price level—a symposium. J. L. Dohr and others. Accounting Review Vol. 23, April 1948, pp. 115–36. Three affirmative papers by J. L. Dohr, W. A. Paton and M. E. Peloubet, three negative papers by W. H. Bell, H. C. Greer and E. L. Kohler on the following proposition "Resolved that departures from the historical cost basis of recording fixed asset depreciation be recognized as falling within the scope of generally acceptable principles of accounting."

6. Depreciation in the tax laws and practice of the U. S. A., Australia, Canada, Great Britain, New Zeeland and South Africa. R. E. Manning, National Tax Journal, Vol. 1, June 1948, pp. 154–74. Comparison of the various depreciation clauses in other countries.

7. Depreciation Schedule. U. S. Bureau of Internal Revenue: length of life of buildings and equipment, construction equipment, bridges, water works, gas and electric plant. Engineering News Vol. 138, April 17, 1947. p. 635.

8. Two commentaries on Anatomy of Depreciation. H. E. Riggs, C. W. Thompsom. Journal of Land and Public Utilities Economics, Vol. 23, November 1947, pp. 433–8. Also discussion by E. W. Morehouse in Land Economics, Vol. 24, February 1948, pp. 79–81.

9. What is actual cost in depreciation accounting? W. A. Paton, Journal of Accountancy. Vol. 85, March 1948, pp. 206–7. Comment on Accounting Research Bulletin No. 33 committee report on depreciation based on appraised values instead of costs on account of inflated replacement costs.

10. Donated fixed assets. Daniel Borth. Accounting Review Vol. 23, April 1948, pp. 171–178. Donations should not be capitalized and if capitalized no depreciation should be accrued.

11. Accounting Research Bulletin No. 33 issued in January 1948 deals with depreciation and replacement costs.

12. Construction costs and trends. Engineering News Record Vol. 140, May 27, 1948, pp. 88–223.

13. Railway Age Vol. 124, January 3, 1948. Statistical Issue.

14. The impact of rising prices upon accounting procedures. S. J. Broad, C. P. A. Journal of Accountancy Vol. 86, July 1948, pp. 10–20. An investigation of the adequacy of depreciation charges under inflated prices; consideration of LIFO; recommendation that index numbers be used to adjust costs.

15. Dual accounting system suggested for depreciation. Journal of Accountancy Vol. 85, February 1948, p. 103. One system for income tax purposes and one for financial reports to stockholders on account of high costs of replacements. Suggested by F. J

Duncombe member of the committee on accounting procedure of the American Institute of Accountants at the 6th annual conference in Chicago.

16. Accounting procedures and private enterprise. W. A. Paton, Journal of Accountancy Vol. 85, April 1948, p. 278–291. A plea for realistic recording, complete disclosure of assets, evils of conservatism.

17. Congressional proposal for accelerated depreciation. Report by S. Payson Hall in National Association of Costs Accountants Bul. 29, Vol. 19, March 15, 1948, p. 884. Report and comment on bill introduced into Congress which would permit the computation for federal income tax purposes on a five-year basis for all capital additions including land subsequent to December 31, 1947.

18. Points to watch in forms control. W. E. Sexton in American Business, February 1948. Comment and review of article in National Association of Cost Accountants Bulletin 29, Vol. 14, March 15, 1948, p. 896. Suggested centralized control and periodic survey of forms with respect to revisions, combinations and cancellations, also evaluation for retention or destruction.

19. Installing manual fixed asset records by D. R. Thompson. National Association of Cost Accountants Bulletin 29, Vol. 6, November 15, 1947, also comments in NACA Bul. 29, Vol. 16, April 15, 1948, pp. 1037–42. Need for supporting detail with respect to capital investment accounts, the basis for more accurate depreciation charges and consequent effect on cost operations, dependable basis for entries reflecting the retirement and sale of assets, proposed numbering of machines by classification instead of location thus saving the renumbering of machines when relocated.

20. Are we giving away our capital without knowing it? M. E. Peloubet, New York C. P. A. June 1948. Also review in National Association of Cost Accountants Bul. 29, Vol. 22, July 15, 1948, p. 1454. Serious consideration given to the practicability of computing depreciation on replacement values. The use of indices is suggested. Appraisal method also mentioned.

21. Most accounting work can now be mechanized. Railway Age Vol. 125, September 4, 1948, p. 471. Review of what is being done on machines in the railroad accounting offices.

22. Aerial Surveys. Railway Age Vol. 125, August 7, 1948, pp. 20–21. Adaptability of aerial surveys to railroads.

23. Replacement reserves; an engineer's view. C. J. Schwingle. Controller. Vol. 16, April 1948, pp. 182–3.

24. Calls for change in handling of depreciation reserves: Abstract C. R. Cox, Iron Age, Vol. 160, October 9, 1947, pp. 134–5.

25. Depreciation assets replacement becoming most serious problem. Iron Age, Vol. 160, October 16, 1947, pp. 237–40.

26. Depreciation on costs prevents income being fairly stated. W. D. Cranstoun. Journal of Accountancy, Vol. 85, March 1948, pp. 207–9. Comment on committee report in Accounting Research Bulletin No. 33 in reference to accrued depreciation on appraised values instead of cost on account of inflation.

Report on Assignment 3 (b)

Modern Drafting Aids

W. M. Ludolph (chairman, subcommittee), Benjamin Elkind, J. P. Ferris, D. E. Field, A. T. Hopkins, A. H. Meyers, H. B. Sampson, D. C. Teal.

This report is a continuation of last year's report and is presented as information.

The following new drafting aids have come to the attention of this committee during this year:

Cleaning Solution For Tracings

A liquid cleaning solution has been placed on the market which is claimed to be especially suitable for cleaning old tracings so that clean reproductions can be made from them. However, it will not prevent the tracing from becoming dirty again.

It should be borne in mind that this material is a new chemical product and only time will prove whether or not the claims for it will be met and also, that variations in climate and temperature may be responsible for results different from those claimed. Caution is advised in connection with its use.

Drafting Machines

Drafting machines have been equipped with engineering scales and civil engineers' protractor heads so that the head can be clamped in a fixed position or the protractor operated independent of the vernier, thereby making these machines specially suitable for mapping from surveyors' notes.

Also, the brackets and mechanisms have been changed so that work can be done easier on long maps and areas up to 42 in. by 72 in. can be covered at one setting.

Report on Assignment 4

Use of Statistics in Railway Engineering

C. C. Haire (chairman, subcommittee), S. H. Barnhart, H. T. Bradley, Spencer Danby, H. N. Halper, C. Jacoby, C. A. Knowles, M. F. Mannion, O. M. Miles, B. H. Moore, J. F. Piper, A. T. Powell, J. H. Roach, S. M. Rodgers, H. C. Wertenberger.

Your committee submits the following report as information.

The use of statistics in the engineering department of the railways is important and necessary in the administration of the affairs of the department that has in its custody the fixed property and the responsibility for construction and maintenance work.

The improvements and changes in fixed property involving capital expenditures and maintenance expense chargeable to operating expenses for the railways of the United States constitute substantial sums of money; in 1947, the gross capital expenditures of Class I railways for road were $285,000,000 and $1,212,053,026 was expended for maintenance of way and structures. The latter constitutes 13.96 percent of the operating revenues. The administrative and supervisors' work of budgeting and controlling these expeditures requires well designed statistical methods.

In administrative and supervisory work the use of proper statistics is a vital tool; however, the interpretation and determination of the significance of the statistics require much skill. Statistics and/or statistical methods must not be confused with railway accounting. Accounting is a routine of reporting chronologically the expenditures for labor, material and miscellaneous costs, according to the accounting classifications of the Interstate Commerce Commission, modified as required to meet the corporate needs of each carrier. On the other hand, statistical methods are superimposed on accounting results with other data in the process of understanding the circumstances of the past and present performance with the view of controlling present or current expenses and in forecasting the future money outlays and other activities of the engineering department.

Description of Statistical Methods

A statistical method is a technique used to obtain, analyze and present numerical data, and the elements of statistical technique include the:

1. Collection and assembling of data.
2. Classification and coordination of data.
3. Presentation of data in:
   (a) Textual form. (b) Tabular form. (c) Graphic form.
4. Analysis of data.
5. Conclusions derived from the analyses.

In the past much statistical work of the railways involved the collection of the data from the accounting results and comparison of current performance with past performance by the use of the unprocessed accounting figures. Comparisons of past values with current operations, and specifications as to the future left much to be desired. The use of averages combined with human judgment might be signficant if prices were stable and if conditions were comparable, but this ideal situation does not exist as there is a lack of stability in labor and material prices, efficiency, and other changing conditions. As a consequence many of the old time statistical methods are of little value today.

Of recent years in most industries modern statistical techniques are gradually supplanting former concepts, bringing into the picture the principle of frequency distribution, correlation, sampling, trends and index numbers, etc. The new school of statisticians is trained to measure whether or not certain data are significant and/or controlling by approved mathematical processes; but while the modern technique is complex, its use is growing as executives comprehend the improved methods.

To use statistics properly there must be an understanding of the substance and composition of the data and this requires a comprehensive knowledge of the principles of accounting and the accounting routines used to build up the data. Primarily, the analyst should be qualified by experience in railway engineering work, i.e., construction, maintenance and operation and, secondly, he should be familiar with ICC accounting classifications and other regulations affecting engineering department activities, in order to evaluate the recorded figures and understand the adequacies and inadequacies of accounting results. He should understand that the accounting dollars are not always representative of current costs, but result from entries of debits and credits that may not always cover current operations and may contain adjustments, non-cash items, accruals, improper distribution or classification, etc.

Statistics to be of value must be factual; also true statistical comparability can only be had by comparison of like values, therefore, disparity in price levels, effect of use and other significant factors should be recognized and given effect. On the other hand, the use of constructed statistics as representing actual costs and/or operating results should be fully understood and capable of reconciliation with the accounting results. Too frequently, estimates or figures are assembled without foundation or taken "out of the air," and will not stand the test of verification with the accounts. The use of estimates and concepts of cost that are speculative and not attuned to actual costs and accounting records may be misleading and are always open to suspicion.

Statistics as an Engineering Tool

Statistics and statistical technique should be broadly viewed as the tools for the work in the engineering department which has to do with the economics of railway engineering, estimating, cost accounting, analysis of data, cost research, etc. Such work is sometimes unpopular and considered to be without romance or value; nevertheless no successful business or department can conduct operations without the use of statistics and a knowledge of the fundamentals of accounting; certainly the railways which are so closely regulated by government with mandatory accounting and financial regulations imposed upon them and with their need of efficiency and economy can not do so.

It has been aptly said that an engineer is a man that can do with one dollar what any dub can do with two. To arrive at this state of perfection proper statistical tools must be understood and used as in no other way can human judgment and fallibility be guided but controlled.

Need of Sound Statistical Methods in Railway Engineering Departments

Railway engineering department activities are dissimilar from those of many compact industries in that their properties are far flung; concentration such as that of separate plants exists only to a limited degree. Close supervision must therefore be exercised over maintenance and construction work that is usually remote from supervisory personnel. Supervision in the field and from the principal engineering executives requires uniform and expeditious action and the procurement of reports covering the daily, weekly and monthly performance. In addition, numerous periodic and recurring investigations and reports of the current and future needs of the property are constantly required.

The time, material and other reports required for the conventional, accounting routine may be a basis for most of the statistical data required by the engineering department, but such reports often require supplementation by other prescribed reports for statistical processes.

In railway engineering it must first be determined that there is a need for the information and that the use to be made thereof will be of value. Attempts should be made to anticipate what use will be made of the data and to avoid the inclusion of unnecessary and inconsequential elements which serve no useful purpose. The test to be applied before making a statistical investigation and establishing a series of statistical reports is to ascertain whether or not the data will aid in the supervision and control of the departmental activities so as to bring about more efficient and economical operation.

It is also necessary in the administration and operation of the engineering department to maintain historical and comparative statistics of the past years down to date, so as to have the results of the past in compact and convenient book form, appropriately indexed and arranged.[1] These data should be a concise and useful series of reports, easily accessible to be of value. Another important element to be considered in the statistical development of historical reports of the past and for comparison with present operations in the engineering department is the necessity to present such reports simply and clearly for use in educational work with younger employes and in training of supervisory forces. As new men are inducted into supervisory positions they must become acquainted with the experience of the past in a clear and convenient manner, otherwise their knowledge of the property will be limited and their efforts will be impaired.

It should be considered a mandatory responsibility of the organization to train supervisory personnel in knowledge of past history and in statistical techniques of analysis

[1] The Missouri Pacific, Southern, Illinois Central and certain other carriers prepare historical statistical data in pamphlet or loose leaf book form that are examples of compact data to show past accounting results, supplemented by additional statistical data.

of the past experiences. It is not sufficient that potential supervisors be trained solely in engineering work, but of equal importance is the need to instill the knowledge and understanding that accounting—particularly cost accounting and use of statistical data—is a necessary requisite to the assumption of supervisory positions. As a companion to this type of training, candidates for supervisors should be indoctrinated with cost consciousness; the use and understanding of statistics are vital to the attainment of this state of mind.

Organization of Engineering Department and Statistical Information Required

To consider the needs for statistical data in the engineering department it seems necessary to visualize an organization of the type that may be considered satisfactory for the purpose of discussion. Such a visualized organization is shown in condensed graphical form.

The principal officer in charge of the fixed property of the railroad may be a vice-president and chief engineer reporting to the president. The theory of this organization is that the principal engineering executive, a vice-president, has complete responsibility for all construction and maintenance work involving fixed property and the expenditure of capital funds and money outlays for maintaining the fixed property.

The vice-president, as responsible for the overall affairs of the department, should establish a statistical and cost department and institute statistical routines as follows:

Administrative

A. Budget—Capital expenditures[2]

(a) Budget of annual capital expenditures.
Each of the subdepartments should prepare a request for annual budget of additions and improvement work, including therein carryover items from previous year and separate the recommendations to show classes of work with the projects listed in order of importance and necessity. Items should show, separately, amounts chargeable to capital account and incidental expenses chargeable to operating expenses.

(b) The vice-president should examine and rearrange the budget in consolidated form and submit to the president for approval.

(c) Upon approval, the vice-president will distribute the budget as the program of work and instruct that AFE's be prepared for projects that should be finally approved and authorized in order of importance.

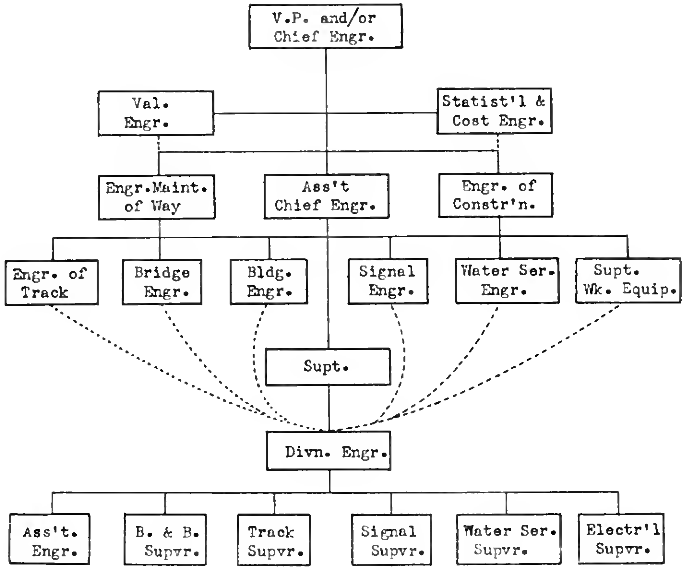
(d) As construction projects are undertaken the costs, both capital expenditures and operating expenses, should be closely checked with the amounts authorized and methods used to control the costs.

B. Budget—Maintenance of way and structures[3]

(a) An annual request for maintenance budget should be prepared by each subdepartment in appropriate detail by classes of maintenance work and summarized according to ICC classification of accounts. The estimates of requirements should be developed separately for the next three to five years and carryover items of the previous year included

[2] The forms and instruction of the U. S. Railroad Administration in Bul. 11, pp. 396–450 (1919) issued by the Division of Capital Expenditures constitute an excellent basis to use in designing a budgetary system of capital expenditures.

[3] The Union Pacific Railroad and certain other carriers have methods and a series of forms that provide a good basis for the study and design of a maintenance budget system.



Organization Chart for an Engineering Department

therein. Amounts of incidental expenses from construction work chargeable to the maintenance budget should be added and total of the estimated maintenance shown.

(b) The vice-president should examine, revise and consolidate the maintenance budget and submit to the president for approval.

(c) Upon approval and determination of the maintenance requirements the budget may be rearranged by months of the year so that allotments can be made by classes of work to operating divisions and/or other subdivisions.

(d) The supervision of the expenditures should be exercised through the issuance of work orders based on recommendations originating with division engineers and monthly comparison of the expenditures as charged to each divisional or departmental work order should be made to develop the over and under amounts.

C. Miscellaneous statistics and data

The vice-president's statistical and cost bureau should be charged with the collection of information and data of a statistical nature affecting annual changes in the fixed property. These data in part may be described as follows:

(a) Annual summary reports of all departmental and divisional activities in changing the property through additions and betterments and from process of maintenance. This reporting is primarily for AFE work but certain renewals may be considered as replacements. Examples of reports are:

1. Lengths of main tracks, yard track and sidings, industry tracks added and retired during the year.

2. Rail, tie, track material and ballast programs.
3. Bridges, trestles and culverts.
4. Buildings and all types of structural property.
5. Signals and interlockers.
6. Telephone and telegraph.
7. Tools and machinery.
8. Other classes of property.
   The data from this series of reports are principally used for reports to the ICC and to other governmental agencies. In addition the reports should be in sufficient detail to historically record the annual activities.

(b) Annual performance reports

Reports of this nature consist of numerous statements of repair and renewal work to various classes of property, in sufficient detail to define the annual activities of the subdepartments, divisions and other subdivisions of the engineering department for general maintenance. These reports supplement the series described in the preceding section. This type of statistical information should be stated in descriptive and quantitative form, and examples in part are as follows:

1. Ditching and embanking.
2. Mowing right-of-way.
3. Stabilizing roadbed.
4. Tunnel repairs and changes.
5. Repairs and painting bridges.
6. Repairs—individual bridges.
7. Track maintenance, rail, track material, and ballast renewals.
8. Labor statistics by divisions:
   Man-hours—for M of W&S work—various operations such as surfacing track, cleaning ballast, etc.
   Man-hours—for other departments and OC&I.
9. Fencing—repairs.
10. Buildings (all classes) repairs and painting by individual structures.
11. Signal and Interlockers—description of work by various classes; also repairs of highway crossing protection.
12. Telephone and telegraph—repairs by miles maintained by classes.
13. Roadway machinery—repairs and condition by individual machines in summary form.

(c) Labor and personnel statistics.

Modern labor relations require analysis and study of construction and maintenance labor rates, rules and working conditions as regards the past, present and future prospects. The engineering department is the employer of a large proportion of nonoperating labor and should assume the responsibility of negotiation with the various crafts. In addition the personnel records of all employees should be maintained and controlled in the department from induction into service until termination for any cause. The records for the purpose of training and promotion of both technical and nontechnical personnel should be meticulously maintained.

(d) Recurring studies to determine where and how the money was expended and relative efficiency or inefficiency of major selected operaerations; also to develop normal or standard costs.

All costs for work done wholly or partly by company forces involve the following elements:

1. Labor
   Man-hours
   Wage rates (or total compensation by work-units and projects)
2. Material
   Kind and quantity
   Unit costs (or total costs by kind and quantities for each work unit)
3. Miscellaneous charges
   Overhead items (supervision, light, heat, power, rentals, depreciation, interest, etc.)
   Contract or other billed items for work performed by others.
   Work train costs.

The above list is intended to be suggestive only, and by no means inclusive of all items that may arise. However, cost-finding practice does classify all costs under the three general headings of labor, material, and overhead.

Statistics for the development of costs which will serve as a guide to the efficiency or inefficiency of work done must be built around the concept of a standard or normal cost for the work unit. Efficiency is a relative term and cannot be stated except in terms of some yard stick. Railroad practice compares costs with those of the previous year; but the most that can be said for such comparisons is that they show which way the costs are headed. Such comparisons may indicate a mere decrease in inefficiency, rather than an operational cost which has crossed the line between inefficiency and efficiency. Only by comparison with a well-established standard can real efficiency or inefficiency be measured. The first object of the establishment of statistical data on maintenance operations or work units should therefore be to determine such standards for the work units.

When the standards have been established, the relative position of the work unit costs on the particular work order or project can be developed and a study made as to the causes of the excessive cost of any inefficient work. It should be understood that the standards themselves are by no means inflexible; in fact, over a period of time the standards themselves should be adjusted in line with progress in efficiency of work. A standard which fits hand work of the pick and shovel period will by no means apply to such work done with the help of modern roadway machines.

In efficiency studies the engineering department should be held accountable for changes in the physical quantities of work units to accomplish a given total amount of work, but should not usually be held responsible for changes in the prices which must be paid for labor, material, etc., to do necessary work. Therefore, the statistical data should be set up with full provision for separation between the physical work units (hours of labor, quantities of material, etc.) and the money cost which is the product of those physical units and the unit prices in effect at the time. The true effect of the changing price level can thus be analyzed and accorded its proper place in the picture.

The work of the cost engineer can be said to consist (in the first instance) of:

1. The separation of physical work units such as man-hours, quantities of material, etc. from the prices or costs paid for these units
2. The allocation of both physical work units and unit prices with total costs to each work operation which it is desired to compare with other like operations.

The following list of work operations is submitted for consideration. It is intended by no means to be complete and inclusive of any and all such operations as all railroads will wish to study:

A. For the track accounts
   (a) Man-hours
      1. Placing cross ties
      2. Placing switch ties (not involving complete turnout)
      3. Laying rail
      4. Placing ballast
      5. Placing turnouts (complete)
      6. Placing crossing frogs
      7. Placing double-slip switches
      8. Installing tie plates
      9. Installing other track fastenings (other than in 3 above)
      10. Raising track and tamping ballast
      11. Lining and gaging track
      12. Surfacing track
      13. Cleaning ballast
      14. Ditching
      15. Mowing and cleaning right-of-way (off track)
      16. Removing snow, ice, and sand
      17. Grouting and repairing embankment
   (b) Average hourly rate of or total compensation of men; separately for each operation under (a).
   (c) Material used on each work operation (allocated). A suggested form of compilation:

Kind of Material	Unit	No. Units	Unit Price	Total Cost	Work Operation Number

   This report should also have the name of the railroad, division or district, location by mile, name of foreman, date of work, etc., as needed. Such reports can best be designed by the statistical and cost department to fit the needs of the particular carrier.
   (d) Cost of work-train service for each work operation.
   (e) Cost of or rental, interest, etc., on use of roadway machines and/or work equipment employed, allocated to each work operation, showing days or hours of use for each machine or piece of equipment.
   (f) Estimate of overhead costs. This should be in such detail as required by the statistical and cost department to supplement the general office information on conditions in the field at the particular location.
   (g) Mileage data:
      1. Type of track worked (first main, other main, all other tracks) for each work operation
      2. Miles of track (mile post to mile post) worked for each work operation covering more than one location

It is possible to design a form to include the above information for the track accounts in convenient check arrangement on the one report. A separate report should be made for each work operation, either in the field by the cost engineer, or in the statistical and cost department from reports sent in by the cost engineers in the field. Information on money costs may have to come from a separate source, but insofar as possible all information should be obtained in the field and on the job.

Statistics for the structural accounts are more difficult to classify. The suggestions given below merely indicate a method of approach which should be given much thought and study after conferences of cost engineers and statisticians as to the needs:

B. For the structural accounts
- (a) Type of structure (building, bridge, etc.) and description (kind, size, identification number, station, mile, etc.)
- (b) Type or kind of work performed
  1. Repairing roof
  2. Repairing walls
  3. Installing partitions
  4. Plumbing
  5. Heating
  6. Lighting
  7. Painting
  8. Flooring
  9. Masonry
  10. Concrete work
  11. Steel work
  12. Driving and/or framing bridge bents including work on piling, caps, stringers etc.
  13. Framing and placing bridge ties
- (c) Labor (man-hours) allocated to each work operation.
- (d) Average hourly rate of or total compensation for each work operation.
- (e) Material used (see suggestions under (c) of A for the track accounts)
- (f) Cost of work-train service for each work operation (if any)
- (g) Cost of rental or interest on investment in or other description of work equipment, pile drivers, etc., used; allocated by work operations. As in the case of the track operations, it may be desirable to compute these costs in the office, but sufficient information should always be reported by work operations from the field to enable such costs to be assigned.
- (h) Special machinery used on the job. Handle as in (g) above
- (i) Estimate of overhead (see (f) of A for the track accounts)

In the case of structural accounts as in the case of track accounts, the final objective is to get all costs together, both physical units and money units, for each work operation, so that the statistical and cost department can study this particular operation in comparson with other like operations, both as regards physical units of labor and material, overhead, etc., and as regards unit prices and total costs of the operation in comparison with others. It may be necessary to set up work units not only in man hours, but also in square yards, cubic feet, etc., on the structural accounts to get any real measure of efficiency.

Such is the kind of information required for a cost analysis which will be informative and sufficient for study to develop normal or standard costs by work units and operations, as required for any conclusions as to the efficiency with which other work is being done. As time goes on these data can be used to advantage for estimating, control of expenses and otherwise.

Supervisory

As the organization chart indicates, the administrative function is vested in the head of the department—a vice-president and/or chief engineer. He delegates detailed supervisory functions to various officers. The engineer of construction is in charge of all items of construction and the engineer maintenance of way is charged with maintenance operations. These officers in turn delegate supervision to subdepartment officers for construction and maintenance work.

Statistical methods for supervision revolve mainly around the control of expenditures by the establishment of sound routines. The statistical and cost bureau heretofore described should be used by the engineer of construction and the engineer maintenance of way to supervise and perform the function of controlling expenses in close liaison with the accounting department. Wherever the accounting routines permit, these should be employed to develop the data required as discussed in the previous section; but, if necessary, the original time and material reports should be consulted and independent records compiled. Unnecessary duplication of record compilation should be avoided, and, in the interest of economy, efforts should be made to blend the engineering department statistical routine with that of the accounting department so as to secure the necessary data in usable form early enough after the work is done to be of value as a means of controlling costs.

It should be remembered, however, that the responsibility to report correctly the data on the work done lies in the engineering department. If foremen, timekeepers, et al, render erroneous and incorrect reports to the accounting department, the costs whether developed in one department or the other will be valueless. It is therefore necessary in any case to provide adequate field supervision through the efforts of cost engineers or others.

Real control of expense for an extensive property requires knowledge of what is occurring day by day, separately by districts, divisions, projects and other details. It is too late to wait days and weeks after events have taken place to apply corrective action and forestall undesirable results. The plan of supervisory control of maintenance of way expenses requires the use of some such routine as that described below.

If the engineering department compiles the data, the cost section in the general office should receive day by day or weekly reports of labor and material used. On large carriers this plan can be modified to decentralize to regions or districts to expedite the handling of detail. The daily time and material reports of track, B&B and other foremen can be used or modified to fit the requirements. In addition, all other organizations, including machine operators, should render their daily reports. These reports may be abstracted weekly on a report rendered in quadruplicate—first copy to accounting office, second for division engineer, third copy to statistical or cost bureau and fourth copy retained at source.

The cost bureau will use a collection sheet to summarize and accumulate the costs for various operations, paying major attention to labor costs (these costs are the most variable, but using material estimates modified according to circumstances. Contract work involving cost plus percent (or fixed fee) or lump sum should be subjected to similar analysis.

The objective is to continually verify allotments and authorized amounts so that overruns, delays, progress, high unit costs, wasteful methods, unauthorized work, and other factors affecting efficiency can be detected and controlled by this routine before it is too late. The costs as developed by this process need not check finally with the accounts, but proper analysis and experience will maintain a tolerance of less than 5 percent.[4]

[4] The Denver & Rio Grande Western Railroad uses a method similar to that described and a study of their routine and results would be helpful in designing a control system of this type.

Another form of control aimed at attaining work efficiency is the needed supervision of forces in the field, particularly, the detailed output of track and other gangs. Such a plan is similar to time studies of manufacturing industries. This method requires the establishment of standard units of work for each operation modified according to traffic and other influencing factors.

The performance of each track and other gang should be constantly measured by the standard units and averages developed for each supervisor or roadmaster and division engineer. The method requires the use of cost engineers who constantly collect the data and compute the standard man-hours for each operation and compare with the actual hours required. A complete and excellent description of this routine is described in AREA Proceedings, Vol. 47, 1946, pp. 286 and 299. Numerous exhibits illustrating the plan are also shown and should be studied for understanding of this routine. This plan can be coordinated with the methods described for cost studies to develop normal costs and the daily control of expenses.

Intelligent Use of Statistics and Cost-Consciousness Needed in Engineering Work

While the accounting classifications of the ICC may not be in sufficient detail for cost accounting work, such classifications may be expanded and amplified by the carriers to develop satisfactory cost finding and statistical routines on their own initiative. Changes are necessary only in the organization, assembly and compilation of underlying detail back of the totals in the accounts; therefore, any carrier can develop cost finding routines along heretofore described lines without additional regulations.

Due to instability of prices of labor and material and the need of more efficiency, the engineering department should train and instill more cost-consciousness in their personnel. The transition to greater use of labor saving machines and high labor costs justifies more attention to statistical methods to develop knowledge and understanding of costs.

As a whole the engineering department should consider wider application of statistical techniques in an effort to attain improved efficiency and to effect further economies.

Conclusions

1. The purpose of this report is to show why engineering departments use and need statistics.

2. The statistical techniques outlined are susceptible to broad or narrow application; i.e., small or large carriers can organize their routines according to size and complexities of engineering activities.

3. Statistics can be used more widely and effectively as a means of promoting economy and controlling costs.

Report on Assignment 5

Construction Reports and Property Records; Their Relation to Current Problems

Louis Wolf (chairman, subcommittee), F. B. Baldwin, H. D. Barnes, B. A. Bertenshaw, W. C. Bolin, A. T. Hopkins, R. M. Nall, H. A. Shinkle, J. L. Willcox.

Your committee reports progress.

The eleven current problems listed and commented on in the report of this committee for year 1947 and again referred to in the 1948 report, continue to be alive and important to the engineer and to any other officer interested in valuation, taxes and in the general financial condition of his railroad.

The committee wishes again, this year, to stress the importance of having properly prepared field completion reports and other basic data furnished by the man in charge of a project and actually on the job, for such items are the base for all property records. A number of roads are conducting educational campaigns along this line, going down as far as foreman, with very good results.

Report on Assignment 6 (a)

Current Developments in Connection with Regulatory Bodies and Courts

H. T. Bradley (chairman, subcommittee), P. D. Coons, Spencer Danby, H. N. Halper, C. Jacoby, E. M. Killough, F. C. Knight, C. A. Knowles, D. O. Lyle, J. B. Mitchell, B. H. Moore, H. L. Restall, J. H. Roach.

While the Interstate Commerce Commission has made no definite allocation of its appropriation to the Bureau of Valuation for its work for the fiscal year beginning July 1, 1948, nevertheless, the bureau is conducting its work for expenditures to encompass the $586,755 which was its appropriation for the previous year. On October 1, 1948, the total force of the bureau numbered 118 employees, and provision was made to add a few additional employees.

Acting under an express direction from Congress, the Bureau of Valuation is engaged in correcting and revising its inventories and valuations of the pipe line companies. As a prerequisite to this work, the Commission served Valuation Order 28 calling for filing by the pipe line companies of revised inventories and statements of original cost for those companies originally valued. Valuation Orders 26 and 27 were served on ten pipe line companies whose properties were never valued by the Commission. These latter orders required the companies to submit an inventory and statement of original cost for their respective properties.

During the year 1947, Class 1 railroads charged to Account 459 Valuation Expenses an amount of $736,269, contrasted with $743,230 for the year 1946. As of October 1, 1948, all Class 1 carriers (135) had filed 588 returns through the year 1944; 129 through the year 1945; 116 through the year 1946 and 15 through December 31, 1947. The accounting section of the bureau is now 92 percent current in its field check of these returns.

The engineering section of the Bureau of Valuation, having completed revised inventories for practically all carriers through 1932, is engaged in bringing their inventories forward to later dates, and as of October 1, 1948, was approximately 76 percent current. The work of the Accounting Section in bringing summaries of original cost other than land is 95 percent* current, and original cost of land is 36 percent* current. The Land section in its work of revising land valuations to current dates has completed 77 percent* of its work.

No tentative valuations as of current dates were completed and served on railroad companies, but, at the request of the Commission, the bureau brought to date the under-

* Based on 7,750,000 mile-years from basic valuation dates through 1947.

lying valuation estimates of carriers involved in reorganization proceedings and other cases. Opportunity is afforded the carrier to check these estimates of original cost, the cost of reproduction new, the cost of reproduction less depreciation, and land values, but in only a few instances have the carriers made a check of the bureau's findings.

Most carriers have participated with the engineering section in the work of bringing their engineering reports to current dates (1910–1914 prices new and less depreciation) when their reports are reached in the bureau's program. This affords an opportunity to check the figures and, at the same time, to secure a carbon copy of the detail pencil sheets which show the cost and depreciation elements on BV Form 643 upon which the information is collected. Likewise, many carriers have secured photostat copies of BV Form 622 on which the original cost summaries are prepared and of BV Form 639 on which the land section's current land values are shown.

Ex Parte No. 166, Increased Freight Rates 1947.—Last year's report contained a summary of valuation testimony and exhibits in the case and included an extract from the Commission's interim report of October 6, 1947. In the final report in the case decided July 27, 1948, under the head of "Value of Property in Common Carrier Service" and "Rate of Return on Property Values, Constructive Year," the Commission said:

VALUE OF PROPERTY IN COMMON CARRIER SERVICE

As stated in our original report, 269 ICC at pages 47–8, at the request of interested parties we placed in evidence data prepared by our Bureau of Valuation, concerning the value of the property in common carrier service of the Class I railroads as of the beginning of the calendar year 1947. The figures for all districts appear on page 47 of that report. The petitioners' statement, also in evidence, showed the amount of depreciation and amortization, which we deducted from the total made up of the original cost item, present value of lands and rights, and the allowance for working capital, to deduce $20,622,713,588 as a rate base. This figure we contrasted with $22,548,967,331, used by petitioners as the basis upon which they estimated the rates of return by districts and regions. We stated (page 48):

"Part of the difference is due to the amounts included for cash and materials and supplies, and in part to the fact that the bureau's figures as to original cost are partly actual costs and partly estimates, and the land figures are estimates of present value, while the petitioners state the amounts carried on their books."

After calling attention to the estimate used by the National Association of Railroad and Utilities Commissioners, $19,591,000,000, derived by adjusting a former estimate made by us to reflect the cost and recorded subsequent changes in property, we said:

"These figures are all much closer together than is usually the case when the aggregate value of railway property is involved, and for present purposes we do not think it necessary to analyze them further, or to divide them by districts or groups."

However, upon the further hearing, the petitions questioned our deduction of a single sum value, but without seriously taking detailed exception to the data submitted by the bureau, other than to protest generally that the rural land values were too small, and that we had not given the weight to cost of reproduction new and less depreciation that the petitioners assumed we had given those items in former proceedings under section 19a of the act. The witness produced by petitioners would have us use $21,380,000,000, instead of $20,622,000,000, as found from the data adduced.

We have considered the data submitted by the bureau as to the estimated costs of reproduction new, and less depreciation. The amounts appear upon page 47 of our original report. In our judgment the fact that cost of reproduction new upon the basis of recent price levels for materials and construction far exceeds the investment of the petitioners as claimed by them, shows the strong effects of inflationary forces, and warrants us in accepting as the basis for computation of the aggregate value of the properties in carrier service the best evidence we have as to original cost and depreciation upon the basis of the accruals by the petitioners, together with present value of lands.

Upon the hearing we were asked to subdivide by districts the values found for the purposes of this case. We have done so, and subjoin our best estimate. For reasons stated in reports in earlier proceedings, it is not practicable to apportion values as between the Western and Mountain-Pacific districts.

Distribution by Regions and Districts, Values Found and Claimed Investment After Depreciation, Class I Railroads, January 1, 1947

	Values Found as Rate Bases	*Investment after Depreciation Accrued*
Eastern district:		
New England region	$ 899,690,747	$ 811,900,040
Great Lakes region	3,353,659,525	3,550,522,316
Central Eastern region	4,197,953,727	4,315,523,417
All regions	8,451,303,999	8,677,945,773
Southern district:		
Pocahontas region	1,068,395,312	1,264,542,549
Southern region	2,819,050,202	2,902,128,201
All regions	3,887,445,514	4,166,670,750
Western district:		
Northwestern region	2,778,978,798	3,049,853,723
Central Western region	3,890,880,955	4,576,349,753
Southwestern region	1,614,104,322	2,078,147,332
All regions	8,283,964,075	9,704,350,808
All districts	$20,622,713,588	$22,548,967,331

As appears by the above table, the values found exceed those set up as investments less accruals of depreciation for the New England region. This is also the case as to important individual railroads in each of the regions in the Eastern district, as appears by inspection of the detailed statement submited for the record by our Bureau of Valuation. On the other hand, large discrepancies between recorded investment and original cost have been pointed out in many of our reports made under section 19a of the act, as to certain large individual carriers.

Without going into a prolonged discussion, we are of the view that the estimates of values stated as rate bases in our original report, and as here subdivided by regions and districts, are reasonable and fair, for the purposes of this proceeding.

RATE OF RETURN ON PROPERTY VALUES, CONSTRUCTIVE YEAR

Applying the estimated net railway operating income to the values stated as above, the annual rate of return from operation is found, as below set forth:

	Percent
Eastern district	5.14
Pocahontas region	9.45
Southern region	5.02
Western district	6.02
All districts	5.70

These computations are based upon continuance of the general level of fuel, material, and supply prices as of November 1, 1947. They are also based on the present going wage level for all crafts, as heretofore explained. They take into account the estimated saving in payroll taxes under the provisions made by the Act of June 23, 1948, reducing the contributions by the railroads, and likewise increasing (but to a lesser amount) their federal corporate income taxes. They presuppose that generally similar increases will be permitted by state authorities on intrastate traffic, or may become effective otherwise.

That the country-wide averages of operating ratios and of rates of return, expressed in terms of percents of operating revenues under the effective rates, fares, and charges for the constructive year, and values, respectively, are affected by the relatively more unfavorable operating conditions in the Eastern district is readily seen when the results for that district are compared with the totals for the remainder of the country. The operating ratio shown for the whole Eastern district is 76.82 percent: for the remainder of the country, 74.64 percent: for the entire country the aggregate ratio is 75.51 percent. The rate of return for the Eastern district is above shown as 5.14 percent, for the remainder of the country 6.09 percent. For the Eastern district and the remainder of the country together the rate of return is 5.70 percent.

Analysis shows that in the Eastern district the unfavorable operating ratios of the dominant lines in each of the three regions are largely responsible for the high figure shown for that district. This appears from the Table I of the appendix to our supplemental report on further hearing, 270 ICC, supra, at page 103.

While the size and traffic position of these particular carriers makes their financial health a matter of great concern, these factors cannot alone control the rate structure of the entire country, or even of the district in which they are sited. It has long been the rule, sanctioned by law and practical experience, that in fixing rates we must have regard not altogether to particular carriers that may be most favorably or less favorably circumstanced, but to the whole situation, and our order must take into account its effect upon all carriers involved. This principle, familiar to all, has applied throughout the history of the act.

As previously pointed out in last year's report, the Commission's finding of aggregate value gave no weight to the Bureau of Valuation's estimated cost of reproduction, apparently, on the ground that the reproduction estimate far exceeded the investment of the petitioners as claimed by them. This decision of the Commission was made notwithstanding testimony given by carrier's witness to the effect that the bureau's price level used in its exhibit was 178 (with 1910–1914 equaling 100) and was about the average of the yearly price level for the 10 years preceding the instant case; and it was far below the current level of prices determined by the bureau to be 257 as a composite for road and equipment for the year 1947. For the Commission to so ignore giving effective weight to current prices would seem to be equivalent to dismissing realities of present price levels and to hold that the investor in railroad securities was entitled to but little consideration when determining the return he should have upon the capital invested in railroad enterprises.

On Novmeber 2, 1948, the Commission released elements of value, as of January 1, 1948, prepared by the Bureau of Valuation for use in Ex Parte 168. A comparison of these elements with those compiled by the same bureau as of January 1, 1947, indicates the cost of reproduction new for all Class I line-haul railways was increased from $32,613,665,594 to $36,391,377,380. An analysis of these figures indicates the bureau's price level was increased from 178 to 200, which again represents an approximate average of the last 10 years. The cost of reproduction less depreciation was increased from $20,653,629,888 to $23,108,194,185. The percent of cost new remained almost static, being 63.328 percent in 1947 and 63.499 percent in 1948. Original cost increased $529,-000,000 during the period. The present value of land and rights decreased about $5,000,-000, which probably represents changes in quantities rather than prices. Working capital, including materials and supplies, increased from $610,000,000 to $703,000,000 due to the increased cost of materials and supplies. Very little cash working capital was allowed in either period.

Court Decisions

No outstanding cases involving valuation were decided by the U. S. Supreme Court during the year.

Report on Assignment 7

Revisions, and Interpretations of ICC Accounting Classifications

H. D. Barnes (chairman, subcommittee), S. H. Barnhart, H. N. Halper, B. H. Moore.

This is a progress report presented as information.

The Interstate Commerce Commission has issued the following orders of interest to engineers since this committee's last report (Proceedings, Vol. 49, 1948, page 322).

Order dated July 22, 1948, effective January 1, 1949, prescribes a new account in Investment in Road and Equipment entitled 59, Unapplied material and supplies—Equipment, to which will be charged the cost of materials and supplies purchased specifically for the construction of new equipment and located at the point of use.

Order dated October 27, 1948, effective January 1, 1949, modifies the texts of Investment Account 3, Grading, and Operating Expense Account 202, Roadway maintenance, to provide for charging the cost of constructing dikes and new channels for streams to the investments accounts.

In addition to these orders the Bureau of Accounts released the following new ruling:

Issued July 1, 1948—

Case A-187. Provides that the cost of passenger car washing facilities be charged to Account 20, Shops and enginehouses.

Report of Committee 24—Cooperative Relations with Universities

S. R. Hursh, *Chairman,*
Lem Adams
L. L. Adams
J. B. Babcock
T. A. Blair
Armstrong Chinn
H. R. Clarke
R. P. Davis
O. W. Eshbach
P. O. Ferris
C. G. Grove
E. M. Hastings
Clark Hungerford
R. B. Kittredge
N. W. Kopp
H. S. Loeffler
E. E. Mayo
A. A. Miller
J. B. Akers, *Vice-Chairman,*
C. T. Morris
C. H. Mottier
W. C. Perkins
W. C. Sadler
E. C. Vandenburgh
Barton Wheelwright
R. C. White
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Stimulate greater appreciation on the part of railway managements of

   (a) the importance of bringing into the service selected graduates of colleges and universities, and

   (b) the necessity for providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

   Progress report, presented as information .... page 478

2. Stimulate among college and university students a greater interest in the science of transportation and its importance in the national economic structure, by cooperating with and contributing to the activities of student organizations in colleges and universities.

   Progress report presented as information .... page 478

3. The cooperative system of education, including summer employment in railway service.

   Progress report presented as information .... page 480

4. Investigate textbooks and other material available for instruction in railway engineering, and make pertinent recommendations thereon.

   No report.

The Committee on Cooperative Relations with Universities,

S. R. Hursh, *Chairman.*

AREA Bulletin 479, February 1949.

A

Report on Assignment 1

Stimulate Greater Appreciation on the Part of Railway Managements of:

(a) the importance of bringing into the service selected graduates of colleges and universities, and

(b) the necessity of providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

J. B. Akers (chairman, subcommittee), H. R. Clarke, C. G. Grove, E. M. Hastings, Clark Hungerford, N. W. Kopp, C. H. Mottier, R. C. White.

This is the third progress report on this subject, presented as information.

Information was developed to supplement and expand the scope of previous studies. Data in replies to questionnaires were received from 48 colleges and 32 railroads. These data have been tabulated and are being studied for publication in later reports.

Preliminary study shows that the starting salaries of college graduates were somewhat higher in 1948 than in 1947. For instance, the average salary of over 2000 graduates reported on was $275 in 1948 as compared with $253 in 1947. Only 24 colleges reported graduates entering railroad service. For these the corresponding average salaries were $283 and $256.

The information received develops the surprising fact that 30 percent of the graduates employed in 1947 have already left the service.

There is little evidence of productive results under item (a) of the assignment. The only way to assure worthwhile accomplishment is for the engineering departments of the railroads to interest themselves in it and impress on managements that the best method of providing officers or engineers for the future lies in the development of a program for the training of college graduates.

Report on Assignment 2

Stimulate Among College and University Students a Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure

By Cooperating with and Contributing to the Activities of Student Organizations in Colleges and Universities

R. P. Davis (chairman, subcommittee), L. L. Adams, T. A. Blair, H. S. Loeffler, E. E. Mayo, W. C. Perkins, W. C. Sadler, Barton Wheelwright.

This progress report is presented as information.

The main activity of Subcommittee 2 has been to promote visits of railroad men to the technical colleges.

L. L. Adams, assistant chief engineer, Louisville & Nashville Railroad, visited five universities in the South during January 1948; namely, Tulane University, the University of Alabama, the University of Tennessee, Georgia Institute of Technology and Vanderbilt University. At Tulane University he was guest speaker at a meeting of the local chapter of the American Society of Civil Engineers and later spoke before the senior engineering class. At the other institutions he spoke before the senior class.

At all these institutions he found the students had but a vague conception of the opportunities offered by the railroads. A number of the men showed interest by requesting private interviews after his formal addresses. Mr. Adams reports that the University of Tennessee has recently started a course in railroading, transportation and traffic.

R. A. J. Morrison, division superintendent of the Baltimore & Ohio Railroad, was the guest speaker early in the year of the civil engineering department of West Virginia University. He talked before a class in railroad engineering for one hour and later in the day, conducted a two-hour question and answer symposium before a group of students in Railway Engineering Economics. He made a very fine impression on the students and directed their thinking along the lines of railroad employment.

I. H. Schram, chief engineer of the Erie Railroad, delivered an address entitled "Advantages of Railroad Employment" on May 7 before a group of junior and senior civil engineering students at Case Institute of Technology.

W. B. Irwin, assistant to vice-president, Great Northern Railway and a former member of Committee 24, reports that he delivered an address on April 16, 1948 at a "Symposium on Civil Engineering Opportunities" held at the Fourth Regional Conference of ASCE student chapters at the University of Minnesota. In his talk he emphasized the magnitude of the railroad industry and discussed the engineering problems of the present day due to faster trains and heavier loading. He then explained the work of technical graduates entering railroad service and showed the opportunities offered young engineers in the operating departments.

N. W. Kopp, assistant engineer design and T. B. Thompson, special engineer, signal department of the Illinois Central Railroad, visited the University of Iowa on February 25, 1948. Mr. Thompson delivered an address entitled, "Railway Signaling" before the student chapter of the AIEE. Mr. Kopp spoke before the engineering college faculty luncheon group on the subject of "The Engineer's Place in Railroading." Later in the day, the latter address was presented to the student chapter of the ASCE. Mr. Kopp reports that the talks were limited to about half of the time allotted, the remainder being spent in answering questions. Quoting Mr. Kopp: "The question and answer period proved to be of great interest to the students and seemed very effective in arousing interest."

On October 1, 1948, Mr. Adams of the Louisville & Nashville, gave a talk before the Georgia Chapter of the ASCE. This meeting was held at the Georgia Institute of Technology, which afforded an opportunity for the ASCE student chapter of the Institute to be present. Mr. Adams spoke on the general subject of damages to the L. & N. Railroad on the gulf coast caused by the hurricane of September 1947. He also devoted some time to presenting to the students the advantages of going into railroad service upon graduation.

Report on Assignment 3

The Cooperative System of Education, Including Summer Employment in Railway Service

O. W. Eshbach (chairman, subcommittee), Lem Adams, J. B. Babcock, Armstrong Chinn, P. O. Ferris, C. G. Grove, A. A. Miller, E. C. Vandenburgh.

This is a progress report presented as information.

Vacation and Cooperative Employment

A desired result of good college relations is the number and quality of graduates attracted to the railroad industry each year. There is no better way to create confidence and understanding than to expose those most concerned to a work experience prior to graduation or concurrently with undergraduate study.

Your committee has emphasized the importance of:

1. Summer employment of undergraduates.
2. Summer employment of faculty.
3. Employment of cooperative students.

There has been much activity on the part of some railroads in vacation employment of undergraduates, some employment of faculty, and increasing interest in cooperative education.

During the year, a study of the extent of vacation employment will be made. Last year the committee confined its efforts to an investigation of postwar employment of cooperative students. A detailed progress report was submitted to Committee 24 summarizing employment last year and in the years prior to the war and also the comments of participating institutions. This report is a generalization of the data furnished by all cooperative schools working with railway companies and is submitted for the information and guidance of all concerned.

Participating Institutions

The following institutions operating on the cooperative plan placed students with railway companies during the last year:

Alabama Polytechnic Institute
University of Cincinnati
University of Detroit
Drexel Institute of Technology
Fenn College
Southern Methodist University
Northwestern University
University of Tennessee

This is approximately half of the institutions engaged in cooperative education. The number of students employed totaled 116. Two-thirds of this number were enrolled in two institutions and about 90 percent in half of the participating schools.

Participating Railroads

Five railway companies employed cooperative students from two or more institutions. They are:

Baltimore & Ohio
New York Central
Louisville & Nashville
Pennsylvania
Southern

Nine other railway companies participated with at least one institution last year, although many of them had more extensive experience in pre-war years.

Comparison With Pre-War Experience

Employment of cooperative students is not yet comparable to that of pre-war years insofar as numbers are concerned. While four institutions which previously placed students with railway companies did not do so last year, it is anticipated that most of these will resume relations as conditions become more normal.

Some of the schools have commented that seniority rules and union shops have prevented the employment of mechanical engineering students in types of work best suited to their development and interests. Others have expressed hope for a better organization of work experience. While it is believed that conditions in different sections of the country will prevent uniform experience, it should be noted that two of the institutions having the longest and most extensive relations are pleased with the fine cooperation and experience enjoyed by their students over many years.

Type of Work and Compensation

Words used in classification of jobs are usually inadequate in conveying proper knowledge of the experience associated with them. The most frequently mentioned assignments of cooperative students are: Surveying, including rodman and instrumentman; drafting; field engineering; maintenance of electrical equipment; engineering assistant and occasionally section hand; locomotive engineman and brakeman. The departments include construction, maintenance of way, signal, and architectural.

The compensation now paid students is approximately twice the pre-war rate. It varies from $155 per month to $300, depending on type of work and experience. A fair median seems to be about $240 per month.

Summary

There is genuine interest among cooperative institutions in developing better relations and work experience with railway companies. Institutions and railways which have had the longest and most extensive experience with the cooperative plan have been pleased with the relationship and have mutually benefited from it.

As a source of influence among engineering students, the experience and knowledge gained by cooperative students while working with the railroads is important. Interest in the work to be done is prerequisite to successful employment. A well planned series of work experiences, uninhibited by some of the traditional practices of the past, is the best insurance of good relations and successful future employment.

Report of Committee 4—Rail

C. B. Bronson, *Chairman,*
J. B. Akers
J. E. Armstrong
S. E. Armstrong
H. Austill
W. C. Barnes
C. H. Blackman
T. A. Blair
W. J. Burton
E. E. Chapman
C. M. Chumley
H. R. Clarke
C. J. Code
L. S. Crane
P. O. Ferris
J. L. Gressitt
R. L. Groover
G. F. Hand
C. B. Harveson
E. M. Hastings
W. E. Heimerdinger
S. R. Hursh
F. R. Layng
H. S. Loeffler
G. M. Magee
E. E. Mayo
Ray McBrian
R. J. Middleton
C. E. Morgan
R. E. Morrison
E. E. Oviatt
R. E. Patterson
W. H. Penfield
W. C. Perkins
L. T. Nuckols, *Vice-Chairman,*
G. A. Phillips
J. G. Roney
J. C. Ryan
E. F. Salisbury
R. T. Scholes
I. H. Schram
F. S. Schwinn
A. A. Shillander
W. D. Simpson
G. L. Smith
E. C. Vandenburgh
J. C. Wallace
Barton Wheelwright
R. P. Winton
J. G. Wishart
Committee.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report .... page 484

2. Conditions affecting service life of rail, and the causes of rail failures and other defects, in collaboration with AISI Technical Committee on Rail and Joint Bars.
   Progress report, presenting 1949 report on the rails investigation .... page 485

3. Rail failure statistics, covering (a) all failures; (b) transverse fissures; (c) performance of control cooled and Brunorized rail.
   Progress report on entire assignment, presented as information .... page 489

4. Methods for hardening and reconditioning rail ends to control rail battering.
   No report.

5. Economic value of various sizes of rail.
   Progress report, presented as information .... page 506

6. Continuous welded rail, collaborating with Committee 5.
   Progress report, presented as information .... page 508
   Appendix 6–a, Laboratory tests of two welded rails .... page 510

7. Service tests of various types of joint bars.
   Progress report, presented as information .... page 513

8. Joint bar wear and failures; revision of design and specification for new bars and bars for maintenance repairs.
   Progress report, presented as information .... page 514

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THE COMMITTEE ON RAIL,

C. B. BRONSON, *Chairman.*

James Moore Farrin

The Committee on Rail records with sorrow the death on July 25, 1948 of a former member, James Moore Farrin. An appropriate memoir to him appears in the report of the Committee on Economics of Railway Location and Operation.

Report on Assignment 1

Revision of the Manual

L. T. Nuckols (chairman, subcommittee), J. E. Armstrong, H. Austill, W. C. Barnes, C. H. Blackman, T. A. Blair, C. B. Bronson, W. J. Burton, J. L. Gressitt, R. L. Groover, G. F. Hand, E. M. Hastings, F. R. Layng, G. M. Magee, R. J. Middleton, E. E. Oviatt, E. F. Salisbury, A. A. Shillander, G. L. Smith, E. C. Vandenburg, J. C. Wallace, Barton Wheelwright.

Your committee recommends reapproval of the following item in the Manual:

Page 4–12

General Requirements of a Rail Joint

1937

Report on Assignment 2

Conditions Affecting Service Life of Rail and the Cause of Rail Failures and Other Defects

In Collaboration with AISI Technical Committee on Rail and Joint Bars

C. B. Bronson (chairman, subcommittee), W. C. Barnes, E. E. Chapman, H. R. Clarke, C. J. Code, L. S. Crane, J. L. Gressitt, G. M. Magee, Ray McBrian, L. T. Nuckols

A progress report on the rails investigation, comprising a cooperative project conducted at the Engineering Experiment Station of the University of Illinois, the expense of which is borne jointly by the Association of American Railroads and the American Iron & Steel Institute Technical Committee on Rails and Joint Bars, is presented below:

Appendix 2-a

Investigation of Failures in Railroad Rails and Their Prevention

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Organization and Acknowledgment

This investigation is financed equally by the Association of American Railroads and the American Iron and Steel Institute.

Student assistants, T. S. Noggle, Frank Bolda, and F. K. Lampson, and M. C. Moore, mechanic, have worked on this investigation during the past year.

Examination of Control Cooled Rails Which Failed in Service

Fifty-five failed control cooled rails were sent to the laboratory by the engineers of 15 railroads. Reports were written on these rails for the railroad engineers, the rail manufacturers and W. C. Barnes.

Table 1 gives a summary of these failures; Table 2 lists each rail separately.

Table 1.—Summary of Failures in Control Cooled Rails

Transverse fissures from hot torn steel	22
Detail fractures from shelling	19
C. F., T. F. and H. S. H. from welded engine burns	4
Base breaks	3
Engine burn fractures	2
C. F. from segregation streak	1
Gage corner shelling	1
Transverse fissure from shatter crack	1
Transverse fissure from inclusion	1
Transverse fissure from small hole near weld	1
	55

Note.—See Table 2 for definitions of C. F., T. F. and H. S. H.

TABLE 2.—FAILED CONTROL COOLED RAILS EXAMINED AT TALBOT LABORATORY FROM SEPTEMBER 1, 1947 TO SEPTEMBER 1, 1948

D. F. = Detail Fracture
C. F. = Compound Fissure
T. F. = Transverse Fissure
E. B. = Engine Burn
H. S. H. = Horizontal Split Head

Source of Failed Rail	*Laboratory Failed Rail No.*	*Size of Rail*	*Mill*	*Heat No. Rail Letter and Ingot*	*Date Rolled*	*Classification of Failure*
C. & O.	533	131	Gary	37004–D–2	1940	C.F. from welded engine burn
M.P.	534	112	Inland	26054–A–4	1939	D.F. from shelling
L. V.	535	136	Lackawanna	4444–A–11	1937	D.F. from shelling
L. V.	536	136	"	8506–A–11	1937	D.F. from shelling
N.Y.C.	537	127	"	5163–A–7	1942	T.F. from hot torn steel
N.C. & St. L.	538	90	Ensley	879573–G–20	1937	D.F. from shelling
S.P.	540	112	Steelton	86013–G–16	1936	C.F. from segregation
C. & O.	541	131	Gary	45057–E–25	1939	T.F. from welded engine burn
C. of N.J.	542	130	Steelton	88573–F–20	1943	T.F. from hot torn steel
N. & W.	543	131	Steelton	85572–B–5	1942	" " " " "
C. & O.	544	131	Inland	20754–C–14	1944	D.F. from shelling
M. P.	545	90	Steelton	83002–F–8	1937	T.F. from hot torn steel
N.Y.C.	546	127	Lackawanna	28005–E–18	1943	T.F. from hot torn steel
U.P.	547	131	Inland	24197–G–14	1940	T.F. from hot torn steel
C. & O.	548	131	Steelton	81219–C–1	1942	D.F. from shelling
C. & O.	549	131	Gary	591971–E–5	1947	Base break from seam
N.P.	550	100	Lackawanna	—	1936	D.F. from shelling
C. & O.	551	131	Inland	16057–F–3	1938	D.F. from shelling
D. & H.	552	112	Steelton	85481–C–9	1939	T.F. from hot torn steel
M.P.	553	112	Gary	46024	1938	D.F. from shelling
N.Y.C. & StL.	554	112	Lackawanna	21170–B–21	1942	T.F. from hot torn steel
C. & O.	557	131	Gary	49010–C–14	1939	H.S.H. from welded engine burn
C. & O.	558	131	Gary	44267–E–21	1937	C.F. from welded engine burn
C. & O.	559	131	Steelton	86338–C–1	1935	D.F. from shelling
C. & O.	560	131	Steelton	86346–D–1	1935	Gage corner shelling
C. & O.	561	131	Steelton	86030–D–5	1938	T.F. from hot torn steel
C. & O.	562	131	Steelton	87205–C–7	1935	T.F. from hot torn steel
C. & O.	563	131	Inland	22097–C–11	1937	T.F. from hot torn steel
C. & O.	564	131	Inland	15147–A–1	1938	T.F. from hot torn steel
C. & O.	565	131	Inland	30042–B–8	1941	T.F. from hot torn steel
C. & O.	566	131	Inland	30042–D–15	1941	T.F. from hot torn steel
A.C.L.	567	131	—	—	—	Base break in switch point
D. & H.	568	112	Steelton	83440–C–12	1942	D.F. from shelling
I.C.	569	112	Inland	36502–	1941	D.F. from shelling
I.C.	570	112	Inland	29551–	1941	D.F. from shelling
I.C.	571	112	Gary	36490–	1941	D.F. from shelling
C. of N.J.	572	130	Steelton	89226–F–7	1942	D.F. from shelling
D. & H.	573	112	Steelton	87553–F–20	1941	D.F. from shelling

M.P.	574	112	Colorado	2071–	1938	Base break from torch cut
C.P.	575	100	Algoma	5174–B–3	1940	T.F. from hot torn steel
B. & O.	576	131	Steelton	88175–D–7	3–1942	T.F. from hot torn steel
W.M.	577	112	Steelton	89435–C–9	8–1943	D.F. from shelling
W.M.	578	112	Steelton	85001–F–8	1–1943	D.F. from shelling
W.M.	579	112	Steelton	85001–G–8	1–1943	D.F. from shelling
D. & H.	580	112	Steelton	85200–G–11	1940	T.F. from inclusion
N. & W.	581	131	Steelton	85572–A–15	11–1942	T.F. from hot torn steel
N.Y.C. & St.L.	582	112	Lackawanna	21170–A–21	3–1942	T.F. from hot torn steel
G.N.	583	110	Gary	32159–D–8	3–1937	T.F. from shatter crack
G.N.	584	112	Inland	36151–D–4	1939	T.F. from small hole near welded joint
C.P.	585	100	Algoma	2133–G–5	6–1935	Engine burn fracture
C.P.	586	100	Algoma	2133–F–5	6–1935	Engine burn fracture
N.Y., N.H. & H.	587	131	Steelton	82119–B–6	1939	T.F. from hot torn steel
N.Y., N.H. & H.	588	131	Steelton	82119–A–6	1939	T.F. from hot torn steel
C. & O.	589	131	Steelton	87205–C–10	10–1935	T.F. from hot torn steel
C. & O.	590	131	Steelton	87205–D–10	10–1935	T.F. from hot torn steel

The detail fractures from shelling are discussed more thoroughly under a separate report on shelly rails. The transverse fissures from hot torn steel were all in rails rolled before 1944 when the mills started taking extra precautions against over-heating the rail blooms. This type of failure occurred in rails from four different mills that reheat their rail blooms. Fig. 1 shows four typical transverse fissures from hot torn steel.

The three base breaks developed from a seam, a torch cut and one was in a switch point from a point of heavy bearing on a steel support. Fig. 2 shows in (a) the fracture of rail No. 574 which broke from the torch cut at the edge of the base. The fractured surfaces in the rail head rubbed together making a bright surface which was mistaken

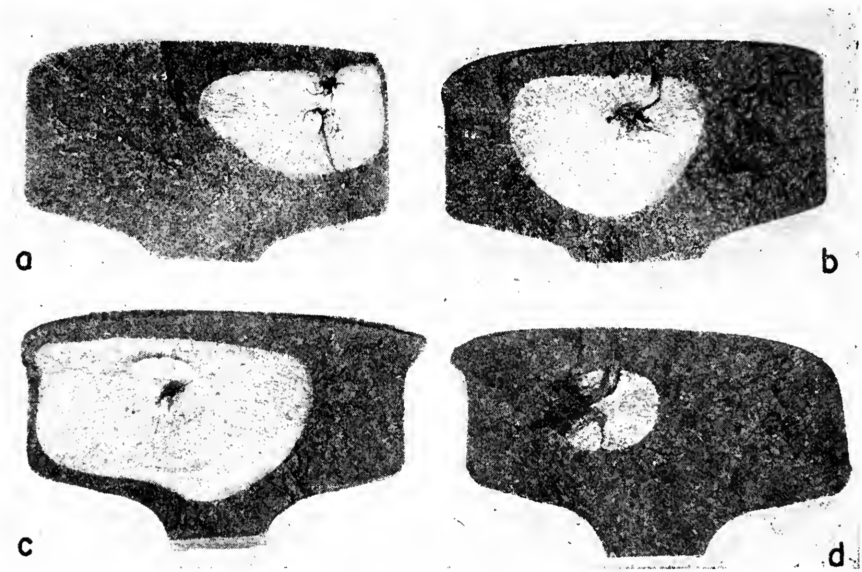


Fig. 1.—Typical Transverse Fissures from Hot Torn Steel.
(a) Laboratory rail No. 554.
(b) Laboratory rail No. 561.
(c) Laboratory rail No. 562.
(d) Laboratory rail No. 564.

for a transverse fissure. Fig. 2 b shows a micrograph of the edge next to the torch cut. The white grains near the top edge are martensite which tested 557 Knoop hardness, which is equal to approximately 500 Brinell hardness.

There were four failures from welded engine burns. There was one transverse fissure in a control cooled rail rolled in 1937 due to improper control cooling. A few transverse fissures were received in rails which were stamped control cooled but were afterwards found to have been hot bed cooled during the time when it was permissible to ship two percent of an order as hot bed cooled rails. The most serious types of failures occurring in recent control cooled rails which seem important to control are detail fractures from shelling, and the more common gage corner shelling spots.

a

b

Fig. 2.—Base Break from Torch Cut Rail 574.

(a) Fracture of rail showing torch cut at edge of rail base.
(b) Micrograph of steel adjacent to torch cut. Mag. 67 X. White layer at surface is chrome plating. Below this is oxide scale. White grains below oxide indicate a layer of martensite which has a hardness of 500 Brinell.

Report on Assignment 3

Rail Failure Statistics

W. C. Barnes (chairman, subcommittee), C. B. Bronson, L. T. Nuckols.

These statistics present the rail failures reported to December 31, 1947, and are submitted as information.

In this report the term transverse fissure includes fissures which originated in shatter cracks and other subsurface defects, such as hot torn steel, inclusions, and welded engine burns.

Table 1, prepared from reports on form 402-L, and for years prior to 1945 on form 402-E, lists the number of rails in which transverse fissures were reported as occurring

Table 1.—Transverse Fissured Rails by Railroad and by Year Failed—All Rollings, of All Processes

SERVICE FAILURES

Year Failed	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	Total
AT&SF	43	85	111	140	341	455	307	141	157	112	1892
ACL	66	67	114	121	250	218	267	50	51	43	1247
Ban & Aroos	0	0	0	0	3	3	4	3	1	2	16
B&OCT							2	0	0	12	14
B&LE							10	6	9	3	28
B&M	28	25	11	20	20	42	64	17	11	26	264
B&O	382	282	341	459	588	425	367	332	205	209	3590
CP	114	164	225	501	425	381	238	274	214	184	2720
C of Ga	59	70	77	109	62	77	61	58	31	40	644
C of NJ	90	69	87	81	77	77	71	48	45	61	706
C&EI	23	15	15	23	31	48	51	62	57	42	367
C&O—Ches Dist	187	145	93	100	123	107	71	57	68	88	1039
C&O—PM Dist	4	2	2	0	9	15	4	1	1	0	38
C&NW	38	47	62	78	162	168	160	135	137	168	1155
CB&Q	134	151	161	199	272	323	287	244	141	152	2064
CI&L							12	16	8	6	42
CMStP&P	46	45	73	77	119	136	136	132	79	87	930
CRI&P	98	74	91	115	158	247	183	168	123	127	1384
C&S							26	21	3	10	60
D&H							67	31	14	19	131
DL&W	72	72	56	85	96	23	27	29	36	22	518
D&RGW							203	212	159	22	596
Erie	123	133	110	129	210	207	177	99	98	87	1373
Fla. EC							152	92	67	86	397
GN	215	246	232	224	225	261	243	247	266	175	2334
GM&O—So Rgn	55	83	62	85	57	48	29	54		26	499
GTW							43	43	13	20	119
IC	515	520	474	556	699	534	311	197	64	65	3935
KCS							14	21	4	0	39
L&HR	6	8	11	2	10	1	8	0	0	4	50
L&NE	1	5	4	1	8	3	5	2	7	2	38
LV	52	41	30	30	79	41	33	49	22	22	399
L&N	178	178	130	139	202	217	160	159	116	133	1612
Me. Cen.							12	15	14	0	41
MStP&SSM							13	49	23	30	115
MKT	35	80	66	110	81	131	92	57	28	31	711
Mo Pac RR						228					228
Mo Pac Lines						68	25	24	31	42	190
NC&StL	19	30	35	48	39	57	58	43	32	19	380
NYC (Sys)*	389	433	357	462	617	652	406	344	225	202	4087
NYC&StL						192	86	47	29	45	399
NYC Transit							3	3	6	2	14
NYNH&H	39	31	28	30	34	24	21	14	3	5	229

DETECTED FAILURES

Year Failed	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	Total
AT&SF	194	326	377	275	566	831	647	538	580	388	4722
ACL	251	141	118	288	809	1220	870	1302	924	1120	7043
Ban & Aroos	0	0	0	0	0	0	0	0	49	0	49
B&OCT							0	0	0	0	0
B&LE							0	0	0	0	0
B&M	45	706	927	785	661	884	276	695	315	212	5506
B&O	807	431	609	797	1421	1269	780	844	978	801	8737
CP	1239	1780	2011	3813	5201	5964	5064	4957	3105	4338	37472
C of Ga	110	91	130	248	223	407	179	157	184	0	1729
C of NJ	0	0	0	0	0	0	0	0	3	0	3
C&EI	77	89	96	120	138	271	352	304	338	316	2101
C&O—Ches Dist	923	786	533	539	417	540	393	458	465	559	5613
C&O—PM Dist	34	27	20	14	111	124	87	27	23	0	467
C&NW	294	465	631	820	1463	1495	1578	1641	1176	1461	11024
CB&Q	602	662	668	747	774	1733	1245	1342	1408	885	10066
CI&L							19	21	57	2	99
CMStP&P	288	285	311	340	684	468	1062	1083	1069	1173	6763
CRI&P	366	336	269	136	390	605	645	643	527	552	4469
C&S							28	47	82	17	174
D&H							192	196	114	111	613
DL&W	461	400	140	0	1089	369	333	300	303	375	3770
D&RGW							114	254	190	14	572
Erie	264	350	238	599	405	1133	971	549	666	619	5794
Fla. EC							367	119	164	279	929
GN	92	142	171	150	258	366	430	535	516	430	3090
GM&O—So Rgn	0	0	0	0	28	298	306	60		265	957
GTW							112	112	83	89	396
IC	557	596	727	471	1483	2000	1925	1907	1314	1418	12398
KCS							178	66	94	0	338
L&HR	0	0	22	0	24	0	24	13	12	6	101
L&NE	0	0	26	0	27	12	4	15	16	13	113
LV	0	218	6	150	171	128	189	156	67	127	1212
L&N	530	408	530	561	925	800	747	684	648	653	6486
Me. Cen.							21	63	50	0	134
MStP&SSM							39	24	96	90	249
MKT	169	61	132	4	455	249	515	214	141	118	2058
Mo Pac RR						1328					1328
Mo Pac Lines						502	728	399	462	507	2598
NC&StL	70	42	115	110	126	218	172	184	68	84	1189
NYC (Sys)*	430	562	352	428	623	844	559	1119	750	724	6391
NYC&StL						392	318	199	215	172	1296
NYC Transit							0	0	0	0	0
NYNH&H	92	110	58	98	121	268	136	74	86	68	1111

Table 1.—Continued

SERVICE FAILURES

Year Failed	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	Total
NYO&W	55	33	20	20	32	16	62	6	1	24	269
N&W	22	21	10	7	9	2	3	1	5	3	83
NP	213	185	147	217	241	317	310	288	289	188	2395
PRR**	513	442	323	425	440	517	365	415	290	259	3989
P &LE	--	--	--	--	--	--	4	0	3	0	7
Reading	164	191	148	283	267	172	173	70	49	47	1564
RF &P	3	2	5	16	27	28	31	27	20	12	171
Rutland	1	2	2	2	1	1	3	1	2	1	16
Seaboard	--	--	--	--	--	--	49	23	24	21	117
SP (Pac Lines)	394	590	347	356	452	426	445	267	209	179	3665
Sou. (Sys)	256	226	258	256	337	311	278	277	246	188	2633
StLSF	--	--	--	--	--	--	111	142	102	101	456
T&NO	--	--	--	--	--	--	239	186	123	66	614
Tex & Pac	--	--	--	98	93	160	128	124	72	71	746
UP (Sys)	923	1033	481	395	447	389	226	241	176	172	4483
Virginian	34	39	30	27	16	12	11	13	10	4	196
W. Md.	133	50	53	43	48	35	26	27	14	33	462
W& LE	--	--	--	--	--	--	3	3	5	1	12
All Roads	5722	5915	4882	6069	7407	7795	6976	5707	4238	3801	58512

DETECTED FAILURES

Year Failed	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	Total
NYO&W	0	0	0	0	0	0	53	0	56	2	111
N&W	45	44	53	63	49	34	40	40	58	17	443
NP	246	310	227	326	470	589	440	471	702	475	4256
PRR**	857	920	1158	1048	858	799	1026	909	646	644	8865
P &LE	--	--	--	--	--	--	4	6	1	5	16
Reading	0	0	0	0	0	0	367	735	287	321	1710
RF &P	52	61	37	186	168	238	228	207	176	106	1459
Rutland	0	0	0	0	8	0	0	0	0	9	17
Seaboard	--	--	--	--	--	--	197	159	299	440	1095
SP (Pac Lines)	637	477	709	1424	1610	2002	1536	1377	1362	909	12043
Sou. (Sys)	1263	1061	1101	2151	2454	3541	2360	1955	1835	1998	19719
StLSF	--	--	--	--	--	--	573	655	415	532	2175
T&NO	--	--	--	--	--	--	795	924	837	739	3295
Tex & Pac	--	--	--	760	758	839	869	582	524	0	4332
UP (Sys)	2032	2525	3022	4226	4479	3045	1587	1356	1148	4957	28377
Virginian	0	0	126	90	173	114	114	0	0	0	617
W. Md.	0	72	82	148	228	152	184	133	144	224	1367
W& LE	--	--	--	--	--	--	0	3	3	0	6
All Roads	13027	14484	15732	21915	29848	36071	31978	30813	25831	29364	249063

--No report received.
*Including IHB failures.
*Including LI RR & PRSL.

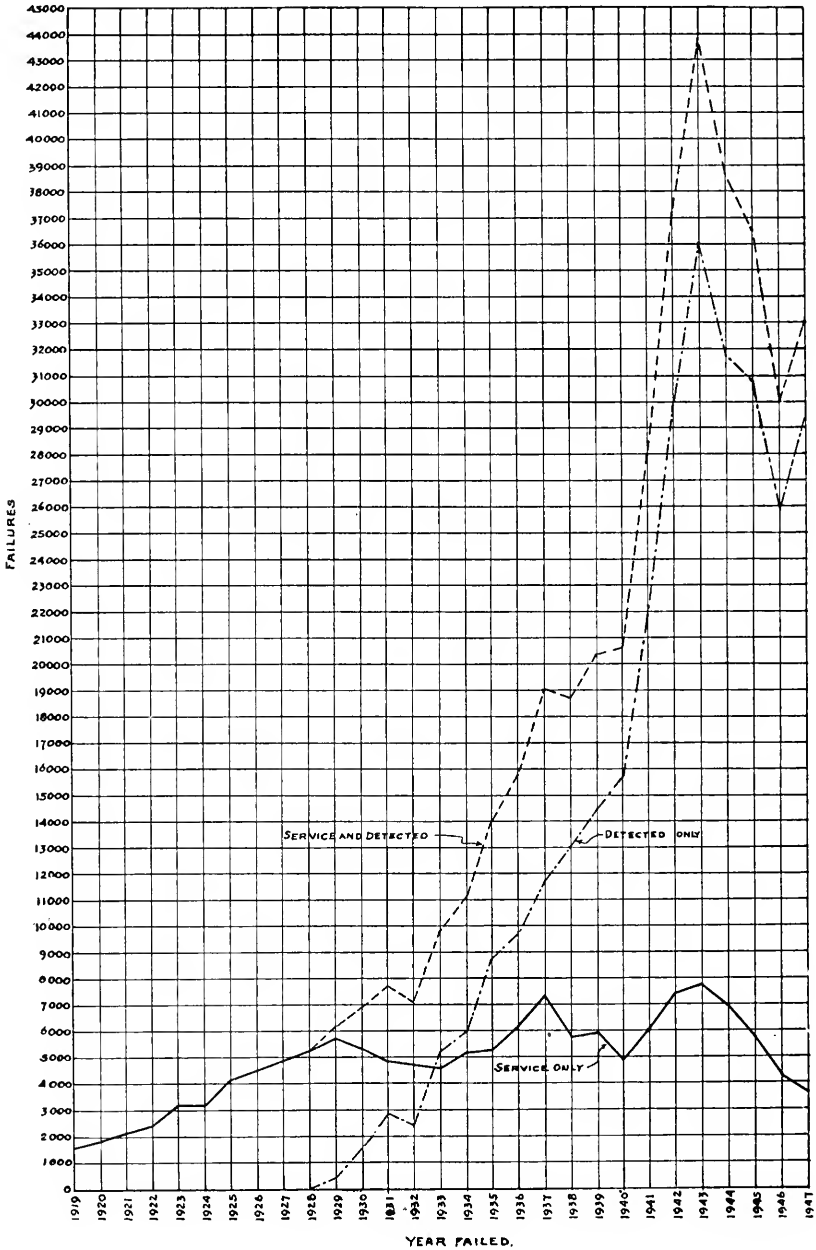


Fig. 1.—Total Transverse Fissured Rails Reported Each Year. Rails Made by All Processes Included. 1930 Includes Eleven Months Only.

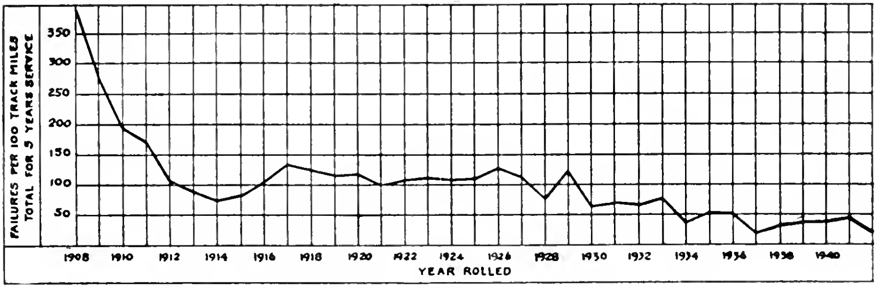


Fig. 2.—Service and Detected Rail Failures in the United States and Canada.

each year from 1938–1947, incl., service and detected separately, in rails of all ages, made by all processes, segregated as to roads. A zero indicates that the road reported no transverse fissures, while a dash indicates that no report was received for that year. As data are lacking on the track miles of rail of various ages included in each road's report, this table should be used for comparison of failures on individual roads from year to year rather than for comparison of failures as between different roads. As rails which are not control cooled and which contain detected transverse defects are not always broken for verification of the type of defect, this table probably includes some transverse defects which are not transverse fissures. The yearly decrease in both service and detected failures continues, influenced no doubt by the increased percentage of control cooled rail in track which rail produces practically no transverse fissures.

Fig. 1 charts the data from Table 1 of this report and from reports of previous years.

Table 2 lists the tons and track miles separately of control cooled and other process rails rolled in the years 1937–1946, incl., which are included in these statistics, with the exception of Table 1 and Fig. 1 which include rails of all ages.

Table 3 shows the combined service and detected failure rates in all types of failures accumulated in one to ten years' service of rail rolled in 1933–1946, incl. This table includes failures from all roads whose reports are complete. The marked decrease in failure rates starts with the 1937 rollings at which year the purchases of control cooled rail first exceeded those of plain open-hearth rail.

Fig. 2 is a continuation of the chart previously presented showing the rates of failure of all types accumulated in five years' service of rollings from 1908 to 1942, incl.

Table 4 shows separately by roads and by mills the track miles of open-hearth control cooled rails, Brunorized rails, and intermediate manganese control cooled rails of rollings 1937–1946 incl., and also the total failures in 1947 by roads. The total failures in open-hearth control cooled rail amounted to 6725 which is a reduction from the total of 7863 reported for the 1946 failures.

Table 5 presents the failures accumulated to December 31, 1947 in rollings 1937–1946, incl., by type of failure and by mill, open-hearth control cooled and intermediate manganese control cooled data shown separately. The excessive number of web failures within limits of the joint bars are under investigation and steps are being taken to reduce them.

Table 6 is a new table which gives a segregation by roads, by mills and by type of failure of the open-hearth control cooled rail failures listed in Table 5. It shows the predominant type of failure on each road and how excessive failures of any type on one or more roads may increase the total failures of that type in rail, from any mill or mills,

(text continued on page 502)

TABLE 2.—TONS AND TRACK MILES OF EACH YEAR'S ROLLINGS 1937–1946, INCL., INCLUDED IN THESE STATISTICS

All Roads and All Processes from All Mills

Year Rolled	OH Control Cooled Only		Brunorized and "Other" Process		Total	
	Tons	Track Miles	Tons	Track Miles	Tons	Track Miles
1937	634,917	3,527.64	235,873	1,289.50	870,790	4,817.14
1938	396,333	2,219.65	60,973	362.14	457,306	2,581.79
1939	790,249	4,225.87	54,128	309.72	844,377	4,535.59
1940	875,235	4,753.84	52,846	316.44	928,081	5,070.28
1941	1,044,487	5,598.96	40,414	232.09	1,084,901	5,831.05
1942	1,090,034	5,876.37	14,129	95.61	1,104,163	5,971.98
1943	1,269,333	6,874.51	11,443	77.24	1,280,776	6,951.75
1944	1,547,644	8,438.93	7,845	54.12	1,555,489	8,493.05
1945	1,499,091	8,010.64	0	0	1,499,091	8,010.64
1946	1,149,299	6,112.30	0	0	1,149,299	6,112.30
Total	10,296,622	55,638.71	477,651	2,736.86	10,774,273	58,375.57

TABLE 3.—SERVICE AND DETECTED FAILURES OF ALL TYPES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1947 PER 100 AVERAGE TRACK MILES, IN ALL ROLLINGS BY ALL PROCESSES FROM ALL MILLS

Year Rolled	Years of Service									
	1	2	3	4	5	6	7	8	9	10
1933	6.2	11.7	25.6	52.4	73.5	91.6	122.9	174.9	246.3	332.0
1934	4.6	13.6	19.3	25.9	35.8	53.1	80.1	116.7	175.9	233.1
1935	4.2	9.6	16.3	32.3	51.0	85.8	129.0	213.5	326.9	445.1
1936	4.2	7.3	18.1	30.6	50.7	90.7	144.7	228.7	333.4	453.2
1937	3.3	5.8	11.3	15.9	23.9	39.3	67.8	100.1	140.4	160.7
1938	2.2	5.2	10.4	20.7	32.6	48.7	63.9	80.9	100.9	
1939	2.6	5.0	9.9	20.8	36.8	58.3	90.0	123.6		
1940	1.3	3.1	8.7	18.3	37.2	73.0	97.5			
1941	1.5	4.0	9.0	23.4	44.8	63.9				
1942	2.2	6.1	11.7	25.7	38.0					
1943	3.6	8.9	17.3	25.0						
1944	3.6	7.3	13.9							
1945	1.4	4.1								
1946	1.2									

TABLE 4.—CONTROL COOLED AND BRUNORIZED CONTRACT RAIL

Track Miles and Failures, All Types, in Rollings 1937 to 1946, Incl.

Road	Brunorized		Open Hearth Control Cooled											
	Trk. Mls.	1947 Failures	Track Miles											1947 Failures
	Gary		Alg.	Carn.	Colo.	Dom.	Gary	Inld.	Lacka.	Md.	Stltn.	Tenn.	Total	
AT&SF					2985		798	107			74		3964	166
ACL				93							263	468	824	3
B&O				702			446	18	144		281		1591	229
B&Aroos											59		59	0
B&OCT							14	13					27	2
B&LE				124									124	3
Bos & Alb				7					177		5		189	0
B&M				139					185		160		484	13
CP			3405			159			119				3683	250
C of Ga.												309	309	28
C of NJ											208		208	13
C&O E Rgn				17			950	508			169		1644	489
C&O PM Dist			106	170				87	40				403	7
C&EI							222	42					264	11
C&NW	96	45					738	209	24				971	63
CB&Q	136	13			837		728	199					1764	29
CCC&StL	16	2					741	8	45				794	28
CI&L							86						86	0
CMStP&P	255	18					1001	323					1324	32
CRI&P					432		1162	353					1947	41
C&S					30								30	0
D&H											442		442	190
DL&W				70					293		12		375	4
D&RGW					502								502	40
Erie				679			275	47	140				1141	22
Fla EC				11							9	301	321	7
GTW							263	68					331	14
GN	121	15					596	169	271				1036	70
IC	32	12					1125	472				396	1993	64
IHB								16					16	11
KCS	27	0					355	64			10		429	27
L&HR											23		23	0
L&NE				6							28		34	1
LV									241				241	8
L&N							285					1674	1959	153
Me Cent									53				53	1
Mich Cent	15	0	348				220						568	8
MStP&SSM							52	18	35				105	10
MKT					68		405	77					550	9

TABLE 4.—Continued

Road	Brunorized		Open Hearth Control Cooled											
	Trk. Mls.	1947 Failures	Track Miles											1947 Failures
	Gary		Alg.	Carn.	Colo.	Dom.	Gary	Inld.	Lacka.	Md.	Stltn.	Tenn.	Total	
MP RR					1014		453	260				146	1873	111
MP Lines				15	275							146	436	11
NC&StL							5					421	426	85
NYC—East				55					1070				1125	215
NYC—West	29	8					498	96	175				769	45
NYC&StL				15			412	98	119				644	56
NYNH&H				361							316		677	60
N&W				916							305		1221	75
NP					305		891	30	407				1633	58
PRR				1164			791	164	40		1278		3437	2282
P&E								12					12	0
P&LE				145									145	2
Reading											272		272	13
RF&P											114		114	88
Rutland									8				8	4
Seaboard											585	530	1115	36
StLSF							10	28				744	782	47
SP					2320						397	525	3242	587
So. Ry.							115				567	1312	1994	141
T&NO					582						105	5	692	20
T&P					401							263	664	20
UP					1720		977	183					2880	660
Va.				118					5		209		332	37
W. Md.				44							61		105	3
W&LE				230									230	23
Total	727	113	3859	5081	11471	159	14614	3669	3591		5952	7240	55636	6725

Intermediate Manganese Control Cooled

Road	Gary	1947 Failures	Alg.	Carn.	Colo.	Dom.	Gary	Inld.	Lacka.	Md.	Stltn.	Tenn.	Total	1947 Failures
D&H											30		30	2
D&RGW					16								16	47
Total					16						30		46	49

TABLE 5.—ACCUMULATED FAILURES AND FAILURES PER 100 TRACK MILES, IN ROLLINGS 1937 TO 1946, INCL., FROM DATE ROLLED TO DECEMBER 31, 1947, SERVICE AND DETECTED, BY MILL AND TYPE OF FAILURE

Open Hearth Control Cooled Rail Only

Mill	Accumulated Failures to December 31, 1947									Avg. Track Miles	Track Mile Years	Failures Per 100 Track Mile Years
	Transv. Fiss.	Comp. Fiss. Det. Frac. from Eng. Burns, Shells, etc	* VSH and HSH	Other Head	Broken	Web		Base	All Types			
						In. Jt.	Other					
Algoma	2	3	279	1	47	181	41	275	829	3,861.55	15,870	5.22
Carnegie (ET)	2	417	168	60	217	3943	1262	9	6078	5,066.39	22,149	27.44
Colorado	0	787	952	356	132	77	512	17	2833	11,196.44	47,841	5.92
Dominion	0	0	3	0	0	6	5	2	16	158.95	1,175	1.36
Gary	4	1102	344	203	303	1172	486	96	3710	14,613.55	64,730	5.73
Inland	19	454	110	48	151	561	273	42	1658	3,669.39	19,532	8.49
Lackawanna	3	292	61	56	116	495	59	126	1208	3,590.51	16,576	7.29
Maryland												
Steelton	39	927	245	194	535	208	514	9	2671	5,952.15	25,046	10.66
Tennessee	0	145	862	349	620	363	603	120	3062	7,094.38	36,560	8.38
All Mills	69	4127	3024	1267	2121	7006	3755	696	22065	55,203.31	249,479	8.84
Failures per 100 Tr. Mi. Years	0.03	1.65	1.21	0.51	0.85	2.81	1.50	0.28	8.84			

Intermediate Manganese Control Cooled Rail Only

Mill	Transv. Fiss.	Comp. Fiss. Det. Frac. from Eng. Burns, Shells, etc	* VSH and HSH	Other Head	Broken	Web In. Jt.	Web Other	Base	All Types	Avg. Track Miles	Track Mile Years	Failures Per 100 Track Mile Years
Colorado	0	400	23	4	4	8	0	0	439	15.81	110	399.09
Steelton	0	1	1	0	0	14	0	0	16	29.58	282	5.67
All Mills	0	401	24	4	4	22	0	0	455	45.39	392	116.07
Failures per 100 Tr. Mi. Years	0	102.30	6.12	1.02	1.02	5.61	0	0	116.07			

Note: Causes of transverse fissure failures are indicated on Table 6.
*Vertical split heads and horizontal split heads.

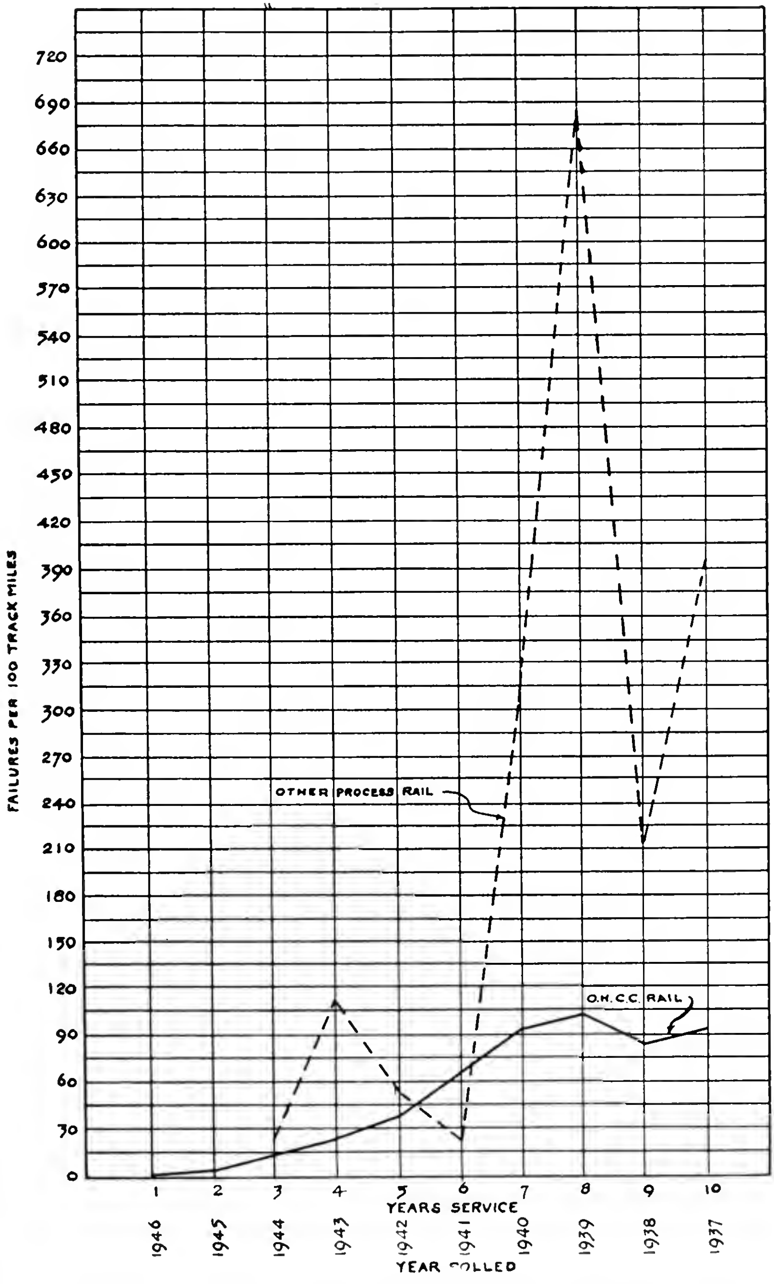


Fig. 3.—Control Cooled and Other Process Rail Failures to December 31, 1947 per 100 Track Miles—Service and Detected—Brunorized Rail Excluded.

Table 6.—Segregation by Roads and Mills of All Types of Failures Shown in Table 5, OH Control Cooled Rail Only, in Rollings 1937 to 1946, Incl., Accumulated Failures to December 31, 1947

Roads	TF	CF EBF DF	VSH and HSH	Other Head	Broken	Web		Base	All Types	
						In Jt.	Other		Total	This Year
ALGOMA										
CP	1	2	277		45	175	39	274	813	238
C&O—PM Dist	1		1						2	
Mich. Cen.		1	1	1	2	6	2	1	14	5
Total	2	3	279	1	47	181	41	275	829	243
CARNEGIE (ET)										
B&O		67	23	5	7	129	41		272	130
B&LE		3		1	8	1	2	3	18	3
B&M					3		23		26	1
C&O		24	12		2	1	1		40	12
C&O—PM Dist			2	5	1				8	2
DL&W			1			1			2	
Erie		18	14	4	7	4	20	4	71	12
FEC			1		1	4			6	4
L&NE			1						1	1
N&W	1	188	33		1	18	60		301	51
NYC—E		12	1	3		15			31	25
NYC&StL		1	2		5	38			46	1
NY NH & H	1	5	13		12	103	1		135	43
PRR		70	48	24	69	3621	1083	1	4916	1581
P&LE		9	3	1			1		14	2
Virginian		20	3		78		5		106	13
WMd.					2				2	2
W&LE			11	17	21	8	25	1	83	23
Total	2	417	168	60	217	3943	1262	9	6078	1906
COLORADO										
AT&SF		196	148	10	78	30	40	3	505	145
CB&Q			56	1	2	2	6	2	69	23
CRI&P		3	16	2	8	1		3	33	4
D&RGW		81	46	15	6	17	21		186	40
MKT			7	1			2		10	2
MPRR		4	50	36	7	17	19		133	40
NP		11	6	3	2	2	5		29	16
SP		43	488	205	22		309	3	1070	266
T&NO		2	20	14	4		3		43	18
T&P			4	1	3	2	2		12	6
UP		447	111	68		6	105	6	743	298
Total	0	787	952	356	132	77	512	17	2833	858
DOMINION										
CP			3			6	5	2	16	7
Total	0	0	3	0	0	6	5	2	16	7
GARY										
AT&SF		26	28	1	14	3		1	73	14
B&O		19	5	1	1	27	4	5	62	37
B&OCT						1			1	1
C&O	1	345	41	5	9	27	5	8	441	193
C&EI		4	3	4	5	12	1		29	9
C&NW	1	16	9	18	26	10	3	6	89	42
CB&Q		6	7	4	5	4	2	5	33	4
CCC&StL		4	3	22		9	10		48	23
CMStP&P			3	1	45		2	16	67	17
CRI&P		5	24	11	63	13	9	11	136	30
Erie			2		1	3	9	1	16	4
GTW			3	5	49	1	4	28	90	9
GN	1	92	28	44	3	10		2	180	46
IC		7	29	7	7	42	10	2	104	30
KCS		46	24		5	2	9	1	87	20
L&N		1					1		2	1
Mich Cen		11	24	5			1		41	3
MStP&SSM			4		1				5	4
MKT		6	6	5		6	2		25	5
MPRR		3	13	7	1	12	59	1	96	43
NC&StL						1	1		2	
NYC—W	1	15	7	1		20			44	18

TABLE 6.—Continued

Roads	TF	CF EBF DF	VSH and HSH	Other Head	Broken	Web In Jt.	Web Other	Base	All Types Total	All Types This Year
NYC&StL		3	11	12	14	40	22	1	103	41
NP		12	9	5	30	15	8	5	84	28
PRR		16	9	3	16	911	243	1	1199	403
So Ry					2	1	3		6	3
UP		465	52	42	6	2	78	2	647	319
Total	4	1102	344	203	303	1172	486	96	3710	1347
INLAND										
B&O		1				2			3	1
B&OCT		1							1	1
C&O	13	336	40	5	24	33	16	5	472	222
C&O—PM Dist		1		6	3		2	2	14	5
C&EI		3	1			4	1		9	2
C&NW		1	3	1	13	14	1	5	38	21
CB&Q			3	1	1		1	1	7	2
CCC&StL			2	1			1		4	2
CMStP&P		2	1	4	33	5	2	8	55	15
CRI&P		1	4		18	3	2	6	34	7
Erie					1	1	2		4	1
GTW			1	1	23			6	31	5
GN			9	9		4		1	23	8
IC		5	11		3	19	4	2	44	13
IHB					3	7	1		11	11
KCS		2	6			1	2		11	7
MStP&SSM					5		1	4	10	4
MKT			6				3		9	2
MPRR		3	13	8	5	18	93		140	22
NYC—W		2	1			133	1		137	22
NYC&StL		3	1	3	5	14	7	1	34	9
NP					1			1	2	1
PRR		11	2	3	12	303	119		450	112
UP	6	82	6	6	1		14		115	43
Total	19	454	110	48	151	561	273	42	1658	538
LACKAWANNA										
B&O		22			1	4	1		28	19
B&Alb.			1			1	2	1	5	
B&M				2	15		1	4	22	1
CP			2				4	28	34	5
C&O—PM Dist				1	1			2	4	
CCC&StL			1	1			2		4	3
DL&W		5	4	2		15	3	10	39	4
Erie		13	2		1		20	2	38	5
GN		22	5	10	2	9	2	4	54	16
LV	1		1		16	5	15	8	46	8
MC				1		1		1	3	1
MStP&SSM					2			1	3	2
NYC—E	2	182	25	21		146	5	20	401	190
NYC—W		9	1	1		237			248	5
NYC&StL			15	12	1	64	2		94	5
NP		2	4	5	27	1	2	30	71	13
PRR		37			33	12			82	4
Rutland					17			15	32	4
Total	3	292	61	56	116	495	59	126	1208	285
STEELTON										
AT&SF		2	1		5				8	7
B&O	3	43	7	2	4	20	14		93	42
B&M	2	2	1	7	10		11	2	35	11
CRR of NJ	1	1		1	8	19			30	13
C&O	5	64	8	4	1	1			83	62
D&H	3	192	69	33	8	15	137	2	459	190
DL&W		1	7				2		10	
KCS		4					5		9	
NY NH & H	6	18	4	2	4	41			75	17
N&W	5	75	3	2		12	6		103	24
PRR		160	9	57	401	83	10		720	182
Reading		12	4	1	1	5	1		24	13
RF&P	2	188	10	1		6			207	88
SAL	3		5		50	3		1	62	9
SP	8	17	111	79	7		319	1	542	154
So Ry		130	4	2	16	2	3	3	160	55
Tex & NO	1		1	2			1		5	2
Virginian		18	1	1	19	1	5		45	24
WM					1				1	1
Total	39	927	245	194	535	208	514	9	2671	894

TABLE 6.—Continued

Roads	*TF*	*CF EBF DF*	*VSH and HSH*	*Other Head*	*Bro-ken*	*Web*		*Base*	*All Types*	
						In Jt.	*Other*		*Total*	*This Year*
TENNESSEE										
ACL	------	3	11	------	11	2	4	2	33	3
Cen of Ga	------	3	5	6	5	39	1	4	63	28
FEC	------	------	------	2	5	3	------	------	10	3
IC	------	1	8	2	3	43	5	2	64	21
L&N	------	51	292	46	239	66	115	26	835	152
MPRR	------	------	8	5	5	9	6	3	36	6
NC&StL	------	4	147	25	31	151	59	16	433	85
StL–SF	------	29	44	62	61	9	29	3	237	47
SAL	------	3	18	2	59	4	2	13	101	27
SP	------	23	290	127	41	------	351	10	842	167
So Ry	------	27	35	72	154	15	25	10	338	83
Tex & Pac	------	1	4	------	6	22	6	31	70	14
Total	0	145	862	349	620	363	603	120	3062	636
All Mills	69	4127	3024	1267	2121	7006	3755	696	22065	6714

(text continued from page 493)
used on such roads in comparison with rail, from the same or other mills, used on other roads.

Table 7 lists the transverse fissure failures in open-hearth control cooled rail accumulated in rollings 1935–1946 from the date rolled to September 1, 1948, all of which have been verified by Professor R. E. Cramer at the University of Illinois. This table segregates the failures by roads, mills and by the year rolled. The origins of the failures are shown. It is noteworthy that in rail from all of these rollings only seven transverse fissures from shatter cracks have occurred and those occurred in the earlier rollings and are ascribed to the use of improper cooling box covers. The 101 transverse fissures reported as originating in hot torn steel occurred in early rollings and were found to be due to overheating of the blooms during manufacture. Greater attention to this matter has obviated failures in later rollings due to this cause.

Table 8 compares the rates of failure of all types accumulated from the date rolled to December 31, 1947, shown separately for control cooled, Brunorized and other process rails. The greater reduction in failures through the use of control cooled rail is evidenced by the failure rates shown for ten years' service of the 1937 rollings. Reference to Table 2 will show the different track mileages underlying Table 8 and it is to be inferred that the control cooled rail was predominantly laid in the heavier traffic track so that the improvement brought about by control cooled rail is no doubt greater than that reported by Table 8.

Fig. 3 charts the data from Table 8. The uniform curve of the control cooled failure rates contrasts with the very irregular curve of the open-hearth failure rates.

Fig. 4 charts the failure rate per 100 track mile-years for open-hearth control cooled rail only, by mills, separately in rollings 1939–1946, incl. These rates are not weighted for traffic and include failures due to design, traffic and manufacturing defects. Many web failures within joint bar limits reported by one road increased the failure rates of certain rollings from several mills, see Table 5.

TABLE 7.—ACCUMULATED TRANSVERSE FISSURE FAILURES BY ROAD, MILL AND YEAR ROLLED TO SEPTEMBER 1, 1948, OH CONTROL COOLED RAIL

CC Failures Verified by Laboratory Investigation

Open Hearth Control Cooled Only

Roads	Mills	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	Total
PM	Algoma						1						1
CP	Algoma						1						1
NYNH&H	Carnegie (ET)			1(d)									1
N&W	Carnegie (ET)					1							1
C&O	Gary		2(b)			1(b)	1(b)						4
C&NW	Gary		1(a)	1(a)									2
CB&Q	Gary		3(a)										3
GN	Gary		1(a)										1
NYC	Gary				1(a)								1
C&O	Inland	1	4(c)	3	2			6			1	1	18
GN	Inland					1(e)							1
UP	Inland					3	3						6
LV	Lackawanna								1	1			2
NYC	Lackawanna								1	1			2
NYC&StL	Lackawanna								2				2
B&O	Steelton								2	1			3
B&M	Steelton						2						2
C of NJ	Steelton									1			1
C&O	Steelton	4		1	4			1					10
D&H	Steelton				1	2	2(f)			1			6
MP	Steelton			1									1
N&W	Steelton					1	1		4				6
NYNH&H	Steelton			3		2	1		1	1			8
PRR	Steelton		2										2
RF&P	Steelton			1			1						2
SAL	Steelton							2		1			3
So Ry	Steelton							1		1			2
SP	Steelton		16	2	5	1							24
	Total	5	29	13	13	12	13	10	11	8	1	1	116
	Algoma						2						2
	Carnegie (ET)			1		1							2
	Colorado	*											0
	Dominion												0
	Gary		7	1	1	1	1						11
	Inland	1	4	3	2	4	3	6			1	1	25
	Lackawanna								4	2			6
	Maryland	*	*	*	*	*	*	*	*	*	*	*	0
	Steelton	4	18	8	10	6	7	4	7	6			70
	Tennessee												0
All Roads	All Mills	5	29	13	13	12	13	10	11	8	1	1	116

*No CC rail rolled.

Note: (a) T F from shatter cracks due to use of improper cooling box covers. (b) T F from welded engine burns. (c) One T F from welded engine burns. (d) T F from silicate inclusion. (e) T F from small hole near welded joint. (f) T F from inclusion. Summary—7 T Fs from shatter cracks, 5 T Fs from welded

TABLE 8.—COMPARISON OF RAIL FAILURES OF ALL TYPES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1947, PER 100 AVERAGE TRACK MILES OF CONTROL COOLED, BRUNORIZED AND "OTHER" PROCESS RAILS ROLLED IN 1937 TO 1946, INCL., SERVICE AND DETECTED

Year Rolled	*1946*	*1945*	*1944*	*1943*	*1942*	*1941*	*1940*	*1939*	*1938*	*1937*
Years' Service	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Control cooled rail (Excl. IM-CC rail)	1.16	4.10	13.82	23.96	37.74	66.12	92.86	102.64	83.42	93.54
Brunorized*	----	----	----	----	----	6.89	9.68	5.27	137.02	235.65
"Other" process rail**	----	----	23.93	111.33	52.41	21.92	307.21	685.07	212.26	397.06
Rail made by all processes	1.16	4.10	13.89	24.98	37.99	63.90	97.53	123.56	100.87	160.69

Note: **"Other" process rail includes bessemer, plain open hearth, medium manganese, control cooled medium manganese, etc., and excludes control cooled OH and Brunorized.

Dates on which rolling of contract rail started

Control Cooled

Dominion .... January 1931
Algoma .... December 1933
Steelton .... March 1935
Inland .... April 1935
Lackawanna .... May 1935
Carnegie .... October 1935
Colorado .... January 1936
Tennessee .... February 1936
Gary .... April 1936

*Brunorized

Gary—old process .... October 1936
revised process .... April 27, 1938
rolling discontinued .... November 18, 1941

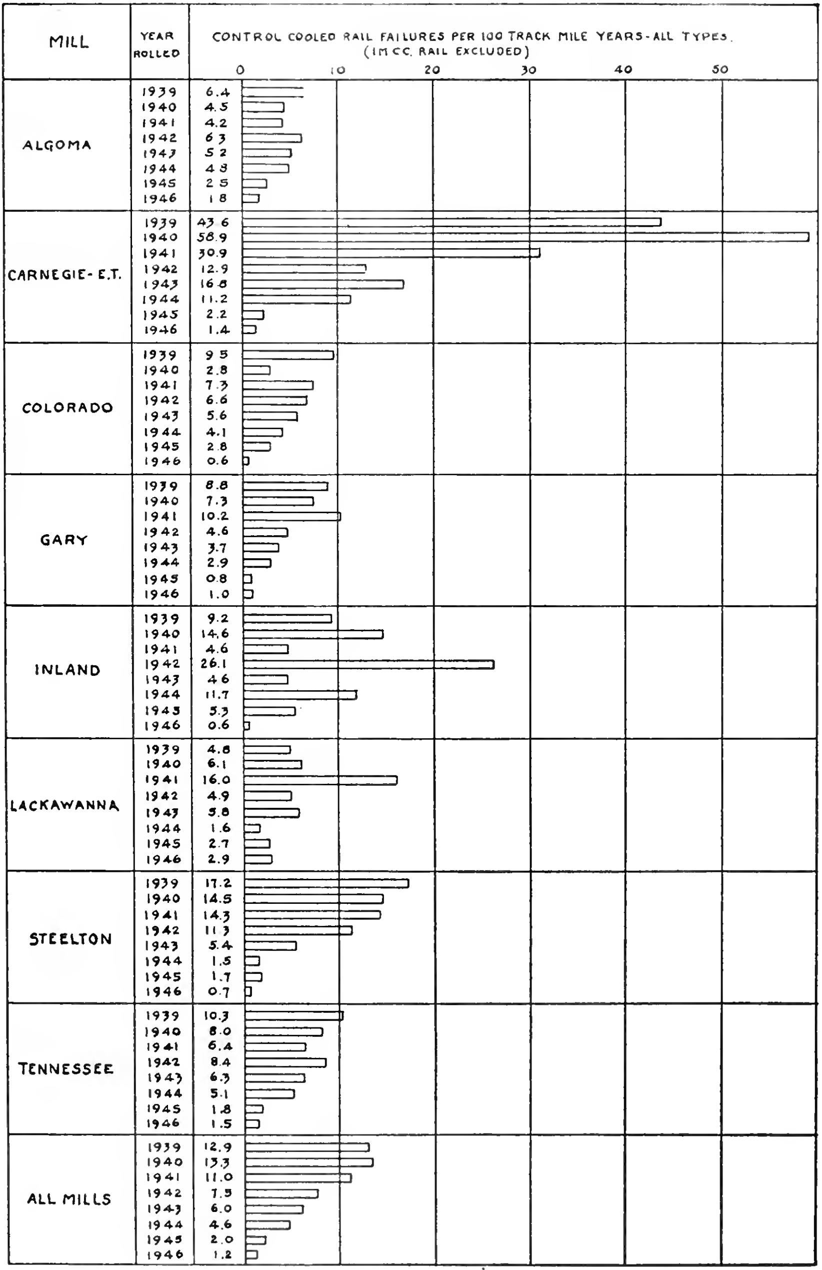


Fig. 4.—Control Cooled Rail Failure Rates to December 31, 1947—All Types—Service and Detected, not Weighted for Traffic. Failures Due to Design, Traffic and Manufacturing Defects Included.

Report on Assignment 5

Economic Value of Different Sizes of Rail

C. M. Chumley (chairman, subcommittee), J. E. Armstrong, W. C. Barnes, C. H. Blackman, C. B. Bronson, W. J. Burton, J. L. Gressitt, G. F. Hand, C. B. Harveson, E. M. Hastings, W. E. Heimerdinger, G. M. Magee, E. E. Mayo, L. T. Nuckols. R. E. Patterson, J. G. Roney, E. F. Salisbury, W. D. Simpson, G. L. Smith, Barton Wheelwright, J. G. Wishart.

Your committee submits the following report of progress as information.

A number of studies have been prepared on this subject in the past which have been necessarily based for the most part on theoretical assumptions as to the relative life of the various rail sections, effect on the tie and ballast life, etc. Where actual costs were kept as to maintenance they were greatly influenced by the drastic curtailment of expenditures during the 1930's. The intense mechanization of track maintenance operations during this period also makes it difficult to obtain comparative figures. During the 1940's the shortage and inefficiency of labor also distort the man-hours. With this thought in mind an endeavor will be made to obtain from various railroads current figures covering various rail sections, traffic and other local conditions. These figures, when assembled, can be used by railroads with similar conditions as a guide in selecting a suitable rail section.

As a start, the Illinois Central made arrangements early in 1945 to study the comparative performance and annual maintenance cost of 112-lb. and 131-lb. rail. In an effort to eliminate as many variables as possible, two 20-mile sections of track were selected on the northward main track between Mattoon and Champaign, Ill. These adjoining sections are located between two terminals and have nearly identical conditions affecting maintenance cost, including tonnage, roadbed, and operation. The gross tons carried by the track are shown in the following table:

Year	*Million Gross Tons*
1943	31.96
1944	31.39
1945	27.45
1946	24.79
1947	26.25
Total for 5 years	141.84
Average	28.37

A statement is presented showing first cost taken from AFE charges and maintenance expense to date as shown on division time rolls and material books. The statement indicates that 131-lb. rail costs approximately $1800 more per track mile in place than 112-lb. rail, but that at the end of 4 years, with a total of more than 115 million gross tons over the track, the average annual cost of maintenance has been 210 man-hours less per track mile. During this same period tie applications ran about 25 ties per mile per year less for the 131-lb. rail than for the 112-lb. rail. It is expected that this test will provide more valuable information as to the life, maintenance, etc., of 112-lb. rail compared to 131-lb. as succeeding years come under observation.

Among excellent reports on this subject are:

1. AREA Proceedings, Vol. 31, 1932, page 1495: Economical Selection of Rail, by A. N. Reece—Kansas City Southern R. R.

112–131-Pound Rail Study—Illinois Central Northward Track, Mattoon to Champaign, Ill.

112-lb. Rail		*131-lb. Rail*	
M.P. 163.68 to M.P. 172.73 (laid 1942)		M.P. 132.00 to M.P. 152.24 (laid 1944)	
M.P. 152.24 to M.P. 163.68 (laid 1943)			
Total track miles maintained (108,173 track feet)	20.48	Total track miles maintained (106,747 track feet)	20.21
Number of turnouts maintained	18	Number of turnouts maintained	21
Number of railroad crossings maintained	1	Number of railroad crossings maintained	3
Number of public grade crossings maintained	22	Number of public grade crossings maintained	22
Number of private grade crossings maintained	2	Number of private grade crossings maintained	6

Cost Statement (1944 Prices)

	112-lb. Rail	*131-lb. Rail*	*Difference*
Cost of rail, other track material, and storehouse expense per track mile	$ 12,642.59	$ 14,413.31	$ 1,770.72
Total cost of rail, other track material, and storehouse expense	258,920.24	291,292.99	
Labor unloading new rail and other track material	1,511.07	809.55	
Labor laying new rail	19,741.26	20,074.65	
Labor picking up relieved rail and other track material	3,829.89	3,175.36	
Work train service	3,233.80	4,809.07	
Total cost of laying rail per mile	1,382.61	1,428.43	45.82
Total cost	287,236.26	320,161.62	
Total cost per mile	14,025.20	15,841.74	
Difference in cost per mile			$ 1,816.54

Maintenance Costs

Year	Labor (Hours) Account No. 202	218	220	221	272	273	415	Material Cross Ties	Switch Ties	Ballast	Rail	OTM
1943	-----	416	49,011	---	---	---	---	14,148	3 No. 10-0 1 No. 15-0	----	----	--
1944	-----	66	8,099	78	311	393	111	102	----------	----	----	--
1945	1,651	281	13,561	6	155	159	26	4,665	----------	----	----	--
1946	1,978	250	22,796	---	16	98	---	8,221	1 No. 15-0	----	----	--

Year	Labor (Hours) Account No. 202	218	220	221	272	273	415	Material Cross Ties	Switch Ties	Ballast	Rail	OTM	Difference Hours
1944	657	680	52,062	---	---	108	---	21,555	5 No. 10-0	----	----	--	+ 4,080
1945	1,221	54	2,589	---	132	195	274	------	----------	----	----	--	— 4,593
1946	673	8	7,474	---	4	10	---	91	----------	----	----	--	— 7,670
1947	1,316	182	14,955	---	42	22	---	3,478	----------	----	----	--	— 8,621
											Total		—16,804

131 lb. rail—annual saving $\frac{16,804}{4 \text{ years} \times 20 \text{ miles}}$ = 210 Man-hours per track mile.

2. AREA Proceedings, Vol. 40, 1939, page 130: Methods or Formulas for the Solution of Special Problems Relating to More Economical and Efficient Railway Operations.

In this report data compiled by the ICC from 93 railroads for the years 1927–1936 incl., show that cost of maintenance per million gross tons decreases as the weight of rail is increased.

3. Robert Faries, then assistant chief engineer, Pennsylvania Railroad, testifying before the Railroad Carrier Industry Committee at Washington, D. C., in 1940, stated:

> Similar studies were made to determine the effect of increased investment in rail, that is, the effect on employment of the use of heavier rail, the comparison being made between 100-lb. and 131-lb. rail, carrying an annual traffic of 16,500,000 gross tons per mile. In making these studies, the costs for each weight of rail were reduced to the annual basis for both investment and maintenance at each rate of wages. It was found that the use of the heavier rail increased the annual investment per mile of track by $75 but reduced the annual expenditure for maintenance by $95. Likewise, at the 35-cent rate these figures became $72 and $113; and at the 40-cent rate they are $69 and $133.

All of these studies indicate that the use of the heavier rail section results in a saving in the annual cost per mile of track maintained, as well as in the cost per gross ton-mile of traffic handled. These savings are confirmed by the actual cost on the Illinois Central test section. While the costs of both labor and material have increased over those figures used in compiling the report, the ratio of saving remains approximately the same. The indicated saving of ties per mile per year on the 131-lb. over the 112-lb. test section assumes considerable importance when consideration is given to the present high cost of ties and the labor to apply them. In addition to these direct measurable savings there are other benefits which result from the use of the heavier rail section. Among these are increased safety, a smoother ride for passengers, less wear on the ballast and increased life of equipment.

Report on Assignment 6

Continuous Welded Rail

Collaborating with Committee 5

I. H. Schram (chairman, subcommittee), S. E. Armstrong, W. C. Barnes, C. H. Blackman, C. B. Bronson, T. A. Blair, C. J. Code, P. O. Ferris, F. R. Layng, H. S. Loeffler, G. M. Magee, R. J. Middleton, C. E. Morgan, L. T. Nuckols, E. E. Oviatt, J. C. Ryan, R. T. Scholes, R. P. Winton.

This is a progress report submitted as information.

The statements that have been prepared this year showing the installations of continuous welded rail are presented in summarized form. Data have been gathered on the installation of newer welding processes (it developed all were gas pressure welds). Twenty such installations have been added. No failures have been reported on these new installations. A column has been added: "Total length of installations," to clarify the first two columns.

Interesting rolling-load tests on pressure welded rail have been made this year by Professor R. E. Cramer and a description thereof with three figures (including two photos) and summary are presented as information.

[illegible] RAIL - SUMMARY TO DATE

Process	Maxi[illegible] Length Welded Without Intervening Joints Road	Feet	Total Length of Installation Track Feet	Number of Welded Joints	Weight of Rail Lbs. per Yd.	Bars Applied	Maximum Wheel Load Lbs.	Annual Tonnage	Traffic Pass.	Traffic Frt.	Speed M.P.H.	Date Installed	In Tunnel Or Open	Failures
"[illegible]" Thermit (Type A) - -	(N. P.)	[illegible]	[illegible]	[illegible]	131 RE	No	37,000	Not known	Pass.	Frt.	30	Late 1942	Tunnel	1
	(G. N.)	[illegible]	[illegible]	[illegible]	110 RE	No	35,000	6,042,000	"	"	55	1937	Open	2
	(D. & H.)	[illegible]	29515	1559	131 RE	No	34,425	9,000,000		"	30	1937	Open	8
	(D. & H.)	2519	7392	253	131 RE	No	34,425	3,000,000	"	"	65	Sept.1939	"	1
	(D. & H.)	5566	Closures Only	98	131 RE	No	32,000	5,353,500	"	"	65-35	June - July 1937	"	11
	(D. & H.)	3168	" "	65	131 RE	No	34,425	11,860,000	"	"	60	1937	"	1
	(D. & H.)	4333	" "	53	131 RE	No	32,000	3,567,000	"	"	65	1937	"	None
	(D. & H.)	[illegible]	" "	47	131 RE	No	34,425	16,969,738	"	"	60	1937	"	7
				2075										28
"C2" Thermit (Full Fusion)	(D.& R. G. W.)	4353 (1)	33298	1552	130 PS	No	36,500	10,000,000	"	"	40	Jan. - July 1943	Tunnel	6
	(Erie)	5577	5577	286	131 RE	No	36,000	23,000,000		"	40	Oct. 1943	"	None
"D" Electric Pressure Weld - - - - - - - - - -	(D. & H.)	6983	2693	70	131 RE	No	34,425	9,000,000		"	45	June - Sept. 1935	Open	2
	(D. & H.)	5953	17477	874	131 RE	No	34,425	9,000,000	"	"	30	1937	"	1
	(D. & H.)	6566	42768	1987	131 RE	No	32,000	3,353,500	"	"	65-35	June - July 1937	"	6
	(D. & H.)	4333	38544	1622	131 RE	No	32,000	3,567,000	"	"	65	1937	"	None
	(D. & H.)	3273	6547	513	131 RE	No	34,425	16,969,738	"	"	60	1937	"	1
	(D. & H.)	3168	21701	1142	131 RE	No	34,425	11,860,409	"	"	60	1937	"	1
	(D. & H.)	1401	13622	1069	131 RE	No	32,000	5,353,500	"	"	65	May 1939	"	1
				7277										12
"E" Gas Pressure Weld (Oxweld) - - - - - - - -	(C. of Ga.)	2574	2574	128	112 RE	No	32,500	11,250,000	"	"	30	May 1944	Tunnel	None
	(C. of Ga.)	1287	1287	64	112 RE	No	32,500	11,250,000	"	"	30	May 1944	"	None
				192										
	(G. N.)	6423	6423	328	112 RE	No	28,000	Not reported	"	"	25	1946	"	None
	(A. T. & S. F.)	3076	5607	284	112 RE	No	35,000	8,000,000	"	"	40	Aug.1945	"	None
	(N.C. & St. L.)	2301	2301	116	131 RE	2 Pr.	29,000	22,000,000	"	"	25-15	Apr.1947	"	None
	(B. & M.)	975	25397	1187	107	No	35,000	20,000,000	"	"	30	1942	"	None
	(B. & M.)	1365	25344	1229	107	No	35,000	20,000,000	"	"	30	1945	"	None
				2416										
	(N.Y.N.H.&.H.)	3627	7240	184	112 RE	No	31,060	6,200,000	"	"	50	1941	"	None
	(N. &. W.)	1167	6925	172	131 RE	No	36,000	38,000,000	"	"	60	Feb. 1947	"	None
	(N. &. W.)	1089	6536	162	131 RE	No	36,000	36,000,000	"	"	30	Jan. 1947	"	None
				334										
	(M. P.)	1677	3354	168	112	No	35,000	14,000,000	"	"	79-55	1943	"	None
	(M. P.)	780	1560	76	112	No	35,000	14,000,000	"	"	79-55	1947	"	None
				244										
	(I. C.)	2046	10421	333	112.3	No	39,000	26,234,600		"	40	July 1941	3 Tunnels	None
	(C. G. W.)	2640	5280	257	112 RE	No	30,500	8,000,000	"	"	60	May 1939	Open	2
	(C. & I. M.)	933	2984	131	112 RE	No	32,400	7,000,000	"	"	15	July 1939	"	None
	(E. J. & E.)	3505	——	1473	131 RE	No	32,850	15,500,000		"	45	Sept. 1943	"	None
	(E. J. & E.)	3191	——	346	131 RE	No	32,850	13,400,000		"	45	June 1944	"	None
	(E. J. & E.)	12782	22610	1128	131 RE	No	32,850	13,300,000		"	45	June 1944	"	1
	(E. J. & E.)	14716	32430	1619	131 RE	No	32,850	20,100,000		"	45	Sept. 1944	"	1
				4566										2
	(B. & L. E.)	1200 (2)	5280	269	131 RE	No	37,900	9,000,000	"	"	55-35	June 1946	"	None
	(C. & N. W.)	2647	2647	134	112 RE	No	36,000	12,400,000	"	"	90-60	Oct. 1946	"	None
	(N. Y. C.)	3739	3739	189	127 Dud.	No	34,400	22,083,730	"	"	80-50	Sept. 1947	"	None
	(N. Y. C.)	3443	3443	175	127 Dud.	No	34,400	19,137,680	"	"	80-50	Sept. 1947	"	None
				364										
	(N.Y.N.H.&.H.)	1521	7640	369	131 RE	No	31,060	24,800,950	"	"	40	July 1939	"	None
	(T. & P.)	1110	1110	28	112 RE	No	31,000	10,000,000	"	"	65	Feb. 1945	"	None
	(T. & P.)	1125	1125	29	112 RE	No	31,000	12,000,000	"	"	40	July 1945	"	None
				57										
	(U. P.)	3822	7644	388	131 RE	No	34,250	37,000,000	"	"	75-50	Oct. 1947	"	None
	(Reading)	663	3000	495	130 HFB	No	40,000	9,600,000	"	"	60	Oct. 1944	"	None
	(I. C.)	1058	4393	202	112.3	No	34,500	17,480,000	"	"	15	Aug. 1944	"	None

(1) Denver and Rio Grande Western RR. Co. formerly Denver and Salt Lake RR. Co.
(2) Replaced Thermit (old type) weld removed June 1946.

Continuous Welded Rail

	Summary of Installations	Removals	Renewals
C–1 Thermit (Type K)	8	0	0
C–2 Thermit (full fusion)	2	0	0
D Electric pressure weld	7	0	0
E Gas pressure weld	29	0	1 Thermit (Old Type)
Total installations	46		
Total removals		0	
Total renewals			1

Summary of Processes

Process	In Tunnels Installations	In Tunnels Welded Joints	In Tunnels Failures	In the Open Installations	In the Open Welded Joints	In the Open Failures
C1 Thermit (Type K)	1	506	1	7	2365	31
Removed	..	..	..	..	..	..
Remaining	1	506	1	7	2365	31
C2 Thermit (full fusion)	2	1838	6	..	..	..
Removed	..	..	..	..	..	..
Remaining	2	1838	6	..	..	..
D Electric Pressure	..	..	..	7	7577	12
Removed	..	..	..	..	..	..
Remaining	..	..	..	7	7577	12
E Gas Pressure Weld (oxweld)	13	4431	..	16	7232	7
Removed	..	..	..	..	..	..
Remaining	13	4431	..	16	7232	7

Statement of Additional Failures

Railroad—Location	Process	Date Installed	previously Failures Reported	This Failures Report	Total Failures
N. P., Stampede tunnel, Wash.	C1 Thermit	1942	0	1	1
D. & H., Port Henry, N. Y.	C1 Thermit	1937	5	6	11
D. & H., Port Henry, N. Y.	D Elec. pressure	1937	1	5	6
D. & H., Plattsburg, N. Y.	D Elec. pressure	1939	0	1	1

Appendix 6–a

Laboratory Tests of Two Welded Rails

By R. E. Cramer

Special Research Associate Professor of Engineering Materials, University of Illinois

Introduction

Two reports on laboratory tests of continuous welded rails were published in the AREA Proceedings, Vol. 40, 1939, page 687 and Vol. 41, 1940, page 737. At that time no 33-in. rolling-load machine was available for testing continuous welded rails as are now used for testing rail joints. It was thought desirable to make a test of one welded rail for comparison with the previous tests, placing the rail head in repeated tension, and also make another test with the base in repeated tension for comparison with rolling-load tests of bolted joints.

Acknowledgment

Two Oxweld welded rails of 127-lb. section were supplied by the New York Central Railroad. A 33-in. rolling-load machine designed by the AAR Engineering Division research staff was used for the tests. This machine was described in the AREA Proceedings, Vol. 40, 1939, page 649.

Rolling-Load Tests

Fig. 1 shows the specimen in the testing machine. A wheel load of 60,000 lb. was maintained throughout the test. When the wheel is directly over the weld the bending moment at the weld is 545,000 in.-lb. with the base in tension. As the wheel passes beyond the support to the cantilever end of the stroke the stress in the base changes to a compressive stress half as large. The specimen ran for 2,000,000 cycles of the machine without failure. Eight bolted rail joints of 131-lb. section have been tested at 500,000 in.-lb. bending moment and averaged only 637,500 cycles for failure of one joint bar of each joint. This test indicates that the welded rail was superior to the bolted joints.

Fig. 2 shows the manner of supporting the second welded joint to place the rail head in tension. The rail is supported as a cantilever beam on the blocks marked B. Block A does not support the rail but is placed there as a safety block if the rail should break. The wheel rolls 10 in. beyond the weld, making the bending moment at the weld 10 times the wheel load. A 60,000-lb. wheel load was used producing 600,000 in.-lb. bending moment at the weld. The specimen developed a fatigue crack directly on the weld line at 1,881,000 cycles. The crack appeared to have started at a ridge on the gage corner which remained from rough grinding of the weld. In service the gage corner would have been worn smooth by the flanges of the car wheels which would be of benefit to the weld. This test can be considered very satisfactory for a welded rail joint.

Physical Tests of Specimens from Welded Rails

Test specimens were cut from both welds as shown in Fig. 3, so that the weld line was at the midlength of each test specimen. Table 1 gives the test values for several specimens in the tensile and charpy tests and for the endurance limit obtained from the fatigue specimens. Only two tensile specimens were made from weld No. 2. It is evident from the test results that the welds were quite uniform in strength and that the properties of the welds compare favorably with the strength of unwelded rail steel.

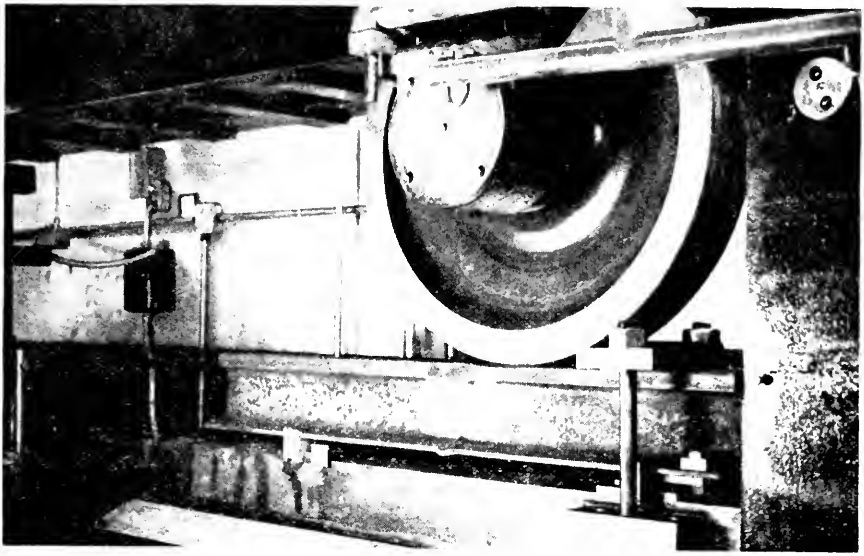


Fig. 1.—Welded Rail in 33-In. Rolling-Load Machine.

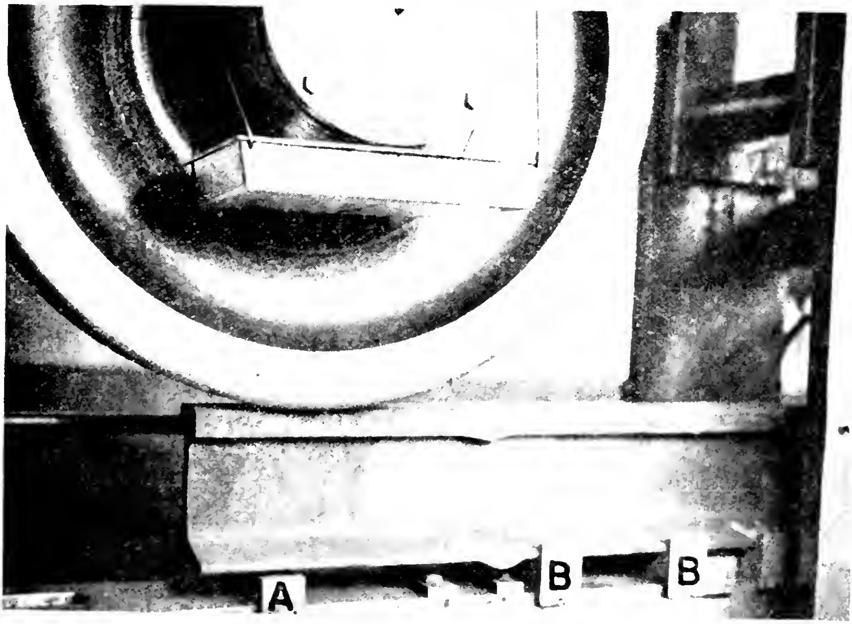


Fig. 2.—Welded Rail with Wheel on End of Cantilever. Blocks B support the rail and block A is used only after rail fails.

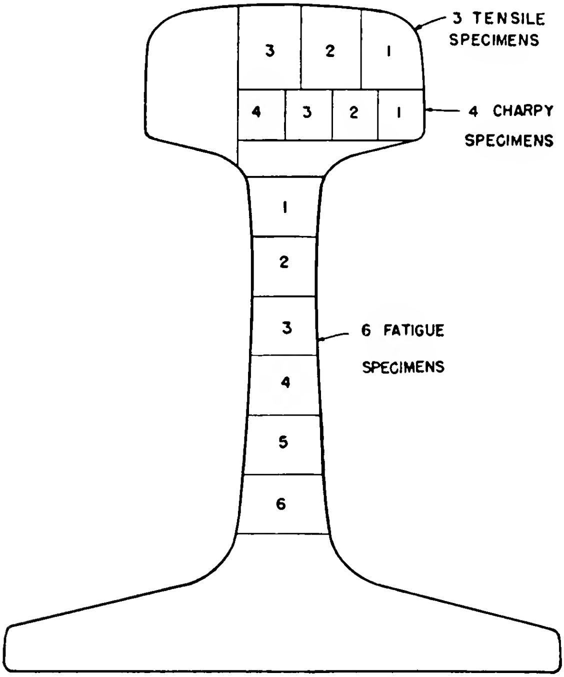


Fig. 3.—Test Specimen for Welded Rails.

Conclusions

1. This test indicates that welded rails were superior in fatigue properties to bolted rail joints.

2. Physical test of specimens with the weld at their midlength gave test values nearly as high as unwelded rails.

TABLE 1.—PHYSICAL TESTS OF SPECIMENS WITH WELD LINE AT THE MIDLENGTH OF EACH SPECIMEN

	Spec. 1	*Spec. 2*	*Spec. 3*	*Average*
Weld No. 1				
Charpy test, no notch	58	47	63	56
Yield strength	71, 000	80, 000	76, 000	75, 000
Tensile strength	135, 000	136, 500	132, 000	134, 500
Percent elongation in 2 in.	7.5	5.5	6	6.3
Percent reduction of area	22.6	12.1	16.4	17.0
Endurance limit	53, 000			53, 000
Weld No. 2				
Charpy test, no notch	68	68	46	61
Yield strength	65, 600	64, 500		65, 000
Tensile strength	132, 300	131, 900		132, 000
Percent elongation in 2 in.	6	6		6
Percent reduction of area	20.6[1]	9.2		15
Endurance limit	48, 000			48, 000

[1]This specimen broke ½ in. from the weld line.

Report on Assignment 7

Service Tests of Various Types of Joint Bars

Ray McBrian (chairman, subcommittee), J. B. Akers, W. C. Barnes, T. A. Blair, C. B. Bronson, W. J. Burton, C. M. Chumley, C. J. Code, L. S. Crane, P. O. Ferris, R. L. Groover, S. R. Hursh, G. M. Magee, E. E. Mayo, C. E. Morgan, R. A. Morrison, L. T. Nuckols, R. E. Patterson, W. C. Perkins, J. C. Ryan, R. T. Scholes, W. D. Simpson, J. G. Wishart.

This is a progress report, presented as information.

Last year the final report was made of the service tests of various types of joint bars for 112-lb. and 131-lb. RE rail which were installed on tangent tracks of the Atchison, Topeka & Santa Fe Railway and the Pennsylvania Railroad in 1937.

With the recent adoption by the Association of new rail and joint bar sections and a new respacing of bolt hole drilling in rails and corresponding bar punching, the subcommittee considered it advisable to establish new service test installations so that the service performance of the new recommendations could be reported. The Santa Fe in laying new 132-lb. RE rail in August 1948 on the east-bound main track 100 miles west of Chicago, included four service tests installations, each one-half mile long on tangent track. All rail ends were end-hardened because in the previous service tests the entire service performance of all the various types of joints was outstandingly superior on end-hardened rail so no further comparison between end-hardened and non end-hardened rail was considered necessary. A description of the locations follows:

Location V—132 RE, headfree, 36 in., 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars

Location W—132 RE, headfree, 36 in., 9–9⅛–9 in. punching, 4-hole bars

Location X—132 RE, headfree, 36 in., 6½–6½–5⅛–6½–6½ in. old AREA punching, 6-hole bars

Location Y—132 Rail Joint Company B-42, headfree, 36 in., 6½-6½–5⅛–6½–6½ in. old AREA punching, 6-hole bars

In October 1948, members of the research staff made the original measurements of rail surface profile, joint camber and out-to-out distances of bars on Locations V, W and X.

In connection with stress measurements reported under Assignment 12, stress measurements were also made on the bars of two joints at each location to determine the dynamic stresses developed under regular traffic. The results will be included in next year's report.

The Chicago & North Western Railway in laying new 115-lb. RE rail in November 1948 on the westbound main track near Nelson, Ill., 106 miles west of Chicago on the Omaha line, installed four service test locations as follows:

Location AA—115 R. J. Co. K-4, headfree, 36 in., 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars

Location BB—115 R J. Co. K-22, headfree, 36 in., 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars

Location CC—115 RE headfree, 36 in., 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars

Location DD—115 RE headfree, 36 in., 9–9⅛–9 in. punching, 4-hole bars

Measurements of rail surface profile, joint camber, and out-to-out distances of bars will be made each year and stress measurements on the joint bars will be made during the summer of 1949.

Report on Assignment 8

Joint Bar Wear and Failures; Revision of Design and Specifications For New Bars and Bars For Maintenance Repairs

Ray McBrian (chairman, subcommittee), J. B. Akers, W. C. Barnes, T. A. Blair, C. B Bronson, W. J. Burton, C. M. Chumley, C. J. Code, L. S. Crane, P. O. Ferris, R. L. Groover, S. R. Hursh, G. M. Magee, E. E. Mayo, C. E. Morgan, R. A. Morrison, L. T. Nuckols, R. E. Patterson, W. C. Perkins, J. C. Ryan, R. T. Scholes, W. D. Simpson, J. G. Wishart.

This is a progress report, submitted as information.

The principal work on the assignment during the past year has been the continuation of the rolling-load tests of joint bars being conducted at the University of Illinois under the direction of R. S. Jensen. The results of these tests are submitted in Appendix 8–a

Service Tests of Joint Bars of Various Metallurgies

In the Proceedings, Vol. 47, 1946, page 411, a description was given of a test installation of joint bars of various metallurgies placed in the single track main line of the Chicago, Burlington & Quincy Railroad, near Fort Morgan. Colo., in July 1939. The joint bars were applied at the time new 112-lb. RE rail was laid, the rail being control cooled, but not end-hardened. The purpose of the test was to compare the service performance, and in particular the resistance to the development of fatigue cracks at the top midlength of joint bars with higher strength steel relative to bars of the AREA specification chemistry and heat treatment. This particular location was selected for the tests because of past difficulty with joint bar cracks.

The test installation includes five test sections of 100 pairs of joint bars each in tangent track. All of the joint bars of one type are laid out of face on both rails. The installation begins at M.P. 460 with bars of type 1 and extends west.

Types of Bars Tested

All of the joint bars are of 24-in. length with four 1-in. diameter heat-treated bolts and triflex springs. All test bars are the Rail Joint Company's designs. Types 1 to 4 incl., are the B–34–1 section and type 5, the B–53 section. The special features of each type of bar are as follows:

Type 1—Head-contact short-toe joint bar of AREA chemistry and heat treatment and of a design similar to one in which cracks had previously occurred. The average surface Brinell was 220.

Type 2—Same design as type 1, but having the top fishing surface of each bar flame hardened for a distance of six inches at midlength. The Brinell of the hardened area was raised from approximately 220 to 300. Some difficulty was experienced with bars warping during the flame hardening which resulted in a slight initial sag at the rail ends when the bars were applied.

Type 3—Same design and chemistry as type 1, but water quenched from 1550 deg. F. for 40 sec. and then drawn at 800 deg. F. for one hour, giving a surface Brinell of approximately 300.

Type 4—Same design as type 1, but rolled from rail steel billets, oil quenched from 1500 deg. F. for 60 sec. and then drawn at 990 deg. F. for two hours, giving a surface Brinell of approximately 320.

Type 5—Headfree short-toe joint bar of AREA chemistry and heat treatment. These joint bars were replaced in 1947 with new headfree bars in connection with the program for changing the bars and building up the rail ends on the 1939 112-lb. RE rail outside of the test stretch.

The chemistry and physical properties of types 1 to 4 incl., were given in the Proceedings, Vol. 47, 1946, page 412. An increase in tensile strength with some loss in ductility accompanied the increase in Brinell for the bars of types 3 and 4.

Joint Wear

On October 26, 1948, measurements were made similar to those previously reported to compare the change in out-to-out distance of the joint bars and the sag or dip at the joints.

The amount of decrease in out-to-out distance is an indication of the amount of joint bar and rail fishing surface wear. The results are shown in Table 1 and represent the average of measurements made at both top and bottom ribs at each end and at the center of ten joints in each test section, except as noted.

TABLE 1.—DECREASE IN OUT-TO-OUT DISTANCE OF JOINT BARS
(November 1939 to October 1948)

	Avg. Decrease in In.			*Avg. to Oct.*
	Top	*Bottom*	*Avg.*	*1946*
Type 1—HC ordinary chemistry	0.150	0.128	0.139	0.105
*Type 2—HC hardened top center	0.146	0.111	0.129	0.095
Type 3—HC water quenched, drawn	0.129	0.112	0.121	0.073
Type 4—HC rail steel, oil quenched, drawn	0.138	0.102	0.120	0.071
Type 5—HF ordinary chemistry	...	...	...	0.051

* Average of 9 joints because one pair of bars was replaced.

Because the available take-up or pull-in of new head-contact joint bars before they contact the rail web is 0.38 in., the decreases recorded in Table 1 are significant in showing the rate at which the service life of the bars is being expended. The average pull-in of the four types of head-contact bars to October 1948, varied from 0.12 to 0.14 in. and the small differences in favor of the harder bars of types 3 and 4 may be of little importance as to increasing the life of these bars. As a matter of interest, the average pull-in from November 1939 to October 1946 is also given in Table 1 to show that the spread between types 4 and 1 and types 3 and 1 is diminishing. In 1946 the performance of the headfree bars was good although allowance must be made for the fact that this type of bar has take-up only at the base.

As in other joint bar tests, the amount of joint bar pull-in varied widely between individual joints of each type. From the 1948 notes as well as the inspection, there were several joints in each of the four head-contact joint bar test sections where the pull-in at one end of the joint was considerably more than at the other end, which means that the take-up at one end will be exhausted long before the other end. The pull-in of the ends of the joints of type 1 was about the same while with types 2, 3 and 4, the joint wear was greater at the east end. During the 9-year test period, the gross tonnage has been heavier in the westward direction.

Joint Droop

The amount of sag or dip at the rail ends is important as an indication of how well the joint bars are supporting the rail ends. In Table 2 is shown the average sag or dip in the rail profile at the joints as measured at a point ½ in. from each rail end with reference to a 36-in. straight edge placed along the center of the rail head with its midlength over the joint gap. The measurements shown are an average of readings taken on 20 joints in each test section, except as noted. Because all rail ends in the five test sections were built up by welding in the summer of 1947, the value of this particular measurement was largely destroyed.

The traffic carried by the test track from November 16, 1939 (date of the initial or base measurements) through October 31, 1948 was 121.6 million gross tons, of which 65.7 million were westbound. Prior to building up the rail ends in 1947 the test bars had carried 102.5 million gross tons.

TABLE 2.—SAG OR DIP AT RAIL JOINTS

(In Inches at Midlength of 36-in. Straight Edge)

Test Section	*November 1939* East Rail End	*November 1939* West Rail End	*October 1948* East Rail End	*October 1948* West Rail End	*Increase* East Rail End	*Increase* West Rail End	*Average to Oct. 1948*	*Average to Oct. 1946*
Type 1 ...	0.000	+0.003	0.011	.009	0.011	0.012	0.012	0.023
*Type 2 ...	0.016	0.014	0.032	.030	0.016	0.016	0.016	0.026
Type 3 ...	0.004	0.001	0.018	.018	0.014	0.017	0.016	0.028
*Type 4 ...	+0.004	+0.004	0.015	.015	0.019	0.019	0.019	0.030
Type 5 ...	0.000	+0.001	....	...	....	....	....	0.025

Note: + Indicates rail end high instead of low.
* Average for 19 joints because one pair of bars was replaced.

The joint sag or dip of the four types of head-contact bars ranged from 0.012 in. for type 1 to 0.019 in. for type 4 for the 9-year service period. The type 1 bars of AREA chemistry and heat treatment showed a moderately better performance than the other three types, although the differences are too small to be significant in judging the relative overall performance of the four types of bars. In Table 2 the average dip or sag of the joints is also shown for the October 1946 measurements, and the droop at that time for the first four types listed was about 0.01 in. more than in 1948. The initial joint dip in November 1939 of the type 2 bars was due to warpage of the bars as a result of flame hardening the middle 6 in. of the top fishing of the bars.

Joint Bar Failures

No cracked joint bars were observed when the measurements were made in 1948. So far, no significant information has been developed on the relative resistance to cracking of the several types of bars.

Acknowledgement

The committee and the Association are indebted to the Burlington Railroad for making the test installation and providing assistance in taking the field measurements.

Appendix 8-a

Seventh Progress Report of the Rolling Load Tests of Joint Bars

By R. S. Jensen

Special Research Associate of Engineering Materials, University of Illinois

Introduction and Acknowledgment

This is a report on the tests of joint bars conducted during the past year in the Talbot laboratory, University of Illinois, as a part of the work of the Engineering Experiment Station in cooperation with the American Railway Engineering Association Committee on Rail under Assignment 8—Investigate joint bar failures and give consideration to the revision of design and specifications. Ray McBrian, engineer of standards and research, Denver & Rio Grande Western Railroad, is chairman of the subcommittee for this assignment. The work is sponsored and financed by the Association of American Railroads.

Included in this report is a summary of all previous tests on joint bars in the rolling-load machines.

Acknowledgment is made of the services of Lewis Franklin and Elmer Hunt, mechanicians in the Talbot laboratory shops, Charles Fournier, student test assistant, and Frank Suter, special research assistant.

Testing Machines and Test Specimens

Joint bar tests were made in three 33-inch stroke rolling machines similar to the one described in the AREA Proceedings, Vol. 40, 1939, page 649. The dimensions of the test joint and method of loading are described in the AREA Proceedings, Vol. 44, 1943, page 587. In all tests the maximum bar bending stresses are obtained with the wheel load at the joint gap and are 50 percent in value and reversed in sign with the wheel load at the cantilever end of the stroke. The criterion for bar failure is taken to be the number of cycles of loading to propagate a fatigue crack to ½ of the bar height.

Individual joint bar tests made previous to this past year are summarized in Table 1. The groupings are by bar types and averages are included for each type for comparison. Joint bar properties are listed in Table 2.

General Observations Based on Summary Table

While many observations might be made and conclusions drawn from the large amount of tabulated data, only a few general observations will be mentioned here. Several factors, some not always apparent, contribute to the rather wide variation in test results, making precise conclusions difficult. Some of these factors are: (a) Inherent variation in the material. Specifications for quenched plain carbon steel bars allow a variation in carbon content from 0.35 to 0.60 percent. (b) Variation in bar hardness. Failed bars listed in Table 1 ranged in Brinell hardness from 154 to 282. (c) "Stress raisers," such as gouging of rail ends, local areas of high bearing pressure, etc. (d) Decarburized fishing surfaces.

Based on the data in Table 1, it appears that:

1. Fatigue life of bars was greatly increased by shot peening the fishing surfaces.
2. Increased fatigue life of bars resulted from wider spacing of central bolt holes.

TABLE 1.—SUMMARY OF JOINT BAR TESTS IN 33-IN. STROKE ROLLING-LOAD MACHINE

Maximum Positive Bending Moment: 44,400-lb. Load = 400,000 in.-lb., 55,500-lb. Load = 500,000 in.-lb.
Maximum Negative Bending Moment is 50 Percent of Positive Moment

Joint No.	Bolt Tension lb.	Wheel Load lb.	Cycles for Failure	Bar Failure N=North S=South	Hardness Failed Bar BHN	Rail Ends H=Hot Sawed C=Cold Sawed	Pinching on Failed Bar in.		Remarks
							Top	Base	
	Bars: 112–B 34	24-in. F.B.							
21	5, 000	44, 000	2, 000, 000	No Failure	177–188	C	--------	--------	Cocked bars
43	5, 000	44, 400	505, 900	Top S	225	C	--------	--------	Canted 1 in 20—High bar failed
22	5, 000	44, 400	1, 921, 000	No Failure	207–211	C	--------	--------	--------
40	5, 000	44, 400	1, 529, 600	Top S	240	C	--------	--------	--------
	Average	--------	1, 489, 100						
16	35, 000	44, 400	506, 000	Base N	241	C	--------	--------	--------
18	35, 000	44, 400	198, 000	Base S	194	C	--------	--------	--------
19	35, 000	44, 400	541, 000	Base N	230	C	--------	--------	--------
31	35, 000	44, 400	590, 600	Top N	235	C	--------	--------	Cocked bars
	Average	--------	458, 900						
7	15, 000	44, 400	543, 000	Base N	228	C	--------	--------	AREA chemistry
49	15, 000	44, 400	387, 000	Base S	218	C	--------	--------	AREA chemistry
29	15, 000	44, 400	379, 600	Base S	205	C	--------	--------	AREA chemistry
									Cocked bars
44	15, 000	44, 400	317, 500	Top N	219	C	--------	--------	AREA chemistry
									Bar relief 1/32 in. by 1¼ in.
46	15, 000	44, 400	464, 400	Top and Base N	240	C	--------	--------	AREA chemistry
									Bar relief 1/32 in. by 1¼ in.
									Failed outside relief
57	15, 000	44, 400	338, 500	Base N	244	H	.000	.010	AREA chemistry
58	15, 000	44, 400	301, 000	Top N	217	H	.014	.010	AREA chemistry
59	15, 000	44, 400	274, 800	Top N Base S	194–209	H	.012	.012	AREA chemistry
									Rail end bevel
	Average	--------	375, 700						
48	15, 000	44, 400	242, 700	Top S	166	C	--------	--------	Bolt holes lowered ¼ in.
51	15, 000	44, 400	150, 600	Top S	158	C	--------	--------	--------
101	15, 000	44, 400	1, 331, 600	Top S	239	C	--------	--------	Fishing surfaces shot peened
102	15, 000	44, 400	443, 900	Top Both	194–205	C	--------	--------	Fishing surfaces shot peened
103	15, 000	44, 400	2, 000, 000	No Failure	216–241	C	--------	--------	Fishing surfaces shot peened
104	15, 000	44, 400	1, 406, 600	Top N	208	C	--------	--------	Fishing surfaces shot peened
	Average	--------	1, 295, 500						

TABLE 1 (Continued)

Joint No.	Bolt Tension lb.	Wheel Load lb.	Cycles for Failure	Bar Failure N=North S=South	Hardness Failed Bar B H N	Rail Ends H=Hot Sawed C=Cold Sawed	Pinching on Failed Bar in		Remarks
							Top	Base	
33	15, 000	39, 000	2, 098, 900	No Failure	239–261	C	--------	--------	------------------------------
47	15, 000	42, 500	1, 000, 300	Base N	263	C	--------	--------	------------------------------
9	5, 000	44, 400	1, 702, 400	No Failure	223–235	C	--------	--------	------------------------------
32	15, 000	44, 400	892, 800	Base N	232	C	--------	--------	------------------------------
50	15, 000	50, 000	282, 600	Base N	221	C	--------	--------	------------------------------
30	15, 000	55, 500	727, 400	Base N	174	C	--------	--------	------------------------------
53	15, 000	44, 400	547, 000	Top S	237	H	.022	--------	------------------------------
54	15, 000	44, 400	690, 300	Base S	265	H	--------	.016	Milled bar relief top
55	15, 000	44, 400	221, 600	Base S	226	H	.019	.020	------------------------------
56	15, 000	44, 400	252, 800	Base N	251	H	.009	.006	Milled bar relief top
	Average	------------	427, 900						
Bars: 112 J16	24-in. H. F.								
35	15, 000	44, 400	1, 580, 900	No Failure	221–240	C	--------	--------	------------------------------
42	15, 000	50, 000	244, 300	Top Both	208–210	C	--------	--------	------------------------------
34	15, 000	55, 500	105, 800	Top N	154	C	--------	--------	------------------------------
36	15, 000	55, 500	660, 600	Top S	221	C	--------	--------	------------------------------
41	35, 000	39, 000	503, 400	Base S	209	C	--------	--------	------------------------------
38	35, 000	44, 400	290, 700	Top S	194	C	--------	--------	------------------------------
45	35, 000	44, 400	303, 600	Base S	242	C	--------	--------	1 1/8 in. bolts used
37	35, 000	55, 500	100, 100	Top N	175	C	--------	--------	------------------------------
39	35, 000	55, 500	144, 600	Top N	203	C	--------	--------	------------------------------
Bars: 112 K2	24-in. H. F.	Lateral Center Overfill and Easement							
60	15, 000	44, 400	509, 000	Base S	260	H—Milled Bevel 1/16 x 1/8	.004	.003	Serial G71 Shell steel
61	15, 000	44, 400	269, 000	Base N	274	H—Milled Bevel 1/16 x 1/8	--------	--------	------------------------------
							.003	.004	Serial G71 Shell steel
62	15, 000	44, 400	184, 700	Base S	275	H—No Bevel	.028	.015	Serial G71 Shell steel
63	15, 000	44, 400	455, 600	Base S	255	H—No Bevel	.013	.013	Serial G71 Shell steel
	Average	------------	354, 500						
64	15, 000	44, 400	872, 200	Base N	275	C—Bevel 1/8 x 1/8	--------	--------	Serial G71 Shell steel
65	15, 000	44, 400	980, 700	Base S	282	C—Bevel 1/16 x 1/8	--------	--------	Serial G71 Shell steel
72	15, 000	44, 400	250, 000	Top N	225	C	--------	--------	Serial G71 Shell steel
73	15, 000	44, 400	462, 300	Base N	263	C	--------	--------	Serial G71 Shell steel
	Average	------------	641, 300						

TABLE 1 (Continued)

Joint No.	Bolt Tension lb.	Wheel Load lb.	Cycles for Failure	Bar Failure N=North S=South	Hardness Failed Bar B H N	Rail Ends H=Hot Sawed C=Cold Sawed	Pinching on Failed Bar in. Top	Base	Remarks
66	15,000	44,400	457,500	Base S	239	H	.018	.007	Serial F92-high manganese
67	15,000	44,400	500,000	Top S	217	C	-----	-----	Serial F92-high manganese
68	15,000	44,400	1,157,400	Base S	245	H	.022	.008	Serial F92-high manganese
69	15,000	44,400	690,800	Top N	236	C	-----	-----	Serial F92-high manganese
70	15,000	44,400	357,900	Base N	223	H	.001	.009	Serial F92-high manganese
	Average	-----	632,700						
71	15,000	44,400	880,100	Top N	217	C	-----	-----	Serial H78 AREA chemistry
74	15,000	44,400	2,000,000	No Failure	229–239	C	-----	-----	Serial H78 AREA chemistry
75	15,000	44,400	750,000	Base N	226	H	.004	.000	Serial H78 AREA chemistry
76	15,000	44,400	611,600	Base S	244	H	.019	.007	Serial H78 AREA chemistry
	Average	-----	1,060,400						
Bars: 112 K16 36-in. H. F.									
91	15,000	44,400	396,300	Top both	216	C	-----	-----	-----
95	15,000	44,400	834,200	Base S	235	H—Milled	.004	.000	Bar cracked to bolt hole
98	15,000	44,400	349,500	Base N	223	C	-----	-----	Bar cracked to bolt hole
99	15,000	44,400	595,600	Base N	203	H—Milled	.004	.000	Bar cracked to bolt hole
107	15,000	44,400	390,900	Top N	207	C	-----	-----	-----
108	15,000	44,400	402,000	Base S	240	C	-----	-----	Bar cracked to bolt hole
	Average	-----	494,700						
Bars: 112 TR-KM8 24-in. H. F.									
83	15,000	44,400	550,700	Base S	245	C	-----	-----	-----
84	15,000	44,400	1,297,300	Base S	221	C	-----	-----	-----
86	15,000	44,400	662,000	Base S	190	C	-----	-----	-----
88	15,000	44,400	475,800	Base S	281	C	-----	-----	-----
92	15,000	44,400	436,900	Base S	207	C	-----	-----	-----
	Average	-----	684,500						
Bars: 131 K14 24-in. H. F.									
77	15,000	55,500	790,700	Top S	200	C	-----	-----	-----
78	15,000	55,500	285,500	Top S	205	C	-----	-----	-----
80	15,000	62,000	219,800	Top Both	186–189	C	-----	-----	-----
87	15,000	55,500	698,400	Top S	192	C	-----	-----	-----
	Average	-----	591,500 —	Joint 80 omitted	from average				

TABLE 1 (Continued)

Joint No.	Bolt Tension lb.	Wheel Load lb.	Cycles for Failure	Bar Failure N=North S=South	Hardness Failed Bar B H N	Rail Ends H=Hot Sawed C=Cold Sawed	Pinching on Failed Bar in.		Remarks
							Top	Base	
90	15,000	44,400	1,321,200	Base S	226	C			
94	15,000	44,400	2,000,000	No Failure	181–221	C			
106	15,000	44,400	1,055,300	Top S	207	C			
			1,458,800						
Bars: 131 K14 36-in. H. F.									
81	15,000	55,500	296,100	Top S	217	C			
82	15,000	55,500	475,100	Top N	225	C			
89	15,000	55,500	819,400	Top N	241	C			
100	15,000	55,500	1,113,400	Top S	229	C			
	Average		676,000						
93	15,000	55,500	713,100	Top N	216	H	.011	.014	
96	15,000	55,500	348,000	Base N	207	H	.006	.012	
97	15,000	55,500	615,900	Top N	241	H	.026	.004	
105	15,000	55,500	609,900	Top N	214	H	.008	.004	
	Average		574,200						
Bars: 131 AREA 36-in. F. B.									
111	15,000	55,500	1,030,800	Base N	225	C			Bar cracked to bolt hole
112	15,000	55,500	689,000	Base S	231	C			Bar cracked to bolt hole
114	15,000	55,500	573,500	Base Both	229–240	C			Bars cracked to bolt hole
118	15,000	55,500	484,600	Base S	247	C			
	Average		694,500						
119	15,000	55,500	328,600	Base N	245	H	.007	.005	
120	15,000	55,500	623,900	Base N	255	H	.030	.018	
121	15,000	55,500	497,200	Base N	266	H	.006	.006	Bar cracked to bolt hole
122	15,000	55,500	872,700	Base S	268	H	.007	.007	
	Average		580,600						
130	15,000	44,400	2,000,000	No Failure	223–271	C			
131	15,000	44,400	1,863,100	Base N	258	C			Bar cracked to bolt hole
	Average		1,931,500						

Table 1 (Continued)

Joint No.	*Bolt Tension lb.*	*Wheel Load lb*	*Cycles for Failure*	*Bar Failure N=North S=South*	*Hardness Failed Bar B H N*	*Rail Ends H=Hot Sawed C=Cold Sawed*	*Pinching on Failed Bar in.*		*Remarks*
							Top	*Base*	
Bars: 115 K4 24-in. H. F.									
109	15, 000	44, 400	2, 000, 000	No Failure	206	C	--------	--------	----------
110	15, 000	44, 400	2, 000, 000	No Failure	196	C	--------	--------	----------
113	15, 000	44, 400	334, 900	Base S	209	C	--------	--------	Bar cracked to bolt hole
	Average	----------	1, 445, 000						
Bars: 115 K4 36-in. H. F. Special Bolt Hole Spacing									
A1 115	15, 000	44, 400	800, 600	Base S	231	H—Milled	.007	.003	Type A Bars—5 1/8-in. spacing between central holes and 6½-in. spacing between remaining holes.
A2 123	15, 000	44, 400	440, 900	Base S	224	H—Milled	.002	.002	
A3 124	15, 000	44, 400	359, 200	Base N	205	H—Milled	.002	.004	
	Average	----------	533, 600						
B1 116	15, 000	44, 400	810, 500	Base S	241	H—Milled	.002	.003	Type B Bars—7 1/8-in. spacing between central holes and 6-in. spacing between remaining holes.
B2 125	15, 000	44, 400	492, 700	Base N	217	H—Milled	.004	.004	
B3 127	15, 000	44, 400	727, 700	Base N	227	H—Milled	.004	.003	
	Average	----------	677, 000						
C1 117	15, 000	44, 400	1, 060, 800	Base S	244	H—Milled	.002	.002	Type C Bars—9 1/8-in. spacing between central holes and 5½-in. spacing between remaining holes.
C2 126	15, 000	44, 400	1, 081, 000	Base S	262	H—Milled	.003	.006	
C3 129	15, 000	44, 400	307, 500	Base N	248	H—Milled	.004	.003	
	Average	----------	816, 400						

3. Averages of tests of bars of the same design (112 K-2) indicated that fatigue life of bars with AREA chemistry was greater than either shell steel bars or high manganese bars.

Results of Rolling-Load Tests

Twenty-five tests on joint bars have been completed since the last annual report was published: These tests, which are not listed in Table 1, include one test of 131 AREA 36-in. F.B. bars with water corrosion, 12 tests of 132 K 42 36-in. H.F. bars and 12 tests of 132 AREA 36-in. H.F. bars. The 132 K 42 bars had a pressed head easement of 1/64 to 1/32 in. over the central 1¼ in. of the bars. Data on these 25 joints are tabulated in Table 3. Tables 4 and 5 list the chemical analyses and physical properties of heats from which the bars were obtained as supplied by the manufacturers.

TABLE 2.—JOINT BAR PROPERTIES

Bar	*For Two Bars*			
			Weight	
	I/c Head	*I/c Base*	*24-in bars*	*36-in. bars*
112 AREA FB	10.3	9.9	75.4	113.2
112 J16 HF	10.7	9.7	70.1	----------
112 B34 FB	10.2	10.0	70.1	----------
112 K2 HF	10.2	9.4	67.18	100.78
112 K16 HF	10.7	9.7	71.26	106.90
112TR KM8	10.8	9.9	----------	----------
115 K4 HF	10.5	9.6	71.52	107.28
115 AREA HF	8.5	9.0	62.6	93.8
131 AREA FB	12.9	12.2	86.5	129.8
131 K14 HF	13.3	12.2	78.47	117.71
132 AREA HF	11.3	11.8	75.3	113.0
132 K42 HF	13.2	12.0	----------	114.0

Hardness Tests on Joint Bars

Both Brinell and Rockwell B hardness values were taken on upper and lower surfaces of all bars before testing. On bars for the 132-lb. rail, the Brinell hardness ranged from 158 to 277. The Brinell readings were taken after removing the scale and filing just enough (probably 0.002 in. to 0.005 in. in most cases) to get a smooth surface for the Brinell impression. Rockwell B readings were taken on the surface of these bars after removing the scale only (no filing). Rockwell B readings converted to equivalent Brinell were lower for nearly all bars. Individual differences between surface hardness as indicated by Rockwell B and standard Brinell ranged from zero to 76 points, while the average surface hardness was 35 points lower, indicating decarburization of the bar surfaces.

Corrosion Test: 131 AREA Bars

Joint 128 with 131 AREA bars and hot-sawed rail ends was tested at a 55,500-lb. wheel load with water as a corroding agent. Before assembly, the bars and rail ends were sand blasted to remove all scale in order to present surfaces uniformly susceptible to the corroding action. By means of wicks, water was siphoned from a container placed

TABLE 3.—ROLLING-LOAD TESTS ON JOINT BARS

Maximum positive bending moment: 55,500-lb. load — 500,000 in.-lb.
Maximum negative bending moment is 50 percent of positive moment
Bolt tension: 15,000 lb. Bolts 1⅛ in. diameter, heat treated, prestressed

Joint No.	*Cycles for Failure*	*Bar Failure N=North S=South*	*Hardness Failed Bar BHN*	*Surface Hardness Equiv. BHN*[1]	*Depth of Decarb. from Micrograph*	*Rail Ends H=Hot Sawed C=Cold Sawed*	*Pinching on Failed Bar in.*	
							Top	*Base*
Bars: 131 AREA 36-in. F. B. Serial 38—Corrosion test with water								
128	1, 500, 000	No failure—2 cracks N-top 1 crack S-top	N-195 S-235	N-160 S-190	------------	H—Milled	.005	.001
Bars: 132 K42 36-in. HF Serial 9 and 11								
132	423, 800	Top both, N-1 in. from end S rail end	N-187 S-196	N-162 S-169	N-.012 S-.021	H—Milled	000	000
133	454, 000	Top N rail end	239	180	.024	H—Milled	000	000
134	565, 000	Top S ⅝ in. from end	199	176	.024	H—Milled	000	000
141	779, 200	Top S rail end	239	176	.020 and .016	H—Milled	000	000
143	534, 400	Top both N rail end S ¾ in. from end to hole	N-242 S-205	N-185 S-159	N-.012 S-.010	H—Milled	000	000
144	478, 500	Top S rail end	231	210	.011	H—Milled	.001	.003
146	531, 500	Top S rail end	205	162	slight	H—Milled	000	000
148	575, 300	Top N rail end	215	180	.007	H—Milled	000	000
149	704, 300	Base N 2¾ in. from end to hole. Fatigue area at hole	218	210	slight	H—Milled	.001	.000
151	696, 900	Top N rail end	254	210	.004	H—Milled	.000	.000
153	332, 400	Top S rail end	193	165	.018	H—Milled	.000	.002
155	200, 900	Top S rail end	185	150	.024	H—Milled	.002	.000
	523, 060	Average						

Table 3 (Continued)

Joint No.	Cycles for Failure	Bar Failure N=North S=South	Hardness Failed Bar BHN	Surface Hardness Equiv. BHNx	Depth of Decarb. from Micrograph	Rail Ends H=Hot Sawed C=Cold Sawed	Pinching on Failed Bar in.	
							Top	Base
Bars: 132 AREA 36-in. HF Serial 4 and 24								
135	720, 200	Top N rail end	242	228	slight	H—Milled	000	000
136	196, 400	Top S rail end	192	162	.024	H—Milled	.002	000
137	487, 500	Top S rail end	239	228	slight	H—Milled	000	000
138	1, 764, 500	Top S rail end	257	248	.004	H—Milled	.002	.000
139	108, 700	Top S rail end	185	169	.012	H—Milled	.004	.001
140	533, 900	Base N 2¾ in. from end to bolt hole. Fatigue area at hole	269	256	slight	H—Milled	000	000
142	2, 000, 000	No failure	N-247 S-242	N-210 S-195	N-slight S-slight	H—Milled	.001	.003
145	1, 515, 700	Top S rail end	241	216	.004 and .021	H—Milled	.002	.000
147	911, 200	Top both rail ends	N-226 S-223	N-205 S-225	N-.009 S-.004	H—Milled	.000	.001
150	442, 700	Top S rail end	231	205	.003	H—Milled	.000	.000
152	659, 100	Top N rail end	231	200	.005	H—Milled	.000	.000
154	189, 200	Top both rail ends	N-158 S-200	N-147 S-165	N-.018 S-.021	H—Milled	.000	.002
	794, 090 —	Average						

[1]Equiv. BHN is average of 5 Rockwell B readings converted to Brinell.

TABLE 4.—CHEMICAL ANALYSES OF JOINT BARS

Bar Type	Length In.	Heat No.	Serial No.	Chemical Composition C.	Mn.	P.	S	Si.
131 AREA F.B.	36	5859	38	.45	.60	.016	.027	.14
132 K-42 H.F.	36	202039	9	.43	.58	.012	.032	.05
132 K-42 H.F.	36	254711	11	.42	.58	.015	.033	.05
132 AREA H.F.	36	----------	4	.46	.55	.014	.036	.13
132 AREA H.F.	36	255049	24	.42	.65	.023	.033	--------

TABLE 5.—PHYSICAL PROPERTIES OF JOINT BARS

Bar Type	Serial No.	Tensile Strength psi.	Yield Point psi.	Reduction of Area Percent	Elongation 2-in. Gage Length; Percent
131 AREA F.B.	38	110,400	73,120	46.3	20.0
132 K-42 H.F.	9	119,900	80,900	41.9	18.5
132 K-42 H.F.	11	101,900	78,900	43.4	18.5
132 AREA H.F.	4	125,900	87,900	46.0	18.0
132 AREA H.F.	24	118,400	80,400	44.9	18.5

slightly above the joint, and the fishing surfaces of both the bars and rails were kept wet for the duration of the test. Since time is an important consideration in corrosion fatigue, the machine was run for only 10,000 cycles per day in order to allow sufficient time for corrosion and rusting to occur.

The results of the test were unique in that no failure had occurred after six months in the rolling machine at the end of 1,500,000 cycles of testing. At that time the batter at the rail ends was so great that the test was terminated in order to prevent damage to the rolling-load machine. Upon disassembly, the bars showed unusually heavy bearing on both top and bottom fishing surfaces for nearly their entire length. These bearing areas are shown in Fig. 1. Magnaflux examination revealed two cracks at the rail end gouges of the north bar ¾ in. and ⅝ in. long, and one crack in a gouge on the top of the south bar ¼ in. long.

In previous tests of 131 AREA bars with no corrosion, most of the fatigue cracks started in or at the edge of an area of heavy bearing or galling. In this corrosion test no galled areas were detected on the fishing surfaces, so it is quite possible that the rusting and corroding of the areas of heavy bearing tended to equalize the bearing and distribute the load more evenly over the entire length of the bars, thereby reducing high local stresses due to heavy contact pressure at the "high spots" on the fishing surfaces. In other words, after a few thousand cycles, with sufficient time for corrosion to take place, the contact of bars on rails approached a more nearly perfect fit than is ordinarily obtained in a test with no corrosion. Gouging of the bars by the rail ends in this test was less sharp than usual and was more in the nature of a shoulder pushed up on the top bar surfaces in the rail gap.

Bolt tension was maintained at 15,000 lb. and out-to-out measurements on the bars as the test progressed indicated a gradual inward movement in which the center of the

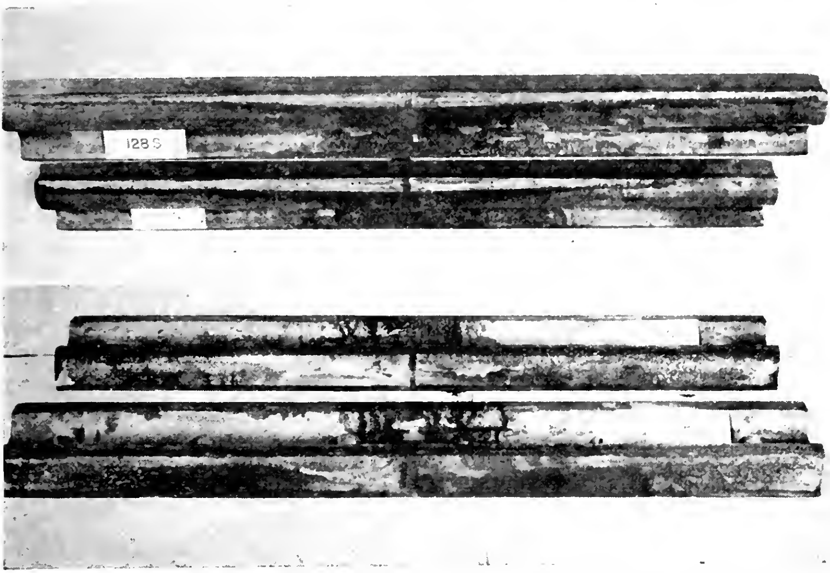
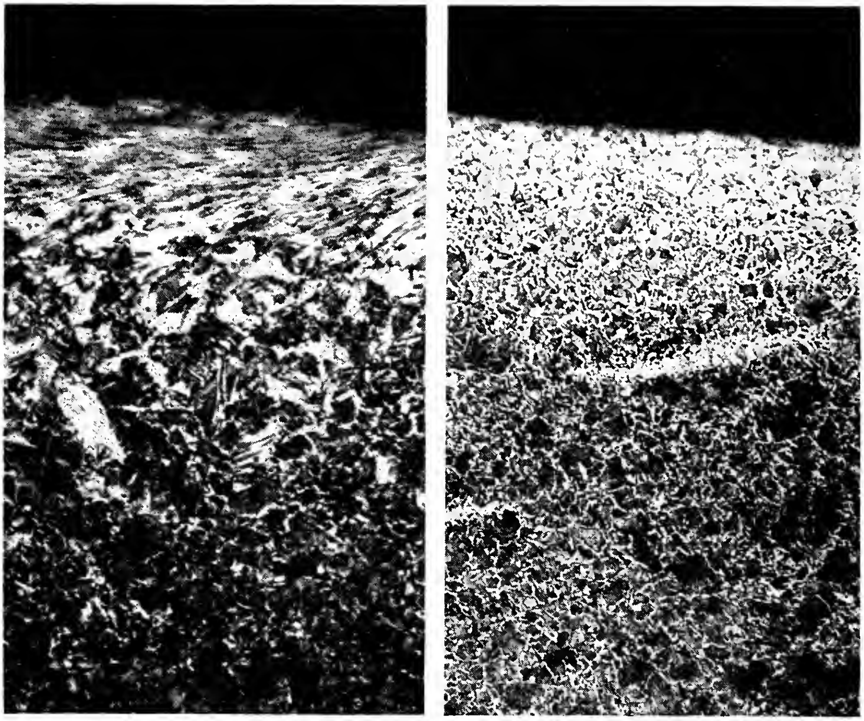


Fig. 1.—Top and Bottom Bearing Areas on Bars of Joint 128 after 1,500,000 Cycles.

Fig. 2.—Fractures of 132 K–42 Headfree Bars, Bar 133 N and Bar 141 S.

Origins of fatigue cracks are indicated by the lines on the curved underside of the head of these bars.



a. b.

Fig. 3.—Micrographs of Bar 141 S. Magnification 75 X.
(a) Top fishing surface, decarburization—0.020 in.
(b) Surface where fatigue crack started—decarburization—0.016 in.

bars pulled in an average of 0.060 in. and the ends 0.016 in. at the end of 1,500,000 cycles.

While conclusions are not warranted on the basis of one test it appears that the longer fatigue life of the bars in the corrosion test was due to a reduction of high local stresses and consequent better fit of bars on rails, giving a more uniform distribution of load.

Rolling-Load Tests of 132 K–42 H.F. Bars

Results of the 12 tests of 132 K–42 bars are given in Table 3. Rails ends for these joints were hot-sawed and milled by the manufacturer, and profiles of the rail fishing surfaces showed practically no rail end distortion. The average cycles for failure for these tests was 523,060.

Since the K–42 bars had a pressed easement of 1/64 to 1/32 in. over the central 1¼ in. of the upper fishing surfaces, gouging by the rail ends was substantially reduced. Several of the bars, however, showed either very light gouges or lips of metal pushed up on the upper bar surface slightly *above* the easement. All bars except one cracked from the top downward, the cracks occurring at or near the rail end. For the one exception which failed from the base upward, the crack started 2¾ in. from a rail end in an area of heavy bearing and progressed upward to an oval hole. Upon examination after sawing

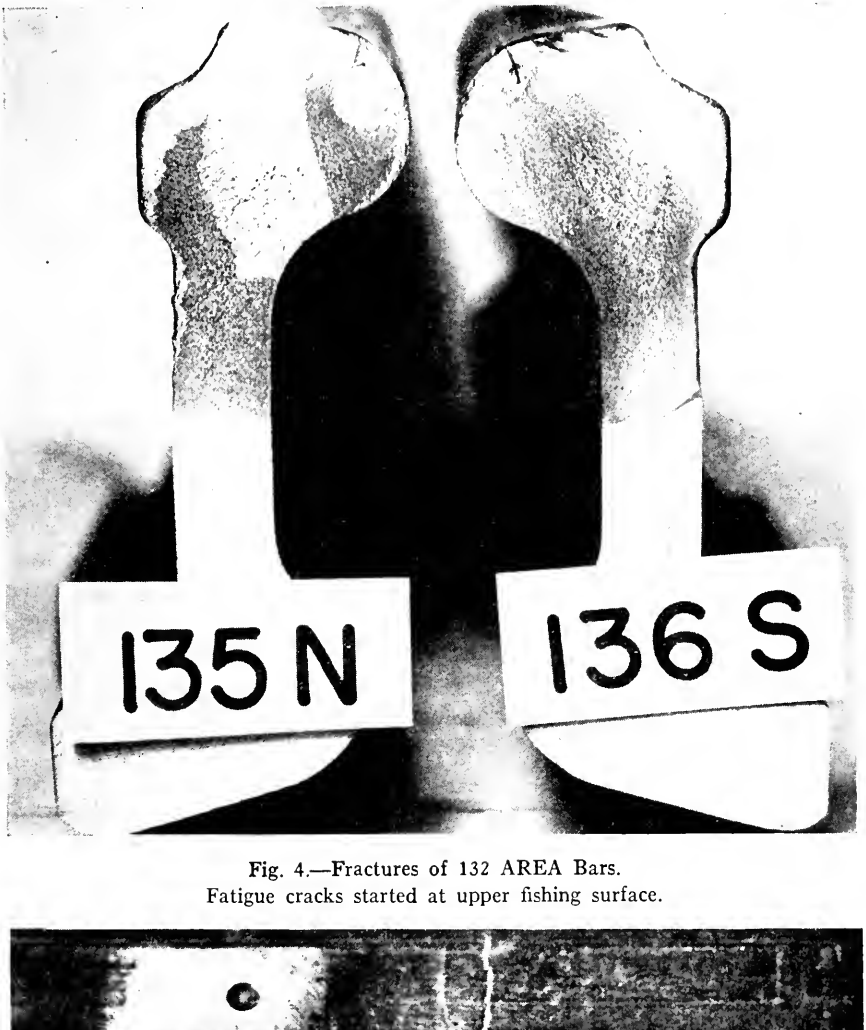


Fig. 4.—Fractures of 132 AREA Bars.
Fatigue cracks started at upper fishing surface.

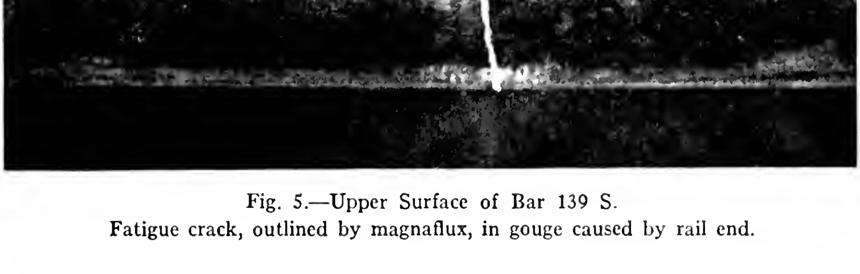
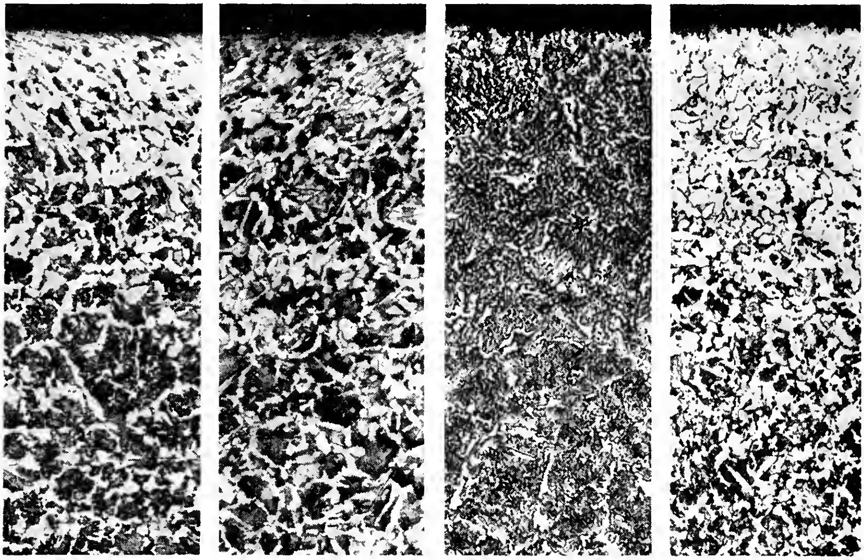


Fig. 5.—Upper Surface of Bar 139 S.
Fatigue crack, outlined by magnaflux, in gouge caused by rail end.



a b c d

Fig. 6.—Micrographs at Upper Fishing Surface of Joint Bars. Mag. 73 X.
(a) Bar 132 S—decarburization—0.021 in.
(b) Bar 132 N—decarburization—0.012 in.
(c) Bar 135 N—decarburization—slight
(d) Bar 136 S—decarburization—0.024 in.

through the bar to complete the fracture, an additional fatigue area was observed at the bolt hole extending downward for ½ in.

Bars from seven of the joints indicated that the cracks originated on the fishing surfaces in areas of heavy bearing or galling, or in rail end gouges, which is not uncommon. However, six bars from five joints, namely 133N, 141S, 143N, 143S, 144S, and 148N exhibited fractures with nuclei on the curved inner faces of the bars about an inch below the fishing surface. Fig. 2 shows two bars with such nuclei. The K–42 bars have ribs on the inner side, and these nuclei occurred at the juncture of the rib with the thin section of the bar. These points of origin of the cracks were at approximately midlength of the bars.

Fig. 3 shows two micrographs taken from sections of bar 141S indicating decarburized surfaces, 0.020 and 0.016 in. deep. Fig. 3a is the section of the upper fishing surface at the crack where there was heavy bearing. Fig. 3b shows the section at the origin of the fatigue crack.

Magnaflux examinations revealed additional cracks on three of the failed bars and on three companion bars, all on the top fishing surfaces in areas of heavy bearing or galling. These cracks ranged in length from ⅛ to 1¼ in.

Lateral deflection readings on the bars indicated the center of the bars were bowed inward from 0.005 to 0.050 in. in elastic bending measured on the upper flanges. Elastic bending on the lower flanges was greater in nearly every case by 0.005 to 0.010 in.

Out-to-out measurements indicated that at 100,000 cycles the lower flanges of the bars had moved inward from 0.035 to 0.074 in. at the center of bar length and about half of that amount or 0.020 to 0.043 in. at the ends. At the same time the upper flanges at the center of the bars had moved in from 0.001 to 0.008 in., while at the ends the movement ranged from 0.003 in. inward to 0.009 in. outward.

Rolling-Load Tests of 132 AREA H.F. Bars

Results of 12 tests of 132 AREA bars on hot-sawed rail ends are listed in Table 3. The average cycles for failure was 794,090. For 10 of the joints, the fatigue crack which caused failure originated on the top fishing surface of the bar in a rail end gouge and progressed downward. Fig. 4 shows typical fractures on these bars and Fig. 5 shows a crack in a gouge on the top surface of bar 139S. For joint No. 140, in which the bar cracked from the base upward to an oval bolt hole, the crack started in an area of heavy bearing on the lower fishing surface 2¾ in. from a rail end. A fatigue area extending downward ½ in. was observed at the hole.

Joint 142 was outstanding in that it withstood 2 million cycles with no bar failure. Magnaflux examination after testing did not reveal any cracks on these bars. The bars for this joint were stamped with the serial number 4 and Table 5 shows a higher tensile strength and higher yield point for bars of this heat, which undoubtedly contributed to their greater fatigue strength. Unfortunately only three bars from this heat were received; the third bar was the south bar of joint 147 which ran to 911,200 cycles. The micrographs taken from top sections of both bars of joint 142 showed a fine grain structure and no decarburization at the bar surface.

Magnaflux examination revealed additional cracks ¼ to 11/16 in. long on the top of two of the failed bars and cracks ⅛ to 1¼ in. long on the top of five companion bars. These cracks were in gouge marks or in areas of heavy bearing.

Lateral deflection readings indicated the bars pulled in at the center 0.002 to 0.023 in. in elastic bending measured on the upper flanges. Inward elastic bending of lower flanges was slightly greater for most of the bars.

Out-to-out measurements indicated that at 100,000 cycles the lower flanges of the bars had moved inward from 0.023 to 0.043 in. at the center of bar length and from 0.009 to 0.028 in. at the ends. The upper flanges moved in at the center of bar length 0.002 to 0.013 in. and at the ends the movement ranged from 0.008 in. inward to 0.012 in. outward.

Metallographic Studies

Sections were sawed from all failed bars at the fatigue fracture and micrographs at 100× magnification were made to determine the extent of decarburization of the bar surfaces. Depths of decarburization are tabulated in Table 3 and range from slight (less than 0.001 in.) to 0.024 in. Fig. 6 shows micrographs from sections of four bars showing various depths of decarburization.

No clearly defined correlation between cycles for failure and depth of decarburization is apparent.

Summary

1. One test of a joint with water corrosion on 131 AREA full bearing 36 in. bars ran 1,500,000 cycles without failure. It is thought that rusting of high spots on fishing surfaces eliminated high local stresses and provided more uniform distribution of loading, resulting in the longer fatigue life.

2. Twelve tests of 132 K–42 H.F. bars averaged 523,060 cycles. On bars from seven joints, cracks causing failure originated on the top fishing surface, which is common,

but on six bars from five joints, cracks started on the ribbed inner bar face about one inch below the fishing surface at the junction of the rib with the thin section on the bar.

3. The easement on the K–42 bars was beneficial in eliminating gouging of the bars at the rail ends.

4. Twelve tests of 132 AREA H.F. bars averaged 794,090 cycles. One joint ran to 2 million cycles with no failure.

5. Micrographs taken on all bars showed decarburized bar surfaces, in some bars this extended to a depth of 0.024 in. No clearly defined correlation was apparent between depth of decarburization and cycles for failure.

Report on Assignment 9

Corrugated Rail: Causes and Remedy

W. C. Barnes (chairman, subcommittee), S. E. Armstrong, C. B. Bronson, E. E. Chapman, C. J. Code, J. L. Gressitt, W. E. Heimerdinger, S. R. Hursh, G. M. Magee, Ray McBrian, C. E. Morgan, R. A. Morrison, L. T. Nuckols, R. E. Patterson, E. F. Salisbury, F. S. Schwinn, A. A. Shillander, R. P. Winton, J. G. Wishart.

Because of the years of work that have been put on the problem of the corrugated rail, both here and abroad, a résumé of the investigations made is given here as information to aid in the decision as to the future disposition of this subject.

Corrugation of rails has been most troublesome on electric railway tracks laid in paved streets and the first exhaustive investigations carried on to determine the cause and remedy were made in 1925–1930 by the American Electric Railway Association.* Those investigations dealth with:

1. Effect of elastic vibrations as affecting variation in pressure between wheel and rail.
2. Rythmic variation in rail head hardness.
3. Rail quality.
4. Relative hardness of wheel tread and rail.
5. Chemical characteristics of corrugated rails.
6. Micrographic studies.
7. Temperature stresses.
8. Contact pressures between wheel and rail.

Despite the comprehensiveness and thoroughness of these tests, the committee in charge was able to draw only the general conclusion that corrugations are due to overloading of the running surfaces of the rails with loads that vary more or less periodically in intensity and that the resulting flow rather than abrasive wear is the chief element in their formation. This conclusion does not explain the prevalence of corrugations on electrically operated street railway tracks where wheel loads are comparatively light.

Assigned to the Committee in 1934

The subject was assigned to the Rail committee in 1934. In its report in 1936, the committee referred to the American Electric Railway Association tests and had the benefit of a report of an investigation made by Dr. Kuhnel of the German State Railways. The committee furnished information regarding the dimensions of corrugations and concluded that the subject should be discontinued on the grounds that the many

* Now American Transit Engineering Association, 292 Madison Avenue, New York.

variables preclude the determination of any general cause of corrugations, that corrugations were not generally a serious problem on steam roads, especially since in the rare cases where corrugations are so bad as to seriously affect the riding qualities of the track they can be removed at moderate cost by grinding, a grinding car having been developed for this purpose by the Lehigh Valley Railroad. The committee did not consider "it advisable or even practicable without a special appropriation to undertake the extensive tests which at best could be expected to determine the cause of corrugations at a given location."

Grinding equipment was later built by the Pennsylvania Railroad which consists of a train of 8 grinding cars providing 48 motor-driven grinding wheels on each rail, capable at a speed of 1½ to 2 mph. of removing approximately 0.01 in. of steel from the surface of the rail, or sufficient to remove the majority of corrugations and light wheel burns and without reducing materially the amount of cold-rolled hardness. This equipment is operated at a cost of $75 to $78 per mile for labor and material. The Pennsylvania Railroad grinds 1400 to 1800 track miles of rail per year.

The subject was discontinued in 1936 and reassigned in 1941. The committee in 1942 reported information obtained from a questionnaire as to the prevalence and locations of corrugations. It also studied reports of investigations made by C. E. Cowdery of the South Wales Railways, Australia, and by J. M. Goodier of the Ontario Research Foundation, and others, which reports presented conflicting theories as to the possible cause without offering any remedy except that of grinding the rail surfaces.

Studies by Professor Cramer

In 1945, Professor R. E. Cramer of the University of Illinois investigated some corrugated rails on the Illinois Central Railroad and reported at the 1946 convention that the crests of corrugations showed a hard layer of martensite from 0.001 in. to 0.005 in. thick. He attributed the cause of some corrugations to wheel slippages which heat a thin surface layer of the rail above the quenching temperature of the steel, which layer is quickly cooled by the metal underneath forming martensite. When such hard spots, due to martensite, are intermittent and the softer areas between them are cold-worked lower than the hard areas, corrugations are formed. The martensite can be softened by tempering to dark straw or blue color with practically no effect on the hardness of the softer areas. Half of a corrugated rail on the Illinois Central was heated with a No. 70 Oxweld torch and in only one week the area which had been flame tempered had lost practically all trace of bright spots, while the untreated portion was still corrugated. In service, the flame-softened hard spots soon cold-worked to a smooth running surface. In the 1947 report of the committee, Professor Cramer described laboratory experiments which produced hard spots on new rail by controlled wheel slippage. Also notches were ground in one rail on the Illinois Central with the thought that they might start vibrations of the car wheels which would produce corrugations. Corrugations did not result in heavy slow speed freight traffic.

He has in mind no further laboratory investigations that would furnish useful information. Field surveys of operating conditions and accurate determinations of locomotive driver slippages, which would be very difficult to obtain, would be the next step.

As outlined above, this subject has been under investigation by various groups since about 1925 and by the committee for a total of 11 years—1934–1936 and 1941 to date, with scant tangible results. Further studies to be of value would necessitate a special appropriation for field investigations of indeterminate duration. If the slippage of locomotive drivers is the cause, the remedy would appear to be a motive power rather than a rail problem.

Recommendation

Because the Committee finds but little interest in this subject, except on one road, because no rail failures have been attributed to corrugations, because an appropriation would be required for further field investigation with uncertainty of determining the means of prevention, because riding quality is usually not adversely affected, and excessive corrugation may be removed by grinding, the committee is of the opinion that further study at this time is not warranted.

Report on Assignment 11

Causes of Shelly Spots and Head Checks in Rail; Measures for Their Prevention

L. S. Crane (chairman, subcommittee), S. E. Armstrong, H. Austill, W. C. Barnes, C. H. Blackman, T. A. Blair, C. B. Bronson, E. E. Chapman, C. J. Code, P. O. Ferris, J. L. Gressitt, G. F. Hand, C. B. Harveson, F. R. Layng, G. M. Magee, E. E. Mayo, Ray McBrian, R. J. Middleton, L. T. Nuckols, W. C. Perkins, G. A. Phillips, J. G. Roney, R. T. Scholes, I. H. Schram, A. A. Shillander, G. L. Smith, Barton Wheelwright, R. P. Winton.

This report is offered as information.

Conduct of the investigation for the past year has been administered along the task lines previously used, the first group being handled directly by the subcommittee, the second by the research staff of the Engineering Division, AAR, the third by the University of Illinois and the fourth by Battelle Memorial Institute.

Funds are provided by the AAR for the work being done by Group 2 and jointly by the AAR and the manufacturers for the work being conducted by Groups 3 and 4. In order to insure vigorous administration of the work being conducted by Groups 3 and 4, a small task group composed of members appointed by the subcommittee and by the manufacturers have met regularly during the year with the research investigators at both the University of Illinois and Battelle Memorial Institute.

The subcommittee has been unable as yet to find any single solution for the problem. It is believed, as a result of research work conducted at Battelle Memorial Institute, that gage corner shelling characterized by spalling of metal from the gage corners and developing in a horizontal direction may be retarded by the use of heat treated rail steel. It is also believed that the modified head contours incorporated in recently revised AREA rail sections will materially assist in retarding the onset of shelling, although rails with this modification have not been in service a sufficient period of time to establish this definitely.

Group 1

Item (a).—A Study of data submitted indicates no definite relationship between the chemistry and shelling, except insofar as the hardness of the running surface of the rail is affected.

Item (b).—A study of data submitted as to curvature, elevations, speeds and grades, reveals no definite trend.

Item (c).—The Delaware & Hudson ran a test on two similar curves, one with lubricators and the other without. The test was in progress about four years, but both curves developed shelling and flaking spots to approximately the same amount.

Item (d).—Experience on the Chicago, Milwaukee, St. Paul & Pacific and the Atchison, Topeka & Santa Fe indicates that transposing shelly high rails to the low rail, if done in time, is well worthwhile.

Item (e).—Tests on the Milwaukee, the Norfolk & Western, and the Pennsylvania have shown that rail slow-cold worked under traffic in nonshelling locations and relaid in shelling locations possesses very little, if any, greater resistance to shelling than ordinary rail.

Item (f).—Trial installations of special high carbon rail with carbon ranging from 0.84 to 0.91 percent, but otherwise conforming to the usual specifications have been made on the Norfolk & Western. Completion of these tests has indicated that high carbon rail will retard but not eliminate shelling. The high carbon rail, furthermore, has a tendency to head check and this in turn causes gage corner flaking or minute shelling.

Continued observation of the performance of 112-lb. Lorain heat-treated rail installed on the Duluth, Missabe & Iron Range in 1943 has been very encouraging. It is believed that additional investigations of heat treated rail should be initiated and for this purpose heat-treated rails produced by the Bethlehem Steel Company at the Steelton plant will be installed on the Pennsylvania, the Norfolk & Western, and the Chesapeake & Ohio during the coming year. Samples of these rails are being retained for the necessary chemical, metallurgy and rolling-load investigations.

Item (g).—Inspections have been made or reports received covering the general experience of the following roads during the year:

Norfolk & Western
Pennsylvania
Duluth, Missabe & Iron Range
Chesapeake & Ohio

Group 2

The Engineering Division research staff has under observation numerous installations of rail of the new AREA sections incorporating modified head contours. These installations have not been in service a sufficient time and no definite conclusions can be made.

Group 3

The third portion of the assignment is covered by a report prepared by Professor R. E. Cramer, which follows as Appendix 11–a.

Group 4

The fourth portion of the assignment is covered by a report prepared by G. K. Manning which follows as Appendix 11–b.

Appendix 11–a

Seven-Year Summary Report of Shelly Rail Investigation at the University of Illinois

By R. E. Cramer

Special Research Associate Professor of Engineering Materials, University of Illinois

In 1942 the subcommittee on shelly rail assigned the following work to be carried out at the Talbot laboratory.

(a) Examination of rail failures caused by shelling.
(b) Rolling-load tests to produce shelling under laboratory conditions.
(c) Study the resistance of different rail steel composition to the development of shelling by laboratory rolling-load tests.
(d) Study the effects of different heat treatments of rail on the development of shelling by laboratory rolling-load tests.

Importance of Shelly Rail Failures

The writer has been privileged to attend the examination of failed rails on a number of railroads. There has been a gradual increase in the number of shelly rail failures observed until at one recent examination it was found that 78 percent of the failures in control cooled rails were shelly rail failures. This was on a heavy traffic line with numerous curves and is probably a much higher percent of shelly rail failures than would be found on the average railroad, but there is no question that if standard carbon rails remain in heavy duty track a number of years many of them will develop shelly failures.

Examination of Shelly Rail Failures

A large number of detail fractures from shelling and a few rails with shelling only have been sent to the university laboratory by various railroads. These have all been carefully examined as to the origin of the shelly cracks and imperfections in the rails which may have acted as starting points for the shelling cracks. Also, most of the shelling cracks which have been developed in the laboratory have been opened up and examined for their points of origin. Rolling was stopped on one specimen before the shelling crack had reached the surface. It had spread to within ⅛ in. of the gage side of the rail head. It is the writer's opinion that most shelling cracks start inside the rail head from ⅛ to ⅜ in. below the rail tread and from ⅛ to 1.0 in. from the gage side.

The Development of Shelling and Detail Fracture from Shelling

A combination of high shearing stresses and flow of the metal toward the gage side of the rail eventually starts a horizontal crack in the weakest spot in the steel. This is likely to be a segregation streak containing small nonmetallic inclusions which are easily crushed or cracked. After an internal crack starts it spreads across the width of the rail head and breaks out on the gage side. A black spot on the rail tread soon develops where the tread is low, due to flow over the gage side of the rail. Some rails, especially the lighter sections, develop a transverse detail fracture from the shelling crack before it reaches the side of the rail head. Experience in developing transverse fissures in the rolling-load machines indicates that vertical bending is necessary to produce the transverse detail fractures. This may explain why more detail fractures are likely to develop in light weight rails.

TABLE 1.—SUMMARY OF ROLLING-LOAD TESTS IN CRADLE MACHINE

Specimen Number	Approx. Chemical Analysis Percent						Brinell Hardness	Yield Strength (0.2% Set) psi.	Tensile Strength psi.	Elong. in 2 in. Percent	Reduc. of Area Percent	Charpy Value Unnotched Bar ft.-lb.	Endurance Limit psi.	Cycles for Failure 50,000-lb. Wheel Load
	C.	Mn.	Cr.	Mo.	Si.	Ni.								
Standard Carbon Steel Rails														
799	0.78	0.83	-----	-----	0.14	-----	283	71,200	135,000	8	14	103	52,000	611,000
804–5	-----	-----	-----	-----	-----	-----	282	-----	-----	-----	-----	-----	-----	1,011,000
818 B	-----	-----	-----	-----	-----	-----	268	-----	-----	-----	-----	-----	-----	1,000,000
819 A	-----	-----	-----	-----	-----	-----	240	-----	-----	-----	-----	-----	-----	1,112,000
820	0.75	0.80	-----	-----	-----	-----	260	-----	-----	-----	-----	-----	-----	1,043,000
Heat Treated Standard Carbon Steel Rails														
803-H-1	-----	-----	-----	-----	-----	-----	368	-----	-----	-----	-----	-----	-----	4,564,000
820-H-1	0.75	0.80	-----	-----	-----	-----	380	-----	-----	-----	-----	-----	-----	2,256,000
1095 A	0.80	0.92	-----	-----	-----	-----	378	134,000	194,000	7	31	264	93,000	4,144,000
1095 B	0.80	0.92	-----	-----	-----	-----	375	134,000	194,000	7	31	264	93,000	3,000,000
1096 A	0.77	0.81	-----	-----	-----	-----	352	117,700	175,800	8	38	292	82,000	4,514,000
1096 B	0.77	0.81	-----	-----	-----	-----	358	117,700	175,800	8	38	292	82,000	4,700,000
1099 A	0.80	0.92	-----	-----	-----	-----	309	109,000	164,000	8	38	286	83,000	800,000
Mill Quench from Rolling Temperature														
813 A	-----	-----	-----	-----	-----	-----	330	-----	-----	-----	-----	-----	-----	989,400
813 B	-----	-----	-----	-----	-----	-----	340	-----	-----	-----	-----	-----	-----	1,000,000
British Sandberg Sorbitic Rail														
814 B	0.56	1.14	-----	-----	0.15	-----	235	64,000	122,700	10.8	28.3	245	57,000	1,557,000
Used 0.45% Silicon Rail														
812	0.75	0.75	-----	-----	0.45	-----	288	-----	-----	-----	-----	-----	-----	720,000
Alloy Steel Bars as Rolled														
123	0.62	0.97	1.04	0.26	0.20	0.62	336	114,000	163,000	8	35	195	75,500	1,002,000
126	0.52	0.90	1.59	0.29	0.21	0.61	353	127,000	187,000	7	31	264	88,500	843,000
128	0.62	1.58	-----	0.48	0.25	-----	270	94,400	134,600	10	36	125	71,500	358,000
Silico Manganese Spring Steel Rails														
1090–1	0.73	0.89	-----	0.49	1.96	-----	348	119,100	145,600	2.3	9.3	395	82,000	983,000
1090–2	0.73	0.89	-----	0.49	1.96	-----	355	119,100	145,600	2.3	9.3	395	82,000	657,000
Heat Treated Alloy Steel Rails														
1084	0.24	1.28	0.64	0.34	0.20	0.57	337	145,400	157,600	11.3	64.5	468	90,000	4,400,000
1085	0.24	1.28	0.64	0.34	0.20	0.57	331	139,500	150,000	11.0	66.7	478	86,000	2,323,000
1086	0.24	1.28	0.64	0.34	0.20	0.57	360	157,000	170,500	10.0	63.0	403	92,000	1,723,000
1087	0.24	1.28	0.64	0.34	0.20	0.57	356	158,500	171,000	10.0	61.0	410	93,000	3,035,000
1088	0.24	1.28	0.64	0.34	0.20	0.57	302	154,000	169,800	11.3	64.0	478	78,000	2,086,000
1089	0.24	1.28	0.64	0.34	0.20	0.57	300	127,400	139,800	11.4	69.1	-----	-----	2,886,000

Table 1 (Continued)

Specimen Number	Approx. Chemical Analysis Percent C.	Mn.	Cr.	Mo.	Si.	Other Alloy	Brinell Hardness	Yield Strength (0.2% Set) psi.	Tensile Strength psi.	Elong. in 2 in. Percent	Reduc. of Area Percent	Charpy Value Unnotched Bar ft.-lb.	Endurance Limit psi.	Cycles for Failure 50,000-lb. Wheel Load
Molybdenum Billets as Rolled														
1 Air Cld	0.63	0.70	-----	0.23	0.24	-----	270	85, 000	136, 400	9.1	48.7	268	67, 000	225, 000
2 Cont. "	0.63	0.70	-----	0.23	0.24	-----	280	87, 100	136, 900	10.5	35.1	261	63, 500	1, 447, 000
3 Air "	0.63	0.75	-----	0.30	0.24	-----	292	95, 500	143, 600	9.2	29.9	224	62, 500	452, 000
4 Cont. "	0.63	0.75	-----	0.30	0.24	-----	271	92, 100	138, 900	10.5	34.8	231	65, 000	1, 000, 000
Oxweld Flame—Hardened Carbon Steel Rails														
1092	0.73	0.77	-----	-----	0.20	-----	360	-----	-----	-----	-----	-----	-----	450, 000
1093	0.73	0.77	-----	-----	0.20	-----	365	-----	-----	-----	-----	-----	-----	427, 000
Ox.3	0.77	0.90	-----	-----	0.20	-----	370	-----	-----	-----	-----	-----	-----	550, 000
Ox.6	0.77	0.90	-----	-----	0.20	-----	355	-----	-----	-----	-----	-----	-----	564, 000
Ox.7	0.77	0.90	-----	-----	0.20	-----	360	-----	-----	-----	-----	-----	-----	459, 000
Ox.8	0.77	0.90	-----	-----	0.20	-----	360	-----	-----	-----	-----	-----	-----	696, 000
Ox.9	0.77	0.90	-----	-----	0.20	-----	365	-----	-----	-----	-----	-----	-----	557, 000
1101	-----	-----	-----	-----	-----	-----	285	-----	-----	-----	-----	-----	-----	1, 100, 000
1102	-----	-----	-----	-----	-----	-----	300	-----	-----	-----	-----	-----	-----	462, 400
1103	-----	-----	-----	-----	-----	-----	290	-----	-----	-----	-----	-----	-----	443, 200
1104	-----	-----	-----	-----	-----	-----	305	-----	-----	-----	-----	-----	-----	1, 800, 000
3 Percent Chrome Steel Rails														
501	0.31	0.64	3.19	-----	0.37	-----	360	129, 900	173, 200	8.5	38.1	300	70, 000	1, 532, 400
1081 C	0.31	0.71	3.00	-----	0.21	-----	376	128, 000	165, 000	9.3	27.0	353	92, 500	2, 867, 800
1083 A	0.31	0.64	3.19	-----	0.37	-----	387	133, 000	177, 000	10.8	41.1	440	104, 000	5, 009, 000
Laboratory Heat Treated Intermediate Manganese Steel Rail														
810-H	-----	-----	-----	-----	-----	-----	340	117, 500	165, 000	8.1	36.2	317	73, 500	718, 000
823-H1	0.59	1.36	-----	-----	0.14	-----	385	111, 800	160, 400	9.0	14.8	310	-----	1, 536, 000
Intermediate Manganese Steel Rail as Rolled														
810	0.59	1.36	-----	-----	0.14	-----	270	69, 100	127, 000	11.0	32.5	246	57, 000	1, 070, 000
823 A	0.59	1.36	-----	-----	0.14	-----	258	69, 100	127, 000	11.0	32.5	246	57, 000	1, 346, 000
823 B	0.59	1.36	-----	-----	0.14	-----	257	69, 100	127, 000	11.0	32.5	246	57, 000	1, 248, 000
Used Intermediate Manganese—Molybdenum Rails														
1091-1	0.60	1.35	-----	0.37	0.12	-----	267	91, 100	125, 000	10.0	34.3	387	58, 000	1, 234, 000
1091-2	0.60	1.35	-----	0.37	0.12	-----	263	91, 100	125, 000	10.0	34.3	387	58, 000	1, 267, 600

TABLE 1 (Continued)

Specimen Number	Approx. Chemical Analysis Percent C.	Mn.	Cr	Mo.	Si.	Cu.	Brinell Hardness	Yield Strength (0.2% Set) psi.	Tensile Strength psi.	Elong. in 2 in. Percent	Reduc. of Area Percent	Charpy Value Unnotched Bar ft.-lb.	Endurance Limit psi.	Cycles for Failure 50,000-lb. Wheel Load
Molybdenum Rails														
1097 A	0.76	0.88	--------	0.35	--------	--------	314	111, 000	164, 000	8	23	177	72, 500	1, 125, 000
1098 A	0.74	0.70	--------	0.34	--------	--------	313	103, 000	152, 000	8	39	196	71, 000	1, 250, 000
One Percent Copper Rails														
1094-1	0.71	0.80	--------	--------	--------	1.11	272	75, 000	135, 900	7.5	16.6	73	62, 000	822, 000
1094-2	0.71	0.80	--------	--------	--------	1.11	274	75, 000	135, 900	7.5	16.6	73	62, 000	803, 200

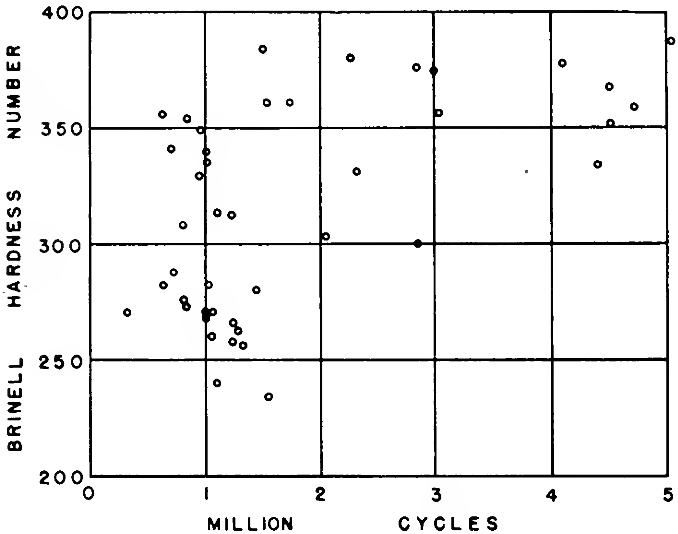


Fig. 1.—Brinell Hardness vs. Cycles in Rolling-Load Machine.

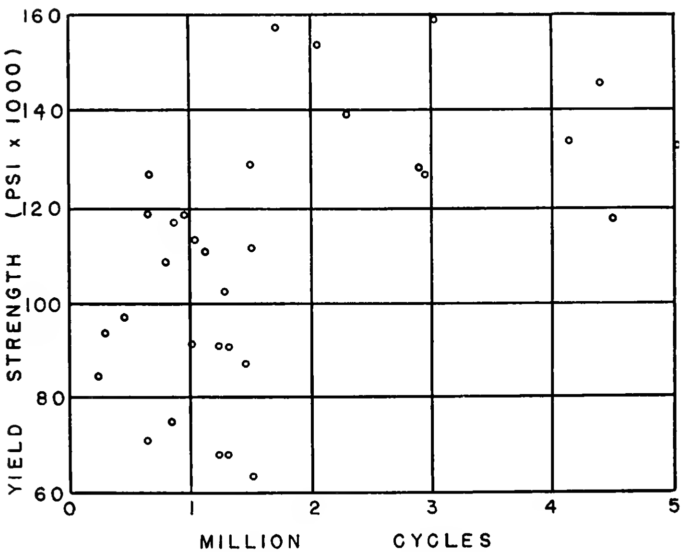


Fig. 2.—Yield Strength vs. Cycles in Rolling-Load Machine.

Causes of Shelling

It should be recognized that shelling cracks are primarily caused by the heavy bearing pressures of car wheels on a small area of contact which produce internal shearing stresses and flow that exceeds the capacity of the steel to withstand such stresses.

All the above considerations indicate that a stronger steel which will resist flow and strengthen the metal above and around the inclusions or imperfections should delay the development of shelling cracks. Rolling-load tests of heat treated and alloy steels as described below confirm this conclusion.

Rolling-Load Tests

Considerable effort was required to design a rolling-load machine which produces typical shelling failures in laboratory testing. A cradle type machine which continuously moves the rail from a flat position to a 1:5 cant under the car wheel has been used successfully since 1943. Fifty-five rails or bars were tested to August 1, 1948 as listed in Table 1. The cycles for failure with a 50,000-lb. wheel load vary from 225,000 cycles for a shatter cracked billet to 5 million for one specimen of 3 percent chromium steel rail. The average for standard carbon steel rail is 955,000 cycles. There are 6 specimens which went above 4 million cycles. Five of these are heat treated and one is a 3 percent chromium rail. A number of the rails contained alloys but these did not give quite as high tests as the heat-treated carbon steel rails.

Comparison of Physical Properties of Rails with Rolling-Load Tests

Table 1 gives Brinell hardness values for each specimen, and yield strength, tensile strength, Charpy values and endurance limit for many specimens. These values were all plotted separately against rolling-load cycles. The tensile strength and Charpy value plots showed very wide scatter. Figs. 1, 2, and 3 show the plots for hardness, yield strength, and endurance limit. In general, the cycles in the rolling-load machines increase

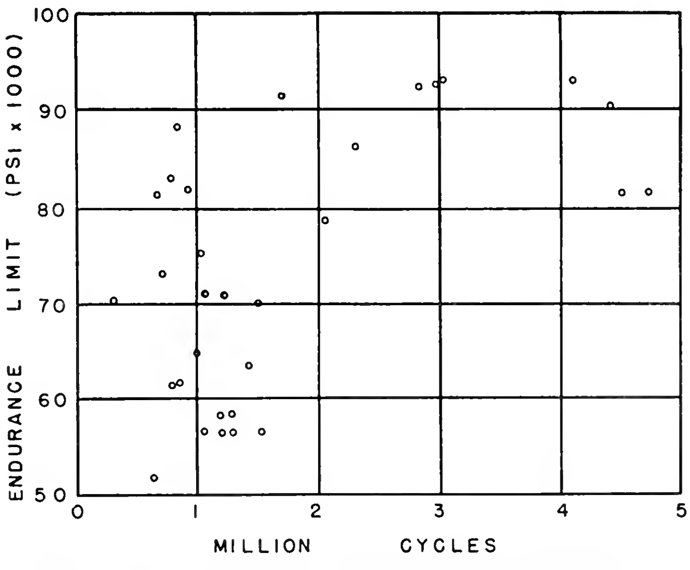


Fig. 3.—Endurance Limit vs. Cycles in Rolling-Load Machine.

as these physical properties increase. Exceptions can be expected due to the presence of small imperfections in individual rails. Because of the ease of making Brinell tests it seems that this should be the criterion for testing heat-treated and alloy rails.

Conclusions

Laboratory tests have indicated that either the addition of alloys or heat treatment of carbon steel rails gives longer tests in the rolling-load machines. Further tests of improved alloy steels may develop a satisfactory alloy steel to resist shelling.

Heat treatment was the solution for shelling in steel car wheels. There are many problems involved in heat treating rails but past metallurgical experience indicates that these may be overcome. Laboratory tests indicate that heat treated rails should last about three times as long in severe service as standard carbon steel rails. However, there may be service conditions such as slipping of car wheels or locomotive drivers, or web and base failures which could make heat treated rails impractical for general use.

Appendix 11-b

Summary Report on the Examination of Shelled Rails

to

Joint Contact Committee on Rails of Association of American Railroads and American Iron and Steel Institute

By G. K. Manning
Battelle Memorial Institute

Abstract

Examination of some 200 shelled spots selected from the track of 11 major roads indicated that the shelled spots were predominately of surface origin. Many small cracks only a few thousandths of an inch in depth may be found by the use of a microscope on the gage corner of a rail which has shelled. These small cracks grow very slowly at first, but as they penetrate into the rail, their rate of growth increases several-fold. This condition apparently accounts for the partially formed elliptical growth rings sometimes observed.

The black spots which appear on the head of a rail over a shell were found to represent depressions or "dished out" areas. They follow rather than precede the formation of a shelled spot and are caused by an increased lateral flow in the metal above a shelled spot. Evidence was found that completely pearlitic rail is somewhat more resistant to shelling than is rail containing pearlite plus a network of ferrite. However, rail that is completely pearlitic certainly will shell and the difference noted is of doubtful practical importance.

It should be emphasized that the procedure used of selecting specimens from track resulted in delivery to Battelle of defects which had no vertical component but only a horizontal crack. Only nine detailed fractures were examined during the two years. Some of these are known to have been of internal origin and, at least these, should be considered as a different type of defect.

Examination of Shelled Rail

Within the past two years, Battelle has received 109 shelled rail specimens from 11 of the major roads in the country. These samples were selected from track and through

Fig. 1.—Opened Shelled Spot from a C. & O. Rail.
Note elliptical shape at each end of the fracture.

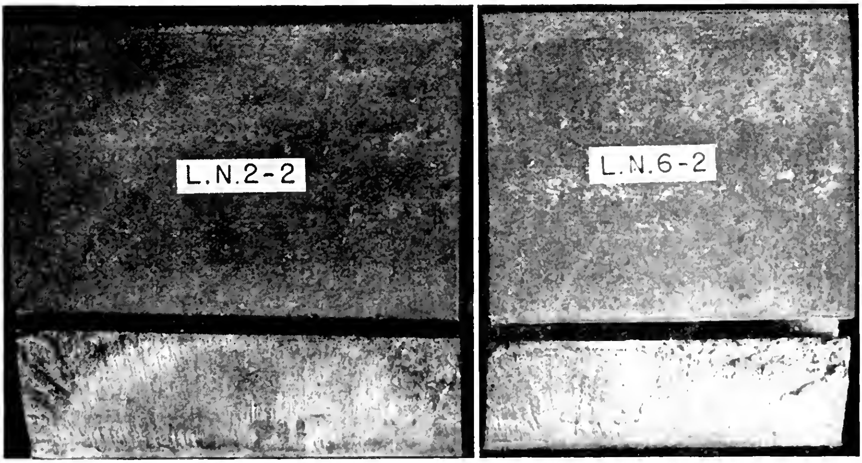


Fig. 2.—Opened Shelled Spots from Two L. & N. Rails.

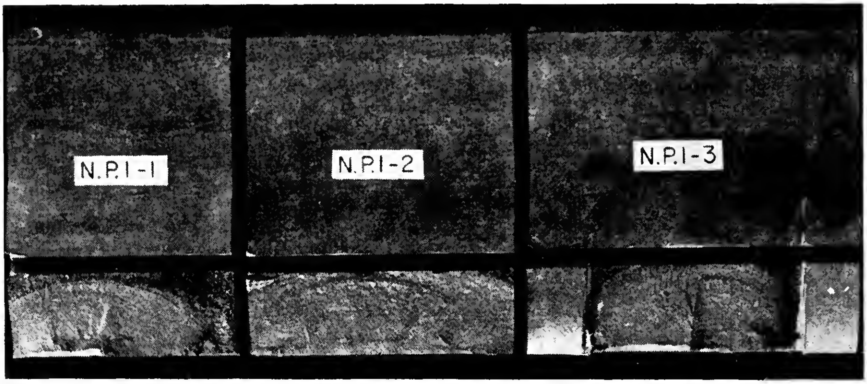


Fig. 3.—Opened Shelled Spot from an N. P. Rail.
Note elliptical growth rings, yet all three apparently started at the surface.

the cooperation of the various roads were removed from service, cut up, and shipped to Battelle. They were examined in various ways. In practically every case, the defect was laid open in order that the fracture surface might be viewed. In most cases, deep etches were made on the cross section of the rail head and metallographic specimens were cut in the proximity of the defect. Both longitudinal and transverse tensile specimens were prepared from about ⅓ of the rail specimens received, and about ½ of the rail specimens were analyzed for carbon, manganese, silicon, sulfur, and phosphorus. Most of the specimens were 4 to 5 ft. long as received. Some of them contained as many as 4 separate shelled spots, and consequently, something over 200 actual shelled spots were included in the examination.

In addition, nine specimens which had been removed from track as the result of detector-car examinations were sent to Battelle. All of these contained vertical components as well as horizontal components. These were examined in a similar manner.

The present report is intended to summarize the examinations that have been made during the last two years, June 1, 1946, to July 1, 1948, and to indicate the manner in which shelled spots initiate and grow.

Shelled Spots (Without Vertical Components)

Appearance of the Fractured Surfaces

A longitudinal notch was made with a saw just inside of the shelled area on practically every sample received. By so doing the defect could be laid open with a chisel and hammer. The fractured surface was invariably covered with rust, and it was necessary to remove this by immersing the specimens in hot acid for a few moments. Typical fractured surfaces are shown in Figs. 1 through 5. Quite a number of the defects contain shadow lines that were perpendicular to the gage side of the rail head such as is particularly evident in Fig. 1; others contained partially formed elliptical growth rings such as are particularly apparent in Figs. 3 and 5. These partially formed elliptical growth rings were invariably absent on the gage side of the rail and in every case the elliptical shape was incomplete, being flattened by the gage side of the rail. At first glance, it might be thought that the defect, such as illustrated in Fig. 5, originated below the surface of the rail and grew in an elliptical shape until it contacted the rail surface on the gage side. However, this is not the case. To the contrary, such shelly spots, generally, originate

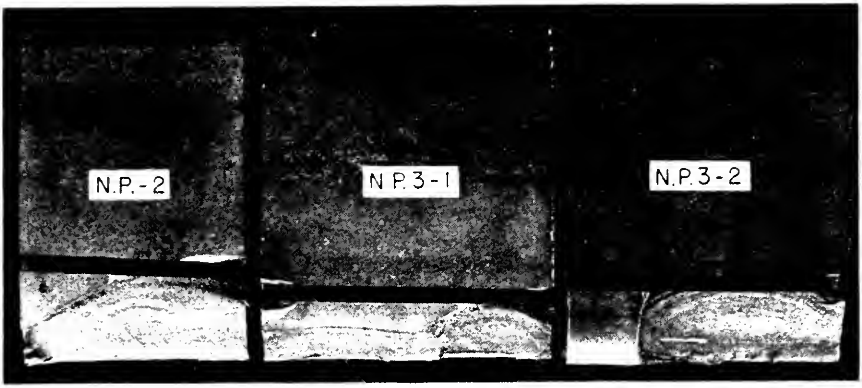


Fig. 4.—Opened Shelled Spots from Two N. P. Rails.
Note elliptical growth rings, yet defects were apparently of surface origin.

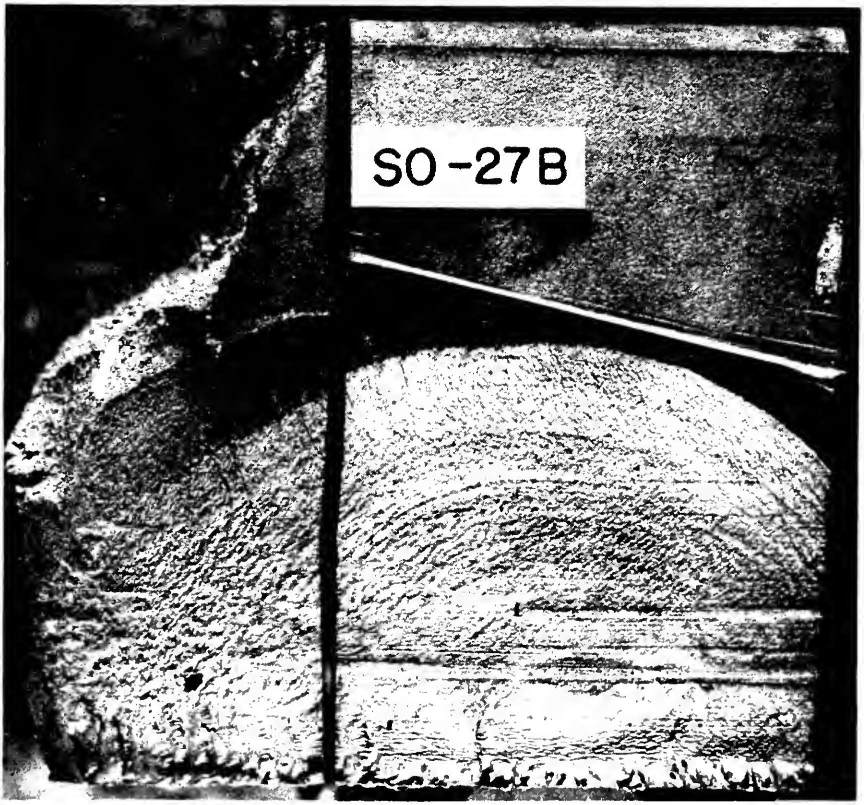


Fig. 5.—Opened Shelled Spot from a Southern Rail.

at the rail surface on the gage side of the head and grow inward. A changing rate of propagation of the crack as it proceeds into the rail is thought to account for the partially formed eliptical pattern of some of the defects. The rate of growth in the early stages is very slow. That such is the case is substantiated by the large number of very shallow cracks only a few thousandths of an inch deep that may be found with the aid of the microscope along the gage side of a rail which has shelled. As these small surface fractures grow deeper the rate of growth increases, probably several-fold, and it is quite possible for the growth lines evident in the fracture to develop a partly elliptical shape.

Strips about 3/16 in. thick were cut from a gage side of a number of rails and then deep etched. Any fractures in such strips would be immediately apparent as the result of deep etching. Numerous small cracks were found on the side of these strips which was the original rail surface; however, not in a single case was a crack found on the internal surface of the strips that was not connected to the external side. If this type of shelled defect were primarily of internal origin, then simply as a matter of chance, one should eventually be able to find defects that had not yet grown to the rail surface. On the other hand, many small cracks were found on the gage side of the rail which had grown inward only a matter of a few thousandths of an inch. From such circumstantial evidence, it is perhaps impossible to say that the type of shelled spot which has no vertical component *never* originates internally. However, it appears that substantially all defects of this particular type originate at the surface of the rail.

In selecting samples from track, a special effort was made to obtain a number of very small defects as judged by the presence of a very small black spot on the surface of the rail. The defects found under these small black spots were in all cases connected to the surface of the rail, although in several cases the surface crack could not be located until the sample had been sent to the laboratory and cleaned up with emery paper. It was interesting to observe that the black spots represented an area in the head of the rail that was somewhat lower than the balance of the railhead. That is to say, the black spots represented a shallow "dished out" area. Some of the very smallest black spots were depressed by only about 0.005 in., and in order to determine that they did represent depressions in the head of rail, it was necessary to move a micrometer gage across the surface of the rail. More fully defined black spots were found to represent depressions upwards of 0.030 in.; and this amount could readily be seen by simply laying a straight edge along the top of the rail head. It is believed that as the shelled spot developes and as the crack propagates into the rail, the lateral flow of the surface metal increases due to the fact that the metal is not tied in place to the underlying metal. In other words, once a crack has formed there are, in effect, two layers present in the rail head, the top of which is relatively free to slide over the bottom.

Deep-Etched Sections of Rail

Figs. 6, 7, and 8 show a number of cross sections of rail heads which have been deep etched in a solution consisting of 50 percent by volume of concentrated hydrochloric acid, 12 percent by volume of concentrated sulfuric acid, and the balance water. With only one exception, these deep-etched slices indicate that the rails shown were free from undesirable characteristics which originate at the time of manufacture. The exception is the slice shown in Fig. 7 marked N.P. 1–2. In this particular specimen, a number of pinholes are evident around the periphery of the rail head. Such pinholes, as they appear on the deep-etched slice, are indicative either of abnormally large nonmetallic inclusions or of subsurface blowholes present in the original ingot which were forced together but not fully welded during rolling. However, that is not to say that these defects were equal in size to the pinholes evident after deep etching. Electrolytic cell effects created during

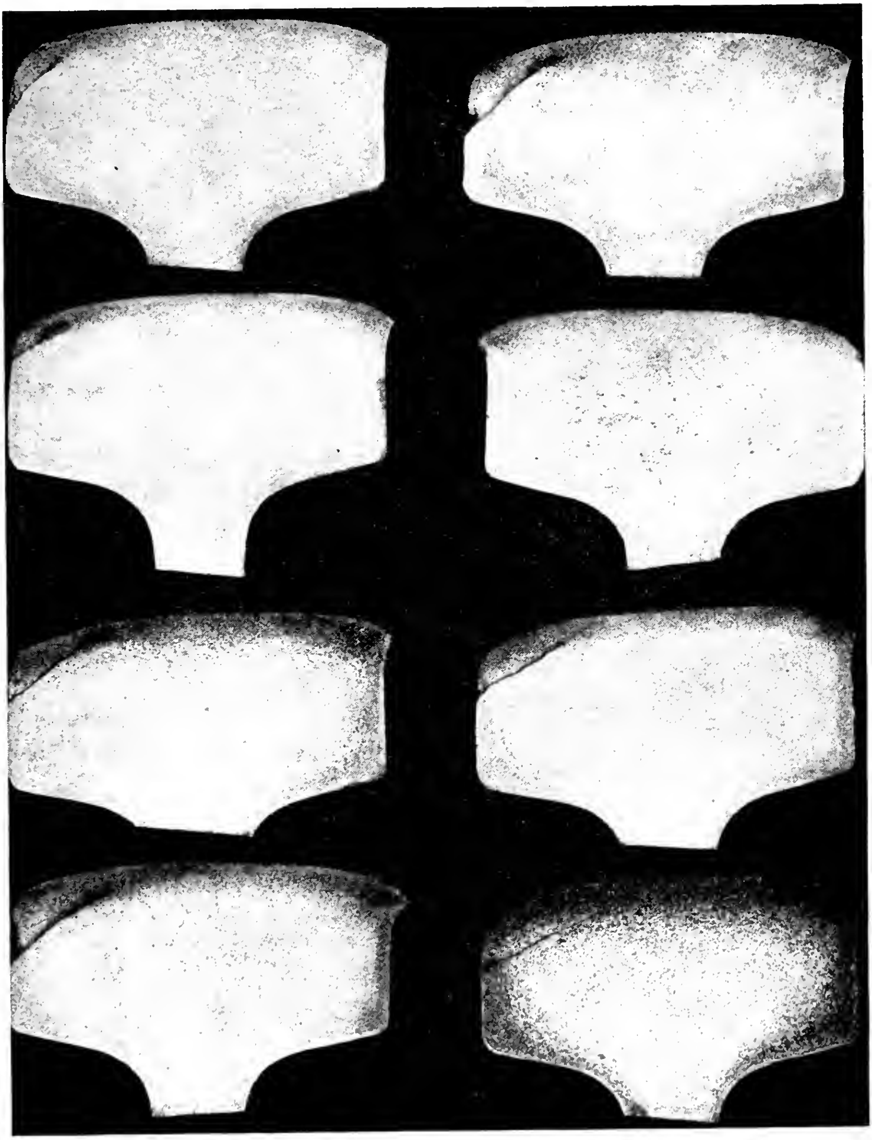


Fig. 6.—Deep-Etched Cross Sections of Eight Rail Specimens Selected from the L. & N.

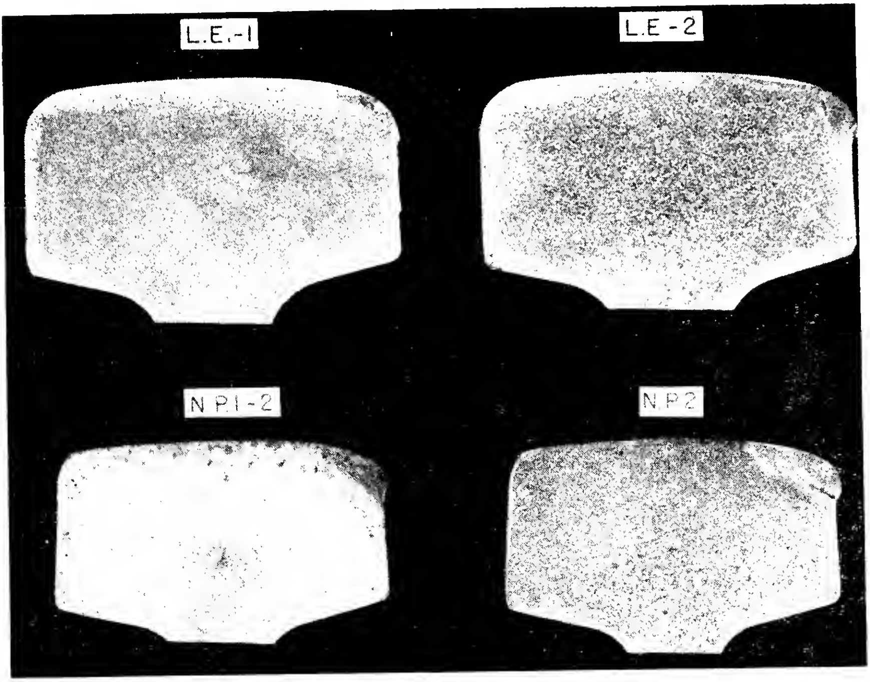


Fig. 7.—Deep-Etched Cross Section of Four Rails from B. & L. E. and N. P.

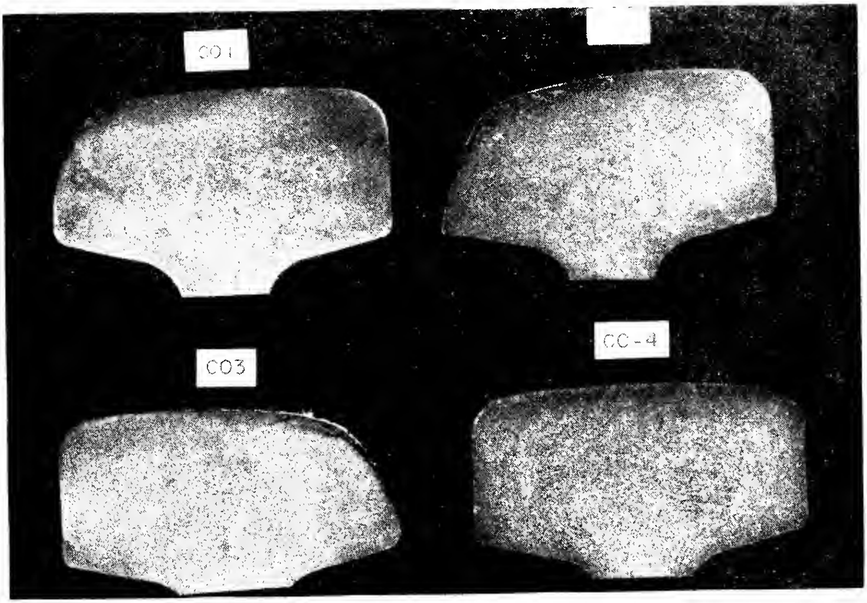


Fig. 8.—Deep-Etched Cross Section of Four Rails from the C. & O.

the etching operation serve to enlarge the size of the resulting pinhole. Incidentally, there is a small shatter crack present at the center of this same specimen which is evident in the photograph. The rail was marked control cooled but it had been rolled in 1936. It had been removed from tangent track and was an "A" rail.

Of the rail samples received at Battelle, eight represented shelling that had developed in tangent track. Of these eight samples, five were "A" rails and deep-etched cross sections indicated that three of these five contained more than a normal number of non-metallic inclusions. The three had a deep-etched appearance similar to that shown for N.P. 1–2. Since five out of eight of the rails laid in tangent track are certainly not "A" rails, it might be argued that "A" rails have less than average resistance to shelling and it might further be postulated that the excessive number of nonmetallic inclusions present in some "A" rails contributed to the shelling. On the other hand, it is possible to build up precisely the opposite argument. The great majority of samples received by Battelle were taken from curves. As a matter of general practice, "A" rails are not used in curves. Deep etches on these rail samples taken from curves indicated that by and large the rails were quite free from abnormally large nonmetallic inclusions and from extreme dendritic segregation. In fact, some of these specimens were all that might have been expected from electric furnace steel; for example, the rail slice shown in Fig. 7 marked L.E. 1. However, in spite of the generally desirable appearance of many of the deep-etched slices of rails taken from curves, the rails did shell. Consequently, it might be argued on this basis that shelling is not materially affected by the cleanliness of the steel. Looking at both phases of the argument, the most that can be said is that it is inconclusive. Probably the role that nonmetallic inclusions play with regard to shelling will continue to be a matter of dispute till such time as comparative field tests have been made of rails possessing different degrees of cleanliness.

It may be noted that the fractures which appear on the cross sections illustrated in Figs. 6, 7, and 8 vary widely in their depth below the surface of the rail. This is quite typical of all the samples received. If one chose, a series of samples could easily be made up which represented a gradual change in the depth of the defect below the rail surface. The most shallow defects found in such a series would only be 1/32 or 1/16 in. below the surface and would most certainly be classified as flaking. The deepest of such defects would be about ½ in. below the rail surface and would most certainly be classified as shelling. The point is, that the transition between these two types of defects, flaking and shelling, is a gradual one and is not marked by a distinct gap. Therefore, it is felt that any distinction that is made between flaking and shelling must be purely an arbitrary one and should not be construed to mean that flaking and shelling are basicly different in nature.

It may be noted that some of the slices shown in Figs. 6, 7, and 8 show no evidence of a shelled spot. These slices were cut just adjacent to the shelled spot. In trying to preserve as much of the shelled spot as possible to be opened up for examination of the fractured surface, occasionally the saw cut fell outside the shelled area and the defect was lost so far as the cross-sectional etch was concerned. Other of the cracks, shown in Figs. 6, 7, and 8, give the appearance of not having reached the surface; for example, the cracks shown in N.P. 1–2 in Fig. 7. This is not the case, however; actually the cracks were all connected to the surface. The explanation is that the saw cut happened to pass through the elliptically shaped end of the shelled spot.

Metallographic Examination

Metallographic specimens were prepared from most of the rail samples that were received. One of the earliest observations was the very severe cold work that had occurred

Fig. 9.—Specimen Cut from the Gage Corner of a Rail Head. Note fine cracks filled with oxide that have originated at a position which corresponds to the lowest point of contact between the wheels and rail. Well-developed shelled spots were found at other locations in this rail. Picral etch X 75.

Fig. 10.—Specimen Cut from the Gage Corner of a Rail Head. The oxide-filled crack which is apparent was located on the gage side of the rail. Picral etch X 187.

in all specimens near the gage corner of the head. Some indication as to how severe this cold work was is indicated in Figs. 9, 10, 11, and 12. As is illustrated by Fig. 9, for example, so much cold work has occurred near the surface of the rail that the original microstructure of the rail is almost completely lost and the metal has a striated appearance.

When the metal above and below a shelly crack was examined, it was found that the metal just above the crack showed much greater evidence of cold work than did the metal just below the crack. However, when one looked at the section just outside of the shelled spot, then a gradual decrease in the amount of cold work was found to be present, as one proceeded inward from the rail surface. It appears that once a shelly crack has formed, the metal above the crack is subjected to an increased amount of cold working.

The cold work observed near the gage corners of the rails certainly is more than could be accounted for by any simple straight-forward flow of metal that might have occurred in this region. Metal near the surface of the rail many times had a hardness that was some 40 or 50 points Brinell greater than the hardness at the center of the rail. Most of the cold work must have been a result of a sort of kneading action which occurred each time a wheel passed over the rail.

Figs. 9, 10, and 11 show small cracks that have just started to form in the rail. The metallographic specimens were cut from rail which had shelled, but the specimens were cut some distance away from an actual shelled spot. The cracks would have been too small to have been seen with the naked eye; eventually, however, they would have grown into a full-sized shelled spot. Fig. 9 shows a crack forming at the lowest point of contact between the wheels and the rail; Fig. 10 shows a crack which formed higher up on the gage corner of the rail; Fig. 11 shows a crack which formed very high on the gage corner and undoubtedly would have resulted in what is termed flaking. These illustrate that it is possible to find such small cracks at various distances below the top surface of the rail head. Fig. 12 illustrates how the metal sometimes flows downward at the lowest point of contact between the wheel and the rail, forming a pronounced lip or fin on the gage side of the rail head.

In selecting shelled spots from track, four cases were found where most of the rails in the curve had shelled but where a few of the rails were conspicuously free from shelled spots. In these cases, it was first determined that all of the rail had been laid at the same time. Samples of both the shelled and unshelled rail were then removed from track and shipped to Battelle for examination. It was found that the rails which had shelled had a slightly lower hardness (20 to 30 points Brinell) and a slightly lower carbon content (0.04 to 0.09 percent less carbon) than the rails which had not shelled. In addition, it was also found that the shelled rails had a microstructure consisting of a ferrite network plus pearlite, such as illustrated by Fig. 13, while the rails that had not shelled had a microstructure consisting entirely of pearlite, such as illustrated by Fig. 14. The difference in carbon content probably was sufficient to account for the difference in hardness and the difference in microstructure. There was nothing about the rails to suggest that the rails that had not shelled had cooled at a different rate.

On the basis of these observations, it might be argued that a notably greater resistance to shelling might be obtained merely by insuring that the carbon content of the rail was always sufficiently high to result in a completely pearlitic microstructure. However, that is not substantiated by the evidence. It should be pointed out that at least ⅔ of the rail specimens examined during the past two years were free from any ferrite network and completely pearlitic in microstructure. Yet they had shelled. It is

Fig. 11.—An Example of Fine Cracks at the Gage Corner of a Rail Head Which Eventually Result in Flaking. Picral etch X 50.

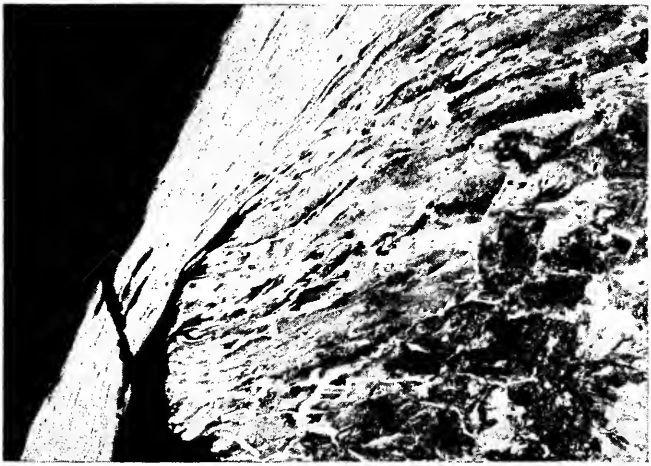


Fig. 12.—An Example of the Flowed Lip of Metal which Forms on the Gage Side of Rail Heads. Note that on the underneath side of the lip a very small crack is evident. Picral etch X 100.

only in instances where two rails, one having a completely pearlitic structure and the other having a ferrite network, are subjected to identical service that it is possible to discern a difference in their respective abilities to resist shelling.

Residual Stress Measurements

The SR–4 type of electric strain gage has been used to measure the residual stresses present near the surface of the rail head in rail that was subjected to service conditions for some time. The strain gages were plastered at different positions on the ball of the rail head and along the gage side of the rail head. Stress measurements were then made by removing successive layers of metal from the underside of the rail head. The results indicate that the surface of the rail contains residual compressive stresses. At the gage corner of the rail, these surface compressive stresses were approximately 20,000 psi. At successively greater depths below the surface of the gage corner, the residual stresses reverse themselves until, at a depth of approximately ⅛ in. below the surface, a stress of approximately 20,000 psi. tension was found to exist. Such a rapid reversal in stress between the surface and metal which is slightly below the surface suggests that rather high shear stresses probably exist in this region. Such a condition may be visualized by imagining that the rail head is built up of a number of layers of paper. The outermost layer is known to be in compression, while a few layers down it is known that the sheets are in tension. Under such conditions, it must be that considerable shear stresses exist between the different sheets of paper. However, there is no known method for even roughly estimating the magnitude of the shear stresses from the available data.

A condition such as this indicates that perhaps the failure exemplified by shelling is a progressive shear-type failure. There are several other things that might substantiate the view that shelling is a progressive shear failure. The tendency of a lip or fin to form on the gage side of the rail is suggestive of high shear stresses. The character of the defect shown in Fig. 9 suggests that the top surface of the rail is attempting to slide past the metal that is below the surface, a shear mechanism.

If shelly spots are formed as a result of a progressive shear failure, then this perhaps explains why the results recently obtained from a rail test with the Pennsylvania Railroad were negative. In this test alternate rails from the high side of a curve were ground at frequent intervals with a band grinder to remove the small fin or lip that formed on the gage side of the rail. Frequently, shelled spots have been observed to start on the under side of this fin. The thought was that this fin might act as a stress raiser and promote the development of a shelly crack on its under side. However, when the test was made it was found that the rails which were ground shelled just as readily as the unground rails. It is not known that notches serve to concentrate shear stresses in the same way that they concentrate tensile stresses. Consequently, there may have been little justification for thinking that the presence of such a notch as found on the underneath side of the lip would materially affect the service life of the rail.

Mechanical Tests and Chemical Analyses

Quite a number of tensile specimens were cut from the rail samples received. These specimens were cut both with their long axis parallel to the direction of rolling and with their long axis normal to the direction of rolling. Table 1 gives the maximum, minimum, and average values that were obtained from the specimens. No over-all correlation could be found between any of the mechanical properties and the gross tonnage carried by the rail. That is to say, if one considered those rails which had handled the largest gross tonnage, it would not be found that their yield strength, for example, was appreciably higher than average. These results certainly do not mean that shelling is not

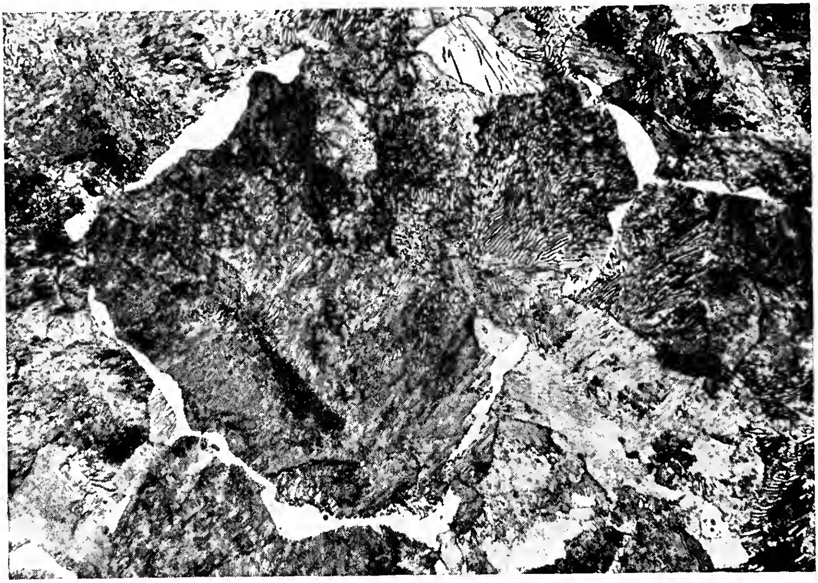


Fig. 13.—Photomicrograph of L. & N. Rail Which Shelled. Note the presence of a ferrite network. Picral etch X 500.

Fig. 14.—This Rail Did Not Shell Although Laid at the Same Time and Adjacent to the Rail Shown in Fig. 15. Note the absence of free ferrite. Picral etch X 500.

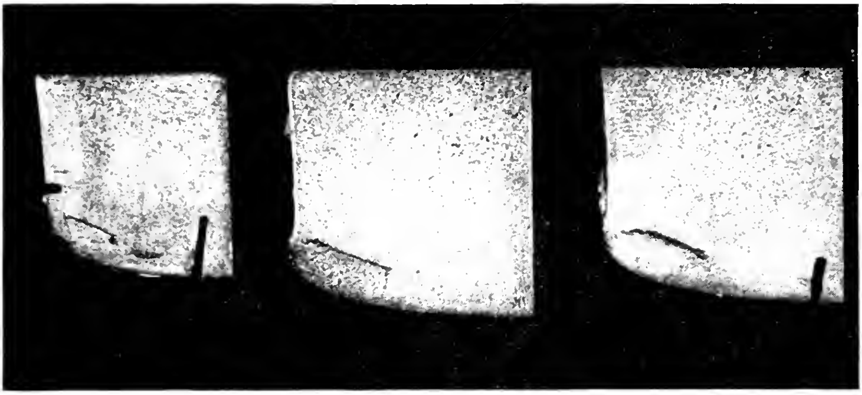


Fig. 15.—A Detailed Fracture which was Entirely Subsurface. Note the horizontal component was in this case quite short, not more than ½ in. in length.

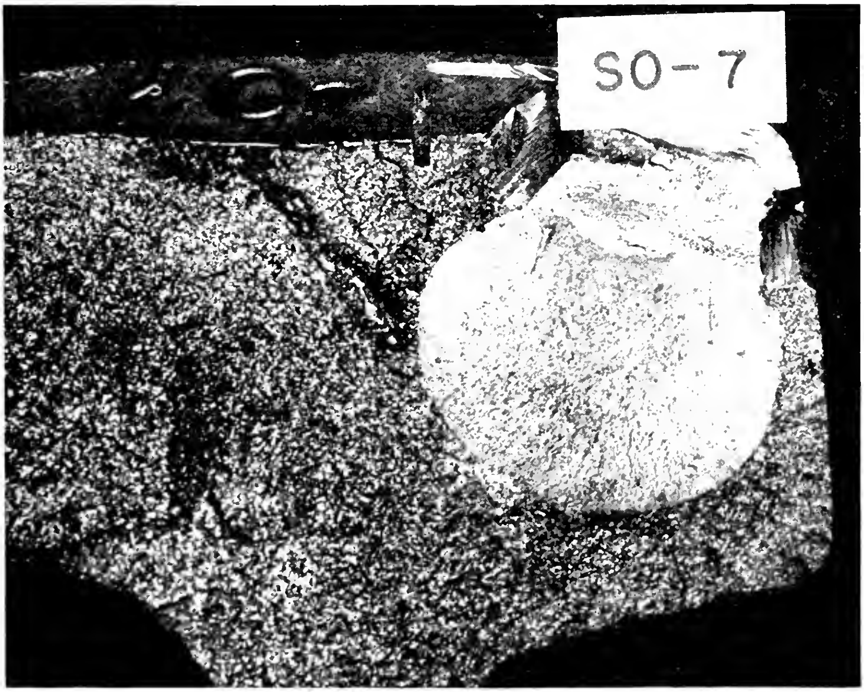


Fig. 16.—Deep-Etched Cross Sections Through Detailed Fracture Specimens.

a function of the mechanical properties of the rail; instead, it means that the method of selecting samples from locations which represented widely different service conditions served to overshadow such a correlation. Samples were taken from curves of widely different curvature and from locations where the average train speed differed greatly. Furthermore, the average wheel contours and the average wheel load vary through a considerable range on different roads. Consequently, it can hardly be expected that an over-all correlation would be found to exist.

TABLE 1.—SUMMARY OF TRANSVERSE AND LONGITUDINAL TENSILE TESTS

	Yield Strength, 1000 psi.*	*Tensile Strength, 1000 psi.*	*Percent Elongation***	*Percent Reduction of Area*	*Brinell Hardness****
Transverse tests[1]					
Maximum value ...	80.7	137.1	18	28.2	
Minimum value ...	57.7	107.9	7.5	13.0	
Average value[2] .	71.0	130.0	12.1	19.8	
Longitudinal tests[3]					
Maximum value ...	75.6	140.4	18	26.5	260
Minimum value ...	55.7	112.3	10.5	12.9	208
Average value[2] .	67.7	128.3	13.8	19.6	243

[1] Specimens cut from web of rail with their long axis at right angles to the direction of rolling.
[2] Average of 34 values.
[3] Specimens cut from the head of rail with their long axis parallel to the direction of rolling.
* Determined at 0.2 percent offset.
** Two-inch gage length.
*** Determined near the center of the rail head.

It may be noted from Table 1 that there is a surprisingly small difference between the average mechanical test values obtained from transverse and longitudinal specimens. Most wrought steel products would be expected to exhibit considerably greater elongation and reduction of area when tested in the longitudinal direction than when tested in the transverse direction. The relatively small differences that were found to exist between the longitudinal and transverse rail test specimens may be caused by the large amount of reduction which the web of a rail undergoes during hot rolling.

More than half of the rails received were analyzed for carbon, manganese, silicon, sulfur, and phosphorus. Just as in the case of mechanical tests, no over-all correlation was found to exist between the chemical composition of the rail and the gross tonnage passing over the rail before it was removed from service. In three specific cases, as mentioned under the section on metallography, it was found that rail with a relatively low carbon content had a shorter service life than comparable rails of somewhat higher carbon content. The values obtained for sulfur and phosphorus were in most cases considerably less than the maximum values imposed by rail steel specifications. Frequently the phosphorus values were as low as 0.020 percent and the sulfur values were as low as 0.025 percent.

Detailed Fractures

It was not part of Battelle's assignment to specifically study detailed fractures. However, during the course of the work, nine such specimens exhibiting vertical components close to the gage corner of the rail were received. All of these samples were removed from track as the result of detector-car tests. Six of the nine samples had defects which were entirely internal in nature, not at any point being connected to the surface of the rail. Some of the samples had relatively short horizontal components such as shown in Fig. 15. Other samples had horizontal components several inches in length.

It is suspected that at least some of these defects originated at the junction of the horizontal and vertical components and that the fracture grew simultaneously both horizontally and vertically. Fig. 16 shows deep-etched sections taken through the gage corner of three rails which contained detail fractures that were entirely subsurface. At least in these three cases, there is nothing on the deep-etched surface to suggest that the steel is of subnormal quality.

The principal point to be derived from these samples is that it makes a considerable difference how the samples are selected as to the character of the defect that is found. Apparently, a sizeable percentage of the specimens removed from track as the result of detector-car examinations are of subsurface origin. These, of course, have vertical components. On the other hand, if one selects samples by looking for black spots on the surface of the rail, then almost invariably defects will be selected which have no vertical components but only horizontal components.

Report on Assignment 12

Recent Developments Affecting Rail Section

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This is a progress report, presented as information.

A year ago, as a result of work done under sponsorship of this subcommittee, revised spacing of bolt holes for 115-lb., 132-lb. and 133-lb. RE rail, and corresponding changes in the punching of joint bars, were adopted as recommended practice.

A report was submitted on measurements, in the laboratory, of stresses in the rail web within joint bar limits, and the effect of bolt hole spacing on these stresses. Progress was also reported on similar measurements in service in tangent track.

A progress report was also submitted on fatigue tests of rail webs at the University of Illinois. The work reported on involved the use of a 36-percent solution of sulfuric acid as a corrosive medium and the effect of certain protective coatings.

Further work at the University of Illinois on fatigue tests of rail webs has been delayed due to the necessity for carrying on other fatigue tests, and no report is available. However, a program of tests has been agreed upon and work has now been started. This includes work on the ranges of stress encountered within joint bar limits, and corrosion fatigue tests using tap water as the corrosive medium.

Work has been started by the research staff on further field measurement of rail web stresses within joint bar limits, and Appendix 12–a reports progress.

No work has been carried out this year by the research staff on field measurements of web stresses in the new sections (outside joint bar limits), but a report is available on similar work done by the Pennsylvania Railroad on its 140 PS section, and this is submitted as Appendix 12–b.

Appendix 12–a

Rail Web Stresses within Joint Bar Limits

As described in Assignment 7, in August 1948, the Atchison, Topeka & Santa Fe Railway in laying new 132-lb. RE rail in the eastbound main track 100 miles west of Chicago, installed four service test sections of various types of joint bars, each one-half mile in length on tangent track. Three locations include RE, headfree, 36-in. length bars. At Locations V and X, the new AREA and old AREA 6-hole bolt spacings were used. At Location W, the 36-in. length bars have four bolt holes spaced 9 in.—9⅛ in.—9 in. Location V is equipped with Rail Joint Company B–42, headfree 36-in. length bars with the old AREA 6-hole bolt spacing.

During November 1948, stresses within the joint bar limits were measured at two rail joints at each of the four locations under traffic. Rail web stresses were measured in the upper and lower web fillets near the rail ends and also in the upper web fillets outside the limit of the rail joints. Stresses in the rail webs at the edge of the bolt holes were measured. The change in bolt tension under moving loads was recorded at a few bolts. High tensions, medium tensions and zero tensions were set in the bolts of some of the test joints to study the effect of bolt tension on the stresses developed within the rail joints under traffic.

It is expected that the experience gained from the results of this Santa Fe test will be of help in laying out a similar test program for next year on the four new service test of joint bar locations just established for 115-lb. RE rail and joint bars on the Chicago & North Western Railway.

Appendix 12–b

Comparison of Web Stresses in 131-lb. RE and 140 PS—(Pennsylvania) Sections

One of the topics under assignment of this subcommittee is field measurement of web stresses in the new rail sections. This refers, of course, primarily to the adopted sections 115 RE, 132 RE and 133 RE. However, since a few railroads other than the Pennsylvania are now using the 140 PS section, it is desired to report the results of field measurement of stresses made by the Pennsylvania Railroad on the 140 PS section.

Design of 140 PS Section

In 1944 it became apparent that the 131 RE rail section was inadequate as to web strength for many conditions of traffic and alinement on the Pennsylvania Railroad. Investigation of split web failures, (head and web separations) showed evidence of such severe stress, and such rapid breakdown under certain conditions, that it was concluded a radical change in the design of the head and web were necessary.

The 140 PS rail section was hence designed to give the lowest possible upper fillet stress, under conditions of eccentric loading, consistent with reasonable weight of the section, without sacrificing girder strength of the rail as compared with 131 RE, and without sacrificing the ability to use head-contact joint bars. It was sought to reduce the maximum service web stress in the new section to the endurance limit of rail web steel as shown by the first fatigue strength curves for rail web steel produced at the

University of Illinois. This goal was not quite reached, but later studies indicate that an adequate reduction was obtained, particularly in view of the relatively infrequent occurrence of the maximum stress in the field.

A comparison of the 131 RE and the 140 PS sections is shown in Fig. 7.

In the course of the design or development of the 140 PS section, an extended laboratory study was made of web stresses in existing and modified sections. Seventeen sections in all were subjected to laboratory stress analysis under controlled static loading.

Fig. 4 shows the distribution of web stress in the 131 RE and 140 PS sections under eccentric load, based on laboratory test. Fig. 5 is a chart showing a comparison of the maximum stress in the upper fillet for various degrees of rail head wear (vertical) and for various eccentricities of load. This chart is based primarily on laboratory tests but the lines are extrapolated beyond the limits of laboratory tests on a theoretical basis.

In these two charts, as well as in all other charts and tables presented the stress reported is the maximum stress in the web in a vertical plane occurring under a concentrated load. The location of this maximum stress is near the bottom of the upper web fillet. It is compressive and occurs on the side of the web toward which the eccentricity of loading exists. If the wheel load is concentrated near the gage side of the rail, the maximum stress occurs on the gage side of the web, and vice versa.

In the service tests, made under conditions under which rails were failing, the maximum stress was always found on the gage side of the low rail and that is where the fatigue cracks developed. Measurements were also made of stresses on the outside of the web of the low rail, and on both sides of the web of the high rail, but in no case were these stresses found to be of consequence. Under different conditions of curvature,

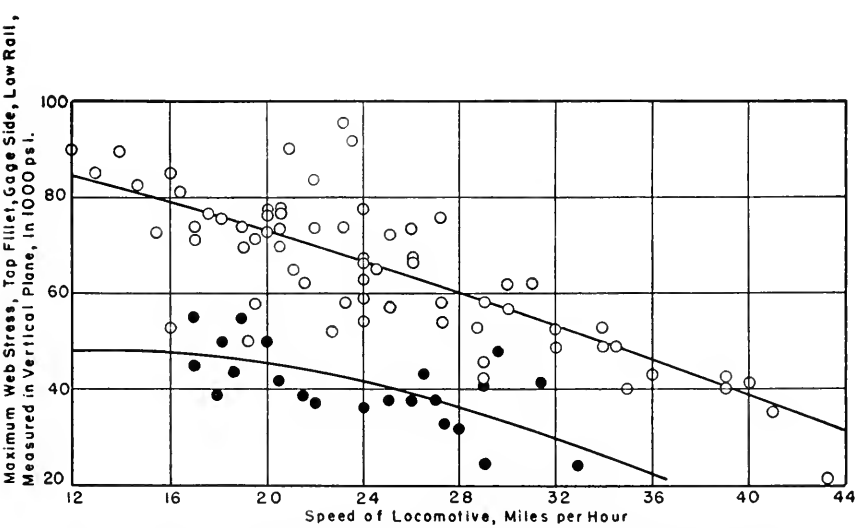

Fig. 1.—Maximum Web Stress vs. Speed of J 1 Locomotive on 6-deg. 30-min. Curve with 6-in. Elevation, 131-lb. and 140-lb. PS Rail.

○ 131-lb. RE Rail, Worn ⅛ in. on Standard Tie Plates: Runs 551–606 (13 Runs); Runs 803–1030 (46 Runs); Runs 1065–1128 (11 Runs); Total: 70 Runs.

● New 140-lb. PS Rail on Standard Tie Plates: Runs 1205–1339 (23 Runs).

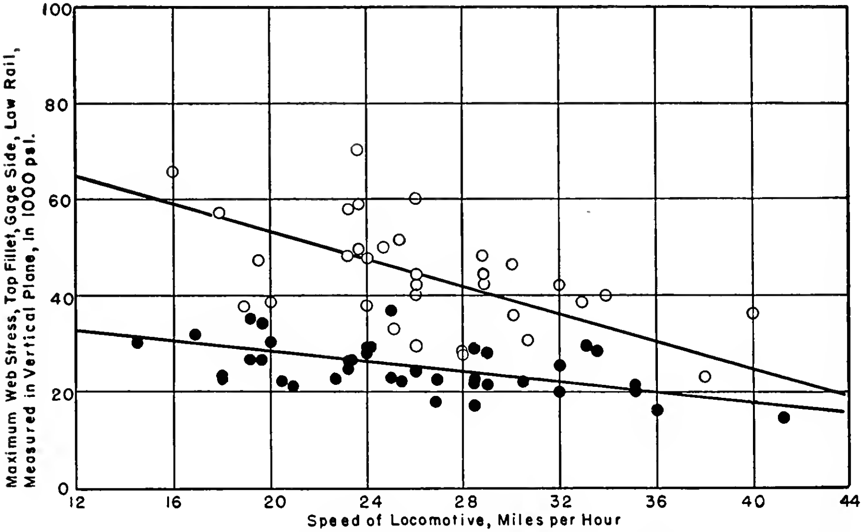

Fig. 2.—Maximum Web Stress vs. Speed of M 1 and M 1A Locomotives on 6-deg. 30-min. Curve with 6-in. Elevation, 131-lb. RE and 140-lb. PS Rail.

○ 131-lb. RE Rail, Worn ⅛ in. on Standard Tie Plates; Runs 551–606 (6 Runs); Runs 803–1128 (27 Runs); Total: 33 Runs.

● New 140-lb. PS Rail on Standard Tie Plates: Runs 1215–1340 (39 Runs).

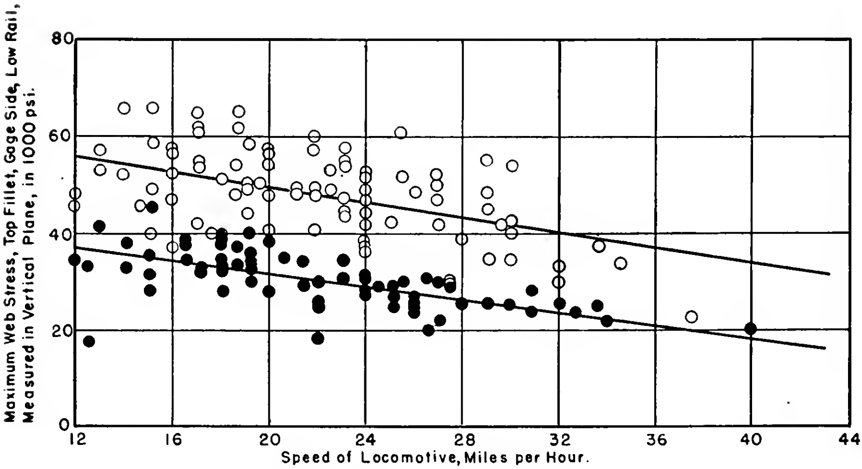

Fig. 3.—Maximum Web Stress vs. Speed of I 1 Locomotive on 6-deg. 30-min. Curve with 6-in. Elevation; 131-lb. RE and 140-lb. PS Rail.

○ 131-lb. RE Rail, Worn ⅛ in., on Standard Tie Plates: Runs 803–1067 (80 Runs); Runs 1096–1128 (15 Runs); Total: 95 Runs.

● New 140-lb. Rail on Standard Tie Plates: Runs 1200–1340 (78 Runs).

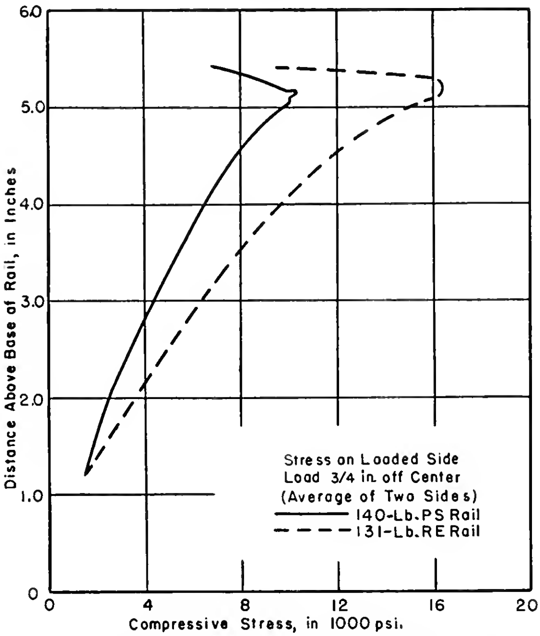

Fig. 4.—Vertical Distribution of Web Stress for 131-lb. RE and 140-lb. PS Rail under 20,000-lb. Eccentric Load.

superelevation, speed, and character of traffic this situation would undoubtedly be different. The service stresses reported here are on the gage side of the low rail in all cases.

It is not proposed to go into detail of the methods of making the tests either laboratory or service, however, as an explanation of Fig. 4 it may be said that due to the lack of perfect symmetry in rails as manufactured, and due to the difficulty of locating the test load at the exact desired eccentricity, tests were made first with the load concentrated near the right hand side of the rail section (as you face it), then with the load concentrated near the left hand side. The results reported on Fig. 4 are the averages of the stresses for corresponding gages for the two tests for the side of the rail web nearest the load. The stresses on the side of the rail web farthest from the load are not reported and are relatively very small.

The purpose of this report is to present a comparison of the measured service stresses in 140 PS rail and 131 RE rail under as near as possible identical conditions. Other phases of the study of causes of failure of the 131 RE section and development of the 140 PS section will not be reported here because of the space which would be required.

Service Stress Measurement

Field measurement of stresses in 131 RE rail were made under the most severe service conditions which could be found. A location was chosen in No. 2 westward track, Panhandle division, west of Carnegie, Pa., where it had been necessary to renew 131 RE rail after two years' service due to web failure. The location is known as Slag Dump Curve. This is a 6-deg. 30-min. curve with 6-in. superelevation on a 0.7 percent ascend-

TABLE 1.—COMPARISON OF RECORDED STRESSES IN 131 RE WORN ⅛ IN. AND 140 PS NEW —VARIOUS CLASSES OF LOCOMOTIVES

Stresses at Various Speeds Taken from Charted Curves of Stress

Class of Locomotive	*15 mph*	*20 mph.*	*25 mph.*	*30 mph.*
	Stress in 1000 psi.			
I1 131 RE	53,5	49.0	45.5	41.5
140 PS	35.0	31.5	28.0	25.0
Percent reduction	34.5	35.8	38.5	39.8
M1 131 RE	60.0	53.0	46.0	38.5
140 PS	31.0	28.0	25.5	23.0
Percent reduction	48.3	47.2	44.5	40.3
J1 131 RE	80.0	73.0	65.0	57.0
140 PS	47.5	45.0	40.5	33.5
Percent reduction	40.6	38.3	37.8	41.2

Maximum Recorded Stress for each Class

	*131 RE**	*140 PS*	*Percent Reduction*
I1	66,000	45,000	32
M1	70,000	37,000	47
J1	96,000	56,000	42

* Runs 551 to 1128.

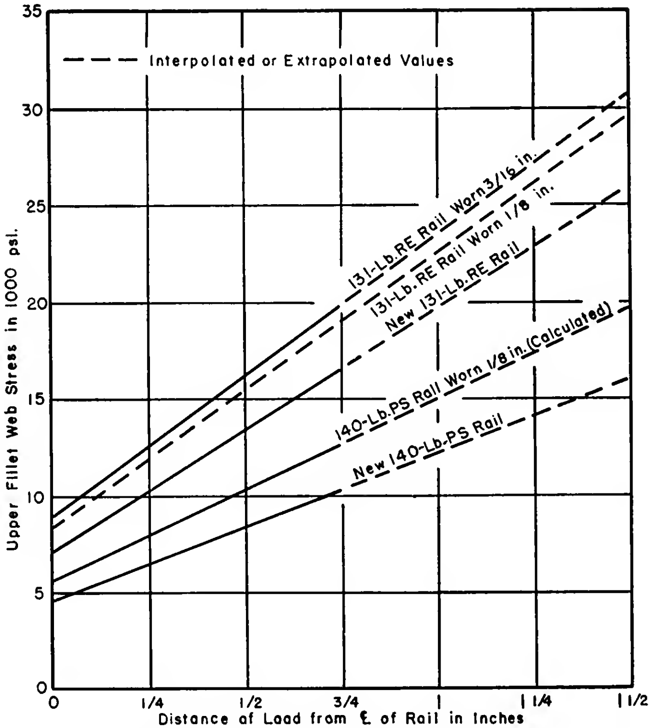

Fig. 5.—Comparison of Stresses in 131-lb. RE and 140-lb. PS Rail under 20,000 lb. Vertical Load at Various Eccentricities.

TABLE 2.—PANHANDLE DIVISION—WESTWARD TRACK—SLAG DUMP CURVE ESTIMATED NUMBER OF CYCLES OF STRESS IN ONE YEAR

Top Web Fillet—Gage Side—Low Rail—6-deg. 30-min. Curve—6-in. Elevation After Adzing of Ties and Resurfacing Track Locomotives and Tenders Only

Compression Stress—1000 psi.	Classification of Locomotives							Total
	J1 (3515)	I1 (4933)	M1 (2610)	L1 (512)	H10 (454)	K4 (9232)	C5 (2018)	
100	------	------	------	------	------	------	------	------
95	------	------	------	------	------	------	------	------
90	59	------	------	------	------	------	------	59
85	176	------	------	------	------	------	------	176
80	469	------	------	------	------	------	------	469
75	644	------	------	------	------	------	------	644
70	469	------	93	------	------	------	------	562
65	410	153	93	------	------	------	------	656
60	410	458	280	------	------	------	------	1,148
55	1,113	1,119	93	------	45	------	144	2,514
50	1,054	1,322	559	------	45	------	------	2,980
45	1,933	2,492	746	73	45	------	432	5,721
40	2,402	3,356	932	183	136	115	144	7,268
35	1,582	1,526	1,212	293	318	1,385	288	6,604
30	1,816	1,170	1,305	146	318	808	1,009	6,572
25	2,285	1,424	1,678	73	91	2,193	432	8,176
20	4,101	1,627	2,424	293	91	4,501	144	13,181
15	3,749	2,543	2,424	768	136	5,193	288	15,101
10	4,042	4,780	2,331	805	1,044	7,501	2,449	22,952
5	3,749	5,644	1,398	878	409	9,001	3,744	24,823
Tension Stress—1000 psi.								
5	12,595	12,611	8,856	805	590	22,272	3,889	61,618
10	6,209	3,711	3,915	329	136	12,002	576	26,879
15	2,285	254	653	------	4,962	------	------	8,154
20	410	51	93	------	------	923	------	1,477
25	------	------	------	------	------	115	------	115
								217,849

Notes—

Based on test runs 803 to 1128 (excluding special runs) August 12 to October 24, 1946.

Rail has head wear of approximately ⅛ in. (131-lb. RE rail).

Rail laid new in 1943 in this curve was removed because of web failure in 1945 (131-lb. RE rail).

SR-4 wire resistance strain gage mounted 5.19 in. above base of rail at point of maximum stress in fillet.

Number of cycles of stress shown expanded from 303 test runs to a basis of one year, based on a train sheet study of one week's traffic and an additional factor based on comparison of this week's traffic with the year's traffic.

ing grade. The maximum authorized speed is 40 mph., but the curve is so located that many freight trains pass around the curve at 15 to 20 mph.

The rail was supported on Pennsylvania standard heavy-duty tie plates, 7½ in. by 14¾ in., 1 in 40 cant, flat bottom, rolled crown. The ties had been adzed to give a uniform support to the tie plates. The track was ballasted with crushed stone.

The work was done by employees of the Pennsylvania Railroad engineering department. The equipment used for the field work consisted of SR–4 wire resistance strain gages and General Electric oscillograph and amplifiers. The test equipment was mounted in an automotive trailer hauled to, or near to, the site of the work over the highway. The trailer serves as a field office during progress of the work. The instruments and methods are very similar to, and in many cases identical with, those used by the research engineer, AAR, for similar work and the Pennsylvania Railroad is indebted to him and his staff for much information and guidance in planning and carrying out the work.

Extensive measurements of web stress on 131 RE rail were made on this curve in the summer and early fall of 1946.

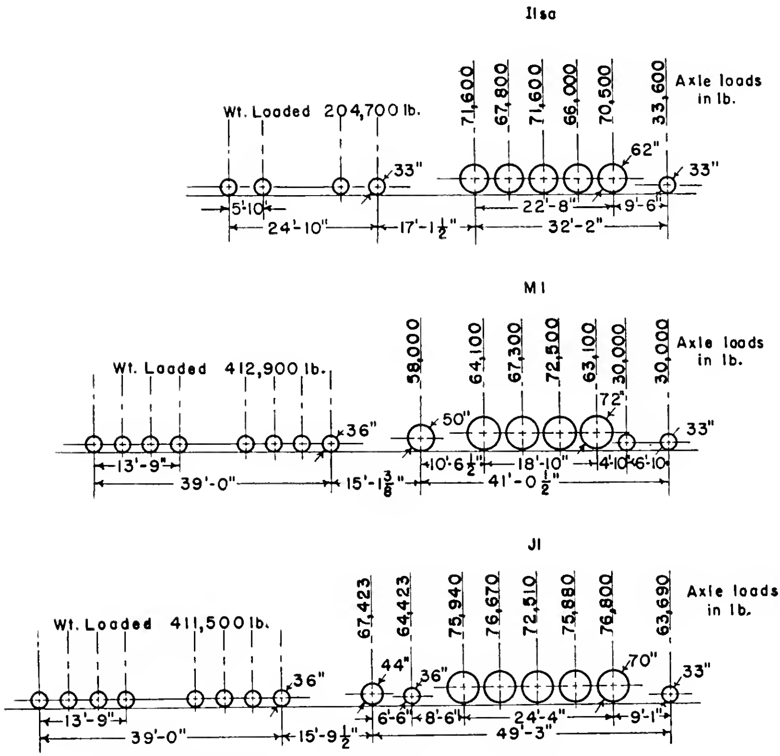

Fig. 6.—Wheel Arrangement and Loading for I 1sa, M 1 and J 1 Locomotives.

The first 140 PS rail was rolled in October 1946. Upon completion of the tests on 131 RE rail, 140 PS rail of one of the first rollings was laid, and stress measurements on the new section were immediately begun. No surfacing was done, and measurements were made under conditions as nearly as possible identical with those under which like stresses in the 131 RE were measured.

Comparison of Stresses 140 PS and 131 RE Rail

Table 1 gives a summary of the comparative stresses, and the percent of reduction in the average stress at various speeds for various classes of locomotives. A comparison is also shown of the maximum stress for each of these classes of locomotives. The theoretical improvement as based on laboratory tests is 45 to 46 percent for new 140 PS, compared with 131 RE worn ⅛ in.

It will be observed that in some cases the theoretical improvement was fully realized in the service stresses, while in others the improvement is somewhat less than anticipated. The over-all picture is however very encouraging as the very high maximum stress with the Class J1 locomotive is reduced 42 percent.

It should be understood that the service tests were not made under controlled conditions, as far as traffic is concerned, the stress measurements being made under regular traffic with a great variety of individual locomotives of each class, and with a variety of speeds and conditions as to weight of train hauled, etc.

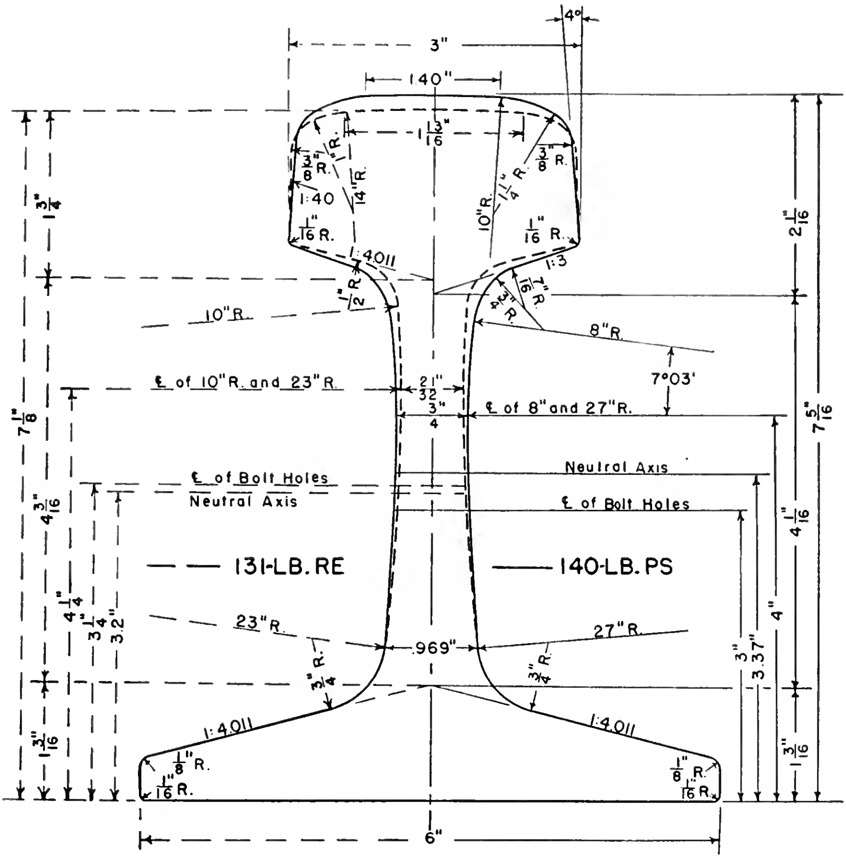

Fig. 7.—Comparison of 131-lb. RE and 140-lb. PS Rail Sections.

	131 RE	140 PS
Weight per yard, lb.	131.2	140.6
Area, sq. in.	12.9	13.8
Height, in.	7 1/8	7 5/16
Width of base, in.	6	6
Moment of inertia, $in.^4$	89	97
Section modulus above N. A., $in.^3$	23	25
Section modulus below N. A., $in.^3$	27	29
Head torsional rigidity*	32.6	44.3

* Note: In millions of in.-lb. per radian per inch.

The figures shown in Table 1 were taken from charts of stress versus speed for the three classes of freight locomotives shown. Fig. 1 shows stress versus speed for the J1 locomotive, comparing results obtained on 140 PS new rail with those obtained on 131 RE rail worn 1/8 in. Figs. 2 and 3 show the same information for the M-1 locomotive and the I-1 locomotive, respectively.

As of interest in this connection Fig. 6 is a chart showing the axle spacing and loading for the I-1, M-1, and J-1 locomotives.

TABLE 3.—PANHANDLE DIVISION—WESTWARD TRACK—SLAG DUMP CURVE ESTIMATED NUMBER OF CYCLES OF STRESS IN ONE YEAR

Top Web Fillet—Gage Side—Low Rail—6-deg. 30-min.—6-in. Elevation
Locomotives and Tenders Only

Compression Stress—1000 psi.	*Classification of Locomotives*							*Total*
	J1 (3515)	*I1 (4933)*	*M1 (2610)*	*L1 (512)*	*H10 (454)*	*K4 (9232)*	*G5 (2018)*	
100								
95								
90								
85								
80								
75								
70								
65								
60								
55	459							459
50	306							306
45	765	124						889
40	1,683	992	142					2,817
35	1,071	1,426	213			512		3,222
30	1,836	2,542	923	171	454	256		6,182
25	3,978	3,906	1,988	342	454	2,048	1,008	13,724
20	4,131	3,348	3,621	399		3,584	1,008	16,091
15	7,650	2,790	4,118	399	454	4,608	336	20,355
10	8,109	5,022	4,826	285		11,264	2,016	31,522
5	7,650	10,540	5,254	1,191		16,128	3,360	44,123
Tension Stress—1000 psi.								
5	11,016	12,152	7,100	1,767	454	29,184	5,712	67,385
10	153	124	142			512		931
								208,006

Notes—

Based on test runs 1200 to 1340 November 19 to December 6, 1946.

Rail is new 140-lb. PS rail.

SR-4 wire resistance strain gage mounted 5.11 in. above base of rail at point of maximum stress in fillet.

Number of cycles of stress shown expanded from 141 test runs to a basis of one year, based on a train sheet study of one week's traffic and an additional factor based on comparison of this week's traffic with the year's traffic.

Another comparison is presented in the form of a tabulation of the number of cycles of stress of each magnitude for the 131 RE rail, Table 2, and for the 140 PS rail, Table 3. The method of preparing these tables is explained in some detail in the footnotes. The elimination of stresses over 55,000 psi., and the general lowering of the over-all level of stress is readily seen from a comparison of these tables.

Conclusions

It was concluded from these service measurements that the laboratory basis of design of the new section was sound and that the laboratory stress measurements forecast the reduction in service stress with satisfactory accuracy.

The reduction in stress which it was sought to make has been realized in track, as shown by service stress measurements. Service experience will, of course, ultimately determine the value of the new section.

Report of Committee 5—Track

E. W. Caruthers, *Chairman,*
Lem Adams
L. L. Adams
J. C. Aker
C. A. Anderson
W. G. Arn
A. L. Bartlett
T. H. Beebe
J. A. Blalock
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H. J. Bogardus
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M. D. Carothers
H. R. Clarke
R. W. Claypoole
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E. D. Cowlin
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I. H. Schram
G. J. Slibeck
R. R. Smith
C. R. Strattman
Troy West
R. P. Winton
M. J. Zeeman

Committee.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

AREA Bulletin 479, February 1949.

THE COMMITTEE ON TRACK,
E. W. CARUTHERS, *Chairman.*

Report on Assignment 1

Revision of Manual

C. R. Strattman (chairman, subcommittee), C. A. Anderson, W. G. Arn, T. H. Beebe, F. J. Bishop, J. A. Blalock, M. D. Carothers, E. W. Caruthers, C. T. Jackson, R. E. Sampson, R. R. Smith, M. J. Zeeman.

Your committee offers for reapproval without change, the following text now appearing in the Manual:

Page 5-19
Welding of Manganese Castings in Special Track Work

Report on Assignment 2

Fastenings for Continuous Welded Rail, Collaborating with Committee 4

A. L. Bartlett (chairman, subcommittee), Lem Adams, F. J. Bishop, E. W. Caruthers, R. W. Claypoole, M. H. Dick, H. F. Fifield, C. E. R. Haight, H. H. Harman, J. deN. Macomb, G. M. Magee, E. E. Martin, F. H. Masters, J. S. McBride, J. A. Reed, I. H. Schram, R. R. Smith, C. R. Strattman.

Your committee submits the following progress report as information.

Continuous rail was first considered by this committee and a report submitted in the Proceedings, Vol. 37, 1936, the subject having been treated in a somewhat historical fashion. A report on the subject in its present form, Fastenings for continuous welded rail, appeared in Vol. 38, 1937, and this report was quite comprehensive in descriptive matter, theoretical data and formulas. However, the amount of continuous rail in service at that time was not sufficient to warrant a conclusive report. Since then several progress reports have been submitted and the last one for the year 1948 described the performance of the 1200-ft. test track at New Haven, Conn., supplied some data on tie and ballast resistance, and included a formula to determine the number of anchors required and other pertinent information.

Any uncertainty concerning anchorage to restrain continuous rail against expansion or contraction within practical limits seems to have been dissipated and modern welds have proved quite generally to be as strong or stronger than the rail. Therefore, it would appear that continuous rail with any fastenings suitable for jointed rail would provide at least equally satisfactory service. This idea was advanced in the report on this subject in Vol. 44, 1943, which reads in part as follows:

CONCLUSIONS

> As the test installations of continuous welded rail have increased, their performance increasingly indicates that the same kind of fastenings which have been found most successful in jointed tracks are dependable for use in continuous welded rail tracks.

In the light of experience since that time, it is obvious that this conclusion might be considered applicable to present day continuous rail track. However it still is a fact that installations of continuous rail with conventional fastenings in track carrying frequent high speed passenger trains or heavy freight traffic are few in number, or of short service duration or in limited continuous lengths.

It is suggested that further study should consist mainly of observations of existing and future installations.

Report on Assignment 3

Track Tools

Collaborating with Committees 1 and 22 and with Purchases and Stores Division, AAR

C. E. R. Haight (chairman, subcommittee), F. J. Bishop, J. A. Blalock, H. J. Bogardus, A. E. Botts, E. J. Brown, M. D. Carothers, E. W. Caruthers, W. E. Cornell, B. E. Crumpler, J. W. Demcoe, L. W. Deslauriers, H. H. Harman, T. R. Klingel, E. E. Martin, R. W. Mauer, J. B. Myers, S. H. Poore, Troy West.

Your committee recommends the following revisions of the Manual:

Rail Fork—Plan No. 10–49

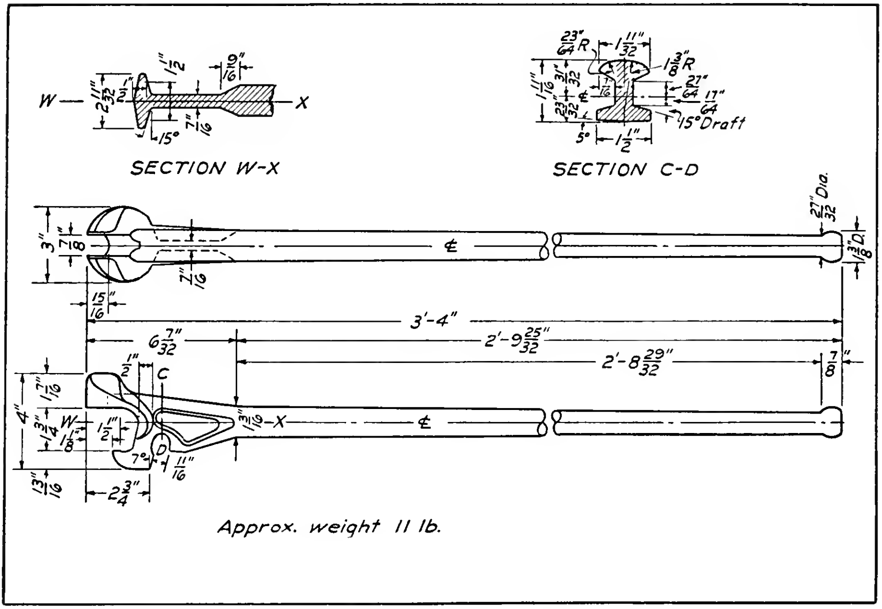
That Rail Fork Plan No. 10–49 be adopted. This rail fork is of a design which has been in satisfactory use for a number of years. It fits generally all sections of rail currently in use, with the exception of headfree types.

Claw Bar—Plan No. 11–49

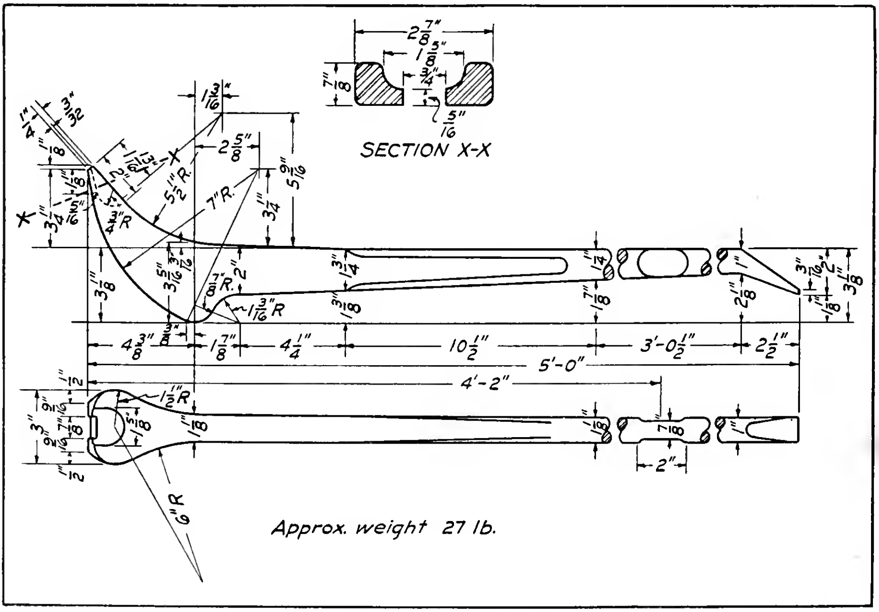
That Claw Bar Plan No. 11–49 be adopted in place of Plan No. 11, and that Claw Bar Plan No. 11–A be withdrawn from the Manual. This new claw bar design is the result of over three years of experimentation and testing by your committee.

Tie Plug Driver—Plan No. 16–49

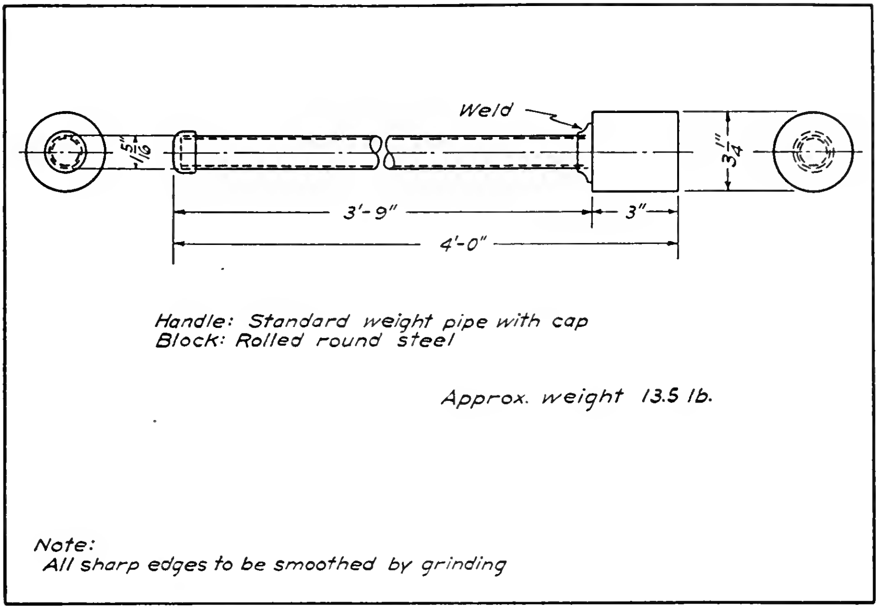
That Tie Plug Driver Plan No. 16–49 be adopted for inclusion in the Manual. This is a new tool which is finding increasing use with mechanized rail laying gangs.



Plan 10–49.—AREA Rail Fork.



Plan 11–49.—AREA Claw Bar.



Plan 16–49.—AREA Tie Plug Driver.

Report on Assignment 4

Plans for Switches, Frogs, Crossings, Spring and Slip Switches

Collaborating with Signal Section, AAR

A. B. Hillman (chairman, subcommittee), L. L. Adams, J. C. Aker, C. A. Anderson, T. H. Beebe, F. J. Bishop, J. A. Blalock, C. W. Breed, E. W. Caruthers, E. D. Cowlin, H. Q. Day, J. W. Demcoe, L. W. Deslauriers, J. W. Fulmer, A. F. Huber, W. G. Hulbert. C. T. Jackson, C. H. Johnson, T. R. Klingel, G. M. Magee, L. I. Martin, F. H. Masters, R. E. Miller, J. B. Myers, G. A. Peabody, S. H. Poore, J. A. Reed, O. C. Rehfuss, I. H. Schram, G. J. Slibeck, C. R. Strattman, R. P. Winton, M. J. Zeeman.

Your committee has prepared plans as follows, which it offers for adoption as recommended practice and publication in the Portfolio of Trackwork Plans:

Plan 641–49 Solid Manganese Steel Self Guarded Frogs.

Plan 325–49 Steel Frog Fillers and Reinforcing Bars.

In view of the issuance of Plan 641–48, which is similar to Plan 640–41, except for modifications in details designed to increase the strength of the frog under current heavier equipment and traffic conditions, your committee recommends withdrawal from the Portfolio of

Plan 640–41 Solid Manganese Steel Self Guarded Frogs.

Your committee also recommends revision of plans as follows:

Plan	111–41	16′ 6″ Straight Split Switch with Uniform Risers.
"	112–41	16′ 6″ Straight Split Switch with Graduated Risers.
"	113–41	11′ 0″ Straight Split Switch with Uniform Risers.
"	114–41	11′ 0″ Straight Split Switch with Graduated Risers.
"	115–41	22′ 0″ Straight Split Switch with Uniform Risers.
"	116–41	22′ 0″ Straight Split Switch with Graduated Risers.
"	117–41	30′ 0″ Straight Split Switch with Uniform Risers.
"	118–41	30′ 0″ Straight Split Switch with Graduated Risers.
"	121–41	11′ 0″ Curved Split Switch with Uniform Risers.
"	122–42	11′ 0″ Curved Split Switch with Graduated Risers.
"	123–41	19′ 6″ Curved Split Switch with Uniform Risers.
"	124–42	19′ 6″ Curved Split Switch with Graduated Risers.
"	125–41	30′ 0″ Curved Split Switch with Uniform Risers.
"	126–42	30′ 0″ Curved Split Switch with Graduated Risers.
"	127–41	39′ 0″ Curved Split Switch with Uniform Risers.
"	128–42	39′ 0″ Curved Split Switch with Graduated Risers.
"	181–44	Spring Switches.

The 17 plans, basic numbers 111 to 181, incl., (listed above) in the Portfolio of Trackwork Plans, as applying to interlocked and spring switches, to be revised to show the tie spacings beginning at the tie immediately ahead of the switch, as 20 in–22 in.–20 in., the first tie under the switch to be centered 4½ in. back from the point of switch and with the remaining tie spaces adjusted as necessary to provide clearance for existing back rod locations.

The Standardization committee of the Manganese Track Society collaborated with your committee in the preparation of the new plans and the recommendations offered.

Your committee presents as information, a final report on stress measurements in solid manganese steel crossing castings and a progress report on special steel crossing support, both reports being prepared by the research staff of the Engineering Division, AAR. In addition, your committee presents as information. a report on the fatigue testing of manganese steel, prepared by R. S. Jensen of the University of Illinois.

Appendix 4–a

Service Tests of Manganese Crossings

The following report is presented as information. It covers the comparative tests of designs of solid manganese steel crossing frogs at McCook, Ill., the tests of manganese insert and solid manganese crossings on structural steel and longitudinal timber supports, and tests of crossing frog bolt tension.

Report on Service Test of Solid Manganese Crossing Frogs at McCook, Ill.

In the Proceedings, Vol. 47, 1946, page 1; Vol. 48, 1947, page 558 and Vol. 49, 1948, page 334, reports were presented to cover stress measurements in the flangeways and at other significant stress areas of five different designs of manganese castings placed in the crossings of the Baltimore & Ohio Chicago Terminal Railroad and the Atchison, Topeka

& Santa Fe Railway at McCook, Ill., and the two latter references included the results of a year's service of the Morden–Ramapo, the Bethlehem and the revised Taylor–Wharton designs of castings. This report covers the service tests of the original design of casting by Taylor–Wharton and the Carnegie–Illinois casting. Instructions were given to install the Carnegie–Illinois casting in the test corner when the revised Taylor–Wharton casting was removed. However, through a misunderstanding of the instructions, the track forces installed the original Taylor–Wharton design in the test corner instead, and the Carnegie–Illinois casting was placed in the corresponding corner of the crossing of the Santa Fe westbound main with the B. & O. southbound track (See Proceedings, Vol. 48, 1947, Fig. 1, page 559). These two castings were placed in service May 26, 1947, and finally inspected May 20, 1948.

Inspection in 1948

The original Taylor–Wharton casting, as shown in Fig. 1, had a flangeway crack in the fillet next to the B. & O. receiving corner at gage position 5 (see Fig. 2, page 560, Vol. 48), and also small flangeway cracks where the guard rails join the casting at gage positions 1 and 12. The Carnegie–Illinois casting (Fig. 2) had flangeway cracks at both gage positions 5 and 9. Due to the error in placing this casting, explained above, gage position 9 (as well as 5) was also at a receiving corner for this casting. This probably explains the crack development at gage 9 which was adjacent to the receiving corner for Santa Fe traffic, for this casting only. A small crack is shown where the guard rail on the Santa Fe side joins the casting at gage position 1. In all other respects the two castings were in good condition.

Summary of Service Test Results

Each of the five test castings has had a year's service, except the Bethlehem design which developed extensive flangeway cracks and was removed after eight months' service. The revised Taylor–Wharton and Morden–Ramapo designs showed the least tendency to develop cracks. The former had small vertical cracks in the top and bottom fishings where the guard rails join the casting near gage positions 1 and 12 and also a similar crack in the fillet at the top fishing where the Santa Fe running rail abutted the casting. No perceptible flangeway cracks had developed. The latter design had small cracks in the flangeways at the B. & O. and Santa Fe receiving corners, but none had developed at gage positions 1 and 12. The original Taylor–Wharton and Carnegie–Illinois castings showed a somewhat greater tendency toward cracking as indicated in Figs. 1 and 2. The Bethlehem casting developed quite long cracks at both of the receiving corners and also shorter cracks at gage positions 1 and 12. Cracks were also found in the grillage supporting the flangeway floors. This casting gave the least satisfactory performance.

The test castings differed only in the design of the base and the method of supporting the flangeway floor. Photographs of bottom views of the castings may be observed in the Proceedings, Vol. 47, 1946, pages 8 and 9; Vol. 49, 1947, page 335. It will be noted that the revised Taylor–Wharton and Morden–Ramapo designs had a solid base except for the small round holes. In the original Taylor–Wharton and Carnegie–Illinois designs the area of the base was reduced by increasing the size of the openings. The Bethlehem casting had no integrally cast base at the center portion, but had a grid construction consisting of three cross members which supported the flangeway floors by means of wedges tack welded in place. The service tests have shown the importance of having a solid base throughout the center portion of the casting to increase the girder strength of the casting.

Fig. 1.—Original Taylor-Wharton Casting After One Year of Service. (Numbers in Flangeways Denote Stress Gage Positions).

Fig. 2.—Carnegie-Illinois Casting After One Year of Service. (Numbers in Flangeways Denote Stress Gage Positions).

Measured Stresses in the Castings

Stresses at 20 gage locations in the castings were measured under traffic and have been reported. Service cracks have most generally occurred in the flangeways at one or both of the receiving corners and at the junction between the guard rails and the castings. The range of stresses measured under locomotives and tenders, based on the average of the three highest compressive (—) and tensile (+) stresses at the gages where the cracks in the flangeways occurred, are shown in the table.

RANGE OF STRESSES IN CASTINGS UNDER TRAFFIC

	Stresses in 1000 psi. Gage Positions				
	At End of Guard Rails		*At Flangeway Intersection*		
	1	*12*	*5*	*9*	*11*
Design of Casting	*AT&SF*	*B&O*	*B&O*	*AT&SF*	
Revised Taylor–Wharton	(+13, —18)	(+10, —26)	+25, —35	+14, —41	+17, —41
Morden–Ramapo	+14, —12	+12, —10	(+21, —62)	+30, —34	(+43, —65)
Original Taylor–Wharton	(+21, —40)	(+13, —41)	(+20, —55)	+15, —45	+32, —14
Carnegie–Illinois†	(+10, —29)	+10, —20	(+11, —58)	(+10, —44)	+23, —55
Bethlehem*	(+21, —46)	(+14, —37)	(+16, —60)	(+10, —50)	(+34, —83)

Note.—Cracks occurred during the one year service tests at the gage positions shown in parentheses.
* After 6 months service period. † This casting had receiving corners at gages 5 and 9; all other castings, at gages 5 and 11.

The stress range at gages 1 and 12 was moderate in three of the castings, but somewhat higher in the other two designs. More cracks developed during the one-year tests at these locations than would be expected from the measured stresses. At these gage locations there is an abrupt change in cross section of the castings. Also, although the stress gages were placed as close as possible to the fillet, it seems probable that the maximum stresses may have been considerably higher in the corner of the fillet than at the gage location. This has been found to be true in measurement of stresses at the bolt hole in rail ends. The results of the service tests show that some improvement in the design is needed for all except the Morden–Ramapo casting.

Generally, higher maximum measured compressive stresses occurred at gages 5, 9 and 11 in the flangeway fillets adjacent to the two receiving corners than at gages 1 and 12. The revised Taylor–Wharton design developed no cracks at these gage locations during the one-year service test and the Bethlehem casting had long cracks at all three gage positions after six months service.

In the report, Appendix 4–b, by R. S. Jensen covering Fatigue Tests of Manganese Steel, tests were made with manganese specimens as cast, ground and shot peened with and without a corroding agent and with a protective coating. All specimens were subjected to a flexural stress variation in which the maximum tensile stress was equal to one-half of the maximum compressive stress, as had been established from the field stress measurements.

The endurance limit of the specimens tested without a corroding agent were as follows:

	Maximum Stresses in psi.	
	Compression	*Tension*
As cast	38,000	19,000
Ground	42,000	21,000
Shot peened	48,000	24,000

From a comparison of the measured stresses in the castings, with these endurance limits at 10 million cycles, it is shown that the service stresses at some of the gage positions were close to the fatigue strength of the manganese castings while at other locations they were considerably above the endurance limit of the material.

Conclusions

It is apparent that some of the designs included in the tests are more resistant to the development of fatigue cracks than others, but in none were the developed stresses low enough relative to the fatigue strength of the manganese steel to give the service life under heavy traffic that should be expected, and efforts to further reduce these stresses should be continued.

Report on Service Test of Manganese Insert and Solid Manganese Crossings on Structural Steel Substructure and Longitudinal Timbers

Four railroad crossings were installed in the double-track main lines of the Indiana Harbor Belt Railroad and the Chicago & Western Indiana Railroad near 55th Street

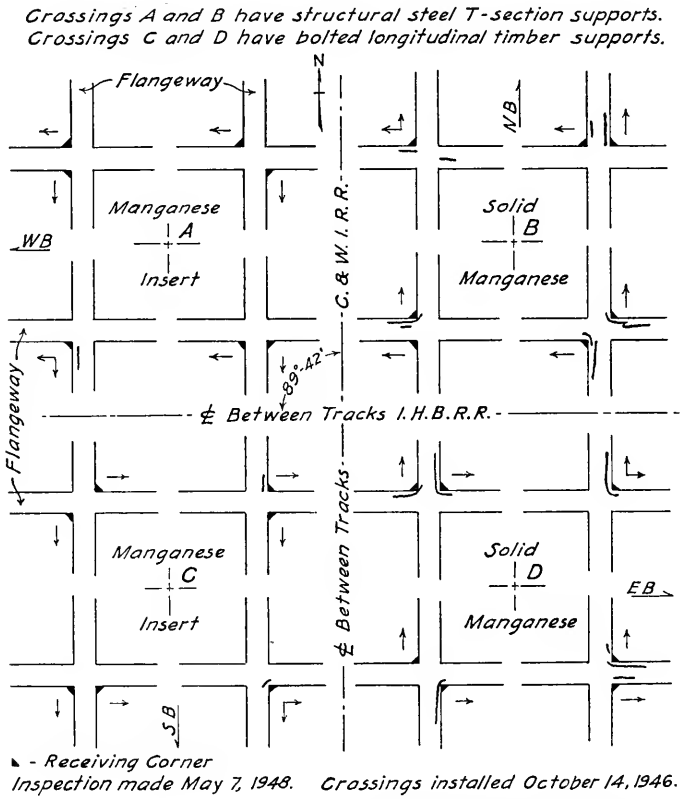


Fig. 3.—Flangeway Cracks in Four Crossings of the Chicago & Western Indiana R. R. and Indiana Harbor Belt R. R. near 55th Street and Cicero Avenue, Chicago, Ill.

and Cicero Avenue, Chicago, on October 14, 1946 and the installation has been reported in the Proceedings, Vol. 48, 1947, page 563. The structural steel T-beam support was placed under one each of the solid manganese and insert crossings and the other two crossings are carried on longitudinal bolted crossing timbers. The inspection made in 1947, after approximately one year's service, showed all castings in the four crossings to be in good condition with no flangeway cracks.

Inspection in 1948

An inspection of these crossings was made May 7, 1948. The crossings with the steel supports were raised twice during the past year. Some of the old asphalt mix left over from original construction was heated and placed under the base plates by the trowel method. A part of the surfacing work since installation was required because the asphaltic concrete ballast below the ground failed to set up properly to give the steel T-beam a solid foundation. Hot asphalt by the penetration method will be used in the next installation which will be located immediately south of the four test crossings in the Belt Railway Elsdon branch crossing of that railway's double-track main line.

A plan of the flangeways of the four crossings showing the flangeway cracks as found on May 7, 1948 is presented in Fig. 3. The length of the cracks is shown to the same scale as used for the flangeway width. The extent of the cracks was about the same, regardless of kind of support, for the two types of crossings. In all other respects the four crossing frogs were in good condition except that some difficulty was experienced with clip breakage and in keeping the clip bolts tight on the crossings with the steel support. This installation has not been successful in preventing flangeway cracks and this is believed to be due to the fact that the asphaltic concrete ballast did not offer satisfactory support. As a result failure of the welds at the intersection of the stem of the T-sections occurred almost immediately, removing much of the anticipated benefits of the steel T-beam support.

Crossing Frog Bolt Tension Tests

The purpose of these tests is to develop information on the rate of loss in bolt tension in relation to the pull-in or wear of the crossing frog assembly and to determine the reactive characteristics of a spring washer required for more economical and satisfactory maintenance of the bolt tension.

Test Measurements

Bolt tension in crossing frogs may be dissipated in three ways: first, by wear of the areas in contact; second, by stretching of the bolts and third, by the nuts cracking off. The initial bolt tension will be set with a caliper extensometer specially designed for long bolts, and the remaining bolt tension will be checked at intervals until the bolts require retightening at which time the procedure will be repeated. In order to correlate the loss in bolt tension with the wear of the crossing assembly or pull-in at each bolt, out-to-out readings will be taken with a newly designed gage each time the bolt tension is measured. Nut back off gages, previously used on track bolts but revised to fit the larger nuts, will be used to take readings on the threaded ends of the bolts with respect to the crown of the nut when the bolt tension is measured. With these data the load-release curve (bolt tension vs. pull-in) of the bolts can be compared with the combined load-release curve for the spring washer and elongation of the bolt necessary to obtain the initial bolt tension. Different types of spring washers will be used to determine if those with a high reactive spring pressure sustain a higher bolt tension for a longer period. Stretching of the bolts will be determined by comparison of the no-load lengths of the frog bolts with a reference bar.

Tests were started at two locations in the fall of 1948, as follows:

Pennsylvania—G. M. & O. Railroad Crossings

This test includes two crossings in the Pennsylvania Railroad (Panhandle) eastbound freight main carrying interchange traffic and the Gulf, Mobile & Ohio Railroad double-track main line near 37th street and Campbell Avenue, Chicago. Traffic is slow on both lines as the normal operation is "stop and proceed." The two test crossings are of triple T-rail construction made of 130-lb. P.S. heat treated rail and were installed in September 1944. The crossing frogs are in good condition with only a small amount of batter. Each crossing has forty-eight 1⅜-in. by 14-in. main bolts. In the easterly crossing one-half of the crossing has the heavy duty Reliance experimental spring washer to compare with the Pennsylvania specification spring washer in the other half of the crossing. In the westerly crossing a Hubbard heavy duty experimental spring washer will also be compared with the Pennsylvania washer. The initial bolt tension was set as close as practicable to 40,000 lb. This tension produces about the same unit stress in the root area of a 1⅜-in. dia. bolt as 20,000 lb. does in a 1-in. track bolt. Both the 1⅜ and 1¼-in. dia. bolts were calibrated in the laboratory to 60,000 lb. without permanent elongation. If it is found advisable, tests will be made with an initial bolt tension greater than 40,000 lb.

Indiana Harbor Belt Railroad and Chicago & Western Indiana Railroad Crossings

This test is being made on crossings A, C and D shown in Fig. 3, where the structural steel support was placed under two crossings near 55th street and Cicero Avenue, Chicago. Traffic is controlled on both belt lines (carrying freight only) by signals in charge of the train director in the tower at the crossing. Train speeds are moderate, or below 30 mph.

Included in this test is the solid manganese crossing supported on longitudinal timbers and two reversible manganese insert crossings of 105-lb. Dudley rail, one being on timber and the other on the steel T-beam support. The solid manganese crossing has 1⅜-in. dia. bolts in the four internal joints and 1¼-in. dia. bolts in the external arms and the existing medium weight spring washers were included in this test. All of the main bolts in the insert crossings are 1¼-in. dia. of three different lengths. The initial bolt tension was set at approximately 40,000 lb. in all three crossings.

In the insert crossing supported on timbers (crossing C, Fig. 3 the west half of the crossing has Reliance heavy duty experimental spring washers on 1¼-in. bolts and the other half has medium weight spring washers as originally furnished with the crossing frog. Two Security nuts were placed in this crossing to check their performance as to backing off. These nuts are hexagonal and have an alloy steel ring with approximately two threads inserted in the crown side of the nut. The ring has an oval shape which, by deforming to a circle when applied to the bolt, sets up thread friction to keep the nut from backing off after the bolt tension drops off.

In the insert crossing (A in Fig. 3) which is supported on the T-beam substructure, the existing spring washers were retained in three corners of the crossing. Elastic stop nuts, which have a fiber collar in the crown side to create thread friction and prevent the nut backing off, were placed in two corners of the crossing, one with spring washers and one without washers. These are hexagonal nuts, made of low carbon steel, and gave trouble with the frog wrench slipping over the corners.

Additional Test

A high speed main line crossing of the manganese insert type carrying both passenger and freight traffic, will be set up for the test in 1949. A reasonably new crossing is desired for the first series of tests.

Some data will also be taken on turnout frog bolts.

Appendix 4-b

Fatigue Tests of Manganese Steel

By R. S. Jensen

Special Research Associate of Engineering Materials, University of Illinois

This report is presented as information.

During the course of an investigation[1] to study the cause of cracks which have occurred with some frequency in the flangeways of solid manganese crossing frogs, additional information was desired to serve as a guide in studying further improvements in crossing design. Determination of the fatigue strength of Hadfield manganese steel, under the same range of stress as encountered in service, was therefore planned as a part of this assignment. Since fatigue tests were proposed covering a range of bending stresses similar to those used on the investigation of fatigue of rail webs, in progress at the University of Illinois, it was decided to use the same vibratory type fatigue machines and specimens conforming in shape and size to the rail web specimens.

Because the flangeways of the crossings accumulate water, dirt and cinders it was expected that corrosion may have been a considerable factor in lowering the fatigue strength of the material; for this reason corrosion fatigue tests were included in the program.

Based on a large number of stress measurements in the field by the Engineering Division research staff, AAR, a range from a maximum compressive stress to a tensile stress 50 percent as great was indicated as being representative of service conditions and was used on all specimens included in this report.

Acknowledgment is made to the American Manganese Steel Division of the American Brake Shoe Company which supplied the manganese steel castings for the specimens, the American Wheelabrator and Equipment Corporation, which shot peened 30 of the specimens, and the National Lead Company whose research laboratories applied corrosion resistant coatings to 30 of the specimens. The valuable services of F. J. Suter, special research assistant, and Elmer Hunt, mechanician in the laboratory shops, are also acknowledged.

Test Specimens

The test specimens were machined from small castings which had been heat treated and radiographed. Nine bars (plus spares) were cast from the same ladle of each of several production heats. Since manganese steel is very difficult to machine, the bars were cast approximately to the size of the specimen (with about ⅛-in. of finish stock) to hold the amount of machining to a minimum. In order to insure that failure would start in a region of high compressive stress, the specimens were made with a T-shaped

[1] AREA Proceedings, Vol. 47, 1946, pp. 1-38.

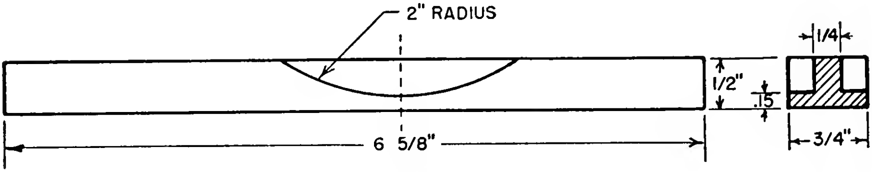


Fig. 1.—Shape of Specimens.

minimum cross section, as shown in Fig. 1. From each side of the rectangular bar, part of the metal was removed, leaving the stem of the "T" in the middle. These specimens were tested as cantilever beams in partially reversed flexure with the maximum tensile stress on the top surface equal to 50 percent of the maximum compressive stress. The shape and dimensions of the specimen limited the maximum tensile stress on the *bottom* of the specimen to a low value and insured fatigue failure starting on the upper or test surface.

A series of nine fatigue tests was completed with surface finishes and under corrosion conditions outlined in Table 1.

Table 1.—Schedule of the Fatigue Tests

Surface Finish	*No Corroding Agent*	*With Corroding Agent 5 Percent Sulfuric Acid*	*With Corroding Agent and Corrosion Protection*
As cast	Series 1	Series 4	Series 7
Ground	Series 2	Series 5	Series 8
Shot peened after grinding	Series 3	Series 6	Series 9

Ten specimens were prepared for each series of tests. Thirty specimens were shot peened on both the top and bottom surfaces after having been surface ground. A very slight bevel was ground on the sharp corner or edge of the stem of the "T" to prevent the formation of small fins by the peening which might have been susceptible to cracking. All shot peened specimens received 4 passes on each side at a travel speed of 3 ft. per min. Shot S–230 was used which has a nominal diameter of 0.023 in.

Thirty specimens received corrosion resistant coatings of the following composition:

One coat—Wash primer—19 percent solids pigmented vinyl resin solution

Two coats—Red lead—vinyl resin primer which is an 18 PV 100 percent red lead pigmented paint carrying a vehicle composed of a copolymer type vinyl resin cut with suitable solvents and thinners.

One coat—Finish coat paint M 5076 which is pigmented with carbon black, red lead and extender pigments. The vehicle is composed of a medium length drying oil alkyd, a chlorinated diphenyl resin, and chlorinated rubber.

A few hardness measurements were taken with a Tukon hardness tester using a small diamond pyramid on specimen with as-cast, ground, and shot peened surfaces. Averaging six hardness readings for each surface condition and converting to Brinell gave the following equivalent Brinell hardness:

As cast	269
Ground	244
Shot peened	455

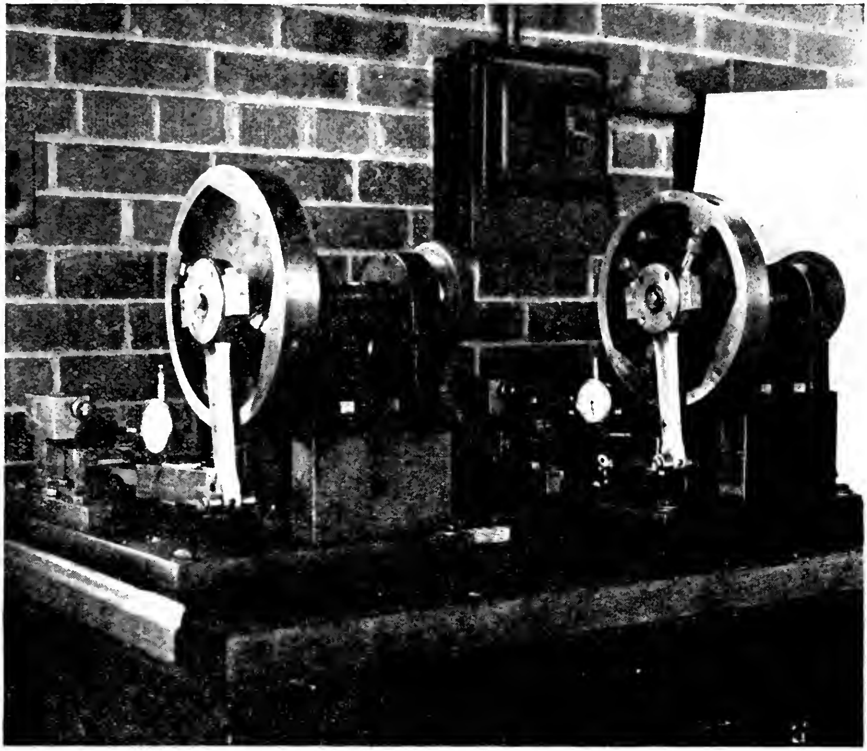


Fig. 2.—Vibratory Type Fatigue Machines.

The pronounced increase in hardness for the shot peened specimens indicates the great susceptibility of this material for work-hardening.

The vibratory type fatigue machines used for the tests are shown in Fig. 2. Before testing, each specimen was calibrated by dead weights as a dynamometer which indicated bending moment and consequently nominal stress for any range of amplitude of vibration which may be set up by the variable throw crank of the testing machine. The machines were run at 800 rpm, and by comparing measurements of the deflection of the specimen when the machine was running and when it was turned over by hand, it was found that the difference in deflection of specimen was very small. During all tests, the constant ratio of maximum tensile stress to maximum compressive stress was maintained at — 0.50 by stopping the machine at intervals, taking readings of deflection of specimen, and if necessary, adjusting the throw of the crank or the tilt of the vise holding the specimen.

Results of Tests

As in previous tests on rail web specimens the criterion of failure was taken to be the number of cycles when the crack could first be detected, since not only is crack growth slow in a region of high compression, but, especially in the case of a T-shaped specimen, it may almost, if not entirely, cease to spread when it reaches the upper edge

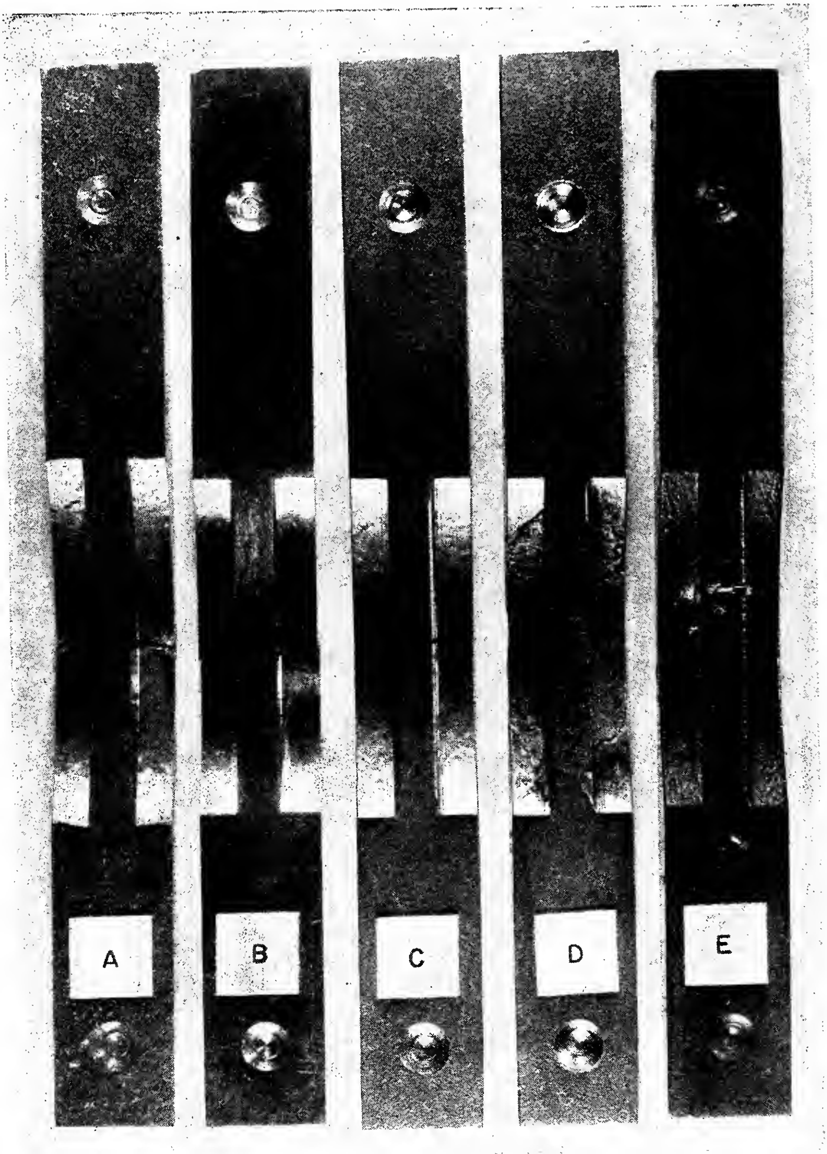


Fig. 3.—T-Shaped Manganese Specimens After Testing.

A—Specimen M6 As Cast—No Corrosion
B—Specimen M81 Ground—No Corrosion
C—Specimen M43 Shot Peened—No Corrosion
D—Specimen M59 Shot Peened—5 percent Acid
E—Specimen M36 Shot Peened—Coated 5 percent Acid

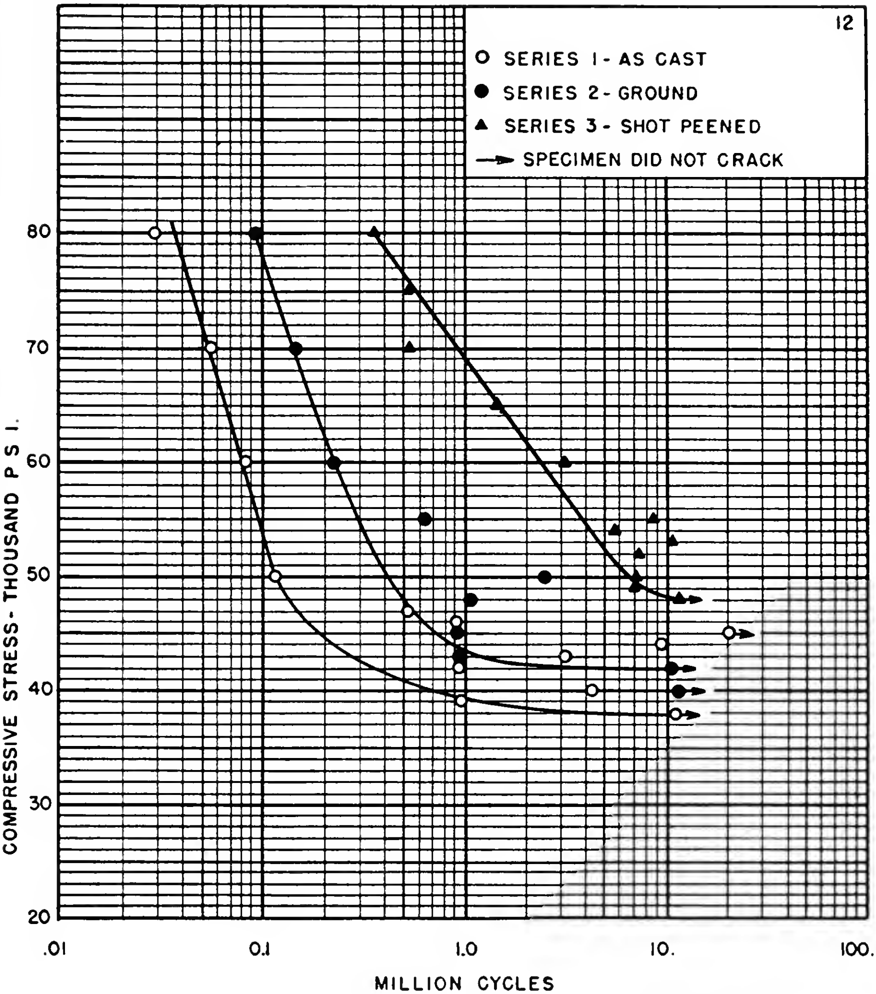


Fig. 4.—Fatigue Tests of T-Shaped Manganese Steel Specimens.
Note: Each cycle of stress ranged from the compressive stress shown to a tensile stress one-half as large.

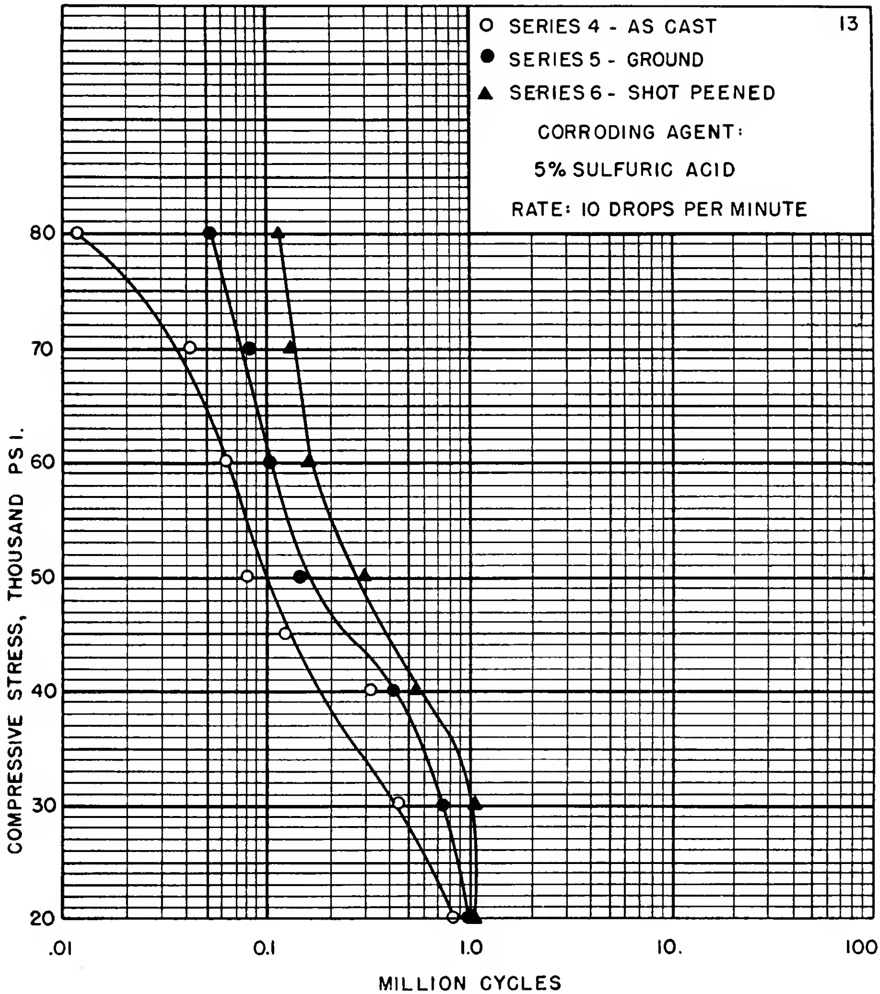


Fig. 5.—Corrosion-Fatigue Tests of T-Shaped Manganese Steel Specimens—Unprotected. Note: Each cycle of stress ranged from the compressive stress shown to a tensile stress one-half as large.

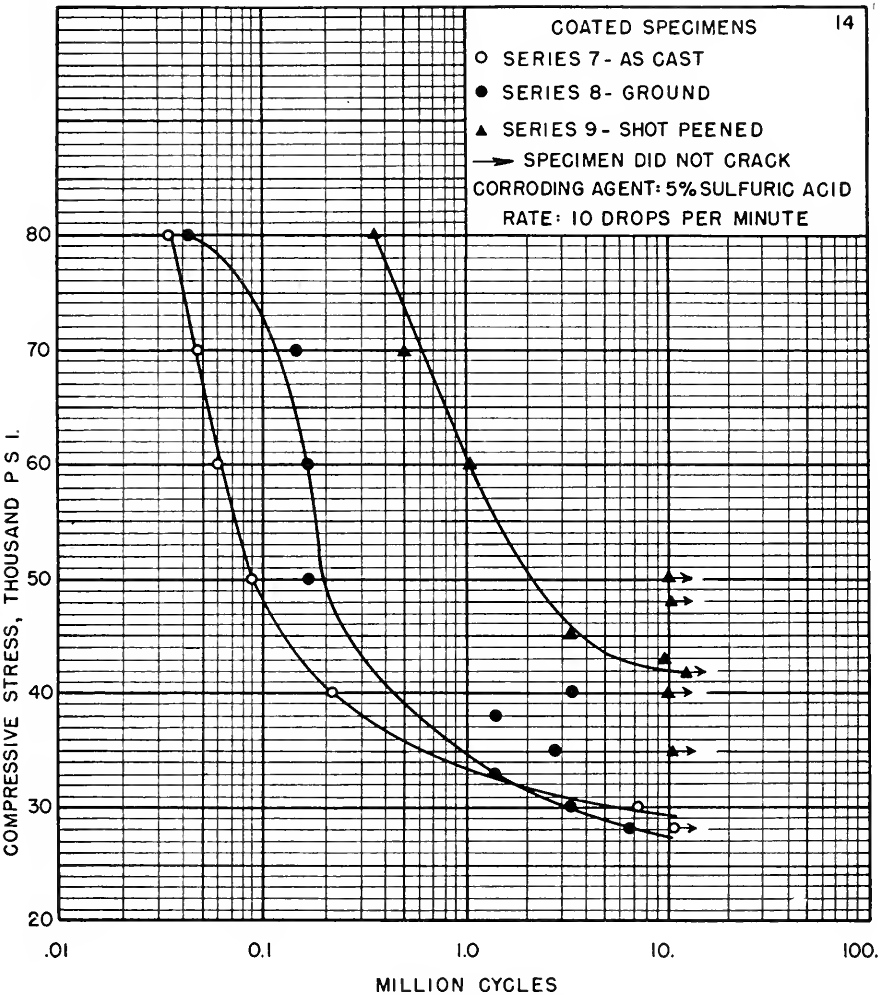


Fig. 6.—Corrosion-Fatigue Tests of T-Shaped Manganese Steel Specimens—Coated. Note: Each cycle of stress ranged from the compressive stress shown to a tensile stress one-half as large.

of the flange—if, as was the case for these tests, the testing machine is of the constant deflection type. Consequently the cycles listed in Table 2 were those recorded at the first appearance of a crack, although the specimens were allowed to run to a greater number of cycles and checked to see whether the cracks spread. Ten million cycles were judged to be sufficient and this number was set as a limiting value in order to complete the tests in a reasonable length of time. On several of the specimens more than one crack was observed although the additional cracks were small compared to the crack which progressed to failure.

Fig. 3 shows five of the specimens after testing.

Results of the tests which are tabulated in Table 2 are plotted in Figs. 4, 5, and 6. For the tests on specimens with no corroding agent shown in Fig. 4 the as-cast specimens indicated an endurance limit of 38,000 psi., the ground specimens an endurance limit of 42,000 psi., an increase of 10½ percent and the shot peened specimens an endurance limit of 48,000 psi., an increase of 26 percent over the as-cast specimens of series 1. Considerable scatter is evident in the as-cast and ground specimens at the lower stresses and to a lesser extent in the shot peened specimens. Probably some of the scatter was due to the fact that the specimens were of a cast material with a rather coarse grain structure and the possibility of variations in the different heats from which the bars were cast. The rough surface condition undoubtedly contributed to the scatter in the as-cast specimens.

Fig. 5 shows the fatigue curves for the three types of specimens under a corroding agent of 5 percent sulfuric acid which was adjusted to drip at the rate of 10 drops per minute. The specimens were readily attacked by this dilute acid and showed a marked reduction in fatigue strength at stresses below 50,000 psi. and a lesser reduction at the higher stresses. The decrease in fatigue strength of the shot peened specimens under the acid was greater than for either the as-cast or ground specimens. This could be reasonably expected since only a relatively shallow layer of the metal is affected by shot peening and it seems probable that its beneficial effect would soon be lost under the attack of an active acid corroding agent. For these uncoated specimens under acid corrosion the fatigue curve approaches a vertical line at the low stresses at approximately one million cycles. This number of cycles corresponds to about 21 hours of testing.

Fig. 6 shows the results of corrosion fatigue tests on the coated specimens. The coating was beneficial in increasing the fatigue life of the specimens under corrosion but not entirely effective. The paint seemed tough and elastic and showed no tendency to crack, peel or scale off. For the highest stress the number of cycles for failure for the coated specimens was not greatly different from the number for specimens with no corrosion. However for the lower stresses, the coated specimens withstood a great many more cycles than the uncoated specimens under corrosion, and although the fatigue curve had a slight downward slope at 10 million cycles it appeared to be approaching a horizontal line or endurance limit. For the as-cast coated specimens the fatigue strength at 10 million cycles appears to be about 29,000 psi., or 76 percent of the endurance limit for the as-cast specimens with no corrosion. For the ground coated specimens the fatigue strength at 10 million cycles was 27,500 psi., or 65.5 percent of the endurance limit with no corrosion and the coated shot peened specimens showed fatigue strength of 42,000 psi., or 87.5 percent of the endurance limit for the shot peened specimens with no corrosion.

Summary

1. All specimens were tested under a range of stress from a maximum compressive stress to a tensile stress 50 percent as great. Endurance limits at 10 million cycles

were indicated as follows: As-cast surface 38,000 psi.; ground surface 42,000 psi.; shot peened surface 48,000 psi.

2. Corrosion fatigue tests using a 5-percent solution of sulfuric acid were made on unprotected specimens with as-cast, ground, and shot peened surfaces, and the S–N diagrams approached a vertical line at approximately one million cycles for all specimens.

3. The protective paint coating applied to three groups of specimens proved to be beneficial, although not totally effective in increasing their fatigue life under 5-percent acid corrosion, as endurance limits at 10 million cycles were from 65 to 87 percent as great as for specimens with no corrosion.

4. A few hardness tests on unstressed specimens with as-cast, ground and shot peened surfaces indicated little difference in hardness for as-cast and ground surfaces (equivalent Brinell 269 and 244, respectively) and a much greater hardness (equivalent Brinell 455) for shot peened specimens.

TABLE 2.—RESULTS OF THE FATIGUE TESTS

Specimen Number	*Heat Number*	*Compressive Stress, psi.*	*Cycles to Start Crack*
Series 1, As Cast Surface, No Corroding Agent			
M7	2	80,000	29,000
M1	3	70,000	58,200
M2	3	60,000	84,000
M3	4	50,000	119,200
M6	3	47,000	519,000
M8	3	46,000	918,700
M5	2	45,000	21,695,000*
M9	2	44,000	9,667,500
M10	3	43,000	3,195,000
M12	5	42,000	945,200
M4	3	40,000	4,473,500
M13	5	39,000	995,200
M15	2	38,000	11,481,000*
Series 2, Ground Surface, No Corroding Agent			
M73	10	80,000	92,000
M74	10	70,000	147,700
M75	10	60,000	211,000
M78	9	55,000	618,500
M76	9	50,000	2,467,000
M79	9	48,000	1,078,000
M81	14	43,000	933,000
M83	14	42,000	10,486,000*
M82	14	40,000	11,467,000*
M80	9	45,000	906,000
Series 3, Shot Peened, No Corroding Agent			
M43	7	80,000	352,000
M44	7	75,000	509,000
M45	6	70,000	532,100
M46	7	65,000	1,460,000
M47	7	60,000	3,031,700
M48	7	55,000	8,837,900
M50	10	54,000	5,795,900
M49	7	53,000	10,390,000
M51	10	52,000	7,335,300
M52	8	50,000	7,110,000
M53	10	49,000	7,041,000
M54	10	48,000	11,386,000*

* Specimen did not crack.

Specimen Number	Heat Number	Compressive Stress, psi.	Cycles to Start Crack
	Series 4, As Cast Surface, 5-Percent Sulfuric Acid		
M17	4	80,000	11,500
M18	1	70,000	42,800
M16	3	60,000	64,000
M19	4	50,000	80,000
M22	5	45,000	120,000
M20	4	40,000	322,000
M17A	4	30,000	447,000
M21	3	20,000	833,500
	Series 5, Ground Surface, 5-Percent Sulfuric Acid		
M84	14	80,000	51,000
M85	14	70,000	81,500
M86	14	60,000	105,000
M87	14	50,000	151,600
M88	14	40,000	421,000
M89	14	30,000	747,000
M90	13	20,000	990,000
	Series 6, Shot Peened, 5-Percent Sulfuric Acid		
M55	7	80,000	112,200
M56	8	70,000	136,000
M57	9	60,000	169,500
M58	6	50,000	297,000
M59	9	40,000	540,000
M60	6	30,000	1,032,000
M61	8	20,000	1,051,000
	Series 7, As Cast Surface, Painted, 5-Percent Sulfuric Acid		
M23	4	80,000	34,000
M24	5	70,000	48,000
M25	5	60,000	60.000
M26	5	50,000	90,000
M27	5	40,000	210,500
M28	5	30,000	7,107,000
M39	No Number	28,000	10,165,000*
	Series 8, Ground Surface, Painted, 5-Percent Sulfuric Acid		
M63	8	80,000	43,000
M64	8	70,000	152,000
M65	8	60,000	170,000
M66	8	50,000	167,000
M67	8	40,000	3,313,000
M68	10	38,000	1,396,700
M69	10	35,000	2,800,000
M70	9	33,000	1,445,000
M71	9	30,000	3,230,000
M72	9	28,000	6,675,000
	Series 9, Shot Peened, Painted, 5-Percent Sulfuric Acid		
M29	2	80,000	354,200
M30	3	70,000	500,000
M31	5	60,000	1,042,000
M32	2	50,000	10,000,000*
M33	2	45,000	3,250,000
M37	8	48,000	10,270,000*
M36	7	43,000	9,970,000
M34	2	40,000	10,000,000*
M38	7	42,000	13,280,000*
M35	7	35,000	10,300,000*

Report on Assignment 6

Design of Tie Plates

Collaborating with Committees 3 and 4

J. de N. Macomb (chairman, subcommittee), C. A. Anderson, F. J. Bishop, Blair Blowers, C. W. Breed, M. D. Carothers, E. W. Caruthers, H. R. Clarke, R. W. Claypoole, B. E. Crumpler, J. W. Fulmer, B. F. Handloser, J. P. Hiltz, C. T. Jackson, C. H. Johnson, G. M. Magee, E. E. Martin, J. B. Myers, J. A. Reed, I. H. Schram, M. J. Zeeman.

This is a progress report, presented as information but includes recommendations embracing two minor revisions of the Manual.

Tie plate plans 1 and 2, adopted for publication in the Manual in March 1948, were designed to locate the ribs on the underside near the gage end on the assumption that these tie plates would be used with rails having base widths of 5⅛ in. and 5½ in., respectively. The experience of the past year has shown that these tie plates are used with rails with base widths of 5 in. and 5⅛ in., respectively, and the plans have been revised by moving the gage rib accordingly.

The committee recommends the adoption of these revisions, as shown in the revised drawings of plans 1 and 2.

The American Iron and Steel Institute has developed plan 19 for a 15-in. double-shoulder tie plate for use with a rail having a 6½ in. base, (136-lb. rail) and this plan is submitted as information.

Service Test Measurements of Tie Plates

This is a progress report of the service test measurements covering seven designs of tie plates for 112-lb. rail for a period of 45 months, and is submitted as information.

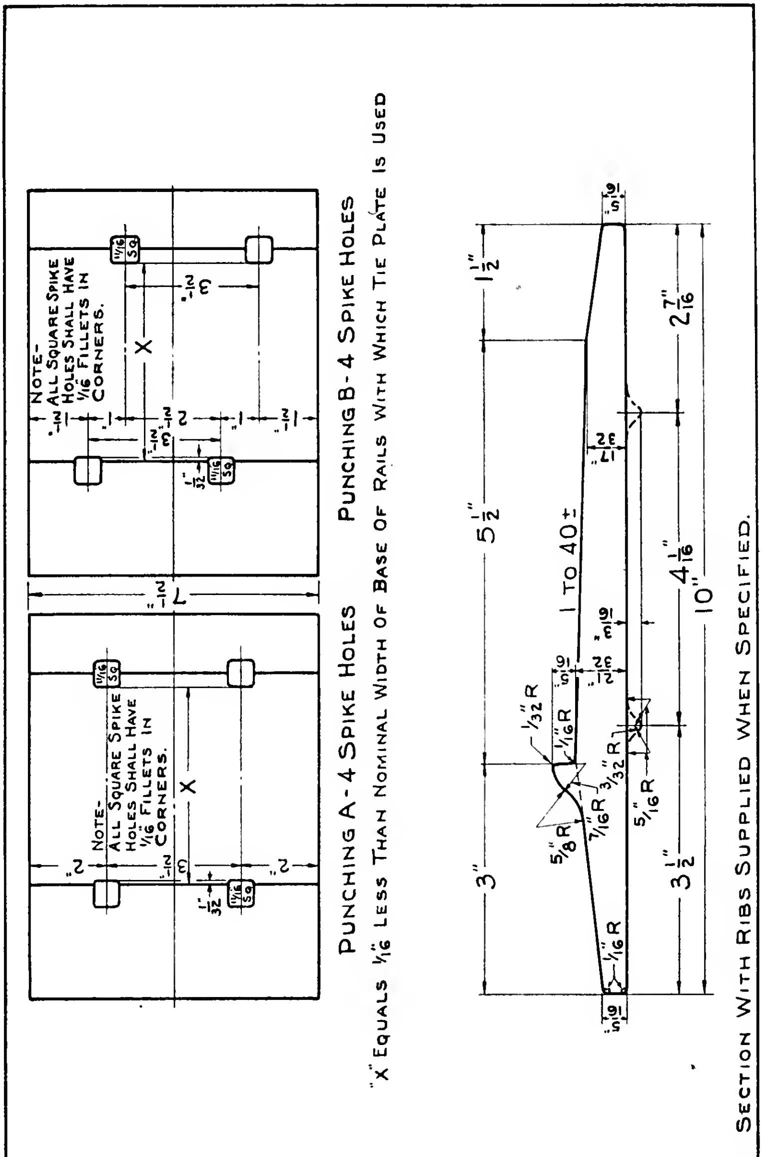
Six designs of 11-in. and one of 13-in. tie plates were placed in the southward main track of the Illinois Central System near Curve and Henning, Tenn., in October 1944. Each design of tie plate was used in a panel of track on the 4-deg. test curve and tangent track with both creosoted oak and pine ties. A description of the tie plates and test location, and results of stress measurements have been presented in the Proceedings, Vol. 50, 1949, page 1.

Tie Plate Penetration Measurements

A summary of the tie plate penetration measurements taken in July 1948 is given in Table 1. A relatively large penetration for 74 million gross tons of traffic has occurred at the field end of the inner rail tie plates on the stretch of 4-deg. curve with creosoted pine ties. On both kinds of ties in the curve the average penetration for both rails for the 13-in. tie plate was less than that for the 11-in. plates. On tangent the penetration for the two lengths of plates was about the same. It is assumed that damaging tie plate pressures have occurred on the inner rail of the curve, and in the softwood tie section the 13-in. tie plate shows a marked reduction in penetration as compared to most of the 11-in. tie plates. For the pine ties on the curve the average penetration of the five 11-in. tie plate designs having ⅜-in. eccentricity, was twice as large on the inner rail as on the outer rail. The inner rail has canted outward appreciably on the softwood ties.

Tie Plate Bending

The data taken in July 1948 showed that only two tie plates of the 419–X design on the inner rail of the curve in the panel with pine ties had bent appreciably. These

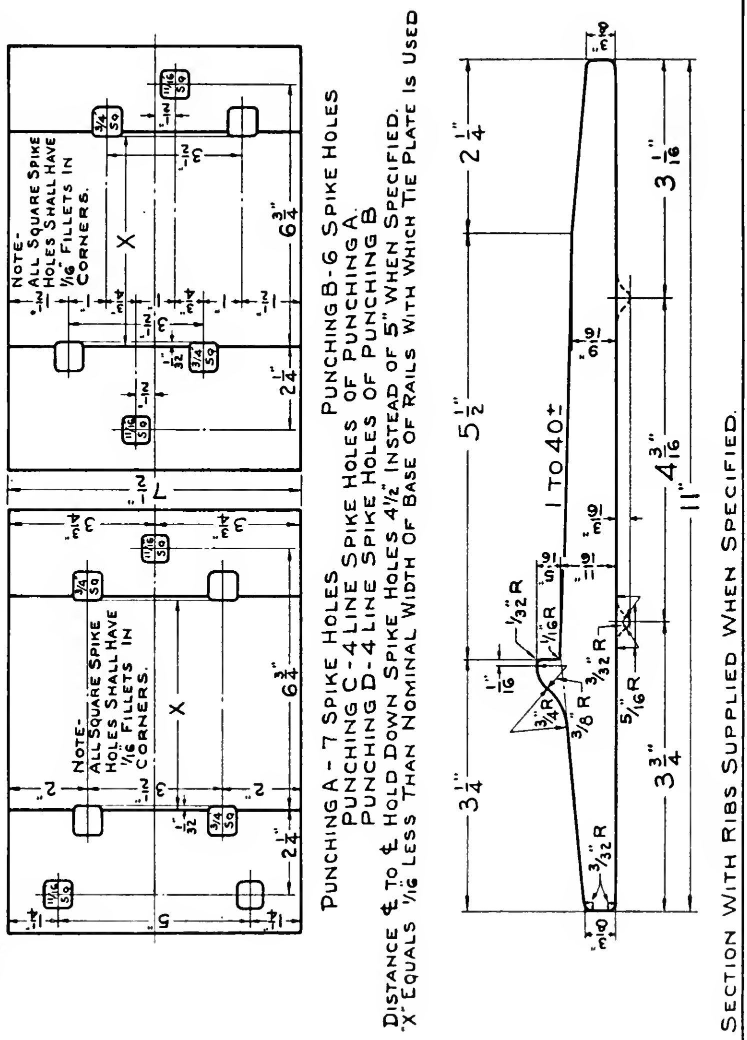


*ESTIMATED WEIGHTS

PER FOOT —— 18.60 LB.
PER 7½ IN. —— 11.63 LB.

PUNCHED 4 SPIKE HOLES.— 11.28 LB.
*ADD .34 LB. TO FOOT WEIGHT AND .21 LB. TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS.

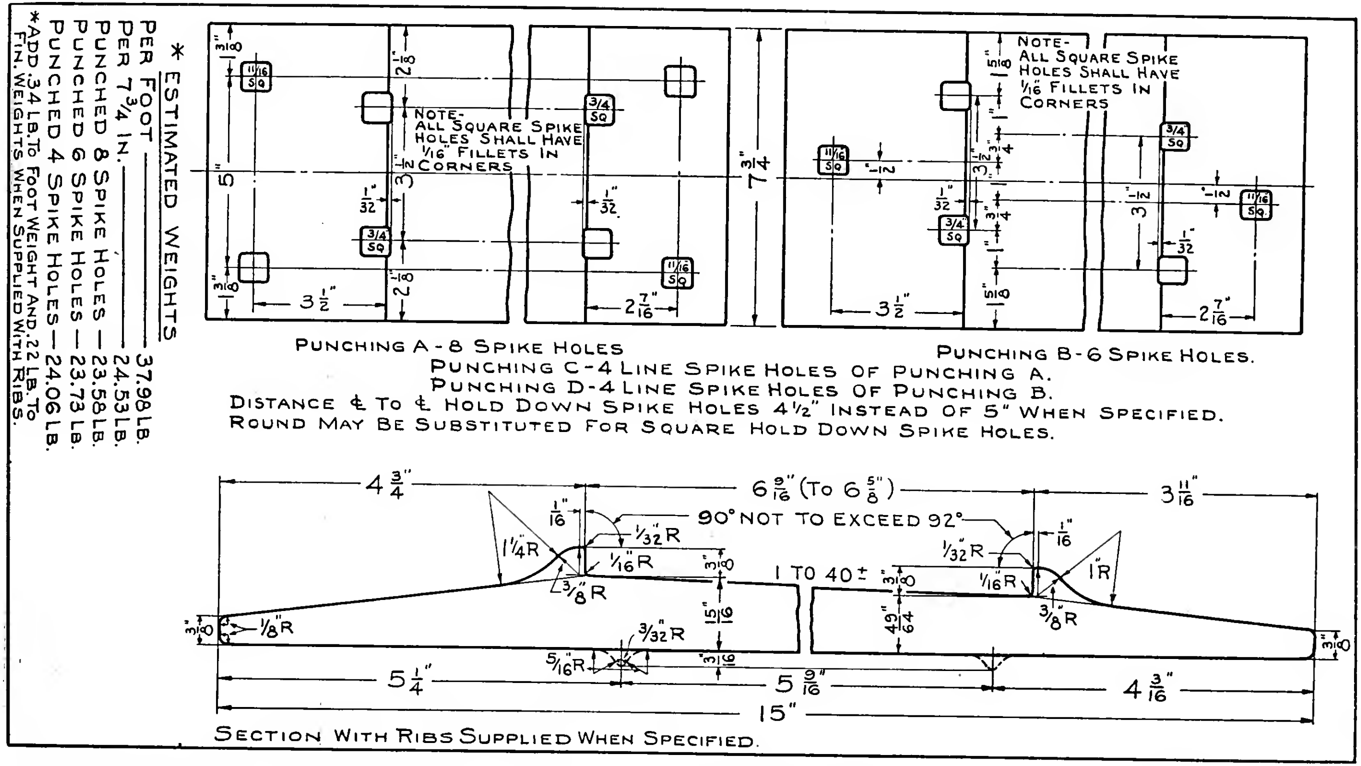
Plan No. 1.—AREA 10-in. Tie Plate.



*ESTIMATED WEIGHTS

PER FOOT —————— 21.58 LB.
PER 7½ IN. —————— 13.49 LB.
PUNCHED 7 SPIKE HOLES — 12.87 LB.
PUNCHED 6 SPIKE HOLES — 12.93 LB.
PUNCHED 4 SPIKE HOLES — 13.05 LB
*ADD .34 LB TO FOOT WEIGHT AND .21 LB TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS.

Plan No. 2.—AREA 11-in. Tie Plate.



American Iron and Steel Institute Plan No. 19 for a 15-in. Double-Shoulder Tie Plate for Use with Rail Having 6½ in. Base.

TABLE 1. SERVICE TEST OF MECHANICAL WEAR OF TIES WITH SEVEN DESIGNS OF TIE PLATES FOR 112-LB. RE RAIL IN THE SOUTHBOUND MAIN OF THE ILLINOIS CENTRAL SYSTEM NEAR CURVE AND HENNING, TENN.

Tie Plate Design No.	Tie Plate Dimensions in.	Rail Seat	Tie Plate Penetration from Oct. 1944 to July 1948 in 0.001 in. - 74 million gross tons						
			Inner or West Rail			Outer or East Rail			Average Both Rails
			Field End	Gage End	Avg.	Gage End	Field End	Avg.	
4° Curve - Creo. Oak Ties									
419	7 3/4 x 13 x 27/32	Flat	117	68	92	57	81	69	81
419-Z	7 3/4 x 11 x 27/32	Flat	143	62	102	79	76	77	90
419-Y	7 3/4 x 11 x 11/16	Flat	145	49	97	54	106	80	89
419-X	7 3/4 x 11 x 9/16	Flat	158	80	119	83	94	88	104
366	8 x 11 x 23/32	Beveled	177	58	118	41	77	59	88
400	7 3/4 x 11 x 23/32	Rolled Circular	187	37	112	57	69	63	88
3170	8 1/2 x 11 x 3/4	Pressed Circular	192	85	139	58	108	83	111
4° Curve - Creo. Pine Ties									
419	7 3/4 x 13 x 27/32	Flat	268	97	182	79	88	84	133
419-Z	7 3/4 x 11 x 27/32	Flat	348	106	227	124	103	113	170
419-Y	7 3/4 x 11 x 11/16	Flat	320	69	194	109	104	107	151
419-X	7 3/4 x 11 x 9/16	Flat	407	99	253	170	114	142	198
366	8 x 11 x 23/32	Beveled	403	107	255	91	89	90	172
400	7 3/4 x 11 x 23/32	Rolled Circular	386	128	257	116	115	116	186
3170	8 1/2 x 11 x 3/4	Pressed Circular	331	102	216	122	95	109	162
Tangent - Creo. Oak Ties									
419	7 3/4 x 13 27/32	Flat	106	172	139	134	85	110	124
419-Z	7 3/4 x 11 x 27/32	Flat	118	145	132	149	108	128	130
419-Y	7 3/4 x 11 x 11/16	Flat	128	131	130	122	93	108	119
419-X	7 3/4 x 11 x 9/16	Flat	122	117	120	128	90	109	114
366	8 x 11 x 23/32	Beveled	95	129	112	108	111	110	111
400	7 3/4 x 11 x 23/32	Rolled Circular	130	153	142	167	104	136	139
3170	8 1/2 x 11 x 3/4	Pressed Circular	93	131	112	167	97	132	122
Tangent - Creo. Pine Ties									
419	7 3/4 x 13 x 27/32	Flat	144	169	156	150	105	131	144
419-Z	7 3/4 x 11 x 27/32	Flat	143	203	173	199	101	150	162
419-Y	7 3/4 x 11 x 11/16	Flat	111	196	154	173	94	133	144
419-X	7 3/4 x 11 x 9/16	Flat	132	177	154	164	92	128	141
366	8 x 11 x 23/32	Beveled	127	191	159	206	134	170	164
400	7 3/4 x 11 x 23/32	Rolled Circular	119	168	144	203	92	147	146
3170	8 1/2 x 11 x 3/4	Pressed Circular	107	188	148	163	88	125	136

All tie plate designs have 3/8-in. eccentricity except 3170 has 1/2-in.

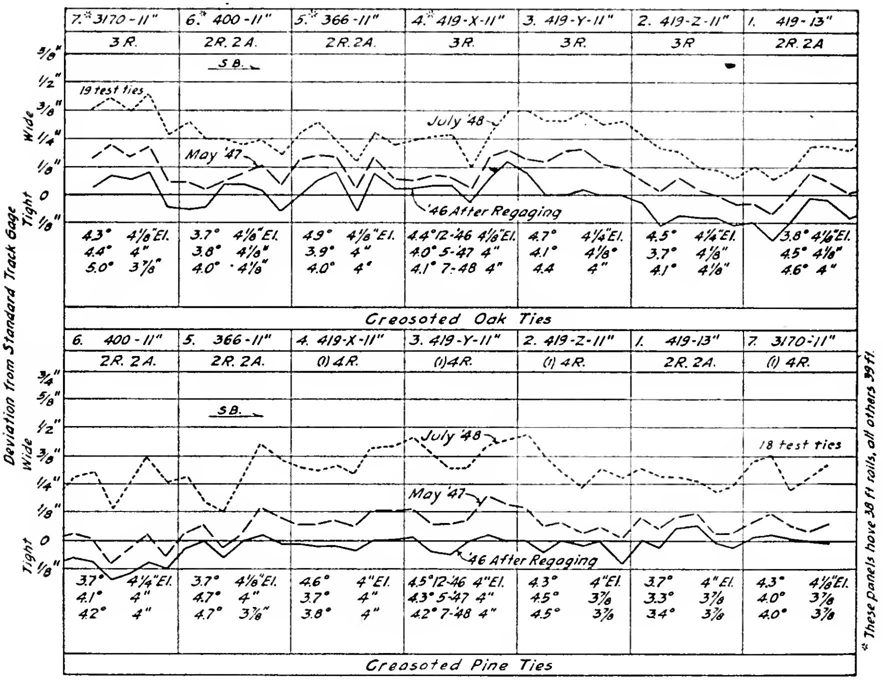
have been previously reported. Two other 419-X tie plates under the same rail have bent upward slightly at the outer toe. No other tie plates were found bent.

Gage of Track

A graphic record of the gage of track measured at six points in each test panel is shown in Figs. 1 and 2. All of the test track was regaged in the fall of 1946 and the gage on the curve has continued to widen, but not quite as much as in the first two-year service period. The gage on the tangent section was moderately irregular, particularly on softwood ties.

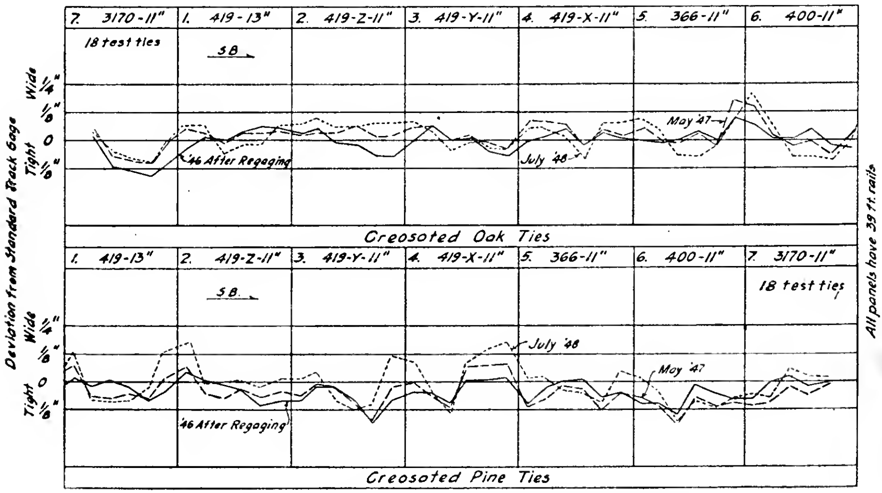
Summary

The purpose of these tests is to develop information on the performance of the several designs of tie plates as to length, thickness, shape of rail seat and eccentricity. Stress measurements in relation to these design features have been reported.



Panels divide at joints in outer rail. (1). The fourth line spike was driven September 1, 1948.
2R, 3R or 4R indicate the number of line spikes per tie plate; 2A the number of anchor spikes per tie plat

Fig. 1.—Gage, Curvature and Elevation of Each Panel of Test Track on the 4-deg. Curve, Mile L–333, I.C.R.R.



Each tie plate has 2 rail and no anchor spikes. Panels divide at Joints in west rail.
Each panel of test track has 23 ties except panels No. 7 which have only 18 test ties.

Fig. 2.—Gage of Each Panel of Test Track on Tangent at Henning, Tenn., I.C.R.R.

The reduction in tie plate penetration of the 13-in. tie plates compared with the 11-in. tie plates having standard thickness (419–Y, 366 and 400 designs) has been less than would be expected from the ratio of the plate areas on the curve, and on tangent the mechanical wear of these plates has been about the same. There were no significant differences in the penetration measurements as to tie plate thickness and shape of rail seat. A comparison of the penetration measurements on tangent and the curve for corresponding test sections, indicates the plate cutting on tangent was somewhat greater than would be expected.

The eccentricity of the tie plates, ⅜ in. and ½ in., has been satisfactory on tangent track and the outer rail of the curve. On the inner rail of the curve the plate cutting at the outer toe was from 3 to 4 times as great as at the inner toe, and a much greater eccentricity than that of the test plates would be required to equalize the penetration and prevent the outward cant of the inner rail of the curve which has a 4-in. elevation.

In Fig. 1 showing track gage measurements for the 4-deg. curve, it will be observed that the gage widening was greater where only three spikes per tie plate were used.

This service test has been of insufficient duration to accurately appraise the various characteristics of the seven tie plate designs.

Report on Assignment 7

Hold-Down Fastenings for Tie Plates, Including Elastic Pads Under Plates; Their Effect on Tie Wear

Collaborating with Committee 3

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This report, submitted as information, describes the tie plate hold-down fastenings test installations made in 1947 and 1948 on the Louisville & Nashville Railroad and includes progress reports of these tests and those on the Illinois Central Railroad.

Foreword

Recent increases in the costs of ties and labor of insertion emphasize the importance of using more effective measures to extend the service life of ties. Mechanical wear of ties can be reduced by the use of larger tie plates or by the application of effective types of hold-down fastenings. Investigations being conducted in connection with Assignment 6—Design of tie plates, are expected to develop information on the economical size of tie plates with respect to traffic density. The hold-down fastenings test installations will indicate the relative effectiveness and economy of the several types of tie plate anchorage and tie pads in relation to reduction of mechanical wear of ties and gage widening on curves caused by unequal tie plate penetration with the resulting outward cant of the rails. It is believed that the information to be obtained for these two assignments will permit the most economical size of tie plate and provision for hold-down fastenings to be determined in order to secure maximum utilization of the service life of ties.

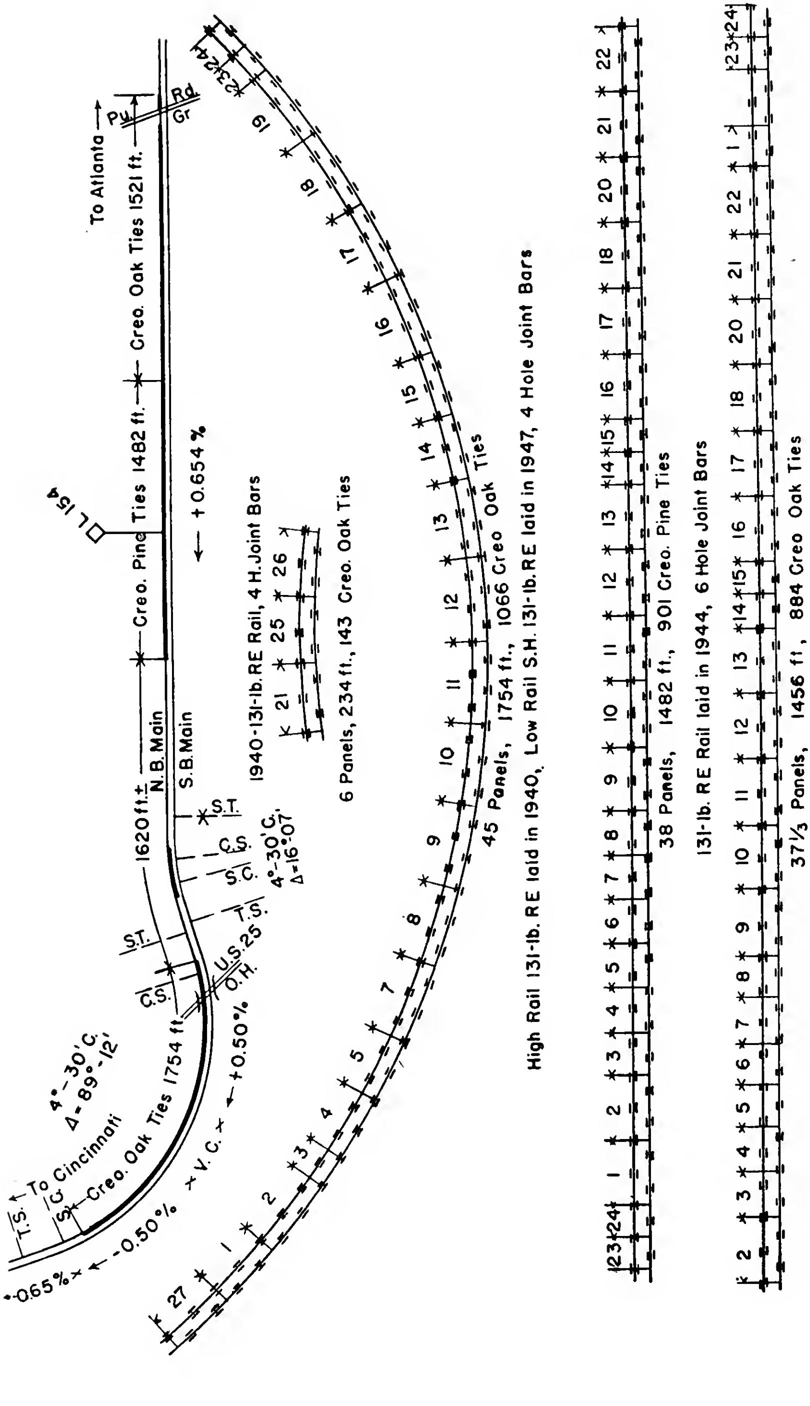


Fig. 1.- Plan of Test Track

Table 1 - Description of Test Sections as Shown in Fig. 1

Section No.	No. of Test Ties: Creo. Oak Curve	Creo. Oak Tang	Pine Tang	Total	Number and Type of Hold-Down Fastenings per Tie Plate and Tie Pads (131-lb RE Rail) 41
1					Adhesives - no anchor spikes - subdivided as follows
1.1	11	6	12	29	Beckosol No. 40. Heated and applied to bottom of tie plate with a paddle
1.2	9	9	9	27	Waterproofing Asphalt, AREA Specifications Applied in the same manner as above
1.3	0	4	6	10	CASCO Flexible Cement NT-442 Applied to tie plate and tie in the field
1.4	3	3	6	12	NT-442 Cement applied to tie plate as a primer and CASCO PHEN RS-216 applied to tie plate and tie in the field
1.5	9	9	9	27	Same as subsection 14 except the tie plates were cemented to the ties before creosoting
1.6	2	0	0	2	Premolded sheet of asphalt, 1/8 in thick, made of regular Bird tie pad coating, designated No. 52
1.7	2	0	0	2	Premolded sheet of asphalt, 1/8 in thick, made of regular Bird tie pad coating modified to further reduce flow, designated No. 53
1.8	2	0	0	2	Same as No. 53 except the asphalt was formed around brass screening, designated No. 54
1.9	2	0	0	2	Same as No. 53 except the asphalt was formed around 1/4 in mesh galvanized screening, designated No. 55
1.10	6	0	0	6	Solvated Sealz Coating, no anchor spikes
2	59	47	48	154	No anchor spikes
3	24	31	32	87	1-ply Bird tie pads, no anchor spikes
4	47	32	32	111	5-ply Bird tie pads, no anchor spikes
5	49	31	32	112	7-ply Bird tie pads, no anchor spikes
6	0	32	32	64	No anchor spikes, 2 Racor Drive Tight (Sandberg) line spikes
7	58	32	32	122	2 each of Racor Drive Tight (Sandberg) line and anchor spikes
8	60	31	32	123	2 cut spikes for line and 2 Racor Drive Tight (Sandberg) anchor spikes
9	59	48	48	155	2 each of cut spikes for line and anchors
10	59	47	49	155	2 cut spikes for line and 2 round head cut spikes with single coil spring washers for anchors
11	59	47	47	153	2 cut spikes for line and 2 round head Dowel Studs with double coil helical spring washers for anchors
12	57	48	48	153	2 cut spikes for line and 2 Oliver Hold-Down Drive Spikes with double coil helical spring washers for anchors
12	2	0	0	2	2 cut spikes for line and 2 cone neck type Oliver Hold-Down Drive Spikes without spring washers for anchors
13	47	47	47	141	2 cut spikes for line and 2 Elastic Spikes of design No. 93 for anchors
13	12	0	0	12	2 cut spikes for line and 2 Tie Plate Lock Spikes for anchors
14	47	24	24	95	2 cut spikes for line and 2-3/4 in. thru bolts with single coil spring washers for anchors (Applied in the field)
15	48	24	24	96	2 cut spikes for line and 2-3/4 in. thru bolts with single coil spring washers for anchors (Applied in shop under load)
(a)16	60	47	48	155	2 cut spikes for line and 2 screw spikes with double coil spring washers for anchors
17	60	47	47	154	2 AAR spring rail clips and screw spikes for line and anchor spikes on tangent plus 2 cut spikes for line on the curve
18	58	48	48	154	No anchor spikes Erie RR standard 13 in single shoulder tie plate with diamond bottom
(a)19	59	0	0	59	2 cut spikes for line and 2 screw spikes with double coil spring washers for anchors using above Erie RR tie plate
20	0	47	47	94	2 Thompson Rail and Tie Plate Clamps with screw spikes and triple coil spring washers for line and anchor spikes on tangent
21	47	47	47	141	Fabco Track Pads, 1/4 in. Thick, no anchor spikes
22	0	48	48	96	2 cut spikes for line and 2 Oliver Tie Plate Drive Spikes with single coil spring washers for anchors
23	24	24	23	71	L.&N.RR. Standard 14 in. tie plate with 2 each of cut spikes for line and anchors
24	24	24	24	72	L.&N.RR. Standard 14 in. tie plate with 2 each of cut spikes for line and anchors and a Rails Co clip on alternate tie plates
25	47	0	0	47	Johns-Manville Track Pads; 1/8 in. thick in North Panel, 1/4 in thick in South Panel, no anchor spikes
26	49	0	0	49	Lackowana D.S. Dia. Bottom 13 in. tie plates, 2 each cut spikes for line and anchors
27	48	0	0	48	Burkart Fibre Pads, no anchor spikes
	1209	884	901	2994	Totals

Notes. AREA Plan 5B (Modified) 13 in tie plate with flat rail seat was used in all sections except as follows: (1) Penn RR standard 14 3/4 in. tie plate cut to a length of 13 in for section 17; (2) Erie RR. standard 13 in single shoulder, diamond bottom tie plate for sections 18 and 19; (3) L.& N RR standard 14 in. tie plate for sections 23 and 24

In the sections on the curve where no anchor spikes were provided, 4 9/16 in. × 5 1/2 in. cut spikes per tie plate were used as line spikes

(a) In the north half of each portion of these test sections the double coil Helical (experimental) spring washer was used and in the south half the double coil Thackery washer was used

Objective of Tests

The purpose of these service tests is to determine from periodical measurement of tie plate penetration, track gage, curvature, cross levels and other observations the relative effectiveness and economy of the several types of hold-down fastenings and tie pads, as to reduction in mechanical wear of ties and the maintaining of good track gage on curves.

Tests on the Louisville & Nashville Railroad—1947 Construction

The Louisville & Nashville Railroad, through L. L. Adams, assistant chief engineer, very kindly agreed to place the hold-down fastenings test installation in the northward main track about five miles north of London, Ky. The location chosen included a stretch of tangent track, ⅞ mile long, on miles L–154 and L–155, and a 4-deg. 30-min. curve to the right with 5-in. elevation and a total angle of 89 deg. 12 min. on mile L–154. Speeds authorized in that territory for passenger and freight trains are 60 and 45 mph., respectively, and the test curves are restricted to 45 and 35 mph. for passenger and freight trains, respectively. A few of the freight trains operate over the test curve at speeds as low as 20 mph. The traffic is estimated at 25 million gross tons per annum, a large proportion being loaded coal cars from the Eastern Kentucky region. Most of the coal trains are double-headed with two M–1 class, 2–8–4 type locomotives or one M–1 class and a Mikado type locomotive. Class M–1 is the heaviest power operated over the test location and has 268,200 lb. weight on drivers, boiler pressure, 265 psi., 69-in. drivers and a tractive force of 65,300 lb. for the drivers and 14,100 lb. for the booster. Six passenger trains are operated over the test track daily and are hauled by diesels or medium size Pacific type steam locomotives.

The test track is constructed with 131-lb. RE rail, 24 ties to the panel and graded stone ballast of 1½ in. maximum size. The outer and inner rails of the long curve have, respectively, 1940 rail and relay rail laid in 1947 with 4-hole head-contact joint bars; the tangent section has 1944 rail with 6-hole head-contact joint bars. Ten forward rail anchors per rail length are used to resist rail creepage. Both curves are protected with a rail oiler. In the upper part of Fig. 1, the location and general alinement of the test stretches are shown. The long test curve and approximately one-half of the tangent test portion are located in cuts. Other test portions of track are on light fills.

Description of Test Installation

Fig. 1 and Table 1 give the location and description of each subdivision of the 27 types of construction as actually installed in 1947 and 1948. During the period from August 11 through August 26, 1947, 103 track panels were completed and dressed out. The balance of the 1947 work, which consisted of the sections involving assembly of the material and shop work, and the L. & N. standard panels of track, was completed September 24, 1947. The 1948 additions consisted of sections 1.10 and 27 on the long test curve and sections 21, 25 and 26 on the short curve, and will be described later.

The various types of hold-down fastenings were selected to cover all suitable existing designs and included some fastenings and other material of recent development. The section with adhesives was developed by the Association of American Railroads research staff and assisted by the Casein Company of America, Denver & Rio Grande Western Railroad and Bird & Son.

The curves had four Bethlehem insulated gage rods per panel and these were removed after construction was completed. It was decided to use four cut spikes for line

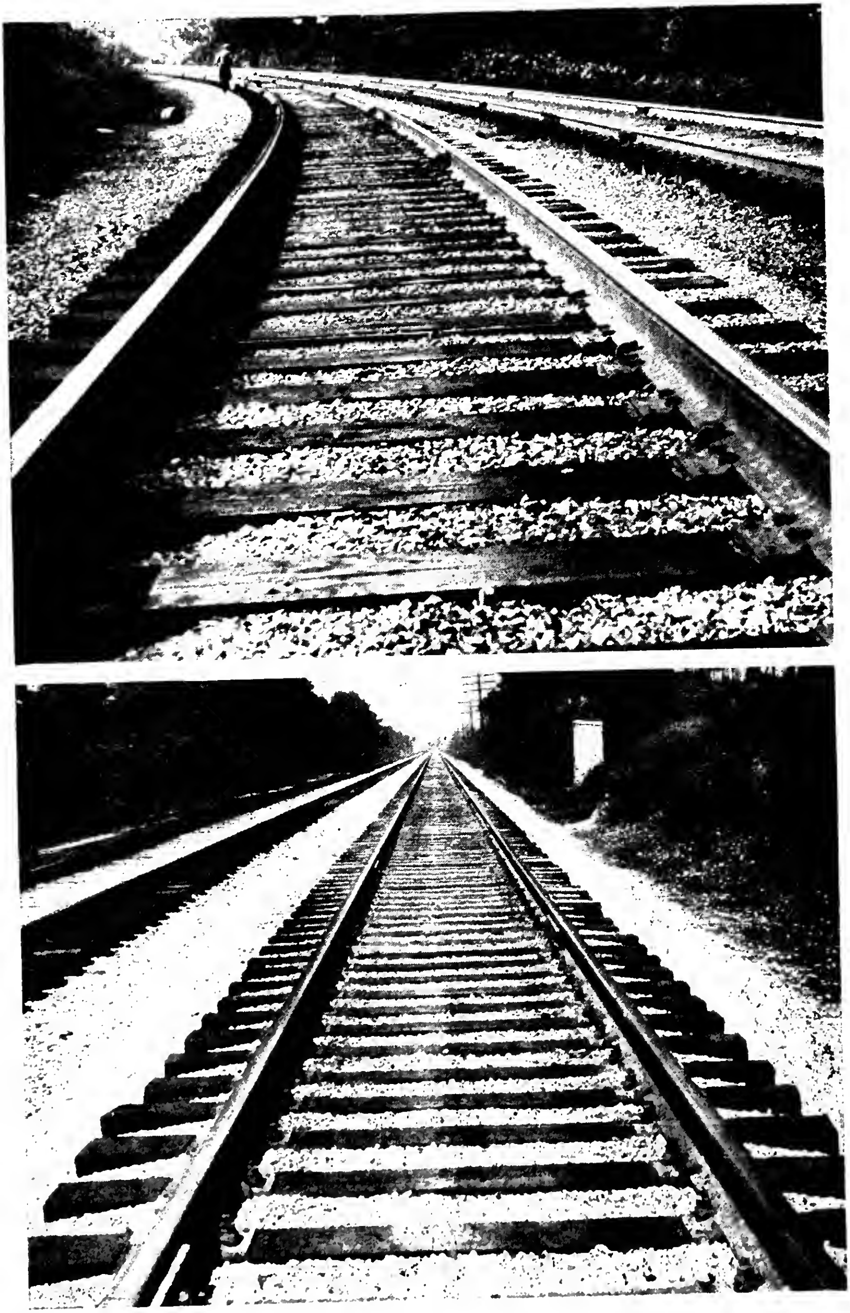


Fig. 2. Top.—Southward View of Test Curve.
Bottom.—Northward View of Tangent Test Track.

on the curves in the sections where no anchor spikes were specified, and this plan provided four spikes of some type per tie plate throughout the test curves. All standard cut spikes used in the 1947 work were 9/16 in. by 5½ in., except as will be indicated later in the report. All ties were prebored and adzed to a 16-in. width before treatment. This involved 18 tie boring plans. Little difficulty was encountered with the holes conforming to the tie plate punching or providing good track gage. Fig. 2 shows two general views of the completed test stretches of track.

Spring washers were provided in the sections where needed in order to increase the effectiveness of the fastening and to extend the interval between retightening or tapping down. With all types of the fastenings, except the dowel stud and through bolts, the bond between the fastening and the wood is reduced and the holding power diminishes with repeated redriving. In general, it is believed the initial cost of the spring washers will be more than offset by the reduction in maintenance labor costs during the life of the material.

Designs of Tie Plates Used

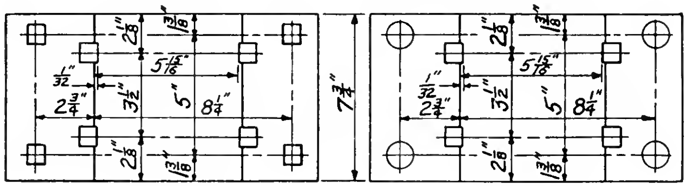
For most of the test sections 7¾-in. by 13-in. by 25/32-in. double-shoulder tie plates with flat rail seat, flat bottom, level shoulder extensions and ¼ in. eccentricity, similar to AREA Plan, 5B, were used, as shown in Fig. 3. In section 17 the Pennsylvania Railroad standard 14¾-in. tie plate for 131-lb. RE rail, sheared to a 13-in. length with an eccentricity of ¼ in., as shown in Fig. 4, was adopted for use with the AAR spring rail clips because the shoulder design was more suitable for keeping the clips in correct alinement. Fig. 4 also shows an assembly view of the clips and screw spikes with the clips unflexed. The Erie Railroad standard single-shoulder 13 in. outside joint tie plate with rolled circular crown, diamond bottom and zero eccentricity when used with a rail base width of 6 in., shown in Fig. 5, was used in sections 18 and 19 for comparison with comparable sections 2 and 16, respectively, having flat bottom tie plates. In Fig. 6 the plan and punching for the L. & N. standard 14-in. tie plate, which is the same design as AREA Plan 6B, except for the punching, are shown.

Section 1, Adhesives

Each portion of this section was divided into subsections, designated 1.1 to 1.9, incl., as shown in Table 1. The subsection numbers increase northward on the long test curve and creosoted pine tie stretch and southward on the tangent where oak ties were used. If in the future better materials or technique are developed for cementing tie plates to creosoted ties, a few ties will be added to the test installation.

No. 40 solid Beckosol was used in subsection 1.1 to attach tie plates to 29 ties. This alkyd, which has a linseed oil base, is very viscous and sticky at room temperature. Its principal use is in paints and is manufactured by Reichhold Chemicals, Inc., Detroit, Mich. Beckosol is nonsetting, remains plastic in warm weather, hardens in cold weather and oxidizes slowly when exposed to the elements. It was first used under tie plates for the purpose of reducing mechanical wear of ties by W. B. Leaf, research technician, Denver & Rio Grande Western Railroad, who, after making an exhaustive investigation of all types of adhesives, selected Beckosol for service tests as being the most promising. The solid Beckosol was heated to a liquid and applied to tie plates with a paddle after brushing off the loose material from the tie plate and adzed surface. The cost of this material was about 20 cents per tie and can be further reduced by using a 50 percent solution of Beckosol in naphtha which evaporates completely.

In subsection 1.2 waterproofing asphalt, manufactured to the AREA specifications, was heated to a liquid and applied to the tie plates with a paddle. All loose material



Punching A
4-¾" sq. line spike holes and
4-11/16" sq. hold-down spike holes
for section Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9,
10, 13, 21, and 22.

Punching B
4-¾" sq. line spike holes and
4 round hold-down spike holes
as follows:
(1) 4-1" dia. holes for section No. 16.
(2) 4-15/16" dia. holes for section Nos. 11 and 12.
(3) 4-13/16" dia. holes for section Nos. 14 and 15.

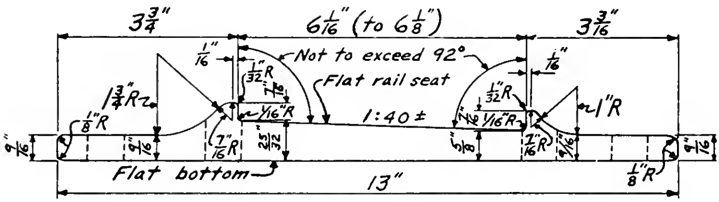
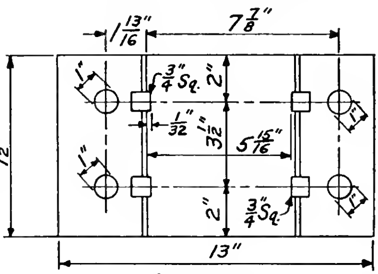


Fig. 3.—AREA Plan No. 5B (Modified) Tie Plate for 131-lb. R.E. Rail.



Punching
4-¾" sq. line spike holes and 4-1" dia.
hold-down spike holes for section 17.

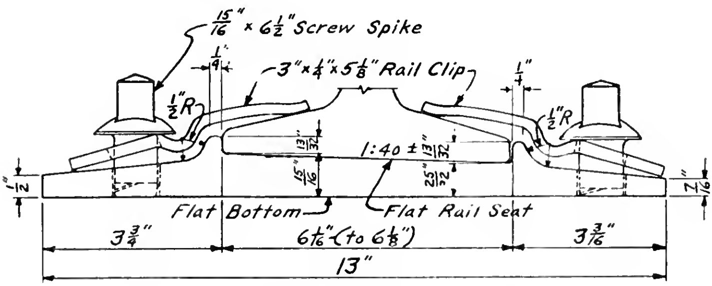


Fig. 4.—Penn. R. R. Standard 14¾-in. Tie Plate for 131-lb. R.E. Rail Sheared to a 13-in. Length and ¼-in. Eccentricity for Use with AAR Spring Rail Clips.

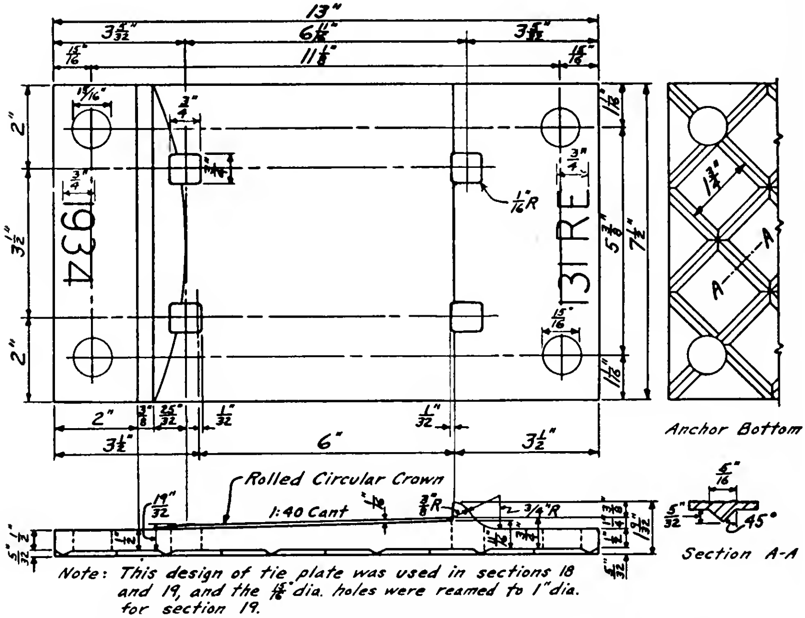


Fig. 5.—Erie Railroad Standard 13-in. Outside Joint Tie Plate for 131-lb. R.E. Rail.

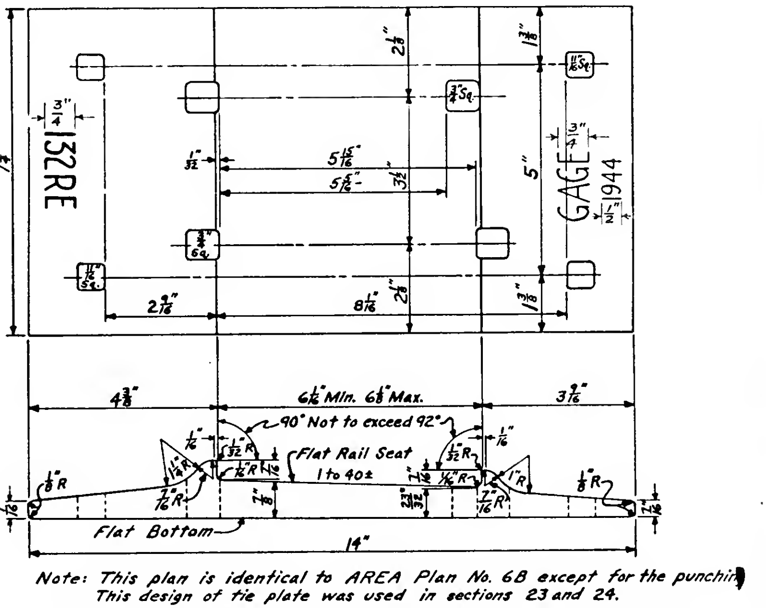


Fig. 6.—L, & N. R. R. Standard 14-in. Tie Plate for 131-lb. and 100-lb. R.E. Rails.

was removed from the tie plate bottom before applying the asphalt and the plates were laid on clean adzed surfaces. Nine creosoted ties for each of three locations, as indicated in Table 1, were inserted in the track. Although, waterproofing asphalt does not have good adhesive qualities for bonding steel to creosoted wood, it is believed that if it remains under the tie plate it will fill the space between the plate and ties, resulting from the irregularities of both surfaces, and possibly seal out the moisture and sand.

Products of the Casein Company of America were used to cement tie plates to the ties in subsections 1.3, 1.4 and 1.5 and their representative supervised application of the cements at the test location. These cements or glues take a permanent set in a few days and have a bond strength in shear between steel and creosoted wood of over 1000 psi. when applied under laboratory conditions. Like all glued joints the tie plates must be clamped to the ties under a pressure of approximately 100 psi. for 5 to 10 hours, depending on the prevailing temperature and the kind of cement used.

Subsection 1.3 involved application of the tie plates in the field to creosoted oak and pine ties with Casco flexible cement NT–442, which is a white dilutable water dispersion of casein and synthetic rubber in liquid form, and to which was added 3 percent by weight of V–18 paste which causes the synthetic rubber to set and the casein to become insoluble. This mixture will bond metal to wood without the use of another cement. Bottom surfaces of the tie plates were cleaned with a power sander which operated with current furnished by a 110-volt d.c., 2½-kw. Homelite gasoline engine-driven generator. The adzed surface of the ties was dressed lightly with a carpenter's plane to remove the creosote on the surface and open the wood cells to receive the cement. This operation was performed immediately prior to applying the NT–442 cement to both surfaces with a paint brush and attaching the plates to the ties by means of four ½-in. through bolts inserted in the holes perbored for the anchor spikes. The total pressure applied to each tie plate was estimated to range from 10,000 to 20,000 lb. The plates were retained under pressure overnight to obtain about 50 percent of the ultimate bond strength of the cement. The ties prepared in the field were placed in the track about two weeks after the tie plates were attached. During insertion of the 10 ties in subsection 1.3, 8 tie plates out of 20 broke bond and became loose. These early failures were attributed, in part, to irregularities in the bottom surface of the tie plates and the adzed surface, because a perfect glued joint should have 100 percent contact of the areas at the glue line. The manufacturer estimates the cost of the NT–442 cement at $11 per M sq. ft. covered.

In subsection 1.4 two cements were used to attach the tie plates and this method had shown in laboratory tests that the bonding strength in shear was approximately twice as large as in subsection 1.3. Twelve ties were prepared in the field by the same procedure as given for subsection 1.3, except that the NT–442 + V–18 paste was applied to the tie plate as a primer coat and permitted to dry. Casophen RS–216, a resorcinol resin glue with 15 percent by weight of FM–60 catalyst added to cause the glue to set, was brushed on both surfaces. The tie plate was then clamped to the tie and left under pressure overnight. None of the tie plates broke bond when the ties were inserted in the track. The manufacturer estimates the cost of the glues used in subsections 1.4 and 1.5 at $68 per M sq. ft.

At the suggestion of R. J. Lodge, manager, liquid adhesives department of the Casein Company, tie plates were attached to 27 ties before creosoting to eliminate the objection to the creosoted surface and obtain a higher bond strength. The ties were prepared in the same manner and with the same cements as used in subsection 1.4, except that no planing was done on the untreated adzed surface. These ties were placed in subsection 1.5 after creosoting the timbers and removing the through bolts. No bond failures occurred during construction.

Subsections 1.6 to 1.9, inclusive, on the long curve only, consist of two ties each for the four variations of premolded sheets of asphalt as described in Table 1. These sheets were suggested and furnished by Bird & Son to broaden the investigation of the use of asphalt which is relatively economical except for the labor costs of heating and applying in the field. It would not be practical to use the asphalt sheets in cold weather because of extreme brittleness except possibly the sheets formed around metal screening.

Section 2

This section, which has no anchor spikes, is representative of considerable existing main line mileage and will serve as the basis of comparison. The portion on the curve has four cut line spikes per tie plate.

Sections 3, 4 and 5

Bird tie pads of 1, 5 and 7 plies, furnished by Bird & Son, East Walpole, Mass., were applied in sections 3, 4 and 5, respectively. All pads were punched to conform with the tie boring. The single ply pad is made of one layer of heavy duck and coated with a special asphalt modified to flow in warm weather. The 5 and 7-ply pads are made of alternate layers of duck and felt bonded together with standard asphalt, stitched with bronze staples and coated as described above. The 5 and 7-ply pads are ⅜ in. and ⅝ in. thick, respectively. The special asphalt coating is covered with soapstone chips to keep the pads from sticking together and to facilitate handling. The asphalt coating is designed to flow in warm weather and keep the moisture and sand from getting between the pad and tie. Fig. 7 shows one of the tie plates in section 4 having a 5-ply pad under it and also the flow of the asphalt coating around and through the holes in the tie plate. The fourth line spike was added after the photograph was taken. In all tie pad sections, anchor spikes were omitted in order to check the effectiveness of the pads without the assistance of any type of anchor spike.

Sections 6, 7 and 8

Sections 6, 7 and 8 have three arrangements of the Racor drive tight spikes. These spikes are manufactured by the Ramapo-Ajax Division of the American Brake Shoe Company and are sometimes called the Sandberg spike, after the inventor, C. H. Sandberg, assistant bridge engineer system, Atchison, Topeka & Santa Fe Railway. Section 6, on tangent only, has two of the drive tight line spikes per tie plate and represents the most economical use of the spike, by virtue of displacing two standard line spikes. Section 7 has two each of the drive tight line and anchor spikes per tie plate and section 8 has two standard line spikes and two drive tight anchor spikes. A photograph of a joint tie plate in section 7 is shown in Fig. 8, and a plan of the two designs of spikes is presented in Fig. 9. The fluting on the shank of the spike is designed to completely fill the tie plate hole, minimize the horizontal movement of the tie plate on the tie and thus reduce mechanical wear. These spikes were driven by hand and there was no difficulty in driving them down to their proper position. However, they are harder to pull from a new tie and tie plate than the standard cut spike.

Section 9

Section 9, shown in Fig. 10 has two each of standard cut spikes for line and anchors, and is typical of the standard used by several railroads. All standard cut spikes used in this section were 9/16 in. by 5½ in. except on the curve portion ⅝-in. by 6-in. spikes were obtained for the anchor position.

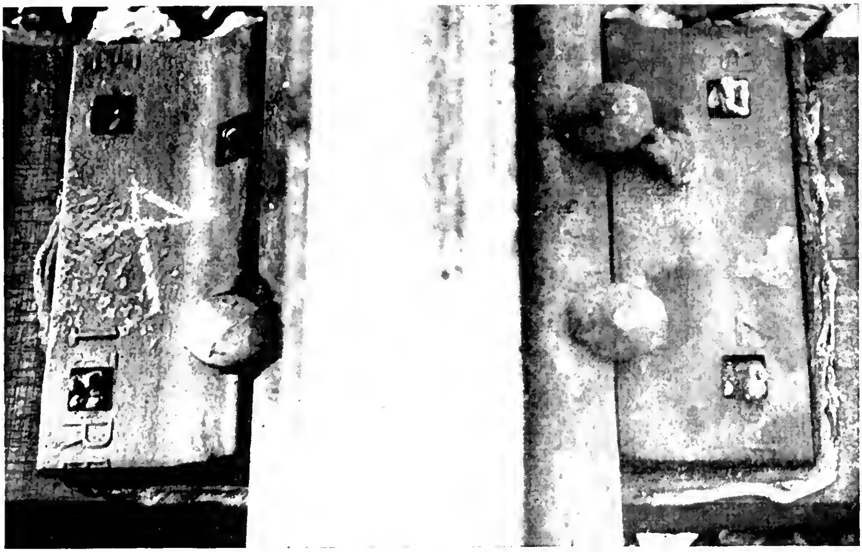


Fig. 7.—Section 4 on Curve with 5-ply Bird Tie Pad.

Fig. 8.—Section 7 on Curve with Two each of Racor Drive Tight Line and Anchor Spikes.

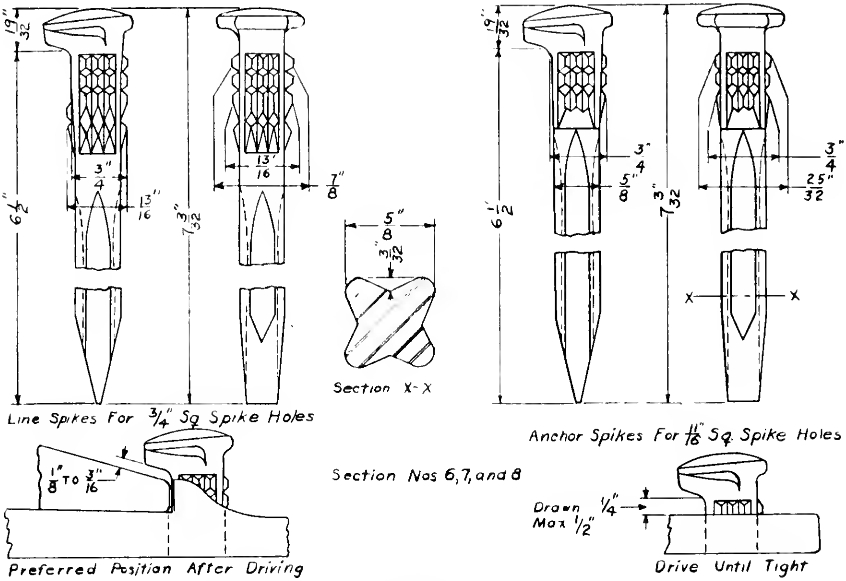


Fig. 9.—Racor Drive Tight (Sandberg) Spikes.

Fig. 10.—Section 9, Two each of Standard Cut Spikes for Line and Anchors.

Section 10

The design of hold-down fastening installed in section 10 is comprised of a round head cut spike with a 7/8-in. single coil Hy-Reaction Hy-Crome spring washer, and was used to increase the effectiveness of this type of anchor spike in reducing mechanical wear of ties. Other tests had shown little difference between the tie plate penetration with tie plates having only two cut line spikes and plates having two standard line and two or four cut spikes for anchors. Because of the small number of round head cut spikes required they were made of cast steel. A photograph of this method of tie plate anchorage and a plan of the round head cut spike are shown in Fig. 11. A special design of spike puller was furnished for pulling the round head spike. In the preliminary study for designing the round head cut spike a specimen was made with an unsymmetrical head which could be pulled with a standard claw bar. Tests in the field indicated this was impractical for pulling the spike.

Section 11

In section 11 there were utilized as hold-down fastenings per tie plate, two round head dowel studs and two double coil helical (experimental) spring washers which are shown in Fig. 12 and the upper right view of Fig. 17. The dowel studs are manufactured by the Pittsburgh Screw and Bolt Corporation, Pittsburgh, Pa., and the double coil helical washer was developed and manufactured by the Reliance Division of the Eaton Manufacturing Company at the suggestion of the Engineering Division research staff. The double coil Thackery spring washer, as shown in the lower right view of Fig. 17, was the only design readily available for use with drive and screw spikes. The double coil Thackery spring washer has a deflection of 1/4 in. when released from a load of 2000 lb., and one large user of screw spikes for hold-down fastenings with a moderate traffic density retightened the screw spikes every three years. It was believed that a double coil washer used with hold-down fastenings should have a large deflection for a moderate change in load. This would keep the tie plates tight on the ties for a much greater amount of traffic, reduce the number of retightenings to about one-half as well as the chance of overdriving the screws, and possibly obtain less mechanical wear over a longer period of time at a lesser overall cost. The experimental double coil spring washer was made of the same stock as the Thackery washer and has 0.43 in. deflection when released from a 2000-lb. load. The dowel stud was driven by hand until the washer was almost solid, and the final tightening was done with a hand wrench. The advantage claimed for this type of fastening is that when the tie plate settles in the tie the slack is taken up by wrenching the nut and the bond between the dowel stud and the wood is not disturbed. Prebored holes of 9/16 in. and 1/2 in. dia. were provided for the dowel studs in creosoted oak and pine ties, respectively.

Section 12

A view of the construction used in section 12 and a plan of the Oliver hold-down drive spike are shown in Fig. 13. The double coil helical (experimental) washer was also used in this section. This fastening was also driven by hand in the same size holes as used in section 11 and the square head was provided only for its removal. It is a standard product manufactured by the Oliver Iron and Steel Corporation, Pittsburgh, Pa. This spike will be tapped down to take up the slack caused by mechanical wear. In two ties at the south end of the portion of this section on the curve, two cone neck type Oliver hold-down drive spikes (without spring washers) per tie plate were used. The cone neck type of drive spike is similar to the one shown in Fig. 13, except that the unthreaded portion of the shank is tapered from 13/16 in. dia. at the top of the threaded portion

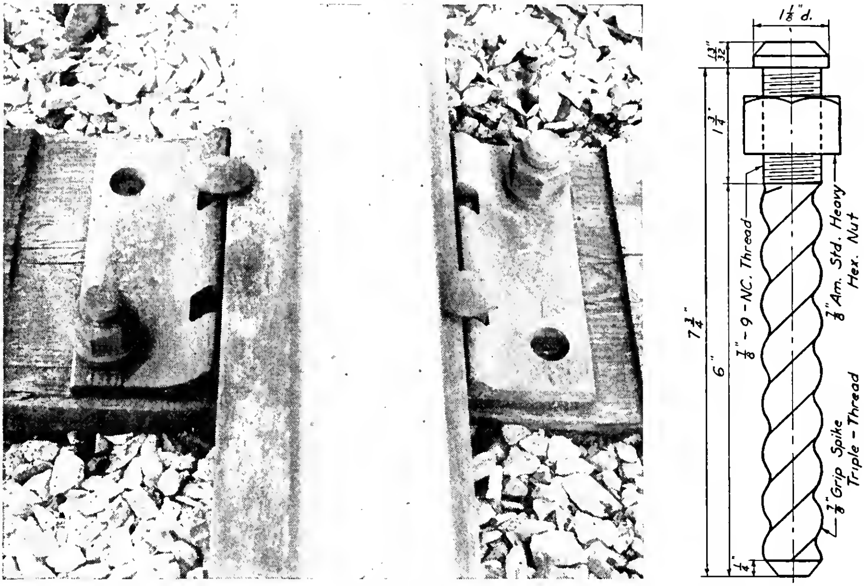


Fig. 11.—Section 10, 2⅝ in. by 6 in. Round Head Cut Spikes with Single Coil Hy-Reaction Hy-Chrome Spring Washers.

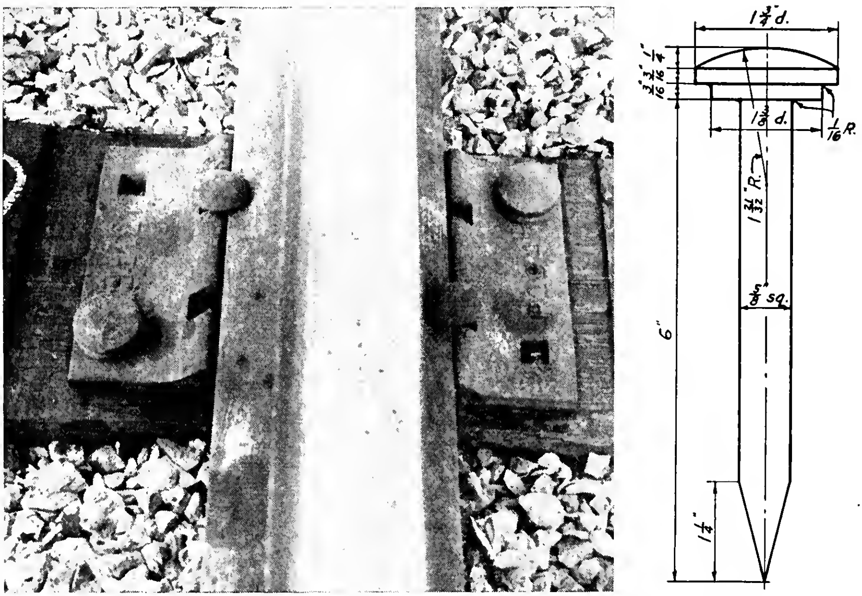


Fig. 12.—Section 11, 2⅞ in. by 7¾ in. Round Head Dowel Studs with Double Coil Helical (Experimental) Spring Washers.

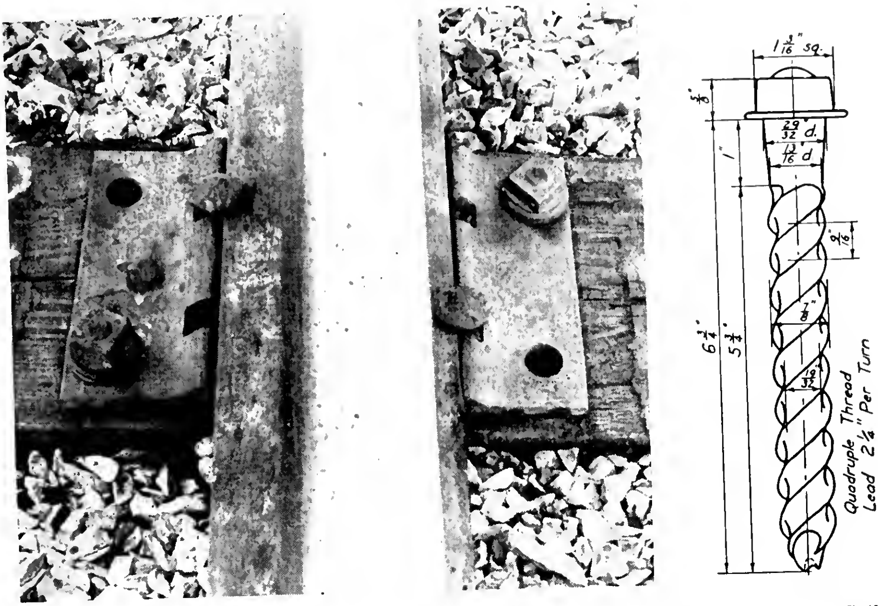


Fig. 13.—Section 12, 2⅞ in. by 6¾ in. Oliver Hold-Down Drive Spikes with Double Coil Helical (Experimental) Spring Washers.

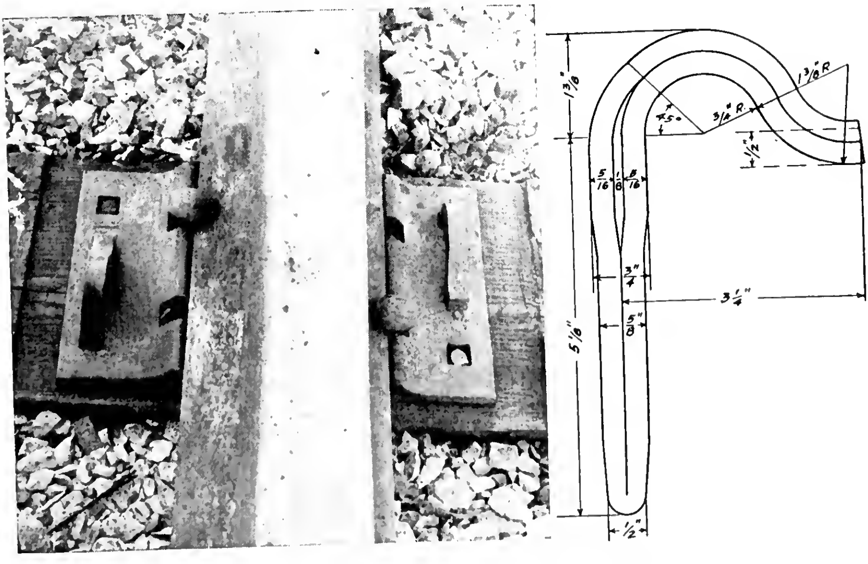


Fig. 14.—Section 13, Two Elastic Spikes of Design No. 93.

to 1-1/16 in. dia. at the junction with the spike head. The cone neck is designed to take out the slack in the 15/16 in. dia. holes of the tie plates and restrain the horizontal movement of the plates on the ties.

Section 13

Two standard line spikes and two Elastic spikes of design No. 93 were used in all parts of section 13 except that the tie plate lock spikes were applied as anchors in the north 12 ties of the 2½-panel portion on the curve. Prebored holes of ⅝ in. and 9/16 in. diameter were used in oak and pine ties, respectively. These hold-down fastenings were designed and furnished by the Bernuth, Lembcke Co., Inc. A view of the Elastic spike construction and also a plan of the fastening are shown in Fig. 14. A plan of the tie plate lock spike and a view of its installation are shown in Fig. 15. The Elastic spike is driven down for a deflection of the free end of about ⅜ in. which places a 1000-lb. load on the tie plate for each spike. The tie plate lock spikes are a new design and were made by hand for the small test installation which will serve to explore its possibilities. They were driven so that the tapered portion of the shank would take up the slack in the tie plate holes transversely to the rail and restrain the movement of the tie plate in that direction.

Sections 14 and 15

Sections 14 and 15 have the same number and type of fastenings per tie plate and differ only in the method used to preload the tie plates. Two ¾-in. by 9½ or 10-in. carriage bolts, threaded through a 2-in. by ⅜-in. by 15-in. headlock bar punched to fit the square shank of the bolts were used with single coil Hy-Reaction Hy-Crome spring washers to fasten the tie plates to the ties. Prebored holes of ¾ in. dia. were provided in the ties for a drive fit. The tie plates were attached to the ties prior to insertion. For section 14 the ties were inserted in the track and final tightening of bolts to approximately 7500 lb. tension was done 2 to 4 days after insertion and before unloading ballast. For section 15 the ties with fastenings attached were shipped to the L. & N. shops at Corbin, Ky., where the tie plates were positioned for standard track gage, loaded to about 15,000 lb. with a hydraulic press and the bolts tightened to approximately 7500 lb. tension. A view of the construction and fastenings used (inset) in section 14 is shown in Fig. 16.

Section 16

Section 16 embraced a typical installation of screw spike construction in which two standard line spikes and two 15/16-in. by 6½-in. screw spikes as anchors with double coil spring washers were used with the 13-in. AREA Plan 5B (modified) tie plate having a flat bottom. The screw spikes were driven with a Raco power track wrench in prebored holes of ¾ in. and 11/16 in. dia. for oak and pine ties, respectively. The screw spikes were carefully driven two to four days after insertion of the ties and eased down to obtain a solid washer without overdriving and stripping the threads in the timber. In Fig. 17 a view of the construction and plans for the two kinds of washers used are shown. The experimental double coil helical spring washer was applied in the north half of each portion of this section and the Thackery washer, in the south half.

Section 17

The AAR spring rail clip, fastened to the tie with a 15/16-in. by 6½-in. screw spike, is designed to serve as a tie plate hold-down fastening, a rail anchor and a line spike. In the tangent construction the temporary line spikes were pulled and the holes

Fig. 15.—Section 13. Tie Plate Lock Spike on the North 12 Ties of the Elastic Spike Section on the Curve.

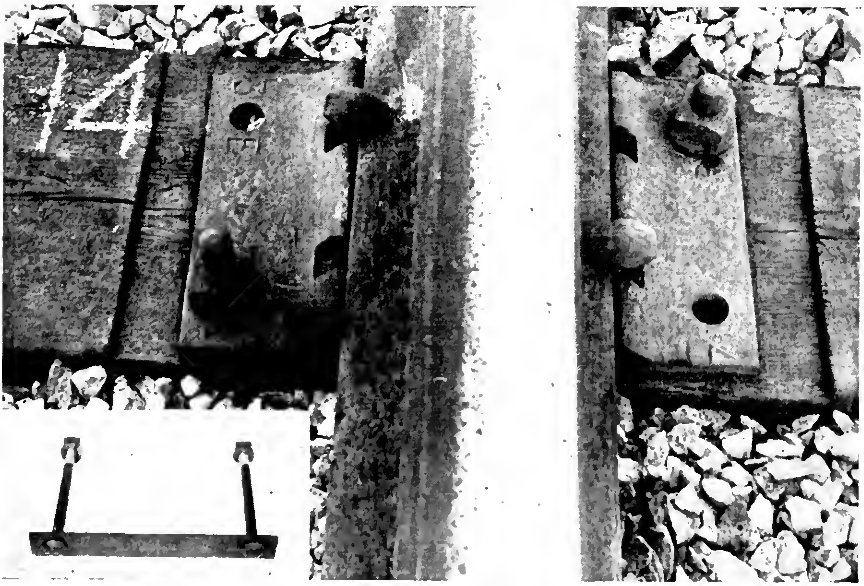


Fig. 16.—Section 14, 2¾ in. by 9½ in. Through Bolts with Single Coil Hy-Reaction, Hy-Crome Spring Washers and Inset of Hold-Down Fastenings.

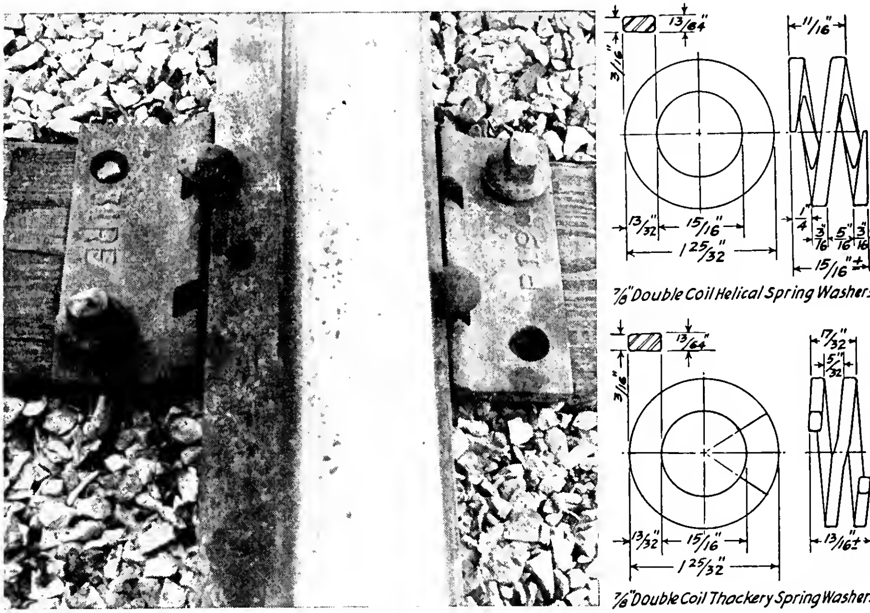


Fig. 17.—Section 16, $2\frac{15}{16}$ in. by $6\frac{1}{2}$ in. Screw Spikes with Double Coil Spring Washers as Shown.

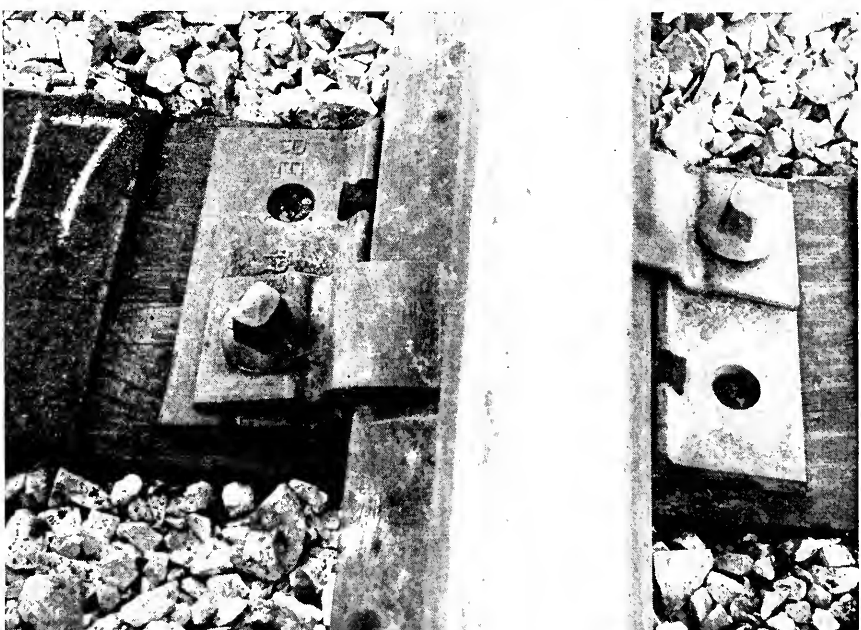


Fig. 18.—Section 17, Two AAR Spring Rail Clips with Screw Spikes. (Tangent Test Section with Creosoted Pine Ties).

were plugged, while on the curve the standard line spikes were left in place to provide four spikes of some design per tie plate to conform with all other sections. Laboratory tests showed that the force required to slip the rail longitudinally, when fastened with 2 clips on one tie plate was between 1100 and 1500 lb. For an average installation one clip will exert loads of approximately 1200 and 2200 lb. on the rail and tie plate, respectively. For this test the rail clip was designed to fit the 131-lb. rail base resting on a Pennsylvania Railroad 14¾-in. tie plate which had a shoulder with a short radius that would prevent the clip from rotating about the screw spike. These plates were sheared to a length of 13 in. with ¼-in. eccentricity to make them comparable with the AREA Plan 5B (modified) tie plate used in most of the sections. An assembly drawing of the tie plate and fastenings is shown in Fig. 4 and a view of the installation is presented in Fig. 18. The rail clips can also be attached with the Oliver hold-down drive spike or the round head dowel stud if desired.

Section 18

Many maintenance of way engineers prefer and some railroads use tie plates with the Sellers or diamond bottom. Accordingly, a number of 13-in. tie plates with the diamond bottom were obtained from the Erie Railroad and used in sections 18 and 19. This design of the tie plate, shown in Fig. 5, has a single shoulder, level shoulder extensions for lag construction, rolled circular crown and zero eccentricity when used with a rail base width of 6 in. Section 18 was installed on both curve and tangent track without anchor spikes and will be compared with the section of similar construction, but with a flat bottom tie plate.

Section 19

Section 19 also utilizes the 13-in. Erie diamond bottom tie plate but with two standard line spikes, two 15/16-in. by 6½-in. screw spikes and double coil experimental helical washers in the north half of the section and Thackery washers in the south half thereof. The 15/16-in. dia. holes in the plates were reamed to 1 in. dia. to accommodate the size of screw spike used. This construction was placed on the curve, only, and can be compared with the performance of section 16 which has the flat bottom tie plates. A view of this construction is shown in Fig. 19, with double coil washers as shown in Fig. 17.

Section 20

The Thompson rail and tie plate clamp is a new design of rail and tie plate fastening and was developed by Thompson Products, Inc. of Cleveland, Ohio, which company also furnished the special fastenings. This section as well as sections 21 and 22 were not placed on the curve because of the lack of track space. This construction is shown in Figs. 20 and 22 and is designed to serve a three-fold purpose, the same as the AAR spring rail clip in section 17. Prebored holes of ¾ in. and 11/16 in. dia. were provided for the 15/16-in. by 8-in. screw spikes in oak and pine ties, respectively. At the suggestion of Thompson Products, Inc. one-half of the oak and pine ties were bored only 5½ in. deep for the screw spikes in order to place some wood hardener chemicals in the holes just prior to driving the screw spikes. These products of the Bakelite Company were used to increase the holding power of the screw spikes as laboratory tests had shown an increase of 100 percent in the torque required to remove the screw spike. The wood hardener chemicals, consisting of 100 parts by weight of Bakelite Resin (liquid) No. BC-17613 and 33 parts of Bakelite hardener (powder) No. XK-17664, were mixed in the field and placed in the anchor spike holes of the north panel of the pine tie section and the west rail of the north panel of the oak tie section. In the east rail

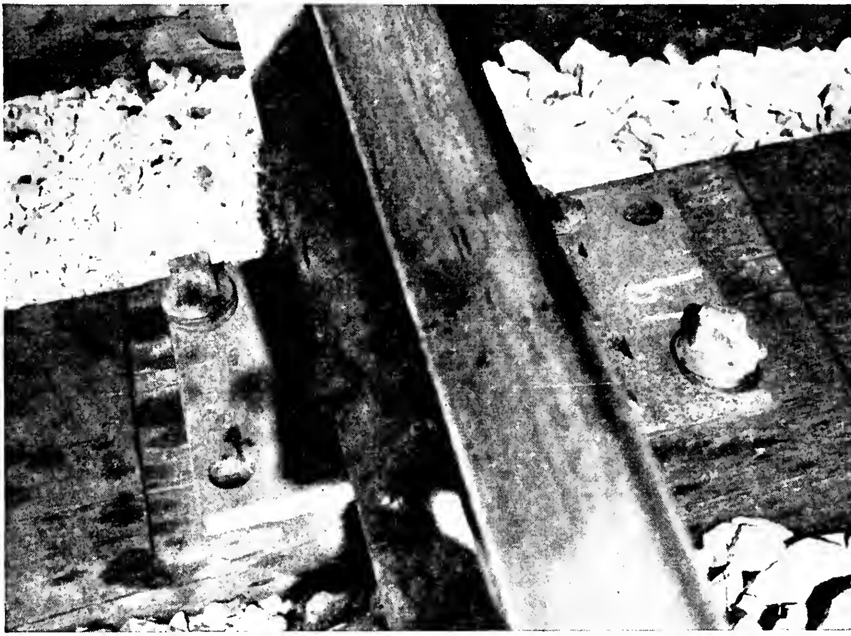


Fig. 19.—Section 19, Erie R. R. Single Shoulder, Diamond Bottom Tie Plate with $2\frac{15}{16}$ in. by 6½ in. Screw Spikes and Double Coil Spring Washers.

Fig. 20.—Section 20, Two Thompson Rail and Tie Plate Clamps. (Tangent Test Section with Creosoted Oak Ties).

Fig. 21.—Section 21. Fabco Track Pad.

of the last mentioned panel of track the same mix, with a plasticizer added, was placed in the prebored holes. Plasticite is a cement intended to give flexibility to the wood hardener when set and possibly further increase the holding power of the spike. The mixture will take an initial set in less than two hours and must be mixed as needed. A representative from each of the two companies supervised the mixing and placing of the wood hardener chemicals. The south panel of each portion of section 20 was placed without the wood hardener and with the holes bored through the ties. In this design of the rail and tie plate clamp the top surface of the bearing block which rests on the rail and tie plate is tapered so that the triple coil washer will go solid on the side opposite from the rail and remain partly open on the rail side.

Section 21

This section, which consists of two panels each of creosoted oak and pine ties on tangent track, has two standard line spikes and a 7¾-in. by ¼-in. by 13-in. Fabco track pad, as shown in Fig. 21. The pads were punched for the line spike holes. These pads are made from the waste fabric and rubber obtained in the manufacture of the original and more expensive material known as Fabreeka. These waste materials are macerated, mixed in a solution of natural rubber and vulcanized.

Section 22

The method of tie plate anchorage used in section 22 is only in tangent track, and consists of two 11/16-in. by 6-in. Oliver tie plate drive spikes and ¾-in. single coil Hy-Reaction Hy-Crome spring washers. These drive spikes were driven by hand in 11/16-in. square tie plate punching and prebored holes of 7/16 in. and ⅜ in. diameter in oak and pine ties, respectively. Fig. 23 includes a view of this construction and a plan of the drive spike. This drive spike is similar to but smaller than the Oliver hold-down drive

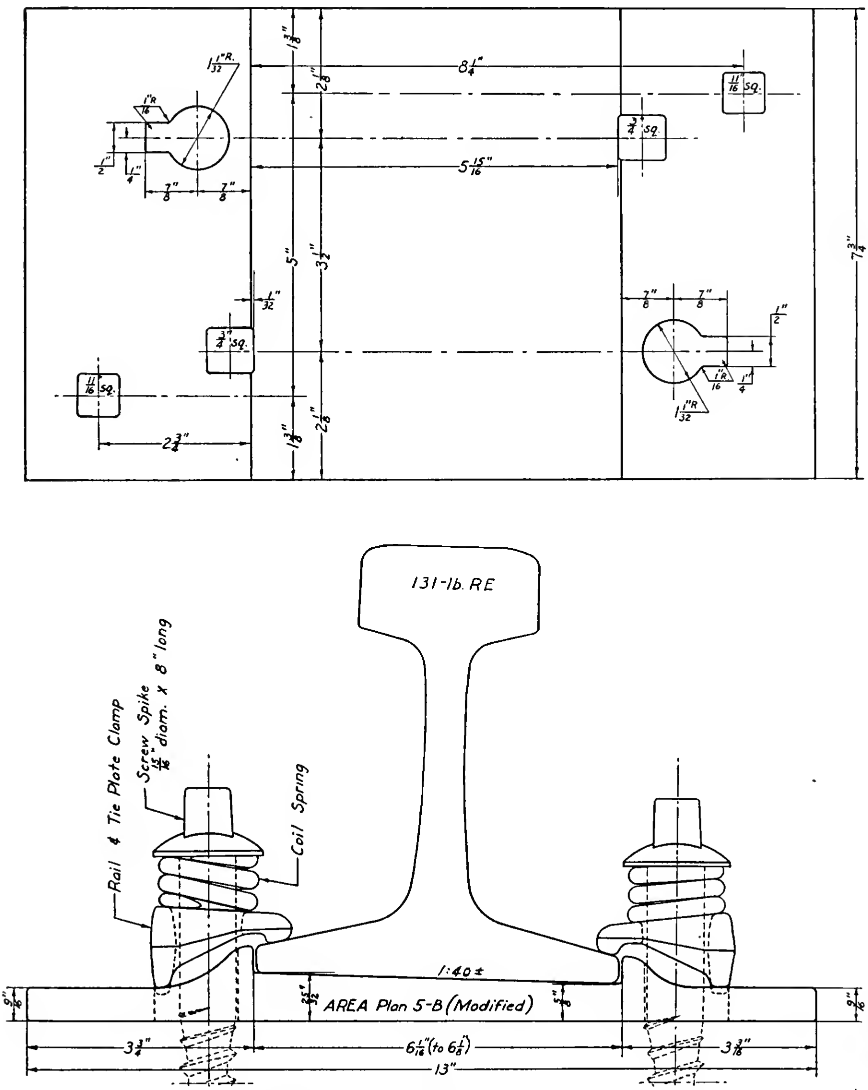


Fig. 22.—Section 20 (Tangent only)—Two Thomson Rail and Tie Plate Clamps with Special Tie Plate Punching.

Fig. 23.—Section 22. Two 11/16 in. by 6-in. Oliver Tie Plate Drive Spikes with Single Coil Hy-Reaction Hy-Crome Spring Washers.

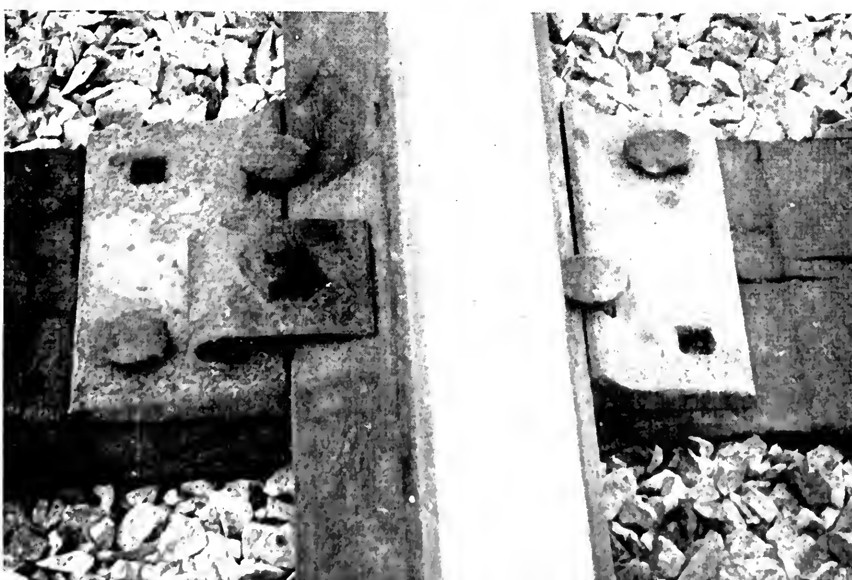


Fig. 24.—Section 24. L. & N. R. R. Alternate Standard Construction with a 14-in. Tie Plate and a Rails Company Clip on Alternate Tie Plates.

spike applied in section 12 and would be more economical to use as standard construction without the necessity of having a special tie plate punching.

Sections 23 and 24

For comparative purposes the L. & N. built two track panels of its standard construction in each of three locations with the 14-in. tie plate, as shown in Fig. 6, and 2 new cut line spikes and 2 second hand cut spikes for anchors. The construction in sections 23 and 24 is the same except that in section 24 the Rails Company clip was added to alternate ties. A view of section 24, showing one of the tie plates having a clip attached on the field side of the rail, is presented in Fig. 24. From the tie plate penetration measurements it will be determined if the mechanical wear of ties is greater with the rail clips than without.

Test Measurements and Observations

Initial test readings were completed November 18, 1947. The data consisted of (1) taking readings for tie plate penetration, or mechanical wear of ties, which involved setting over 10,000 2-in. No. 14 gage round head brass wood screws and the same number of chisel marks on the tie plates, and taking dial readings, (2) measurement of the gage of track at four points in each panel of track, (3) elevation of the curve and cross-levels on tangent at two points per track panel and (4) the middle ordinate for each outer rail on the curve. The three views in Fig. 25 will serve to show some of the work required for the measurement of tie plate penetration.

Each year the track gage will be checked on the curve and an inspection will be made of the entire installation to note loose fastenings, tie plates, etc. Because the mechanical wear of ties progresses very slowly with new ties all other test measurements will be repeated at longer intervals, perhaps every two or three years. The L. & N. will furnish a monthly progress report showing the bond failures of the tie plates in sections 1.3, 1.4 and 1.5 where products of the Casein Company were used. A record will be maintained of the general retightening and tapping down of the hold-down fastenings, which will be done only as required for a good standard of maintenance.

Additions in 1948

Section 1.10

This subsection, consisting of six creosoted oak ties with new 13-in. AREA plan 5-B (modified) tie plates, was placed near the north end of the long test curve adjacent to the original section 1—Adhesives: A thick paddle coat of liquid Solvated Sealz was applied to the bottom of the tie plates and over the entire adzed surface of the ties and permitted to dry before placing in the track. Solvated Sealz is a tacky material consisting of reclaim rubber combined with natural and synthetic resins, and is manufactured in slab or liquid form by the Naugatuck Chemical Division of the United States Rubber Company. Its use on ties is intended to seal out moisture and abrasive materials from under the tie plates and also for waterproofing the adzed surface. After two months of traffic the material had squeezed out along the edges of the tie plate and in the tie plate holes. It remains plastic and does not become brittle in cold weather.

Section 21

This section and also sections 25 and 26 were placed on the short 4-deg. 30-min. curve located immediately south of the long test curve (Fig. 1). Section 21 which had 13-in. Fabco track pads, ¼ in. thick (originally designated as Fabreeka SA–47), was

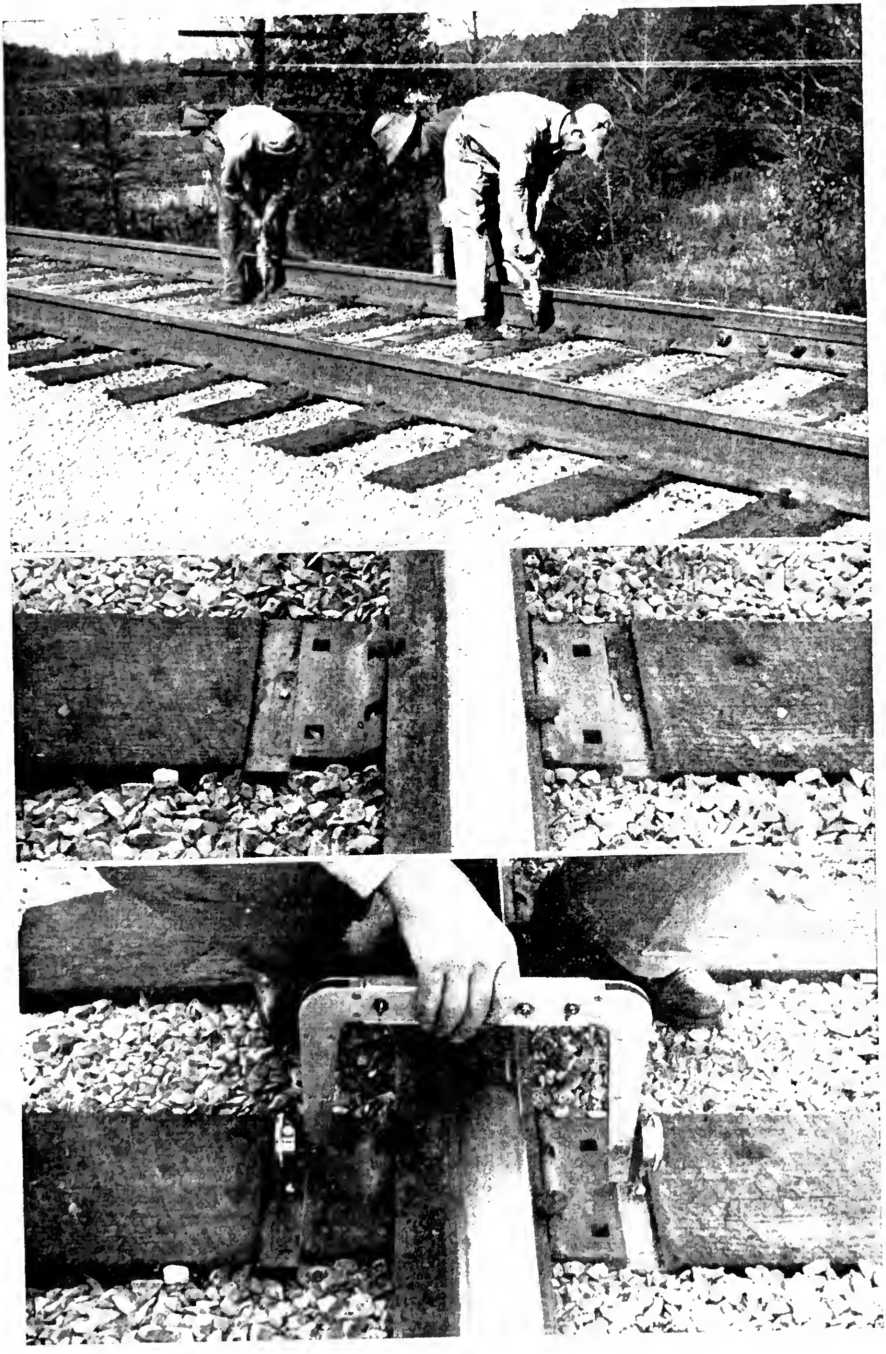


Fig. 25.—Preparing Track for Measurement of Mechanical Wear of Ties.
Upper View—Preboring Ties, Distributing, Setting and Driving Brass Screws.
Center View—Finished Work with Two Brass Screws and Two Chisel Marks on Tie Plate.
Lower View—Tie Plate Penetration Gage Set for Taking Dial Readings.

originally placed only in tangent track in 1947, and it was decided to place the pads in curved track for a more severe test. These pads are made of the same material as those used in the tangent installations last year. Four ⅝-in. by 6-in. line spikes without anchor spikes were used in sections 21 and 25 on the short test curve.

Section 25

This section on the short curve comprised a new type of track pad developed and furnished by Johns–Manville for the research staff. This pad is made of asbestos fiber in laminated form and a small amount of synthetic rubber. It is somewhat harder and stiffer than the Fabco pad. The north track panel of section 25 was laid with 13-in. pads with ⅛ in. thickness on creosoted oak ties while in the south panel ¼-in. pads were used. No cement or other coating was used to apply the pads to the ties in sections 21 and 25.

Section 26

At the suggestion of the Delaware, Lackawanna & Western Railroad, two panels of its 7½-in. by 13-in. double shoulder, diamond bottom tie plates with flat rail seat, 1 to 40 cant and ½-in. eccentricity were installed on the short test curve. These plates have a 6-hole unsymmetrical punching, a 2-in. spacing of the ribs on the bottom and a thickness of 53/64 in. at the outer shoulder. Creosoted oak ties were used and 2 each of ⅝-in. by 6-in. cut spikes were applied for line and anchors. The 13-in. Erie Railroad diamond bottom tie plates installed in 1947 in sections 18 and 19 had only a single shoulder and zero eccentricity when used with a rail with a 6-in. base width.

Section 27

This section was installed near the north end of the long test curve for the purpose of testing some fiber tie pads manufactured by F. Burkart Manufacturing Company and distributed by the Achuff Railway Supply Company, both of St. Louis, Mo. Some of the southwestern railroads placed the pads in service in 1947. Those were made of sisal fiber. For this test the manufacturer furnished an improved fiber pad in which Abacca fiber was used instead of sisal. Abacca is an imported hard structural vegetable fiber and is the most durable of the higher strength and weather resisting fibers. The fiber is needled, thoroughly impregnated with an organosol and is then cured and compressed to form a pad 3/16 in. thick. Creosoted oak ties, SH 13-in. AREA. Plan 5–B tie plates and four ⅝-in. by 6-in. line spikes were used.

Alterations to Original Installation

These changes were made in cooperation with the manufacturers in order to develop the merits of certain improvements of the materials or the method of application. It is realized that some of the fastenings and pads are in the development stage and it will be mutually advantageous to include in the test the improved products which are developed to provide more effective and economical means of reducing mechanical wear of ties.

Bird Tie Pads

In the original sections 4 and 5, five and seven-ply Bird tie pads, respectively, were applied. These pads had alternate layers of duck and paper felt with laminating asphalt and a special asphalt coating modified to flow in warm weather more than the standard asphalt. Because there was a tendency for the paper felt plies to work out of place, Bird & Son, Inc., replaced the felt with jute burlap and furnished replacement pads for

20 ties in each of sections 4 and 5 on the long test curve. The 5-ply pads were placed on the south 20 ties of section 4 and the 7-ply on the north 20 ties of section 5. Four ⅝-in. by 6-in. line spikes were used with the same 13-in. tie plates.

Racor Drive Tight Spikes

This design of spike was used in the anchor position in sections 7 and 8 and in the line position in sections 6 and 7. The inspection made in August 1948 developed that the fluting on the spikes was too shallow to fill tightly the holes in a number of the tie plates and it was decided to replace all of the anchor spikes in sections 7 and 8 with a new design (Fig. 9) which was not available at the time of the original installation. The replacement of the drive tight anchor spikes was completed in November 1948.

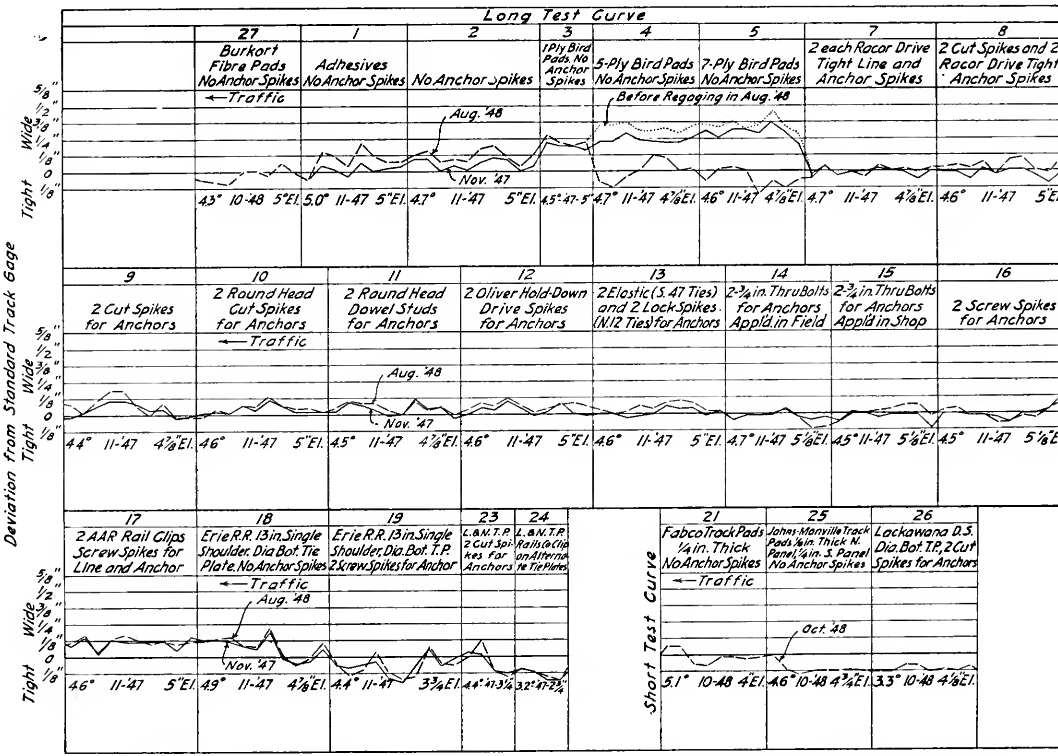
Thompson Rail and Tie Plate Clamp

Section 20, on tangent only, involved two screw spikes with bearing blocks and triple coil spring washers per tie plate which serve as line and anchor spikes as well as rail anchors. In the north panel of the two tangent test portions a wood hardner chemical in liquid form was placed in the holes before driving the screw spikes. In 1948 the torque to loosen the screw spikes was measured in the oak and pine tie sections both with and without the chemical. The results indicated the chemical was not effective and this was attributed to poor conditions of application such as liquid creosote in the prebored holes, the method of applying the chemical and possibly some oil on the screw spikes. The north 23 ties of each portion of section were replaced with new ties with the holes prebored through the ties. The holes were ⅝ in. dia. in the creosoted oak ties and 9/16 in. dia. in the softwood ties. Before placing the liquid, the holes were plugged at the bottom of the ties by driving a short piece of hardwood dowel in the holes. The screw spikes released were cleaned with a wire brush. The wood hardener chemical used for replacement consisted of the same liquid resin, but premixed with a plasticiser and then mixed on the job with a liquid wood hardener or catalyst. The mixture was applied with a grease gun and no difficulty was encountered in filling the holes completely. The Thompson Products, Inc., have found in other tests that the initial loosening torque for the screw spikes was doubled where the wood hardener chemical was used.

1948 Inspection

Track Gage on Test Curves

The initial gage measurements for the original construction were taken in November 1947 and checked in August 1948. Initial readings for the 1948 construction were taken in October 1948. A record of the track gage on the two test curves is shown in Fig. 26. It will be observed in sections 3, 4 and 5 on the long test curve having the Bird tie pads there was some wide gage when the gage was first measured, which was after about three months of traffic. When the pads on 20 ties in each of sections 4 and 5 were replaced all of these two sections on the curve were regaged. The cause of the gage widening, most of which had occurred prior to the original gage measurements, is not fully understood. The outward canting of the tie plates caused by greater compression of the Bird pads under the outer toe was too small to account for the amount of increase in the track gage. In 1948 where the Bird pads were replaced on 40 consecutive ties in the long curve the track gage was measured the next day after application. This will afford a better opportunity to determine in 1949 if the pads were a major contributing factor to the gage widening. Generally, the gage in all other test sections on the long curve was holding well.



Note: All test sections have the 13 in. AREA Plan 5B (Modified) tie plates with flat rail seat except those shown otherwise and as follows: Section 27, S.H. 13 in. Plan 5B with rolled crown; Sec. 17, Penn. R.R. 14¾ in. tie plate sheared to a 13 in. length and Sections 23 and 24, 14 in. AREA plan 6B tie plates. All sections without anchor spikes have four line-spikes and sections with anchor spikes have two line spikes.

Fig. 26.—Gage, Curvature and Elevation of Each Section of Test Track on the 4 deg.–30 ft. Curves, Mile L–154, L. & N. R. R. Near London, Ky.

Other Observations

In sections 1.3, 1.4 and 1.5 where the tie plates were cemented to the ties under pressure with products of the Casein Company of America, all bond between the 98 tie plates and the ties had broken as of October 1948, except 9 tie plates in section 1.5 on tangent with creosoted pine ties where the tie plates were attached to the ties with Casco cement NT–442 and Casophen RS–216 before creosoting. Under the prevailing conditions, such as an uneven tie plate bottom, irregularities in the adzed surface and the presence of surplus creosote on the wood, it does not seem practical (and definitely uneconomical) to endeavor to reduce mechanical wear or extend the tie life by this method.

In section 4 and 5 with 5 and 7-ply Bird pads the paper felt plies showed a moderate tendency to be working out of a few pads. The pads removed on the long curve were generally in good condition and the ties had been well protected. The tie surface was clean and showed no abrasion of the wood. One of the single ply Bird pads in section 3 on tangent track with oak ties worked out of place and was replaced with a new pad.

A few of the Fabco tie pads in section 21 on pine ties were found to project beyond both ends of the same tie plates. One of these was removed and inspected. Irregularity in the hewn pine tie adzed surface and a high knot caused the elongation of the pad. Visual inspection indicated no particular damage to the pad.

In all the other test sections the condition of the anchor fastenings was excellent. Little change would be expected with new ties and other track material after a year's service, or about 25 million gross tons of traffic.

Test Measurements

Tie plate penetration measurements were not taken for the original test installation in 1948 because other tests have shown that tie plate abrasion was so small afer a year's traffic that the data would have little significance. In many instances a tie plate has not become finally seated in one year. This is evidenced by the fact that tie plates cut into the ties more on one end and the opposite end of the plate may show an uplift for several months.

Tie plate penetration readings were taken before and after changing the Bird tie pads and the Thompson rail and tie plate clamp sections.

Initial or base measurements for the new sections added in 1948 were completed October 14, 1948.

Acknowledgement

This was a cooperative project between the Association of American Railroads and the Louisville & Nashville Railroad. The Association furnished at its expense all of the 13-in. tie plates and hold-down fastenings and the L. & N. furnished all labor and other material for construction, and also assisted in preparing the ties and tie plates for taking the test data. The Association is indebted to the L. & N. for its contribution. cooperation and keen interest in performing an excellent job expeditiously.

The Association is indebted to the suppliers and extends its appreciation for the services rendered in expediting manufacture and delivery of material, donating considerable material, and assistance and cooperation in many ways.

The planning of the test and installation work were under the direct supervision of H. E. Durham, track engineer, research staff, and at the general direction of G. M. Magee, research engineer. Olaf Froseth, assistant track engineer, supervised taking the original or base series of measurements after the installation was completed.

Tests on the Illinois Central Railroad

These tests are being conducted by the Illinois Central Railroad north of Manteno, Ill., and the research staff is keeping a progressive record of the tie plate penetration. The first progress report was published in the Proceedings, Vol. 48, 1947, page 648.

Tests on 131-lb. RE Rail

This installation is in the middle main track which carries high speed traffic in both directions and covers three miles of tangent track, three kinds of ties, two lengths of tie plates and seven arrangements of hold-down fastenings.

Table 2 is presented to show the tie plate penetration measurements taken July 1948 after 45 months' service in which the traffic amounted to 66 million gross tons.

TABLE 2. - SERVICE TEST OF MECHANICAL WEAR OF TIES WITH TWO DESIGNS OF TIE PLATES AND THREE KINDS OF TIES IN THE WEST RAIL OF THE MIDDLE TRACK OF THE ILLINOIS CENTRAL SYSTEM.

Between M.P. C-42 and M.P. C-45, north of Manteno, Ill. Tangent Track - Traffic in both directions. New 131-lb. RE rail with 6-hole joints laid in 1943. All ties 7 in. by 9 in. by 8 ft. 6 in. renewed in 1943.

Mile	Kind of Cross Ties	Number and Kind of Anchor Spikes	Tie Plate Penetration in 0.001 in. October 1944 to July 1948 (66 Million Gross Tons) — End of Tie Plates: Outer	Inner	Avg.
7 3/4-in. by 13.-in. by 27/32-in. double-shoulder tie plates, rolled circular crown, 1:40 ± cant, flat bottom, level shoulder extensions, eccentricity 1/4 in., AREA Plan No. 5 B.					
C-43	Creo. Pine	None - - - - - - - - - - - - - - -	68	86	77
C-43	Creo. Pine	4 S.S.* - - - - - - - - - - - - - -	38	62	50
C-43	Creo. Pine	2 S.S.- - - - - - - - - - - - - -	45	54	50
C-43	Creo. Pine	4 S.S. with double coil washers -	41	47	44
C-43	Creo. Pine	2 S.S. with double coil washers -	43	44	44
C-43	Creo. Pine	4 Cut Spikes - - - - - - - - - -	56	79	68
C-43	Creo. Pine	2 Cut Spikes - - - - - - - - - -	66	74	70
C-44	Creo. Gum	None - - - - - - - - - - - - - - -	39	52	46
C-44	Creo. Gum	2 S.S. with double coil washers -	19	24	22
C-45	Creo. Oak	None - - - - - - - - - - - - - - -	33	51	42
C-45	Creo. Oak	2 S.S. with double coil washers -	12	10	11
C-45	Creo. Oak	2 Cut Spikes - - - - - - - - - -	39	52	46
7 1/2-in. by 14 3/4-in. by 31/32-in. double-shoulder tie plates, rolled circular crown, 1:40 ± cant, flat bottom, tapered shoulder extensions, eccentricity 1/2 in., Penna. R.R. standard.					
C-43	Creo. Pine	None - - - - - - - - - - - - - - -	67	97	82
C-43	Creo. Pine	2 S.S. with double coil washers -	27	32	30
C-44	Creo. Gum	None - - - - - - - - - - - - - - -	59	61	60
C-44	Creo. Gum	2 S.S. with double coil washers -	26	30	28
C-45	Creo. Oak	None - - - - - - - - - - - - - - -	32	50	41
C-45	Creo. Oak	2 S.S. with double coil washers -	26	24	25
C-45	Creo. Oak	2 Cut Spikes - - - - - - - - - -	46	58	52

*S.S. = Screw Spike

TABLE 3. - SERVICE TEST OF MECHANICAL WEAR OF CREOSOTED GUM TIES WITH THREE ARRANGEMENTS OF ANCHOR SPIKES IN TRACK NO. 3, NORTHBOUND MAIN OF THE ILLINOIS CENTRAL SYSTEM NEAR M.P. C-43, NORTH OF MANTENO, ILL.

New 112-lb. RE rail with 6-hole joints laid in 1944, tangent track.

7 3/4-in. by 13-in. by 27/32-in. double-shoulder tie plates, flat seat, 1:40 ± cant, flat bottom, tapered shoulder extensions, eccentricity 3/8 in., 15/16 in. dia. holes for anchor spikes. Branded 419.

Number and Kind of Anchor Spikes	Number of Test Panels	Tie Plate Penetration in 0.001 in. from August 1945 to July 1948 (63 Million Gross Tons)				
		West Rail		East Rail		Both Rails Average
		End of Tie Plates				
		Outer	Inner	Inner	Outer	
2 Cut Spikes	1	34	37	48	34	38
4 Cut Spikes	1	33	50	52	42	44
2 Elastic Spikes-No.91	2	23	19	30	19	23

Tie abrasion has been remarkably slow in this test stretch which was rebuilt with all new material in 1943. Generally, two or four cut spikes used as anchors were the least effective and two or four screw spikes with double coil spring washers were the most beneficial in reducing the mechanical wear of ties.

Tests on 112-lb. RE Rail

In track No. 3 which carries northbound traffic, consisting largely of freight trains, a comparison of mechanical wear of 13-in. tie plates on creosoted gum ties with three arrangements of hold-down fastenings is being made.

Table 3 gives the penetration measurements for the 35-month period ended July 1948 in which 63 million gross tons of traffic were carried by track No. 3. The mechanical wear has been quite small. However, the tie plate penetration with the Elastic spikes was about one-half of that with cut spikes for anchors.

Report on Assignment 8

Effect of Lubrication in Preventing Frozen Rail Joints

C. W. Breed (chairman, subcommittee), F. J. Bishop, Blair Blowers, E. J. Brown, M. D. Carothers, E. W. Caruthers, R. W. Claypoole, E. D. Cowlin, J. W. Demcoe, H. F. Fifield, C. T. Jackson. C. H. Johnson, T. R. Klingel, J. de N. Macomb, G. M. Magee, R. W. Mauer, M. K. Ruppert, R. R. Smith, Troy West.

This is a progress report on service tests of rail joint lubrication, submitted as information, and includes information concerning the test on the Chicago, Burlington & Quincy Railroad and a résumé of tests made by the Wabash Railroad on rail joints packed with a lubricant. (Appendix 8–a)

Service Tests on the Chicago, Burlington & Quincy Railroad

Foreword

This test installation was made by the research staff in cooperation with the Burlington Railroad in July 1945, and has previously been reported in the Proceedings, Vol. 47, 1946, page 523 and Vol. 48, 1947, page 603, the latter being a discussion of the first year's test results.

This report, which covers the 5-mile stretch of the westward main near Earlville, Ill., laid with 131-lb. RE rail and 6-hole joints, includes data for the third year's service with brief mention of the second year's performance which was not included in last year's report. The third test period covers the eleven-month period ended June 30, 1948 in which the traffic carried amounted to 15.7 million gross tons of which 11.2 million tons were freight. Total traffic carried by the test section from July 4, 1945 through June 30, 1948 was 52.2 million gross tons. A general plan of the test track is shown in Fig. 1.

Discussion of Test Data

Rail Joint Gap

Data on rail joint gap are presented in Figs. 2 to 5, incl.: the first two figures covering measurements taken in cool weather and the latter two at summer temperatures. For each one-half mile of rail the joints have been shown by percentages in the several increments of rail gap width. For the cooler temperatures (Figs. 2 and 3) there is no section having an outstanding rail gap width uniformity. In Figs. 4 and 5 for the higher rail temperatures, with few exceptions, there was a greater percentage of joints in the first increment (0.00 to 0.04 in.) in the south rail with 6-hole reformed head-contact joint bars than in the corresponding sections on the north rail with headfree bars.

By comparing the last winter gap measurements with those of the first winter for corresponding test sections, the following trends are noted. Generally, the latter measurements show an increase in the percentage of the joints in the first increment of joint gap width (0.00 to 0.04 in.) A similar comparison of the summer rail gap data indicates, in general, a decrease in the percentage of the joints in the first increment. These observations indicate an increase in slippage resistance of the joints, with a resulting increase of closed joints in the winter and open joints in the summer. So far, the joint gap measurements have not shown any significant differences in the uniformity of joint gap width for the several lubricants or that the lubricated sections are superior to the stretch without lubricant.

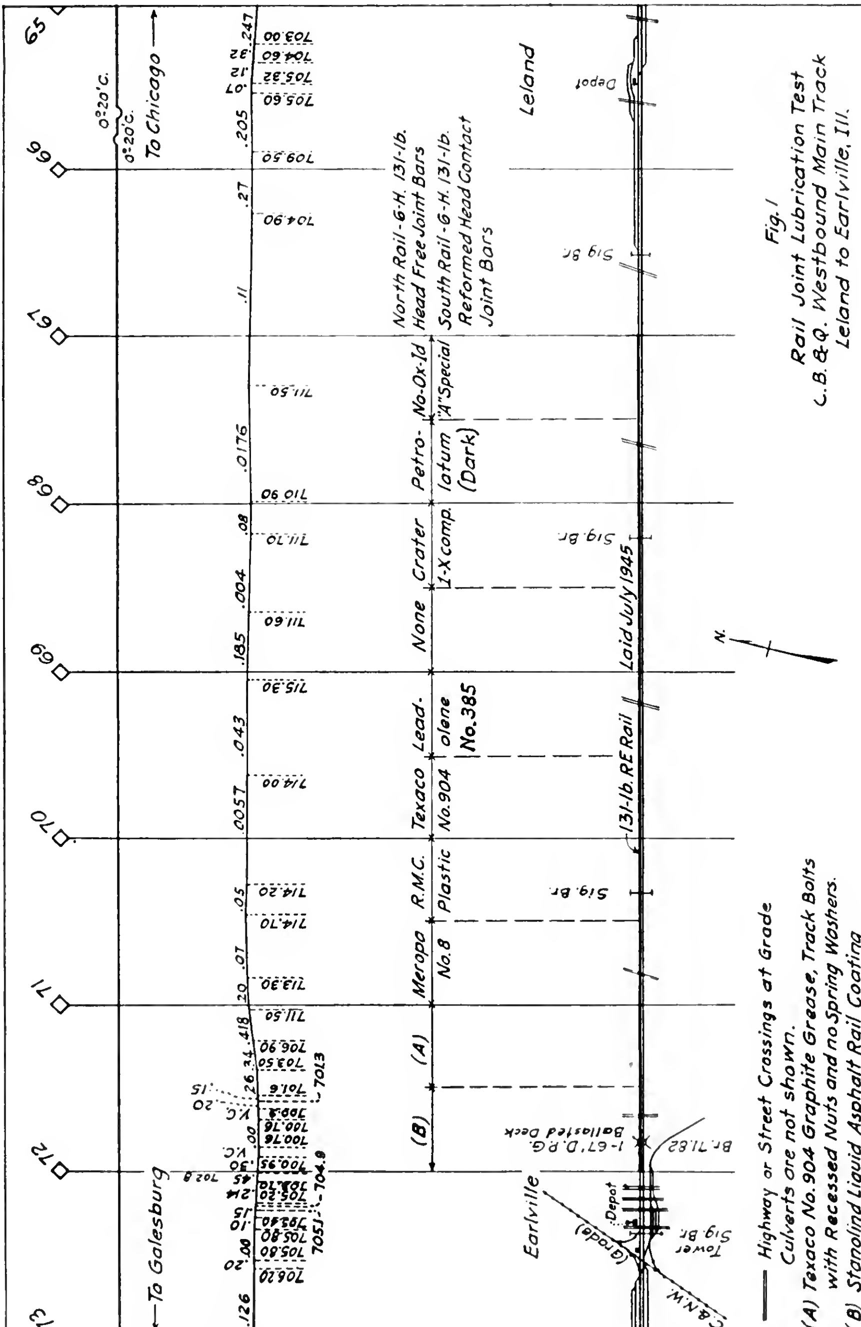


Fig. 1
Rail Joint Lubrication Test
C.B.&Q. Westbound Main Track
Leland to Earlville, Ill.

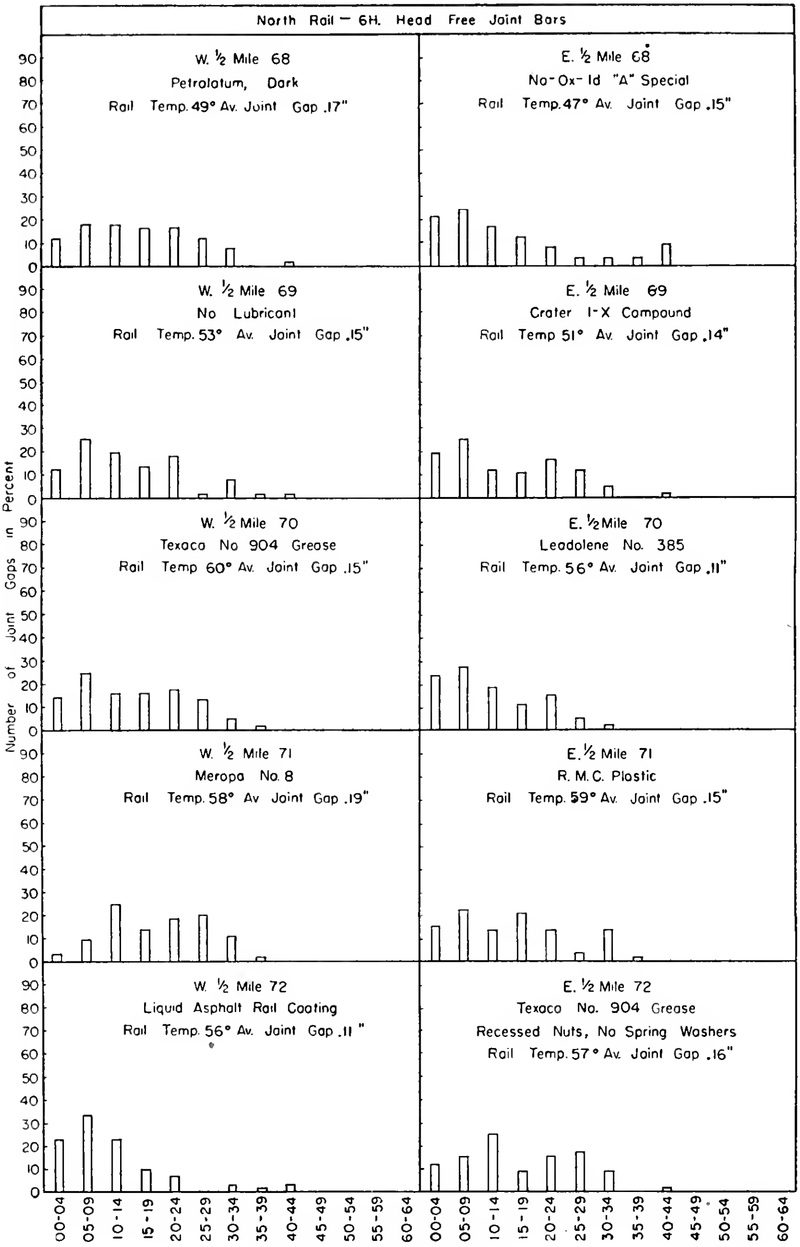


Fig. 2.—Joint Gap Measurements for Rail Joint Lubrication Test April 2, 1948
C. B. & Q. R. R. Leland to Earlville, Ill.

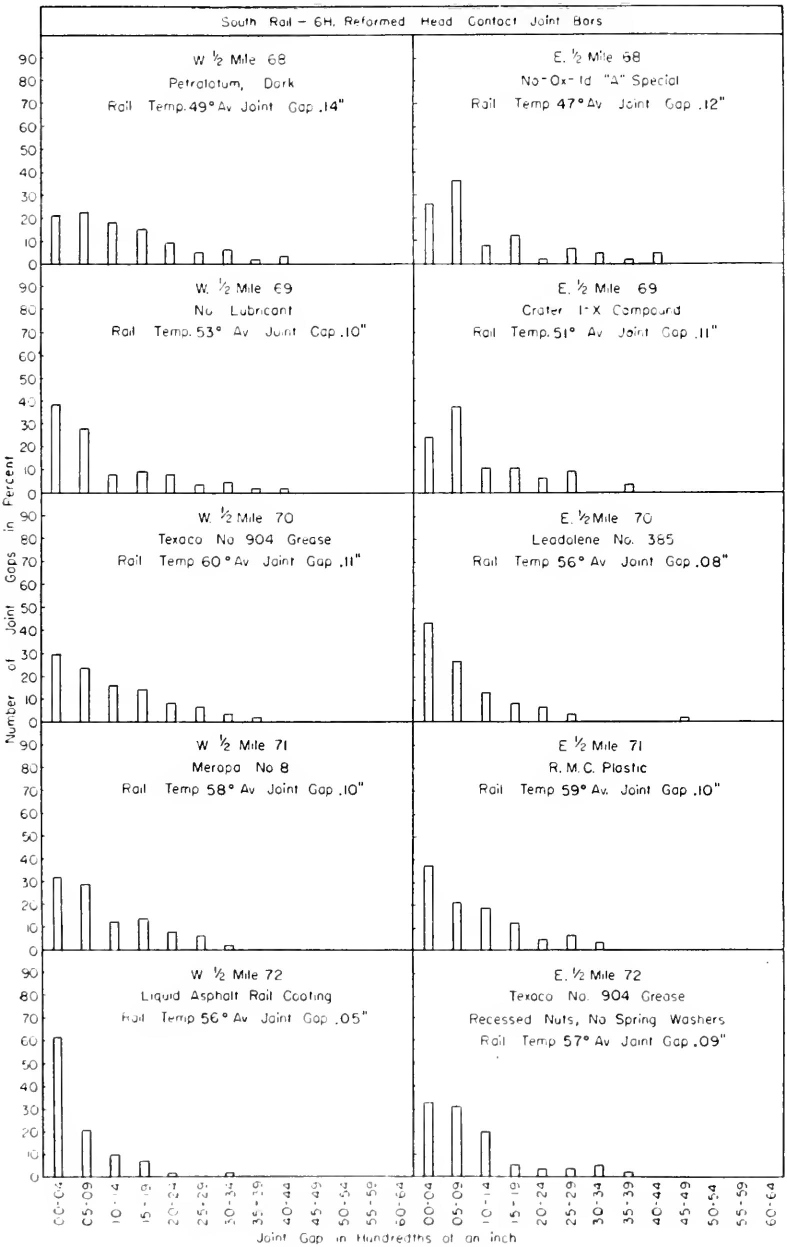


Fig. 3.—Joint Gap Measurements for Rail Joint Lubrication Test April 2, 1948
C. B. & Q. R. R. Leland to Earlville, Ill.

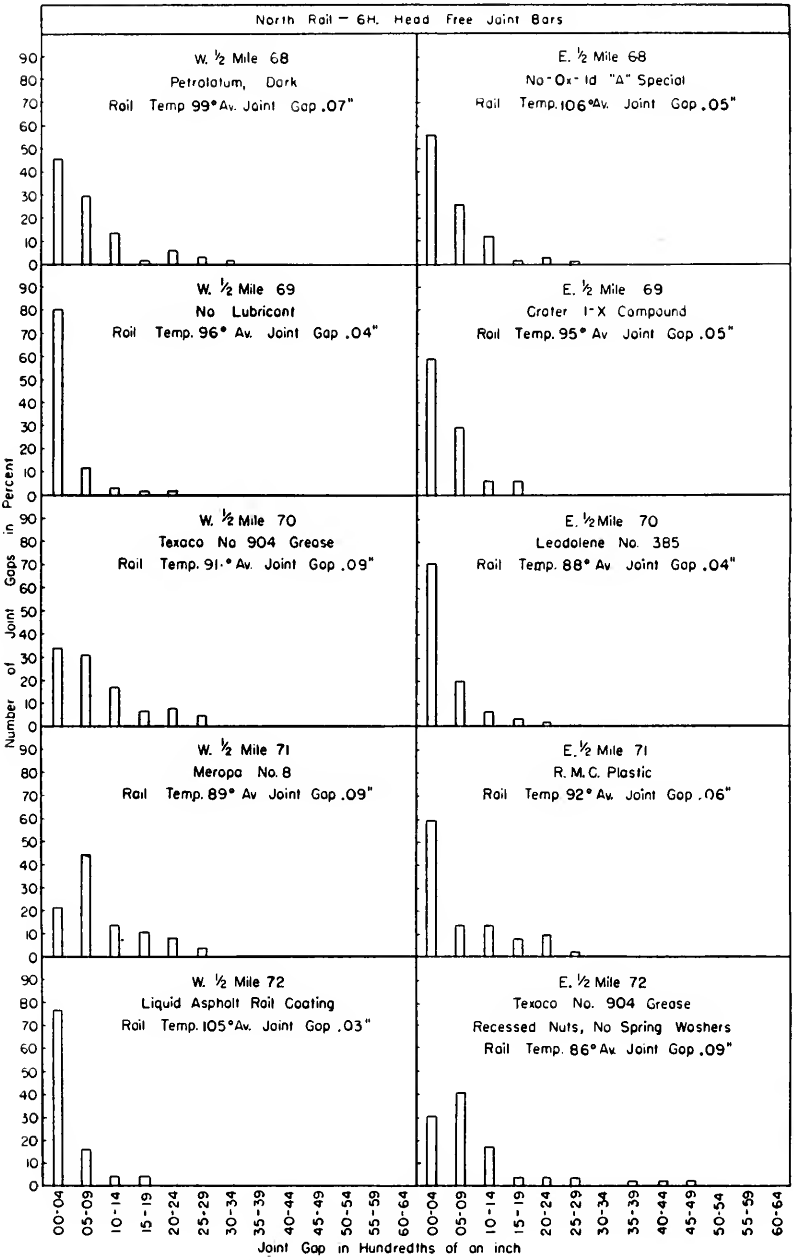


Fig. 4.—Joint Gap Measurements for Rail Joint Lubrication Test July 6, 1948
C. B. & Q. R. R. Leland to Earlville, Ill.

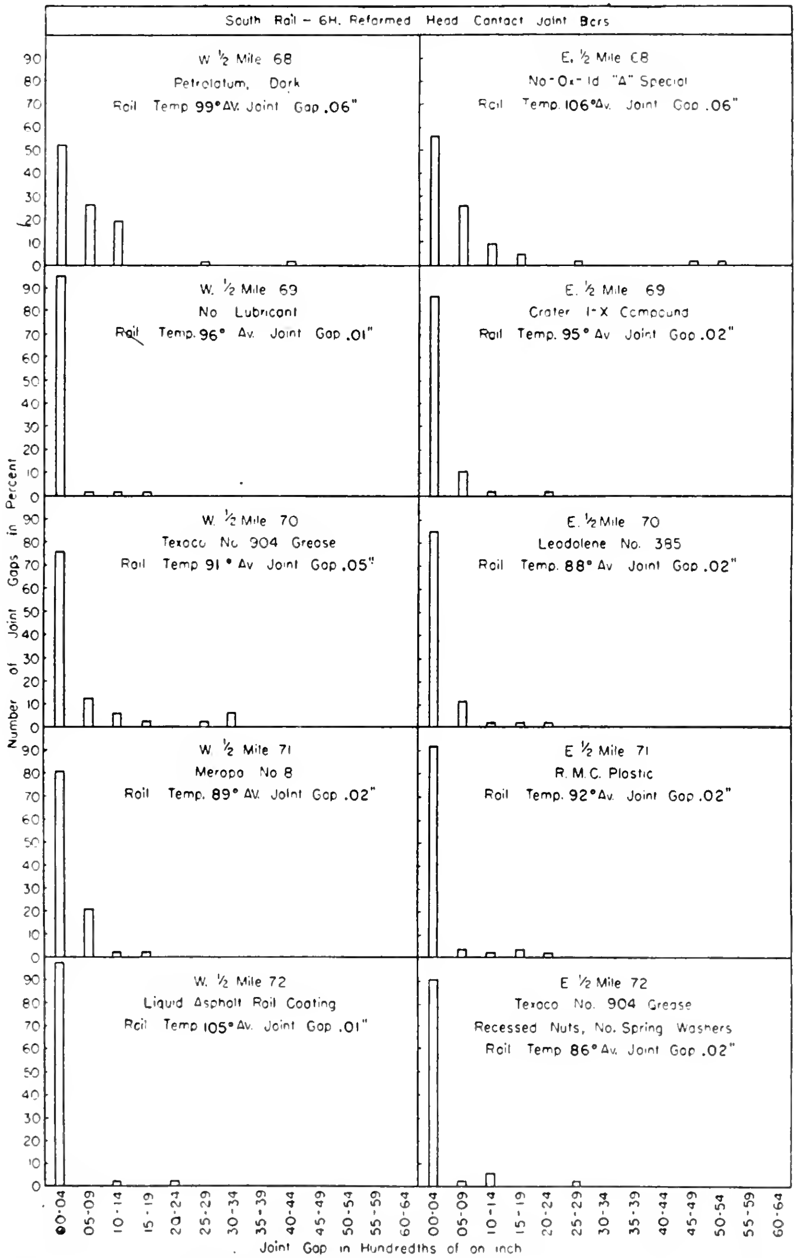
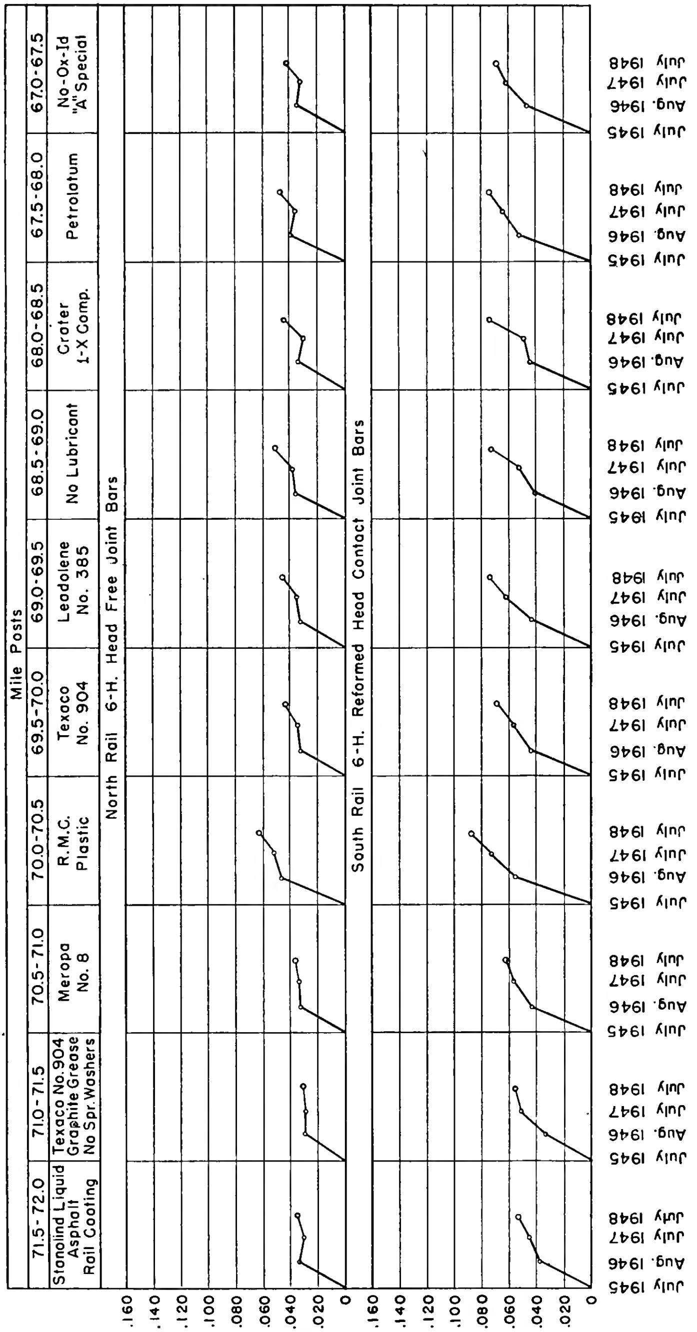
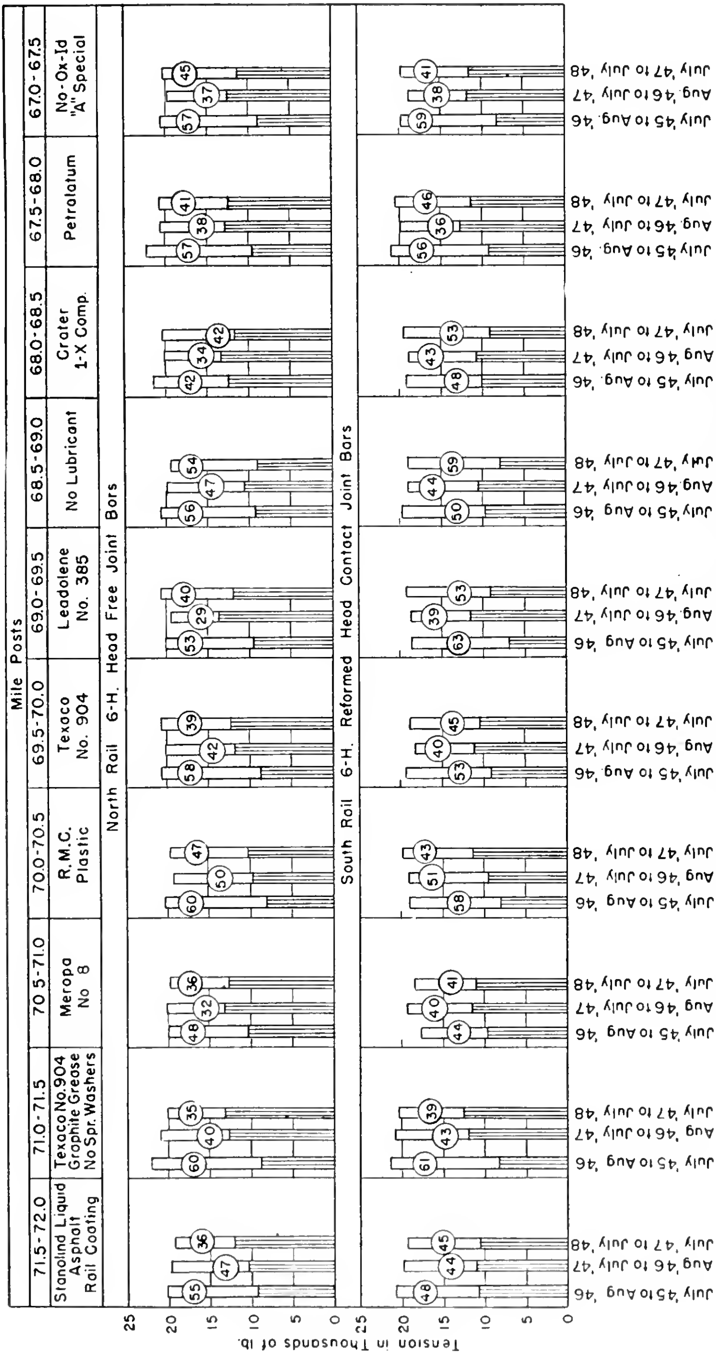


Fig. 5.—Joint Gap Measurements for Rail Joint Lubrication Test July 6, 1948
C. B. & Q. R. R. Leland to Earlville, Ill.



Note: Out-to-out measurements taken at top and bottom of ends and middle of all joint bars.
Values shown are the mean of top and bottom of bars.

Fig. 6.—Average Pull-in of Joint Bars, C. B. & Q. R. R. Leland to Earlville, Ill.



Note Top of columns shows Average Tension in 15 joints at the beginning of Test periods.
Top of Shaded Part of columns shows Remaining Tension at the end of Test periods.
Figures in circles indicate Percent of Tension Lost.

Fig. 7.—Bolt Tension C. B. & Q. R. R., Leland to Earlville, Ill.

Joint Bar Pull-In

Measurements of joint bar pull-in have been taken on all test joints each summer and are shown for the three-year test period in Fig. 6. It is believed the headfree joint bars have finally become seated. It will be observed in the upper portion of the figure the curves assumed a descending slope in most of the sections with headfree bars during the second test period. This was caused principally by cocking of the bars; that is, by the bars moving upward in the upper rail fillet and showing an increase in the out-to-out dimension at the top of the bars which was greater than the pull-in at the bottom of the bars. The average pull-in of the headfree bars in the 10 test sections for the three-year period ranged from 0.031 to 0.063 in. which is really a small difference, especially if the wide variation in seating of the bars during the first two service years is considered.

The average pull-in of the reformed head-contact bars for the three-year test period as shown in the lower portion of Fig. 6, ranged from 0.053 to 0.088 in. and the variations were greatly influenced by the wide scatter in the first year's pull-in while the bars were becoming seated. It was expected that the lubricated joints should show a lesser rate of wear than those without lubrication, but so far, little difference is indicated. Possibly, another year or two of service will develop more significant differences in the joint wear with the various types of lubricants.

Bolt Tension

Bolt tension measurements have been made each year on the middle 15 joints of each of the one-half mile sections of rail. These data are presented in Fig. 7. The average applied tension in the 1-in. track bolts for the north rail test sections with headfree bars varied from 19,300 lb. to 20,600 lb. and the corresponding figures for the south rail with reformed head-contact bars were 18,300 lb. to 20,600 lb., resulting in an average for the north and south rails of 20,100 lb. and 19,400 lb., respectively. In both rails, the greatest percentage loss in bolt tension for the third test period occurred in the section without lubrication. The lowest percentages were in the three west sections of the north rail and in the sections with the recessed nuts and Texaco 904 grease, Meropa No. 8 and No-Ox-Id "A" special of the south rail. For the third period, the average loss in bolt tension for the entire north and south test rails, respectively, was 42 and 46 percent. The corresponding percentages for the first test period were 55 and 54; and 40 and 42 for the second period.

The loss in bolt tension is not entirely consistent with the joint bar pull-in; that is, the greatest loss does not always occur in the section with the largest pull-in nor the lesser loss where the pull-in is the lowest. It should be noted that the bolt tension data are based on 15 joints in each test stretch of rail while the average joint bar pull-in for a section is based on all joints, or approximately 68.

As a matter of interest, Table 1 is presented to show the percentage of bolts having less than 5000 lb. tension in 15 joints of each test section at the end of the third service period. In both rails, the no lubricant section had the highest percentage. For the north and south rails, respectively, the average percentage for the five miles was 10 and 12 as compared to 4 and 6 for the second test period. A 5000 lb. bolt tension is considered the minimum required for the proper functioning of the symmetrical type of bars.

Maintenance of Way Report

This report includes the number of loose and broken bolts found by the Burlington Railroad forces during the third test period and is presented in Table 2. There were no stripped joints. The section having the recessed nuts without spring washers continues with the largest number of loose bolts, particularly in the north rail with headfree bars.

TABLE 1.—PERCENTAGE OF BOLTS IN 15 JOINTS OF EACH TEST STRETCH WITH BOLT TENSION LESS THAN 5000 LB. FOUND AT THE END OF THE THIRD TEST PERIOD AFTER 11 MONTHS' TRAFFIC

South Rail H.C. Joints Percent	M.P. to M.P.		Lubricant	North Rail H.F. Joints Percent
4	67	67½	No- Ox- Id "A" Special	8
5	67½	68	Petrolatum (Dark)	2
10	68	68½	Crater 1-x Compound	14
27	68½	69	No Lubricant	31
7	69	69½	Leadolene No. 385	11
7	69½	70	Texaco No. 904 Grease	6
7	70	70½	R.M.C. Plastic Packing	20
7	70½	71	Meropa No. 8	8
13	71	71½	Texaco No. 904, Recessed nuts, no spring washers	9 (a)
8	71½	72	Liquid Asphalt Rail coating	9
10			Average	12

(a) Includes one loose bolt.

TABLE 2.—SERVICE REPORT OF LOOSE AND BROKEN BOLTS* C. B. & Q. R. R. RAIL JOINT LUBRICATION TEST, M.P. 67 TO M.P. 72, W. B. MAIN AUGUST 1, 1947 TO JULY 1, 1948

South Rail H.C. Joints No. of Bolts						North Rail H.F. Joints No. of Bolts		
Loose	Broken	Total	M.P. to M.P.		Lubricant	Loose	Broken	Total
0	0	0	67	67½	No- Ox- Id "A" Special	0	0	0
0	0	0	67½	68	Petrolatum (Dark)	0	0	0
0	0	0	68	68½	Crater 1-x Compound	5	1	6
0	0	0	68½	69	No Lubricant	0	0	0
4	0	4	69	69½	Leadolene No. 385	16	3	19
0	0	0	69½	70	Texaco No. 904 Grease	0	0	0
0	0	0	70	70½	R.M.C. Plastic Packing	13	1	14
6	0	6	70½	71	Meropa No. 8	11	1	12
8	0	8	71	71½	Texaco No. 904, Recessed Nuts, No spring washers	35	1	36
0	0	0	71½	72	Liquid Asphalt Rail Coating	6	0	6
18	0	18	Totals			86	7	93

* Also includes loose bolts (shown in Table 1) found by AAR Research Staff when checking bolt tension in July 1948.

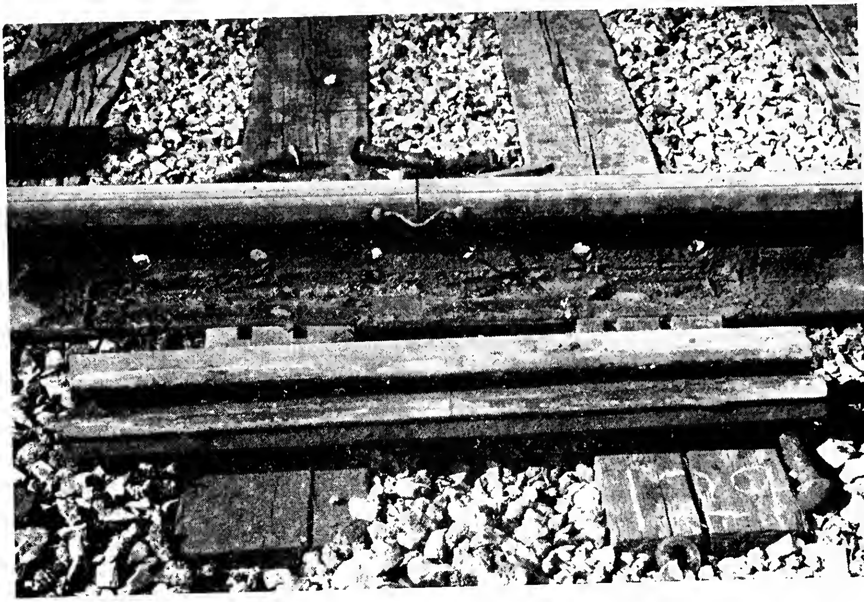


Fig. 8.—No-Ox-Id "A" Special.

Fig. 9.—Petrolatum (Dark).

Fig. 10.—Crater 1-X Compound.

Fig. 11.—Leadolene No. 385.

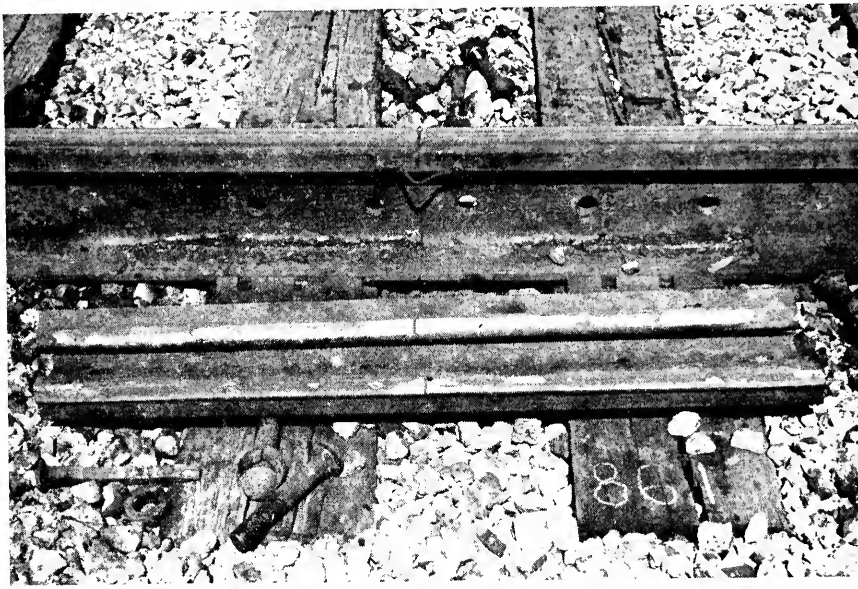


Fig. 12.—Texaco 904 Graphite Grease (Standard Construction).

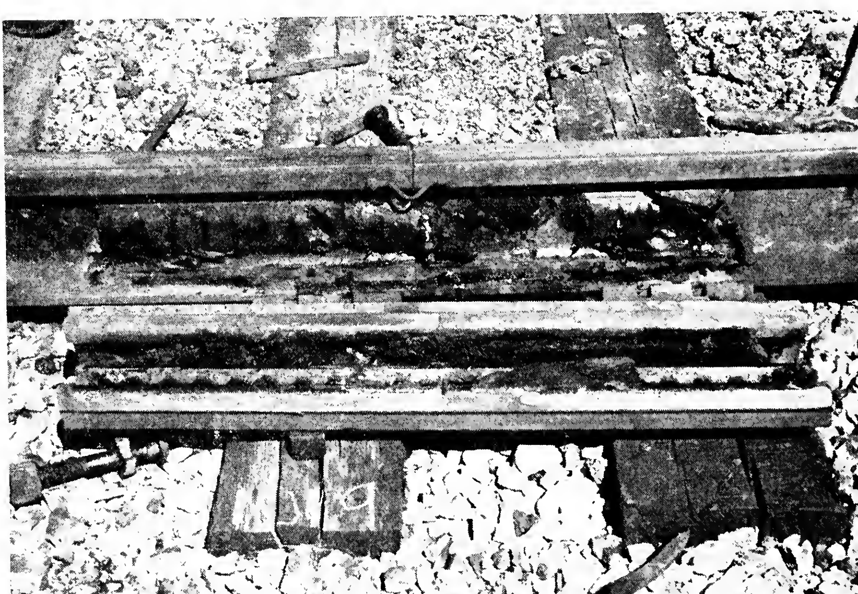


Fig. 13.—R.M.C. Plastic Joint Packing.

Fig. 14.—Meropa No. 8.

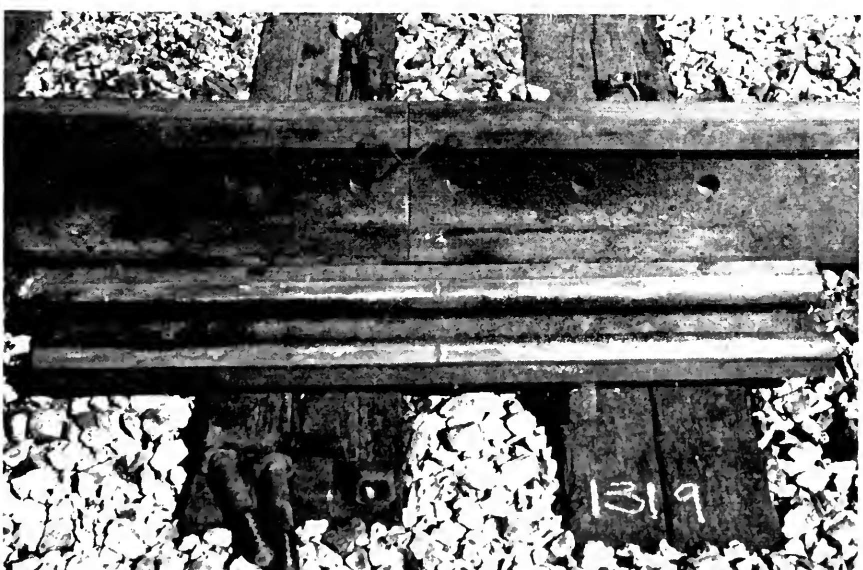


Fig. 15.—Texaco 904 Graphite Grease (Recessed Nuts, No Spring Washers).

Fig. 16.—Liquid Asphalt Rail Coating.

During the last service period, there has been a marked increase in loose bolts in the north rail of the 5-mile test. The loose and broken bolts in that rail increased from 24 in the second period to 94 for the third period. No information has been developed that would satisfactorily explain this sudden increase in loose bolts in the joints with the headfree type of bar.

Inspection of Dismantled Joints

In September 1948, 16 pairs of head-contact joint bars were removed from joints not previously dismantled, for the purpose of inspecting the condition of the lubricants. Two joints in each of the test sections were dismantled, except in the no lubricant section and only one joint was inspected in each of the sections with Texaco 904 graphite grease with standard construction and with RMC plastic joint packing.

This year, several of the lubricants had been seriously affected by the elements and the sandblasting caused by passing trains. Liquid asphalt rail coating, Texaco 904 graphite grease and Meropa No. 8 had weathered away the most. These coatings were generally dry and had begun to flake off. Leadolene No. 385 and Crater 1–X compound were in a moderately better condition as to weathering. RMC plastic packing, petrolatum (dark) and No-Ox-Id "A" special, showed outstanding resistance to weathering away. Condition of the lubricants may be observed in Figs. 8 to 16, incl.

Little lubrication was found on the upper fishings except in the sections with petrolatum (dark), No-Ox-Id "A" special, Leadolene No. 385, and Crater 1–X compound, where from 25 to 60 percent of the surface was lubricated. Generally, the lower fishings had more lubrication than the upper fishings. The amount of lubrication on the lower fishings was greatest in the sections with petrolatum (dark), RMC plastic packing, No-Ox-Id "A" special, Leadolene and Meropa, ranking in the order named.

The bolt threads in all sections inspected were well lubricated and battered threads were found on only two bolts.

The condition of the lubricants brushed on was better on the field side of the rail than the gage side where the sandblasting effect is more intense. Most of the debris collects in the receiving end of the joints and causes the lubricants to weather more than on the leaving end of the joints. However, it will be noted from the photographs that No-Ox-Id "A" special, petrolatum (dark) and RMC plastic joint packing have resisted the effects of the elements remarkably well.

Results of the inspection seem to emphasize the need for plugging the ends of the joints with a suitable non-setting plastic material to keep out the debris, brine and abrasive materials for the dual purpose of extending the service life of the lubricants and reducing corrosion.

Installation of Solvated Sealz Slabs

The Naugatuck Chemical Division of the United States Rubber Company has developed a thermoplastic material in slab form which is used widely as an expansion joint filler in pavements. The Solvated Sealz slabs are made of reclaimed rubber combined with natural and synthetic resins to form a tacky, plastic material which has been used successfully in pavements where temperatures range from —60 deg. F. to 140 deg. F.

For a rail joint, this material will fill the space behind the bars and keep out the weather but has no lubricating properties.

A small test installation was made in September 1948, in the south rail immediately east of M.P. 69 at the west end of the section with no lubricant. Six 6-hole reformed head-contact joints were packed with the Solvated Sealz slabs which were 1 in. thick by 36 in. long. Before application, the rail and bars were cleaned with kerosene which acts as a slow solvent and produces a good bond between the slab and metal surfaces. The slabs squeezed out beyond the ends of the joints and a part of the material was rammed in the joint ends to seal out the weather, brine, etc. The slabs were difficult to place because of having too much material for the space to be filled.

This test will indicate the effects of protecting the inner areas of the joint from the weather, etc. without the use of a lubricant.

Conclusions

After three years of service, No-Ox-Id 'A" special, petrolatum (dark) and RMC plastic joint packing had outstanding weather resisting qualities. The test has been of insufficient duration to develop any significant differences in joint wear of the several types of lubricants or rust preventives as well as the uniformity of joint gap.

Acknowledgment

The committee and Association are indebted to the Burlington Railroad for its cooperation in making the test installations and assisting with the annual measurements and inspection.

Appendix 8–a

Rail Joint Lubrication on the Wabash Railroad

By W. E. Gardner

Principal Assistant Engineer, Wabash Railroad, St. Louis, Mo.

For a number of years the Wabash Railroad has been trying to improve the lubrication of rail ends and eliminate frozen joints. It was the practice for many years to paint the fishing surfaces of the rail ends with a grease type lubricant when laying rail, and while the results were satisfactory, frozen joints developed too soon. We were successful in freeing the rail ends in frozen joints by spraying a penetrating oil in the joint openings, but the results were not lasting and the joints froze again within a short time.

When the preformed joint packing made of a mixture of lubricating oil and wood flour came on the market, it appeared to provide the means for a lasting lubrication job, and we applied it to all joints installed for several years. The benefit received from it was a considerable improvement over the painted grease, but we feel now that frozen joints develop with the packing too soon to justify its cost. Although we have found that water sometimes collects in the packed joints even during the dry season of the year, we have not had trouble with the development of rail cracks as reported on some roads.

During 1942 we used the method developed by the Texas Company for packing the joint spaces with its No. 904 graphite grease. The results were very satisfactory and we have continued this procedure, making several improvements in the method of packing the joints. While we are still experimenting with various lubricants, we are going ahead with the Texaco method with the feeling that we are getting better results than from anything tried up to this time. With an improved method of application we feel we should secure several years' satisfactory lubrication before it will be necessary to add grease to the joint. The procedure we are following now is outlined below:

Rail is laid with two bolts holding the joint until the crane has passed over it. The joint bars are removed and the rail ends flame descaled. The fishing surfaces of rail ends are given a heavy coat of Texaco No. 904 grease, the bars applied and the bolts tightened. After the rail has work hardened under traffic for about 60 days, the ends are hardened, and the joints are packed with No. 904 grease.

To pack the joints, we use a pumping outfit mounted on a push car. A gasoline engine-driven 15-cu. ft. compressor provides air through a 30-gal. storage tank for operating the grease pump. Two hose lines carry the grease to the joint in one rail ahead of car and the joint in the other rail behind the car. The grease gun on the end of a hose is fitted with a ¼-in. elbow and a 24-in. length of ¼-in. pipe.

Before packing a joint, one end is sealed with plugs of Texaco plastic "H". This material which is of the consistency of a heavy grease, is applied by hand and shaped to cover the end of the joint bar to seal out foreign matter and hold the grease in the joint. After one end of the joint is plugged, the 24-in. pipe is inserted in the opposite end of the joint and pulled out slowly while grease is being pumped. After the pipe has been withdrawn to the last bolt hole, flow of grease is stopped. The open end of the joint is then sealed with plastic "H". In filling the joint, the man operating the grease gun is soon able to judge when the joint space is filled to the bottom of the rail head. Care should be used to keep grease off of the surface where plastic is to be applied as it will not adhere satisfactorily to a greasy surface.

With this power outfit, a foreman and five men can pack about 800 4-hole joints per day at a cost of about 50 cents per joint for labor and material.

Contrary to some opinions, there appears to be a pumping action which carries the grease up to the top fishing surfaces. Due to this action, it is essential that swinging joints be eliminated—traffic pumps the grease out over the top of a swinging joint in a very short time. In stretches of track where the joint gaps are open during hot weather, the rail ends are not moving freely, and by loosening the bolts the rails will usually jump together, although a blow from a maul on the bar is sometimes needed to free it enough to let the rail move. On long stretches where we have had almost all gaps open during hot weather, we have found the gaps entirely disappear within two or three days after the grease is applied; at this time the top surfaces of the joint bars begin to show oil creepage over the top.

We are not in a position to say that this is the most economical method of lubrication, but the results obtained so far are the best of the many methods we have tried, and the benefits listed below appear to justify our efforts to a considerable extent:

1. Protects rail ends, bars and bolts from excessive corrosion.
2. By having the ends of joint sealed, brine, dirt and all foreign matter are kept out of the joint spaces.
3. Frozen joints loosen within a day or two after packing.
4. Pull-aparts in cold weather are eliminated.
5. By maintaining free movement of rail ends in joints a considerable improvement is noticeable in line and surface by the elimination of the wavy conditions resulting from frozen joints in hot weather, and the necessity for cutting out rail for expansion at such times is eliminated.

Report on Assignment 9

Rail Anchorage for Various Conditions

E. E. Martin (chairman, subcommittee), Lem Adams, L. L. Adams, J. C. Aker, W. G. Arn, A. L. Bartlett, T. H. Beebe, F. J. Bishop, H. J. Bogardus, A. E. Botts, E. J. Brown, M. D. Carothers, E. W. Caruthers, W. E. Cornell, B. E. Crumpler, H. F. Fifield, J. W. Fulmer, A. B. Hillman, J. P. Hiltz, A. F. Huber, T. R. Klingel, G. M. Magee, S. H. Poore, M. K. Ruppert, R. R. Smith, Troy West.

This report, submitted as information, covers a test with a panel of dummy track to measure the force required to move ties in the ballast with four arrangements of rail anchors.

Object

The purpose of this test was to determine the magnitude of the forces transmitted from the rail anchors to the ties that were required to move the ties in the ballast, the forces being applied by jacking the rails of a panel of track longitudinally.

Test Set-Up

A 39-ft. panel of disconnected track was built by the New York, New Haven & Hartford Railroad near North Haven, Conn. The test panel consisted of 131-lb. RE rail, 23 creosoted oak ties, 12-in. double shoulder, flat bottom tie plates, two lines of spikes per tie plate and graded trap rock ballast of medium size, with about a 6-in. depth below the ties. Sand was added to the ballast to fill the voids. A large hydraulic jack was placed at each end of the test panel for jacking the rails back and forth. The jack at the west end was used for taking the data and the other jack was utilized to restore

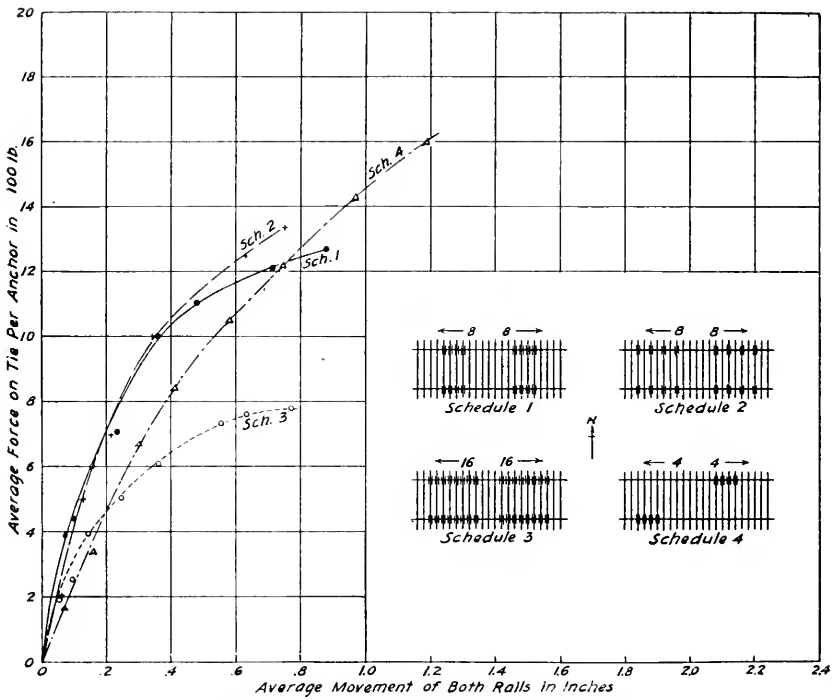


Fig. 1.—Rail Movement and Average Force on a Tie per Rail Anchor, Series I, with Double Shoulder Tie Plates.

the rails to their original position. The total pressure on the rails could be measured to the nearest 335 lb. which corresponded to 5 psi. on the 9¼ in. diaphragm of the jack. The total force on the two rails was limited to 28,000 lb. which corresponded to 415 psi. maximum reading on the pressure gage. Hand pumps were used to operate the hydraulic jacks.

Test Procedure

Two series of tests were made; one with tie plates, the other without. Before applying the Fair rail anchors in accordance with the four arrangements shown in Figs. 1 and 2, the rails were jacked from ½ to 1 in. to determine the frictional resistance per tie per rail in order to make corrections for this resistance on the unanchored ties. Generally, for each schedule the rails were moved 1 in. or more, or to the maximum pressure gage reading of 415 psi. The series without tie plates was made in order to reduce the frictional resistance to the minimum and improve the accuracy of the test. However, when the rails were spiked without the tie plates the same spike-holes were used and the frictional resistance was only reduced from 185 to 90 lb per tie per rail. After each schedule the ballast was rammed against the sides of the ties. Gage pressures were read at various increments of rail movement which was shown by the Ames dials at the west ends of the rails. Movement of the unanchored ties was determined from the difference between the total rail movement and the relative movement of the rail with respect to the ties studied.

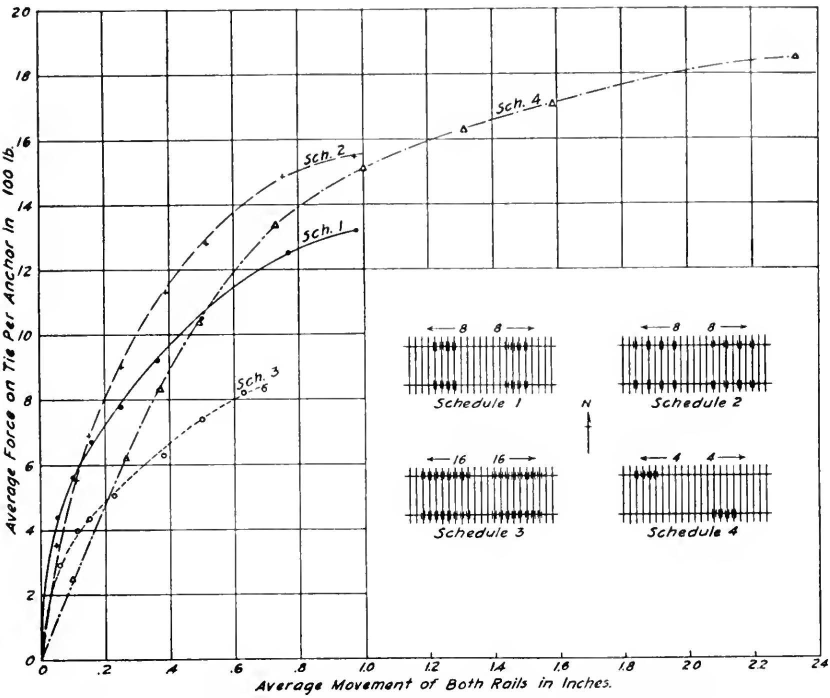


Fig. 2.—Rail Movement and Average Force on a Tie per Rail Anchor. Series II, without Tie Plates.

Test Results

The data are shown in graphical form in Figs. 1 and 2, for Series I and II, respectively. The average force on a tie per forward anchor has been plotted against the average rail movement. In each schedule. the anchors were boxed for the purpose of restoring the ties to their original position to avoid disrupting the ballasts from a cumulative rail movement in the same direction. In Series I, schedules 1 and 2 were about the same up to about ¼-in. rail movement while in Series II the divergence began at about ⅛-in. movement. This indicates the holding power of alternately spaced anchored ties is greater than that of consecutive ties. Schedule 3 involved moving two groups of 8 consecutively anchored ties and showed the least holding power of the anchored ties after 0.2-in. rail movement. This illustrates, possibly to the extreme, the reduction in resistance of ties to movement in the ballast when consecutive ties are anchored. Schedule 4 with the end-of-rail method of anchorage showed less resistance to tie movement in the range of movement of schedule 2 for both series and exceeded schedule 1 at ¾-in. rail movement in Series I and at ½-in. movement in Series 2.

The tabulation on following page shows a comparison of the resistance of the ballast to tie movement in pounds per forward anchor for average rail movements of ¼ and ½-in.

It will be noted from the table, that although schedule 4 which has a full tie to resist the force transmitted by one anchor (by virtue of skewing the anchored ties), corresponding values for that arrangement were less than those for schedules 1 and 2, but exceeded the forces for schedule 3 in which 16 ties were being moved. In this test the force required to move the ties initially in the ballast was not determined.

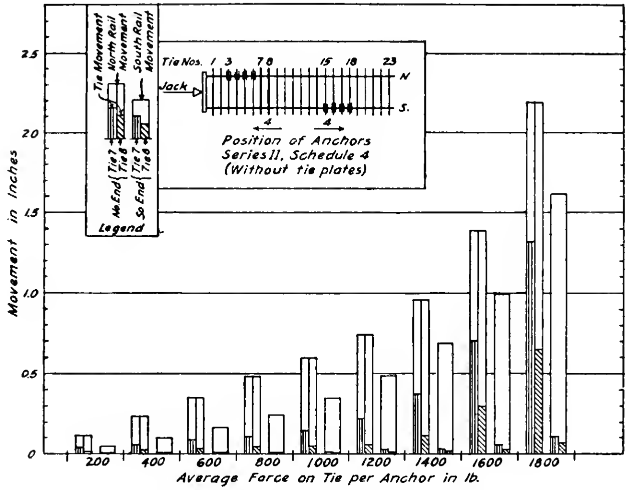


Fig. 3.—Comparative Movement of Rail and Unanchored Ties 7 and 8.

Schedule	Series I lb.	Series II lb.	Average lb.
¼-in. Rail Movement			
1	790	790	790
2	810	900	855
3	520	530	525
4	550	590	570
½-in. Rail Movement			
1	1110	1060	1135
2	1150	1280	1215
3	710	740	725
4	960	1040	1000

Fig. 3 is presented to show in Series II, without tie plates the movement and skewing of unanchored ties 7 and 8 immediately adjacent to four ties anchored by the end-of-rail method. It will be observed in the figure where 1800 lb. per anchor was transmitted to the ties and the average rail movement was 1.9 in., ties 7 and 8 had skewed 1.2 and 0.6 in., respectively. It was assumed that the anchored ties moved with the rail, approximately.

Summary

It is believed Series II, (Fig. 2) shows the more accurate comparison of the four methods of rail anchorage because the tie plates were omitted, which reduced the frictional forces and eliminated the variations that could be caused in the binding action of the tie plate shoulders on the unanchored ties, particularly, in schedule 4 where some of the anchored ties were skewed. While the test results are chiefly of academic interest, in that the ballast had not been compacted by traffic, they do show that schedule 2 is superior to all other schedules and that schedule 3 is the least efficient method of using anchors.

Additional tests will be made by the Research Staff in 1949 to develop similar information on a main track and to investigate the dynamic forces transmitted to the ties by the anchors under traffic.

Acknowledgment

The committee and the Association are indebted to the New Haven Road and to A. L. Bartlett, assistant to chief engineer, for the construction of the test panel of track and assistance in making the test.

Report on Assignment 10

Critical Review of the Subject of Speed on Curves as Affected by Present Day Equipment

J. W. Fulmer (chairman, subcommittee), J. C. Aker, T. H. Beebe, F. J. Bishop, C. W. Breed, E. W. Caruthers, M. H. Dick, C. T. Jackson, C. H. Johnson, G. M. Magee, E. E. Martin, R. W. Mauer, R. R. Smith.

Your committee submits the following report as information.

The present recommendation in the manual for maximum speed on curves for comfortable riding is that corresponding to three inches unbalanced elevation. This was established many years ago and was based upon personal observation and experience.

The speed at which trains can be operated on curves without discomfort to passengers is dependent upon both track and equipment. Many developments have been made in truck design, such as more flexible springs and the use of snubbers, cross stabilizers, etc., which make riding more comfortable on curves.

The Engineering Division research staff of the Association of American Railroads has accelerometer equipment with which it is possible to obtain measurements indicating the extent of riding discomfort on curved track for various degrees of curvature, the amount of unbalanced elevation and speeds. It was the opinion of the committee that this equipment should be used to make tests to compare the riding comfort on curves under various conditions and with different types of equipment.

The committee requested and was granted $15,000 by the AAR for use in 1949 in conducting such tests.

Report of Committee 1—Roadway and Ballast

H. W. Legro, *Chairman,*
W. T. Adams
H. S. Ashley
George Auer, Jr.
E. W. Bauman
F. W. Biltz
T. A. Blair
A. J. Boase
J. M. Boles
L. H. Bond
A. E. Botts
H. F. Brown
W. J. Cable*
J. E. Chubb
L. B. Craig
L. S. Crane
B. H. Crosland
A. P. Crosley
J. P. Datesman
T. F. de Capiteau
J. C. DeJarnette, Jr.
J. W. Demcoe
D. J. Evans
J. M. Fair
J. G. Gilley
A. T. Goldbeck
Albert Haertlein
G. B. Harris
F. W. Hillman
J. W. Hopkins
S. M. Jackson
L. H. Jentoft
H. G. Johnson
L. V. Johnson
H. W. Johnston
L. R. Lamport
R. R. Manion
F. H. McGuigan
Paul McKay
G. L. Morrison
J. F. Newsom, Jr.
G. W. Miller,
Vice-Chairman,
J. A. Noble
G. W. Payne
J. W. Poulter
C. S. Robinson
L. S. Rose
A. W. Schroeder
J. R. Scofield
R. G. Scott
C. R. Shaw
F. H. Simpson
W. C. Swartout
H. M. Tremaine
C. D. Turley
W. J. Turner
Stanton Walker
C. S. Wicker
A. A. Winter
Edward Wise, Jr.

Committee

* Died July 23, 1948.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Physical properties of earth materials:

   (a) Roadbed. Load capacity. Relation to ballast. Allowable pressures.
   Progress report, presented as information .... page 651

   (b) Structural foundation beds, collaborating with Committees 6 and 8.

   No report.

3. Natural waterways: Prevention of erosion.

   No report.

4. Culverts:

   (a) Wood culverts.

   No report.

   (b) Conditions requiring head walls, wing walls, inverts and aprons and requisites therefor.

   No report.

   (c) Installation of culverts.

   No report.

5. Roadway drainage: Critical review of recommended practice.

   No report.

AREA Bulletin 479, February 1949.

THE COMMITTEE ON ROADWAY AND BALLAST,
H. W. LEGRO, *Chairman.*

Ward John Cable

Ward John Cable, division engineer on the Minneapolis, St. Paul & Sault Ste. Marie Railway, at Stevens Point, Wis., died on July 23, 1948.

Mr. Cable was born at Gladstone, Mich., on July 14, 1904. During much of his early life he was at Minneapolis, Minn., where he attended the University of Minnesota. Thereafter, he entered the employ of the Soo Line, serving in turn as rodman, instrumentman and assistant engineer. He was advanced to division engineer at Stevens Point in June 1935.

Mr. Cable became a member of the Association in 1937 and was appointed to serve on Committee 1 in 1944. He was intensely interested in the work of the committee and contributed generously of his time and efforts to its program. His passing is deeply regretted by his many friends on the railway and in the Association.

Report on Assignment 2 (a)

Physical Properties of Earth Materials

Roadbed. Load Capacity. Relation to Ballast. Allowable Pressure

L. R. Lamport (chairman, subcommittee), L. S. Crane, J. C. DeJarnette, Jr., J. W. Demcoe, J. G. Gilley, Albert Haertlein, F. W. Hillman, L. H. Jentoft, J. W. Poulter, C. S. Robinson, A. W. Schroeder, R. G. Scott, A. A. Winter.

This is a progress report submitted as information, dealing with the use of pressure cells and other means both in the field and in the laboratory for determining pressures in railroad subgrades under moving loads and characteristics of various types of soils in service.

It is the purpose of this subcommittee to approach the problem from a practical angle so far as possible, with field tests and observations of conditions under service, backed up to the extent required by laboratory tests, and laboratory tests designed to simulate field conditions. Under these categories two series of tests have been set up under the sponsorship of this committee. The work is being done by the research office of the Engineering Division of the AAR and the Engineering Experiment Station of the University of Illinois under the general direction of G. M. Magee, research engineer and Dr. R. B. Peck of the university staff. The field work is handled by Rockwell Smith, roadway engineer of the research staff.

At present the field tests consist of an installation of soil pressure cells on the Chicago, Burlington & Quincy Railroad about a mile west of Red Oak, Iowa. Fig. 1 shows the location, depth and other details of the gages. They were installed the last week in May 1948, and a series of runs under normal traffic were begun during the week of October 18, 1948. A report on this installation follows on page 652.

Due to the highly experimental nature of the tests, the members of the subcommittee and the personnel of the research office cannot at this time state what will be determined or whether any useful information will come of the tests. It is the hope that the investigation will be fruitful and bring about a better understanding of the functioning of the railroad structure from the foundation of the roadbed up through the subgrade, the ballast, the ties and the rail.

Another field investigation which is getting under way has to do with the construction of a relocated line near Grenada, Miss., on the Illinois Central Railroad. This relocation, necessitated by a government dam and reservoir, will be constructed under the latest methods of moisture and compaction control. The soils going into the grade will be tested and all this information will furnish a good record for comparison with the field performances when in service.

In connection with this investigation a series of laboratory tests is being run with the oscillator now in operation at the University of Illinois. The first report of the apparatus and test procedures is included as Part II of the report on roadbed stabilization. This oscillator is designed to apply simulated traffic loads to a small section of ballast and subgrade soil. By correlating the same soils in field performance and accelerated laboratory tests it is expected that this apparatus may be valuable in determining the rate and manner in which instability in railroad subgrades first takes form.

This year it is hoped that field tests can be made with an oscillator of different and heavier design to determine among other things whether or not it is possible to classify embankment now in service with regard to instability. Also projected is a series of penetration tests with a cone penetrometer on a number of slipping fills in an attempt to determine shear strengths of soils. This method has been used extensively and successfully in Holland and Belgium to determine safe heights of fills on questionable foundations and should be adaptable to problems encountered on American railroads.

For all these projects laboratory tests will be required to identify the soils and their characteristics.

Soil Pressure Cells

Introduction

Last year a preliminary report was made on the use of soil pressure cells, Proceedings, Vol. 49, 1948, pages 499–506. This report dealt mainly with the various types of cells tested and on the basis of results obtained, 13 pressure cells of the AAR type were placed under a main line track in 1948, and records obtained with normal traffic. This work was conducted, under the general direction of G. M. Magee, research engineer, by Rockwell Smith, roadway engineer and M. F. Smucker, assistant electrical engineer of the research staff of the Engineering Division, Association of American Railroads.

There is still considerable difference of opinion among members of the engineering profession dealing with soil pressures and allied subjects as to whether present designs of pressure cells permit any quantitative measurement of actual pressures. The results shown by the limited tests in 1947 indicate very strongly that qualitative measurements are possible and the tests last year, while limited in extent, were designed further to verify the qualitative measurements and so far as possible to indicate the quantitative properties. In addition, last year's tests included cells in a vertical plane to measure horizontal pressures, as well as vertical pressures. It is in regard to horizontal pressures occurring within a soil mass that the least is known and this is a very important consideration in the study of stability in railroad subgrades. Last year's tests also included test runs of normal traffic both before and after grouting. Refinement in measurement

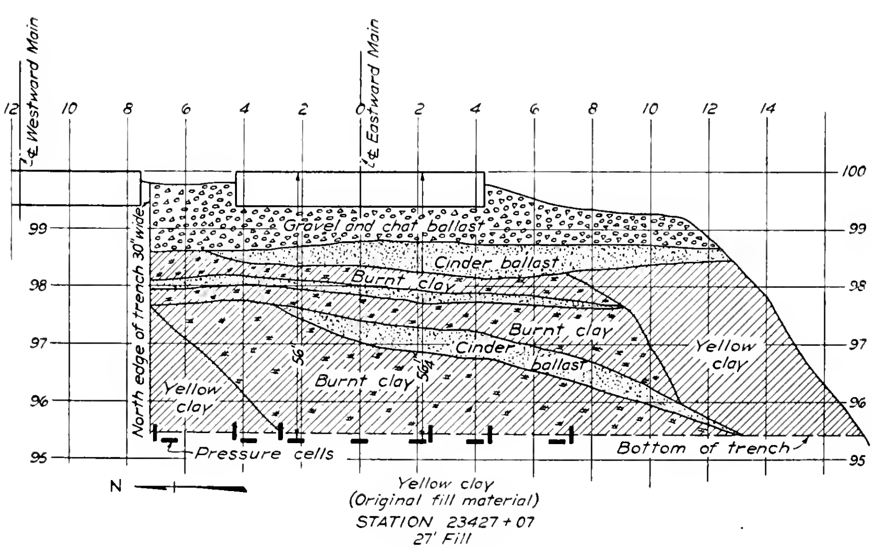


Fig. 1.—Trench Section Showing Location of Soil Pressure Cells.

of soil pressures has not reached the point where it was thought that a three-plane system of measurement, theoretically required for complete analyses, would produce information of sufficient value to justify the greater expense.

Discussion

A total of 31 runs were recorded. Data obtained include oscillograph records both for the pressure cells and for maximum bending stress in five tie plates in the track over and immediately adjacent to the pressure cells. These latter records will give by conversion, a close approximation of the actual load on ties and will assist in evaluating the degree of accuracy of the registered soil pressures. Time has not permitted the tabulation and analyses of the data for inclusion in this report but a brief discussion of the test methods follows:

The cells were installed under the eastward main track of the Burlington, M. P. 443–70 near Red Oak, Iowa, on May 19, 1948. This fill is discussed in the report on methods of roadbed stabilization. The location of the pressure cell installation is at the west end of the unstable portion of the fill. Instability here had not developed to an extent affecting the slopes, but had progressed sufficiently to provide more than four feet of ballast material. Fig. 1 shows a cross section of the trench as dug and the location of the pressure cells. In back-filling the trench the burnt clay and cinders were mixed to give a covering of uniform material. The clay in which the cells were placed

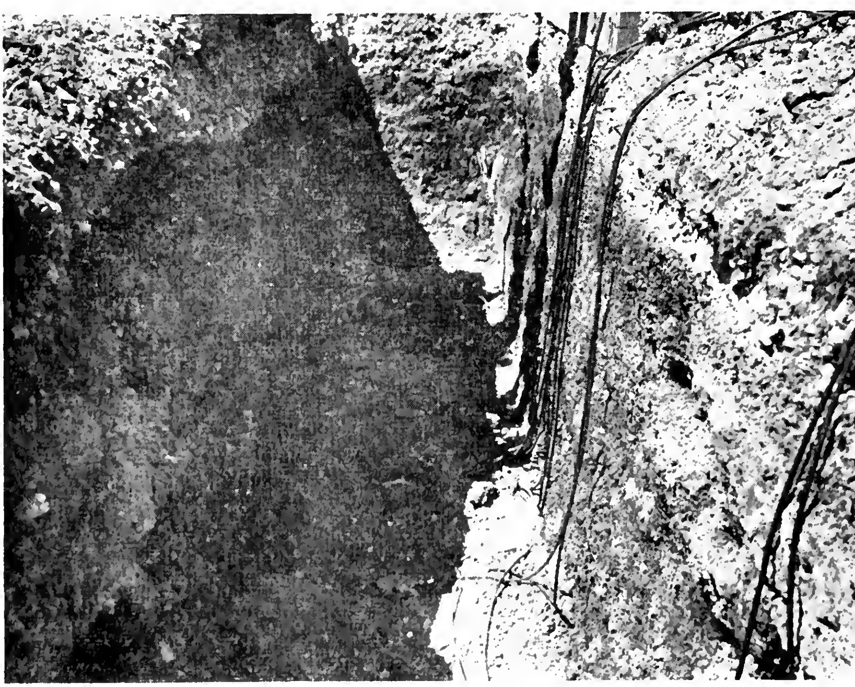


Fig. 2.—Trench Excavation Showing Pressure Cells.

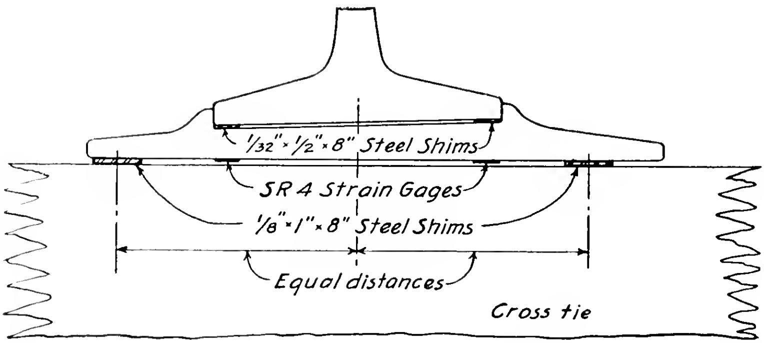


Fig. 3.—Strain Gages Attached to Tie Plate to Measure Actual Tie Loading.

was of medium to high plasticity and tests showed a field moisture condition of 4 to 6 percentage points above the plastic limit. Fig. 2 is a photograph of the open trench with the cells in place.

Fig. 3 shows the shimming arrangement and SR–4 strain gages on the tie plates on the south rail. Five tie plates were so connected: The tie over the center of the trench and two ties each way. Wire cables from the strain gages led to the oscillographs which permitted the stress in the plates to be recorded simultaneously with the pressure cell readings. The recording equipment was set up in a truck at the foot of the fill as shown by Fig. 4. The 10 gages on the tie plates and 13 pressure cells, necessitated the use of 23 oscillographic channels, recording on two rolls of sensitized paper. A marker also recorded passage of each wheel over the cells.

Records were made of 31 train movements over the cells, on both passenger and freight trains with steam and diesel locomotives. These runs were completed October 27, 1948. Twenty-two runs were recorded prior to grouting, one run during grouting, and eight runs four days after grouting.

The grouting of this fill was extended to cover the location of the pressure cells. Injections with 6 and 8-ft. points were made on each side of the trench location for each side of the track but no injections were made directly into the backfilled trench and onto the cells. Fig. 5 pictures the grouting around the cells. The oscillograph was switched on during the grouting and the record indicates that the grouting pressure was reflected to a small extent on the cells. These traces also show the pulsations of the group pump at regular intervals. It did not appear that the grout penetrated around the cells but that this pressure was transmitted through the soils from the pressure behind the grout. Grout acceptance ran approximately 6 cu. ft. per track foot in the vicinity of the cells.

The sensitivity of the pressure cells and the recording equipment enabled the records to show galvanometer trace deflections of approximately one inch for vertical pressures of 2.0 psi., and horizontal pressures of 1.65 psi. All pressure cells functioned satisfactorily throughout the tests except No. 5 which did not register because of failure in the electrical circuits within the cell itself. Both vertical and horizontal pressures showed the same pattern for any cluster of two cells; that is, any impact or load application shown by the cell measuring vertical pressure is also shown by the other cell, their traces being similar in detail. The horizontal pressures recorded were in general 40 to 80 percent of the vertical for cells under the tie but considerably higher for the cells outside of the tie limits.

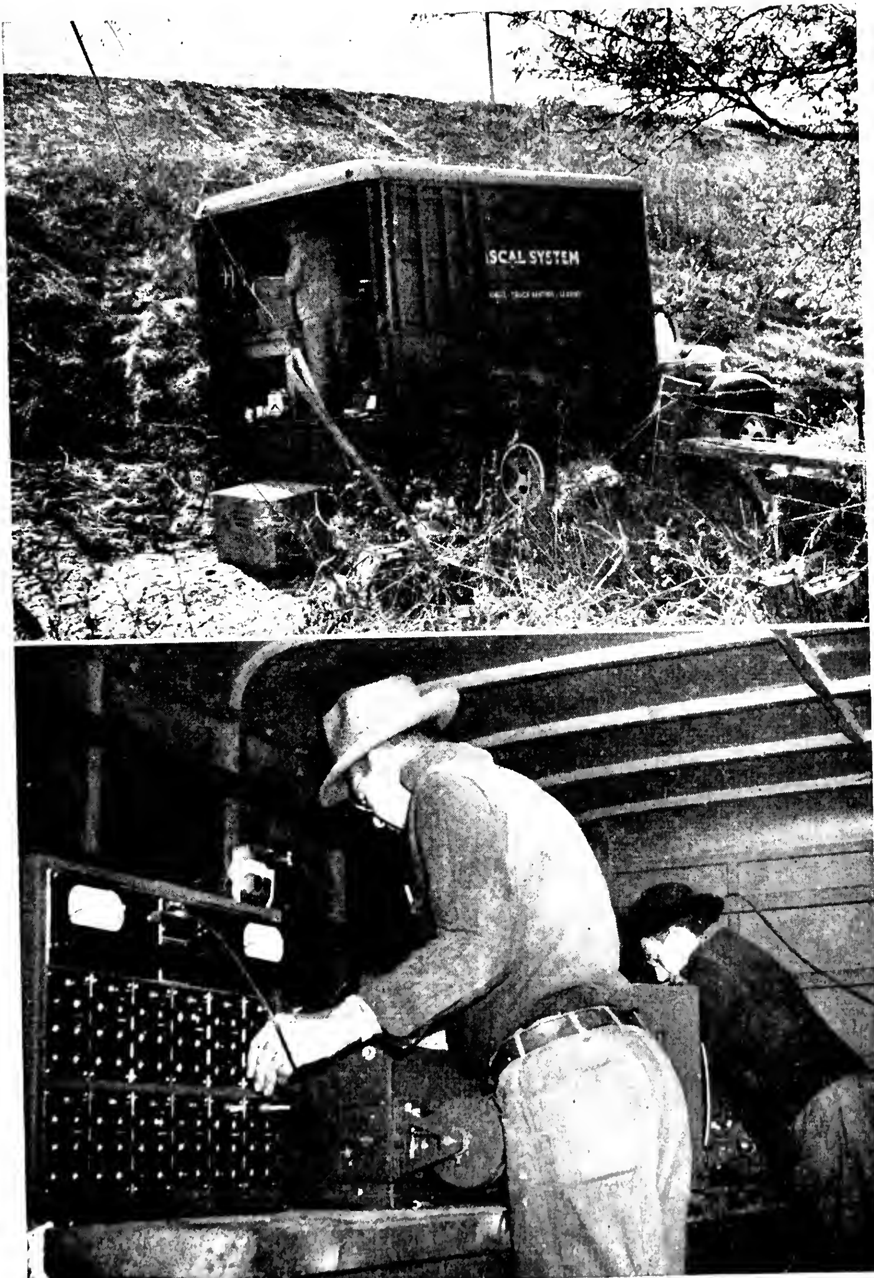


Fig. 4.—Oscillator Equipment and Truck Used for Dynamic Recordings.

Fig. 5.—Grouting in Area of Pressure Cell Installation.

Conclusion

Until the recorded data have been all tabulated and tie pressures computed no conclusions can be drawn as to the accuracy of the recorded pressures. Inspection of these records does show however that sufficient detail has been recorded to make the records of interest and value even if the presence of the cells has disturbed the soil structure and broken up the normal stress pattern. It is apparent that the cells are registering pressures and variations in pressures faithfully and showing impact and vibratory effects in detail. From inspection of the records there is not apparent any appreciable change in either vertical or horizontal pressures after grouting, but the cells have been left in place and another series of runs will be obtained in the spring of 1949. Last year's records show again as did those taken a year earlier that the condition of tamping of the tie will affect appreciably the load carried by that tie and the magnitude of soil pressures thereunder.

Report on Assignment 6

Roadway: Formation and Protection

B. H. Crosland (chairman, subcommittee), W. T. Adams, T. A. Blair, A. J. Boase, J. M. Boles, L. H. Bond, L. S. Crane, J. P. Datesman, T. F. de Capiteau, J. C. DeJarnette, Jr., G. W. Payne, J. W. Poulter, C. S. Robinson, A. W. Schroeder, F. H. Simpson, A. A. Winter.

Your committee has been given three subassignments under the general assignment of Roadway Protection, namely: 6 (a) Roadbed stabilization; 6 (b) Construction and protection of roadbed across reservoir areas; specifications and 6 (c) Chemical eradication of vegetation.

In order that these three subjects might be properly progressed, your subcommittee has been further subdivided into three sections, each with its own section chairman to cover the specific assignment.

Report on Assignment 6 (a)

Roadbed Stabilization

F. H. Simpson (chairman, section a), A. J. Boase, J. W. Poulter, A. W. Schroeder.

This is a progress report, presented as information.

1949 Report of the Investigation of Roadbed Stabilization

This is the fourth progress report on the investigation of methods and results of stabilization of railroad roadbeds, and has been conducted under sponsorship of Committee 1—Roadway and Ballast by the Engineering Division research staff in cooperation with the Engineering Experiment Station of the University of Illinois. G. M Magee, research engineer of the Engineering Division, AAR, and Dr. R. B. Peck, research professor of soil mechanics of the university staff, directed the work. Rockwell Smith, roadway engineer, research staff, performed the field work and prepared this portion of the report. Laboratory tests and research and the report on these activities were under the direction of Dr. Peck, assisted by Dr. T. H. Thornburn and H. O. Ireland, also of the university staff.

Part I—Field Studies and Results of Roadbed Stabilization Grouting

During 1948 more than 35 railroads pressure grouted various lengths of track. There is now a record of more than 55 railroads that have used this process for the correction or improvement of unstable track. The widespread use of the procedure is indicative of its acceptance as a possible corrective measure for certain types of subgrade instability, and each year the method has been adapted to cover a greater range of instability problems and more severe conditions. Grouting of fills up to 100 ft. in height is an example. Injection of grout is no longer considered an experiment but is expected to lead to successful stabilization. However it is stated emphatically that treatment by grouting, like any other procedure is not a cure-all. Methods of grouting must be adapted to fit the individual project and a study of the conditions involved is as necessary for specifying treatment as a survey is for a track layout. This study may also indicate other methods of stabilization to be equally or more effective at less cost. No one panacea for all subgrade ills has been discovered and none is expected.

Cost Data

The success in terms of labor or dollar savings that can be attributed to grou stabilization is tabulated in Tables 1 and 2. A majority of the projects reported have been inspected in the field. On a number of projects full data can not as yet be reported. These jobs are listed to provide in future years a continuous record of projects that embrace interesting features or unusual conditions. It is of interest to note that the Pennsylvania Railroad (Table 2) reports two jobs, one 12 years old and one 10, on both of which the assessable savings for the period involved have been appreciable and continuing. The New York Central and the Atchison, Topeka & Santa Fe (Table 1) report jobs six years old with similar results. These data indicate the maintenance costs over these sections have been reduced to normal by the restoration of stability to the roadbed through pressure grouting, and that normal maintenance requirements have continued over a number of years without appreciable increase with time.

The savings reported are those of labor only. The saving in material, especially ballast is known to be great but the various roads have usually not attempted to assign a definite quantity or cost to this item. In the case of the Great Northern Railway, however, a saving in ballast is reported. No value has been assigned to the ballast that is included in the man-hour savings, but the maintenance cost prior to grouting includes the working of this ballast. The track on which these savings were obtained passes through low cuts and fills containing severe water pockets and squeezes; prior to grouting the additional ballast was required to maintain line and surface.

A study of the tabulation indicates that the greatest saving has been obtained from the grouting of soft track, water pockets and squeezes. This confirms the experience of a number of roads that have kept a close check. In addition to the stabilization of ordinary soft track considerable of the grouting activity this year has been on slipping and sliding fills. Other factors that can not be evaluated directly in terms of dollars or man-hours, such as elimination of slow orders, correcting an incipient failure or a possible hazard to safe operation, have been determining factors overbalancing the direct savings effected on soft track grouting.

Fill Grouting

It is in fill grouting that the most spectacular corrections have been achieved. Later on in this report a few individual projects will be discussed in more detail. Some fills have accepted grout in volume equal to 10 percent of the volume of the fill and in one case a short section accepted grout in a quantity that approximated 20 percent of the volume of the fill. Some of these fills of high grout acceptance are on practically flat land and there is little probability that any of the grout emerged outside the limits of the fill. Fig. 1 shows a fill of this type. Such break-outs are more probable on fills on sloping ground or along river banks, on which grout acceptance often runs higher.

It is along rivers that fills are subject to greatest stress. Several factors are involved; such as a possible slippage between the fill and original ground aided by seepage and surface water lubrication, the possible undermining of the stream slope by high water and the additional stress put on the soils by the withdrawal of lateral support and the unfavorable seepage pressures following a drop in the water elevation. Fig. 2, pictures a sliding fill of this type. Fills often start sliding after a sudden draw down of water. Such slides can easily develop into a break of serious proportions.

TABLE NO. 1

A.T.& S.F. GROUT TEST SECTIONS
WATER POCKETS AND SOFT TRACK

Location	Date Grouted	Length Section Miles	Mixtures	Cu.Ft. Grout per Lin.Ft. Track	Cost per Tr.Ft.	MAINTENANCE SPOTTING TRACK: Before Grouting Man Hours Per Year Per Mile	After Grouting - Man Hours Per Yr. Per Mi.: 1st year	2nd year	3rd year	4th year	5th year	6th year	Avge	Avge Saving Man Hours Per Mile Per Year
Thatcher, Colo. MP 595-603 4 locations	5/42 to 9/42	3.4	1/8-1/40	1.42	0.535	7359	1463	2544	*3742	2860	2670	2652	3155	4204
Maxwell, NM MP 684-685	12/42 to 8/43	1.0	1/4-1/8	1.26	0.68	3614	1803	1424	846	1169	1218		1292	2322
Dermott, Tex. MP 748-749	2/43	1.0	1/8	1.45	0.56	2952	731	1443	2015	1718	304		1242	1710
Maxwell, NM MP 682-683	7/43	1.0	1/8	1.05	0.65	2743	2927	1746	555	216	856		1260	1483
Edgerton, Kas. Curve 47	11/43	0.218	1/6	3.17	1.46	6595	1464	2840	3574	2935	2546		2672	3923
Taiban, NM MP 704-709	5/44 to 7/44	5.0	1/10	2.18	0.50	1813	321	606	630	798			589	1224
Onava-Azul, NM MP 761-762	7/45	1.0	1/16	3.95	1.58	6750	2541	1415	1813				1923	4827
Texico, NM MP 649-651 Double Trk.	12/45 to 7/46	4.0	1/16	6.21	2.43	2535	1581	629					1105	1430
#Snyder, Tex. MP 775-776	7/46	1.0	1/32	2.5	0.52	806	622	328					475	331
Average of water pocket test sections................................						3927	1828	1422	1882	1616	1519		1524	2403
- - - - - - - - - - -														
Sliding Fill														
#Brenham, Tex. MP 126 plus Sliding embankment	9/46 to 3/47	0.354	1/16	35.14	8.89	6215	424						424	5791

#A.R.E.A. designated test sections.
*Includes spotting behind out-of-face resurfacing.

NEW YORK CENTRAL - GROUT TEST SECTIONS
WATER POCKETS & SOFT TRACK

						Dollars per year per mile	Dollars per year per mile							Dollars
Monroe, Mich.	1941	0.362	1/1	1.25	0.65	7800	245	212	1875	1570	314	311	754	7046
Port Clinton, O.	1942	0.555	1/1	1.50	0.90	14600	288	862	829	304	0.0		471	14312
Canada Division	1943	0.827	1/1	2.77	1.60	10500	1038	1410	1760	922			1283	9217
(" ") (Welland, Ontario)	1945	1.403	1/1	5.75	2.83	10080	943	360					652	9428
Hillsboro, Ill.	1945	0.615	1/1	4.54	1.07	21300	5760	160					2960	18340
Corunna, Ind.	1946	0.488	1/1	5.62	2.95	5450	0.0	211					106	5344
Average of water pocket sections - - - - - - - - - - - -						11623	1379	536	1488	932	157	156	1038	10614
Sliding Fills: $ Per year for section grouted														
Bridge 222 Guilford, Ind.	1945	233 feet	1/1	31.8	18.06	2859.72	31.20	0.0					15.60	2844.12
M.P. 33.16 Near Weisburg, Ind.	1947	400 feet Double tr.	1/1	15.0	9.60	228	0.0						0.0	228

TABLE NO. 2 -- GROUTING AND MAINTENANCE DATA

Railroad and Location	Year	Length of Section Reported Tr. Feet	Grout Acceptance cu.ft. per tr. ft.	Grout Mixture Cu. Ft. Cement	Sand	Fly-Ash	Gal. Asphalt	Character of Track Ballast Type & Type of Instability Max Cut & Fill	Cost of Grouting tr.ft.	Cost of Grouting cu.ft.	Maintenance Data Before Grouting	Maintenance Data After Grouting	Period of Record Before	Period of Record After	Remarks Grouting Equipment & Type of Work
AT&SF - See Table No. 1															
B&O															
North Baltimore, O.	1946	6,274	2.50	1	10	-	-	Crushed stone, squeezes, pockets, cinders	0.74	0.30	3,672 hrs.	1,760 hrs.	9 mo.	9 mo.	Hydraulic, track only
Near Sibley, Mo.	1946	6,917	9.02	1	14	-	-	" " unstable fill, soft track	4.46	0.49	5,529 hrs.	2,554 hrs.	9 mo.	9 mo.	" track & fill
E. St. Louis, Ill.	1947	7,562	5.76	1	8	-	-	" " " 10' fill	2.31	0.40	-	-	-	-	" " "
Can.Nat.															
Stevensville, Ont.	(1946)	1,232	2.01	1	1.5	-	-	Crushed stone & gravel 10' max. fill	2.35	(1.14)	3,440 hrs. per yr.	(541 hrs.) (per yr.) (Eliminates shims)	1 yr.	2 yr.	Pneumatic track only
	(1946)	520	1.67	1	1	-	-		2.15	(1.29)					
CB&Q															
Alliance Div.M.P. 430	1946	6,336	7.85	1	7	0.5	0.67	Crushed stone, soft track, unstable fills	2.20	0.28	$550.80 per yr.	$402.24 per yr.	5 yr.	2 yr.	Hydraulic track & fill
Near Beardstown, Ill.	1946	200	14.59	1	3	0.5	0.5	Cinders, sliding 50' fill	6.12	0.42	2,107.28	6.0 per yr.	1 yr.	2 yr.	" " "
Alliance Div.M.P. 460	1947	1,320	5.76	1	7	0.5	0.67	Crushed stone low fills	2.56	0.44	*661.80 per yr.	0.0 per yr.	5 yr.	1 yr.	" " "
St.Joseph Div.M.P. 130	1947	2,884	5.23	1	4	0	0	Chat - Low fills	2.58	0.49	1,335.68 per yr.	89.42 per yr.	1 yr.	1 yr.	Pneumatic track only
C&NW															
Near Mondamin, Ia.	1945	10,560	4.2	1	7	-	1.0	Cinders, unstable 7' fill	1.59	0.39	6,440 hrs.	1,824 hrs.	1 yr.	1 yr.	Hydraulic, track only
Near Council Bluffs, Ia.	1946	12,500 (approx)	4.1	1	7	-	1.0	Crushed stone, gravel, cinders, unstable 10' fill	1.89	0.46	2,085 hrs.	448 hrs.	6 mo.	6 mo.	(Hydraulic & pneumatic, track only, welded rail)
Near Clinton, Ia.	1946	325 "	27.9	1	3	-	0.5	Crushed stone & cinders, sliding 30' fill	16.02	0.43	-	-	-	-	Hydraulic, track & fill
Near Salix, Ia.	1947	6,500 "	4.0	1	7	-	1.5	Cinders, soft track, unstable 4' fills	-	-	3,360 hrs.	1,805 hrs.	1 yr.	1 yr.	" " "
CMSt.P&P.															
Near Owego, Ia.	1945	16,297	1.65	1	4	-	-	Gravel, cinders, pocketed soft track, 6' fill	1.36	0.83	$2,370.00	$748.00 per yr.	1 yr.	2 yr.	Contract pneumatic, track only
CRI&P															
Mercer-Princeton, Mo.	1945	14,095	3.16	1	6	-	-	Chat & mine waste, soft track, cuts & fills	0.79	0.25	(100%) (100%)	(50%) (100%)	2 yr.	3 yr.	(Hydraulic, variable maint. saving)
D&H															
Whitehall, N. Y.	1947	(524)	2.00	1	1½	-	-	Stone ballast on timber mat over wet clay	3.04	1.52	1,129 man hrs.	0.0	1 yr.	1 yr.	Pneumatic over mat
		(335)	4.78	1	1⅓	-	-	" " " " " " " "	6.93	1.45					" under mat
Smith's Basin, N. Y.	1948	2,841	3.60	1	1-1/3	-	-	" " , pockets 6' cut to 10' fill	3.35	0.93	2,366	No record yet	1 yr.		" Ballast Pockets
D&RGW															
Near Silt, Colo.	1946	900	2.64	1	10	-	0.75	Black Slag, unstable 10' fill	-	-	(per month) (63½ hrs.)	(per month) (17.8 hrs.)	1 yr.	1½ yr.	Pneumatic, track & fill
Clay, Colo.	1948	8,962	1.64	1	10	-	1	" " " hillside	1.10	0.67					" " "
Great Northern											Man hours per yr.				
Near Glasgow, Mont.	1946 & 1947	8,012	4.51	1	6	-	1	Gravel, pocketed & splitting fills 10'	1.73	0.44	11,930	728	1 yr.	1 yr.	Pneumatic, 1570 C.Y. ballast saved
Near Fargo, N. Dak.	1946 & 1947	10,545	5.36	1	5	-	1	" soft track 4' fill	1.88	0.35	15,015 800 c.y. ballast	7,600 300 c.y. ballast	1 yr.	1 yr.	" track only
Near Wahpeton, N.Dak.	1947	19,701	2.65	1	5	-	2	" " " " "	1.12	0.36	15,368 5800 c.y. ballast	4,176 No ballast	1 yr.	1 yr.	" " "
Illinois Central															
Robbs, Ill.-Tunnel No. 2	1945	3,215	1.90	1	0	-	-	Crushed rock, tunnel, mud boils	4.07	2.13	(per month) (516 hrs.)	(per month) (256 hrs.)	1 yr.	3½ yr.	Hydraulic on track equip.
Chicago Terminal	1944	80	13.9	1	4	1	-	Crushed rock, soft track, double slip switch	8.42	0.61	Weekly	Occasional	1 yr.	3 yr.	Pneumatic, track only
Carbondale Yards	1946	3,577	1.48	1	7	1	-	Cinders, squeezes, soft track	0.38	0.26	(per month) (192 hrs.)	(per month) (10 hrs.)	1 yr.	2 yr.	Hydraulic, on track equip.
Near Bluford, Ill.	1947	1,521	23.30	1	7	1	-	Crushed slag, cinders, sliding fill	8.18	0.35	1,248 hrs. per year	Normal Maintenance	1 yr.	1 yr.	Hydraulic, track & fill
Litchfield & Madison															
Near Glen Carbon, Ill.	1947	4,214	6.04	1	6	1	-	Cinders, 10' sliding & unstable fill	-	-	(100%)	(5%)	1 yr.	1 yr.	Hydraulic, track only
Louisville & Nashville															
Near Cullman, Ala.	1947	1,200	2.00	1	1	-	-	Crushed slag, wet 20' shaly cut	-	-	-	-	-	-	Hydraulic, track only
Mo.Kan.Tex.															
Moran-Savonburg, Kans.	1945	8,941	3.74	1	8	-	1.0	Chat, pockets & soft track, 10' cuts & fills	2.45	0.65	Estimated 3,730 hrs. per yr.	655 hrs. per yr.	2 yr. 9 mo.	2 yr. 9 mo.	Contract hydraulic, track only
Northern Pacific															
Centralia, Wash.	1947 & 1948	16,620	8.85	1	6		1.2	Gravel-soft track unstable fill - 8'-12'	4.05	0.457	-	-	-	-	Hydraulic, track & fill
Pennsylvania															
Near Bedford, O.	(1946 & 1947)	6,416	5.02	1	1	2 Lime dust	-	Crushed stone, soft track, 20' cut	2.64	0.53	-	Annual Saving $2,015.00	1 yr.	2 yr.	Hydraulic, track only includes 2,204 tr. ft. grouted twice.
Fort Wayne, Ind.	1938	-	-	-	-	-	-	5 water pockets - 62' to 90' in length	Total	$1,000	360 hrs. per yr.		1 yr.	10 yr.	
[illegible] Point, Md.	1936	75	-	-	-	-	-	Water pocket	"	700	1,400 " " "		1 yr.	12 yr.	
New York Central System - See Table No. 1															

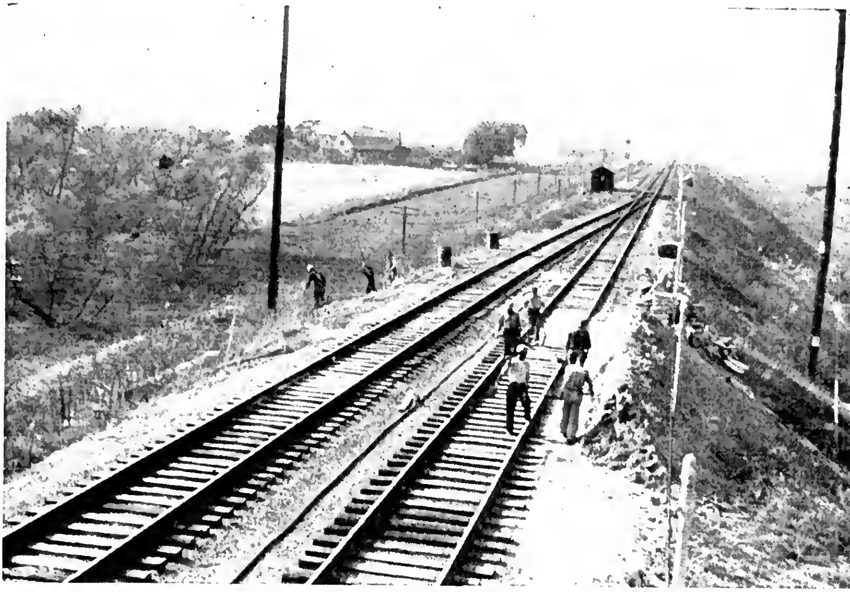


Fig. 1.—Fill on Level Ground with High Grout Acceptance. Burlington, Western Iowa.

Fig. 2.—Typical Sliding Fill Along Yellowstone River. Northern Pacific, Eastern Montana.

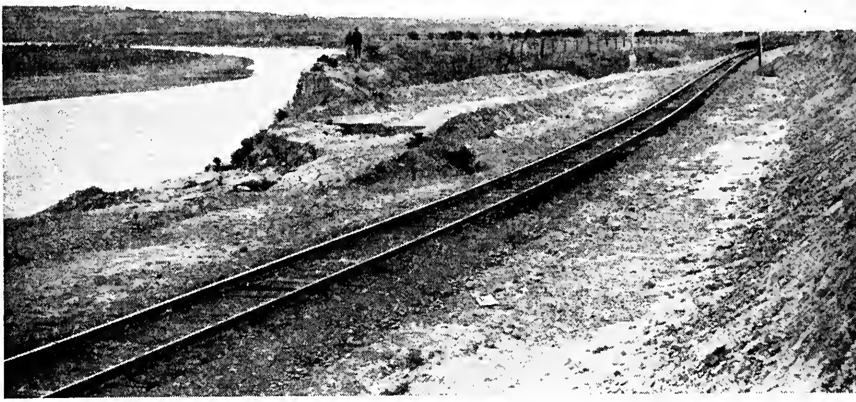


Fig. 3.—Slide in Silt. River Bank. Yellowstone River, Montana, Northern Pacific.

Fig. 4.—Unstable Fill Showing Shoulder Cracking. Wheeling & Lake Erie, Baltic, Ohio.

Several railroads have grouted fills of this type. The Santa Fe reports six in Missouri and Kansas, five of which have been very successful. The sixth fill broke to a greater depth than was anticipated, behind and under the grout and was regrouted in 1948. Details on these fills are not available for this year's report. The Northern Pacific has also grouted several fills of this type, one of which is later described in some detail.

Grout acceptance on these fills also can run very high especially in rough country where the fills may contain considerable broken rock. As mentioned above there is a possibility that grout may escape into the adjacent river. However, by limiting the quantity pumped into any one hole and allowing a period for this grout to set up before further injection in the same area, such losses if any will be reduced considerably. This is further verified by the fact that grout break-outs occur eventually within view and usually within the confines of the embankment.

High grout acceptance in fills of this type containing a quantity of broken rock is more readily explainable than the high acceptance in fills composed principally of soils. While most of these latter type of fills have been predominantly clayey in the cores, a few have been observed in which the soils have been silts. Three of these have slid rapidly and extensively but have not yet been grouted. Fig. 3 shows one such slide in silty soils along the Yellowstone river. A fourth has been grouted with a grout acceptance comparable to that of many clay fills. This fill had not been subject to any definite slide but the track was distorting badly and had been a source of high maintenance costs. Observations on these and other fills indicate that fills of silty soil while stable when compact can lose stability suddenly when saturated and subject to vibration. Clay fills tend more to plastic flow distortion, relatively slow, but more continuous.

Some fills are now showing unstable characteristics after many years in service with no abnormal maintenance. Others that have been troublesome for years have required additional measures and expense for maintenance. Fig. 4 shows such a fill. Two general reasons appear as possible contributing factors.

1. Increase in speeds, axle loads and tonnage. As an example of increased transportation performance the average freight car-day has more than doubled as measured in net ton-miles since 1918, according to the Association of American Railroads. The average speed of freight trains has increased by 52 percent and the capacity of the average freight car has been increased 22 percent during the same period. Average cargo tons per loaded car in 1943 (the maximum year to date) was 41.0 tons against 35.1 tons in 1926 and 35.5 tons in 1933. The increase in speeds especially tends to require greater maintenance attention.

2. The second factor possibly affecting the development of instability is the increased rainfall over portions of the midwest and northwest during the past nine years. Following the severe droughts of the 1930's, rainfall in many areas has been above normal. This is especially true of the Dakotas and Montana, where large crops have been recorded for the nine years just past. During this time considerable instability developed on railroads traversing the area. Both the increased rainfall and the additional traffic entailed by the bumper crops would tend to increase subgrade troubles.

The considerations outlined above are possible contributing causes to subgrade instability but the chief causes are the moisture conditions, the character of the soils comprising the subgrade, and normal wear and tear on the earth structure. All these causes apparently affect roadbed stability according to the strength of the soils in service. Granular soils are usually stable under most conditions obtaining in railroad subgrades.

As an example, unstable subgrades have been noted in central California with a rainfall of about 15 in. per year falling 60 percent within three continuous months, and

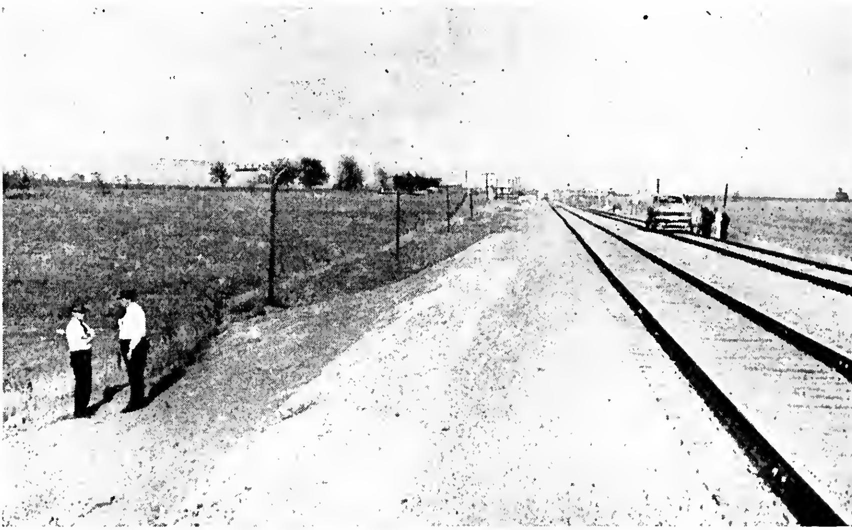


Fig. 5.—Unstable Fill, Pottsboro. Sadler Revision M-K-T R. R.

Fig. 6.—Soft Track Across Reservoir Area. Illinois Central Railroad, Coldwater, Miss.

also in northwestern Nebraska and southwestern South Dakota, with less than 20 in. annual rainfall. Other sections, such as portions of the eastern seaboard, and Florida with 60 in. of annual rainfall show little or no instability on subgrades predominantly sandy.

Nor is the stability problem limited to old grades. Elsewhere in this report two line revisions are discussed. By all known criteria these roadbeds were stable when built for the loads imposed. One went into service in 1942. On this project, mostly fill about 12 ft. high, no moisture or compaction control was specified, but the procedure did entail construction in lifts of approximately 8 in. The fill was built with off-track crawler and rubber tired equipment and sufficiently compacted by normal procedure to preclude the possibility of any large voids. The other project was put into service in 1944. On this job density and moisture control was specified. The maximum cut and fill for the project are approximately 30 ft. each. The grade was capped with 10 in. of limestone screening prior to the placement of crushed stone ballast. Some of the slopes were later flattened by the railroad to 2½ to 1. Soils were predominately shaly clays. Fig. 5 shows a view of this revision.

Both of these revisions have been extremely troublesome since the advent of operation. The first was subject to soft track conditions and continuing off level and off grade track. There was little or no apparent distortion of the fill. This fill was grouted this year. The second revision has been subject to soft track, sliding and sloughing cuts and fills, and water pockets. Even fills with 2½ to 1 slopes have split at the shoulder and moved out. Maintenance has included the installation of a large number of French drains, poles and ties driven at the tie ends, and berms. These corrective measures have helped but have not been permanent. Grouting is now proposed. Water is present seasonally along only a very small portion of this revision.

Experience on these revisions raises serious doubt that without soil selection or special treatment, present-day construction practice will produce sufficient strength in plastic soil embankments to maintain their stability under prevalent traffic and weather conditions. As the same procedure is used to build stable earth dams at much greater heights, it would appear that the make up of the ballast and track section and the vibration of moving loads are important factors in the performance of railroad roadbeds. Brief descriptions of a number of specific projects follow.

Illinois Central

Fig. 6 shows views of an Illinois Central fill across the reservoir area of the Coldwater river near Coldwater, Miss. This grade was constructed in 1942 at the time of the construction of the Coldwater dam and lies 58 ft. west of the old line and 10 to 15 ft. higher. The soils used were borrowed from several pits to the north and south of the revision. The upper portion of the embankment north of the bridge consists of very heavy plastic clay and to the south the fill is predominately silt of low plasticity as compared to the clay. As an example, a sample of the clay showed a plasticity index of 36 and of the silt 10. Both portions of the fill, however, are sections with high maintenance costs and the Illinois Central started grouting on the south portion this year, and is considering the grouting of the remainder of the revision later. The south portion of this fill is the first section of considerable extent containing predominately silt soils that has come to the attention of this investigation.

Although the specifications governing the construction of this embankment did not call for moisture and compaction control, the fill was built in lifts of about 8 in. with the hauling equipment passing over each lift. This would be sufficient to insure considerable compaction. The fill itself does not seem to be unstable. The work in maintaining track involves only the top of the embankment, pumping ties and line and surface maintenance. Pockets have been developed especially in the clay subgrade. Water is present along the sides of the fill for portions of each year. For the silty soils with their high and rapid capillarity this ready supply of water, together with the rainfall on top of the grade, probably has led to saturation. Silts when saturated can rapidly lose their stability, and troubles in the fill itself are a future possibility if untreated. The grouting can reduce this tendency.

Grout acceptance on the portion of this fill, composed of silt (6806 ft. long) that was grouted this year, averaged of 7.63 cu. ft. of grout per track foot. Portions of this fill accepted 35 cu. ft. per track foot which for a 12 ft. fill is approximately 7½ percent of the volume. During grouting considerable water was forced from the embankment. This acceptance is relatively high for a new fill, but it should be good insurance against future possible fill failures. Grouting was done with a mud-jack using a mix of 1 part cement, 1 part fly-ash and 6 parts sand. Results are satisfactory to date.

The experience of the Illinois Central on this fill indicates that high maintenance may occur on new roadbeds even where constructed with modern methods and equipment. Further indications of this are more forcibly shown in the revision described immediately below.

Missouri–Kansas–Texas

The Missouri–Kansas–Texas in 1944 put into service its Pottsboro–Sadler revision on the Fort Worth division in north Texas. This revision approximately 8 miles long was built by the U. S. Government to replace an old line which was inundated by the reservoir waters of the Denison dam across the Red river. The specifications provided for the latest approved practice in moisture and density control with sheepsfoot rolling, shallow lift construction, etc. The subgrade was capped with 10 in. of limestone screenings on which the ties were laid and the ballast applied. Care was taken to avoid rutting of the subgrade or subballast during any of these operations.

Fig. 7.—Unstable Cut Slopes and Berm. M–K–T R. R., Pottsboro—Sadler Revision.

The soils are chiefly clays and clay shales, which slake rapidly in air and moisture. They were classified by the U. S. engineers as developed from Eagle Ford shale, the parent material. Little or no attempt was made at soil selection but there was little choice, as all the soils were similar except for one cut consisting of a sandy clay material. It is interesting to note that this cut and the fills adjacent are the only ones on the whole job that didn't develop a marked degree of instability. One cut especially gave trouble before the revision was put into service. The slopes sloughed badly and in two places extensively. This cut is approximately 30 ft. in depth through clays and shales which apparently slake rapidly. To reduce slope failures it was necessary to flatten slopes and to provide a berm at about half the depth of the cut (Fig. 7). These measures have been only partially successful and it appears doubtful that they will be of permanent benefit.

Beginning in the fall of 1944 the maintenance troubles multiplied. Large installations of vertical ties and poles, numerous French drains, berms and buttresses along the fills, and much additional ballast were among the corrective steps taken. All these measures have been somewhat effective but have not continued to be successful enough to reduce the abnormal maintenance nor to eliminate the slow order usually in effect. Slopes as flat as 2½ to 1 have broken and moved out. A number of the vertical ties and poles have tipped out and the ballast pockets have developed below the outlets of the French drains. In some sections pockets as deep as 5½ ft. have developed in the 4 years of operation. It is now proposed to attempt stabilization of some of this revision by grouting and some by driving piles into two fills from a berm about half way down the slope. The progress and results of this additional stabilization work will be observed as it is of interest to all in connection with the behavior of revisions built with moisture and compaction control.

This project is a good example of the effect of traffic on new roadways. The old line while in service had presented no unusual maintenance requirements. This project and the Illinois Central fill described above indicate that under the plastic soil conditions encountered lasting stability for railroad use is not being successfully built into the roadbed by procedures commonly considered the best practice. Traffic is needed to bring out and develop the weaknesses before corrections can be made. A further discussion of this problem appears elsewhere in this report.

The Santa Fe

The Atchison, Topeka & Santa Fe has continued its program of stabilization through the year using 20 hydraulic type outfits. This work has aggregated about 90 miles of track during 1948 and has consisted of out-of-face work generally plus a number of sliding fills. In considerable of the out-of-face work however unstable fills were included but not reported as separate projects.

On one project the Santa Fe reports success in the use of a procedure called double grouting. This has consisted of grout injections at one elevation followed later the same day by injections below that elevation. This procedure was adopted for those areas where acceptance for the first grouting was small but where the soil was very wet and the ballast section very shallow. On yard tracks it was used successfully on tracks with no ballast. It is possible that the same procedure would be of value in cuts where acceptance often runs low and where in some cases grouting over several years has been required for full stabilization.

The Santa Fe has kept excellent records on a number of grouting projects. These are reported in Table 1 which shows the average saving over the years since the grout stabilization. In these tables the man-hour savings are reduced to the basis of man-hours per mile for each section reported, regardless of the length of the project. These figures indicate that the general trend of the savings for each succeeding year is upward or that the average annual saving for the period since stabilization is greater than the saving for the first several years. Very definitely there is no trend showing that the savings decrease with the years. This compilation and those of the other roads on which full figures are given in Table 1 go far towards indicating that stabilization by pressure grouting has considerable permanency and is self amortizing—usually within three years.

New York Central

The New York Central has used 14 pneumatic outfits during 1948 in continuation of its grout stabilization program, using generally, mixtures of 1 part of sand to 1 part of cement. Work has varied from water pockets to sliding fills and very good success has been obtained. The work has been over the entire system west of Buffalo. In general the stabilization has been over localized areas rather than out-of-face work. These areas however often total considerable track footage in the same region.

The New York Central has also kept very complete records on the maintenance savings assignable to the results of the stabilization. These are reported for each year in Table 1. The results as shown by these figures cannot be ignored, as the savings are very appreciable. Like those of other roads the savings only include the direct assignable values and do not include intangibles like elimination of slow orders, improved track, etc. The trend of savings is generally upward for each year since the stabilization and no project shows an increasing cost with increasing years. The stabilization work is shown to pay for itself very quickly. The records were kept for the stabilized section but have been converted to track miles and annual dollar costs for Table 1.

The Burlington

The Chicago, Burlington & Quincy this year has grouted a fill near Red Oak, Iowa, on the west approach to the East Nishnabotna River bridge. This fill is 30 ft. in height carrying double track on stone and slag ballast. A portion of this fill, approximately 1880 ft. long, has been a source of high maintenance costs for years. An elaborate cross drainage system and a number of pile installations have been used in the past in attempts to stabilize this fill. They were all beneficial, but not completely successful or permanent. A number of the drains are still functioning and some of the piling has not moved.

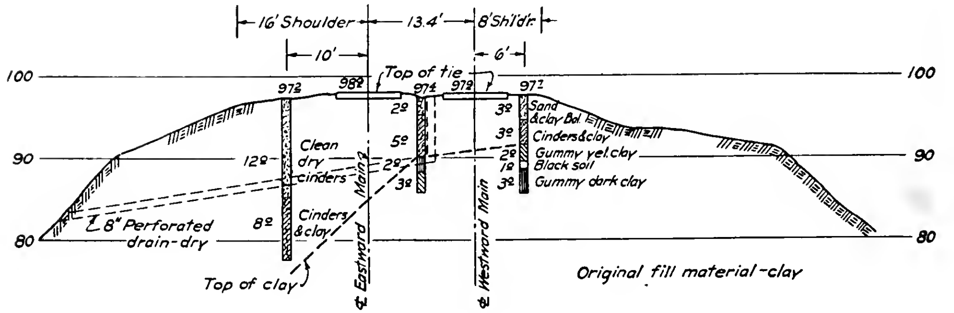


Fig. 8.—Typical Section of Unstable Fill on the Burlington, Showing Clay Line as Determined from Borings.

Fig. 9.—Grouting Sliding Fill. Burlington, Red Oak, Iowa.

Fig. 10.—Displaced Piling on Sliding Fill. Burlington, Red Oak, Iowa.

Fig. 11.—Fill Grouting on the Burlington, Red Oak, Iowa, Showing Pushup and Breakout.

In these areas the fill has given good service. In other areas both the drains and the piling have moved out or broken and in these sections grout acceptance was extremely high. Fig. 8 is a cross section of one of these areas determined by power auger borings. It shows the drain as placed originally is now considerably above the bottom of the granular material. Piling also has been driven as shown by Fig. 9. Apparently the fill had moved down and out, stopping the drain and breaking or tipping over the piles. Figs. 9 and 10 show photographic views of this section. Piling in place, but bent outward, and a wide lateral movement that destroyed the piling can be noted in these figures.

The grouting followed the usual Burlington procedure of grouting the slopes as well as the top of the grade. Points 6, 10, 16 and 20 ft. long were used for injections, depending on conditions encountered and the results of the borings. For the section between station 16+50 and 18+50 grout acceptance was approximately 60,000 cu. ft., or 3000 cu. ft. per track foot. This is about 12 percent of the volume of the fill. Fig. 11 shows a view of a slide and the grout injections points. The raised ground in Fig. 11 shows how the slope pushed up before the grout breakout.

The grouting work was done with two mud-jacks. The mix was 1 bag of cement to seven cu. ft. of sand, plus approximately ⅔ gal. of asphalt and water, as required. In most cases it was necessary to jet the points down with water. This is generally true when the points must be driven through fine sand, cinders, etc. In general, the attempt was made to inject the grout at or slightly below the top of the clay core of the fill.

Grouting on this project was started in May and carried to practical completion in November. The first portion grouted has been under traffic about six months and has shown no instability in that time.

The Burlington has made a practice of investigating all fills proposed for grouting or other stabilization by means of a gas-electric soil auger. During 1948 the average cost of drilling was 37 cents per foot with an average depth per hole of approximately 30 ft. It is on the basis of the drilling data that the fills are selected for stabilization and the procedure for grouting established. It is hoped that with time, these soundings plus sample analysis, plus moisture and soil conditions will permit a better basis for analyses of fill stability and the establishment of the stabilization program.

Great Northern

Another fill exhibiting much the same characteristics as regards action under service and in grout acceptance is on the Great Northern about ½ mile south of Noyes, on the Minnesota–Canadian border. This fill has an average height of 12 ft. and is composed of black and dark grey clays obtained from ditch borrow. The terrain is very flat as is characteristic of this part of the Red River valley.

The fill is over a mile in length apparently constructed with very similar soils throughout, but only the portion grouted showed instability. This portion ran about 200 ft. south and 615 ft. north of bridge No. 89.6 a pile trestle. Here the fill was pushing and sliding laterally, requiring constant maintenance and speed restrictions. There is a record of one or two bents of the original trestle having been filled in. The unstable section crosses the lowest portion of the terrain and is subject to inundation in the spring. This may account for the limited extent of the slide area.

Pneumatic grouters were used on this project to inject a 1 to 5 mix of cement and sand. The usual procedure provided for injections through five rows of holes on each side of the track, usually starting with the row near the toe of slope and working up. The greatest acceptance appeared to be in the two rows of holes nearest the shoulder. Grout acceptance for the 815 ft. treated averaged 46 cu. ft. per track foot. This roughly is 11 percent of the volume of the fill. Certain portions of the fill accepted over 20 percent of the volume.

This fill has performed excellently since grouting. The roadmaster reports that no further work has been required to maintain line and grade. In general, on the Great Northern, grouting has resulted in the elimination of the necessity for winter shimming of the track, formerly a serious problem.

Northern Pacific

Fig. 12 pictures the Northern Pacific track near Hathaway, Mont., where 7505 track feet were grouted in 1945. This section of track is on a fill of about 3 ft. composed of heavy clay soils with ballast pockets and soft track conditions. Original acceptance was rather low, averaging about 0.8 cu. ft. per track foot. During 1946 and 1947 about 5000 ft. were regrouted with an average weighted acceptance of 1.80 cu. ft. per track foot. Since regrouting the stabilization work has been fully effective.

Fig. 2 shows a fill at M.P. 158 along the Yellowstone river on which grouting or piling is proposed. The view shows that the fill has moved out on the river side. Mud type slide fences electrically activated to detect earth movement, are in place on both sides of the track. Cracks in the embankment have occurred at the toe of bluff slope on the hill side. Test pits encountered a greasy blue clay 15 to 20 ft. below the track. This is a possible surface of sliding and appears to be close to the original slope.

Figs. 3 and 13 show a slide along the same river at M.P 31 † 2000 where the bank is 50 ft. high. The track here is in a cut and it was the bank of the river rather than the embankment that failed. The soils here are silty and similar slides may occur in other areas along the bank. The slide itself appears to be a slope failure with the surface of

▲

Fig. 12.—Regrouted Track on the Northern Pacific in Eastern Montana.

Fig. 13.—Slide in Silt Soils. Northern Pacific—Eastern Montana.

slide passing through or near the toe of the bank. Stabilization of this condition would be difficult and uncertain. The most apparent and least expensive correction is to realine the track as has been done, but other factors may eventually demand the original alinement.

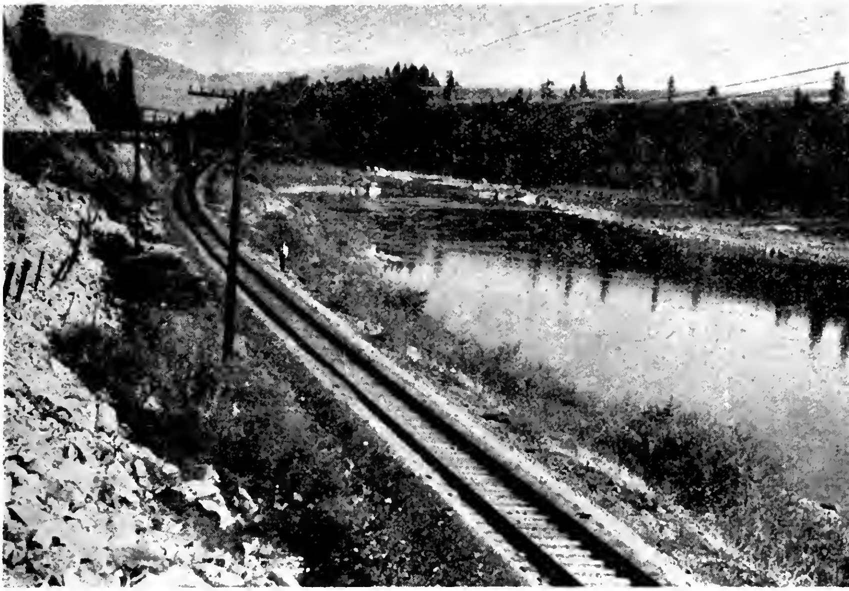


Fig. 14.—Grouted Fill Along Clark Fork River in Western Montana.

In western Montana, the North Pacific has grouted a number of slides along the Clark Fork river. Fig. 14 shows the first, grouted in the spring of 1948. This fill is about 15 ft. above the river, apparently composed of rock fragments and founded on the shaly soils of the mountain slope; 320 track feet were grouted; injections were made along either side of the track on top of the fill. Average acceptance was 61 cu. ft. per track foot, approximately equivalent to 15 percent of the volume of the fill. Movements in this fill usually occurred in the spring following a rapid subsidence of flood waters. Since grouting, these flood conditions have not recurred, but according to local trackmen the action of the fill has definitely been improved.

Two other fills along rock cliffs at the edge of the river near M. P. 65 + 1500 and 65 + 2300 have also been grouted. These fills prior to grouting displaced almost vertically, leaving marks of sliding along the face of the rock. These fills are about 35 ft. above the river. Acceptance was 91 cu. ft. and 103 cu. ft. per track foot.

A river bank fill is also being grouted at this writing at M. P. 112 + 1800 near Kalama, Wash., along the Columbia river. Fig. 15 shows a view of this location.

Conclusion

It has become evident in the course of this investigation that by far the greater proportion of subgrade instability has been produced by surface water rather than underground flow. In some cases, as has been pointed out in previous reports, this surface water may be channelled through the ballast for some distance to the weakest portion of a fill. In other cases, such as a fill between two open-deck structures, the fill failure can be caused only by the precipitation that fell within its limits. In either case the correction of the instability depends on the diversion of this water before it reaches that portion of the subgrade where instability has developed. In the case of soft track and water

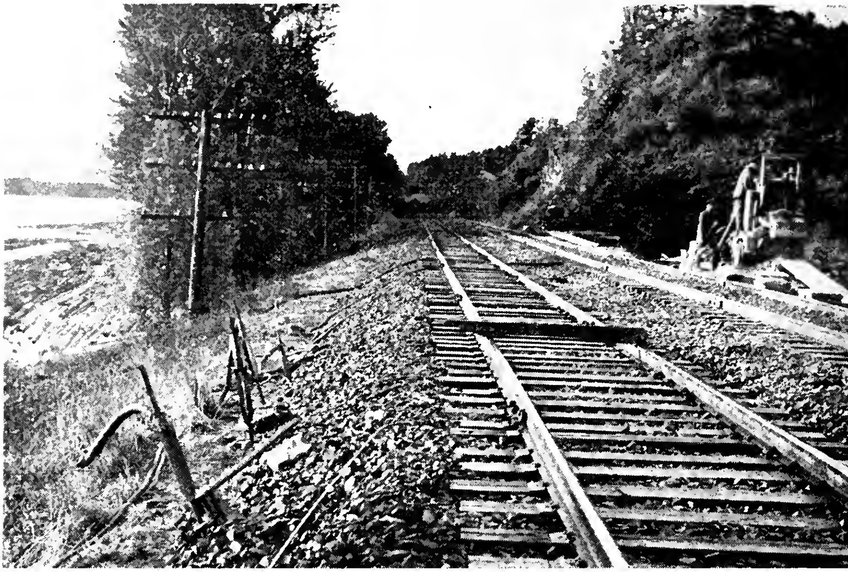


Fig. 15.—Grouting Sliding Fill Along Columbia River. Northern Pacific, Kalama, Wash.

pockets the vulnerable area is originally at the bottom of the ballast section below the rails. In the case of sliding and sloughing fills the critical area may be anywhere within the fill, between the fill and original ground, or in the foundation. Slope failures are the most common ailments of unstable fills and in the zone of movement are usually relatively close to the slope and the toe of fill. A sliding condition often accompanies water pockets where the latter have developed on fills over 6 ft. high.

These considerations help in the attempt to understand the action of the grout in promoting stability. For soft track, squeezes and pockets the grout is usually injected immediately below the ballast. This tends to distribute the grout above the subgrade and often to fill the pocket with grout-impregnated ballast and thus in effect putting a roof over the roadbed. Water is often driven out or away during the process and this roof protects the subgrade from a continuing water supply. As only a very small depth of saturated soil, probably less than ½ in., is needed to deepen the pocket, by shutting off additional water the track can be bettered almost immediately by grouting. The degree to which grouting does put a roof over the subgrade appears to be a direct measure of the success of the stabilization.

This conclusion is supported by the fact that there is no evidence that grouting can prevent the development of these pockets. In one case grouting did not eliminate instability on a grade two years old where the pockets had developed only slightly. Apparently until this instability has reached a certain stage of development there is no place for a roof to be established. The conclusion is also supported by the record of grouting in cuts where the pockets usually are shallower and more slowly developed than in fills. A number of cuts have been grouted twice over a period of three or four years before full stability has been obtained. Related to this is the fact that these cuts have accepted less grout than fills. It appears axiomatic to state that if very little grout is accepted very little good will be done. The amount of grout per track foot that will produce good results has not been definitely determined, but from results observed an acceptance of 1 cu. ft. per track foot, or over, appears desirable in most cases. This does not imply that acceptance of larger quantity will guarantee satisfactory results, but only that less acceptance will probably not give lasting benefit. Technique and procedure should be established for injecting all possible grout to correct water pockets, soft track and similar defects limited to the track only.

In fill grouting the roof is also placed under the track but in addition an attempt is made to inject grout along any possible zone of movement. Almost invariably some portion of the zone is reached by grout injected under the track or through the slopes. In these places the grout acts as a binder, holding together parts of the fill between which there has been a relative movement. This binder may be considered to act in two ways:

1. By filling voids, water is kept out of the channels lubricating the movement or destroying the soil strength. The large amount of grout that is often accepted in fill grouting indicates the presence of considerable void space.

2. The sand and cement in the grout restore cohesion and friction along the sliding surface.

These considerations are partially borne out and are nowhere contradicted by excavations in grouted fills. However, more data are needed which can be obtained only by additional excavation through high fills with large grout acceptance. This cannot easily be done.

In addition there are two other factors which possibly enter into the achievement of stability through grouting, namely:

1. The compaction of the subgrade soils by the injection of grout under pressure. This is possible, but no evidence has been obtained to support it. If grouting does result in increased density, stability would be increased.

2. The extent to which the injection of cement and sand dries up or reduces the moisture content. Since the grout is injected as a liquid with a surplus of water over that required to fill the voids in the sands and cement it is doubtful if its effect as a desiccating agent is sufficient to aid stability.

Whatever the action of the grout within the subgrade, the results of grout stabilization have been excellent in general. There is one precautionary note to be sounded, however, in fill stabilization. It is probable that failures in stability occur through a zone of weakness and that grouting reaches this zone to restore stability. There is the possibility that future failures may occur behind or below this zone if conditions become sufficiently aggravated and if the grouting does not protect the entire soil structure from a decrease in strength. This investigation has a record of only two fills on which grouting was not sufficiently successful to amortize the cost either directly or indirectly by the reduction of slow orders and hazards. On one of these fills the grout was not injected over an area large enough to include the probable zone of failure. On the other these conditions were fulfilled apparently and the primary failure was corrected but there was a secondary incipient failure zone on which sliding occurred after grouting. In no case has it been noted that grouting itself has caused or accelerated instability of fills.

Tie and Pole Driving

No new installations of tie and pole driving were observed in 1948. The projects reported last year have continued to give good service. A number of roads in the southwest have continued the use of poles and ties in low fills and cuts as a cure for soft

Fig. 16.—Fill Stabilized by Piling. Northern Pacific, Noxon, Mont.

track. One of these roads reports an average cost last year of approximately $1.50 per track foot for two miles of this type of treatment installed. The best results in pole and tie driving have been obtained on low fills where at least one-half of the pile or tie length is driven into the original ground. On one installation made in 1945 and 1946, a number of 5-ft. ties were used in cuts and 8-ft. poles in fills over 5 ft. high. These have pushed out from their original position and were ineffective in arresting the unstable condition.

Piling

Two installations of piling previously placed were observed this year. The first of these jobs was on the Northern Pacific near Noxon, Mont., at M. P. 73 + 4700. This installation is a double row of 80-ft. piling along a 40-ft. fill adjacent to the Clark Fork river. One row is along the shoulder and the second row is at the toe of slope at the edge of the river. The roadbed is benched out on the side of a mountain talus slope. The fill in itself is composed of heterogenous materials, many of them placed to take care of fill subsidence. It was assumed that the fill was moving toward the river on a surface near the original ground. The piles were driven in 1947 and have arrested all fill movement to date. Fig. 16 is a view of the fill showing the upper row of piling. Like other fills in this general vicinity, the greatest and fastest movement downward and outward occurred during the spring of the year at the time the flood waters subsided quickly or an ice jam broke. In either case, there is a sudden withdrawal of the lateral support afforded by the higher water and seepage pressures possibly are actuated. In addition to supplying needed support at this time this piling installation has to date prevented erosion of the bank and fill by the river.

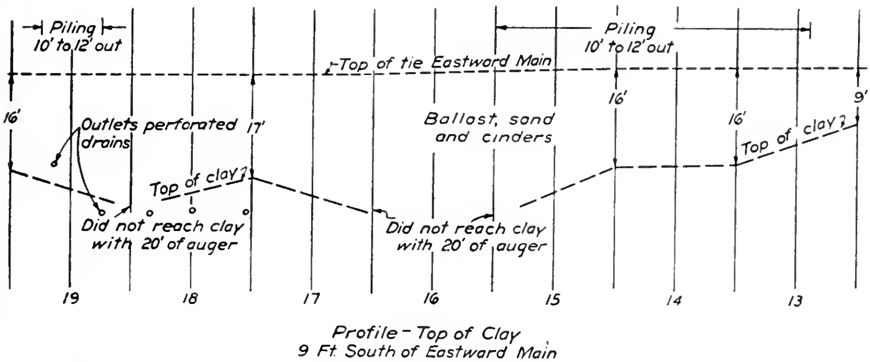


Fig. 17.—Profile on Top of Clay on Unstable Fill, C. B. & Q., Western Iowa.

Figs. 9 and 10 show views of a 30-ft. fill on the Burlington near Red Oak, Iowa, that has considerable piling driven from 1921 to 1938. This fill, about 1800 ft. long on the west approach of the Nishnabotna river, has a number of pile installations on both shoulders, although the greater number and the greater instability appear to be on the south. Fig. 17 also indicates the position of the piles in two of these sections and the profile of top of clay along the south shoulders. These figures indicate that while the piles have held fairly well over certain portions, they have not arrested all fill movement. In some places, the piles have moved out at the top as much as 15 ft. and in others they have apparently broken and disappeared in the slope movement. Most of these piles were 32 and 36 ft. long. They were usually tied to anchor piling on the opposite shoulder with steel cables which in a number of cases have broken. This fill has been grouted this year and is discussed elsewhere in this report.

In the course of this investigation a number of piling installations have been seen. Only incomplete information on these could be obtained, but it can be said that where the piles are of sufficient length to penetrate approximately two-thirds of their length into undisturbed material they will usually arrest movement of the fill. Where they penetrate less than one half their length into undisturbed material the piles are usually not effective over an extended period of time. Almost all installations, however, are of value at least temporarily. There is now a growing tendency among various roads to drive piling along the toe of slopes or through a berm part way down the slope. It is felt with considerable justification that piling of equal length in the lower locations will be more effective than those through the shoulder.

Sand Filled Blast Holes

The Southern Railway has recently adopted a stabilization process in which a pipe is driven into the subgrade, dynamite inserted and the holes sprung, then filled with sand. Considerable success has been reported. A description of the process has recently appeared in a periodical and no additional information is available for this report.

Sand Filled Spud Holes

There are no new developments to report on the methods and results of sand filled spud holes. The Camp Sibert, Ala., installation reported last year, continues to give excellent service with high maintenance savings.

Part II Laboratory Studies of Roadbed Stabilization

By Dr. R. B. Peck
Research Professor of Soil Mechanics, University of Illinois

Introduction

This is the first progress report of a laboratory investigation to study the factors that cause the development of soft spots in roadbeds. The investigation is part of the research work of the Engineering Division, AAR, and is being done at the request of the AREA Committee on Roadway and Ballast by the Engineering Experiment Station of the University of Illinois under the direction of the writer.

Unstable roadbed conditions associated with soft spots or water pockets continue to be a source of abnormal maintenance cost for many railroads. Several methods have been used, with varying degrees of success, to remedy these conditions and stabilize the roadbed. However, the successful use of any of these remedies depends on a thorough understanding of the factors contributing to the formation of soft spots.

The field investigation that has been in progress for the past four years has been able to supply information about prevailing conditions after a soft spot has formed. This information is very worthwhile but its usefulness is limited to some extent because of the variability of field conditions. On the other hand, a laboratory investigation provides an opportunity for control that does not exist in the field. That is, in the laboratory one factor may be held constant, or varied, with relation to the other factors. In this way, the effect that each factor has on the formation of soft spots may be determined. When these factors are better understood, consideration will be given to remedial methods.

Apparatus

About 10 years ago, equipment was developed in Germany to investigate the factors that influence the compacting effect of vibration. This equipment utilized centrifugal force to provide pulsating vertical loads. Inasmuch as this was the type of load desired to duplicate field conditions insofar as possible and since nothing suitable was available through commercial sources, a testing machine was designed that incorporated the principles of the German equipment. The machine simulates actual conditions in that it reproduces as nearly as possible the action of a railroad tie on the subgrade while a train is passing.

The loading apparatus consists of a framework of angles which supports three eccentrics. Two of these rotate in a direction opposed to the third in such manner that the horizontal components of centrifugal force nullify each other, whereas the vertical components are additive. The load is delivered to a simulated roadbed section about 2.5 ft. square by means of a pedestal. A photograph of the apparatus is shown in Fig. 18.

Figs. 19 and 20 show sections to clarify the details of construction. The two eccentrics on the outside have a combined thickness equal to that of the middle one. The latter is mounted on a hollow shaft which is driven by a bevel gear on the solid center shaft, an idler gear, and a third gear on the hollow shaft. Tapered roller bearings are used. Lubrication is accomplished by hand packing the bearings, in place, with wheel bearing grease.

One requirement of the apparatus is that the loading plate which rests on the simulated roadbed must be able to move downward as the sample deforms, in order that the load may continue to be delivered to the sample. This was done by incorporating the loading mechanism into a unit free to move in a vertical direction. Ver-

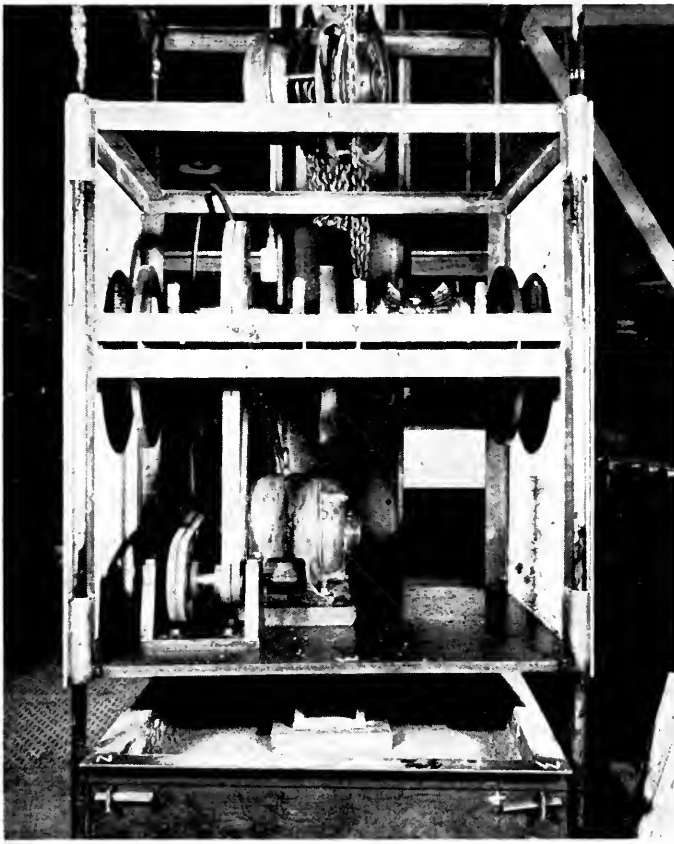


Fig. 18.—Oscillating Apparatus for Soil Tests.

tical guide rods fastened to a common base plate serve to hold the loading mechanism in position. A chain hoist supported by a frame attached to the vertical guide rods serves to raise the loading mechanism so that the sample may be placed under it. The apparatus is powered by a 2-hp. motor.

Calibration of Apparatus

After completion, the machine was calibrated. The dead load was measured directly by weighing, but in order to measure the live load a special dynamometer was constructed. A rectangular ring was made up by welding together pieces of 1-in. by 1-in. cold rolled steel as shown in Fig. 21. Ball bearings were welded in place on each side at the center line and the ring was heated in an oven to relieve any residual welding stresses that might be present. Its load-deformation characteristics were then determined. The deformations were measured by a scratch gage that consists of a pointer and a piece of smoked glass.

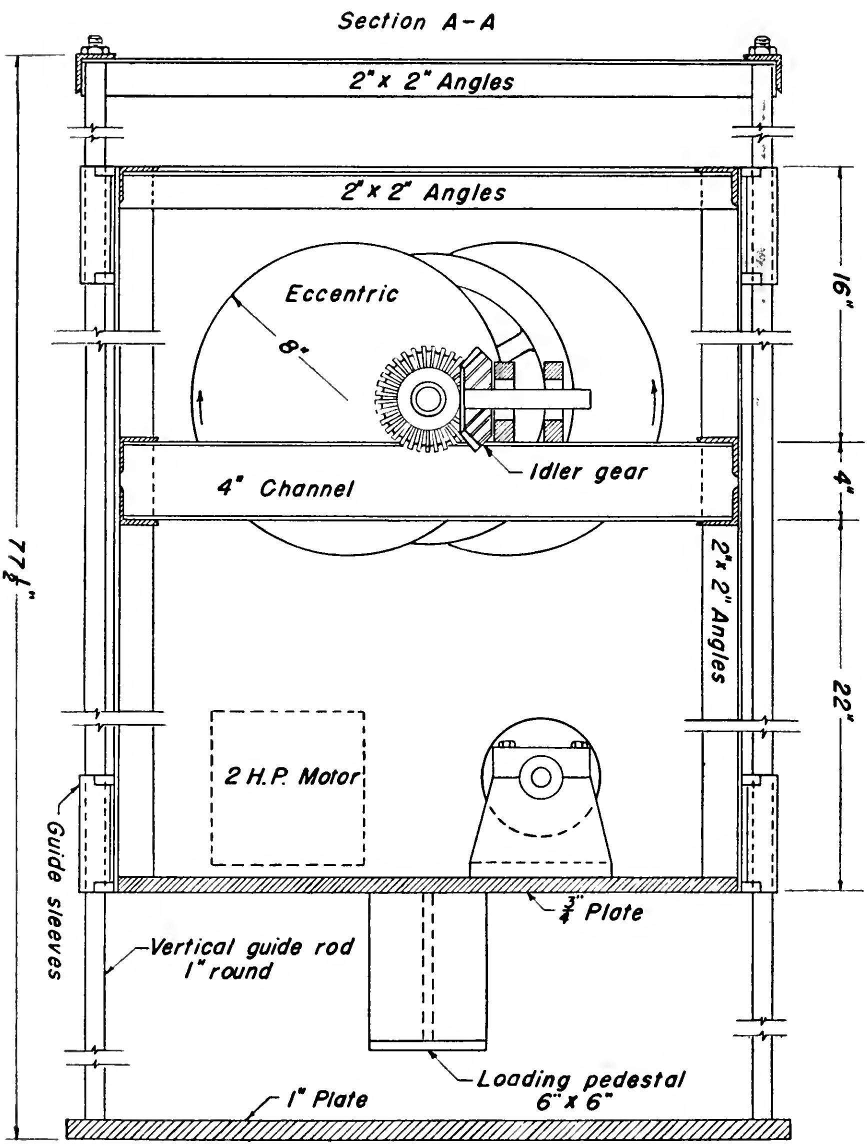

Section A-A
2" x 2" Angles
2" x 2" Angles
Eccentric
8"
Idler gear
4" Channel
2" x 2" Angles
16"
4"
22"
77½"
2 H.P. Motor
Guide sleeves
¾" Plate
Vertical guide rod
1" round
Loading pedestal
6" x 6"
1" Plate

Fig. 19.

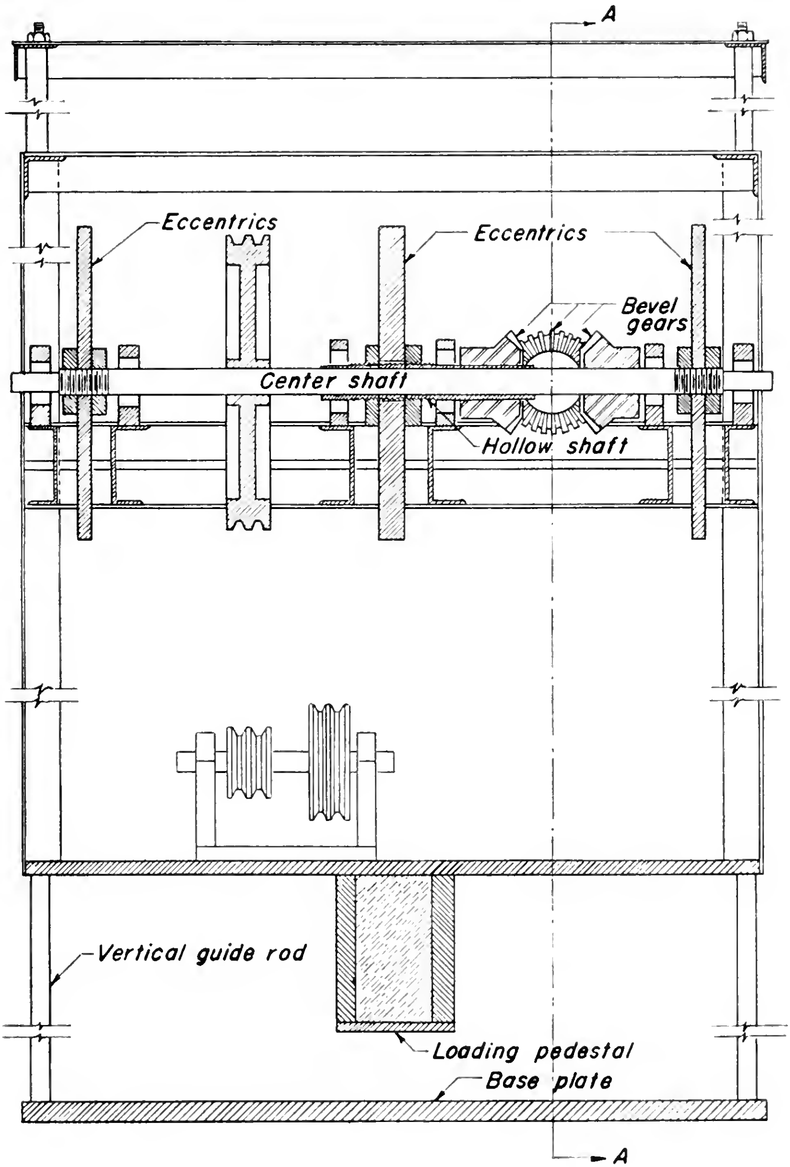

A
Eccentrics
Eccentrics
Bevel gears
Center shaft
Hollow shaft
Vertical guide rod
Loading pedestal
Base plate
A

Fig. 20.

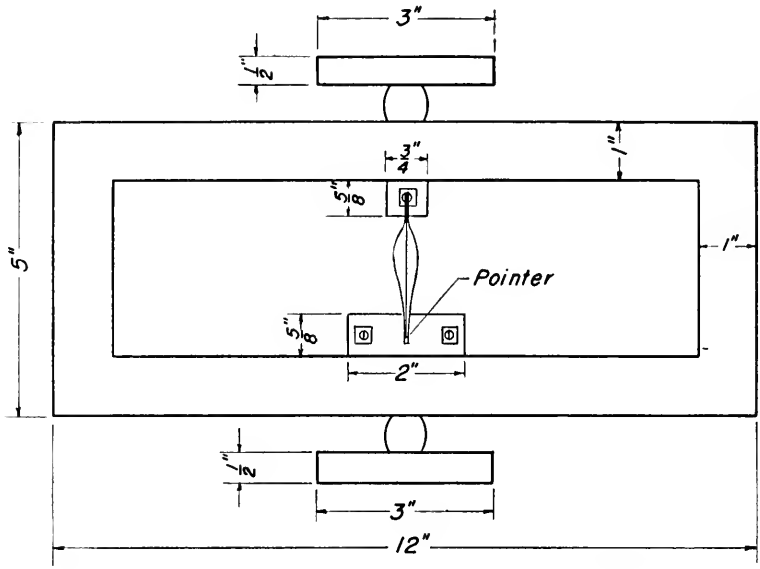


Fig. 21.—Steel Rectangle Dynamometer for Measuring Live Loads.

Loads

Assuming that a train travels 60 mph. and that each combination of front and rear truck constitutes a single loading, each tie undergoes about 120 loadings per minute. Each truck delivers a load of about 70 kips which is distributed through a distance equivalent to about 4.2 ties. Hence a maximum pressure of approximately 3 kips per sq. ft. acts at the base of each tie. With 6 in. of ballast between base of tie and subgrade, the average pressure on the subgrade is about 1 kip per sq. ft. The loads that are delivered by the loading pedestal of the testing machine vary from 0.01 kip when the centrifugal force is acting upward, to 1.91 kips when the force acts downward. Hence, by varying the size of the loading pedestal from 6 in. square to 12 in. square, pressures corresponding to those obtained in the field can be reproduced. The frequency of loading is up to 229 per min. maximum.

Test Samples

The simulated roadbed consists of a sample contained in a box measuring 29¼ by 32 by 12 in. deep. This requires a minimum of about 6 cu. ft. of sample material. The material that has been tested to date was obtained locally from an excavation on the University of Illinois campus. It is a yellow silty clay with a liquid limit of 17.9 percent and a plastic limit of 13.3 percent. A maximum dry density of 125.7 lb. per cu. ft. was obtained at an optimum moisture content of 8.8 percent as determined by the modified AASHO test.

In filling the test box, the soil sample is broken down so that it passes through a No. 4 sieve. The water required to obtain the desired moisture content is added and the sample is mixed in a Lancaster type SW counter-current rapid batch mixer. The mixing is continued until the water is uniformly distributed through the soil. After

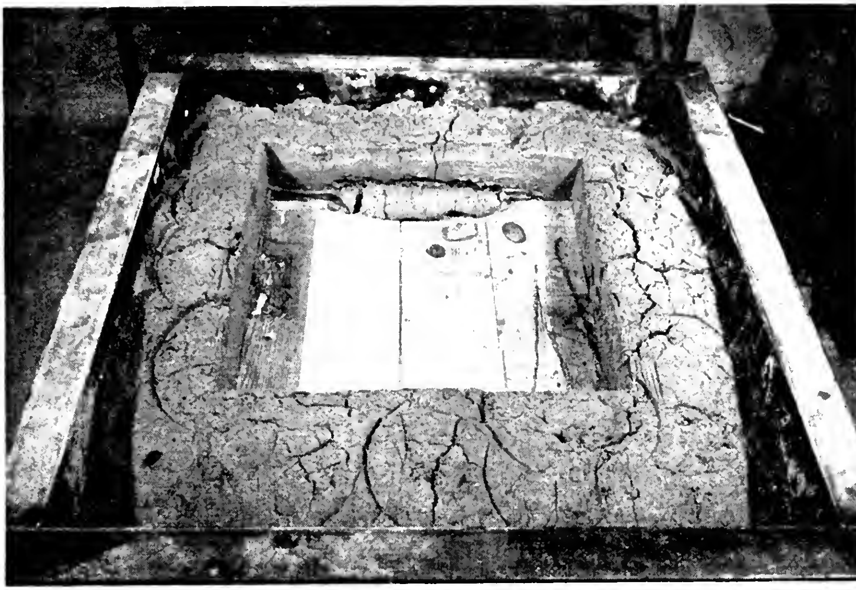


Fig. 22.—Soil Sample 3A After Test.

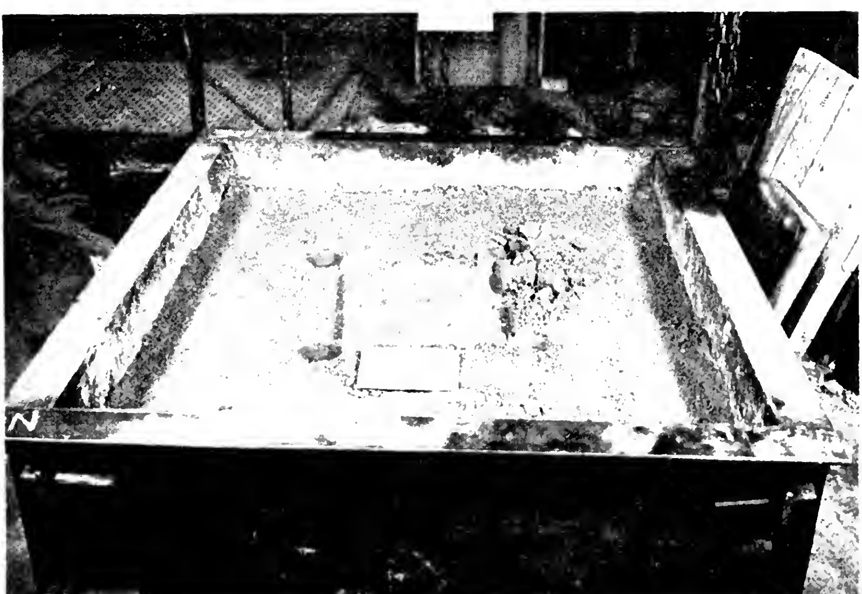


Fig. 23.—Soil Sample 4 After Test.

the sample has been thoroughly mixed, it is placed in the sample box and compacted in three layers. Each layer is tamped with a ram 8 in. in diameter that weighs 24¾ lb. This ram is dropped about 12 in. a sufficient number of times to obtain 5 complete coverages of the sample.

Tests Completed

So far the testing has been performed with the vibrator operating directly on the sample without any ballast. The bearing area has been varied in order that the maximum load shall not exceed the bearing capacity of the sample as placed.

For Test No. 1 the sample was placed at an average water content of about 8.9 percent which is very near the optimum. The bearing area was 6 by 6 in. and the compacted sample was 6 in. deep. At the end of 4 min. the bearing plate had made a pocket having an average depth of about 0.07 in. This increased to 0.12 in. at 900 min. During the elapsed time of 900 min. there are 206,000 load repetitions, corresponding to about 2000 hundred-car trains. Water was then added to the surface of the sample and the bearing plate began to work its way into the sample. The average depth of the pocket formed was 0.35 in. at the end of about 105,000 additional loadings and was 1.15 in. at the end of 285,000 additional loadings. After the test was completed, water contents were determined at each corner of the bearing plate and in the center. The water content at the center was fairly uniform from top to bottom at about 12.3 percent. However, the water content at the corners varied from about 16.5 percent near the surface to about 14.5 percent near the bottom of the sample.

The sample for Test No. 2 had a water content of about 9.7 percent as placed. The sample had a depth of 8¼ in. and the bearing area was 6 by 6 in. The average depth of the pocket formed was 0.1 in. after 4 min. which increased to 0.19 in. after 1800 min. or 412,000 cycles. This test was then stopped.

The sample for Test No. 3 was placed to a depth of about 9½ in. at an average water content of 16.0 percent. The test was started on a bearing area 6 by 6 in., but the strength of the sample was not enough to support the load. In less than ½ min. the bearing plate had punched 4½ in. into the sample.

Inasmuch as considerable work is involved in preparing a sample, the material from Test No. 3 was taken out of the box and replaced by compacting in the usual manner to a depth of 9½ in. A small specimen was then removed and subjected to an unconfined compression test. The strength was 0.42 ton per sq. ft. Based on this value, a bearing plate 18 by 18 in. was used for this test, designated No. 3 A. After 4 min. or 916 cycles, this bearing plate had punched into the sample an average depth of about 1.8 in. At 120 min. or 27,400 cycles the depth was 3.1 in., and when the test was discontinued at 665 min. or 152,000 cycles the average depth was 3.5 in. Fig. 22 shows the appearance of this sample after the test had been completed and before the bearing plate was removed. The cracks that are in evidence resulted from a heaving of the sample. They should not be confused with the circular marks that show the imprint of the tamper.

Test sample No. 4 was placed at a water content of about 11.7 percent and a depth of 8 in. The 9¼ by 10 in. bearing plate formed a pocket 0.21 in. deep at the end of 1 min. This increased to 0.33 in. when the test was interrupted at 1490 min. or 341,200 cycles. A period of 10 days elapsed during which the sample was kept moist but not subjected to any live load. Thereafter, water was added to the surface of the material in considerable quantity. At the end of 671 additional minutes the bearing plate had made a pocket 0.85 in. deep which remained unchanged at the end of 1166 min. Fig. 23 is a picture of this sample after it was removed from the machine. The circular holes at the corners of the pocket are where water content samples were taken.

Conclusions

The foregoing tests have served to show that the loading apparatus is satisfactory and may be expected to operate with only minor maintenance. Further, the technique for handling a sample has been worked out so that this phase of the testing should be more or less routine in the future. The rapid failure of sample No. 3 indicated that information was needed concerning the bearing capacity of the samples as prepared for test. This information was obtained commencing with Test No. 3 A.

The purpose of the tests that have been conducted was to find out what relationship existed between the water content of the material and its action under load. This approach should be investigated further. Sufficient tests have not been completed to justify definite conclusions about the formation and control of soft spots. However, there is an indication that a critical water content exists that marks the boundary between soils that are stable and those that create soft spots. The field investigation of roadbed stabilization shows that the soils usually encountered in soft spots are more plastic than the one tested. A sample with plasticity characteristics similar to those encountered in field failures will be obtained for future tests. Further study into the nature of soft spots is necessary and future tests should be governed by the results of the tests currently in progress.

Report on Assignment 6 (b)

Construction and Protection of Roadbed Across Reservoir Areas; Specifications

B. H. Crosland (chairman, section b), J. M. Boles, G. W. Payne, C. S. Robinson.

This is a progress report, presented as information.

Last year your committee presented as information a preliminary report giving general coverage as to the experience of various railroads in carrying out the construction of roadbeds across reservoir areas as a result of the public construction of dams (Proceedings, Vol. 49, 1948, pages 530–534 incl.). In that preliminary report your committee announced that it would proceed with studies leading to recommendations covering the construction of roadbed sections under specific conditions resulting from locations through reservoir areas where a part of the embankment would be in a permanently saturated condition.

As a result of these continued studies there is submitted now a proposed tentative, typical roadbed section for construction through reservoir areas (Fig. 1). Your committee requests comments and criticism on this proposed section.

Due to the unusually severe conditions imposed by continual saturation and wave action, extra care must be taken to assure the maximum compaction provided in the Specifications for Formation of the Roadway.

The riprap is to be dumped in place and be of size not less than Class C in the Specifications for Riprap. Attention is specifically invited to the fact that in Fig. 1, your committee has not indicated the use of a pervious cushion under the riprap. It is recognized that this is a controversial point and comments in regard to the use of cushior material are specially requested.

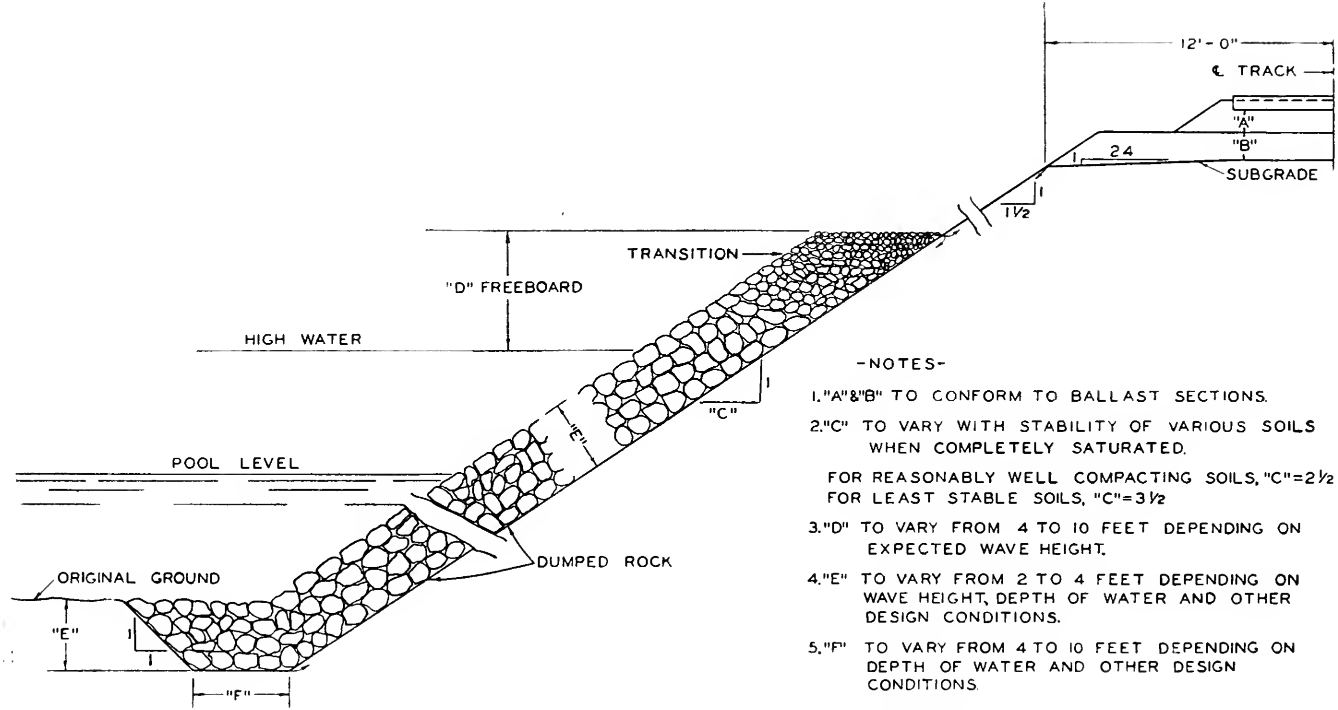


Fig. 1.—Typical Roadbed Section for Construction Through Reservoir Areas.

Studies are now being carried on in collaboration with Subcommittee 2 of Committee 1 in an effort to develop more specific slope ratios to be used for various soils when completely saturated.

Your committee is also continuing studies toward the development of more specific data with respect to notes 3, 4 and 5 of Fig. 1.

Report on Assignment 6 (c)

Chemical Eradication of Vegetation

J. C. DeJarnette, Jr. (chairman, section c), L. H. Bond, L. S. Crane, J. P. Datesman, A. A. Winter.

This is a progress report, presented as information.

The first use of chemicals for weed killing in the United States appears to have been in 1906. In 1910 an English company offered a complete service, including application to American railroads. Tank cars were equipped with crude sprinkling devices to apply a solution of sodium arsenite. The concentrated chemical was specified to contain 4 lb. of arsenic trioxide and 1¼ lb. of caustic soda per gallon. This concentrate was generously diluted with water at a rate of 20 to 30 parts to 1 and sprinkled with coarse spray nozzles at the rate of 1000 gal. of solution per mile. This generous use of water was only justified on a dense heavy growth of grasses and weeds. It unnecessarily increased work train costs and was soon changed to a lighter form of spray train equipped with high pump pressure and semi-atomizing nozzles so that the dilution with water was greatly decreased and the total volume of solution reduced to approximately 450 gal. per mile of track, treating 8 ft. each side of the center line.

The early experiences with arsenic were characterized by a high rate of cattle killing and poisoning and many unsuccessful attempts were made to make this solution repellent to these animals.

From 1910 to 1916 many railroads accepted this arsenical chemical weed control and used large quantities when track labor costs were as low as one dollar a day. This work was temporarily halted from 1917 to 1920 due to a war shortage of arsenic and then resumed on a fairly large scale. During the 1930's the United States and Canadian railroads used approximately 4,000,000 gal. of concentrate annually.

Sodium Chlorate—Calcium Chloride

In 1924 a French application for a United States patent described a process for using chlorate to eradicate moss-like weeds and ferns. Experiments with sodium chlorate quickly proved its worth as a substitute for arsenic and it is non-poisonous to animals. It killed annual plants and certain perennials more broadly than arsenic and gave a slightly longer suppression of regrowth and seed germination. It was, however, a serious fire hazard and it was formulated with calcium chloride to form a relatively safe mixture. This chlorate product was first used in 1925 and was quickly accepted by many railroads to the extent of approximately 2,000,000 gal. per year. It still remains as one of the major chemicals used in railroad weed programs. Concentrated gallons containing 3 lb. of sodium chlorate and 2¼ lb. of calcium chloride are used at an average rate of 50 to 125 gal. per mile of track, 8 ft. each side of center line.

Tar oils and fuel oils have been used by some railroads as weed killers. One western road has been using a mixture containing 10 percent creosote and 90 percent light petroleum distillate at the rate of approximately 210 gal. per mile. Other roads have used this mixture at different proportions up to 30 percent creosote and 70 percent fuel oils.

The chemicals mentioned above have been the principal weed killers in the past. The future presents a different picture. An immense amount of time and effort is now being spent in research and experimentation, the result of which may be expected to simplify the problem for railroads in the future. Beginning with World War II there has been a tremendous expansion in organic chemistry in the United States particularly in the development of many forms of drugs, hormones and life regulating agents.

There are now organic compounds which are nonreactive with soil elements and will enter a plant system, translocate downward and affect the roots, for example, 2, 4–D (2, 4–dichlorophenoxyacetic acid) for certain broad leaved plants and isopropyl-phenylcarbamate for grasses. These and others can be incorporated in weed killing mixtures to gain better results. Altogether there are more than 100 different chemicals used for weed killing.

Deficiencies in Weed Control Practices

Some of the deficiencies of past and present chemical control of vegetation may be summarized as follows:

1. While most annual weeds and grasses are easily killed, many resistant perennial weed, grasses and vines profit by the removal of the annuals and invade the territory where this competition has been removed.

2. After a few years of inadequate chemical treatment, many roadbeds become infested with hardier types of biennials and perennials, such as bindweed, Bermuda grasses, Johnson grass, quack grass, trumpet vine and milkweed.

3. Poor timing of treatments with relation to (a) habits of vegetation, (b) growing season and (c) rainy and dry season.

4. Variable factors of nature, particularly changeable seasons with respect to rainfall which often make an early appraisal of results difficult. The soluble chemical salts of arsenic, chlorate and others are oftentimes washed away after two or three inches of rainfall. The variable growing seasons of different sections of the country whereby early applications in the relatively short growing seasons of the northern states cannot be compared to results in the south where the long growing season and shallow frost line constantly encourage regrowth.

The problem before the railroads is to select combinations of chemicals which will serve distinct purposes:

1. Treat the roadbed area to eradicate all vegetation.
2. Treat the right-of-way with selective chemicals which will control the growth of brush, vines, etc., and leave the grasses to prevent erosion.

Conclusion

Past experiences of the railroads have proved the value of the use of chemicals for the eradication of vegetation. New chemicals now being developed and tested indicate the necessity of continuing the study of results obtained.

Report on Assignment 10

Ballast

A. T. Goldbeck (chairman, subcommittee), George Auer, Jr., T. A. Blair, J. M. Boles, L. H. Bond, H. F. Brown, J. E. Chubb, L. B. Craig, B. H. Crosland, A. P. Crosley, J. P. Datesman, J. C. DeJarnette, Jr., J. M. Fair, Albert Haertlein, F. W. Hillman, L. H. Jentoft, H. G. Johnson, F. H. McGuigan, J. F. Newsom, Jr., G. W. Payne, J. W. Poulter, C. S. Robinson, J. R. Scofield, F. H. Simpson, C. D. Turley, Stanton Walker, C. S. Wicker.

Under the general assignment, Ballast, this subcommittee has three subassignments, each covered by a section of the subcommittee.

Reports of the sections covering Assignments (a) and (c) follow:

Report on Assignment 10 (a)

Ballast: Tests

Stanton Walker (chairman, subcommittee), J. C. DeJarnette, Jr., J. M. Fair, A. T. Goldbeck, Albert Haertlein, L. H. Jentoft, G. W. Miller, C. S. Wicker.

Revisions in Los Angeles Abrasion Test of Aggregates

This report is presented as information.

The subcommittee has been directing its principal attention to the Los Angeles abrasion test as applied to ballast. The test, as described in "Standard Method of Test for Abrasion of Coarse Aggregate by Use of the Los Angeles Machine" (ASTM Designation C 131–47),[1] provides for no grading coarser than ⅜ to 1½ in. However, based principally on representations from your committee, ASTM adopted tentative revisions in 1947[2] which provide for testing three additional gradings as follows:

Grading E	1½ to 3 in.
Grading F	1 to 2 in.
Grading G	¾ to 1½ in.

The 1947 tentative revisions also outline the procedure for testing these new gradings and call attention to the need for further study of various details of the method of test. A limited amount of research conducted by interested parties resulted in new proposed tentative revisions which are currently being considered by ASTM and which almost certainly will be adopted in the near future.

The proposed tentative revisions, given in Appendix A to this report, retain gradings E, F and G, as previously described, but modify the test procedure. For these new gradings a 10,000-g. test sample is required to be used instead of the 5000 g. required for gradings A, B, C and D; the test is made with an abrasive charge of 12 steel balls (same as grading A); the machine is rotated for 1000 revolutions instead of 500.

The limited research referred to indicates that, for aggregates of the same quality in all sizes, about the same loss will be obtained in the rattler test for new gradings E,

[1] 1947 Supplement to Book of ASTM Standards, Part II, p. 114.
[2] Ibid, p. 454.

F, and G as is obtained with current standard gradings, A, B, C and D. However, additional study is needed and it is suggested that members of your committee, and others of the Association, help to develop data on the new coarse gradings. Data are especially desired which afford comparisons with gradings A or B. In the case of those not having facilities for making the test, the National Crushed Stone Association, the National Slag Association and the National Sand and Gravel Association have offered to test samples submitted to them by the railroads.

Study of Significance of Los Angeles Test

Current Specifications for Ballast of the AREA limit the maximum wear in the Los Angeles abrasion test to 40 percent and the question has been raised as to the adequacy of this limit. While it has not been demonstrated that the Los Angeles test is quantitatively significant, it is clear that it does afford some measure of both toughness and resistance to abrasion. Further, good correlation has been shown by Shelburne[3] between the results of the test and the resistance to breakdown under rollers. Also, good correlation has been found between results of the test and breakdown under pick tamping.[4]

While it is felt a reasonably good quality of rock is described by a loss of 40 percent, the subcommittee believes that it would be worth while to re-examine that limitation in relation to known service records. With that in view it is suggested that all members of Committee 1 be invited to cooperate by furnishing this subcommittee with descriptions of ballast concerning which they have developed well defined opinions of service records, either *good* or *bad*. These descriptions should include such information as:

1. Source.
2. Grading. It should be had in mind that any small sample collected for test might not be representative of the average grading.
3. In the case of gravel, approximate percentage of crushed particles.
4. Some statement as to the general shape of particles, i.e., rounded, cubical, flat, elongated, etc.
5. Such physical test data as are available.

In the case of (5) it is suggested that arrangements be made to secure adequate physical test data if they are not already available. Such data should include:

(a) Specific gravity.

(b) Absorption.

(c) Mineral composition as determined either petrographically or by a lithologic examination.

(d) Soundness as measured in either, or both, the sodium and magnesium sulfate test.

(e) Resistance to abrasion in the Los Angeles rattler.

Here again, the National Crushed Stone Association, the National Slag Association and the National Sand and Gravel Association will be glad to cooperate by testing samples which committee members submit.

[3] T. E. Shelburne, Degradation of Aggregates under Road Rollers, ASTM Proceedings, Vol. 39, 1939, p. 150.

[4] Investigation of Various Types of Stone Ballast, Appendix A to Report on Assignment 12, AREA Proceedings, Vol. 44, 1943, p. 539.

Consideration has been given to laboratory crushing tests of ballast as a measure of resistance to breakdown in the track. Some data along these lines were secured by the committee many years ago[5, 6] which suggest that it might be worth while for further work to be done along these lines. However, that would represent a fairly ambitious project for which careful preparation should be made in advance. It would require the accumulation of a considerable number of large samples of known service record and, also, the development of new equipment.

This progress report should make clear that there is plenty of work to be done within the scope of the subcommittee. It is urged that it is immediately practicable to start collecting data on resistance to abrasion of the coarser gradings which have been tentatively adopted and, also, to develop further information on the resistance to abrasion of ballasts of known service record.

Appendix A

Proposed Tentative Revision of Standard Method of Test for Abrasion of Coarse Aggregate by Use of the Los Angeles Machine (C 131-47)

Delete the tentative revisions adopted in June 1947[7] and insert the following as tentative revisions of C 131-47.

Section 3 (b).—Change this section to read as follows:

(b) The abrasive charge, depending upon the grading of the test sample as described in Section 4, shall be as follows:

Grading	*Number of Spheres*	*Weight of Charge, g*
A	12	5000 ± 25
B	11	4584 ± 25
C	8	3330 ± 20
D	6	2500 ± 15
E	12	5000 ± 25
F	12	5000 ± 25
G	12	5000 ± 25

Section 4.—Change to read as follows:

4. *Test Sample.*—The test sample shall consist of clean aggregate which has been dried in an oven at 105 to 110 deg. C. (221 to 230 deg. F.) to substantially constant weight and shall conform to one of the gradings shown in Table 1 (Note). The grading or gradings used shall be those most nearly representing the aggregate furnished for the work.

Note.—It is recognized that different specification limits may be required for gradings E, F and G than for A, B, C and D. It is urged that investigations be conducted to determine the relationship, if any, which exists between results for these coarse gradings using the 10,000 g. samples and the finer ones using the 5000 g. samples.

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[5] Appendix B to Report of Committee II—Ballast, Proceedings, Vol. 31, 1930, p. 761.
[6] Appendix A to Report of Committee II—Ballast, Proceedings, Vol. 33, 1932, p. 350.
[7] 1947 Supplement to Book of ASTM Standards, Part II, p. 114.

Table 1.—Change to read as shown in the accompanying Table 1.

TABLE 1.—GRADINGS OF TEST SAMPLES

Sieve Size (Square Openings) Passing In.	Retained On In.	*Weight and Grading of Test Sample, g.* A	B	C	D	E	F	G
3	2½	..	..	..	..	2500a	..	..
2½	2	..	..	..	..	2500a	..	..
2	1½	..	..	..	..	5000a	5000a	..
1½	1	1250	..	..	..	..	5000a	5000a
1	¾	1250	..	..	..	..	..	5000a
¾	½	1250	2500	..	..	..	..	..
½	⅜	1250	2500	..	..	..	..	..
⅜	No. 3	..	..	2500	..	..	..	..
No. 3	No. 4	..	..	2500	..	..	..	..
No. 4	No. 8	..	..	..	5000	..	..	..

a. Tolerance of plus or minus 2 percent permitted.

Section 5.—Delete the first sentence and insert the following:

5. The test sample and the abrasive charge shall be placed in the Los Angeles abrasion testing machine and the machine rotated at a speed of from 30 to 33 rpm. For gradings A, B, C and D the machine shall be rotated for 500 revolutions; for gradings E, F, and G it shall be rotated for 1000 revolutions.

Report on Assignment 10 (c)

Special Types of Ballast

C. D. Turley (chairman, subcommittee), G. Auer, Jr., L. H. Bond, L. B. Craig, B. H. Crosland, J. P. Datesman, H. G. Johnson, F. H. McGuigan, G. L. Morrison, G. W. Payne, J. W. Poulter.

This is a progress report presented as information.

In September 1943 the Illinois Central Railroad installed a test section of asphalt ballast covering, beginning at M.P. 46 and extending northward 2485 ft. The test, which is located just north of Manteno, Ill., was sponsored by the Asphalt Institute of Washington, D. C. and received the cooperation of the research department of the Association of American Railroads.

In this locality there are three main tracks, the center one of which was selected for the test. This track has traffic in either direction, is laid with 131-lb. rail, is ballasted with stone ballast to a depth of 12 in. beneath the ties and tamped with power tools. All tracks are on 15-ft. centers and the finished asphalt coating covers the track for approximately 12 ft., measured 6 ft. either side of the center line. The entire test section is on tangent track.

The hot asphalt was sprayed on the track by a pavement distributor, mounted on a flat car and penetrated into the ballast from three to four inches. Complete details of installation and costs were published in the Proceedings, Volume 45, 1944, page 330.

It was anticipated that the ballast covering would prevent fine materials from entering and fouling the ballast and that surface water would be drained away quickly, leaving a dry and rigid roadbed.

Performance To Date

The track has held line and surface well and riding conditions have been exceptionally good. The test has shown that it is both possible and practical to maintain an asphalt covering on track. When light repairs are made, such as spotting in ties, jointing up or lining track, the original asphalt material which has been disturbed is tamped back in place around the ties and additional asphalt applied which seals the surface and leaves the covering in its original condition.

Maintenance Costs

Total track repairs made to date are as follows:

July 1945.—After approximately two years of service, 58 tie ends were tamped and old asphalt put back in place around the ties and sealed by applying additional asphalt. The following labor and material were used:

Labor—43 man-hours
Foreman—7 man-hours
Two 55-gal. drums emulsified asphalt

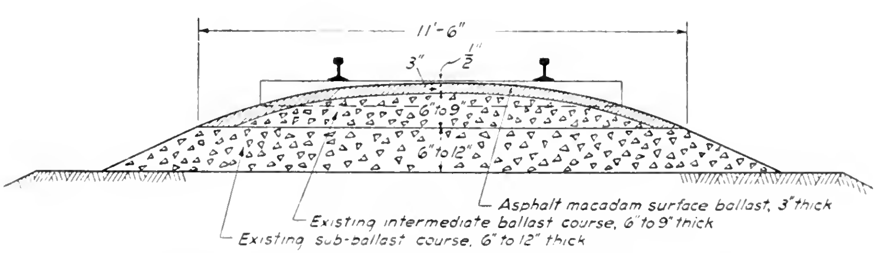
August 1946.—The line and surface of the track remained good but a number of the ties commenced to work slightly under traffic and the following repairs were made. Forty-four joints were raised slightly, involving the tamping of 544 tie ends. Chat ballast was used and was applied from the ends of the ties with paddles.

Labor—200 man-hours
Foreman—9 man-hours
Five 55-gal. drums asphalt

October 1947.—To place track in condition for the approaching winter, slight irregularities in line and surface were corrected and asphalt sealed back around ties. Four hundred eighty tie ends were tamped and four rail lengths of track were lined by picking asphalt from the ends of the ties and using track jacks.

Labor—200 man-hours
Foreman—38 man-hours
Ten 55-gal. drums asphalt

September 1948.—After five years of heavy fast traffic approximating a total of 70 million gross tons the track needed general repairs. To obtain full benefit from the asphalt covering, it was necessary to find some efficient and economical method to maintain the track on the existing firm tie beds without unduly disturbing the asphalt covering. Accordingly a plan was devised whereby the track was raised and held to grade and surface by track jacks and a thin grout consisting of 1 part lumnite cement to hasten



Cross Section of Asphalt Ballast Covering on the Illinois Central.

setting, 5 parts standard portland cement and 13½ parts of fine sand, was pumped under the ends of the ties, completely filling the old tie beds up to the bottoms of the ties and leaving the track in perfect surface.

The equipment used was a small mud jack, 50 ft. of 1¼-in. hose, and an injection nozzle made from heavy 1½-in. pipe with an end flattened out to a ½-in. opening and a 45-deg. bend from the injection end to assist in the insertion under the tie ends. Water was added in sufficient quantities to produce a grout that could be handled readily through the machine and hose. Approximately 20 min. was required after injection to permit the grout to harden sufficiently to permit the passage of trains, otherwise, the process was repeated. The asphalt covering replaced was then tamped in place around the ties and sealed by applying additional asphalt. The results obtained were considered satisfactory.

Labor—821 man-hours
Machine operators—64 man-hours
Foreman—148 man-hours
Portland cement—67 bags
Lumnite cement—14 bags
Sand—8 cu. yd.

Cross ties—eleven 7 in. by 9 in. by 8 ft. 6 in. creosoted oak.

At the end of five years, the annual track maintenance of the asphalt covered track has been at the rate of 505 man-hours of labor per track mile, including the general repairs this year, while the maintenance of the entire Illinois division, approximately 1220 miles, on which the asphalt covered track is located, has been at the rate of more than 1000 man-hours per mile of track.

Conclusions

During five years' experience with the asphalt ballast covering, observations have been made as follows:

1. It is possible and practical to maintain an asphalt ballast covering on track. The condition of the track after five years' service, indicates that the asphalt covered ballast can be maintained for several more years.

2. The covering prevents fine materials from entering and fouling the ballast.

3. Surface water is drained away quickly, leaving the roadbed dry and rigid.

4. The asphalt anchors and holds all ballast in place, thus preventing ties from working loose under traffic.

5. The hot asphalt when sprayed on the track, filled the checks and adhered to the tops of the ties, forming a bituminous covering and thus providing protection against weathering. Only 11 ties were removed during the past 5 years and it is anticipated that future tie renewals will continue to be low.

Now that the asphalt covering has proved its merit, the immediate problem is the continued maintenance of the track at a cost materially less than for track of present day standard practices.

The grout surfacing method used last year offers considerable promise of satisfactory results at greatly reduced cost.

PROCEEDINGS

PROGRAM

Forty-Eighth Annual Meeting

Palmer House, Chicago

Morning Session, Tuesday, March 15, 1949, Grand Ballroom—9:45 to 12:30

Address of C. H. Mottier, President, AREA
Report of W. S. Lacher, Secretary, AREA
Address of Max Ruppert, President, NRAA
Address of J. H. Aydelott, Vice-President, AAR
Address of Ralph Budd, President, Burlington Lines
Address of H. T. Heald, President, Illinois Institute of Technology

Afternoon Session, Grand Ballroom—2:00 to 5:00

Reports of Committees	Bulletin Numbers
1—Roadway and Ballast	479
Roadbed Solidification, by Rockwell Smith, Roadway Engineer, AAR	
3—Ties	477
The Future of Timber Supply, by C. D. Turley, Engineer of Ties and Treatment, Illinois Central Railroad	
16—Economics of Railway Location and Operation	476
27—Maintenance of Way Work Equipment	477
22—Economics of Railway Labor	476

Afternoon Session, Red Lacquer Room—2:00 to 5:00

Reports of Committees	
15—Iron and Steel Structures	478
Future of Structural Engineering in Relation to Railroad Bridges, by Shortridge Hardesty, Consulting Engineer	
30—Impact and Bridge Stresses	478
What We Know About Impact, by A. B. Chapman, Assistant Chief Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad	
20—Uniform General Contract Forms	476
29—Waterproofing	477
7—Wood Bridges and Trestles	478
8—Masonry	477
The Repair of Masonry Structures, by A. N. Laird, Chief Engineer, Grand Trunk Western Railroad	

Tuesday Evening, Grand Ballroom—8:00

The Achievements of the AREA, by H. R. Clarke, Chief Engineer, Burlington Lines
An Hour of Diversified Entertainment
Motion Picture—"Wheels A'Rolling"

Morning Session, Wednesday, March 16, Grand Ballroom—9:00 to 12:30

Presentation and Approval of Manual Material

Addresses as follows:

- The Effect of Diesel Operation on Fixed Property of American Railroads, by J. B. Akers, Chief Engineer, Southern Railway System
- Investigation of the Relation Between Track and Equipment, by J. R. Jackson, Mechanical Engineer, Mechanical Division, AAR
- Future of Soil Mechanics in Railroading, by Dr. R. B. Peck, Research Professor of Soil Mechanics, University of Illinois
- How Can the Railroad Construction and Maintenance Engineer Best Meet Increasing Cost of Labor and Material?
  - By Heavier Rail—F. R. Layng, Consulting Engineer, Bessemer & Lake Erie Railroad
  - By Increased Mechanization—S. R. Hursh, Assistant Chief Engineer—Maintenance, Pennsylvania Railroad
  - By Roadbed Stabilization—T. A. Blair, Chief Engineer System, Atchison, Topeka & Santa Fe Railway

Afternoon Session, Grand Ball Room—2:00 to 5:00

Reports of Committees	*Bulletin* Numbers
17—Wood Preservation	478
Recent Developments in Preservation Treatment, by Dr. Hermann von Schrenk, Consulting Timber Engineer	
5—Track	479
4—Rail	479

Afternoon Session, Red Lacquer Room—2:00 to 5:00

Reports of Committees	
14—Yards and Terminals	476
11—Records and Accounts	478
6—Buildings	477
13—Water Service	476
Recent Developments in Water Treatment, by R. C. Bardwell, Superintendent Water Supply, Chesapeake & Ohio Railway	

WEDNESDAY EVENING, ANNIVERSARY BANQUET

Address by W. T. Faricy, President, Association of American Railroads

Address by J. E. Gheen, philosophical humorist

Thursday, March 17—9:00 to 12:30

Reports of Committees	
9—Highways	476
Achievement of Grade Crossing Protection, by W. J. Hedley, Assistant Chief Engineer, Wabash Railroad	
24—Cooperative Relations with Universities	479

Presentation and Approval of Manual Material

- The Future of Research on American Railroads, by G. M. Magee, Research Engineer, AAR
- The Future Opportunities of the AREA, by E. M. Hastings, Chief Engineer, Richmond, Fredericksburg & Potomac Railroad
- Installation of Officers

Adjournment

PROCEEDINGS

Report of the Opening Session of the Meeting on Tuesday Morning, March 15, 1949; the Closing Session on Thursday, March 17; Addresses; other Business and the Presentation of the Committee Reports

Opening Session, Tuesday Morning, March 15, 1949

The opening session of the forty-eighth annual meeting and the Commemoration of the Fiftieth Anniversary Year of the American Railway Engineering Association, held at the Palmer House, Chicago, March 15–17, 1949, convened at 9:45 a.m., President C. H. Mottier* presiding.

President Mottier: The meeting will kindly come to order. It has been our practice to invite members of the Board of Direction to the platform at the opening of our annual meetings and to have them remain on the platform until after the photograph is taken. As this three-day annual meeting will conclude the first fifty years of the life of our organization and, because of its historical significance, I am also inviting to the platform all past presidents who are with us this morning. Will members of the Board of Direction and past presidents kindly take their places on the platform and, in doing so, will all past presidents be seated on my right, and the vice-presidents, directors, secretary and treasurer be seated on my left?

This is the 48th Annual Meeting of the American Railway Engineering Association and, as I have just stated, will conclude the first 50 years of its existence. No annual meeting was held in either 1943 or 1945 because of war conditions. This meeting is also the concurrent session of the Construction and Maintenance Section of the Engineering Division of the Association of American Railroads. The meeting is now declared open for business. However, before we start on the regular program, I will introduce those at the speakers' table.

We are deeply indebted to our past presidents. Twenty-six have already departed this life. We revere their memory. Several of the living are not able to be with us this morning. Where we are today in no small measure is the result of the sacrificial effort you, our past presidents, have expended in the work of the Association. You have demonstrated your loyalty. You are elected president by your associates because of your demonstrated ability and because of the service you had rendered this organization.

(President Mottier then introduced the following past presidents: L. C. Fritch, E. F. Wendt, J. L. Campbell, G. J. Ray, D. J. Brumley, G. D. Brooke, A. R. Wilson, E. M. Hastings, H. R. Clarke, F. R. Layng, A. A. Miller, J. B. Akers, and Armstrong Chinn. Introductions of the vice-presidents, directors, the treasurer and the secretary followed.)

Mr. Mottier: The first order of business is the reading of the minutes of the last annual meeting. These minutes have been printed and a copy has been furnished to each member. We will dispense with the reading of the minutes unless I hear an objection. Hearing no objection, the minutes stand approved as printed.

In accordance with precedent and in conformity with the provisions of the constitution, the next order of business is the president's address.

* Vice-President and Chief Engineer, Illinois Central Railroad.

Address of President Mottier

This is an historic occasion. We are now beginning the annual meeting of the fiftieth year of our Association. Fifty years is a short or a long time depending upon whether you are looking backward or looking forward. Today we propose to look both backward and forward in addition to reviewing the work of the current year.

Because of the importance of a golden anniversary in the life of any institution and because we are proud of our past achievements, we have made the observance of our golden anniversary the dominant factor in this year's activities. Every effort has been made to give it proper recognition. It is not my purpose to burden you with a review of all that has been done. Others have been working throughout the year on special features of the program. Before the conclusion of this convention, the results of their efforts will be apparent. I do not wish to assume the part they are to play in this program, but I do wish to touch briefly on some of these activities to give appropriate recognition to their efforts.

The history of our Association for its first 50 years has been written in a most interesting and informative manner by Merwin H. Dick, engineering editor, Railway Age, and I wish here again publicly to express the appreciation of our Association for the great and permanent contribution he has made to our golden anniversary. Will Mr. Dick please rise and take a bow. (Applause)

You will all wish to review thoroughly the historical exhibit on display in the foyer and adjoining halls. It is the result of cooperative effort of our Association and our friends of the National Railway Appliances Association. I commend to you this exhibit, which depicts progress in railroad engineering for the last 50 years. I am sure you will find it most interesting and instructive.

Members of our standing committees and our research staff have also participated in the preparation of this exhibit. They also have worked with Major Macomb in the preparation of a statement of our past achievements. This record has been fittingly recorded in our Golden Jubilee year book, copies of which have been sent to you. Several of these achievements are of such magnitude that singly they have justified all the expense incurred by our Association in the first 50 years of its existence. Will Major Macomb please rise and take a bow. He has done a tremendous amount of work as chairman of the Historical Committee. (Applause)

Tonight at 8:00 o'clock Past President Clarke will speak to us on the achievements of the AREA. No one is better qualified to bring us this message. In addition, several special speakers will discuss progress made in various fields in the past 50 years. Thus we will preserve in our Proceedings a carefully prepared record of our accomplishments which will be a fitting tribute to those who have contributed to this progress.

I regret that in the recording of such events, proper recognition cannot be given to many individuals who have made the achievements possible. Relatively few have been honored by being elected officers. However, our Association stands today where it is because of the loyalty and service of those members who have contributed through committee activities, payment of dues, attendance at annual meetings and in many other ways, but who have never received official recognition. There are also many committee and subcommittee chairman who have contributed substantially to our progress.

At a time like this we naturally think of those who were responsible for the organization and early development of our Association. There was included in the March issue of the AREA News a fitting reference to Augustus Torrey, L. C. Fritch and

J. F. Wallace, members 1, 2 and 3 on our membership list. These three men composed the triumverate which I mentioned earlier. A review of our early history will impress anyone with the contribution which these three men made to the formation and early development of our organization. Mr. Torrey was chairman and Mr. Fritch was secretary of the organization committee which did much to bring the Association into being. It was unfortunate for the Association that Mr. Torrey met death in an accident in line of duty in 1902; otherwise he would have contributed much more to its development. Mr. Wallace was chairman of the committee that prepared the first constitution and also served as the Association's first president, acting in that capacity for two years. He played a leading role in formulating the policies that have had so much to do with shaping the course of the Association. Mr. Fritch also served as the first secretary of the Association, filling that position for seven consecutive years. Furthermore he served one term as president 1910–1911. We are greatly indebted to these men. They did their work well and left an indelible imprint on this Association.

It is remarkable that the fundamental policies and general program established by the founders of our organization have been so little changed through the years. The object of the Association, as stated in the constitution first adopted, remains unchanged to this day, "the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railroads."

Mr. Wallace, in his president's address at the end of his first term, delivered forty-nine years ago yesterday, emphasized this objective. These are his words: "It is the function of the railway to furnish transportation to the public with the maximum amount of speed and safety to person and property, the greatest convenience to its patrons and at minimum cost." * * * "While the question of what is economical management respecting maintenance of way and structures is one which the management of each property must solve for itself, we can certainly assist each other by a full and frank comparison of views and a discussion of the various elements that constitute an economical handling of our maintenance of way work. The establishment of certain recognized principles as the result of our investigations and discussions will materially assist our managements in adopting a policy that will lead to the truest and highest economy."

In that first annual meeting President Wallace outlined a policy which has guided the course of our Association's activity through its first 50 years, when he stated "This Association is for a distinct purpose—honest, hard work and not entertainment." I can see no good reason why the same policies should not be followed for the next 50 years.

We are particularly grateful to the NRAA for the outstanding exhibit of railway appliances now on display at the Coliseum. Your Board of Direction visited it yesterday and we commend it to you as being worthy of your careful and conscientious study.

For nearly 30 years we have maintained a cooperative arrangement with the Association of American Railroads and its predecessor, the American Railroad Association, that has been beneficial to both Associations. Under this plan the AREA functions as the Construction and Maintenance Section of the Engineering Division of the AAR and by virtue of his office, the president of the AREA is chairman of the Engineering Division of the AAR. Our Association is still independent in that it is made up of dues-paying members and this independence preserves to it the advantages inherent in the original AREA organization. On the other hand it secures financial support and prestige by operating as an agency of all railroads through its affiliation with the AAR. Up to the present time this has been evident primarily in its research activities.

The value of the cooperative arrangement under which the AREA committees and the research organization of the Engineering Division, AAR, function as a central agency for the conduct of investigations for all of the railroads was emphasized in the series of anniversary articles published in the AREA News last year. This joint effort has become so important in recent years, and the inter-relation of these activities with our committee work has proved so valuable that they are sure to play an ever increasing part in the work of the AREA.

Few of our members realize the fine work that has been done in recent years by our research committee, which now consists of Messrs. Clarke, Grove and Blair. Mr. Clarke has been chairman of this committee since it was organized in 1944, and his service on this committee and his deep interest in our research program are in a large measure responsible for the honor which we propose to bestow on him later today, in which action I am sure you will all concur.

Before concluding my reference to our past, I wish to refer to a branch of our organization which has contributed much to the success of our Association and to our individual members. Its constituents are not mentioned in our constitution, nor are they given recognition in any of our several classifications of membership. They do not pay dues as such but needless to say they have contributed much to the success of our efforts. A few of them are present here this morning. I refer to our wives, who through the years have made possible many of our individual successes. Without their encouragement and sacrificial efforts, we could not have made the contributions which we have made. Many of them in their earlier years lived rugged lives and endured what most women today would consider hardships, in order that we might measure up to the responsibility that a railroad man is called upon to meet. We owe much to our life companions, who through their sympathy and help have made real contributions to the work of this Association. (Applause)

Much has already been done in connection with the celebration of our fiftieth anniversary. However, these activities have been conducted in such a manner that the regular work of the standing committees has not been adversely affected. The secretary's report is most enlightening, and I will not repeat the information contained in it. I suggest that all members read it carefully. In it you will see evidence that committee activities and the committee reports have not suffered.

I am hopeful that the enforced changes in our convention procedure all of which have been carefully considered by your officers and by a special committee under the direction of G. P. Palmer, will meet with your approval. It was imperative that some such program be adopted for this meeting. Experience at this meeting will demonstrate whether the holding of separate and concurrent meetings is desirable. Such a program has been suggested to us on previous occasions and it is being used successfully by other organizations somewhat similar to ours. We recognize that it has limitations and objections, but it also has some decided advantages. We ask that you cooperate with us and adjust yourself to the program to the fullest possible extent.

All of the special activities that have been undertaken in connection with the fiftieth anniversary have been carefully considered to make sure that their ultimate effect on the Association would be constructive and, insofar as possible, be permanently beneficial. The accomplishments of the Membership Development Committee, under the chairmanship of Vice President Schwinn, have been particularly gratifying. Our membership now exceeds 3000 and is considerably larger than ever before. A net gain for the year of 674 (29 percent) is no small achivement. This increase in membership not only increases our potentialities for greater usefulness but in a like degree increases our responsibilities.

Much has been said in recent years, in connection with our Association activities as to the necessity of interesting young engineers in railroad employment, and much has been accomplished in this regard in the last two or three years. It is equally important that we interest younger men in the work and activities of the Association. Our junior membership has increased this year from 37 to 145 and many of the new members are young and occupy subordinate positions. We have a challenging opportunity to serve and interest these new members and thereby protect the future of the Association. Recognizing the challenge which faces us, your President last August appointed a committee of board members, Messrs. Loeffler, Schwinn, Sitton and Blair to study the problem carefully and recommend changes or new activities that would improve the effectiveness of our Association. We must not lose the impetus which we have received through the fiftieth-anniversary-year activities. The older members of the Association can help by stimulating the interest and activity of our new members.

Another enterprise of the current year which has been discussed in detail by our secretary is the revamping of our committee memberships. It too represents a major achievement. The principal purpose of the new rules is to spread the committee work among as many members as possible. The new program should result in better committee work and increase its usefulness.

The new plan of completing committee rosters and assignments for publication and distribution before the end of the year, instead of after the March meeting three months later, is very constructive and should improve the work of the committees.

The change in the constitution increasing the number of directors and reducing the number of past presidents on the Board of Direction, which will become operative with the election of new officers for the ensuing year, is a forward step and should have beneficial results.

I have been impressed during the year with the possibilities of development in our monthly publication, the AREA News. On five different occasions during the year when the anniversary series article contained an appropriate message, an issue of the News was sent with a personal letter from your president to the presidents and operating vice-presidents of railroads of the United States and Canada. Responses were sympathetic and encouraging.

I have discussed our beginning, our past and our current year; may I now generalize briefly as to our future? Our profession and our Association are faced with real challenges. As engineers we perform an essential function in the construction, maintenance and operation of railroads. Our future lies in their successful perpetuation. Railroads have become an essential part of our national and economic life, and they must be preserved. They *will* be preserved only as long as they perform essential service at a cost which patrons can afford to pay and at which competitors cannot undersell, when all factors of cost are considered. Our challenge as individuals is to do our full share in achieving this goal of economy and usefulness. Our past contributions to that end have been great, but the field before us is no less fertile. Our opportunities are unlimited.

As an association and working together as a body our opportunities and our accomplishments are multiplied because of the greater effectiveness of cooperative effort. The increased costs of labor and material, coupled with the pending 40-hour week and the entrance of competitors into the transportation field, have posed the problems of doing more with less and constantly improving production with what we have. Such problems create the need for the best possible "know how." It is just such situations as this that make the AREA imperative. The AREA today stands in better repute in the railway engineering profession and among railway managements than ever before. It is our responsibility to improve the quality of the work, so that its value to the members and to the railroads will be greater each succeeding year.

Mr. Hastings has been selected to speak to you on our future opportunities, which he will do on Thursday when our new officers are inaugurated. I recognize that the heavy responsibility for our future rests on future presidents rather than on the retiring president. However, I could not close this address on the occasion of the Fiftieth Anniversary of our Association without emphasizing the need for and the essentiality of the service which we can render, and my confidence in the future.

Our membership is larger and more members are working on committees than ever before. Our secertary and his staff are loyal, experienced and efficient. Our research staff is larger and better trained, and our appropriations for research projects stand at an all-time high. The new research laboratory will soon be a reality. We will profit by the experience and achievements of our first fifty years. Our momentum and our "going concern" value are high. We have a most loyal membership. I marvel at the loyalty of our members—a loyalty which can be explained only by man's love for his work, his ambition to learn, to develop and to achieve an objective, and also by the friendship which comes from association with others working in a common cause. One of the greatest assets of membership in the AREA is the opportunity it affords of working with brother engineers. Some of the warmest friendships that many of us enjoy have been kindled and intensified by working together in and for this Association.

I have never felt more confident of the potentialities of the service which the American Railway Engineering Association can render than I do at this moment. Whether it meets the challenge or fails depends almost entirely on us, its present 3,000 members. We must face the future with a full realization of our responsibilities and with a willingness to do our full share in meeting them. Those who have preceded us have done their work well. We have a past of achievement, but we also have what is much more important, a future of opportunity. Let us meet it with the best we have.

(The audience arose and applauded.)

President Mottier: Thank you.

The next order of business is the report of the secretary and treasurer. I will ask Mr. Lacher, the secretary, to present these reports.

Secretary's Statement

Secretary Lacher: I am glad that the president said to you what he did about the reading of the secretary's report because it has always been my idea that the report should be read by the members, at least glanced at, rather than to have me attempt to tell you what is in it.

Of course, this year, with this Golden Jubilee Year Book, which contains so much information that is of much greater immediate interest than the reports of the secretary and treasurer, I suppose that most of you have not even found those two reports in the Year Book. They are about a third of the way through rather than being either right in front or right in the back. I still hope that you will look at them.

This year there is a special reason why most of the members should be interested. There should be considerable curiosity about the financial outcome. You should have curiosity about that, by way of a check on the sagacity of your Board of Direction in recommending to you in the summer of 1947 that you vote a 50 percent increase in the dues, beginning with January 1, 1948.

Unfortunately, you are doomed to disappointment. In the first place, the increase in revenue from the entrance fees and the membership dues paid by the large number of new members that came into the Association during 1948 served to submerge the influence of the increase in dues. It is there but it is pretty hard to distinguish it.

On the other hand, the expenditures that were made during the course of the calendar year of 1948—it is also the fiscal year—in preparation for this celebration that we are having here these three days served to upset the balance, also, with respect to the expenditures. As a result, it would have taken all kinds of accountants to figure out just what the effect was of the increase in the dues.

Further than that, those same two influences are carried over into the present year. We have continued to have a more than normal increase in the number of applicants for membership, which will affect the revenues.

On the other hand, of course, you realize that we still have a great many bills to pay for this convention. As a result, it will be necessary to wait until we have the financial outcome for 1950 to get a really good idea of just what good guessers the Board ot Direction were in arriving at that 50 percent increase.

The report of the secretary makes brief reference to one problem that has to do with the Manual. We have now issued 12 supplements to the Manual. The next one, the one for 1949, will be the thirteenth since the Manual was placed in the form of a loose-leaf book in 1936, and we hope that with that many issues of the supplement we have encountered all of the difficulties that will come up in the perpetuation of that sort of a document.

It has developed a few things that were not anticipated, and some of them are going to be rather hard to handle. One thing that we have discovered is that in a chapter that is revised frequently, we get a rather spotty appearance of the pages because, as you insert new type in place of old type, the new type is nice and clean, whereas the type that has gone through a considerable number of printings gets worn down, and you get a rather unfortunate appearance of the page. But what I wanted to speak of briefly is a problem that we encounter, by reason of the nature of the book.

After all, the only purpose of issuing a book like that in loose-leaf form is to save money in the issuance of the supplements. The idea, of course, is beautifully simple. You simply print new pages for new material that is to be inserted. They go out to the members who have copies of the Manual and, in the case of a revision, all they do is take out the sheets that are replaced.

However, a number of rather complex problems come up in connection with that. Our Manual is so devised with respect to paging that we have consecutive page numbers for each chapter. That implies that, when some new material that has not previously been in the Manual is issued, it would have to come in at the end of a chapter; in other words, if the last page in the chapter is page 98, the first page of this new material would be page 99. Well, the effect of that is that you get a chronological arrangement of the material in the Manual. Some of the committees do not like that. They have their own ideas as to what to them is a logical topical arrangement of the material, and I think they are right.

The only way to give them what they want is to introduce decimal fractions in the page numbers. If you will examine the Manual, you will find in some of the chapters we have gone to the third decimal place in those fractions. That has been unsatisfactory, with the result that we already have made complete reprintings of three chapters to effect the desired rearrangement of the material and get it in some sort of a topical order.

There are two other chapters that are under consideration now for the same treatment. In addition to that, the Committee on Masonry has come forward with a plan for the setting up of an entirely new system of page numbering of the chapters, so that it would be possible to introduce material anywhere. On paper, the plan looks very good but, if we do adopt it, it will be necessary to reprint the entire Manual, so perhaps we should wait until we exhaust our present stock of the Manual and have to print another edition. But before we can do that, we will have to find out whether this scheme will fit the plan of things with respect to all of the chapters.

You have heard a good deal so far, and you are going to hear still more during this and the following two days about the reputation that your Association has earned as the fountainhead of reliable knowledge on the subject of railroad engineering.

I would like to talk to you for just a moment about a by-product of that reputation, namely, the information service that we have had to conduct for the purpose of answering the many questions that are addressed to the AREA, or which are relayed to me from the Washington office of the Association of American Railroads.

I try to answer those questions myself, so far as it is possible, but in cases where the element of time is not too important and the question is of a rather technical nature, I try to get the assistance of the appropriate committee and, also, in more recent years, Mr. Magee's organization has been very cooperative. In some cases, obviously, the questions are such that he or members of his staff should answer, rather than the secretary. The questions cover a wide range, both as to source and to subject. I have written down here a few of the questions to illustrate the kind of stuff we get.

A high school boy has chosen railway engineering as the subject for a term paper and won't I please write to him about it? (Laughter)

A reporter for the International Railroad Congress sends in a questionnaire that could not be answered satisfactorily short of 10,000 words.

Most of the letters are more specific. "Please identify the following brand"—which is given in the letter—"on rail laid in the North Missouri Railroad in 1858."

Occasionally—and I am always glad to get letters like this, although it is sometimes rather difficult to supply the answer—there is a request to recommend a man to undertake a particular assignment. Recently I was asked to supply information as to men who are authorities on tunnel ventilation.

The Humane Society relayed a complaint from Newfoundland to the effect that farm animals were cruelly hurt when they stepped on cattle guards.

But whether the question is a serious one or one that may seem frivolous to us, I am ever mindful of the fact that we have a responsibility to carry out, that we have an enviable reputation to maintain. For that reason, I feel that it is always important to give a courteous and informative reply. At this point I want to express my appreciation for the assistance that I have received in providing answers to the many questions asked. I know in some cases it has taken considerable time from some very busy railroad men.

As many of you already know, this has been a strenuous year for the secretary's office. At the same time, it has been an interesting and stimulating one. We have had to do lots of things in less time than we have done them before.

The processing of the applications for membership which were received at a rate not previously dreamed of, and the complete reorganization of the personnel of the committees to which your president referred a short time ago were an enormous job. It was a burden that placed great demands on the staff of the secretary, and the industry, initiative and ingenuity that the members of the staff displayed are to be highly commended. (Applause)

President Mottier: Thank you, Mr. Lacher.

You have heard the report of the secretary-treasurer. What is your pleasure?

(Upon motion regularly made and seconded, the report of the secretary and treasurer was adopted.)

President Mottier: I wish to make two comments in amplification of what Mr. Lacher stated about the large number of applications increasing our revenues for the year and interfering with the possible determination of the justification for the increase in dues.

If you look at the secretary's report, you will find that we closed the year with a profit of $4,678.96. It is very fortunate for me, the Board, you and everybody else that we had that situation, because you are all going to be greatly pleased by receiving a medallion commemorating the 50th anniversary of the Association, which you are going to keep as long as you live, and perhaps some of your grandchildren will keep it after you are dead and gone, but not forgotten. I predict that those medallions, for the next 50 years, will be displayed on the desks of engineers all over this country.

One of the strong arguments and impelling justifications for spending the money to purchase the medallions which cost almost $5,000 was the fact that we had in our possession $4,678.96 which you men had contributed as dues. (Laughter)

I wish once more to pay tribute to Mr. Schwinn and his membership committee. Our year, as far as membership statistics is concerned, ends with February 1 but apparently the membership committee did not stop working then because since February 1, and up to yesterday, we have received 95 additional applications for membership.

The National Railway Appliances Association and the American Railway Engineering Association have worked together cooperatively for many years. As a matter of fact, the predecessor of the National Railway Appliances Association was older than the AREA. During those years, when a show was held concurrently with our annual meeting, one of the principal incentives for many to attend was to view the exhibits of the National Railway Appliances Association.

We have, as I stated earlier, a very fine exhibit at the Coliseum, and you should all make every effort to see it before you go home.

Recognizing the contribution that our appliance friends have made in the welfare of the railroads and the fine spirit of cooperation which the National Railway Appliances Association has shown to our Association through the years, we have invited Max K. Ruppert, president of the NRAA, to address us at this time. He will now speak to us on the subject, The National Railway Appliances Association and Its Relationship With the American Railway Engineering Association. Mr. Ruppert! (Applause)

The National Railway Appliances Association and its Relationship with The American Railway Engineering Association

By M. K. Ruppert
President, National Railway Appliances Association

The members of the National Railway Appliances Association are deeply conscious of the honor which has been accorded us by the thoughtful and generous action of the American Railway Engineering Association in giving our association a position of prominence in the scheduled activities commemorating your golden anniversary. As spokesman for our members, I extend congratulations on the achievements which have marked your history as an association, and express sincerest wishes for an uninterrupted record of progress in the years to come.

As an individual, may I say, my emotions are a mixture of pride in being given the opportunity to speak for my fellow members—and of awe at finding a peddler addressing so many of your membership without having to hasten my remarks to a conclusion for fear of the sudden appearance at the door of a staff member announcing you are wanted at once in another part of the building—or an overlooked appointment which necessitates an adjournment of our discussions. However, I shall not indulge myself in this unexpected luxury. I am mindful that there will be other days and other occasions when this circumstance will not prevail and if I show discretion now—perhaps you will be more lenient when the shoe is on the other foot.

Our organization was created for the purpose of promoting the welfare of transportation industries; our activities are wholly educational, dedicated to advancement in the efficiency, safety, maintenance and operation of the tools and appliances which we are privileged to provide. Our constitution and by-laws specifically state that our activities shall be dedicated to the cooperation required in the development of conventions of engineering, research and scientific associations; that we shall sponsor and hold exhibitions of an educational nature pertaining to the development of equipment, appliances and supplies to complement the activities of the conventions to which I refer.

My privilege is therefore a happy one for it entails only the telling of a simple story of how these ideals are being achieved by the continuous cooperation afforded us through your great Association.

Beginning in 1894

The story began many years ago, in 1894, when men of wisdom in our industry foresaw that the appetite of the iron horse would become greater and greater. The vision of these men is indeed to be complimented. The small beginning of our Association in 1894 formed the nucleus around which has grown a gigantic industry whose entire endeavors are devoted to meeting the ever-increasing demands of that then novel, but today, commonplace, iron horse whose abilities to expand our country's frontiers and serve its thousands of communities constitute one of the romantic epics of transportation which is the envy of every country in the world.

Mechanical genius and resourcefulness for creation were natural in this country of unlimited opportunity. From the beginning of recorded history—locomotion has always been an attraction to the mechanical minded. Ever and ever, man has tried to move heavier loads at higher speeds. The result in the railroad field was the creation and introduction of equipment sustaining greater axle loads and moving at speeds which fifty years ago would have been considered fantastic. In the field of passenger equipment, our modern day streamlined light weight air-conditioned cars and locomotives—steam—electric and diesel powered, would have frightened the designers of 1898 should there have been anyone sufficiently bold to project the thought of such equipment.

Without the slightest thought of detracting from credit richly deserved by the mechanical branches of railroading, it must be noted and emphasized that the products of their ingenuity could have conceivably lain dormant but for another growth which was taking place. I speak of the expanding of knowledge of applied engineering which kindled a spark of imagination in the minds of men of that profession and resulted in conceptions of the foundation and the physical accouterments essential to the growth of the iron horse. I have always felt that when credits are being handed out in connection with the growth of the railroads that too frequently the contribution of the civil engineer and his departments have not been given the emphasis they deserve. It has been your inspired services which have made possible the achievement of the dreams of those whose responsibilities are attached to the mechanical phases of railroad operation.

Genesis of the AREA

The engineering fraternity quickly realized that erection of these essential foundations could come most quickly and progress parallel with mechanical invention achieved, if an Association was formed—an association within which the multitude of problems could be considered—studied—examined—tested and resolved into answers from which all elements could find solutions to fit their individual problems. From this knowledge of need came the answer in the founding on March 30, 1899, in Buffalo, N. Y. of the American Railway Engineering Association. The wisdom of this move and its effect upon modern day rail transportation is too well known to each of you to require any further description on my part. The material benefits of the past of achievement are effectively high-lighted in the historical display surrounding the halls of this floor. The physical results of your contributions to improved maintenance of way are revealed in manifest form at the Coliseum where our Association is presenting its 34th Exhibition.

I spoke earlier of the wisdom of the industrialists who founded the NRAA. I desire to relate that reference to the action that transpired in Buffalo in 1899. It is obvious that the founders of our Association realized that as scientific study progressed, it would result in ideas seeking outlet in material form. It was equally apparent that as this natural development grew there should be at hand an association of manufacturers whose resources would provide services that would form an inexhaustible reservoir from which science's appetite could be served. Such association would need be so broad in its scope that those who would find need of its services would never find themselves confined in having their desires given material and physical form in a myriad of ways.

The founding of the NRAA was timely. It preceded the action at Buffalo sufficiently to create interest on the part of many manufacturers. It stimulated individual initiative and a searching endeavor on the part of manufacturers to integrate their activities to meet the growing demands of the railroads for the tools that would be necessary in building the physical foundations required for support of the growing mechanisms which must be introduced to meet adequately the ever-increasing demands for service.

Marked Growth

Thus has a far-visioned conception become a reality. From a beginning of 40 members in 1894, the NRAA now proudly lists a membership of 165 companies and corporations. Many of the companies devote their entire endeavors to the service of supply to the American railroads. Numerous others have divisions within their corporate structure whose activities are confined wholly to the needs in the field of railroading. Over the years, these companies which make up our membership have concentrated their endeavors on creating organizations whose personnel are specialists in this chosen field. In the training of this personnel—the emphasis is always on rendering *service* to the organization through which we enjoy our contacts with railroad managements—specifically, the engineering department.

Proceeding on this sound premise, the relationship of the activities of our Association to those of the AREA can readily be appreciated. As problems arise affecting need for changes of established maintenance practices necessitating refinements in the tools, machinery and appliances connected therewith, the fact is generally disclosed through the activities of the various committees at work within the structure of the AREA. In the meantime, suppliers' representatives through their individual contacts with members of the AREA on railroads all over the country have gained some knowledge of the needs for changes and refinements to which I referred and have promptly transmitted this knowledge to their respective companies which immediately undertake studies to effect a constructive solution. A result is achieved that is valuable to both user and supplier. The user finds a source of supply available for his needs which is unlimited—the supplier finds an outlet for the products of his ingenuity which is unrestricted. The achievement realized is the product of *combined action*. The activities of our respective memberships have been complementary because of team work and confidence. Our joint endeavors have resulted in economies in maintenance of way costs to the railroads; likewise for industry they have made possible the widening of horizons for service as a result of the ingenuity displayed by members of the AREA in their constant endeavors to serve their managements with constructive foresight and ability.

Progress in Research

Our joint endeavors have resulted in another development of far reaching proportions—and I refer to the matter of research. Frequently you will hear or read of some individual making observations to the effect that the railroads have not directly availed themselves of the benefit of research. I contend that the railroads of the United States have, in addition to their own vast resources for research, a still greater reservoir to draw from in the form of facilities afforded by the industry which serves their needs. The benefits which have accrued to each of us are well known and too numerous to be described on this occasion. I am confident that in this field of research, the activities of your Association will be co-related with those of the members of our Association in the same spirit of cooperative effort which has characterized our relationships for the half century just concluded.

Our joint exchange of knowledge in the field of research is essential to further progress of the economies so far achieved by such action. Failure to follow this course leads to an abuse of the advantages offered by research in that it tends to circumscribe or place limitations on ingenious and resourceful thinking and the application thereof to the results of research. Research should point the way—human ingenuity should develop the manifold forms by which the desired results can be achieved. Our industrial greatness has been built upon this principle, and failure to keep this fact uppermost in our minds invites sterility of thought and cessation of progress.

The respective positions of our Associations are described well, I believe, by an observation made to me recently by a railroad officer who has watched our activities for a number of years and who takes an unusual interest in them. This gentlemen related an experience of his which left a lasting and beneficial impression. An elder officer of his railroad was discussing a proposed advancement which was to come to this young man. After the usual pleasantries, the senior officer made an observation to the effect that regardless of this individual's personal ability—no matter how resourceful and ingenious he might be in resolving operating problems, he should remember *always* that without the understanding on the part of his associates of his objectives and their constructive cooperation in carrying out his wishes, he could never achieve real success. This gentleman has told me that this friendly advice, never forgotten, and frequently applied, has benefited him and his management more than any other experience in his career. I felt that both of our Associations were paid a distinct compliment when this officer recently likened the results of our joint activities to the benefits which he has attributed to this realistic advice given him many years ago. We, of the supply industry, are justly proud of the trust, the confidence and dependence which you gentlemen of the AREA have reposed in us. Our endeavors are dedicated to the improvement of our abilities to be of service.

As to the Future

My remarks have been confined to the activities of the past and present time. It is fitting, I believe, to conclude on an inspirational note about the future. A coincidence of fate affords, to my mind, an extremely fine foundation for what I am about to say. The coincidence to which I refer is the knowledge we all have that the first president of the AREA was J. F. Wallace, who at the time of his election was assistant vice-president of the Illinois Central with general supervision over the engineering department. One-half century later, the president of your Association is the vice-president and chief engineer of the Illinois Central Railroad, Charles H. Mottier. To give point to my remarks I am asking you to indulge in fancy and imagination. Let us assume that Mr. Wallace had been asked on the occasion fifty years ago to describe his thoughts regarding the form and physical characteristics of the railroad structure in general and the Illinois Central in particular as they would be found in the year 1949. Can you believe that he would have cared to predict the mechanical advancements as represented by dieselization, streamlined trains, air conditioning and other improvements too numerous to mention? Would he have ventured to predict the electrification of suburban services or the advances in signaling and controls which stem from it? To envision the future, Mr. Wallace would doubtless have referred to conditions as they were found on the Illinois Central as revealed by its statement at the close of the year 1898. An examination of only a few items as they appear comparably in the years 1898 and 1948 reflects changes in only fifty years which I doubt Mr. Wallace would have predicted.

In the year 1898, the Illinois Central had 6034 miles of all tracks—in 1948, 11,190 miles. The maximum weight of rail was 85 lb. and today it is 131 lb. per yd. There were in service in 1898 an approximate total of 15 million ties on the system and in 1948 this had increased to 30 million. Of these ties, none were tie plated in 1898 but in 1948 this condition has been improved and 95 percent of all ties are plated. The maximum weight of the locomotives was 79 tons in 1898 and 240 tons in 1948. The system carried a total freight tonnage of 14,474,000 tons in 1898; in 1948 this had grown to 72,857,000 tons. The total passengers carried in 1898 amounted to 14,735,000 and in 1948 the road carried 48,387,000. Fifty years ago, the running time from Chicago to New Orleans was 25 hours—the same run in 1948 consumes only 15 hours and 55 minutes. In 1898 the total operating revenues of the Illinois Central amounted to $33,014,000. In 1948, the operating revenues were $268,200,000. The maintenance of way and structures expenses in 1898 were $5,100,000 and in 1948 were $43,445,000. The taxes paid by the Illinois Central in 1898 amounted to $1,435,000 and this same item in 1948 reached the staggering figure of $33,653,000, which you will note exceeds the total operating revenues for the year 1898.

While the foregoing comparisons reflect the changes on a single carrier, we all know they can be translated into the experiences of every railroad, large or small—in meeting the problems resulting from the transition which has taken place in our country's growth in the last fifty years. The engineering fraternity has had a direct part and responsibility connected with the needs created by the comparisons I have recited.

Progress Will Continue

Use of these particular data brings me to the point I wish to establish—Mr. Wallace would, I believe, have been reluctant to express his ideas of the changes which would be found on his railroad in the year 1948; I believe Mr. Mottier would be equally reluctant to venture a prediction of a similar nature regarding the Illinois Central as it will be found in the year 1999. But when that date is reached, there is every reason to believe that the railroads will have made their accustomed contribution to progress between now and that time as they have so outstandingly done in the years between 1898 and 1948.

This magnificent country of ours has not approached its zenith. Its frontiers have been expanded—its industrial development heightened; the most prominent participant in this modern day phenomena is the American system of railroads whose utility will play a constant part in meeting the requirements for service which our nation's expanded growth will require.

Conditions may change—the rules by which we live may be modified—these are factors which must be confronted by each one of us as growth continues. We have not enjoyed a static experience in the past fifty years and there shall be no such luxury for those who are destined to manage the interests of our railroads in the coming years. The members of the AREA, present and future, will play their role in shaping the form of rail borne transportation which will transpire with our nation's continued growth. I refuse to believe that the railroad industry will be found wanting in depth of intelligence, resourcefulness or ingenuity in meeting its current and future problems which will be contiguous with this growth.

If my sincere belief in this future of which I speak, serves to inspire a single listener here today, I shall have been worthy of the honor bestowed upon me by those for whom I have the privilege of being spokesman. (Applause)

President Mottier: I would like to make a comment about Mr. Ruppert's very fine address and some of his comparisons. He spoke about Mr. Wallace and the Illinois Central and, incidentally, he mentioned how much money we are now spending on maintenance; as he spoke I looked in this Golden Jubilee Year Book. Of course, my innate modesty is quite a handicap to me, but I noticed that there were 279 charter members of this Association and, if you look real carefully, you will observe that there were 13 railroads that had more mileage than the Illinois Central but the Illinois Central led the field with its 30 members. It had about 11 percent of all the charter members of the Association, with about 2½ percent of the railroad mileage. I have just made some fast calculations and it appears that with our present membership of 90 we have dropped to about 3 percent of the total Association membership where originally we had 11 percent.

I would say that Mr. Wallace was a pretty good man in getting the boys lined up for membership in the Association.

President Mottier: As I explained previously, the American Railway Engineering Association functions as the Construction and Maintenance Section of the Engineering Division of the Association of American Railroads. The Engineering Division is a unit of the Operations and Maintenance Department of the AAR, and it is our privilege to have with us the head of that department.

In addition to the problems of engineering, he must deal daily with all the matters that come to the attention of a railway operating officer.

Mr. Aydelott needs no introduction to this Association or to a Chicago audience. For many years he was an officer on the Burlington Railroad. We are very pleased to ask Mr. Aydelott to address us at this time. Mr. Aydelott!

Address by J. H. Aydelott

Vice President, Operations and Maintenance Department, AAR, Washington, D. C.

I appreciate the action of your Board of Direction in giving me a place on this program. It gives me opportunity on behalf of the Operations and Maintenance Department of the Association of American Railroads to extend congratulations to you on this 50th anniversary of your organization; also to extend congratulations to your most capable president and to his staff and the Board of Direction who have gone to special efforts to make this convention one of the most noteworthy in the history of the AREA and one you will look back upon with a feeling of pride in the organization.

I also wish to congratulate the officers and members of the National Railway Appliances Association whose fine machines and appliances have so greatly facilitated our construction and maintenance work to render possible many of the achievements which will be recorded in these sessions.

I shall devote much of the time allotted to me to discuss the potentials of the future with respect to our industry and more particularly as to what it may hold for the railway engineer. Yours is a profession which must be able to adjust itself to meet new situations as they arise. Today, we look back upon the accomplishments of the early railroad engineers and marvel at their ingenuity in so locating and building these pioneer railroads that many of them today are operating on line and gradient as originally constructed. The building of new railroad lines in extensive mileage ceased almost entirely with the advent of competition in the transportation field from the motorized highway vehicle—to accommodate which large sums of public money have been spent.

The Advent of Diesel Power

The development which will go down in history as of great importance to the railroad industry came during the depression as a challenge to the newer forms of transportation to which much passenger and freight traffic had been lost. This was the introduction of the modern diesel engine into passenger train service and we are indebted to your next speaker, Ralph Budd, a great engineer, who had faith in this new type of equipment and launched its operation without heed to the collapse of railroad systems all around him. These new trains caught the public fancy and are now quite well established throughout the network of our American railroads. Prior to the introduction of diesel power in road service progressive increases in the size and weight of steam locomotives and of freight and passenger train equipment had created serious roadway problems. Expenditures of millions of dollars were faced by many railroads in financing the cost of strengthening bridges and track if modern locomotives were to be accommodated. The diesel locomotive has pushed these expenditures far into the future. The day will doubtless come when a turbine locomotive also may be developed to permit a reduction in axle load to give those engines some measure at least of the versatility of the diesel locomotive.

It will be agreed, I am sure, that the development of the diesel locomotive and light-weight equipment marked a turning point in the fortunes of our railroads, particularly as to construction expenditures, and the fact that this came about in the depression years makes the event all the more noteworthy.

I am hopeful that you may be furnished during the course of this convention the results of research activities conducted last year for the purpose of determining whether any undue strain was being placed on the outer rail of curves under the operation of diesel-powered high-speed freight and passenger trains. The preliminary reports indicate we have nothing to fear in this connection. However, it is most evident that as the cruising speeds in both classes of service are accelerated that we shall have to maintain our track structure to more perfect standard if good riding qualities are to be insured. This refinement in the physical characteristics of the roadbed and track will involve an easing of both vertical and horizontal curves which improvements will have beneficial results not only by reason of permitting higher sustained speeds for greater distances and a more comfortable riding track, but will produce economies in maintenance and will likely give opportunity to relieve many drainage problems.

Pyramiding costs of labor and material give indication of the problems of progressing work of this nature and focus attention upon the adequacy of railroad earnings to support these needed improvements. Railroad earnings further must support the purchase of more machines with which to supplant hand labor in maintenance work as well as in construction work. Obviously, the railroads cannot continue to seek increases in their charges without possibly forfeiting some of the traffic which they enjoy. Therefore, if the railroads are to be in a position where they can continue to improve the quality of their service through the use of better track and equipment, they must not only secure the very maximum of economies in their operations and maintenance but there must also be a moratorium on increases in wages and in the costs of materials which the railroads buy.

Further Economies Needed

The engineering of further economies into the railroad maintenance and construction work is largely a responsibility of the railway engineer. Clearly we have not exhausted all the means for bringing about these economies but to obtain many of them sizable capital expenditures will be necessary. Wage levels of the groups which do the maintenance and construction work are in many cases three times as high as pre-war. Further in the not too distant future their productive hours will be reduced by eight each week without a corresponding reduction in payroll expense. While these trends in labor and material costs are of wartime influence, the traffic pattern of railroads today is far different from that of the wartime years. Railroads made money during the war because they had the best possible balancing of tonnage by direction and most cars were loaded to capacity and many carried freight of the highest earnings class. The length of the average haul was unusually high but began to recede with the close of the war and that pattern continues. As an industry, therefore, the railroads face a rather disquieting future, particularly so if other forms of transportation are able to continue their inroads upon our traffic volume. While subsidies to their competitors are increasing to offset losses in operation, the railroads are being urged to maintain themselves ready at all times for a national emergency.

We are inclined to wonder, and justifiably so, if the people of this country really understand the problems of the railroads and the important position which they hold in our national economy and security. The railroads carry a terrific tax burden. It is said that in one state on the eastern seaboard, they pay out more in taxes than the traffic handled in that state nets them. Railroads are taxed exorbitantly in sparsely populated states because of the growing cost of government and there being few industries besides the railroads upon which this tax burden can be placed. The railroads carry unusually high taxes for Social Security—at present about four times as much tax as industry pays into the Social Security fund. Increasing taxes, wage and material costs are offsetting economies in operation and maintenance faster than the railroads can make them.

A review of the railroad abandonments of the past two decades will indicate the extent to which public schools are dependent upon railroad tax money for their existence. Many schools have been closed where these abandonments have been made.

Carry the Railroad Story to the People

These conditions and other disturbing trends bring me to ask what is it you engineers might do in assisting executives and public relations officers in carrying the railroad story to the people. There is no one to whom the continuing solvency of our railroads means more than to the railroad engineer because without adequate earnings to support construction and maintenance programs his future certainly is not bright.

The railway engineer has an unusual opportunity for meeting the people in the territory served by his railroad. He sees a lot of farmers, highway commissioners, city officers and other groups including employees of his railroad in other crafts and among these people there must be a great number who would welcome an opportunity for a discussion of the railway problem.

Our competitors in one way or another are kept in business through subsidies from the federal or state governments. The public body which regulates the air industry is required by law to make them whole on the losses which may be incurred in their operations. Untold millions of the taxpayers' money including some of that paid by the railroads have been wasted on our rivers in the interest of navigation, flood control or public power. Navigation is primarily in the interest of those who own both the vessels and the cargoes. Obviously, this is a subsidized operation of little public interest. Those of us who have had long years of experience in the Missouri valley honestly believe that much of the submerging of farm areas and busy railroad tracks in the area has come from the efforts of army engineers to try to harness this unruly stream for the purpose of aiding navigation in an area which already is more than adequately supplied with transportation. Some way must be found to stop the waste of the taxpayers' money on these ill-conceived schemes for whatever purpose they are intended. In most respects they come in conflict with private enterprise and if continued will destroy what private enterprise has built up through the years.

A Failure of Public Relations

Only recently the railroads of England passed into the hands of the government and the English railroad people tell us that as they look back on this process, they have come but to one conclusion as to how it was brought about, namely the failure in their public relations. We believe that an enlightened public will not readily consent to the surrender of our railroads to nationalization if it is properly informed. The taxing of industry to the point where profits cannot be made is the objective of those who believe in a socialistic state. The spirit of enterprise is lost when profits disappear. It is not in human nature to work to the utmost without hope of reward and already we are told that as a result of the seizure of the British railroads by the government the decline in the morale of the officers and employees of the railroads is unmistakably plain.

The railroad industry is the agency which has welded this country together and enabled it to grow and expand and become the leader among nations. The fact that several railroads compete with one another for business has played no small part in the development of this country. The outcome of World War II might have been vastly different had it not been for the competitive spirit that abounds in the railroad industry in which one railroad endeavors to surpass a competitor in performing service to the public and to the nation.

In closing, I should like to say to you engineers, therefore, that besides being the good engineers which you are, you must also in the future be public-minded citizens to a far greater degree and as such seize every opportunity to state the case of the railroads. Your profession is known to be a conservative one and people, more than you think, will be inclined to listen to what you have to say and profit by it. It is with pride that we are celebrating this 50th anniversary of your great organization but we cannot escape the responsibility for seeing that those engineers who follow you and who shall dominate the policies of this organization in the future shall have the same opportunities of achievement which you have had and the fulfillment of this obligation will depend in my opinion upon how earnestly we seek and work for the preservation of our railroad system as a free enterprise institution. (Applause)

President Mottier: Thank you, Mr. Aydelott, for that very interesting and informative address.

Presentation of Honorary Membership

President Mottier: We now have a surprise for you that I am sure you will all greatly appreciate. By action of the Board of Direction at a meeting held on November 16, 1948, Herbert R. Clarke, chief engineer, Burlington Lines, and a past-president of the AREA, was elected an Honorary Member.

I will ask Ralph Budd, president of the Burlington Lines to conduct him to the platform at this time.

(Past-President Clarke was escorted to the platform.)

Ralph Budd (Burlington Lines): You have elected this candidate for honorary membership to the highest office within your power and, therefore, I assume you know something about him. It might be embarrassing if I should undertake to say anything that would in any sense dim the luster of his campaign biography. Therefore, I shall assume that you know the good things about him and, having seen him work with you for many years, I believe you have arrived at your own views regarding his capabilities.

Then another reason why I am a little reluctant to do anything that might affect, unfortunately, the size of his ego is that I still expect to get some good work out of him (laughter) and I do not want to do anything that would ruin that prospect or lessen it in any way.

However, it is appropriate to the occasion for me to say that oftentimes presentations of this kind are made in general terms and based on general knowledge. On this occasion, it is factual for me to say that I personally know the gentleman, I personally have observed his performances for many years, and I thoroughly endorse the action taken and have great pleasure and pride in seeing him given this great honor.

Thank you. (Applause)

President Mottier: Mr. Clarke, it gives me great pleasure, on behalf of the American Railway Engineering Association, to present to you this diploma of honorary membership. It is the highest honor that the Association can bestow on a past-president, and I am delighted to be the individual to hand it to you.

I beg your indulgence for a moment because I am sure that all of your friends out here in front of you would like me to read this certificate to them, and we can look at it together.

HONORARY MEMBERSHIP HAS BEEN CONFERRED ON HERBERT RENTOUL CLARKE BY THE AMERICAN RAILWAY ENGINEERING ASSOCIATION THIS 15TH DAY OF MARCH, 1949, IN RECOGNITION OF HIS COURAGEOUS AND FORCEFUL LEADERSHIP AS PRESIDENT DURING TWO CRITICAL YEARS OF THE SECOND WORLD WAR, AND OF HIS UNTIRING EFFORTS AND ADMINISTRATIVE SKILL IN ADVANCING THE PROGRAM OF SCIENTIFIC RESEARCH IN THE FIELD OF RAILWAY TRACKS AND STRUCTURES.

Mr. Clarke, I congratulate you. We now have seven honorary members. These honorary memberships are not lightly bestowed. They must be earned, and they must be merited. You have earned this high honor, and it pleases me greatly to present you this diploma. (Applause)

H. R. Clarke (Burlington Lines): As President Mottier has just said, honor and recognition in this Association must be earned and deserved. I have always believed that, and I would like to continue to think that it is so, although just now I am a little uncertain.

If I have served this Association in such a way as to merit the honor which has just been bestowed upon me, I am glad, but, if so, it has been due to the help and the support so freely given me by the officers, members and staff of the Association.

Mr. Budd, Mr. Mottier, if this is merited by my service to the Association and the things which I have done, and had I been able to have done much more, I would still be greatly indebted to the American Railway Engineering Association for what it has done for me.

The years of work and association with a group of men such as make up the AREA have given me a wider acquaintanceship, a broader vision and a keener understanding of the problems of my fellow railroad officers than could have been obtained in any other way. I am sure that it has made me a better engineer and so more ready to serve the railroad for which it has been my pleasure and privilege to have worked for over 40 years.

The friendships formed mean more to me than I can tell you and they strengthen with the years.

It has been and is a pleasure to work in and for this Association. It has also been a challenge, because I believe that this Association has done much and has played an important part in making the railway industry what it is today, an industry which has served our country well in time of war and which will continue to serve it well in time of peace, unless that is made impossible by unwise and unwarranted control and regulation, or by the selfish action of short-sighted groups, some of which at least should have known the unfairness and the lack of soundness of their position and have realized the tragic and disastrous results which will surely follow if that course is continued.

This Association, I think, can and will continue to do its part to change that course and reverse that trend before it is too late.

President Mottier and members of the American Railway Engineering Association, I express to you my very deep appreciation of the honor which you have bestowed upon me. (Applause)

President Mottier: It is really an honor for us to have Mr. Budd address us this morning. He needs no introduction to this audience. He himself is an Honorary Member of our Association, an engineer, and a past director of the AREA.

A few weeks ago, in commenting on the centennial of the Burlington, the Railway Age, in an editorial, quoted from Emerson, that an institution is the lengthening shadow of one man. Mr. Budd goes beyond the Burlington. He has long been active in the councils of the Association of American Railroads, and he has often been referred to as the dean of railroad presidents.

It is a real honor to present Mr. Budd to you at this time and he will speak on the subject, The Engineer and American Railroads. I picked the subject! (Applause)

The Engineer and American Railroads

By Ralph Budd
President, Burlington Lines

The subject assigned to me is "The Engineer and American Railroads." If we use the term engineer in its broadest sense, we may mean one who directs the use of labor and materials in a manner that will produce the maximum of accomplishment with the minimum of expenditure. In that sense, although the science of railroad engineering as we know it today did not exist when the first railroads were laid out, the engineer has had a truly vital part in building and maintaining our railroads since their inception. And it is surprising how many of the problems that were considered by him at the very outset are before the railroad engineer at the present time. The width of roadbed and slopes, both in cuts and fills, the matter of drainage, the type and length of bridges, the kind and size of ties, and the best track rail and fastenings to use, were among the things to be determined then and are among our important problems of today. Research concerning these subjects was carried on in the best engineering tradition, although it was a far cry from the methods and refinement of present day research.

The matter of track gage, as well as maximum practical gradient and curvature were among the early questions, and since there was no experience with motive power other than the horse, there was a great deal of speculation as to how steep a grade might be feasible for a steam locomotive. Some of the earliest railroads were built along rivers and over the divides between waterways, being in reality great portages connecting up canals and the headwaters of rivers on opposite sides. Thus relatively steep grades were encountered by America's first railroads. The Baltimore & Ohio was one such line, the record of which became important as a measure of what would be the useful maximum in mountainous areas.

How Some Standards Were Established

Perhaps the best treatise of that early date which I have seen on the subject of railway location and operation was written in 1854 by Captain George B. McClelland for the United States Engineers, and is a part of the Report on the Pacific Railway Surveys. It is a fine example of research, containing accurate interpretations of results from experiments in a new field, for that is what the earliest railway construction and operation amounted to. Of evident significance was the showing in this report that a rise of 116 ft. to the mile of track had been found not too steep, we find that the Pacific Railways' Land Grant Act of 1862 contained the following provisions:

> The track upon the entire line of railroad and branches shall be of uniform width, to be determined by the President of the United States, so that when completed, cars can be run from the Missouri River to the Pacific Coast; the grades and curves shall not exceed the maximum grades and curves of the Baltimore & Ohio Railroad, (i.e., 116 ft. to the mile and radius of 400 ft.)

Thus railway engineers were given some far reaching standards to follow. President Lincoln selected 4 ft. 8½ in. as the gage for the Pacific Railways. Soon thereafter all of the other widths were discontinued except the narrow gages, generally three feet, and mostly in the mountains. Enough was known of the West as a result of the Pacific Railway Reports of 1855 to justify fixing 116 ft. rise per mile, or the equivalent of 2.2 percent as the maximum gradient and it became prevalent in the western mountains. Seldom however was it necessary to use curves with a radius as short as the 400 ft. minimum specified.

In developing an entirely new and spectacularly growing industry, railroad engineers were at first concerned almost wholly with the problems of construction and with what physical characteristics would be most practical for the operation of trains. That is to say, they were not at first concerned with efficiency so much as with the feasibility of operation, and in most cases they desired to build as rapidly and cheaply and as many miles as possible with the resources that were available to them. It was inevitable that the question of economics should enter into the railroad field and that there should come an era, as there did long before the turn of the century, when millions of dollars would be spent for revising and shortening lines, and reducing radient and curvature.

Application of Sound Economics

Arthur M. Wellington's classic, "Economic Theory of the Location of Railways," which appeared about 1880, had great influence with railroad engineers during the era of most active expansion of railway mileage. In the next three decades more than half of all the railroad mileage in the country was built. Railway location and construction generally was carried out during this time according to sound economics. In other words, the balance between higher construction cost and lower cost of operation was scientifically considered. When the first cost was too great to be assumed at the time of construction, a final line was located then, but the roadbed often was built on temporary alinement and grade, to serve until the permanent route could be financed. Hundreds of miles of railway lines were rebuilt, in some cases more than once, as the value of better grades and curves was demonstrated, and partly also because of growing volume of traffic. One of the finest examples of such rebuilding was the Union Pacific, which was so thoroughly revised that it became, and is today, a model of efficiency. During that period of most rapid extension of the railways the locator and builder of new lines was the popular type of railway engineer. There was more appeal in a job of building in far away new territory than there was in the more prosaic job of maintaining the tracks once they were built. A notable company of builders held the stage during that time; two who may be considered prototypes were General Grenville M. Dodge and John F. Stevens. It may be said the locating and construction engineers were the aristocrats of the profession. On many railroads two engineering departments were maintained, one under the chief engineer which handled the new work, and the other under the maintenance engineer.

The rounding out of the railway network into a national system with complete interchangeability of cars led to a need for some degree of standardization. A great step in this direction was the adaptation of Theodore Cooper's system of rating to indicate the wheel loads that could safely be handled over railway bridges.

The organization of the American Railway Engineering Association fifty years ago was in response to a need for greater uniformity in practice and standards of construction and maintenance. To meet this need the AREA provided for consideration of the many problems common to all carriers, by a group of railway engineers and operating officers who had responsibility for the roadway and structures of their respective companies. The rapid growth of many railroads necessarily without a background of experience in many phases of maintenance problems, resulted in individual ideas being incorporated in each road, without any way of knowing how other roads were meeting the same problems. It was clear to these alert founders that all of them could learn by comparison and exchange of ideas and experiences.

At that time there were about 190,000 miles of railway in the United States and henceforth the greater part of railway engineering was to be in maintaining and improving the properties rather than in building new lines. The work of the various committees of the AREA was, however, equally available to and useful as a guide in building the nearly 70,000 miles which were later to be constructed. The appearance on the scene of the first Manual of Recommended Practice in 1905 was a milestone of real progress in railroad engineering and a boon to the engineer. For the first time he had a railroad Bible. The men who were most prominent in this final phase of railway engineering are too numerous to mention individually, but their names are found in the roster of the AREA officers. Under their guidance the fixed properties of the railways were improved and patterns of organization were set up which have been followed since. These assure the railway engineer of today and the future that they will have the benefits of new developments in science and industry through research as soon as such developments are available.

Contest Between Roadway and Equipment

Throughout the years railway construction and maintenance engineers have engaged in what is sometimes characterized as perpetual warfare with mechanical engineers who have been responsible for the continually increasing size of locomotives and cars. The struggle has been to improve track and bridges so as to handle ever heavier and faster moving loads. Every round of increase in the capacity of track and rolling stock found the two complementary parts of the railroad physical plant in balance, but about to embark upon another upward spiral as the increasing weight and strength of rail and roadbed made it possible to carry at higher speeds the heavier cars and locomotives which were being designed. It appears now that that particular battle is ended, with the roadbed forces victorious, although in truth it may be said that the mechanical engineer ended the war by finding a way to increase tractive power through the use of more driving axles, rather than by heavier weight per axle. The diesel axle loads are lighter than those of the largest steam locomotives. The limit in size of cars seems also to have been reached, largely because vertical and horizontal clearances of structures, and the distance between track centers control the width and height of cars. Of course this contest between roadway and equipment was a mutual and parallel development of the two major parts of physical plant, the track and the rolling stock. But there was too much dealing, so to speak, at arm's length. A creditable achievement based on a broad view of the industry's best interest and on common sense was the joint investigation of the relation between track and equipment on the part of the civil and mechanical railway engineers undertaken formally in 1941. It should and no doubt will be a continuing effort. Even the briefest sketch of railway progress should mention the name of the late Arthur N. Talbot. He may be technically listed as professor of the University of Illinois, but he belongs to all the railroads and all railroad engineers, for his great work in the study of track made him one of their greatest benefactors.

Today there is a wide margin of safety in the track over and above what is needed for sheer strength to carry the train load, but the demand for speed, and the economies which come from heavy track construction, have brought other problems. Greater precision in line and grade is required than ever before. Line and grade revisions continue to be made, not only to reduce operating cost but to improve railway service, in step with the progress which has been made in science and industry generally, particularly as these advances have been applied to the railways' competitors in transportation. So there is today as much debate as ever about the best construction and maintenance standards and methods to meet the most modern and exacting requirements of schedules and service, and there is a continuing tendency toward perfection in the track so that heavy tonnage trains can be handled at high average speed, and so that the maximum passenger speeds and minimum overall time schedules can be successfully maintained. New materials to work with and new track tools and machines have placed upon the railway engineer a new responsibility in selecting the best from among the many superior appliances. Higher cost of material of all kinds, as well as high labor cost, makes it imperative to choose and use materials wisely, care for them scrupulously, and supervise the work most carefully.

Increased Responsibilities

Speaking of responsibility, it may be pointed out that in the era of railway expansion which chiefly featured new construction the engineer usually had no part in deciding whether or not to build the lines of railroad under his charge. Those decisions were made by others and his duty was to build the tracks and structures as well and efficiently as circumstances would permit. Thus he should not be held responsible for the building of an ill-advised line, or for its failure. The passing of that phase of railway history brought a change. The engineer has now the great responsibility for the adoption and use of proper standards of roadway and track. The inescapable logic that credit for results goes with authority and responsibility properly gives the railway engineer a good deal of the credit for the splendid physical plant of today's railways. In this day of accelerated progress in mechanization of maintenance work, the railroad engineer must be alert not to be found doing work in the old-fashioned way, with obsolete hand tools, when it can be done better and cheaper by machines. On the other hand, he must not be caught making a change when the practice being followed is better that that proposed. The very multitude of new things, new ways of doing old things, including the use of off-track machines and conveyances, call for an alertness which in my opinion exceeds that required by the railway engineer of any earlier generation.

In giving the railway engineer the fullest praise and credit for producing the finest transportation plant the woild has ever seen, it is no detraction from his achievements to say that he has had the assistance of very able industrialists and appliance people.

The superior quality of steel, which long ago took the place of iron, is the basis for the most spectacular improvement in strength and endurance of track. And it continues to improve. The metallurgists have been among the greatest contributors to railroad progress.

The perfection of the detector car for finding hidden flaws in rails, the passing of the old hand car, the advances in wood preservation, and the use of adequate tie plates are typical of the efficiency that has come to practically all items of roadway maintenance.

It would indeed be a disappointment to members of this Association to feel that the evolution in rail transportation is complete and that their position may become static. Have no such fear—dynamic is the word for your situation. The recent agreement with the Illinois Institute of Technology represents another great step forward in research. What the future will bring in the way of new problems for him no one knows, but I can see enough railway projects at hand and in the offing to feel assured that the life of the railway engineer will continue to be filled with fascinating activity. (Applause)

President Mottier: Thank you, Mr. Budd. It was very kind of you to come and address us this morning.

Two or three days ago someone said to me, "I noticed your program, Mottier, and I am satisfied you had a good deal to do with making it. Did you?"

I said, "Yes, but what makes you arrive at that conclusion?"

He replied, "Well, I notice there are five addresses the first forenoon, and you are the first fellow on the program. I sure feel sorry for that fifth man."

A bystander listening in said, "That fifth man worked for the Illinois Central one time but quit to get a better job."

I don't know whether that is true or not. I know at one time he worked for the Illinois Central, but I hope you won't hold that against him. He needs no introduction to this audience, or to those who live in Chicago. The transformation going on at the Illinois Institute of Technology is really most remarkable, and I think Dr. Heald has had much to do with it. The address he is going to give us now is most timely because of the interest of that institution in research and because of the early construction of our research laboratory there.

Mr. Heald will speak to us on Industry and Education: Partners in Research. Dr. Heald! (Applause)

Industry and Education: Partners in Research

By Dr. Henry T. Heald
President, Illinois Institute of Technology

I am pleased to have an opportunity to attend this fiftieth anniversary meeting of the American Railway Engineering Association. Through these many years, your Association's important work has been an outstanding example of the contribution of American engineers to the growth of industry and to improved service for the general public.

Everyone is aware of the notable strides made by the railway industry in the past half century, many of them recorded in the annals of your Association. It is equally apparent that railroads will be confronted in the years to come by problems whose solution will tax the ingenuity and challenge the best effort of you and your successors.

I have been asked to discuss the relationship between education and industry, or, more exactly, industrial research. Probably no one would have thought of such a topic fifty years ago; not that research was then unknown—for the research process as a search for new knowledge has of course been going on for a long time—but fifty years ago, industry was scarcely using organized research as we know it today and the colleges were not thinking much about the application of research to industry.

The history of our country's industrial development during the past half century is filled with examples of whole new industries that have grown up as a result of technological and scientific discoveries. Electricity and electronics, automobiles, radio and television, and air transportation are a few of the more obvious examples. Developments in one industry usually are not confined solely to the single industry of first discovery;

applications extend into other industries and often have profound effects upon the whole industrial economy. Specifically, in your case, the technology of the railroad industry has affected, and has been affected by, developments in many other industries. The advancement of an industrial society requires research on the widest possible front.

Research Now a Group Effort

In recent years, the character of research has changed from the individual to the group effort. It is probably true that every research discovery still is the result of individual effort, but the growth of research as an organized activity has been marked. Research effort is applied today in much different fashion than in the day of Fulton, Marconi, or Edison. The same kind of men are at work in laboratories, discovering new knowledge, perfecting new processes, contributing new developments; but they are working in the laboratories of industry, universities and colleges, or group organizations where extensive facilities and learned colleagues provide the advantages required for modern research.

Increased interest in research is readily apparent in the growth of industrial research laboratories. In 1915 there were only 100 such laboratories in the United States; by 1920 the number had tripled with a total personnel of 9300; at the beginning of World War II the National Research Council listed 2350 laboratories with 70,000 employees. In 1946, more than 130,000 persons were employed in 2400 laboratories; and the total expenditures exceeded three quarters of a billion dollars. A year later the Steelman Report[1] estimated that the nation's research and development budget totaled 1.1 billion dollars with the federal government supplying more than half the funds. The same report urged continued research at an increased tempo and recommended expenditures of double the 1947 rate by 1957.

Even now research has become a highly organized business operated by industry, government, universities and colleges, foundations, and commercial laboratories. Its continued productivity requires an adequate supply of competent personnel, extensive facilities and equipment, and large appropriations of money—all brought together in a pattern of operation insuring maximum effectiveness of individual investigators.

From the beginning, colleges and universities have played an important part in the development of American research. Higher education's basic objectives are the education of young men and women and extension of the frontiers of knowledge. Through the years, the country's educational institutions have produced a steadily increasing supply of research personnel, many with post-graduate training, all well grounded in fundamentals. Much of the fundamental scientific and engineering knowledge has stemmed from discoveries made by faculty members and graduate students in college and university laboratories. It is this fundamental work that provides the background for applied research, resulting, in time, in greater technological progress in American industry.

Research in a university is ideally conducted by faculty members with complete freedom to direct their work along the lines of their own interests without compulsion to produce commercially useful results. This is the way research began; and many of the principles so discovered, although seemingly remote from practical application, later were applied by others with great benefit for society. Continuance of this kind of search for new knowledge—for the sake of knowledge itself—is of vital importance to the future of science Unfortunately funds to support fundamental research have always been too limited.

[1] U. S. President's Scientific Research Board, *Science and Public Policy: A Report to the President*, by John R. Steelman.

Engineering research falls in a somewhat different category than research in the so-called pure sciences because engineering itself applies fundamental scientific principles to the solution of technological problems. By its very nature, engineering is an applied science and it is difficult to draw a line between fundamental and applied research in engineering. Engineering theory and practice are—and should be—closely related for the best instruction in engineering colleges.

Because of this relationship, engineering research on college campuses is likely to be of rather direct interest to the public and certain segments of industry. Consequently, there has been a growing trend toward the support of research by industry in engineering colleges. Such support ordinarily takes one of three forms:

First—Research contracts leading to prescribed objectives usually with stated arrangements for reports and patents.

Second—Grants in aid for the promotion of work in a general field without specific requirements as to results.

Third—Graduate fellowships and scholarships for assisting talented graduate students in developing their professional capabilities.

Industry-sponsored research, properly administered, furnishes valuable assistance in vitalizing teaching and in training research personnel, in addition to producing valuable results. Unless proper procedures are developed for handling sponsored research in the institutions, faculty members are prone to divert their attention to strictly commercial research, resulting in less fundamental research and less effective teaching.

Little benefit can be expected if research projects are assigned to faculty members without regard for their interests and desire or if the projects are accepted with the compulsion of financial gain as the faculty member's dominant motivation. There is also danger that the sponsoring industry will have an unsatisfactory experience if projects are undertaken without a clear understanding of the manner of handling the work in each separate institution.

Six Patterns of Industry-Sponsored Research

These factors have been responsible for the development of six well-defined relationships between industry and colleges in the conduct of industry-sponsored research. The objective in each case is maximum benefit to the sponsor, the institution, and the public at large. These research patterns take the following forms:

First—Individual relationships between faculty members and sponsoring companies. Frequently such agreements involve only indirect participation by the college. They are difficult to control and seldom satisfactory for extensive laboratory investigations.

Second—Engineering experiment stations, usually in state supported institutions and largely financed by public funds to work on problems of broad interest. Experiment station staffs frequently include faculty members with teaching duties as well as full-time research personnel. The experiment station provides an organization for the administration of research and for the publication of results. Grants from individual companies or industrial associations often supplement state funds. Results are generally made available to the public.

Third—Departments of engineering research in colleges. These enter into research contracts with industry and arrange part-time research direction by faculty members or establish full-time staffs.

Fourth—Research foundations in a variety of forms, organized by colleges to provide a mechanism for serving industry through sponsored research. Ordinarily these foundations are separate but related corporations. The foundations contract with sponsors and.

in some cases, arrange for faculty participation using college facilities. Others operate as separate entities with their own full-time staff and laboratories. Armour Research Foundation of Illinois Institute of Technology is the largest organization of the latter type.

Fifth—Affiliated research institutes designed to serve the research needs of a particular industry and to encourage the training of research personnel. A pioneer of this type was the Institute of Paper Chemistry established twenty years ago at Lawrence College in Appleton, Wis. This organization and the Institute of Gas Technology at Illinois Tech. provide fellowships for graduate education and conduct research of broad interest to the industries that support them. Dissemination of scientific information is another phase of their activities.

Sixth—This final pattern of cooperation between industry and education is the establishment of what might be termed affiliated industrial research laboratories at educational institutions. An example is the research laboratory to be built this year for the Association of American Railroads on the campus of Illinois Tech. Here the laboratory's own staff, directed by the Association, will work on problems of common interest to its members. It will enjoy the full cooperation of faculty members and other research personnel on the campus. Members of the laboratory staff will have the advantage of association with engineers and scientists actively at work in a wide variety of fields. Library facilities and specialized services and equipment will be accessible. Members of the Association research staff may improve their competency through part-time graduate study in the various educational departments of Illinois Tech. We believe, too, that teachers and students in engineering will profit by association with the work and personnel of the new laboratory. Thus the long-term relationship will have substantial benefits for the railroad industry and the general public.

New Obligations

The growth of sponsored research has brought about the patterns of college research administration I have just described. As long as university research could be conducted with the institution's general funds by members of the faculty and their students, no special administrative organizations were needed. But the acceptance of research support from outside sources in substantial volume and for specific purposes imposed new obligations on the colleges and universities. Extensive war research projects sponsored by the federal government hastened the trend.

In actual practice several different patterns are frequently put in operation at a single institution. My own is an example. We have a large volume of research, perhaps 5 million dollars in the current fiscal year. Research of a fundamental character, with published results, is done by anyone on our campus who is interested and qualified. It may be supported by outside sponsorship, by general grants, or by the Institute's own funds if any are available. Usually graduate students participate in such research.

Industrial research directed toward specific clearly-defined objectives is conducted in our Armour Research Foundation, using the pooled talents and facilities at our disposal. The Foundation's objective is service to industry, and it attempts to concentrate on each sponsor's problems. Faculty members do not take responsibility for this type of research, although they occasionally assist in a consulting capacity; but then only by their own choice.

Thus we avoid the dangers to teaching and fundamental research that sometimes arise through preoccupation with industrial research. For this reason, too, individual faculty members do not conduct research for corporations in Institute laboratories on a personal basis, although again they do engage in outside consulting activities to a reasonable degree when the work is important enough to add to their own professional stature.

Establishment alone of any of the patterns of research organizations I have been discussing will not insure successful research. Successful research depends primarily upon the persons who are engaged in it. No organization plan—no matter how good—can produce a significant research accomplishment without a competent staff, free to use their talents and abilities to the greatest advantage.

Too many colleges and universities have thought that industrial research offered a great opportunity for them. Not all of the industrial research organizations established around the country in the past decade are going to be sucessful. A college administrator who thinks his institution can make money by a program of industrial research is likely to be mistaken. He will be fortunate if such activities prove self-supporting in the long run. However, it is quite possible to develop useful and mutually advantageous areas of cooperation between industry and education.

The Place of the Federal Government

A discussion of the partnership between industry and education in research is not complete without mention of a third partner that has gradually assumed an important role in recent years. I refer to the federal government.

Government sponsorship of research and development assumed huge proportions during the war. University and industry laboratories were given tough assignments directly related to the development of weapons and materials of vital importance to the successful termination of the war. When the chips were down, American laboratories made phenomenal records.

Although many persons forecast a drop in government research expenditures after the war, such a decrease has not materialized. In 1947 federal appropriations for research and development were 625 million dollars, of which 200 million dollars were funneled into government laboratories and the remainder allotted to contracts with university and industrial laboratories. A great share of this money went for military research, although it also included research for public health and agriculture and the support of such organizations as the National Bureau of Standards. Additional large sums were assigned to atomic energy projects reserved for government support and control.

Federal support of certain types of research certainly will be an important factor in the years ahead. Research on weapons of war and related problems are clearly in the purview of the national military establishment. Recognizing the absolute necessity of new fundamental knowledge, the military has supported a surprising amount of fundamental research in the colleges and universities of the nation since the end of the war.

Research is vital to the national welfare, and all of us agree that government must take responsibility for some research. By the same token, government research should be confined to its proper sphere.

The most important problems in research are: first, to insure an adequate supply of qualified research workers, and, second, to make sure that basic new knowledge is developed in all fields of science. Both were seriously depleted during the war; neither is being adequately replenished at the present time.

Colleges and universities are greatly disturbed by these facts. But in most cases they lack funds and facilities to support an adequate amount of basic research or to support an adequate program of graduate education. The growth and maintenance of American industry and the security of the nation are imperiled by these shortages.

Industry has recognized the direct importance of industrial research, carried on either in its own laboratories or in the universities and research institutions; but it cannot long be successful without new fundamental knowledge and personnel to develop it. Few industries can afford fundamental research laboratories of their own, but many can afford to support fundamental research in universities and colleges.

Perhaps 200 companies now support graduate fellowships or make modest research grants for fundamental work in specific fields. This practice needs great extension. It is one of the most obvious ways to increase knowledge and educate research men and women. Certainly it is better for industry to assume a greater share of the responsibility for research and education than to wait for government to move out of its rightful sphere and move into an area which industry, for its own protection, should reserve to itself. Thus in fundamental and applied research the railroad industry, with its past of achievement, has a future of opportunity.

President Mottier: Thank you, Dr. Heald. We all look forward to our continued and closer relationship with the Institute in connection with our research program.

With the opening of the sessions this afternoon, your Association will undertake an innovation in the conduct of its annual meeting. Instead of one session, there will be two, in order that the groups of committees may present their reports concurrently, thereby affording greater time and permitting freer discussion of the reports presented. However, to insure that all members present at this convention have an opportunity to participate in the consideration of materials submitted for adoption and publication in the Manual, all Manual material to be offered by the committees that will present their reports this afternoon will be submitted for your consideration at a general session in this room tomorrow morning.

Report of the Tellers

Presented at the Dinner on Wednesday, March 16, 1949

We, the Committee of Tellers, appointed to canvass the ballots for officers and for members of the nominating committee, find that the count of the ballots is as follows:

For President

F. S. Schwinn	1528

*For Vice-President**

H. S. Loeffler	1517

For Directors (Four to be elected)

I. H. Schram	972
A. B. Chapman	852
N. D. Howard	836
C. B. Bronson	828
A. B. Stone	718
E. J. Brown	682
P. O. Ferris	623
G. W. Miller	577

For Nominating Committee (Five to be elected)

R. P. Hart	1030
J. C. Aker	1028
F. H. Simpson	930
G. M. O'Rourke	858
A. N. Laird	707
Ray McBrian	701
E. S. Birkenwald	671
B. R. Meyers	611
W. E. Cornell	599
H. L. Restall	439

Respectfully submitted,

THE COMMITTEE OF TELLERS.

H. F. KING, *Chairman*
G. F. METZDORF
G. W. PAYNE
A. R. WILSON
C. D. HORTON
G. P. PALMER
E. R. SCHLAF
R. M. STIMMEL
W. O. BOESSNECK
H. M. SHEPARD
C. A. ROBERTS
B. J. SHADRAKE
H. L. MCMULLIN
W. H. BUNGE
C. E. FISHER
A. R. NICHOLS
R. E. WARDEN
C. M. BARDWELL
M. A. BRYANT

* Under the provisions of the Constitution, G. L. Sitton, advances from junior vice-president to senior vice-president.

By action taken at a meeting of the Board of Direction March 17, 1949, G. W. Miller, assistant engineer maintenance of way, Canadian Pacific Railway, Toronto, Ont., was elected a director to fill the vacancy created by the advancement of H. S. Loeffler to vice-president; Mr. Miller's term extends to March 16, 1950.

Presentation and Discussion of Committee Reports

This year the presentation of the committee reports embodied an innovation in that all the committees except two (which offered their reports on Thursday morning) presented their reports on Tuesday and Wednesday afternoon when sessions were held concurrently in both the Grand Ballroom and the Red Lacquer Room.

As compliance with the provisions for adoption and publication of Manual material imposed the requirement that all recommendations of committees with respect to the Manual be voted on at general sessions when all in attendance could be present, the committees with Manual recommendations to offer appeared a second time at a general session. However, for the purpose of simplifying the record of the presentation of the reports and avoiding needless repetition, it was deemed advisable to merge the transcripts covering the two appearances of committees as they are presented in the following pages.

Discussion on Roadway and Ballast

(For Report, see pp. 649–692)

(President Mottier presiding).

Chairman H. W. Legro (Boston & Maine): I hope you have noticed from the kind of reports that have been made by the Roadway and Ballast Committee that they now deal with practices important to the maintenance and operation of railroads, and rather less with new construction. The change is indicative of the change in railroad engineering in the past 50 years.

Roadway and ballast have come to be considered to a greater degree as having physical and structural properties that may be understood by study and research and our practices thereby adapted to them so that we may make them acceptable to receive the ties and the rail and carry the heavy traffic loads that are now imposed upon them.

The work of this committee has been supplemented to a large degree by the research work authorized by the AAR. It has added life to our committee work and I feel sure is a very important supplement to its work.

I suggest to the members of the Association that, if they find they have on their railroad indications of roadbed disease—we used to call them soft spots—and if they are willing to undertake the cure of that disease, they might well get in touch with "Dr." Magee and let him, with his clinical staff of "surgeons and medics" prescribe the cure.

They will admit that, like most surgeons and doctors, they do not know the whole answer yet, but we feel that they can help tremendously if any railroad is willing to undertake the cure.

The committee is making reports on three of its assignments. The practice of this committee is to rotate the reporting of assignments, giving each subcommittee about three years to prepare its report.

The report on Assignment 2—Physical properties of earth materials: (a) Roadbed. Load capacity. Relation to ballast. Allowable Pressures—will be presented by the chairman, Mr. Lamport.

L. R. Lamport (Chicago & North Western): The assignment of subcommittee 2 (a), dealing with physical properties of earth materials is at this time reported as a progress report.

It has been the purpose of the subcommittee to approach its assignment through the practical application on railroad roadbed, supplemented by tests with pressure cells and other means, through the collaboration of the research staff of the Association of

American Railroads, with the assistance of Mr. G. M. Magee, and also through the experiment station at the University of Illinois, headed by Dr. R. B. Peck, field work being carried out by Mr. Rockwell Smith, roadway engineer of the AAR.

One of these tests, the one now in progress, is on the Chicago, Burlington & Quincy near Red Oak, Iowa, where a series of pressure cells were installed in May 1948. Test runs were made in October 1948, and observations taken not only on the earth pressure cells but on tie plates in the immediate area. Further tests will be made in the spring of 1949.

Another test location is on the Illinois Central in the vicinity of Grenada, Miss., where that company is making a relocation on account of a government dam. On that work, the earth materials will be controlled as to compaction and moisture and the observations will be supplemented by laboratory tests made of these materials at the University of Illinois experiment station, with an oscillator which has been developed at that point.

To date we do not have the complete information on the pressure cell tests made last fall, of which there were 31. Those data are being worked up and will be presented to you in bulletin form as soon as completed. It is hoped that we will learn something from these tests.

At the present time, that is the extent of the committee's report.

President Mottier: Does anyone have any question to ask the subcommittee chairman on this report? If not, it will be received as information.

Chairman Legro: Assignment 6—Roadway: Formation and protection: Included within this general assignment there is an exception to the statement which I made earlier as to maintenance and construction.

Probably the construction of new sections of line across reservoir areas is the principal construction which we may have to deal with for a long time because of flood control measures taken by the government which will necessitate relocation of lines.

The report on Assignment 6 will be presented by the chairman of the subcommittee, Mr. Crosland.

B. H. Crosland (St. Louis–San Francisco): Subcommittee 6 embraces three assignments: (a) Roadbed stabilization; (b) Construction and protection of roadbed across reservoir areas, and (c) Chemical eradication of vegetation.

Because the subcommittee felt that the three subjects could be progressed more efficiently, we have divided our subcommittee into three sections, each with its individual section chairman, and it was my hope today that each one of these section chairmen would present the results of his studies to you. Unfortunately, I am the only one present, so I am going to have to do it for all of them.

The question of roadbed stabilization is a very vital question, of course, to all of us. This is the fourth progress report which is being presented as information, and later, Mr. Rockwell Smith, who is roadway engineer of the research staff of the AAR, is going to give you a complete report on the work done during the year. So, I do not want to steal any of his thunder at this time, and we will leave it all to him. I will say this to you, though, that we felt the question of roadbed stabilization was so important, we should study and report on every possible means of roadbed stabilization that is now being used or has been used.

Up until the last year, you will recall that our reports on roadbed stabilization dealt exclusively with grouting. At the request of the committee, the research staff this year has attempted to include some studies of other types of stabilization, for example, driving ties, poles, and is also studying wet cuts which many of you have been familiar with many years.

During the past few years, the Southern Railway had some very interesting experiences with roadbed stabilization through the driving of spud holes with piling and filling them with sand, and also by driving holes and opening the holes with dynamite blasts and then filling them with sand, all of them based on the premise that the stabilization of gumbo can be accomplished by a proper admixture of sand.

All of us know that frequently a mixture of sand with the gumbo is made at the time of construction. Unfortunately, we are dealing with construction that is many years old, and it is hard to get the sand mixed with the gumbo at this late date.

The work done on the Southern was based on attempting to impregnate the existing gumbo fills with the proper amount of sand for stabilization. I do not know whether Rockwell Smith knows why grouting stabilizes the roadbed; probably he will tell you. My personal opinion is that the benefit comes from the fact that we get the roadbed impregnated with sand through the medium of grout. I may be a heretic in making that statement because I know some of you do not believe it.

This report is presented as information.

Our next subject—Construction and protection of roadbed across reservoir areas: I am chairman of that section as well as chairman of the subcommittee. Last year we attempted to give you a general report on the subject matter as information. This year we have eliminated from our studies all subjects pertaining to negotiations and other matters that all of us have to go through in dealing with relocation or construction of our railroads in reservoir areas as a result of reservoirs constructed by public agencies or private agencies.

The report is very brief. We have attempted to present to you a suggested typical section. We have given a great deal of latitude in the report as to slopes, thickness of riprap, and so forth, because we appreciate that, to a certain extent, this must be based on design conditions dealing with the locale and the particular conditions that surround the project in hand.

We have had some very fine comments from all over the United States about such material as we have presented to date. We are particularly thankful to the Corps of Engineers. The Chief of Engineers of the Department of the Army was given an opportunity to review the material presented to you this year, and he gave us some very fine comments on it, most of which came too late to be included in this year's report, but he was very cooperative. In our report next year we hope to be able to progress our studies considerably as a result of the information he has given.

There is one difference, of course, in the studies of the Corps of Engineers as compared to ours. Nearly all of their studies deal with the construction of earth dams at the end of the reservoir area and, as such, deal largely with deep water conditions. Many of our relocations, in fact most of the relocations, are deliberately placed in portions of the reservoir where the water is not so deep, and wave action, for example, in shallow water is entirely different from wave action in deep water.

I want to call your attention in the schedule given in the report, to one particular point that we think is extremely controversial and on which your subcommittee would thank you all if you would either get up on the floor now and talk about it or write us and give us your views. That is, first of all, we have discarded in our studies the use of hand placed riprap and are recommending dumped riprap.

In using the riprap, the Army Engineers recommend a pervious underfill. Your committee does not believe that that is practical, although it is highly controversial, and we would like to have the opinion and advice of the entire AREA. We would certainly like to have your opinions before we attempt to present something that is supposed to represent the combined engineering ability of this fine organization.

This report also is offered as information.

For some years we have had an assignment dealing with chemical eradication of vegetation. Mr. DeJarnette, who is the chairman of this section, is not present today so I will have to do the honors for him.

He has given us a very interesting historical report on chemical eradication to date. Mr. DeJarnette has discovered what I think most of us know, that the question of chemical eradication of weeds is a very difficult one to present in any definite manner, because different climate and different types of weeds require different treatment. He is, however, going to attempt through questionnaires and studies to determine what kinds of chemicals are best for certain conditions in certain climates. Just how much we will be able to boil this down, I do not know at the present time but we do feel that with rapidly mounting labor costs, the question of control of weeds through chemical application is a much more important subject than it was just a few years ago.

Many of us tried it in the last 15 or 20 years, and some of us got discouraged and gave it up. But with advances in the chemical industry and, as I said, the increase in labor costs, we feel it is time to make a new study in an effort to develop a more economical control of vegetation than we have now.

I hope that all of you will help us in trying to develop some definite recommendations for you in our next report.

The report is offered as information.

President Mottier: Thank you, Mr. Crosland.

Chairman Legro: The next assignment to be reported on by this committee is that of Ballast.

I think a few years ago there was some inclination to regard our ballast specifications as having become, perhaps, static, that we had reached the climax in our ballast specifications. That certainly was not true. We need to know more through tests of our ballasts as to their capacity, their ability to carry the heavy, faster loads which we now have. We know from experience that modification in our ballast specifications is necessary. Consequently, we are studying, through tests, the quality of our ballast. It is also necessary, we found, to devise means of protecting the ballast, or using special types of ballast. I think you will find these reports interesting.

The assignment will be reported on by the chairman of subcommittee 10, Mr. Goldbeck.

A. T. Goldbeck (National Crushed Stone Association): The work of the subcommittee on Ballast is done by sectional committees. We have three such committees: One on Ballast Tests under the chairmanship of Stanton Walker; one on Ballasting Practices, under the chairmanship of F. H. Simpson, and one on Special Types of Ballast, under C. D. Turley.

Mr. Simpson will not report, not because he has not done work, because he has done a tremendous amount of work, but he is collecting a lot of statistics, and it is a question of analyzing those before he can present a report.

In connection with this matter of ballast tests, I can think back on this subject about 38 years. The secretary of this committee came to me at that time and said he wanted to see whether he could not develop some tests for railroad ballast. I was connected with the Bureau of Public Roads at the time and, of course, it was natural that we would use the kinds of physical tests used for highway construction.

We made a lot of tests on ballast submitted to us, making use of the calibration test, hardness test, specific gravity, absorption, and a lot of those things.

We finally ended up with a table, and that table was correlated with the reports of service on these various ballast. There was more or less of a correlation, fairly good, showing that perhaps the calibration test was not so bad as a means for determining the quality of ballast. The toughness test also was fairly good.

In the meantime, various developments have been made. The Los Angeles abrasion test has come into use, and that is being developed continuously.

Mr. Walker, the chairman of the section of the Committee on Ballast will give you the most up to date information on that particular test. I will call on Mr. Walker to report on the subject of ballast tests.

Stanton Walker (National Sand & Gravel Association): As Mr. Goldbeck has said, the history of the development of tests for railroad ballast is a long one, and has been carried on hand in hand with the development of tests for mineral aggregates for other uses, principally in highway construction.

The hardness test, the toughness test and the various abrasion tests to which he referred have more or less become crystallized and replaced by a single test, the so-called Los Angeles rattler abrasion test, which is a measure of the toughness and a measure of the hardness of the ballast. That test was developed initially by the American Society for Testing Materials, with principal attention toward aggregates in highway construction. It was not, as developed, broad enough in scope to cover the tests of the larger sizes of material used in the railroad ballast.

Because of the need of a wider range in grading presented by railroad ballast, and largely due to representations made by Committee 1, the test procedure has now been revised as is outlined in the report of the committee. I shan't go into the details of what those revisions are, except to say that they provide for test of larger materials.

I think there is a research job to be done in connection with this revised test procedure, and that is to develop better information on what constitutes significant limitations on the percentage of wear.

With that in view, the subcommittee has recommended that samples of material be submitted for subjection to the Los Angeles rattler test as revised, from sources of supply of ballast on which there is good knowledge as to service record.

I think that outlines the scope of the report.

President Mottier: Thank you, Mr. Walker.

Any comments or questions?

Mr. Goldbeck: The next section report is on special types of ballast under the chairmanship of Mr. Turley. When you stop to think about it, it would seem that ballast in the railroad is especially designed to convey the water directly from the surface down to the subgrade just where you do not want it. Furthermore, cinders and dirt get in very readily, and, when any material gets into the voids in the ballast, there is no question, under the relative motion of the ballast which takes place under traffic, that grinding ensues.

We have had an analysis made of the mud taken from railroad ballast. The analyses show that a very large proportion of the mud was actually cinders that had become ground up under the action of the relative motion of the particles of ballast. Of course, the rest of it was the dust formed by grinding of ballast itself.

It would seem, then, that we ought at least to investigate the possibility of improving ballast, improving, perhaps, with the idea of preventing water from getting into the subgrade, and also preventing extraneous material from getting into the voids of the ballast.

Mr. Turley has been looking into this matter, and it will be reported under the title—Special types of ballast. I am going to call on Mr. Turley.

C. D. Turley (Illinois Central): With the rather general and extensive use of prepared stone and slag ballast in the heavy-traffic high-speed railroads, the problem of cleaning ballast became as much a part of maintaining track as renewing ties or alining and surfacing track.

Most of you know that cleaning ballast is a slow and expensive operation. Naturally, maintenance engineers were anxious to find some way to avoid this expense or at least keep it as low as possible.

The Asphalt Institute, Washington, D. C., suggested an asphalt covering to prevent the fine materials from entering and fouling the ballast.

As stated in the report, such an experimental installation was made on the Illinois Central in one of its main tracks about 45 miles south of Chicago in 1943. The results to date are encouraging.

After five years of experience and observations, we have arrived at some rather definite conclusions:

1. It is possible and practical to maintain a covering on track.

2. The fine material does not enter and foul the ballast.

3. The surface water is drained away quickly, thereby leaving the roadbed dry and rigid and eliminating the possibility of the usual churning of the ties.

4. The asphalt seals the different particles of ballast together, anchors it and holds it there and thus prevents the ties from working loose in the ballast. You can visualize what happens when the stone toward the slope of ballast moves, permitting the next stone to move, and so on, until you get up to the ends of your ties and the particle of ballast that was tamped in there rigidly also moves and you have a loose tie.

Then there are the ties to think about. A very large percentage of the defects that develop in ties in the track start from the surface that is exposed to the weather; I mean that portion of the tie above the ballast.

When this asphalt was sprayed over the track, naturally, the ties were covered. The checks and splits in the top surface of the tie would fill with this asphalt, and a bituminous covering was formed over the top of the ties, serving as an excellent waterproofing.

This track had ties with the usual variation as to ages, many of them over 20 years old. This last year, when we did rather general work on this track, this half mile of track, 14 ties were removed at the end of five years, and we think there must be a great possibility in a covering over the tops of ties.

That leaves us with the one important problem, and that is to continue the maintenance of this track, still taking advantage of the solid tie beds and without unduly disturbing the asphalt covering.

You know what happens to a track after five years of heavy service. It is beaten down in the ballast, and it must be raised, given a new surface and a perfect line.

This past year we used what we call the grout surfacing method. The rail was brought up to a true surface and held there by jacks, and fine grout of quick setting portland cement mixed with sand, was pumped under the ties from the ends, filling the space, whatever that happened to be, from, perhaps, ¼ or ½ in. down to nothing toward the center of the track. We worked from the ends of ties on either side rather than take the whole tie at once.

To date the track is holding surface and line well, and these observations will be continued. From time to time we hope to be able to give you progress reports, and we hope that they will be favorable.

President Mottier: Any question or comments from the floor?

Mr. Goldbeck: That completes the report on ballast. It is presented merely as information.

Chairman Legro: This completes the report of the Committee on Roadway and Ballast.

President Mottier: Mr. Legro, you have given us an excellent report.

The Committee on Roadway and Ballast is now dismissed with the thanks of the Association. (Applause)

Discussion on Ties

(For Report, see pp. 355–357)

(President Mottier presiding).

Chairman C. D. Turley (Illinois Central): Committee 3 is prepared to report on three of its regular assignments.

Assignment 2—Extent of adherence to specifications—will be presented by the chairman of the subcommittee, Mr. Brentlinger.

P. D. Brentlinger (Pennsylvania): Our report has been printed. There is very little to add to it, except to call attention to one statement we did have to make, that everyone is not following AREA specifications. Some of the deviations are just due to human failures, and others are absolute disregard of specifications.

Each one who is responsible for buying ties or using them should certainly realize that it is not economical to buy a tie that is not going to give the full life of standard tie, because today's cost, (purchase price, treatment, placement in track) is too high to permit the use of substandard material.

We have continued our field inspection trips, and we will continue to make them. We would like to have all of those who have anything to do with the inspection try to restore it to the old AREA standard because it will pay better dividends in the end.

Chairman Turley: Assignment 4—Tie renewals and costs per mile of maintained track: Obviously, when we speak of tie renewals and costs per mile of maintained track, at least four fundamental things are involved: Demand, supply, labor, and the ability of the railroads to pay.

During the war emergency, tie renewals in the United States increased to 48 million in 1942 and 1944 but have decreased since then to 37 million in 1947.

During the same period, the cost of ties has steadily increased, advancing from an average of $1.29 per tie in 1945, to an average cost of $2.40 in 1947, an indication, of course, that further increases will be recorded for 1948 and 1949.

Over the years, many railroads have found these tables valuable when analyzing cross tie performance. However, just one word of caution. Care must be exercised in comparing the service records of individual railroads. All information involved, including the tie renewal cycles, the volume and nature of traffic and the maintenance conditions, must be available and taken into consideration before any definite conclusions can be reached.

It is evident that, in order for this record to be correct, we must have the cooperation of all the railroads in furnishing this information to the Interstate Commerce Commission.

President Mottier: Any comments or questions? If not, we will proceed.

Chairman Turley: Assignment 6, which deals with mechanical wear, splitting and methods of preventing and reducing them, collaborating with the National Lumber Manufacturers Association, through research, to find the answers, will be presented by Mr. R. S. Belcher, manager treating plants system, Atchison, Topeka & Santa Fe Railway.

Cross Tie Research in Cooperation Between the Association of American Railroads and the National Lumber Manufacturers Association

By R. S. Belcher

Manager of Treating Plants, System, Atchison, Topeka & Santa Fe Railway

For many years the lumber industry has realized that there is a community of interest with the railroads in the improvement of railroad cross ties. It was for this reason that the Products and Research Committee of the National Lumber Manufacturers Association sponsored a cooperative research program to be participated in by the railroads and interested affiliates of the NLMA. Organization plans were started approximately three years ago, but the interested groups could not be brought together until the spring of 1948. By May of that year organization phases had been so far completed that the necessary funds were available to start actual research in the laboratory. It was decided by the controlling committees that approximately $40,000 per year would be necessary for the railroad cross tie program and that $10,000 to $12,000 was desirable for a related program on dimensional stabilization. These two projects are so closely related that for the purpose of this discussion no differentiation will be made between them.

The Association of American Railroads is providing 50 percent of the funds for the cross tie research project. The lumber industry provides the other 50 percent for this project and all of the money for the closely related project on dimensional stabilization. The subscribers to both of the projects are as follows:

Association of American Railroads
West Coast Lumbermen's Association
Western Pine Association
Southern Pine Association
Hardwood Research Committee
C. A. Bruce
Ozan Lumber Company
National Hardwood Lumber Association
Minnesota and Ontario Paper Company
National Association of Commission Lumber Salesmen, Inc.
Winton Lumber Company
National Wood Treating Corporation
Gurdon Lumber Company
Crossett Lumber Company
Southern Pine Lumber Company
Southern Lumber Company
Angelina County Lumber Company
Kirby Lumber Corporation
W. T. Smith Lumber Company
Canadian Lumbermen's Association

After the funds were made available, the subscribers selected a committee to represent them. The function of the committee is to devise an adequate work program, set forth the detailed objectives of the work for the research organizations and to render general supervision over the conduct of all details in carrying through the projects, The committee is responsible to the subscribers for the expenditure of funds and can alter or change the program in any way it sees fit as long as it stays within the framework of the broad objective for which the funds were subscribed. Each year the subscribers are notified of a meeting in which new committee members are appointed or those already on the committee are reappointed. The present committee is made up of five members from the AAR and five members from the lumber industry. The committee as now constituted is made up of the following people:

G. M. Magee, Chairman
C. D. Turley
R. S. Belcher
H. R. Duncan
C. J. Code
A. J. Neils
Paul Miller
H. F. Jefferson
C. D. Dosker
C. A. Bruce

Objectives

The objective of the railroad cross tie research is to develop methods whereby the service life of ties may be increased through the reduction or prevention of mechanical wear and preventing or minimizing tie deterioration due to end splitting or checking.

It is also the objective of this research to develop economical and practical means of effectively decreasing the shrinking and swelling of wood used for construction lumber, railroad cross ties, and other wood products.

Description of the Laboratory

The technical research on the foregoing projects is being conducted in the wood research laboratory of the Timber Engineering Company located in Washington, D. C. The Timber Engineering Company is affiliated with the NLMA and is engaged in practically all phases of wood research. The director of research TECO is also director of research for the NLMA and is the NLMA project manager for the cross tie and dimensional stabilization programs. He is also secretary of the committee and is directly responsible to the project committee through its chairman.

The staff at the TECO laboratory is made up of technicians who have specialized in wood research. This staff is composed of wood technologists, chemists and engineers.

The physical equipment of the TECO laboratory includes among other things a wide variety of equipment for making strength tests and for the determination of the physical properties of wood. The chemistry department is well equipped for making chemical analyses, wood fiber studies and has a complete pilot plant for producing pulp and fiber board materials. The laboratory is also well equipped with woodworking machinery, a dry kiln, facilities for determining decay resistance and to make microscopic studies of wood structure. Since the start of the cross tie program, space has been set aside where a large number of treated tie sections are subjected to outside exposure for the purpose of determining the effectiveness of various types of end coatings. The laboratory is being rapidly equipped with supersonic facilities which will be used principally in the studies on dimensional stabilization. Within the next few months these facilities will be widely expanded. Also it is anticipated that within a short time testing equipment will be installed in the laboratory where full size ties can be subjected to accelerated loading tests. Other specialized equipment specifically for the cross tie and dimensional stabilization programs is being added as rapidly as funds and time will permit.

The foregoing is a brief history of the organization of the project and a brief description of the laboratory facilities accomplishing this. The remaining part of this discussion is a summary of the preliminary work and contemplated studies to be carried on at the TECO laboratory under the project for "Improving The Service Life of Cross Ties."

Determination of the Causes of Tie Deterioration

T. G. Gill of the TECO laboratory, technologist in charge of this research project, made an inspection trip over the Burlington, the Illinois Central, the Pennslvania, the Santa Fe and the Northern Pacific, in the order named, in company with representatives of these roads in an attempt to observe ties under most of the climatic conditions encountered in this country, particularly as to the mechanical wear under various conditions of track and traffic. As a result of this inspection, the conclusion was reached that even with the ever increasing faster and heavier loads the mechanical deterioration of ties will be reduced with improvements in roadway and track structure. The cross tie itself, however, must be improved to extend its life to the maximum extent economically possible and to remain abreast of other railroad improvements and thereby reduce track maintenance costs.

Reasons for the removal of treated ties have been standardized by this Association and a suggested form of reporting was published in the Proceedings, Vol. 47, 1946, page 133. However, comparatively few data are available showing tie removals classified as to the reasons for removal. Practically all published data show merely the average life of the tie and disregard the cause of removal, except as to decay and type of preservative treatment. The data presented by the report of Mr. Gill who made this inspection show that most ties are now being removed because of plate cutting. Split, shatter and decay are probably the next three most important reasons for tie removal. However, tie deterioration is usually the result of a combination of factors, with one cause more or less pronounced.

Macroscopic and microscopic examinations of the wood fibers under the tie plate area of sample ties selected during the inspection trip and sent to the TECO laboratory for detailed study indicate that there is a deformation of the wood structure in cross ties caused by the loads imposed on the wood by passing trains. Although the extent of this deformation of wood structure or failure of wood is very slight in comparison with the total deterioration caused by plate cutting, it does contribute to the weakening of the first few annual rings adjacent to the tie plate.

In a deeply plate-cut tie a considerable portion of the spring wood adjacent to the bottom of the tie plate is completely destroyed. It has the appearance of being abraded and pulverized. This condition may extend to a depth of one inch below the tie plate and is usually accompanied by considerable infiltration of sand and other foreign particles. The summer wood of several annual rings forms separate lawyers and often fall out of place when the tie is handled. Microscopic examination shows sand observed in crevices of many ties has rounded edges. It is expected, therefore, that a "ball mill" action has taken place within the structure of the wood. This would account for the abraded and torn wood fibers. Abrasion of the wood under the tie plate area was observed on all ties examined. Sand was found to penetrate into the wood through checks, splits and spike holes to varying depths. Although deformation of wood fibers was found, it is believed that abrasion accounts for practically all tie plate cutting.

Chemical analysis has been made of samples of the wood from the tie plate area of the ties collected on the inspection trip made by Mr. Gill with the object of determining whether ferrous metals in contact with the wood destroy the natural properties of the wood that resist decay and mechanical wear. There are very few data on this subject other than those which are being developed by the studies made in connection with this project, but such meager data as are available indicate that under certain circumstances deterioration because of the influence of ferrous metals takes place. Additional work is being performed to show more conclusively the effect of ferrous metals on wood.

Review of Patents

A review of patents was undertaken to locate patents which seemed to hold promise and which might be the basis of further development.

Survey of Literature

A survey of the literature on the subject has been necessary to analyze previous records of the cause of tie failure and to become familiar with cross tie history and tie service records, and also to learn what other work has been done in this field. This phase of the work has been completed but it is being currently maintained.

Modification of Wood Cross Ties

A—*Use of Coatings During the Seasoning Period To Minimize Checking and Splitting.*—During the past months more than 200 test specimens have been end treated and placed in the seasoning yard. Monthly records will be maintained on checking and splitting. Since end treatments now appear to be inadequate to prevent surface checks from progressing down into the end section of the tie and becoming a major cause of splitting, it is expected that a different type of coating will be developed, which will be applied not only to the ends but also to a portion of the surfaces of the tie.

B—*Improving Penetrability of Wood.*—In the dimensional stabilization research program it was found that to prevent checking and splitting an anti-shrink efficiency of more than 50 percent must be obtained. A 50-percent anti-shrink value, however, can be obtained at present only in woods that are easily treated. Therefore, to obtain an anti-shrink value that is effective in prohibiting checking and splitting during exposure to the elements a method must be developed to fully impregnate even the most refractory woods. One of the most practical ways of securing stabilization of wood would be by complete impregnation of the wood with a material that will in one way or another prevent this undesirable movement of wood. Complete penetration of wood is very difficult and is impossible in many species of wood. Therefore, improving the treatability of wood is a major factor in securing stabilization.

The supersonic treatment of wood offers possibilities of securing thorough penetration in even the most refractory species. The work which is being done in the laboratory on supersonics is rapidly approaching the stage where there will be some indication of the effectiveness of using supersonic vibrations to increase the penetrability of wood with various materials such as liquids and gases. Supersonic equipment is being increased to permit a more detailed and accurate study of the penetrability of wood and it is planned to proceed with this study on an expanded scale.

C—*Treatment of Ties in Track.*—If the physical qualities of wood can be maintained after placement in the track many of the causes for tie removal such as checking, splitting, shattering and weathering will be eliminated. Work to date has indicated that coatings provide better protection against checking and splitting than does partial impregnation. It is, therefore, planned that in the event complete impregnation is not feasible that a suitable coating be developed for spraying immediately after the installation of the tie in the track, with the object of minimizing checks, splits, shattering and other deterioraiton caused by exposure to the elements. This coating must be very inexpensive, simple to apply and capable of staying on the tie during the extended life of the tie.

Design of Ties

Work is already under way in connection with the design of composite ties of wood that will assist in achieving the main objective of this research. Models of composite ties of various types have been prepared and these are being studied and new models manufactured from time to time as suggestions are received and new ideas are developed. Among these composite ties of wood that will be studied are:

Laminated ties, designed to use the minimum amount of wood but yet able to carry the stresses required of a cross tie.

Wood inserts, both flat and end grain, as bearing surfaces for the standard metal tie plate.

Consideration is being given to special treatment of the tie plate area by chemical and physical means, whereby the tie plate area will be made more resistant to mechanical wear.

Since the ultimate proof of the desirability of any development under this general program will be tests in track the objective of this phase of the program will be to provide for actual service tests. Accelerated tests would be of great value in determining the value of a specific tie improvement and it is hoped that a piece of equipment to accomplish this testing will be available at the laboratory during the coming year.

Fastening the Tie Plate to the Tie

It is realized that improving the method of fastening tie plate to the tie is very desirable and some laboratory work along this line will be done which will include bonding the tie plate to the tie with mastics, glues and other similar material. The object of this study is to develop a method of preventing movement of the tie plate on the tie, thus eliminating abrasive action.

President Mottier: Thank you, Mr. Belcher.

That is all of the report of the Committee on Ties. Mr. Turley, you and your committee are excused with our thanks. (Applause)

Discussion on Economics of Railway Location and Operation

(For Report, see pp. 147–161)

(President Mottier presiding).

Chairman C. H. Blackman (Louisville & Nashville): Committee 16—Economics of Railway Location and Operation was assigned eight subjects for this year. That is too many to work on at one time. We are making preliminary progress reports only on two of these eight subjects.

In the first one we have a rather extensive description of a gas turbine locomotive, and I will ask Dr. L. K. Sillcox, first vice-president, New York Air Brake Company, to present that to you.

L. K. Sillcox (New York Air Brake Company): The subcommittee's report appears, beginning on page 149.

(Mr. Sillcox read a synopsis of the report.)

Mr. Sillcox: There is one further view I would like to leave with you, and that is, this is a liquid fuel nation. I do believe that, if we ran short on our oil supply, we would find some way of making it artificially, and if we were short in oil supply we would be short on highway operations which would affect almost everyone. If that were cured on a synthetic basis, it would also take care of the railway necessity.

President Mottier: Thank you, Mr. Sillcox.

Chairman Blackman: The next subject on which we have anything to report is Assignment 8—Economics of operation of union railway passenger terminals. This is only a preliminary description of a new terminal in which several members of this Association are interested.

I will ask Mr. John Barriger, president of the Monon Railroad, to present that subject.

J. W. Barriger (Chicago, Indianapolis & Louisville): Railroads meet and say good-by to most of their patrons in passenger stations of great cities. Railway passenger stations and terminals are matters of civic importance and development and, therefore, are questions of public and political interest outside and beyond railroad official circles.

Facilities of this nature have important influence upon railway operating expenses and, to some extent, upon railway operating revenues. They are, therefore, an appropriate subject for this organization to deal with and assign to Committee 16 for specific analysis.

Unfortunately, on the question of passenger terminals, it is one in which the interests and wishes of the railways and of the communities do not always run parallel, as those of us who live in Chicago well know.

However, in one city notable success has been achieved in finding a common ground on which to develop a thoroughly modern and satisfactory facility. Very appropriately, that is in a city which is conspicuously identified with the good work of the president of this organization, and, as we might expect, in the formulation and development of the plans there, he has played a leading role.

The subcommittee on this subject has been studying these union passenger terminals and their comparative economics of construction, operation and maintenance in various cities, but the one on which our preliminary report is focused is the one to which I alluded, that one in New Orleans. We wish to commend for your careful reading the preliminary report on that subject which outlines the significant economic, engineering, political, operating and other characteristics of that important development which might well point the way for those of us on other railroads and in other cities to follow.

President Mottier: Thank you, Mr. Barriger.

Chairman Blackman: Committee 16 has suffered the loss during the past year of two of its important members. There is a memoir to Mr. James Moore Farrin on page 148.

After the publication of this bulletin we lost Mr. J. F. Pringle, vice president, Central Region, Canadian National Railways, Toronto, who died on February 8, after a brief illness.

We appointed a committee consisting of Mr. W. B. Irwin, Professor J. S. Worley and Mr. E. E. Kimball, to prepare a memoir to Mr. Pringle. That has been done. Mr. Irwin, chairman of this committee, and Professor Worley both had to be absent today, and Mr. Kimball has asked me to read this memoir. It is rather long. I do not know whether you want it read or whether we should submit it for publication.

President Mottier: I suggest it be published.

Chairman Blackman: We will submit it for publication, and I trust that you will all read it.

James Farrand Pringle

James Farrand Pringle, vice president, Central Region, Canadian National Railways, Toronto, died February 8, 1949 after a brief illness.

Born at Cornwall, Ontario, June 3, 1885, the son of Robert A. Pringle, an eminent lawyer, and Ada Van Arsdale Pringle, he attended primary and high school at Cornwall and was graduated from Queen's University, Kingston, Ont., in Arts (BA) 1905, and in Civil Engineering (B.Sc.) 1907. He entered railway service in 1907 as instrumentman on construction of the National Transcontinental Railway (now Canadian National Railways) in northern Quebec and served in that capacity and as resident engineer until 1912, when he engaged in Dominion land surveys in the Peace River district, Alberta, 1912–13. He then became assistant engineer in charge of railways diversions and construction on the Welland Canal project, 1913–15.

Mr. Pringle served in the Canadian Expeditionary Force from 1915 to 1919, retiring from the army with the rank of Major of Canadian Engineers; during his service at Halifax, N. S. he was one of the officers in charge of reconstruction of the docks following the disastrous explosion of a munitions ship which caused a heavy loss of life, December 7, 1917. Upon the termination of his military service he entered the office of the chief engineer of the former Grand Trunk Railway at Montreal in November 1919, as assistant engineer, and continued in the service of what became the Canadian National Railways as transportation engineer and assistant general superintendent of transportation at Toronto to 1930. In 1930–31 he was one of two technical experts loaned by Canadian National Railways to advise in the reorganization of the National Railways of Mexico. Following his return from Mexico he served the Canadian National Railways continuously, as shown, until his death:

1932–36 General Superintendent of Transportation, Central Region, Toronto
1936–41 General Superintendent, Southern Ontario District, Toronto
1941–43 Chief of Transportation, System, Montreal
1943–44 Vice-President and General Manager, Atlantic Region, Moncton, N. B.
1944–48 Vice-President and General Manager, Central Region, Toronto
1948–49 Vice-President, Central Region, Toronto

Mr. Pringle was elected to AREA membership November 6, 1920 and served efficiently as a committee member from 1922 until his death, being a member of former Committee 21—Economics of Railway Operation, 1922–37; vice-chairman 1931–35; and member of Committee 16—Economics of Railway Location and Operation 1938–49. He was active in civic affairs and social organizations, being a member of Council, Toronto Board of Trade; honorary vice-president, Canadian National Railways War Veterans Associations; member American Association of Railway Superintendents; member Phi Sigma Kappa, Mason, and member of following clubs: National, Granite, Rotary, and Thornhill Golf, Toronto, and Mount Stephen, Montreal. In sports he was fond of golf and curling.

Mr. Pringle is survived by his widow, the former Mildred Cooke, daughter of the Anglican Rector of Pakenham, Ont.; a daughter Constance (Mrs. J. L. Wright), Aurora, Ont. and four sons, James F., London, Ont.; Robert A., Belleville, Ont.; William A., Coteau, Que., and John, Toronto, Ont. He was a member of the Anglican Church and funeral services, attended by a vast gathering of friends, were held at St. Clements Church, Toronto, interment being at Catarsqui Cemetery, Kingston.

Mr. Pringle was a devoted husband and father and a transportation officer of outstanding ability whose wise counsel and genial personality will be greatly missed by all who knew him.

Chairman Blackman: There is one other subject that we have had, that probably should be mentioned, since it has been given a good deal of prominence.

Committee 16 has become involved in quite a little controversy. The committee has realized for some time that the so-called Yager formula for determination of proper allowance for maintenance expense due to increased use and increased investment needed revision.

The Manual now contains several words of caution concerning the use of this formula and limits its use to a variation of not over 1/3 in the amount of business. I am afraid that the limitation has been forgotten by some of the people who have attempted to use the Yager formula.

Our Manual subcommittee undertook last year to give this subject some study but found that it was a rather heavy subject, too heavy for the time that the subcommittee had to devote to it.

This year we have appointed a special subcommittee to consider the problem. That subcommittee, however, has not had time to work on it, and probably does not realize as yet just how much work has to be done.

In the meantime, some of members of the Association have found the formula being used against them in certain litigation. Some of the engineers engaged in important litigation in this country, fearing that the formula would be used to their detriment, requested Committee 16 to withdraw the formula from the Manual until it could be properly revised. On short notice of such request, Committee 16 agreed to do so, and notice of such proposal was issued to the membership on February 15 in the following form:

Committee 16—Economics of Railway Location and Operation
Supplemental Report

To the American Railway Engineering Association:

Your committee offers the following supplemental report:

Report on Assignment 1

Revision of Manual

The committee feels that revisions should be made in Methods of Determination of Proper Allowance for Maintenance of Way Expense Due to Increased Use and Increased Investment (popularly known as the Yager formula), which appears on Manual pages 16–78 to 16–84, incl., and to avoid having misleading material in the Manual, your committee recommends the withdrawal of this material, pending the necessary revisions.

February 15, 1949.

This notice brought quite a storm of protest, and the committee has since decided, with the approval of the Board of Direction, to present no proposed revision of the Manual this year except to publish as page 16–82.1 of the Manual the following statement:

> Committee 16 recognizes that the Yager formula is seriously out of date and, with the approval of the Board of Direction, recommends that it not be used until revisions can be made. It is now studying the subject and expects to recommend revisions.

I have presented this instead of calling on the chairman of our Manual committee, Mr. E. E. Kimball, because he asked that I present it. I should have called upon him. It is a question that has been discussed at great length by the Board of Direction, which spent considerable time on the subject yesterday, and we are presenting that statement to be published in the Manual.

I move that this statement be published in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Blackman: That concludes the report of this committee.

President Mottier: Thank you, Mr. Blackman. Your committee is excused with our thanks.

Chairman Blackman: Before we leave, I want to call attention to the fact that Committee 16 has one of the oldest past-presidents in its membership, and we have him here, Mr. Campbell. (Applause)

President Mottier: We recognized Mr. Campbell this morning. Mr. Campbell is 86 years *young*.

Discussion on Maintenance of Way Work Equipment

(For Report, see pp. 323–353)

(President Mottier presiding).

Chairman Edgar Bennett (Southern Railway System): It is with deep sorrow that this committee records the passing of two of its members last year. George Eugene Boyd died May 14, 1948. Clarence Richard Knowles died on August 5, 1948. Both of these men were devoted to the work, not only of this committee but other committees of which they were members. They also did much other work for this Association.

We have an assignment of 10 subjects. On two of these subjects—Revision of the Manual, and Motor cars, trailer and push cars—we will not have a report this year. We do have some material in the Manual that we recognize is subject to revision but it will not be ready for at least another year. The other eight subjects will be submitted as information. The first subject that we are to report on is Assignment 3—Portable conveyors. Mr. F. F. Zavatkay of the New Haven is chairman of that subcommittee and in his absence, I will briefly refer to this report which covers portable conveyors.

Your committee submitted a report to the Association two years ago, published in Proceedings, Vol. 48, 1947, page 341, covering power-operated portable conveyors for use in the maintenance of way department and this is to be considered a continuation of that report.

The report outlines numerous types of portable conveyors that are manufactured and now available for railroad use in almost every type, size and capacity. The report will speak for itself.

Our next subject is Power ballasting machines. The report will be presented by Mr. Rothe, chairman of this subcommittee.

F. H. Rothe (Pennsylvania): Your committee has presented two previous reports on this same subject, one in the Proceedings, Vol. 45, 1944, page 100, and in Vol. 49, 1948, page 151.

This final report is presented as information. It gives a rather detailed description of the electric vibratory ballasting machine and makes reference to the ballast kicking device now available on the impact type of ballaster.

The conclusions reached in this report are that these two machines are labor-saving devices which, when properly applied to the work they are fit for and given satisfactory supervision, will produce a considerable saving for the railroads.

Chairman Bennett: Our next assignment is 5—Equipment for oiling rail and track fixtures in the track. Mr. Etchison is subcommittee chairman and will give this report.

F. L. Etchison (Atlantic Coast Line): This is a progress report presented as information. The following are, briefly, the important features of the report.

(Mr. Etchison read a synopsis of the report on Assignment 5.)

Chairman Bennett: Our next assignment is No. 6. Mr. A. A. Keever is chairman of that subcommittee but he notified me he could not be here. I have asked Mr. Tracy to give his report. Mr. Tracy!

S. E. Tracy (Chicago, Burlington & Quincy): This report on Assignment 6 is presented as information, with the recommendation that the subject be discontinued. An earlier report appears in the Proceedings, Vol. 49, 1948, pages 158–161.

Only machines capable of cleaning any type ballast from the crib, without preliminary loosening of ballast by auxiliary equipment, were studied. One type of cribber removes the ballast from half the crib and deposits the material beyond the ends of the ties by a pivoted digger boom equipped with an endless roller chain on which are mounted digger flights. This is an on-track machine. A 7½-in. space is required between the ties for insertion of the digger boom.

This machine has successfully demonstrated its ability to clean a half crib of solidified ballast of the most extreme kind at a rate of 60 cribs per hour.

Another on-track cribber employs a heavy crosshead which extends across the track, the full length of the crib, and transversely acting digging bars are mounted on this crosshead. The digging action is accomplished through impact of the falling crosshead.

A minimum of five inches is required between the ties for insertion of the digger bars. The machine is equipped with power-operated transverse set-off wheels and a power lift so it can be removed easily from the track. Air controls are used in operation.

The unit is self-propelled and has a traveling speed of 25 mph. It has demonstrated its ability to clean 60 cribs per hour in the most resistant ballast.

Another on-track crib cleaning machine employs a bucket type conveyor which picks up the ballast from the crib, within the area between the rails, and delivers it to a vibrating shaker screen where it is cleaned and redeposited on the track while the dirt is deposited on the shoulder by a belt conveyor. The unit is self-propelled with hydraulic controls.

A 9-in. space between ties is required for operation of this machine which will clean up to 40 cribs per hour in partially solidified ballast.

Chairman Bennett: The next assignment is No. 7. Mr. Buss is chairman of the subcommittee and will give the report.

R. E. Buss (Illinois Central): The report on Assignment 7 covers portable power units and power tools for roadway terminals gangs. This is a final report, presented as information.

Roadway terminal gangs are naturally subjected to more frequent delays from train movements than outlying divisional gangs. As a result of these additional delays it is obvious that productive work time is lost. To offset this loss of productive time, portable power units and power tools offer some relief.

Then we go on to enumerate a number of such power units and power tools in common use in railroad terminals. Such tools, of course, are used on outlying divisions in the same manner. We mention 13 different devices in common use. The conclusion is that real economies are derived from the intelligent and regular use of the above-described power units and tools. Their use not only results in savings in man-hours, but also takes the drudgery out of tasks formerly done by hand methods.

Chairman Bennett: Our next assignment is No. 8. Mr. Todd is chairman of that subcommittee, which is on diesel engines.

J. N. Todd (Southern Railway): This is a final report presented as information. It is a continuation of the same subject last reported in the Proceedings, Vol. 47, 1946. It would be incorrect to say that this report brings the subject up to date. Much has happened since it was written, and the data on which it is based were made public months before it was put in final form by your committee. Therefore, much of the data is more than a year old now. Needless to say, further advances have taken place. At least one American maker of large diesels has announced a small model in the 10 to 15-hp. range.

I will not read the report, but I would like to mention two of its highlights. The diesel engine has just had its 50th anniversary; 1948 marked 50 years since Dr. Rudolph Diesel presented his engine to the public at the Munich Exposition, although the patent was dated six years before that.

The second feature is one that should receive the attention of other than work equipment men, such as bridge engineers. I refer to that portion of the report covering the unit pile hammer operating on the diesel principle. Essentially, it is similar to one of the gasoline unit tampers. A model on the task test weighs 2000 lb., of which the piston is 1100 lb., and the stroke about 6½ ft., giving a gross energy of more than 6600 ft.-lb.

This is a foreign development and our military forces brought back models after the last war. It is still undergoing tests and development.

Chairman Bennett: Our next assignment is No. 9—Portable power units and power tools for bridge and building gangs. Mr. McKenney is chairman of that subcommittee and will give the report.

F. H. McKenney (Chicago, Burlington & Quincy): The report on Assignment 9—Portable power units and power tools for bridge and building gangs—is a final report, submitted as information.

(Mr. McKenney then read the second and third paragraphs of the report on Assignment 9.)

Mr. McKenney: Since the report is simply a description of the various types and sizes of electric and pneumatic tools and power units available, I will not take the time to read it through. It is submitted as descriptive information.

Chairman Bennett: The next assignment is No. 10—New developments in maintenance of way equipment. Mr. N. W. Hutchison of the C. & O. Railroad is subcommittee chairman but he could not be present today, so I have asked Mr. Westcott, who is now retired from active duty on the Missouri Pacific, to give this report. Mr. Westcott has also told me that he will retire from the committee in a short time. He is a past chairman. He has always given us splendid advice and instruction in our work. We will miss him.

G. R. Westcott (Missouri Pacific): After such an obituary, or whatever you might call it, I ought to give you something worth while this afternoon.

A previous report was made in 1942, and in that report an historical outline of the transition from hand labor to machine work was given. This report may be considered a continuation of that one, as present conditions demand the changes to machine work as rapidly as possible. Fortunately, the manufacturers of equipment have been very alert in learning as rapidly as they could the needs of the railroads and have been energetic in carrying out their plans to meet those needs.

The current report is in three divisions. There is, first, a listing of a number of items with a brief description and discussion of each that have been provided in the last few years. I think I will not take time to enumerate those.

The second part of the report lists seven needs that were mentioned in the earlier report, and attention is called to the fact that five of those needs have been met in the intervening time.

The third part of the report is a list of six further suggestions as to the needs of the railroads. Perhaps I should add that this is a continuing subject, because the needs of the railroads cannot always be foreseen and they come up from time to time. This report, however, is submitted as a final report until such time as the Board of Direction may call upon us for a further study.

President Mottier: Thank you, Mr. Westcott.

Chairman Bennett: This concludes our committee report.

While I have the platform, I would like to impress again on all of our engineering personnel, the men on the railroads who have to do with the use of maintenance of way work equipment, that it is one of the most important things we have confronting us now.

These men, your work equipment supervisors, cannot do the job unless you give them the proper encouragement and assistance. You have invested heavily in work equipment. The chief engineers and the division engineers cannot get the work done with that equipment unless they support these men whose responsibility it is to keep the equipment repaired and in service. Those things are largely in your hands. These fellows will do the job, if you help them in the right way.

We are indebted for our past work, particularly in power equipment, to the help of the manufacturers. They have always been ready to work at it and spend large sums of money, in many instances, on new equipment that has been suggested, developing it to a point where it really will perform the job for which it is intended.

The only way that we can continue and take advantage of our future opportunities is to suggest different things in new equipment, changes in old equipment, and new equipment that is needed on the railroad to do different jobs, as well as tools that are needed, so that the manufacturers will continue their help and aid in producing these things that we need.

Through the requirement of rotation of our committee chairmen, this brings me to the last year of my assignment as chairman of Committee 27.

I wish to take this opportunity to thank all members that have been working on the committee with me during the last three years. It has been a great source of pleasure and satisfaction, and our work has come through, I think, each year on time. As expected, Mr. Bob Johnson of the C. & O. is to be the next chairman of this committee and Mr. Cliff Morgan will be vice-chairman.

If Mr. Morgan is here, I am going to ask him to stand for a minute to be recognized.

That concludes our work.

President Mottier: Thank you, Mr. Bennett. You and your committee are excused with our thanks. (Applause)

Discussion on Economics of Railway Labor

(For Report, see pp. 217–232)

(President Mottier presiding).

Chairman J. S. McBride (Chicago & Eastern Illinois): Since the report was published, the committee has suffered the loss of a valuable member, Mr. Hurd Cassil, who was instantly killed January 13, 1949 when struck by an automobile on the street near his home in Detroit.

Mr. Cassil, a life member of the Association, was a member of this committee for 25 years, from 1924 until the time of his death. He served as chairman of this committee for three years. He will be missed on the committee not only for his work, but also for his wise counsel. The committee has prepared a memoir to him which it asks leave to publish.

President Mottier: It is so ordered.

Hurd Alexander Cassil

Hurd Alexander Cassil was born at Mount Vernon, Ohio, November 8, 1877 and was instantly killed on January 13, 1949 when struck by an automobile on a busy thoroughfare near his home at Detroit, Mich.

He was educated in the public schools at Mount Vernon and had two years' study in civil engineering under a private tutor.

Mr. Cassil started his engineering career as a rodman for the city of Mount Vernon in July 1898, and in January 1899 entered service as a rodman with the Pennsylvania Railroad. He started with the Pere Marquette Railway in July 1900 as instrumentman and in August 1902 he became chief clerk to the chief engineer and was promoted to division engineer in August 1904.

He left the Pere Marquette in August 1905 to become assistant general manager of J. G. White Company, contractor for railway and construction at Montreal, Quebec In 1908 he re-entered the service of the Pere Marquette as chief clerk to the superintendent. He was employed by the Cincinnati, Hamilton and Dayton Railway in November 1909 as chief clerk to the vice president and general manager, and in March 1912 he became division engineer. He was in the service of Baltimore and Ohio Railroad as division engineer from December 1913.

He again re-entered the service of the Pere Marquette in 1917 as engineer of maintenance of way. In August 1922 he was promoted to chief engineer and continued in that position until he retired in 1946. After his retirement he was vice president of Armond Cassil, Inc., railroad contractors, at Detroit, Mich., and was occupying that position at the time of his death.

Mr. Cassil became a member of the American Railway Engineering Association in 1914 and a life member in 1947. He was a member of Committee 8—Masonry, for five years, 1914–1919. He was a member of Committee 3—Ties, from 1921–1925, Committee 4—Rail, 1938–1945.

He was a member of Committee 22—Economics of Railway Labor, for 25 years from 1924 until the time of his death. He was a valuable member of this committee and very active in its work. He was chairman of the committee for three years, 1942–1945

Mr. Cassil will be missed on Committee 22 not only for his untiring work but also for his wise counsel. He will be long remembered by associates and friends because of his devotion, loyalty and genial personality.

Chairman McBride: The committee is submitting reports on four of the seven subjects assigned to it. The first report is Revision of Manual. I will ask Mr. Haire, chairman of the subcommittee, to make this report.

C. C. Haire (Illinois Central): The report is divided into two parts, the first being a revision of existing Manual material, and the second part appears under the title of Inspection of Bridges and Buildings.

The text of the report beginning at the top of page 218, under the heading, Programming of Bridge and Building Work, is designed to replace the text and the forms under the same title in the Manual on page 22–5 and ending on page 22–9, which was adopted in 1934.

This material outlines a recommended method to obtain data from field inspections and to reduce that information for preparation of a budget and to show how work programs should be developed. There is also outlined a method for controlling the expenditures for a program and a budget. Form 2202 Rev. has been provided for these purposes to take the place of the 1934 form bearing the same number, and it shows how to set up the program to develop maintenance and capital expenditure budgets. A plan is also outlined in the report to analyze the expenditures for program items so as to control the progress and the costs.

There is a correction needed for Form 2202 Rev. The note under heading of form reads, "This report is a recapitulation of Reports on Form A, B and C", etc. It should read, "This report is a recapitulation of Reports on Forms A, B, C and D", etc.; that is, Form D should have been included in the note, but it is now desired to delete this note as the inspection forms have not yet been approved for Manual material.

It is the opinion of the committee that the routine outlined under the heading of "Programming of Bridge and Building Work" plays a very important part in the supervisory and administrative work of maintenance of way officers.

I therefore move that the new Manual material as proposed in the report, beginning on page 218 and ending at the middle of page 220, together with Form 2202 Rev., with the note deleted, appearing on page 225, be approved for publication in the Manual.

(The motion was seconded, put to a vote and carried.)

Mr. Haire: The committee also offers, as the second feature of its report, the information that appears under the title of Inspection of Bridges and Buildings, beginning at the middle of page 220. The report outlines the organization and methods for conducting field inspections of bridges and buildings. There has been designed an entirely new series of forms for these inspections, designated as Forms A, B, C and D, also the inspection routine contemplates the use of summary Form 2202 Rev. This summary form will be offered as Manual material, except the note referring to Forms A, B and C will be deleted as they are not being offered for the Manual. Form 2202 Rev. is required to summarize the result of field inspections as well as to develop a work program and budget. The report shows that the inspection of bridges and buildings serves two basic purposes, the first being to ascertain from field investigation, conditions as to safety and measures needed to maintain proper operation. The second function of field inspection is to secure, concurrently, the needed information for immediate repairs and the programming of repairs and improvement work.

The series of field inspection Forms A, B, C and D can be used to satisfy both functions, and the report describes the methods that should be followed in preparing the reports on these forms.

Attention is called to the fact that the Forms A, B and C duplicate, in part, similar bridge inspection forms now appearing in the Manual under the chapter devoted to the work of Committee 11. This does not apply to Form D covering building inspections, as previously no specific form for buildings existed. Our committee, in studying the problem of proper bridge and building inspection forms to be used for the dual purpose of ascertaining conditions in the field as to safety and needed work to maintain operations and the need to develop in advance, work programs and budgets for approval of the management, found it is desirable to design an entirely new set of forms and to revise Form 2202. We therefore offer this year as information and for future study purposes, the new series of forms that seems to satisfy all requirements with respect to bridge and building inspections, including the need of securing budget appropriations and to lay out programs of work. This is offered as information.

President Mottier: Thank you, Mr. Haire.

Chairman McBride: The report on Assignment 2—Analysis of operations of railways that have substantially reduced the cost of labor required in maintenance of way work—will be submitted by the subcommittee chairman, Mr. Cornell, engineer of track, Nickel Plate.

W. E. Cornell (New York, Chicago & St. Louis): The report on Assignment 2 is offered as information.

This report covers one road's comparative cost of doing certain major items of track work with a large gang (almost 150 men) with track detours during the work period, as compared to doing similar work under traffic, with smaller gangs. A saving of some 53 percent is indicated in favor of the method using larger gangs.

Your committee concludes that substantial savings may be obtained by the use of the detour method for doing certain major items of track work as compared to doing the work under traffic.

Further in connection with the economics of railway labor and possibly in a somewhat broader sense, I would like to add that, in my opinion, labor is one of the most important subjects before us today. Your committee more than 20 years ago prepared a very excellent report on the extent to which it is economical to stabilize employment in the maintenance of way department. May I therefore respectfully direct your attention to Proceedings, Vol. 28, 1927, pages 285 to 288, inclusive, covering the above-mentioned subject.

Chairman McBride: The report on Assignment 5—Organized training of supervisors, will be presented by Mr. Wise.

Edward Wise, Jr. (Louisville & Nashville): In the opinion of your committee, the organized training of supervisors is most important to the railroads to insure a constant supply of an efficient class of supervisory officers who can effectively and economically conduct maintenance of way work to meet the desired standards, and to provide personnel from which officers of higher rank can be recruited for the engineering and operating branches of the railroads.

We sent a questionnaire to some 20 leading railroads of the United States and Canada, inquiring as to their practice in this respect. Three of the railroads replying had definite training courses. Three of them had partial training courses; six replied that they use no training courses, and eight railroads did not reply to the questionnaire. In the report there is a description of the training course of the three railroads that have a definite setup in that respect.

In conclusion, our committee observes that large industries, other than railroads, have been very active in securing engineering graduates and training them for future supervisory officers. Moreover, your committee is of the opinion that the railroads should give serious consideration to competing for these young graduates and to inaugurate a training plan to qualify them for responsible positions in the maintenance of way and operating departments. Such training is feasible and produces results for those railroads using such a plan.

This report is submitted as information.

President Mottier: Thank you, Mr. Wise. It will be so received.

Chairman McBride: The report on Assignment 7—Track maintenance in CTC territory—will be presented by the subcommittee chairman, Mr. Reese.

A. G. Reese (Chicago, Burlington & Quincy): This is a final report submitted as information. The questionnaire submitted to a number of railroads in the United States having considerable mileage in CTC elicited replies from 16. These replies indicate that there is no more difficulty in maintaining track within CTC limits than with track of comparable tonnage and speeds outside of these installations.

However, it does offer a challenge to every railroad, and each individual railroad is obligated to take care of this condition by assuring itself of the proper assignment of its men and supplies to take care of the switches in CTC territory which are usually located in remote spots, at some distance from section headquarters.

President Mottier: Thank you, Mr. Reese.

Chairman McBride: That concludes the report of Committee 22.

President Mottier: Mr. McBride, I believe this is the termination of your third year.

Chairman McBride: That is right.

President Mottier: We bow to you. Thank you for your faithful service. We dismiss you and your committee with our sincere thanks.

Discussion on Iron and Steel Structures

(For Report, see pp. 423–456)

(Vice-President Schwinn presiding).

Chairman E. S. Birkenwald (Southern Railway System): On pages 423 and 424 your committee reports on four out of eight assigned subjects: 1. Revision of Manual; the second, Assignment 4, and you will note there is an error in the title of the assignment, it should be "Stress distribution in bridge frames–floorbeam hangers," instead of "stringers"; Assignment 5, Design of steel bridge details; and Assignment 8, Design of metal culverts of 60-in. diameter and larger, including corrugated metal arches.

You will notice in the report memoirs on Allen Wadsworth Carpenter and Harold Todd Livingston, and also directing attention to the memoir of Mr. Visintainer appearing in the annual report of the Committee on Wood Bridges and Trestles. These three members each gave a considerable part of their time in the service of the work of Committee 15. We are sorry to lose them.

Our first report is on Assignment 1. Revision of Manual, and I wish to call attention to some errors.

In Article 107 on page 429 under (B) 2 in the third line, the word "as" should be "at" coming after the word "effect" and before the word "synchronous."

In the same article, the second last line, the words "for static live load" have been omitted before the word "and" at the last of the line and the word "placed" the first word of the last line.

In Article 109 under (a) it should read "For girder spans 1½ times the vertical projection of the span" and it has been suggested and the committee is agreeable to the suggestion that we insert a phrase before the word "that" and after the word "a" in the fourth last line, reading "when the wind velocity exceeds 70 mph." and in the third last line delete "if the wind velocity exceeds 70 mph." The reason for this is it does make better reading and while the change is editorial, we feel that in the interest of everybody concerned it is a little clearer to have it in this way.

On page 431 there is also a typographical error in the second paragraph underneath the table that gives formulas. There is a sentence that starts "For comparison members," this should be "For compression members."

You will note in this Assignment 1 that there are some comments on the Test Results on Relation of Impact to Speed, and some tables and charts are furnished which illustrate the results of the test that the AAR has made since, I should say, about 1940. Considerable data are presented here and on the basis of this we have based Article 107, Impact on page 429.

Revision of Manual will be handled by Mr. Webb, chairman of the Subcommittee on Revision of Manual.

C. Earl Webb (American Bridge Company): The committee recommends the adoption of the following revisions:

Paragraph 211—page 15–9: We are adding one sentence to that paragraph: "For bracing systems or for longitudinal members entirely without a bracing system"—that is the added portion. Then it goes on to read: ". . . the lateral force to provide for the effect of the nosing of locomotives (in addition to the other lateral forces specified) shall be a single moving force of 20,000 lb. applied at the top of the rail, in either lateral direction, at any point of the span. The resulting vertical forces shall be disregarded."

That phrase was added to clarify the meaning of the paragraph.

Paragraph 516 is merely an editorial change, where we add the word "current", which is explanatory.

Paragraph 1810—page 15–48.6 given here—it should have been 48.1—we substitute a sentence as follows: "Flame-cut edges shall be machined to a depth of ¼ in. except that machine-flame-cut edges of silicon steel may be used without removal of metal if they are softened by post-heating in a manner satisfactory to the engineer."

The specifications as originally written mean that all high-strength steel, such as silicon and others, have to be machined if they have been flame-cut. It has become very difficult in some of the designs now made, where cover plates are used which have large manholes placed in them, to machine these round edges. Experiments have been made, and it is found that by post-heating these flame-cut edges you have a material that will stand the test better than machined edges.

I move the adoption of these changes for these three items.

(The motion was seconded, put to a vote and carried.)

Mr. Webb: Instructions for the Mill Inspection of Structural Steel. That has been in for the past 10 years, and it is resubmitted for approval, without change. This also applies to Instructions for the Inspection of Fabrication of Steel Bridges which has been in for the past 10 years.

I move the reapproval of these two parts of the specifications.

(The motion was seconded, put to a vote and carried.)

Mr. Webb: We have in the past year reviewed the Instructions for the Inspection of Bridge Erection which have been rewritten to a large extent and are shown in this report on the next two pages.

I move the adoption of these changes.

(The motion was seconded, put to a vote and carried.)

Chairman Birkenwald: It is the intention of the committee subject to further comment from the members of the Association to present the rating rules for adoption and publication at the next annual meeting. In the meantime, we ask that those who are interested in the rules on rating to write to the committee and if they have some different views than the committee is here presenting, to let us know what they are.

The rating rules have been a matter of controversy a good many years and many railroads have their own ways of rating system structures. It was the hope of the committee that we could compromise and get as many people as possible to agree to these rules with the idea that we could have a more uniform practice in rating existing bridges.

I am asking Mr. Sandberg, who is Chairman of the Subcommittee on Stress Distribution in Bridge Frames—Floorbeam Hangers to give you a few remarks in regard to our report on Assignment 4.

C. H. Sandberg (Atchison, Topeka & Santa Fe): Work on this assignment has been in progress for three years and this work was occasioned by numerous failures of the floorbeam hangers being reported on several railroads. Tests have been made by Mr. Magee's organization and also by Purdue University on modern designed trestles and laboratory tests made at the Purdue University to try to determine cause for these failures and to find a remedy so that new bridge hangers can be designed adequately.

We are also looking forward to making some tests on present old bridges to determine the stresses in the hangers in an effort to determine what the range of stress might be at various critical sections that cause failure, and then it will also be necessary to see what can be done in strengthening these members to avoid failure.

We are again reporting progress this year, but with the hope that next year we can at least begin to make a final report. Thank you.

Chairman Birkenwald: I am asking Mr. Staley, who is Chairman of our Subcommittee on Design of Steel Bridge Details, to give a few remarks in connection with Assignment 5.

G. L. Staley (Missouri–Kansas–Texas): We have a report on Faulty Details. This is a continuation of the same subject taken up about 14 years ago, and over the past three years we sent questionnaires to bridge engineers and got some information on the failures, mostly partial failures, but it was so much like that in the previous report, that we decided to hold it in abeyance for a while at least.

In both of these collections of faulty details, floorbeam hangers were among the main troubles reported, and of course that is now being taken up by special study, so we feel that this subject can be discontinued for the time being and recorded as information.

The next subject we have to report on is Deck Fastenings. Some member of the committee brought this up with the idea that we would specify certain typical examples of practice of American railroads for publication in the Manual as a means of establishing practice. We collected a number of examples, but never did fully agree on any particular type. As a matter of fact, everyone seemed to like what he had very well, so we decided on four typical examples as shown on page 447. Those are not put there as being the only thing that could be done in that manner. We considered a hook bolt was a hook bolt regardless of all dimensions and shapes, a tie anchor was a tie anchor regardless of how it was made and washers and combinations of washers were still the same thing. So we are presenting these four examples shown on page 447 as information with the view to being held over for a year and eventually offering them for the Manual as representative practice of American railroads.

This report is presented as information.

Chairman Birkenwald: I might add one other thing in connection with Assignment 5 and that is one of the reasons that we were asked to prepare the details for deck hardware came about through other countries desiring to buy steel spans in this country and the fabricating companies felt that if they could have some typical example of deck hardware to present to these people from other countries, then they could decide what they wanted. I merely give you that as information to show that the things that we do here, not only concern this country, but practically every country in the entire world.

A report on Assignment 8 will be given by Mr. Marsh who has succeeded Mr. Livingston, chairman of this subcommittee.

J. F. Marsh (Chicago, Rock Island & Pacific): I would first like to make a few corrections in the printed matter on pages 449–451. About the middle of page 449, Talbot's formula should read:

$$M = 1/16\ (1 - q)\ Wd$$

The same correction occurs under Table 1, and also in Table 2.

The committee chose to analyze culverts by two basic formulas, the Talbot's formula and Spangler's formula and we found from our analysis that the tables which have been commonly accepted show a certain reasonableness in stress as being slightly under the yield point, which has also been considered adequate in flexible metal culverts.

At this time I would like to read the last three paragraphs of the report.

(Mr. Marsh read the last three paragraphs of the report on Assignment 8.)

Vice-President Schwinn: Mr. Marsh has read a recommendation, a very specific one, made by his committee. The Board of Direction has considered this recommendation and other pertinent facts. The result of that consideration was the reversal of a previous action, and the material structural plate culverts has been restored to Chapter 1. Coincidentally with that action, the Board has directed that Committee 15 give consideration to the subject of culverts, and I will read for your information the directive:

> Committee 15 shall review these specifications for metal culverts and arches, and prepare such revisions thereof, or such new specifications therefor as are deemed necessary. Coincident with the submission of revised Manual material as here required, the interested committee (which in this case is Committee 15) shall recommend the withdrawal of any Manual material in conflict therewith.

Have you any further comment, Mr. Marsh?

Mr. Marsh: No, sir.

Vice-President Schwinn: Does that appear to take care of your original recommendation?

Mr. Marsh: I think it does, sir.

C. A. Ellis (Retired Professor of Structural Engineering, Purdue University): I heard a discussion today on the effect of floor beam hangers, but there is a second cousin to that problem, the effect of knee braces giving way due to fatigue.

Chairman Birkenwald: Just within the past several months we sent out a questionnaire trying to find out just how many failures we have been having as a result of knee braces giving way due to fatigue, and we find that with certain types of details, that sooner or later the old cycle catches up and you are going to have trouble, but there appear to be details that can be used which can overcome this and it is quite possible that Committee 15 may make a report of this in a later annual report.

Vice-President Schwinn: Is there any other discussion or any comment that anybody cares to make?

Mr. Birkenwald, your committee has, as usual, presented a very valuable report, and it is now dismissed with the thanks of the Association. I wish also to thank you in behalf of the Board of Direction of the Association for your competent service as chairman of the committee during the three years which you are now concluding. [Applause]

Discussion on Impact and Bridge Stresses

(For Report, see pp. 419–422)

(Vice-President Schwinn presiding).

Chairman A. B. Chapman (Chicago, Milwaukee, St. Paul & Pacific): Committee 30—Impact and Bridge Stresses presents a progress report on nine assignments out of the ten. The nine assignments are as follows: Viaduct columns, collaborating with Committee 15; Steel girder spans with open decks and with ballasted decks; Dynamic shear in girder and truss spans; Impact and bending stresses in columns and hangers of truss spans; Concrete structures, collaborating with Committee 8; Determination of braking and traction forces in bridge structures, collaborating with Committees 7, 8, and 15; Stresses and impacts in timber stringer bridges, collaborating with Committee 7; Steel truss spans with open decks and with ballasted decks; Stresses in lateral bracing of bridges.

The one assignment which we have no report on is No. 9, which is distribution of live load in transverse floors and longitudinal stringers.

Those progress reports are on pages 420–422 are presented as information.

Vice-President Schwinn: If there are no objections they will be so received.

Vice-President Schwinn: Thank you, Mr. Chapman. I understand that you are terminating your services as chairman of the committee. The Association is indebted to you for the manner in which you have carried out your term as the leader of this important committee.

If there is no further discussion, the committee is now excused. [Applause]

Discussion on Uniform General Contract Forms

(For Report, see pp. 253–263)

(Vice-President Schwinn presiding).

Chairman W. R. Swatosh (Erie Railroad): This year our report is prefaced with a note of sadness. The Association's Committee 20 feels deeply the death of Clark Dillenbeck which occurred on October 9, 1948. Mr. Dillenbeck joined the Association in 1916 and became a member of this committee and served on it from 1921 to 1928 and again from 1938 to 1942. He was its vice-chairman during 1927 and 1928. The Association and his friends have lost a cultured gentleman of sterling character and endearing personality who had the faculty of making lasting friendships.

Your committee had five subjects assigned for study and has presented reports on four of them. The first report on Assignment 1—Revision of the Manual, was to have been made by Mr. Lillie who is unable to be present, so I will submit it.

The committee recommends readoption of the Form of Agreement for Joint Use of Freight Terminal Facilities and the Form of Agreement for Crossing of Railways at Grade, subject to the minor revisions as indicated on page 254.

I move that this be adopted.

(The motion was seconded, put to a vote and carried.)

Chairman Swatosh: The committee also recommends the Form of Agreement for Trackage Rights, Form of Agreement for Industrial Track, Form of Lease for Industrial Site, Form of License for Private Road Crossing, and Form of Agreement for Purchase of Water be reaffirmed without change.

(His motion was seconded, put to a vote and carried.)

Chairman Swatosh: On Assignment 2, Mr. Olson, who was supposed to present this report was unable to be present.

Last year your committee presented as information, a tentative draft of Form of Agreement to Permit Subsurface Exploration by State or Other Governmental Agencies, on Railroad Right-of-Way. This form of agreement with minor revisions is now submitted with the recommendation that it be adopted and published in the Manual. I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Swatosh: The next report is on Assignment 3, Form of Agreement for Maintenance and Operation of Flood Protection Works. Mr. C. J. Henry, who was to present the report is not present. The Manual at the present time, does not contain the form of agreement for the maintenance and operation of flood protection works located upon lands and right-of-way of a railway company. The committee has drafted a form of agreement which it believes will permit maintenance and operation of flood control works, so located, to be progressed under the control of the railway and assure minimum interference with the operation of trains. Each member of the Association who is interested in the tentative draft of the agreement is urged to give your committee the benefit of his criticisms and suggestions.

The next report of the committee is on Assignment 4, Form of Agreement for Railway Force Account Work on Flood Control Projects. This report, together with the one just presented, plus the Form of Agreement for Construction of Stop Logs for Flood Control which the Association adopted last year as recommended practice will ultimately give the Association several contract forms. The text will interpret various engineering and other requirements involving experimental reconstruction and maintenance of railroad facilities pertaining to the flood prevention project. Mr. Brockett of the Santa Fe will present the report.

H. F. Brockett (Atchison, Topeka & Santa Fe): As you know, the national government is sponsoring and constructing under the supervision of army engineers, numerous flood control projects. Some of these projects involve changes in railway facilities and in some cases it works out to best advantage that the railway involved handle these changes on the force account basis.

Your committee, in the interest of promoting uniform practice, has drafted a form of agreement which is offered as information.

Chairman Swatosh: This concludes the report of your Committee on Uniform General Contract Forms and also my term as chairman, so I take this opportunity now to thank each member of the committee for the splendid cooperation and assistance that I have received during my tenure of office. I thank you.

Vice-President Schwinn: Thank you, Mr. Swatosh, for presenting the report of this committee. I also wish to thank you for your faithful service as chairman of this committee which is now terminating. The committee is now excused. [Applause]

Discussion on Waterproofing

(For Report, see pp. 354)

(Vice-President Schwinn presiding).

Chairman G. E. Robinson (New York Central System): We have three subjects under consideration. For two of them we have no report. The third subject which is Waterproofing protection to prevent concrete deterioration, we have a short report, merely to tell the Association what is going on at the moment. Under this subject we are conducting two series of tests, one on waterproofing membrane, the principal object of which is to determine its action under expansion of the various parts of the structure.

A report on that subject will be made later. That subject, by the way, is being studied in collaboration with three members each from Committees 8—Masonry and 15—Iron and Steel Structures. This collaboration has been very effective. Those members attend our meetings and the conduct of these tests is thoroughly gone over in the subcommittee of which they are a working part.

The second part of our test program is just now getting under way and it involves testing materials for the surface waterproofing of concrete. The qualities we are trying to get are permanence and, of course, waterproofness, and either a colorless material or a material which will resemble concrete. We have upwards of 50 samples which have been supplied by the various manufacturers and these will be exhaustively tested in the laboratory and those that stand up, or show some sign of promise, will be further tested in the field. A report on this test will also be made in the future.

Mr. Chairman, that completes the report of the committee.

Vice-President Schwinn: In dismissing your committee from the platform, Mr. Robinson, I wish to extend to you all the sincere thanks of the Association. I also wish to thank you personally for your service as chairman which is now being brought to a conclusion.

Chairman Robinson: Thank you, sir.

Discussion on Masonry

(For Report, see pp. 289–321)

(Vice-President Schwinn presiding).

Chairman F. R. Smith (Union Railroad Company): About a month ago we were all crushed to learn of the death of Arthur J. Boase, known to all his many friends as plain "Art."

Arthur J. Boase

Arthur J. Boase was born on October 10, 1892 in Central City, Colo. On February 9, 1949 he died of a heart attack in his office. For the past 16 years, Mr. Boase was manager of the Structural and Railway Bureaus of the Portland Cement Association. and he joined that organization in 1930 as regional structural engineer in the Philadelphia district. A civil engineer, he was a graduate of the University of Colorado. Mr. Boase later received his master's degree from the University of Pennsylvania and spent his entire professional life in structural design work. Upon completing his college work, Mr. Boase designed dams and tunnels in the Rocky Mountain region for eight years, principally for the Boston Colorado Power Company, and then for three years as manager of the Fair Engineering Company in Denver, he worked on the design and construction of reinforced bridges in Colorado. After serving on the staff of the Civil Engineering Department of the University of Pennsylvania, he was appointed professor of civil engineering to handle a similar department at Pennsylvania Military College. He left this work to join the staff of PCA. Mr. Boase was an internationally known authority in the field of reinforced concrete design. He traveled extensively for PCA in Europe in 1936, studying European practices in reinforced concrete design and in 1944 he was granted a leave of absence from the association to visit South America and write an extensive series of articles for Engineering News on design for South American engineers, and in the field of reinforced concrete building he was selected as the man best qualified in his field to handle this assignment.

At the time of his death, Mr. Boase was chairman of the Executive Committee of the Structural Division of ASCE and served as a member of this committee since 1944. In 1947 he was elected to the Board of Directors of the American Concrete Institute.

He joined the American Railway Engineering Association in 1946 and became a member of Committees 1 and 8, and served as chairman of both the ACI Building Code Committee and the ASCE Committee on Masonry and Reinforced Concrete. He was a member of the Reinforced Concrete Research Council and the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete and author-chairman of the ACI publication, "Reinforced Concrete Design."

Although Mr. Boase was a member of our Association for a relatively short time, he contributed much to its work for many years. Many of his suggestions are embodied in the report on design which the committee has recommended for publication in the Manual at this convention. His passing is a shock to the Masonry Committee, which had recommended that he be assigned to speak on the subject of masonry as part of the 50th Anniversary Program. He will be remembered for his genial personality, fine leadership, eager desire to be helpful and because he was an exceptionally kind, capable, conscientious, and cooperative engineer.

Chairman Smith: We also lost another one of our esteemed associates during the past year, George Eugene Boyd, on May 14, 1948. Members of Committee 8 endorse the sentiments expressed in the memoir prepared on behalf of th Committee on Maintenance of Way Work Equipment which appears on page 324.

Mr. Boyd was born at Roseville, Ill. on February 26, 1874 and was graduated by the University of Illinois in 1896 with the degree of Bachelor of Science in Civil Engineering.

He served on the Masonry Committee for 34 years. The younger men who had the privilege of being associated with Mr. Boyd miss him particularly. He had the faculty of tempering their ideas with his judgment and experience, conveying at the same time the impression that those ideas were valuable and constructive to the matter at hand. We record our appreciation of his most valuable service and profound sorrow at his passing.

Let us now pause in a moment of silence in tribute to the passing of these two outstanding men, George Eugene Boyd and Arthur J. Boase.

[The audience observed a moment of silence.]

Chairman Smith: Committee 8—Masonry was assigned eight subjects for study. We are reporting on the following subjects under five of these assignments: Assignment 2, Report on crib walls presented for adoption and publication in the Manual, and also report on design of plain and reinforced concrete members; Assignment 3 report on pile foundations for adoption and publication in the Manual; Assignment 5, tunnels, report on timber lining for adoption and publication in the Manual; Assignment 6 masonry repairs, report on repairing and solidifying masonry structures presented as information; Assignment 7, Concrete manufacture, report on proportioning concrete mixes presented as information.

As a report on Assignment 1, Revision of Manual, I am going to ask Mr. Johnson, chairman of the subcommittee, to tell you a few things about what we have been talking about in the committee which we think might improve the Manual.

A. C. Johnson (Elgin, Joliet & Eastern): In our subcommittee, we have limited our work to the revision of our chapter from the mechanical standpoint only. We have two thoughts in mind, one to make further revisions as simple as possible so that in minimizing the cost, we could make mere numerous revisions and thereby keep our chapter more up to date. Secondly, in placing this material in the Manual, we have kept in mind the useability of the matter in the viewpoint of the designer. Now to make revisions as simple as possible, we propose to subdivide our chapter into sections, each section to be numbered with a Roman numeral, and each section to be set up as an independent and complete unit in itself. It would contain all of the subject matter in our chapter that relates to one subject. These various sections would be subdivided again into articles which would have capital headings. Each article would be broken down into paragraphs which would have Arabic numerals and we can subdivide paragraphs into subparagraphs with the lower case capital letter.

Our ultimate aim is to change the paging of our Manual so that each section requiring a change would not change the page numbering in successive sections or chapters. We propose to do that by the three-principal-digit system, in place of the two which are now being used. In other words, we would use the chapter designation "8" for the first digit, the second digit for the section, and the third would be the page number of that section. In so doing, you would have no repetition of page numbers and you would not change any other numbers in any other section.

Our second thought was, as I said, to present the material in the manner best suited for the designer and we propose to do that by arranging our material so that as a problem of the designer is approached, he will automatically follow through the various parts of our chapter. We were given permission to present all of our future revisions in our chapter in this manner with the exception of the page numbering, but it is our ultimate aim that we can adopt our program fully and thereby reap the total benefit from our proposed changes.

We welcome any suggestions or constructive criticism from any member of the Association in our proposed scheme of revision.

Chairman Smith: Thank you, Mr. Johnson.

Secretary Lacher: Those of you who listened attentively to the Secretary's remarks may remember that I referred to the proposal of the Committee on Masonry of a new system of page numbering of the Manual which would eliminate some of the objections to our present plan which I attempted to explain this morning. It is the intent of the Board of Direction to explore the plan proposed by the Committee on Masonry. One thing that will have to be done is to call the people of the other committees into consultation for the purpose of ascertaining whether there are any obstacles to the plan as applied to other chapters. I think that the Committee on Masonry is to be complimented on its initiative and enterprise in endeavoring to do something that will overcome shortcomings of the present form of the Manual.

Chairman Smith: We of Committee 8 appreciate that a revision of the arrangement of the Manual is a tremendous job and we appreciate that if we don't start, there will never be anything done. We all know that to get a tomato, you have to plant the tomato seed. We are trying to find a better way. I think that is one thing we can do in the Association is try to find a better way in all of our work.

This year Committee 8 has four reports to be presented for adoption and publication in the Manual: Two under Assignment 2, Design; one under Assignment 3, Foundations, and one under Assignment 5, Tunnels.

The report on Design will be presented by Mr. Mays, chairman of the subcommittee.

R. L. Mays (New York, Chicago & St. Louis): Under Assignment 2, the first specification which your committee desires to offer is for crib walls. To prepare this specification, a special subcommittee was appointed, with Mr. Dayett as chairman. This subcommittee did a very fine job. I would like to ask Mr. Dayett to offer this specification.

G. H. Dayett (Baltimore & Ohio): Last year your committee presented as information, tentative specifications for reinforced concrete cribbing, metal cribbing, and timber cribbing.

A

During the past year, amendments have been made as follows: The word "outside" has been inserted before the word "faces" in the third line of the second paragraph under Design, of each of the three specifications.

In the specifications for metal cribbing, under Article 3, paragraph (c), the last paragraph at the top of page 248 is omitted.

These specifications are offered this year with exceptions as just noted, identically as they appear in the Proceedings, Vol. 49, 1948, pages 244–250.

I move the adoption of the three specifications.

(The motion was seconded, put to a vote and carried.)

Mr. Mays: The second specification under assignment 2, which your committee desires to offer is Specifications For Design of Plain and Reinforced Concrete Members.

Tentative specifications for design were submitted as information in 1947. They appear in Proceedings, Vol. 48, 1947, pages 418–449, incl.

The specifications were submitted with an invitation and request for critical review, comments and criticisms, so that they could be constructively amended before offering them for adoption and publication in the Manual. Your committee has received much advice pertaining to these specifications, and there has been a great amount of controversy over certain issues within the committee.

The design specifications have resulted from much concerted effort, collaboration and debate. Recognizing the importance of this issue and the difficulty involved in preparing tentative specifications understandingly, after careful consideration, and utilizing the best thinking of authorities on the subject, your committee offers these specifications for adoption and publication in the Manual to replace the material now included on pages 8–35 to 8–52.5, incl.

I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Smith: About two years ago Mr. Dayett suggested the Masonry Committee should have a specification for cribbing, steel, concrete and wood. We all thought, since he suggested the specification, he would be a good man to be the chairman. He accepted the chairmanship and did a magnificient job, and I want to take this opportunity to congratulate him for his fine work.

I also want to thank Mr. Mays for his leadership in directing the Design subcommittee. The design specifications have been worked over by three chairmen, Mr. Chapman, Mr. Ornburn and Mr. Mays, and I think they have done a fine job. I want to congratulate Mr. Mays and his committee for their fine work.

The report on Assignment 3—Foundations—will be presented by Mr. Nearing.

M. Nearing (New York Central System): The assignment of this committee is preparation of specifications for foundations for masonry structures.

We merely took as the first step the revision of the present Manual Specifications for Pile Foundations, and our revision was published in the Proceedings, Vol. 49, 1948, page 254.

Following the submission of these specifications, discussion in the committee resulted in further revisions which are published beginning on page 311 of this volume.

The first paragraph of Article A was reworded to restrict the application of these specifications to piles for underground substructures as distinguished from trestle piles.

Article C—Allowable Load—was rewritten, with a number of changes, with a paragraph added referring to a pile formula. The other revisions are editorial.

Subsequent to the publication of this bulletin, the subcommittee on piles of the Committee on Building Codes of the American Iron and Steel Institute very kindly reviewed our specifications and, at its suggestion, the following changes are proposed by your committee:

In Article D—Loading Test—paragraph 9, the words "if feasible" should be inserted in the first sentence, so that a load test need not be carried to failure in all cases.

To conform with this revision, certain minor changes will be made in reference to this article.

Part III, paragraph (c), where reference is made to this subject, the words "to failure" would be deleted. Again, in Article D, paragraph 10, insert the words "within 12 hours" after the word "rebound", making the sentence read: "In determining net settlement of tested pile, deduction shall be made for the allowable recovery of the pile as indicated by the rebound within 12 hours following the release of the test load."

In Article J, paragraph 1, the sizes of pipe piles should be changed to the corresponding outside diameter to conform to commercial practice. That is, where we call for 10-in. pipe, that would be changed to 10¾-in. outside diameter.

In Article J, paragraph 6—Allowable Stresses in Pipe Piles—provision that the total load carried by the steel shall not exceed one-half of the total load carried by the piles, is deleted.

In addition to this, it was suggested that paragraph 3 be lifted from Article J—Pipe Piles—and placed in Article B—Design, making it apply to all piles instead of pipe piles alone. This paragraph refers to the projection of the piles in a concrete foundation.

I move that the Specifications for Pile Foundations as submitted, with the suggested revisions, be adopted for publication in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Smith: Thank you, Mr. Nearing. You and your subcommittee have done a commendable job in preparing our pile specifications. We all appreciate it.

The report on Assignment 5—Tunnels—in the absence of Mr. Porter of the Chesapeake & Ohio Railroad, will be presented by Mr. Van Eenam.

Neil Van Eenam (U. S. Public Roads Administration): Your committee prepared a report last year on the subject of lining railway tunnels with timber. This report was submitted as information in the form of a tentative specification.

A critical review was invited from the Association so that the specification could be constructively amended before offering it for adoption and publication in the Manual as a new section in Chapter 8.

Your committee now recommends as new material for adoption and publication in the Manual, the Specifications for Lining Railway Tunnels with Timber as they appear in the Proceedings, Vol. 49, 1948, pages 264–268, incl., and revised as follows:

Paragraph 17, page 268, after the first sentence, add: "When treated timber lining is used, packing timber shall be treated as outlined in Paragraph 4."

Paragraph 18, page 268, change Paragraph 203 to Paragraph 7.

I move the adoption of the specification for inclusion in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Smith: Thank you, Mr. Van Eenam.

This concludes the reports of Committee 8 of material to be included in the Manual.

We have no report to make at this time on Assignment 4. I have asked Dr. Peck of the University of Illinois, chairman of the subcommittee to tell us a few things about the kind of thinking they are doing in regard to soil mechanics as related to foundations.

R. B. Peck (University of Illinois): For the last three years, as many of you know, through our own contributions, the subcommittee on earth pressure has been collecting information on the failure and continued movement of retaining loads and abutments. That information has been studied and analyzed.

With that background, the subcommittee is now endeavoring to draft new specifications for the design of these structures. We hope that there will be a draft ready for your consideration at this time next year.

Chairman Smith: Thank you, Dr. Peck. The report on Assignment 6 on masonry repairs will be presented by Mr. Schantz.

C. P. Schantz (Pennsylvania Railroad): The report on methods of repairing masonry, including internal pressure grouting is submitted as information with a view of offering it next year for adoption and publication in the Manual at which time it will replace the specifications now included on pages 141 and 142 of the Manual.

The committee welcomes any comment or criticism of the report. Thank you.

Vice-President Schwinn: It will be received as information.

Chairman Smith: Thank you, Mr. Schantz. We have practically completed the preparation of a field manual to be presented under Assignment 8 specification. Unfortunately, we were unable to have it ready for this convention. I am going to ask Mr. Wilson, chairman of the subcommittee, to tell you a few things about this Manual.

W. R. Wilson (Atchison, Topeka & Santa Fe): Your committee realized that in the aggregate, a large part of the concrete made and placed on the railroads in the country consists of very small jobs, small culverts, station platforms, foundations for small buildings, and a lot of this was put in by sending a small gang with a mixer, or even without a mixer, under the supervision of the foreman who would come up from the ranks as a bridge carpenter. As a consequence, we are getting a lot of poor concrete. These foremen just don't know how to proportion, mix, place and cure concrete to get the best that can be secured with the material. As a consequence, Committee 8 instructed the subcommittee to prepare a manual for the use of the people actually doing the work. That was quite a job. We had to eliminate all technical terms, and words of more than three syllables, so after about four rewritings, the manual is ready to go before the committee for their criticism.

We hope to have it ready for publication in the next report. This manual, by the nature of the different railroads' requirements, won't be in such shape that it can be taken in toto for use by each railroad, but it will include everything, we hope. It will include everything that the railroads will need to make up their own manual to give to their foremen. Thank you.

Chairman Smith: Thank you. Under Assignment 7, concrete manufacture, Mr. Morris is chairman of the subcommittee and he has prepared a table for controlling field mixes for concrete. I will ask Mr. Morris at this time to present his report.

L. M. Morris (Pennsylvania Railroad): The report is presented as information and presents a sheet which is entitled "Proportioning Concrete Mixes For Field Use." In 1945, the Masonry Committee presented a report on a design of concrete mixes which was a rather complete exposition of all the details required in designing concrete mixes by various methods. Since that time, most of the members of the Masonry Committee and others have felt that we should endeavor to prepare a simplified sheet which could be used by the division foreman on small jobs where it is impossible to go into all the detailed analyses that you would for the large job where the more complicated procedure is used. So after considerable writing and rewriting, your committee has prepared this sheet which is arranged particularly to give trial mixes and we believe that it will be possible to use this sheet if you make the necessary corrections to obtain proper final mixes. Naturally a sheet such as this contained on two sides of one small piece of paper has to be based on average conditions.

These figures have been based on the results of many tests by the United States Bureau of Reclamation, and naturally are presented in average form. This sheet is presented as information at this time and it is hoped that the railroad construction forces will give it a fair trial and let us have your comment because we hope to have this sheet in shape for inclusion in the manual which Mr. Wilson spoke about in the previous talk.

Chairman Smith: Thank you, Mr. Norris. The reports from Committee 8—Masonry are now completed. Concluding my three year term as Chairman of this fine committee, I want to extend my sincere thanks to each member for his excellent cooperation for presenting our work during the past year. It has been a privilege and a pleasure to be your chairman for the past three years. I know the work of Committee 8 will go forward with more success than during the last three years under the leadership of your new Chairman, Mr. C. B. Porter.

Vice-President Schwinn: Before I dismiss your committee I want to thank you, Mr. Smith, on behalf of the Association, for your outstanding record as chairman during the last three years. The committee is now excused.

Discussion on Wood Preservation

(For Report, see pp. 359–418)

(Vice-President Schwinn presiding).

Chairman C. S. Burt (Illinois Central): Your committee has carried on this year 12 different assignments, and it is a source of real satisfaction to me to point out to you that our subcommittees are now prepared to report on all but two of those assignments.

We have come a long way in wood preservation since Committee 17 was formed during 1909, but we still have a long, long way to go.

I am sure that members of this committee will join me in the declaration that today we stand on the threshold of new and improved methods and the still further use of wood.

The first assignment, No. 2, has to do with service test records of treated wood. The report of that subcommittee will be offered by Mr. Loom.

A. J. Loom (Northern Pacific): Our inquiries and requests during the past year did not produce any service test records of treated wood other than have already been published.

Therefore, this report is confined principally to such information as we have been able to obtain concerning the nature of the creosotes and creosote–petroleum solutions with which some of the previously reported test ties were treated.

It has come to our attention that some railroads are reluctant to have published the results of all of their service tests. One of the reasons given for this is that in some instances their test track reports indicate an extraordinary long life for ties of so-called inferior species of wood. It is said that publication of such reports has resulted in much correspondence and difficulty in explaining to what extent heavier than usual treatment and better than average protection from mechanical wear or other circumstances may have contributed to longer than average life of the inferior species in certain test sections.

Publication of such reports and the difficulty of offering a satisfactory explanation, it is claimed, have resulted in undue efforts to induce extensive use of inferior species of wood and to maintain prices the same as for other species that are known to produce definitely better ties.

Unless otherwise instructed this subcommittee will continue its efforts to obtain and report all available information pertaining to service records and the preservatives that were used in treatment of the various materials and species of wood that have been placed in service tests.

Your cooperation is hereby solicited and so when you are asked by any member of this committee for records of service, preservatives or other information pertaining thereto, it is hoped that your response will be favorable. Please be assured that your compliance with such requests will be greatly appreciated.

This is offered as information.

Vice-President Schwinn: Thank you, Mr. Loom. Your report will be received as information.

Chairman Burt: In the absence of Dr. Clapp, chairman of Assignment 3—Destruction by marine organisms; methods of prevention—may I urge each one to read quite carefully the report beginning on page 375? It describes various tests in marine waters and calls attention to the unusual activity in the New England areas during recent months. We commend this report to you for very careful reading.

Subject 4—Specifications for creosote-petroleum solution. This is one of the most important subjects now before the Association. This fine committee has again done some marvelous work during the current year. For more about their findings, we will now hear from Mr. Roy S. Belcher.

R. S. Belcher (Atchison, Topeka & Santa Fe): This report is one of a series of reports on this subject beginning in 1943. It is presented as information, with recommendation for adoption and publication in the Manual of a footnote addition to the specifications for petroleum for blending with creosote.

The specifications were adopted at the 1944 annual meeting and appear on page 17–23 of the Manual. That is, Specifications for Petroleum for Blending with Creosote. However, your committee has found a considerable proportion of the petroleum used in creosote-petroleum solutions is of lower specific gravity than that given as the minimum in the specifications. Such petroleums, in general, have been reported compatible with creosote, meeting the specifications of this Association and otherwise generally satisfactory.

Chairman Burt: It is recommended, therefore, that the following footnote be shown in the Manual following the specifications. I will read the footnote: "Petroleum of lower specific gravity may be used, provided experience or tests shows the oil to be satisfactory."

I move the adoption of the footnote just read, for inclusion in the Manual.

(The motion was seconded, put to a vote and carried.)

Mr. Belcher: Standard Volume Correction Table For Creosote–Petroleum Solutions, that appears on page 378, is given this year as information, with the object of presenting again next year for inclusion in the Manual. This will give the members, who will make use of such a table, an opportunity to try it for a year before it is presented for adoption.

That completes the report.

Chairman Burt: For Assignment 5—Destruction by termites; methods of prevention—we present what we think is a very interesting progress report, in which the committee summarizes briefly and again points out some of those interesting points particularly pertaining to the prevention of termite damage. It is well worth reading.

Assignment 6—New impregnants and procedures for increasing the life and serviceability of forest products—is one of the most vital subjects to the entire industry. Good service life depends on proper treatment with a good preservative.

Mr. Gottschalk, has assembled a great deal of valuable information on these subjects during this year. The report will be presented by Mr. Gottschalk.

F. W. Gottschalk (American Lumber & Treating Company): The subcommittee on new impregnants and procedures for increasing the life and serviceability of forest products has studied four new impregnants. Two of these are salt preservatives that have been in use for many years and are used in water solution. They are chromated zinc chloride and tanalith.

To give you an idea of what the preservative solution looks like, tanalith, in water solution, light yellow; chromated zinc chloride is orange solution (displaying samples). Then for the treated wood—tanalith treated wood; chromated zinc treated lumber—clean treatments (displaying samples).

These treatments are used for car decking, roundhouse roofs, icing stations, bridge timbers and general building and construction lumber. These two preservatives, with zinc chloride account for over 97 percent of all the "clean" treatment.

The committee submits the specifications for chromated zinc chloride and tanalith to the Association for adoption and publication in the Manual, and I so move.

(The motion was seconded, put to a vote and carried.)

In addition, the committee offers as information data and a draft of specifications for two newer chemicals that are used as preservatives in oil solutions. These are pentachlorophenol and copper naphthenaté.

Pentachlorophenol in an oil solution, a petroleum solution, used as a chemical to fortify creosote; and copper naphthenate, a greenish preservative, also in an oil solution (displaying samples).

Most of the uses of pentachlorophenol and the copper naphthenate at this stage are for pole treatments, pressure treatment of poles. Here is a sample that will illustrate approximately the treatment of these two new chemicals (displaying samples).

Detailed information on pentachlorophenol and copper naphthenate appears in the committee report.

Chairman Burt: Thank you, Mr. Gottschalk.

For study on Assignment 7, we have another subject which commands more attention as we gain more experience—incising forest products. Mr. Walter Arnold, and his committee have conducted further experiments during the year, about which we will now have him tell us.

W. P. Arnold (Koppers Company): The report of subcommittee 7 presents information on the effect of incising of cross ties of the T–C species mixed hardwoods on treating and checking characteristics. No appreciable improvement was found due to the incising in the treatment. However, a very considerable improvement developed during the seasoning with the incised ties as compared with the unincised controls. The difference in the amount of checking was further pronounced during service in track over a period of seven years. Each year seemed to show an increasing advantage with the incised ties.

The report is submitted as information.

Vice-President Schwinn: It will be so received.

Chairman Burt: Thank you, Mr. Arnold.

Assignment 8—Use of straight coal tar for tie treatment and results obtained: This is one that we have had under consideration for a good many years but just now the committee is offering its first progress report.

Dr. Hermann von Schrenk, consulting timber engineer, is chairman of that committee, but I am going to call on his associate, Mr. Kammerer, to give us this report.

A. L. Kammerer (St. Louis, Mo.): Dr. von Schrenk had planned to be here to present this report himself but due to the Wabash strike and other circumstances, he was unable to get here, and I have been asked by the chairman to present this report for him.

As its report on the assignment, the committee is presenting a monograph prepared by its chairman, and the chairman assumes complete responsibility for any statements that appear therein. The title of this paper is An Historical Statement on the Use of Straight Coal Tar for Tie Treatment.

(Mr. Kammerer then read various paragraphs of the monograph appearing on pages 387 to 400, with the following interpolation preceding "Use of 100-Percent Coal Tar Treatment" on page 390:

I might interject here that four ties were removed in September of last year and are now being examined at the University of Minnesota. The reason we are taking out four ties at one time is that it is the purpose of the investigation to string out the period so that there will be enough ties left over the years that there will be quite a time period that can be developed so as to get the effects of longer exposure.)

Chairman Burt: Treatment of wood to make it fire resistant is one of the most difficult assignments we have today. Our committee, however, has done remarkable work on that subject. To bring us up to date on our findings, we are going to hear now from Mr. Fulweiler, consulting chemist.

W. H. Fulweiler (Philadelphia, Pa.): This is a progress report submitted as information, pertaining to the fire resistant treatment of wood. The committee has been active in observing the results of treatment made by several railroads, and by the various departments of the United States government. It also has followed closely the results of many tests made by manufacturers and users for determining whether fire resistive treatments give a high degree of fire protection.

In the absence of anything more effective to date, the committee still recommends the methods of testing fire resistance as printed in its previous report, namely the use of either the crib or the tube test.

There have, to be sure, been differences of opinion as to the method of taking samples for fire resistive tests. These differences have arisen largely because of uncertainty as to where these samples should be taken, particularly in the case of large timbers used for bridges and buildings. One of the bureaus of the federal government has suggested that where large pieces are ordered to be treated with fire resistive chemicals, extra pieces of the same size should be included for test purposes, using either the crib or the tube test or some other method such as that recommended by the Underwriters' Laboratories. Your committee has taken no stand, either for or against these suggestions, because it believes that a great deal more work will have to be done in order to determine the degree of fire resistance obtained.

One of the principal difficulties with treatments heretofore recommended has been the fact that the chemicals used are generally water soluble. This has made it necessary to restrict the use of fire resistant wood to structures which are roofed so that no rain can reach the treated wood. Recently a number of processes have been suggested whereby the leaching of the fire-resistive chemicals can be reduced by the application of suitable paints or sealers, but no definite conclusions can as yet be drawn.

Chairman Burt: In the opinion of most of those interested in wood preservation, proper conditioning of wood before treatment is vitally important to good treatment. Your committee has Assignment 11—Artificial seasoning of forest products prior to treatment—and they have studied several different methods of preliminary conditioning. For the results of that work to date we will again hear from Mr. Arnold.

Mr. Arnold: Subcommittee 11 reports results obtained with three chemical solutions applied by pressure treatment to forest products for the purpose of preventing decay or checking during seasoning.

The first, phenyl-mercury-oleate, shows that southern pine may be carried considerably longer without development of decay during air seasoning.

The second and third, urea and borax-boric acid solution, without urea, showed somewhat less checking developing during air seasoning.

Subcommittee 11 also presents as an Appendix A a report by M. S. Hudson on Vapor-Drying of Oak Cross Ties. The report indicates results to date on ties in service, the reduced amount of checking as compared to comparable air seasoned ties. The report is submitted as information.

Vice-President Schwinn: It will be so received.

Chairman Burt: For our last report, that of Assignment 12—Preservative survey—we will ask Mr. Jaeger, chairman, to present that report.

M. F. Jaeger (Central Railroad of New Jersey): This report is the result of the cooperation and the efforts of officers of railroads represented in the tabulation. It is a progress report submitted as information. It brings up to date the treating practices as of March 1938 which accompany the report of your committee in the Proceedings, Vol. 41, 1940, page 517.

(He read the report on Assignment 12.)

Mr. Jaeger: That is offered as information.

Vice-President Schwinn: It will be so received.

Chairman Burt: That completes the report of Committee 17—Wood Preservation.

Vice-President Schwinn: Thank you, Mr. Burt.

Mr. Burt, this presentation completes your term as chairman. On behalf of the Association, I thank you for your leadership of the committee which has presented some very, very fine and interesting reports. The committee is now dismissed with our thanks.

Discussion on Highways

(For Report, see pp. 233–252)

(President Mottier presiding).

Chairman W. J. Hedley (Wabash): We have to give to you some recommendations for revisions in the Manual. The chairman of our subcommittee, Mr. H. G. Morgan of the Illinois Central, is a bashful person, and he just suggested I go ahead and present these revisions.

He and his committee, in cooperation with the Signal Section of the AAR, have developed some requisites for highway grade crossing signals and requisites for automatic crossing gates. Those are shown at pages 234, 235, 236 and 237.

There is one suggested change which would bring this material in conformity with that adopted by the Signal Section. On page 237, near the top of the page, in paragraph (b), it is suggested that we eliminate from that, at the end of the first line "not more than" and, in the second line, "5 sec."

That will not materially change the effect of these requisites but will, as I said, bring them into conformity with Signal Section material. This is not materially different from the material that has heretofore been developed. I do not believe it needs any further explanation.

I move the adoption of this material for publication in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Hedley: We have some specifications for construction of various types of crossings developed by Subcommittee 2, whose chairman is Mr. Warden. He will present that portion of the report.

R. E. Warden (Missouri Pacific Lines): On page 238 you will find Specifications for the Construction of Prefabricated Treated Timber Crossings, on which you will find several paragraphs. On page 240 you will find Specifications for the Construction of Precast Concrete Slab Crossings. Under the paragraph, Design, fifth line, we have printed "elastic limit of the reinforcement, and 2/3 of the ultimate strength of concrete at 28 days." It has been suggested to our committee that that "2/3" be changed to "½ or 0.5" and the committee has considered it and accepted it.

On page 242 we have Specifications for the Construction of Monolithic Concrete Crossings. Those are the three specifications brought up to date in this report.

I move the adoption of these specifications.

(The motion was regularly seconded, put to a vote and carried.)

Chairman Hedley: Unfortunately, Mr. Hartsell, chairman of Subcommittee 4, is not able to be present. His committee has prepared, and there are shown on pages 245 and 242 some typical location plans for highway crossing signals. These are presented for publication in the Manual.

I move their adoption for that purpose.

(The motion was regularly seconded, put to a vote and carried.)

Chairman Hedley: Our Assignment 5, which was handled by the subcommittee under the chairmanship of Mr. Christianson is next. He will present that portion of the report.

H. B. Christianson (Chicago, Milwaukee, St. Paul & Pacific): This report, which is a progress report, is a summary of the methods used by the state highway departments for determining priorities for grade crossing protection programs based on information furnished by them in 1946.

There are a few typographical corrections to make in the report. Just below the middle of page 247, in the formula designated (A), lower case letter "l" should be changed to the number "1" (one), and the same should be done with the letter "l" appearing by itself in the fourth line of the paragraph explaining "T" of the formula and in the sentence following that paragraph.

One-third the way down on page 248, the "T" in the formulas should be made "F_1".

The formulas are used by 18 states, and independent engineering judgment of 14 others. Brief explanations of the formulas are given in the report.

It was found that the rating of crossings by means of the various state formulas give inconsistent results, and there is no way of determining which formula is most nearly correct. It is the opinion of the committee that information which would take into consideration all of the conditions prevailing at the time of experience at a large number of crossings will have to be obtained before a comparison can be made of existing formulas and a satisfactory one developed.

The Traffic Committee of the American Association of State Highway Officials is also working on this problem. We have had preliminary contacts with them, and the secretary of the subcommittee attended our luncheon meeting yesterday. Such cooperation is desirable, and we are confident it will be helpful.

Chairman Hedley: This material is presented to you as information.

President Mottier: It will be so received.

Chairman Hedley: The dean of our committee has decided to retire from it. Mr. Maro Johnson, recently retired from the Illinois Central organization, has been one of our most active members. He joined the committee when he joined the Association in 1912; that is 37 years ago. His record of continuous service is remarkable. We are sorry to lose him, but he has chosen to take it easy.

Mr. Johnson, I believe it would be well, for your last trip to the platform, if you would stand and take a bow. (Applause)

M. Johnson (Illinois Central): I am just taking it as an old man, not because I am entitled to any encomiums of that sort.

Chairman Hedley: No, I do not agree with that, Mr. Johnson.

That completes the report of the commitee.

President Mottier: Thank you, Mr. Hedley. You and your committee deserve the thanks of the Association for the comprehensive material that you have just presented. Your committee is now excused with our thanks.

Discussion on Cooperative Relations with Universities

(For Report, see pp. 477–481)

(President Mottier presiding).

Chairman S. R. Hursh (Pennsylvania): This committee is quite unique, in that we cannot depict our activities by charts and graphs. It is mostly carried on by correspondence and subcommittee activities. To my mind, it is one of the most important committees of the AREA.

The future of opportunity of the AREA, I think, springs from our efforts and the proper functioning of our activities with the colleges and universities and with the railroads.

Our influence and our efforts cannot only be exerted with the colleges and universities, we must take home what we learn from our work in this committee to our respective railroads and sell management on its responsibility, if we are going to get new blood into the railroad industry and, in turn, into this organization.

I hate to bring up the subject of age but of over 2000 registrations at this convention, I think you will find that the average age is rather high. If we are going to keep this organization functioning in the manner in which it should, it devolves upon this committee and the railroads to bring new blood each year to the railroads that make up this organization. We need these young men, the railroads need them. It is only by the individual railroad's effort of going to these schools that we are going to get them.

We have had wonderful results in the last year or two. There has been a great response from colleges and universities that are not represented by the professors that are on this committee. I have had many inquiries through Mr. Aydelott of the AAR, and colleges all over this country as to what the railroads want, what courses the universities and colleges should offer in order to fit young men to do the work that we expect of them.

So I feel, while this committee has only been in existence, this last time since 1940, the last eight years, regardless of the handicaps of the war, we are making progress.

All the reports here are a matter of progress. There are three subcommittee reports to be made.

Assignment 1, by Mr. J. B. Akers: Stimulate greater appreciation on the part of railway managements of

(a) the importance of bringing into the service selected graduates of colleges and universities, and

(b) the necessity for providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

Mr. Akers will present the progress report on Assignment 1.

J. B. Akers (Southern): This subject, as all the subjects of this committee, is, to my mind, under the heading of intangibles. It is based on what you can prevail upon someone to do, if you can do that.

This assignment asks us to find the means to stimulate further appreciation on the part of our managements of bringing into the service selected graduates and also providing an adequate means of holding them in service.

That sounds like it ought to be easy to do because of selfish reasons, if nothing else. There is an indication that we are not accomplishing what we set out to do. We have gathered an enormous amount of data, data of a character that we could not publish in the proceedings because too much of it has to do with rates of pay and things of that sort that they do not want to make public.They do give it to us for our own use in an analysis of the situation. We find the difference in the rate of pay is quite nominal. It is low, at best, and the most surprising thing of all is that the turnover is so high. Thirty percent of the graduates in 1947 have already left the service. Of course, we do not cover the whole of the United States, or every railroad because, I am sorry to say, all of you do not send us the information. The more information you can give this committee, the better the result to you and the industry as a whole.

There is little evidence of any productive results under item (a) of the assignment, which is the fact that managements must realize the importance of bringing selected graduates into the service. The principal means, in my opinion, of doing this is for all of us in responsible positions, to impress that on the managements. I think you will find that many of them will act on these recommendations if you and I will present them.

Whoever heard of a management, as a rule, building a new passenger train unless the superintendent asked for it, or that you got a new transit without making the requisition? Likewise, the management must know what we want or what we think to be best for the management. That is the meat of the whole thing. It is for the improvement of industry, the improvement of the profession generally. So, anything you can do or I can do in this group, in the way of impressing that on management, the better we will be.

It is to your interest as well as ours for you to give us the best answers you can to the questionnaires we send. Our questionnaires, if they get very long, get in your hair and get in my hair, but be as patient as you can and give us the information, please.

President Mottier: Thank you, Mr. Akers.

Chairman Hursh: Assignment 2—Stimulate among college and university students a greater interest in the science of transportation and its importance in the national economic structure by cooperating with and contributing to the activities of student organizations in colleges and universities.

Last year, if I recall, I enlisted everyone's aid to help out on this problem, whether you were a member of Committee 24 or not. In other words, there are about 143 accredited schools of engineering in the country, scattered throughout, and it is not possible for this committee, because of the positions they have in the railroad industry to accept all invitations to address ASCE student bodies. So we have got to depend on your help, and if any railroad gets a request from Dean Davis to provide a speaker, I would impress upon you the importance of carrying out that assignment. It does not necessarily have to be a top man in the organization. The supervisor can well do the job. He is down lower; he can talk the language of the boys at school. They can learn a lot from him. It is only by doing this work that we are going to acquaint the boys at school with the railroad industry.

Dean Davis will present the report on assignment 2.

R. P. Davis (West Virginia University): The report of the subcommittee charged with the stimulation among college and university students of a greater interest in the science of transportation is presented as information.

One of the most effective methods of cooperating with and contributing to the activities of student organizations is by providing speakers to give talks on railroad subjects before student groups, usually chapters of the American Society of Civil Engineers.

In our report we have cited a number of such visits. Doubtless, other lectures have been given through the direct contact of individual railroads with schools in their sections of the country.

As an aside, Mr. Hastings just informed me that he had made a number of talks during the past year, of which I had no record. Doubtless, other men have done the same.

The future accomplishments of the railroads and of this Association depend in no small degree on the type of young men brought into the railroad service. Railroads should be in a position to attract a fair share of the ablest technical school graduates properly trained in the fundamentals of railroad engineering.

Unfortunately, civil engineering graduates do not hold railroad service in the high esteem which prevailed when this organization was founded and when railroad construction projects were under way. As a consequence of this, over the years, less and less emphasis has been placed on railroad subjects in civil engineering curriculum. Fifty years ago the railroad course was a popular one, partly on account of the railroad offers and partly on account of the glamour of railroad construction work.

With the advent of the motor vehicle, there came a demand for highway engineers, as a consequence of which most schools started comprehensive courses in highway engineering at the expense of the railroad courses.

This Association, recognizing the need for stimulating closer relations between railroad officers and officers of universities and colleges, some years ago authorized the formation of this committee.

Two of the main objectives of Committee 24 are: (1) To convince the schools that the railroads offer a real future to a limited number of graduates, and, (2) to call to the attention of railroad management the fact that engineering graduates are excellent sources of officer material.

The school members of this committee should be helpful in carrying out the first objective. The second objective must be sought primarily through the railroad members.

As an example of the thinking of the school man, for many years I avoided recommending railroading to our seniors because of the railroad's reputation for paying low salaries and because of the uncertain tenure resulting from the seniority rules. Another common concept of school men is that, since the era of construction is almost closed, the opportunities for advancement with the railroad must, of necessity, be limited.

A survey of salaries paid on half a dozen typical railroads made a few years ago by a subcommittee of Committee 24 brought out information that the committee thought it best not to publish. Since that time, starting salaries have been substantially raised and, at the present time, the railroads are offering salaries that compare favorably with those of competing industries.

The practice of many railroads, of selecting many of their operating officers from the engineering group, indicates that chances for advancement on the railroads are excellent.

Rather ironically, the highway engineering field is now experiencing the same type of reaction on the part of graduates, that faced the railroads some years ago. Starting salaries for highway engineers are, in general, very low, and the tenure and advancement are uncertain, because of politics. Graduates from many of our state universities will not accept positions in highway engineering.

Many agencies interested in highway construction and maintenance are beginning to exert pressure for higher salaries and less politics in highway engineering.

In closing, may I say that school officers are more and more becoming convinced that railroads do offer a future for our engineering graduates. This change of mind has come about, to a considerable extent, through the work of this Association, through its Committee 24. However, the work is not yet finished. (Applause)

President Mottier: Thank you, Dean Davis.

Chairman Hursh: The next report will be that of Assignment 3—The cooperative system of education, including summer employment in railway service. The report will be submitted by Dean Eshbach.

O. W. Eshbach (Northwestern University): It is approximately eight years since I first joined the discussions of this committee. While I have a deep respect for age and experience, it is my ambition to live to be old enough to talk to a group that is younger than I am. When that is accomplished, I feel that we have real tangible evidence of the effectiveness of the work of this committee in which we from the colleges are deeply interested.

During the last year the committee, in what we might call interim or temporary employment, concentrated on information in one problem. We are interested in three phases of temporary employment, that of the employment of college graduates during vacation periods, that of the employment of college faculties during the same period, and that of employment of cooperative students during their work experiences in industry. It was the latter that we investigated. All three of them make contributions in this respect: While it is desired to talk to students, to have experienced people talk to them about the opportunities and the work in the railroads, much of the information is given by word of mouth.

It is far better to convey information through people in whom students have confidence, who speak from contact and experience. The only way to get the picture of the railroad situation is to work with the railroad people, whether it is faculty or whether it is student.

During the coming year, the committee will try to make a comparison of the activities of summer employment and in employment both of students and faculty to add to the report which it submitted.

It submitted during the year a rather detailed report showing a comparison of the activities of schools engaged in cooperative education before the war and after the war, and the general conclusions are something like this: Sixty percent or more of the students were veterans who had experience in the war, and were givn permission to go through school without fulfilling the requirement of the cooperative program, so that the number of students engaged in this work is considerably reduced from prewar years. It is picking up rapidly.

There are about 16 schools now active in this work and, among them, half of the institutions have placed men with the railroads. Placing them on a cooperative job means giving them work experience at alternate periods with their school periods, during the time that they are in school, usually beginning somewhere around the sophomore year, when we know something about them, and continuing to graduation.

Last year there were in the neighborhood of 120 of these students employed by about 14 railroads; 5 of the railroads employed students from more than one institution. They came from 8, or half, of the institutions engaged in cooperative work.

The interesting thing is that 90 percent of them came from half of these institutions participating, and that the most satisfactory reports were received from the institutions that had the longest, most successful experience with the railroads, largely with the five railroads that employed students from more than one institution.

Some criticisms were recorded. I had the feeling, as I read them, that many of them were not valid, but we recorded them, and the most serious criticism came from four institutions that had participated before the war and have not participated since the war but intend to do so. They felt they were unable to place their students in the kind of work on the railroad which would give them the greatest experience and help them most in education, because of seniority rules and labor regulations.

In closing, I would like to emphasize again that the confidence which students in college get of their opportunities in various businesses comes from their association with their fellow students who have had direct experience, and from faculty members who have worked with the railroads.

The pay situation is a competitive one. It is not a bad situation today. The pay of cooperative students doubled from the time before the war to after the war. It ranges today from $155 a month to $300 a month, with a median—and, remember, these are undergraduate students—of about $240 a month, which is a fair salary for them. Those I have had contact with, and some of my associates, have spoken of the experience these young men have had. (Applause)

Chairman Hursh: To emphasize a little bit what Dean Eshbach said as to the confidence the boy in school has, just as a suggestion, if you are going to these colleges to recruit young men, you will find it is a big help, instead of sending just the "topper" to interview them, to pick out some young boy from that same college who has had reasonable success and has had the same problem when he started on the railroad. Take him along and let him talk to them. It will be a big help.

It was the consensus last year that, geographically, we should expand this committee, to get men located in far remote parts of the country and not too far away from the best institutions of learning. We also want to get younger men on the committee. For those who are in this room and who have not seen the committee members for 1949, I would like to take this opportunity of mentioning the new members of Committee 24.

(Chairman Hursh then read the list of new members of Committee 24.)

Chairman Hursh: That completes the report of the committee.

President Mottier: I know this is a very interesting subject, and if we did not have a close schedule here this morning, I would throw this subject open for discussion, because I am sure there are many here who would like to speak on it. We could spend the rest of the forenoon on this very interesting subject.

Mr. Hursh, your committee is excused with our thanks.

Discussion on Yards and Terminals

(For Report, see pp. 193–215)

(President Mottier presiding).

President Mottier: The chairman, Mr. Hand, will not be with us and Mr. Giles, vice-chairman, will present the committee report. For many years, I have been and still am a member in good standing on this committee.

Vice-Chairman W. H. Giles (Missouri Pacific): I might mention for the benefit of those that haven't been informed that Mr. Hand retired from active service with the New Haven on March 1, and I am pinch-hitting for him today. There were 12 assignments made to this committee last year of which we have 9 in the report. Two of these assignments, Assignment 1—Revision of Manual, and Assignment 3—Scales used in railway service, are matters concerning the revision or re-adoption of material in the Manual. Mr. Lyford will present the report on Assignment 1—Revision of Manual.

L. L. Lyford (Illinois Central): This report on revision of Manual, exclusive of scales, deals with the material in the section on "LCL Freight Facilities" and contains equations from which can be obtained the approximate cost of such freight house operations, the cost of hand trucking, installing, spotting of cars at freight houses, and so forth.

The report has been approved by more than the necessary two-thirds of the members of the committee, and it is submitted for approval of the Association.

I move the adoption of the report.

(The motion was seconded, put to a vote and carried.)

Vice-Chairman Giles: The report on Assignment 3—Scales used in railway service, will be presented by Mr. Harrison.

M. J. J. Harrison (Pennsylvania): The primary purpose of the presentation is to comply with the instructions of the Board of Direction relating to material which is 10 years old.

In complying with that instruction, the committee has reviewed critically all of the material now in Chapter 14 of the Manual relating to scales and has submitted foı your consideration the various rearrangements, no new material being added and no material being deleted, as outlined on page 195, until near the bottom of the page we are suggesting, as a matter of straightening out an inconsistency, a two-line footnote.

With these rearrangements and correction of somewhat ambiguous language, I move that the material now appearing on pages 14–33 to 14–83 of the Manual be readopted.

(The motion was seconded, put to a vote and carried.)

President Mottier: Here is another case where a committee has brought its material up to date.

Vice-Chairman Giles: On Assignment 2, there will be no report.

The report on Assignment 4—Bibliography on subjects pertaining to yards and terminals, will be presented by Professor Sadler.

W. C. Sadler (University of Michigan): This subcommittee report on bibliography was developed by the late E. E. R. Tratman, and the report this year is the first annual report which has been prepared without the assistance of Mr. Tratman. It seems rather appropriate to the committee that a note be made of this fact. The policy in the past has been to direct attention to the principal technical articles.

At the present time, the committee has under consideration and will probably expand the bibliography to include house organs, Modern Railroads, Fortune Magazine, and one or two others of that type. This material has been presented as information.

Vice-Chairman Giles: Thank you, Professor Sadler. The next assignment is No. 5—Locomotive terminal facilities. It will be presented by Mr. Hoving.

J. E. Hoving (Northern Pacific): In connection with Assignment 5—Locomotive terminal facilities, reports have previously been presented on facilities for steam locomotives and diesel locomotives. Our report presented at this time, covers terminal facilities for electric locomotives.

[Mr. Hoving read the paragraph under "General" on page 200.]

Mr. Hoving: This report is presented as information.

President Mottier: Thank you, Mr. Hoving.

Vice-Chairman Giles: The report on Assignment 6—Facilities for expediting freight traffic yards and terminals, will be presented by Mr. Hess.

F. A. Hess (Indiana Harbor Belt): This was not a new subject, but we wanted to examine the situation as it appeared up to date and see if there was anything new that we could add to that subject. We appreciate that much has been done to expedite movement over large sections of our main lines, and we realize that there is a great problem in expediting movement through yards and terminals. The subjects that we covered which we thought were necessary for review or there was something new to add, are the following: 1. Revamping of yard facilities to consolidate operations and avoid extra moves and retrograde movements. We felt there was a great deal of movement being made that might be reduced through consolidation, lengthening of tracks and improving the yards.

A subject that we thought was quite new was improved communication systems. We covered the subject of radio and inductive train communication systems, the walkie-talkie, the carryphone, two-way loud speakers using the paging and inter-communication units, and the voice recorder for car lists. That subject seemed to present information that I think to many members is of interest at the present time. We also went into the subject of mobile or fixed facilities for servicing locomotives at various locations in yards and terminals. The subject matter dealt with the question of having more than one location in yards and terminals for servicing locomotives. We also went into the subject of operation of main line and other switches at the entrance and departure ends of yards. We felt that something ought to appear in our reports as to the possibilities of expediting movements through the use of switch tenders or power operation of switches and improvements such as that.

President Mottier: Thank you, Mr. Hess. We are making fairly good time. Does anyone have a question or comment on the last report Apparently no one is moved to speak. Mr. Giles, proceed!

Vice-Chairman Giles: Thank you, Mr. Hess. We have no report under Assignments 7 and 8 at this time. Assignment 9—Rolling resistances of freight and passenger cars equipped with roller bearings, will be presented by Mr. Meyers.

B. R. Meyers (Chicago & North Western): There was no money appropriated for field tests and the assignment was limited to gathering and assembling existing information. The committee found that there are approximately 9000 passenger cars equipped with roller bearings, and approximately 3700 cars equipped with roller bearings in service or on order for freight and miscellaneous service when the number of freight cars was checked up early in 1948. That figure may have changed by now. The information available to the committee indicates that it takes approximately 3 or 4 lb. per ton to start cars equipped with roller bearings. This is equivalent to 0.15 and 0.2 percent, respectively. Cars equipped with friction bearings will take roughly 10 times that amount to start. However, after the cars are in motion, the difference is not nearly so great, and tests made in 1927 and 1942 indicate that through a range of 10 to 85 mph., the journal friction of cars equipped with roller bearings is only 10 to 17 percent, less than that of cars equipped with friction bearings. The committee was unable to get any information on humping cars equipped with roller bearings. The increase in acceleration in roller bearings over friction bearings would not be great; however, when classified in existing retarder hump yards, special handling may be required. When a friction bearing car reduces to slow speed, the oil film breaks down and the friction between metals stops the car. This condition is not present in roller bearings. Those yards I know about where roller bearing cars have been used have required riders on the cars to set the brakes.

Another thing that developed which was rather startling to the committee was the fact that the friction in roller bearings does not increase as the temperature lowers, and we all know that that is a fact with friction bearing cars.

This report is submitted as information.

President Mottier: Thank you, Mr. Meyers. Does anyone have any question or comment you would like to make on this report?

Vice-Chairman Giles: The report on Assignment 10—Advantages and disadvantages of low and car floor level passenger platforms, will be presented by Mr. Krefting.

A. S. Krefting (Minneapolis, St. Paul & Sault Ste. Marie): The committee came to the conclusion as stated in the report, that car floor level platforms had sufficient merit to warrant their installation under conditions of heavy movement of passenger traffic, particularly of the commuter type that must be loaded and unloaded quickly. At stations where such conditions exist, the use of a car floor level platform would permit more rapid handling of passengers and make tracks and platforms more quickly available for succeeding trains.

The use of car floor level platforms makes it more difficult to inspect and service running gear, air conditioners and other equipment located under the cars and would probably also increase the difficulty and expense of transferring mail, express and baggage. The low type of platform is most favorable at all locations except at those stations which handle a heavy volume of traffic as mentioned.

The initial cost of a platform of this type is less than for a car floor level platform. There is no difficulty in transferring the mail, express and baggage across tracks for delivery to trains on adjacent platforms, and it is possible to service running gear and other equipment located under the cars without difficulty.

Mr. Chairman, this report is presented as information with a recommendation that the subject be discontinued.

Vice-Chairman Giles: Thank you. The next assignment—Recent developments in undercar inspection of passenger cars, will be presented by Mr. Biermann.

A. E. Biermann (Terminal Railroad Association of St. Louis): Little consideration had been given in the past year to special facilities in coach yards for the inspection of passenger train equipment. These inspections normally were made and in a majority of cases today still are made from the sides of the car. However, with the introduction of the modern streamlined cars in regular service, various railroads gave thought to special facilities for the inspection of this equipment. The streamlined cars with their skirted sides, increased mechanical features installed under them and the generally short layover time scheduled for this equipment presented minor inspection problems which developed the undercar inspection pit and the increased use of it. The report describes the three types of inspection pits now in service together with the advantages and disadvantages of each and essential design features for any of the three types of pits.

This report is given as information only, with the recommendation that the subject be discontinued.

President Mottier: Thank you, Mr. Biermann.

Vive-Chairman Giles: Assignment 12 on Length of freight cars as the basis for determining the capacity of yard and terminal tracks will be presented by Mr. Hastings.

D. C. Hastings (Richmond, Fredericksburg & Potomac): In the AREA Manual we have only one reference to the recommended length of freight tracks for determining track capacity. The Manual states that a length of not less than 45 ft. should be used for determining the capacity of yard tracks and terminals. Because of the new types of equipment that are much longer than that, our committee decided to study the question and see exactly what the figures would represent. The results are very interesting.

We have divided the various types of equipment between automobile cars, stock cars, tank cars, box cars, refrigerators, flats, hoppers and gondolas. The survey of course was limited to the information we could obtain through the members of the committee and the entire survey covers three-quarter of a million pieces of equipment. The averages in each case are weighted averages. We find the results of the overall summary of three-quarter of a million cars to give us an average length of 43 ft. 3/16 in. So, our figure of not less than 45 ft. is perhaps OK. However, for particular types of installations, particular tracks, particular terminals it might be of interest to decide what type of equipment is there and use the averages for the particular types we have in the report.

The subject is presented as information.

President Mottier: Thank you, Mr. Hastings.

Vice-Chaiarman Giles: Mr. Chairman, that concludes the report of Committee 14.

President Mottier: Thank you, Mr. Giles. I submit to you gentlemen, that is a good committee. They do a lot of work and very little talk. They made reports on seven different subjects covering 23 pages and made seven reports and you listened to three speeches by the President in 28 min. and that is something for you to shoot at! [Laughter]

George Hand is not here and this happens to be his third year. He was retired and he has been a very hard worker and a very efficient chairman, and Mr. Giles, will you express our regrets to him that he was not able to be with us?

Discussion on Records and Accounts

(For Report, see pp. 457–476)

(Past-President Hastings presiding).

F. B. Baldwin (Atchison, Topeka & Santa Fe): Before proceeding with the presentation of the report of Committee 11—Records and Accounts, I should like to take this opportunity to briefly record the committee's deep sense of loss occasioned by the death of F. C. Knight, valuation engineer, Canadian National Railway, at his home at Toronto, Ont., December 31, 1948. While Mr. Knight had been a member of this Association only a short time, since 1947, there had grown in the hearts of the committee members a great admiration for his very fine character and unequalled friendliness. A memoir to Mr. Knight has been submitted to the secretary for inclusion in the Proceedings.

Frederic Carr Knight

Frederic Carr Knight was born in Alberton, P.E.I., June 3, 1886. He was the son of a Methodist minister, Rev. Matthew Knight and Louise (Beer) Knight, and great grandson of Rev. Matthew Richey, D. D., noted educationalist and first principal of Upper Canada Academy, now Victoria College, University of Toronto.

At an early age Mr. Knight's family moved to Halifax, N. S., where he attended public schools, the Halifax County Academy and Dalhousie University, from which in 1909 he was graduated in civil engineering.

During the summer months of 1905–1906, Mr. Knight was employed as levelman with the Standard Railway and Coal Company and the Nova Scotia Eastern Railway, and as a draftsman on location with the latter compny for nine months during the years 1907–1908. During the summer of 1908 he was employed as timekeeper at the Intercolonial Railway shops at Moncton, N. B. Following a period of three years' employment in the construction department of the Canadian Pacific Railway at Montreal, first as cement tester and later as instrumentman, he resumed his academic studies at McGill

University, Montreal, from which he obtained the degree of Master of Science in 1915. In the same year Mr. Knight took charge of a party laying out sewer systems in Great Neck, Manhassett and Port Washington, Long Island. Returning to railroading, he joined the Grand Trunk Railway at Montreal in 1916 in the valuation department, which had recently been formed in connection with the appraisal of the railway's subsidiary lines in the United States. After the amalgamation of the Grand Trunk System with the Canadian National Railways, Mr. Knight moved to Toronto in 1923 with the transfer of the department, with which he had been continuously associated in various capacities, except for the period September 1917 to July 1919, when he served with the Canadian Expeditionary Forces in World War I and saw service in France. He was appointed valuation engineer January 4, 1946.

In 1922 Mr. Knight married Beatrice Adelia Sills. Mrs. Knight and two sons, Frederic and Robert, and two daughters Mary and Dorothy Louise survive him.

Mr. Knight became a member of the American Railway Engineering Association in 1947 and served on the Committee on Records and Accounts. He was also a member of the Association of Professional Engineers of Ontario.

Mr. Knight had been active in the SO'ED program of the YMCA and in the Public Speaking Association in connection with the University of Toronto of which he was past president. His reading covered a wide range. He possessed an exceptionally retentive memory and had a great fund of general knowledge on which he could draw on any occasion. He was at all times a gentleman, a devoted husband and father and his passing has created a sense of personal loss to all who knew him. He died suddenly at his home in Toronto, December 31, 1948.

Chairman Baldwin: In this, the 50th Anniversary Year of the Association, we have seen a great growth in the membership in excess of any previous record, not only in the Association, but also in the Records and Accounts committee which with 50 members has topped its previous record. During the year, the average attendance of committee meetings was 30 members and guests which also exceeded previous records. The meetings have been featured by serious and heavy discussion on subjects pertinent to the committee's assignments and which involved matters of accounting, depreciation and valuation, of great importance in connection with the freight rate cases, income taxes, and other factors vital to the financial welfare of the railroads.

On the first assignment—Revision of the Manual, the committee has no report this year, but is proceeding, following Secretary Lacher's suggestion, of not offering minor revisions until we have some important revisions to make. In the meantime, the committee is giving consideration to some necessary revision to be made at a later date.

Assignment 2—Bibliography on subjects pertaining to records and accounts, in the absence of the chairman of the subcommittee, Mr. V. H. Doyle, I will attempt to present this report.

With respect to this report, you will note that many items having reference to depreciation, depreciation accounting, depreciation of price levels, depreciation of tax laws and accelerated depreciation, are matters giving railroad managements and other corporations very grave concern, and they are subjects that should concern the engineer as well as the accounting profession. Representatives of this committee are now actively engaged, jointly with accounting office committees making a study of this important subject of depreciation, its effect on railroad expenses, railroad income and railroad investment.

Assignment 3—Modern drafting aids. This report will be presented by Mr. Ludolph, chairman of the subcommittee.

W. M. Ludolph (Chicago, Milwaukee, St. Paul & Pacific): This report covers two drafting aids, namely, cleaning solution for tracings and drafting machines.

Other aids came to the attention of the committee, but it was decided to withhold reporting on these until further investigation could be made. This report is a continuation of last year's report and is presented as information.

Past President Hastings: Thank you, Mr. Ludolph. It will be so received.

Chairman Baldwin: Assignment 4—Use of statistics in railway engineering. The report on this assignment will be presented by Mr. Haire, chairman of the subcommittee.

C. C. Haire (Illinois Central): In this report an attempt is made to show the part statistics play in engineering department work. This is difficult to do because there is not much interest in the subject and certainly there is no romance to statistics, yet statistics play an important part in work of the engineer.

We should not confuse statistics with accounting as the term is broadly used in the report as synonymous with accounting, cost finding, estimating and the whole field of work where figures are put on paper to show something. Broadly speaking, statistics may be ton-miles, hours of labor, payrolls, estimates, inventories, valuations, bills against others, and the great mass of figures that are prepared and used by the railroad in its day by day operations.

We have stressed in the report the importance of budgeting and control of expenditures. To handle a budgeting system successfully requires a sound statistical foundation.

In this report there is also much discussion about cost accounting, unit costs and cost finding—this last term is one that our Washington friends are popularizing today.

One of the prominent features of the report is the emphasis which we have placed on the matter of statistical education and development of supervisory forces among the younger men. These young men should be well grounded in the understanding and use of statistics and statistical processes for their future benefit and that of the carriers. They should be primarily indoctrinated with cost consciousness and the habit of employing statistics in their work and in the formation of their judgment.

The committee is fully aware that statistics, accounting and allied subjects are unpopular and distasteful to the average engineer. There is some repugnance for paper work, red tape, accountability for costs and restrictive controls in the way of spending money that retards creative work; however, all of us know that control of costs, economy and efficiency, for a far-flung and not closely integrated railway plant, requires the constant employment of proper statistical tools.

Most of us are conscious of the prevalent feeling that the railroads are possibly pricing themselves out of the market from continual rate increases. That sentiment appears to exist prominently in the mind of the Interstate Commerce Commission and as indicated by a statement in the 62nd annual report of the ICC dated November 1, 1948, page 3. I quote the following:

"For a number of reasons, the railroads in their own interests must not rely or expect us to rely solely on what their cost sheets show. Rate increases may be carried to the point where they are largely self-defeating."

With respect to efficiency and economy, the Commission says in the same publication on page 3, and I again quote:

"We are of the view that much more must be done to increase the efficiency and reduce the costs of railroad operations . . . A thorough searching out of these lesser things which constitute a railroad's day's work must be undertaken . . . Imagination and ingenuity must be brought to the task."

If this admonition and advice is followed then the searching out process requires the use of proper statistical methods. The report of the committee gives some ideas as to what some of these methods might be.

At the end of the report are three general conclusions which I will read:

(Mr. Haire read the portion of the report on Assignment 4 under Conclusions as shown on page 471.)

Past President Hastings: This is a very interesting report, gentlemen. I wish that I might do as President Mottier has done on two previous occasions and make a supplemental report for this committee, but permit me to say in a minute or two, that someone certainly talked to a few of the students from the Chinese railways that were in this country during the war, many of them returning back to China prior to the close of the war with Japan, others having gone back since. I found in my study of the Chinese railroads this last summer that they make tremendous use of statistics. The statistics which were prepared in their engineering departments were almost a wonder. I went through many of their principal engineering offices and they have carried that on through the director's office where they carry the statistics of all of their operations. There wasn't a question on three of their great railroads that I rather intensively studied, not a question I could ask that they did not have statistics on.

I rather felt as I looked at much of the information that was there contained that we might well give a good deal more study to the use of statistics, particularly in our engineering department than we do in this country at this time.

I commend this report to you. It is worthy of very serious thought. One of the statistical reports I saw in China was rather humorous because it shows the working of the Chinese mind, and that was with reference to the personnel that was employed on this railroad. They had almost a perfect record in charts and also given numerically and for my particular benefit, they had it all taken out of Chinese characters and translated for me into English so I could understand it, and this man very proudly pointed to the personnel lists of his railroad. I speak of a railroad that is somewhat less than 330 miles in length. This was a chart on what he called his "staff" which included all of his supervisory heads, and the clerical forces connected with them, their secretaries and statistical experts, and the main clerks. He called those the staff, and then the other chart was a record of what he called the workers. Bear in mind, please, this was on 330 miles of railroad. He had over 15,000 employees on his staff and over 17,000 workers!

If you figure that out proportionately, we would be bankrupt, wouldn't we? Money didn't mean much there because it didn't represent anything but a piece of paper. If we try to translate it into our own dollars, the best way I could give you a comparison is that in the last five days that I lived in Shanghai in August of last year, I paid 44 million dollars a day for my hotel room.

Chairman Baldwin: I would like to add to what Mr. Hastings has said, just briefly. If you have not done so, I urge all members to read this report and study it and then take time to write to the committee your reaction to it. That is most important. The committee will welcome suggestions for further development of the subject.

I would like to point out this one idea that has been mentioned by other speakers on the Association's program, not in the meetings here, but in other meetings, that the report lays much stress upon the importance of statistics based on work units or material units rather than dollars. With the radical change in the dollar value, this is quite important.

On the next assignment, No. 5—Construction reports and property records; their relation to current problems, the report will be given by Mr. Louis Wolf, chairman of the subcommittee.

Louis Wolf (Missouri Pacific): Your committee reports progress. The 11 current problems listed and commented on in the report of this committee in 1947 and again referred to in 1948 continue to be alive and important to the engineer and to any other officers interested in valuation, taxes, and the general financial condition of his railroad. The committee wishes, again this year, to stress the importance of having properly prepared field completion reports and other basic data furnished by the man in charge of a project and actually on the job, for such items are the base for all property records. A number of roads are conducting educational campaigns along this line, going down as far as foreman, with very good results.

The 11 current problems commented on in the 1947 report show that the records are now being used, first for accounting, the cost of a railway acquired by purchase, merger, reorganization; second, depreciation accounting; third, federal income and excess profits taxes; fourth, bankruptcy, trusteeship or reorganization; fifth, finance cases, stock or bond issues or refunding; sixth, taxation, state or local; seventh, rate cases; eighth, contractural relations between railroads; ninth, retirement of railroad property; tenth, cost data as a basis for estimating; eleventh, fire insurance.

This report is submitted as a progress report and will be continued.

Past-President Hastings: Thank you, Mr. Wolf.

Chairman Baldwin: On assignment 6—Valuation and depreciation, the report will be given by Mr. Bradley chairman of the subcommittee.

I want to point out that Mr. Bradley is well qualified to report on this subject by reason of having appeared as a witness on valuation matters in ex parte 166, increased freight rates, in 1947 on behalf of the engineering committee of the general committee of the Valuation Division of the AAR, and in addition, he is scheduled or possibly will appear as a witness in the same capacity in ex parte 168, increase in freight rates, for 1948.

H. T. Bradley (Missouri Pacific): The subcommittee on Assignment 6—Valuation and depreciation, prepared during the current year, a report which was published under Assignment 6 (a)—Current developments in connection with regulatory bodies and courts. This report covers the current activities of the Bureau of Valuation, ICC which were largely of a routine nature. There were no outstanding decisions by the United States Supreme Court during the year which affected the subject of valuation. The report covers in some detail the valuation aspect of the ICC final report of July 27, 1948 In ex parte 166, increased rates, 1947, in this case the Commission found an aggregate value for rate-making purposes for all Class I common carriers of 20 billion 622 million, in round figures. This total was developed by the rather simple expedient of getting the sum of original cost, the present value of lands and working capital and deducted therefrom depreciation and amortization approved on the carrier's books. This process has the virtue of simplicity, but reduces the ultimate of judgment on the part of the Commission to the vanishing point.

In ex parte 168, increased freight rates, 1948, the Commission has introduced as Exhibit No. 1, elements of value as of January 1, 1948 similar to those introduced in ex parte 166 in January 1, 1947. The cost of reproduction new in Exhibit No. 1 is approximately 36 billion dollars, and the cost of reproduction less depreciation, 23 billion dollars in round figures.

Whether the Commission will see fit to use these figures or stick to the original cost hypothesis is yet unknown. It might be observed in passing that all of the steel rail in the United States in 1948 considered as scrap was worth an amount considerably greater than its rate making value on an original cost basis as found in the Commission in ex parte 166.

This report is presented as information.

Past-President Hastings: Thank you, sir, it will be so received. Is there any discussion of this informative report? I couldn't help but think as it was mentioned that we suddenly dropped from 36 billion, nearly 400 million in reproduction new and find ourselves down the scale to 23 billion. That is a quick way of getting rid of 13 billion.

As I heard someone say last night in a jovial mood—I expect he was when he mentioned it—"Where was the capital of the United States?" and the answer came, "It's in Europe."

Chairman Baldwin: The report on the next and last assignment. No. 7—Revisions and interpretations of ICC accounting classifications, will be presented by the chairman, Mr. Barnes.

H. D. Barnes (Chicago & North Western): The subcommittee's report for the past year contains references to only two orders and one interpretation issued by the ICC and these are of minor importance. There has been a gradual decline in the number of changes in the accounting classifications over the past few years but it may well be that this is just a calm before the storm again breaks.

The Bureau of Accounts is now considering a group of four related subjects providing for: (1) Adjustment of road and equipment property accounts to the basis of estimated original cost as found by the Commission's Bureau of Valuation; (2) depreciation and retirement accounting for ties, rails and other track material; (3) change in the minimum rule from $500 to $100; and (4) past accrued depreciation not previously provided for. The impact of these proposals, if adopted, will be of profound importance to the industry.

This report is submitted as information with the recommendation that the subject be continued.

Past President Hastings: Thank you, Mr. Barnes. Are there any questions? Any discussion? All right, Mr. Baldwin.

Chairman Baldwin: That completes the report of Committee 11.

Past President Hastings: Mr. Baldwin, this completes your term as chairman of this committee, and you are retiring now and joining the "Order of Pasts" of which I found myself a member for some time.

Through the years, there have been many years, I have watched this committee work and the valuable information that they have placed in the libraries of all the members of this Association in the printed reports that have been published from year to year and now are the foundation and a part of our proceedings, and much of it is also found in our Manual, and I see still on your committee many familiar faces that I have looked upon in many years past and we certainly wish to thank your committee again for bringing this perfectly splendid report.

I see my friend Mr. Wendt is on his feet.

E. F. Wendt (Pittsburgh, Pa.): I note the committee now has 50 members. That is a very good sign because in 1902 when I was chairman of the committee, we had difficulty in finding men to serve on this committee. Now, what is the committee going to do in the next years? I suggest the members use their imagination and ingenuity, and think up a broadening of the general subject of records and accounts. They will find many ideas through later acquaintances that will lead to consideration, particularly in view of the great national debt which our country has, all of which has to be paid. If they remember that following the Napoleonic wars England was greatly in debt at that time and England has never been able to pay its debts since, and she has put much of her debts into permanent stocks, which is not reliable. Well, activities of that kind affect the railroads.

There is another thing I would suggest, and this should be of interest to engineers and that is the question of the creation of a uniform system of accounting. There is a good deal of history in connection with this matter that would be of interest. The committee will want to study it. In 1840 Mr. Haupt, a graduate from Gettysburg College applied for a position with the railroad and he hadn't been able to connect up with one when Edward Thompson saw him and he thought a good deal of this gallant boy and hired him. They asked Herman to prepare a system of accounts, which he did, and Mr. Hastings has a book in his library that tells the story.

When I was chairman of this committee, Walter Berg, chief engineer of the Lehigh Valley, was one of the younger members then and he was helping me along. He told me how the Lehigh Valley needed help and they called on him to write a suggestion as to the division between the work that could be capitalized and work that was asserted to be maintenance. That paper which he wrote is in the Proceedings back in 1905, 1906 or 1907, I am not sure which. It is worth reading.

There was an engineer on the construction work of the Pennsylvania between Pittsburgh and Chicago, I think his name was Shinn and when they finished the railroad in 1852, they asked this fellow Shinn to take over the accounting, which he did and he constructed a system of accounting. His work was a wonderful influence on the preparation of the present uniform system of accounts which is not recognized.

Now this committee is a committee for engineering accounting. We have an Association of Accounting Officers which has done many great things, but this committee is a board of experts on cost accounting, cost analysis, and I may say that you won't find anywhere else in the United States, 50 men who are as expert and as highly experienced in this matter of cost accounting and determination of regional costs as well as with production costs and depreciation as we have on the committee at the present time.

Past President Hastings: Thank you, Mr. Wendt. [Applause] Mr. Wendt, as you have always done, you have come in with some thoughts that are profitable to all of us. Through many years, Mr. Wendt has given of his time and of his thinking, and has assisted us all the way along.

Now, Mr. Baldwin, your committee is excused. I am sorry we kept you here so long. I want to express the committee's thanks to Mr. Wendt for his generous remarks.

Discussion on Buildings

(For Report, see pp. 265–288)

(President Mottier presiding).

President Mottier: Mr. Dorland, chairman of Committee 6—Buildings, will now report.

Chairman A. G. Dorland (Elgin, Joliet & Eastern): Committee 6 had 10 assignments during the past year and this is a big job for busy men. We have all got another job besides the AREA. We have reported on only three of these assignments. The first subject on the Revision of the Manual, will be presented by Mr. Schaub, chairman of the subcommittee.

J. B. Schaub (Illinois Central): I would like to say, before presenting this for acceptance, that in some instances matter of an editorial nature has already been taken care of in the report. In some instances the titles of cross reference specifications have been changed, especially with the ASTM references. Those are also going to be taken care of in the editing.

(Mr. Schaub then read the Roman numeral headings under Assignment 1, down to and including XVII Hardware.)

Mr. Schaub: Those are, in most cases, revisions of an editorial nature or simply submitting the specification for reapproval without change.

I would like to present a motion that they be accepted.

(The motion was seconded, put to a vote and carried.)

Mr. Schaub: XXI Brick Pavements and Floors: This revision is bringing the specification which had previously been brought up to 1929 or 1928, whichever it was, up to date. The revisions covered here are with reference to more careful grading of materials and some changes in the method of carrying out the work. If it is agreeable, I would like to present a motion that it be accepted.

(The motion was seconded, put to a vote and carried.)

Mr. Schaub: On page 276, 2301 and 2302, we have creosoted wood block pavements and wood block floors. Those specifications, as you note, were 1928 and 1929. There have been a number of improvements in wood block flooring and paving. So the committee thought it advisable to delete those two specifications and present, in its place, a new specification which you will find on page 277, Wood Block Flooring and Paving. It covers both of the previous specifications in a more complete manner.

I would like to present a motion that we accept them.

(The motion was seconded, put to a vote and carried.)

Mr. Schaub: On page 281 we have 2501, Asphalt Block Pavements, and 2502. Asphalt Block Floors, both of which apparently were not in use any more, taking up Manual space and adding to the cost of printing. The committee felt they should both be deleted. I would like to make a motion to that effect.

(The motion was seconded, put to a vote and carried.)

President Mottier: To me, this is quite impressive. There is a tremendous amount of work that has been done by these committees. Here is an excellent example of the work of the committees in keeping our Manual up to date. They are correcting specifications; they are substituting new ones for old ones; they are deleting old ones. It is a fine example of what a committee can do to keep our Manual of Recommended Practice up to date, and we are all indebted to them.

Mr. Schaub: Thank you, Mr. Mottier. I think all of you appreciate that considerable work was done before it was printed in the bulletin.

2601 and 2602. Macadam Pavements and Asphalt Macadam Pavements: There was a slight correction, which apparently was a typographical error in specifying the gallons of water.

I would like to make a motion that these corrections be accepted.

(The motion was seconded, put to a vote and carried.)

Mr. Schaub: XXII Sprinkler System. Paragraph 2721, we felt, should have a slight addition as noted in the bulletin. I would like to make a motion that that correction be accepted.

(The motion was seconded, put to a vote and carried.)

Mr. Schaub: Over on page 282, Freight Houses: In the case of handling freight, as we all know, there have been considerable improvements, heavier equipment for handling freight, mechanized, and so on. So we felt that there should be a paragraph added as noted, to take care of equipment like fork lift trucks and motorized equipment.

I would like to make a motion that that correction be accepted.

(The motion was seconded, put to a vote and carried.)

President Mottier: Thank you very much, Mr. Schaub. Your committee has done a tremendous amount of work.

Chairman Dorland: Assignment 2—Specifications for railway buildings, will be presented by Mr. Wilbur.

O. G. Wilbur (Baltimore & Ohio): Under this Assignment—Specifications for railway buildings, your committee submits specifications for hollow concrete masonry units which are offered as information with a request for comment and critcism and with the view of resubmission in another year for adoption and publication in the Manual.

Under the heading of Specifications for hollow concrete masonry units, I direct your attention to the statement that these specifications closely follow both federal and ASTM specifications for hollow concrete masonry units.

As previously stated, we welcome any criticism or comment, and they can take those things under consideration in the coming year and this subject will be resubmitted for inclusion in the Manual.

President Mottier: Any question or comment from the floor? Apparently not. Thank you, Mr. Wilbur.

Chairman Dorland: As a matter of information, Assignment 3—Shop facilities for diesel locomotives, and Assignment 4—Servicing facilities for diesel locomotives, we were unfortunate in the fact that both of the chairmen of these committee have been very ill during the past year. Although they both have some material collected, it was not deemed advisable to try to complete these reports for this year's convention, and we ask that these subjects be continued. On Assignment 6—Specifications for lumber for railway building purposes, our committee thought we had a complete report on this subject. but we haven't had any close contact as to the material of some other committees, so this report will be held in abeyance until next year. I think Mr. Church will speak about that later.

Assignment 5—Fire retardant coatings, will be presented by Mr. Church, chairman of the subcommittee.

H. M. Church (Chesapeake & Ohio): The report on this assignment, Specifications for fire retardant coatings for railway structures, is designated as a final report. It is not in form for final adoption, and should be preferably considered as information.

The report deals generally with fire retardant coatings. It is supplemental to the previous report we had on this subject. We have quoted here certain fundamental definitions in the different classes, but these are in very tentative form. The ratings are given as information on some of the classifications and material under question, but it is questionable whether these ratings will finally prevail. We have given a few of the recent developments on specifications and we hope that these will be quite extensively used by some of the outstanding paint manufacturers.

It is quite pertinent to know that one of the railroads that had need for this protection and desired to maintain wooden structures without replacing them with more permanent building materials has made such remarkable strides. So we hurriedly included in this report certain tests that are outstanding and somewhat different from those previously set up. It is my suggestion that we continue this subject because I think the information this railroad is developing will prove very enlightening from the standpoint of simplified tests and will be very practical.

On the subject of specifications for lumber for buildings assigned to us by the Board of Direction, there have been a great many advances, and both Committee 6 and Committee 7, as indicated by our last meeting, will have something to present to the Association.

Chairman Dorland: Before leaving the platform I wish to thank all of the members of Committee 6 for the assistance they have given me as the new chairman, and also to express my regrets on losing some of these men from the committee, and especially Mr. A. T. Hawk. I think some special recognition for his contribution to our committee work is in order. Committee 6 has absorbed the former Committee 23—Shops and Locomotive Terminals. Mr. Hawk has served on one of these committees and part of the time on both of them for over 30 years and is a past-chairman of Committee 23. He was a regular attendant at our committee's meetings and his advice was always excellent. He has retired from the Rock Island and has moved to California and so has withdrawn from the committee. We will miss him.

Discussion on Water Service and Sanitation

(For Report, see pp. 163–192)

(President Mottier presiding).

President Mottier: We are somewhat handicapped this afternoon. Mr. Silcox, who is chairman, and Mr. Bardwell who was to give an address cannot be here, so Mr. Guy Martin who has had some experience in water service on a little railroad in mid-America, will present the report.

Vice-Chairman G. E. Martin (Illinois Central): In connection with our report, I have two comments that I wish to make before going into it. First, let me say that we sincerely regret that circumstances beyond his control made it impossible for Mr. Silcox, our chairman, to be here this afternoon. I feel certain that he is thinking of us at this time.

Secondly, the entire membership of Committee 13 is quite conscious of having to sustain the great loss in the death of one of our members this past year and desires to collectively express regret at this time on account of the death of Clarence Richard Knowles on August 5, 1948. He became a member of the Association in 1915 and was an ardent worker of this committee from that time until his death, and was chairman from 1923 to 1930. Since he served as a director of the Association from 1930 to 1933, a memoir to him will appear in the allotted place in the Proceedings instead of with the report of Committee 13.

There will be eight reports out of ten assignments which will be submitted by the subcommittee chairmen.

Since I am chairman of the subcommittee on assignment 1 which has to do with Revision of Manual, I will present that report.

We have made quite a few changes in the Specifications for Welded Steel Tanks for Railway Water Service. They have to do mainly with uniformity in terms used by welders in steel tank work. There are several changes that are relatively unimportant.

I move it be accepted as shown in the bulletin.

(The motion was seconded, put to a vote and carried.)

Vice-Chairman Martin: The second change we have is in Specifications for Salt to be Used in Regeneration of Zeolite Water Softening Plants. Our previous specification did not result in securing a quality of salt suitable in all cases for use in zeolite plants, and resulted in some inconvenience. Consequently, the proposed change was made, and we think it will result in securing the desired results.

I move that the changes as shown be approved.

(The motion was seconded, put to a vote and carried.)

Vice-Chairman Martin: That concludes the recommendations from Committee 13.

President Mottier: Thank you, Mr. Martin.

Vice-Chairman Martin: Mr. Coughlan, chairman of the subcommittee on Assignment 2 has not arrived. I think he will be here. We are going to Assignment 3—Federal and state regulations pertaining to railway sanitation, collaborating with Joint Committee on Railway Sanitation, AAR, Mr. Van Hovenberg, chairman.

H. W. Van Hovenberg (St. Louis, Southwestern): This is a report of progress presented as information. More recent activities of the research project have centered on the development of a retention valve as a practical means of controlling the discharge of hopper wastes. The same research project is also extending its studies on the air sampling of the amount of waste discharges that are dispersed to the atmosphere following hopper discharges from speeding trains. They are also studying the amount of pollution running off of roadbed grades included in the water that fails on the track as compared with the pollution of adjacent woodland streams that do not receive right-of-way drainage. The research project, as you know, was set up under the AAR to investigate some practical means of controlling the discharges from hoppers on railway cars, and it is thought that it will conclude its work, making its report sometime the latter part of September or October of this year.

President Mottier: Thank you, Mr. Van Hovenberg. Proceed, Mr. Martin!

Vice-Chairman Martin: There is no report to be made on Assignment 4, so we will pass on to the report on Assignment 5. Mr. Teal, chairman of this subcommittee, is also unable to be here today but I believe he has prepared his report and I am going to ask Mr. Van Hovenberg if he won't give Mr. Teal's report.

Mr. Van Hovenberg: I will have to read this report by Mr. Teal, it is short, because it was handed to me not too long ago and I would like to read it just as he wrote it because it is very good.

Last year your committee made a preliminary report on sanitation in which past practices and current developments were reviewed in some detail. The general conclusions were that the provision and maintenance of healthful living conditions for camp car employees will pay money dividends by eliminating excessive labor turnover due to discontent and by reduction of time losses on account of sickness. Further conclusions were that good sanitation on railway camp cars depends on two things, the first being reasonably adequate equipment and the second, good housekeeping.

This year's report presents specific recommended sanitation practices. These were derived in part from the study of past and present conditions and in part from a review of all the federal and state health service regulations pertaining to camps that could be found.

The recommendations regarding design and equipment appearing on pages 170 and 171 deal entirely with the physical aspects of camp car living quarters. Space requirements are mentioned, as crowded conditions will encourage the transmission of diseases. The proper construction of floors and walls will aid in keeping cars clean and discourage the harboring of insects. The provision of adequate heat and ventilation, screening, lighting, washing and bathing equipment and sanitary drinking and toilet facilities will enable employees to live a more normal and healthy life. Proper design and equipment of kitchen and dining cars is considered particularly important as the morale and working efficiency of the entire crew is largely dependent on the kind of food they eat and the environment in which the food is prepared and served.

The second phase of the report, or the recommendations regarding the maintenance and operation of camp car outfits, appears on pages 171 to 175. This section calls attention to responsibilities of supervisory officers over sanitation, as well as other matters, and recommends fundamental sanitary housekeeping practices that have been found good. Specific recommendations are made regarding personnel for sanitary work, procurement of sanitary supplies, procedures in case of sickness and disease, physical examination of cooks and food handlers, cleaning of bunk cars, operation of kitchen and dining cars, dish washing, disposal of kitchen wastes, procurement and handling of drinking water, toilet facilities, and insect and rodent control.

The recommendations presented here may be summarized by the general rule that "Camp car outfits should be constructed, operated and maintained in such a manner as to provide healthful living conditions for the occupants and not endanger the health of the public."

This report is presented as information.

Vice-Chairman Martin: Thank you, Mr. Van Hovenberg. The next assignment is Assignment 6—New developments in water conditioning for diesel locomotive cooling systems and steam generators and the report will be given by Mr. Hanson, who has had quite a lot of diesel experience and I am sure he has a good report for us.

M. A. Hanson (Gulf, Mobile & Ohio): During the past year, very little new development work has been done beyond that previously reported by this committee. The definite recommendations made by this committee during the past three years have received quite general acceptance throughout the industry where they are being followed. Little if any difficulties are experienced on either scale or corrosion. No progress has been made in developing any other corrosion inhibitor of the alkaline chromate type now being used universely in diesel locomotive cooling systems. We all recognize the limitations of this type of corrosion inhibitor, but no adequate substitute has been developed to date. As to the steam generators, a marked improvement has been made in service performance and coil life. This has been accomplished primarily through the proper use of water treatment. The previous recommendations made by this committee in the Proceedings, Vol. 49, 1948, pages 84 through 87, still continue to serve as a guide in the selection of the method of treatment to be used. I think their validity has been further proved by their relatively wide adoption.

The new type of water wall steam generator which some of us have purchased during the past 18 months has also responded quite satisfactorily to water treatment. A report was presented at the annual meeting of the Railway Fuel and Traveling Engineers Association which indicates that a Clarkson type steam generator will waste up to 29 percent of the fuel used for steam generation. With fuel at 9 cents per gallon, this represents a fuel loss of $2.45 per 1000 gal. of feedwater evaporated. This alone economically more than adequately justifies the water conditions. This report is submitted as information.

Vice-Chairman Martin: The next is Assignment 7—Water hammer: Its effect on pipe lines and methods of control. This is a problem that causes water service men trouble. At this time I am certain that Mr. Fisher, chairman of the subcommittee will have a good report for us.

C. E. Fisher (Virginian): Water hammer is the hydraulic shock which occurs when a liquid such as water undergoes a sudden change in velocity and is generally caused by the following conditions which can cause serious damage:

1. In starting or stopping a pump or in abrupt changes of the pump's speed.
2. Sudden closure of a valve in the discharge line.
3. Power failure.
4. Accumulations of air in the pipe lines.

Control of water hammer to reasonable limits can be effected by:

1. Slow closing outflow valves properly maintained, with or without auxiliary bypass piping.
2. Quick closing check valves.
3. Spring type arrestors for small lines.
4. Surge suppressors and hydraulic-operated adjustable water hammer eliminators

The maximum water hammer in any system can be determined by calculation when the following fundamental factors are known.

1. Velocity of flow in the pipe line
2. Length of pipe line
3. Time of valve closure
4. Pressure wave velocity

The necessary formulas and tables are given in the report whereby a study can be made of the effect of water hammer on the various classes and types of pipe.

This is most important in the design of water works piping at which time the flow line velocity can be kept as low as economically possible, whereby dangerous conditions can be avoided.

President Mottier: Thank you, Mr. Fisher. Does anyone have any comments or discussion?

Vice-Chairman Martin: The next assignment is No. 8—After-precipitation from treated water; cause and prevention, and will be given by Mr. McMullin, chairman of the subcommittee.

H. L. McMullin (Texas & Pacific): After-precipitation is defined in the report as that precipitation in water treatment which occurs after the water has left the treating chamber and up to the point of use. It occurs in two forms.

One is sludge because the milky water, as you men in the water service know, results in foaming if it gets into the engine tender tank and into the boiler. This is particularly troublesome, but it is not as troublesome as the other form of after-precipitation which is the incrustation that is formed on the inside of the pipe lines, pumps, injectors, branch pots, water checks and even in the boiler. It can easily be seen that if an incrustation is allowed to accumulate in the water pipes, it will reduce the efficiency of the water system. This holds true with accumulation at any point. After-precipitation occurs in a number of places but it seems to occur more frequently at the point of change in temperature of the water and point of agitation.

The principal ingredients in after-precipitation are usually calcium carbonate, iron oxide and sometimes there is a phosphate also and some tannins. For the prevention, the cause and the cure, the first consideration should be given to the operation of the treating plant. If the treating plants, particularly of the lime-soda type, are operated to reduce the hardness to a minimum, naturally there will be less incrustation in the water, that is, there will be less hardness in the water to form incrustation. Beyond that, there have been certain chemicals found to be of assistance in preventing or ending after-precipitation. I don't know if anyone has prevented it entirely. Sodium, calcium, hexametaphosphate and some compounds are inclined to be helpful in this connection. Coagulants help also, such as sodium aluminate, in that they help to reduce the residual hardness in water. After-precipitation causes incrustation, but it should not be assumed that all incrustation is due to water treatment. It is frequently experienced where no water treatment has occurred, nor should it be assumed that all after-precipitation is entirely without disadvantage. This is particularly true where feedwater heaters are used and oil finds its way into the boilers. It is of course, well to know when to expect after-precipitation and how much.

President Mottier: Thank you, Mr. McMullin. Does anyone wish to make any comments on the report? Proceed!

Vice-Chairman Martin: The next report on Assignment 9, which is a real problem facing all railroads, Stream pollution from sludges and waste on railway property, will be given us by Mr. Tennyson, Jr., chairman of the subcommittee.

T. A. Tennyson, Jr. (St. Louis Southwestern): Your committee submits this report on Assignment 9 as information. The general scheme for classification of industry waste adapted to railway operation is presented.

Some specific railway waste products which have a definite bearing on the public health are named. Some of the operations involved in the disposal of those waste products, which are likely to be involved in stream pollution, are discussed. Oily wastes and toxic chemicals from tank cars are discussed briefly as these seem to be of major importance at this time.

It is pointed out that increasing governmental activity toward the prevention of pollution will make the cost of satisfactory waste disposal a necessary part of the operating cost of any industry, including the railroads, but a critical study of the waste disposal problem will undoubtedly result, as it has in some industries, in the development of better methods of disposal practices and the recovery of valuable materials which are now being lost and which may in some cases pay for the cost of disposal. The solution to this problem will require trained personnel, adequate authority and equipment.

Vice-Chairman Martin: We will now have the report on Assignment 2—Intercrystalline and other types of corrosion of steam boilers, which will be given by Mr. Coughlan, who has been chairman of this subcommittee for a number of years.

R. E. Coughlan (Chicago and North Western): During the past year special attention was paid by your committee to the excellent results reported by one of the eastern railroads on the use of sodium nitrate treatment as an inhibitor for intercrystalline corrosion.

It had been previously noted that when locomotive feedwater was conditioned for boiler use by treatment to prevent scale and corrosion without the addition of an inhibitor, the clean boiler sheets and scale-free seams appeared to be more susceptible to the attack of intercrystalline corrosion than boiler sheets and seams coated with scale.

Inasmuch as the railroad water chemists have never subscribed to the theory of sulfate ratio as an antidote for intercrystalline corrosion, considerable work had previously been done on the use of tannin compounds and sulfite liquor. Sodium nitrate as an inhibitor was applied later.

The use of sodium nitrate simplified the addition of the inhibitor inasmuch as a positive control can be maintained. Positive control was one of the drawbacks in the use of tannin compounds and sulfite liquors and, while excellent results were secured by the use of tannin and sulfite liquor, the introduction of sodium nitrate on this particular railroad coincided perfectly with a decided reduction in intercrystalline corrosion in the locomotive boilers using this material.

The use of the embrittlement detector, described in the report of your committee this year, has been a very decided help in conditioning of the boiler water in locomotives formerly affected by intercrystalline corrosion.

Vice-Chairman Martin: Thank you, Mr. Coughlan. That completes our report and it is offered as information with the exception of the assignment 1 which will be offered for acceptance. Thank you, gentlemen.

President Mottier: Thank you, gentlemen, on the committee. This is a hard working committee. You presented fine reports. The committee is excused with the thanks of the Association.

Discussion on Track

(For Report, see pp. 567–647)

(Vice-President Schwinn presiding).

Chairman E. W. Caruthers (Pennsylvania): The Track committee wishes to present a revision to the Manual. Mr. Strattman, who is chairman of the subcommittee, will present the material.

C. R. Strattman (New York Central): There is only one item on revision of Manual. Your committee offers for reapproval, without change, the text now appearing in the Manual on page 5–19, under the following head:

Welding of Manganese Castings in Special Track Work.

I so move.

(The motion was seconded, put to a vote and carried.)

The second assignment covers fastening for continuous welded rail. The chairman of subcommittee 2, Colonel Bartlett, will present the report covering that subject.

A. L. Bartlett (New York, New Haven & Hartford): The report on fastenings for continuous welded rail is short this year. At the outset, we call to your attention the fact that the subject has been before the committee since 1936. Since that time a number of progress reports have been made which have dealt with both theoretical and practical sides of the subject and have covered, to some extent, anchorage, tie and ballast resistance and have given some description of the 1200-ft. test track which we built in New Haven.

In 1943, in the progress report, the following statement was made:

"As the test installations of continuous welded rail have increased, their performance increasingly indicates that the same kind of fastenings which have been found most successful in jointed tracks are dependable for use in continuous welded rail tracks."

Then we carry on from there. In the light of experience since that time, it is obvious that this conclusion might be considered applicable to present day continuous rail track. However, it still is a fact that installations of continuous rail with conventional fastenings in track carrying frequent high speed passenger trains or heavy freight traffic are few in number, or of short service duration or in limited continuous lengths.

It is suggested that further study should consist mainly of observations of existing and future installations.

Vice-President Schwinn: Thank you, Mr. Bartlett.

Chairman Caruthers: The next assignment is on track tools. Mr. Haight, the chairman, is not present, but Mr. Blalock will present the report.

J. A. Blalock (Richmond, Fredericksburg & Potomac): The report consists of recommendations for the adoption of three tools, which are as follows:

Rail Fork—Plan No. 10–49. This has been in general use for some years, and the committee recommends its adoption.

The second tool is Claw Bar—Plan No. 11–49. The committee recommends that Claw Bar Plan No. 11–49 be adopted in place of Plan No. 11, and that Claw Bar Plan No. 11–A be withdrawn from the Manual.

The third tool is Tie Plug Driver—Plan No. 16–49. This is a new tool that has found widespread use with rail laying gangs.

I move that all three plans be adopted.

(The motion was seconded, put to a vote and carried.)

Chairman Caruthers: The report in connection with Assignment 4, covering frogs and switches, will be presented by the chairman of the subcommittee, Mr. Hillman.

A. B. Hillman (Belt Ry. of Chicago—Chicago & Western Indiana): Your committee has prepared plans as follows, which it offers for adoption as recommended practice and publication in the Portfolio of Trackwork Plans:

Plan 641–49—Solid Manganese Steel Self Guarded Frogs.

Plan 325–49—Steel Frog Fillers and Reinforcing Bars.

In view of the issuance of Plan 641–48, which is similar to Plan 640–41, except for modifications in details designed to increase the strength of the frog under current heavier equipment and traffic conditions, your committee recommends withdrawal from the Portfolio of

Plan 640–41—Solid Manganese Steel Self Guarded Frogs.

The committee also recommends revision of the 17 plans, basic numbers 111 to 181, incl. This committee is cooperating with the Signal Section of the AAR in making these revisions.

(His motion for the adoption of the plans and revisions was seconded, put to a vote and carried.)

Chairman Caruthers: We will now hear from Mr. Magee, who will describe the research work that has been carried on in connection with Assignments 4, 5, 6, 7 and 10.

G. M. Magee (Association of American Railroads): The first report has to do with an investigation we have been conducting in an effort to find a cure for the development of flangeway cracks in manganese castings. I am reminded a little bit in this connection of one of Mr. Kettering's remarks, when he said that some of these research jobs are like a man starting out to walk from Chicago to California. By the time he gets to Aurora he may be awfully tired but he still has a long way to go. I do not mean by that that we are getting tired. I think we have found out a lot, and we have made some headway but we have not found the answer. We still have a little way farther to go.

Our first undertaking was to measure the stresses in flangeways under actual service trains on a busy crossing at McCook on the B. & O. Chicago Terminal and the Santa Fe. We found that these stress measurements were high enough to be within the range to explain development of fatigue failures in manganese steel.

Our next step was to ask the frog manufacturers to design castings in an effort to provide more flexural strength and reduce the range of bending stresses. Five such castings were designed and submitted to test. Stress measurements were made on each of these. In certain of the castings, at certain critical locations, we found that improvement had been made but not as much as we had hoped for.

Following these measurements, the castings were all put in and left in service for a year, and each one of them was observed after the end of the year's service. Some of the castings performed much better than others, but there were none of them as good as we had hoped for. In other words, in each casting tested some cracks developed in the flangeways to a greater or lesser extent. It seems that we need to continue our efforts to improve the design, to still further reduce the bending stresses.

Another method of approach was to support the castings on a steel base support which would have a great stiffness in itself and remove flexural bending from the castings. Such a design was built and was installed on the Indiana Harbor Belt and the

Chicago & Western Indiana Railroad near 55th Street and Cicero Avenue, Chicago. This has been in service now for about two years. Here, again, we have not found the right answer. We did find that we had appreciably lowered the stresses of the flangeways but still, after the 2 years' period, some cracks have developed. We feel that one reason for this was that our welding in the steel base support was not sufficiently strong, and it broke shortly after the installation was made. So, we are planning to make another installation with a stronger base support.

The maintenance of this crossing has offered some rather interesting possibilities. It is a very simple matter to raise it, merely tamp material underneath the top flange of the T-section. It gets away from the necessity of digging out ballast around the ties. Inasmuch as it is supported on asphalt ballast, drainage is not much of a problem.

Along with this, in arrangements last year with the University of Illinois, Mr. Jensen, on their staff, conducted extensive laboratory tests on specimens of manganese steel to determine the fatigue strength in a stress cycle of 100 percent compression to 50 percent tension, which was about the stress range that was found in the field measurements. These tests are described in the report.

They were carried out in 9 different series. The manganese was tested both in the as-cast, ground and shot-peened state. The tests were made with and without a corroding agent and with a protective coating.

One of the interesting things from these tests was the effect that shot peening had on raising the fatigue strength of manganese. It looks very promising. As a result, we are planning this year to install a casting in which the flangeways have been shot peened.

Another rather interesting result of the laboratory test was the fact that the endurance limit of the manganese steel as determined in these tests is below the maximum stresses measured in the flangeways in actual service, so that there is every reason to expect the development of flangeway cracks unless we can either raise the strength of the steel or improve the design to bring the developed stresses within the capacity of the steel.

I would like to speak a few minutes about the research project on the design of tie plates. The report this year gives the results of measurements made on the tie plate installation for 112 RE rail on the Illinois Central Railroad near Henning, Tenn. This installation was made in October 1944 on a 4-deg. curve and also on tangent track.

On both of these, new creosoted oak ties were used for a portion of the test and also new creosoted pine ties; in other words, each design of plate was tested on each.

The different plate designs were selected to study and obtain data on the effect of the area of the tie plate, on the thickness of the plate, on the eccentricity and on the shape of the rail seat.

Previous reports have already given some of the data obtained. For example, we found that the crowned rail seat produced high stresses in the rail base, particularly on the curves. The thickness of plate has also been reported on. Stress measurements made last year and measurements made of bending indicated that the thinnest sections, when used on the lower rail of the curve, did occasionally bend, but, generally speaking, the thickness of plates now used in our AREA designs was found to be adequate.

Measurements were made this year of the amount the tie plates penetrated into the tie and of the bending of the plate and of the track gage. The amount of penetration has not been very great as yet. We cannot give any very conclusive results but so far there was little difference between 11-in. and 13-in. plates insofar as tie wear is concerned. Neither was there any appreciable effect on tie wear due to difference in tie plate thickness or in the shape of the rail seat.

So far as eccentricity is concerned, the measurements showed that ⅜-in. eccentricity gave fairly uniform tie plate seating on tangent track.

On the low rail of the 4-deg. curve, however, the measurements have indicated that we would have to have as much as 1¼ to 1½-in. eccentricity to keep the outer toe of the plate from cutting in more than the inner toe.

One rather interesting finding with respect to gage widening on the curve was that on certain plates where only three spikes were used, there was quite a difference in the amount of gage widening compared to other plates where four spikes were used.

The next subject I would like to mention is the research work on the corrosion of track and structures from brine drippings. This is an investigation that has continued for several years, and, as I have previously reported, our work has consisted of developing an inhibitor to be used with the salt to neutralize its corrosive action on the track and structures.

We have found in the laboratory tests that the use of sodium dichromate neutralized with soda ash is quite effective in this respect. However, this inhibitor is toxic, and, for that reason the Medical and Surgical Section, AAR, contended that we would have to find some way to add it after the brine drippings had left the car, to prevent any possible contamination of the lading. This indicated the necessity to develop some type of filter that could be attached to the discharge nozzles on the car and add the desired inhibitor content to the brine drippings before they were sprayed on the track.

Our work on this has been delayed during the war. Just this year we have an appropriation and have recently entered into a research agreement with Armour Research Foundation for the development of such a filter, and I am hopeful that by the end of this year we will have made some substantial progress on this.

The next subject is the installation to study the effect of hold-down fastenings and tie pads to prevent the cutting of tie plates into the ties.

The hold-down fastening test installation was made originally, on the L. & N. Railroad near London, Ky., in 1947 and some additional sections were added last year. Now there are 27 different types of construction included in this test series.

The test includes installations on both tangent track and on 4-deg. 30-min. curve. The tie plates are 7¾ in. by 13 in. throughout. The test installation includes various types of hold-down fastenings such as screw spikes with spring washers, through bolts, drive spikes, dowel spikes, and so forth.

Another rather interesting innovation was an effort to develop a means of cementing the tie plate to the tie, and several sections were included in which the tie plate was fastened to the tie with adhesives.

Also the test included four different types of test pads. There is quite a bit of interest in tie pads at the present time throughout the country. Our observations will include detailed measurements of tie plate penetration and the effect on gage.

The installation has not been in very long but there have been one or two definite findings. For one thing, we are pretty sure that the use of adhesives is going to be rather difficult to make a success. In fact, we are not very enthusiastic about its possibilities. While some very effective adhesives were developed during the war, it is necessary to have a perfect fit between the steel and the wood to secure the proper bond, and this would mean surface grinding of the bottom of the plates and a very precise adzing job, which would be so expensive and difficult as to make it almost out of the question.

In the test sections with the 5 and 7-ply Bird pads, the pads have been made in alternate layers of canvas and paper felt, and in some of the pads there was some difficulty with the paper felt working out. Accordingly, at the request of the Bird people, a certain number of these pads were replaced during the year by new pads containing jute rather than the paper felt.

One other project I would like to mention is the study of the permissible speed on curved track, with particular regard to new types of equipment. An appropriation of $30,000 has been granted this year to carry on joint tests between the Mechanical Division and our division on this subject. We hope during the year to make tests on several different degrees of curvature, covering a complete range of speeds up to the maximum permissible, measuring the degree of riding comfort with accelerometers and including in the test both old equipment and new, modern equipment with both inboard and outboard springs.

Vice-President Schwinn: Thank you Mr. Magee.

Chairman Caruthers: Major Macomb, chairman of the subcommittee in connection with Assignment 6, will make the report and recommendations for modification of the Manual.

J. de N. Macomb (Chicago, Ill.): Tie plate plans 1 and 2, adopted for publication in the Manual in March 1948, were designed to locate the ribs on the underside near the gage end on the assumption that these tie plates would be used with rails having base widths of 5⅛ in. and 5½ in., respectively. The experience of the past year has shown that these tie plates are used with rails with base widths of 5 in. and 5⅛ in. respectively, and the plans have been revised by moving the gage rib accordingly.

The committee recommends the adoption of these revisions, as shown in the revised drawings of plans 1 and 2. And I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Caruthers: In addition to the information that was presented by Mr. Magee in connection with Assignment 6, the committee wishes to inform the Association that the American Iron and Steel Institute has developed Plan 19 for a 15-in. double-shoulder tie plate for use with a rail having a 6½ in base. This plan is submitted as information only.

Vice-President Schwinn: It will be so received.

Chairman Caruthers: The report on Assignment 8—Effect of lubrication in preventing frozen rail joints—will be presented by Mr. C. W. Breed, the chairman of the subcommittee.

C. W. Breed (Chicago, Burlington & Quincy): This year the progress report of the subcommittee contains the observations taken annually on the service tests of the various lubricants established near Earlville, Ill., in July 1945.

It also includes a report by Mr. W. E. Gardner, principal assistant engineer, Wabash Railroad, of a method of rail joint lubrication being used on that railroad.

The Burlington service test observations were made after three years of service. The measurements of rail joint gap have continued to show little difference in the effects between the different lubricants used or, in fact, whether any lubricant is used.

However, there is some indication from the comparison of a number of open joints in summer and closed joints in winter that the slippage resistance of the joints is increasing somewhat with the longer service.

The out-to-out measurements of joint bars taken to show fishing surface wear do not show any outstanding differences between any of the lubricants, or any reduction compared with no lubricants. It was anticipated that lubrication of the fishing surfaces would result in a reduction in the rate of wear. The Burlington maintenance forces reported that there have been no stripped joints in any of the test sections. Several loose bolts have occurred with recessed nuts without spring washers; some loose bolts and a few broken bolts have been found.

Two joints were dismantled in each of the test sections for detailed observation. The No-Ox-Id "A" special, petrolatum (dark) and R.M.C. plastic packing have resisted weather remarkably well. Even with these lubricants, however, only a portion of the top and bottom fishing surfaces was found to be lubricated but the web of the rail was well protected.

The effect of wind and sand blasting from fast moving trains was quite evident on the gage side, particularly on the exposed portions of the bolt threads. Because of this sand blasting effect and the corrosive effect of brine dripping, it appears there may be considerable advantage in plugging either the receiving end or both ends of rail joints.

This was particularly apparent in some of the joints where the lubricant had practically all weathered away, but on the bolt threads protected by the nuts, in all cases of lubrication, the lubricant was in good condition.

It is proposed to augment the test installation this year by providing joints in which lubricants showing the best performance will be included with end plug protection, together with other lubricants that have been suggested.

The field work for this investigation has been carried out by the Engineering Division research staff, by H. E. Durham, track engineer, under the general direction of G. M. Magee, research engineer, assisted by the track department of the Burlington Railroad.

Attention is directed to Mr. Gardner's report on rail joint lubrication on the Wabash Railroad. This describes a very interesting method they are using in which the rail joints are plugged at the ends and the interior portion is filled by pumping in No. 904 graphite grease.

Vice-President Schwinn: Thank you, Mr. Breed.

Chairman Caruthers: The report in connection with Assignment 9—Rail anchorage for various conditions—will be presented by the chairman of the subcommittee, Mr. Martin.

E. E. Martin (Pennsylvania): This assignment had its beginning in 1943 when the committee was requested to study and submit recommendations on the number and placing of rail anchors for various conditions.

Following a canvas of rail anchor practices on 33 Canadian and American railroads and three-year service testing, recommended practice governing the number and placing of rail anchors was submitted and adopted by the Association in 1948 and is now included in the Manual under Rail Creepage.

It is recognized that little is known at the present time of the forces transmitted from rail anchors to ties and the magnitude of such forces necessary to move ties through the ballast with various arrangements of anchoring.

Continuing under the assignment, the committee is proceeding with a series of studies, with the view of obtaining information of the nature included in this initial test and report. This report presents results of a static test made during the past year on a short panel of disconnected track prepared by the New York, New Haven & Hartford Railroad to determine forces transmitted from rail anchors to ties of sufficient magnitude to move ties through stone ballast.

Increment loading was applied to rail ends by hand-operated hydraulic jacks, registering gage pressures, and rail movements were measured by Ames dials at the opposite end of the short test panel.

It will be observed that four arrangements of anchoring were used and two series of tests conducted, one with and one without tie plates, to compensate for variations in frictional resistance, ballast rammed against sides of ties but not tamped or compacted as would occur under service conditions.

The average force on the tie graphically plotted against rail movement, for each arrangement of anchoring, is shown in Fig. 1 and Fig. 2 on pages 644 and 645. The results indicate that greater holding power would be obtained with anchors applied on alternate ties throughout a rail length. This is indicated in both graphs as Schedule 2.

The four arrangements of anchoring give relative values in this static test, and it is intended to develop similar information under dynamic conditions in main track.

All measurements and analyses in this assignment have been made by the research staff of the Engineering Division, AAR. Acknowledgment is made to the New Haven Road and to Mr. A. L. Bartlett, assistant to chief engineer, for the construction of the test panel of track and assistance in conducting the test. The report is offered as information.

Vice-President Schwinn: It will be so received.

Chairman Caruthers: That will conclude the report of the Track Committee.

Vice-President Schwinn: Thank you, Mr. Caruthers, for the very informative report made by your committee today. The committee is now excused with the thanks of the Association.

Discussion on Rail

(For Report, see pp. 483–566)

(Vice-President Schwinn presiding).

Chairman C. B. Bronson (New York Central): It seems to me that we should take a few minutes to review what has transpired over these 50 years. The slogan "A Past of Achievement" is certainly descriptive of the work that has been done by this committee.

It was my privilege and my duty to review, page by page, the entire record for 50 years, and I was amazed to note the wonderful accomplishments of the committee. For example, in one year one entire volume of the Proceedings was devoted to the Rail Committee report. In four years this committee had turned out 1600 pages of intensive literature. There is only one thing we can do. We have to honor those men for their achievements.

There are some who say that we lack the progressive spirit. However, I contend, that anybody who will read the record, just as Al Smith said, would be convinced that, the Rail Committee, has really achieved much.

I was asked to pick out what would represent important accomplishments of this committee. Let's bring it right down to a present-day basis, rather than to go back and do honor and justice to the men that were here at the inception of this affair, and let's just take two outstanding examples. First, let me ask you a question: Where do you think you would have been today if you did not have control cooled rail? The scourge of fissures would still be upon you. When you look at the record and consider there are 10 million tons or more of control cooled rail in this country, and there has been only a handful of fissures that you can almost count on your hands, isn't that an achievement?

Of course, we have to do honor and justice to the men that developed it, that is Mr. Mackie and Mr. Sandberg but, nevertheless, this committee was largely responsible for that development.

Let's take another example. Where would you have been today if we did not have a detector car that has picked out over 1½ million defective rails and avoided derailments and a lot of difficulty? Again, we have to give credit to Dr. Sperry for the development of that device. But, nevertheless, this Association and this committee can take credit for their part in that development.

For 10 years I was an alternate, for 25 years, a quarter of a century, I have been a member of this committee, and, for three years I have been honored as chairman, and now I drop back to the ranks. It seemed to me that this was my one and only opportunity to let you know just exactly how I feel and what I think about the wonderful accomplishments of the Rail Committee over this half a century. I want to say, as far as the future is concerned, this committee is going to be placed in the hands of young men, and that is what we need today. You can rest assured that the other half of the slogan, "A Future of Opportunity" may be handled by these men with full credit to this Association. (Applause)

Vice-President Schwinn: I assure you that is not a swan song. We will hear some more from him, gentlemen.

Chairman Bronson: We are seeking reapproval of General Requirements of a Rail Joint. I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Bronson: Rail failure statistics will be presented by Mr. Barnes.

W. C. Barnes (Association of American Railroads): The rail failure statistics for the year ending December 31, 1947 are submitted as information.

(He reviewed the report.)

Mr. Barnes: I wish to make a slight correction in the first paragraph on page 493. In the last sentence, the words, "The yearly decrease in both service and detected failures continues," should be changed to read, "The yearly decrease in service failures continues."

Chairman Bronson: Subject No. 5—Economic value of different sizes of rail—will be reported by Mr. Chumley.

C. M. Chumley (Illinois Central): The assignment—Economic value of different sizes of rail—has proved to be rather difficult. In the past, a number of studies have been prepared, mostly from a theoretical standpoint, with a view to determining the service life of various rail sections handling a given tonnage, effect on ties, ballast life, and other maintenance cost.

Information thus obtained has not proved entirely satisfactory for forming definite conclusions. In 1946–47 the subject was approached by securing information from engineering officers of 31 representative railroads operating a total of more than 207,000 miles of main track. These reports indicated mileage designated as heavy rail territory, the rail section being used, and average age of the rail when removed, as well as cause for removing, also the opinion of these officers as to the tonnage that would justify a heavier section than 90, 112 and 131-lb. rail.

The average of the estimates obtained were that 5.9 million gross ton miles per year would justify rail heavier than 90-lb., and 9.6 million gross ton miles would justify rail heavier than 112-lb. and 18 million gross ton miles would justify heavier than 131. But the wide range of these estimates indicates that there are other factors than tonnage alone which govern the selection of weight of rail used by the various roads, among which are speed, comfortable riding and the road's immediate financial status that would enable them to take advantage of the saving in maintenance cost by investing in the heavier rail section.

Our latest report of progress, which I will not read in detail, refers to a test being conducted on the Illinois Central covering a 40-mile section on the northward main track between Champaign and Mattoon; 20 miles of this section are laid with 112-lb. RE section and 20 miles with 131-lb. RE section. This location is between terminals, where the volume of traffic is nearly equal. For the 5 years, 1943 through 1947, the average annual gross tons handled over this track was 28.37 million.

The cost figures in this report show that the material cost on the initial installation of the 131-lb. rail ran $1770.72 per mile more than the 112, and labor costs, handling, installing, were $45.82 greater, making the total cost in track $1,816.54 per mile more for the 131-lb. than the 112-lb. rail.

The report on maintenance cost indicates a saving of 210 man-hours per mile of track per year on the 131-lb. as compared with the 112. This compares favorably with the report made by Robert Faries, then assistant chief engineer-maintenance Pennsylvania Railroad, when testifying before the Railroad Carrier Industry Committee at Washington, D. C., in 1940. Also, other excellent reports on this subject are mentioned in our progress report: (1) The Proceedings, Vol. 31, 1931, page 1495: Economical Selection of Rail, by A. N. Reece, Kansas City Southern Railroad; (2) Proceedings, Vol. 40, 1939, page 130: Methods or Formulas for the Solution of Special Problems Relating to More Economical and Efficient Railway Operations. by C. H. R. Howe, cost engineer, Chesapeake & Ohio Railroad.

All of these studies indicate that the use of the heavier rail section results in saving in annual cost per mile of track maintained, as well as the cost per gross ton mile of traffic handled. While the cost of both labor and material is steadily increasing, the ratio of saving remains approximately the same. In addition to these direct, measurable savings, there are other benefits which result from the use of the heavier rail sections. Among these are increased safety, smoother ride for passengers, less wear on ties and ballast, and increased life of equipment.

This report is that of progress.

Vice-President Schwinn: It will be so received.

Chairman Bronson: Subject 6—Continuous welded rail—will be reported on by Mr. Schram.

I. H. Schram (Erie): This is a progress report and contains the usual tables. The interesting thing about it is that there have been a considerable number of new installations of welded rail. These were all of the gas pressure type welds, and we are gathering information on them to compare with the older types in the older installations.

Another portion of the report was prepared by Professor Cramer and gives the results of some laboratory tests of welded joints. It is very interesting.

Chairman Bronson: Subjects 7 and 8 will be combined—Service tests of various types of joint bars; Joint bar wear and failures. In the absence of Mr. McBrian, these will be presented by Mr. Magee.

G. M. Magee (Association of American Railroads): You may remember in the previous reports of the Rail Committee that service tests of joint bars for 112 and 131-lb. rail sections were installed on the Santa Fe and Pennsylvania Railroads in 1937, and that. in the annual reports of this committee, data were given on relative rates of wear and other performance characteristics of these various joint bar designs.

As a result of the information gained in these service tests and also of additional information gained in the rolling load tests conducted in the laboratory at the University of Illinois, the new joint bar designs were adopted last year for the 115 and 132-lb. rail sections.

As previously mentioned, these designs have effected considerable reduction in weight and economy relative to the older AREA designs for the 112 and 131-lb. section. We are confident from the results of the service test and the rolling load tests, that these new bar designs will give much improved performance in track.

However, to be sure of that and to have an accurate follow-up on these new designs, we arranged last year with the Santa Fe to install a service test of joint bars for the new 132 RE rail, and with the Chicago & North Western Railway to install a service test of joint bars for the new 115 RE rail.

The Santa Fe test includes the new AREA head-free design for the 132-lb. rail and two different Rail Joint Company designs. With the 132 AREA design, there are also included three different bolt spacings. One spacing is the old AREA standard with the bolt-hole 2½ in. from the rail end. A second one is 3½ in. from the rail end (the new AREA standard). Then the third spacing is one which is rather radically different. It is a 4-hole spacing for a 36-in. bar, having the bolts 9 in. apart.

On the test on the Chicago & North Western there is included the 115 AREA head-free design, and three designs of Rail Joint Company bars. In the 115 AREA design there are two bolt spacings, the new AREA recommended practice, and another test with a 4-bolt spacing for the 36-in. bar.

Last year stress measurements were made on the Santa Fe test, including joint bar stresses and web stresses around the bolt hole. This year similar measurements will be made on the North Western installation.

In addition, we will follow up with periodic measurements from year to year, as done previously, to obtain accurate data on relative performance of the various bar designs of these two sections.

These measurements will determine the rate of wear of the bars and rail and the relative performance with respect to maintaining joint surface and loss of bolt tension.

With respect to the joint bar wear and failures, in July 1939, a service test was installed on the Burlington Railroad near Fort Morgan, Colo. The purpose of this test was to determine the effect on preventing the development of cracks in joint bars of using different metallurgies.

In this test there were four different metallurgies. One was regular AREA chemistry and heat treatment. The second was the AREA chemistry and heat treatment, with the middle portion of the bar flame-hardened. The third was AREA chemistry but water-quenched and drawn. The fourth was a rail steel chemistry oil-quenched and drawn. Both of these latter two types of bars had the Brinell hardness increased from the ordinary range of around 225 to 275, up to a range of 325 to 375.

So far this test has been rather disappointing because we have had no cracks develop in any of the bars, either of the present AREA chemistry and heat treatment or of the other test metalurgies.

Our measurements of relative wear have shown somewhat less rate of fishing surface wear of the harder bars, but not to as great an extent as would be anticipated due to the relative Brinell hardness.

The remaining portion of this report has to do with the rolling load test conducted at the University of Illinois. Mr. Jensen, who is conducting these tests, will present that later.

This is presented as information.

Vice-President Schwinn: It will be so received.

Chairman Bronson: No. 9—Corrugated rail—will be presented by Mr. W. C. Barnes, engineer of tests of the Rail Committee.

Mr. Barnes: This report on Assignment 9—Corrugated rail: causes and remedy—is presented as information.

It gives a summary of the results of investigations made both here and abroad since before 1925, as well as of studies made by this committee from 1934 to 1936 and 1941 to date, all of which have been unproductive of any really tangible result.

The problem has reached the stage where future work would require a special appropriation for extended field investigations, the results of which are doubtful.

For this and for other reasons, your committee recommends as follows: Because the committee finds but little interest in this subject, except on one road, because no rail failures have been attributed to corrugations, because an appropriation would be required for further field investigation with uncertainty of determining the means of prevention, because riding quality is usually not adversely affected, and excessive corrugation may be removed by grinding, the committee is of the opinion that further study at this time is not warranted.

Chairman Bronson: Subject 10—Engine burn fractures—will be reported by Mr. Akers.

J. B. Akers (Southern): There is no report, Mr. Chairman.

Chairman Bronson: No. 11—Causes of shelly spots—will be reported on by Mr. Crane.

L. S. Crane (Southern): The assignment of subcommittee 11 is Causes of shelly spots and head checks in rail; measures for their prevention. This assignment is being jointly sponsored by the AREA and by the American Iron and Steel Institute, and is under the direction of subcommittee 11 but very actively controlled by a joint contact committee composed of members of Subcommittee 11 and members of the steel manufacturers' technical group.

Considerable work is being done by two major agencies, first, the University of Illinois and, secondly, Battelle Memorial Institute; the work at the University of Illinois being done by Professor Cramer and that at Battelle under Mr. Manning, both of whom are with us today and will give reports on their particular work.

So far, no definite answer has been found for shelling. There does seem to be some indication that gage corner shelling as evidenced by spalling of metal from the gage corner of the rail may be decreased by the use of heat treated rail steel.

To investigate this feature, which has already been done on a laboratory scale, field installations are now being placed on the Pennsylvania Railroad, the Chesapeake & Ohio and the Norfolk & Western. The Pennsylvania installation has already been made, and those on the N. & W. and C. & O. are expected to follow in a short period of time.

It is hoped that some answer to this problem, as far as gage corner shelling is concerned, will be obtained by means of heat treated rail, but it is recognized by the committee that the cost of such a solution will be excessive. We are still attempting to seek something which may be more desirable from an economic standpoint.

We also recognize that there is another major type of shelling, what might be referred to as detail fractures or transverse defects which occur at shelly spots. These seem to be on the increase and are certainly the particular type of shelling which is most dangerous, from the standpoint of broken rails and possible derailment.

So, the work of the committee has now turned to a close investigation of this particular problem. To this end, samples are being collected which will be forwarded to Battelle for investigation there, and some consideration is being given to an effort to do some fundamental research work into the problem of exactly what sort of stresses are causing these types of failures.

Some discussion has been had with Mr. Jackson, who is one of the outstanding stress analysts in the country, at Battelle. Some thought is being given to the use of x-ray detection of fractures. We expect within the coming year, possibly, to take some samples and subject them to those methods of analyses, with the thought of attempting to find out what the distribution of stresses is within our rail head, so we will have some way of knowing just what our problem is and what we have to do in order to solve it. We feel that that is the only way it can be done because otherwise we will be going at it hit or miss, with the hope of trying to come up with some possible solution.

There is some evidence that the modified head contours now embodied in the AREA rail design sections will give some assistance in those conditions of shelling where you might say a threshold condition occurs. We have installations of that type out in the track, which are being watched and which we hope will give us some information.

The research staff of the Engineering Division is also planning to make a survey this coming summer in an effort to find out just what scope shelling has on American railroads.

The committee has been somewhat surprised by statements made by railroads that they do not have shelling and, when we actually get out on the scene, we find things that we call shelling and which certainly are causing them quite a bit of difficulty. So, in order to assit people's thinking on the subject and to clarify the problem, the research staff hopes to have one of its men in the field this year to make a survey and see if we can once again review some of the statistical data which we had previously (and which did not give us very much information) and by that means bring some light to bear on the subject.

Vice-President Schwinn: Thank you.

Chairman Bronson: Next we have rail section studies by Mr. Code.

C. J. Code (Pennsylvania): The assignment of Subcommittee 12 is Recent developments affecting rail section. The work sponsored by this subcommittee resulted two years ago in the adoption of new rail sections and last year in the adoption of revised bolt hole spacing.

The first step was taken with the primary object of reducing or eliminating as far as possible split web failures of the rail outside of the limit of the joint bar, commonly known on most roads as head-web separations.

The second step was taken for the purpose of reducing the likelihood of split web failures in the joint at the bolt hole or simple bolt hole failures.

Certain additional work along these same lines was indicated as necessary: First, a field check on the results being obtained with the new rail sections, based on stress measurement; second, additional field work on stresses in the rail web within the joint bar; and, third, additional laboratory fatigue investigation is desirable as a means of tying together the results of field measurements with a sound theory of the cause of web failures both within and without the joint bar.

Additional field work is under way on the measurement of stresses as referred to by Mr. Magee, and this is described in Appendix 12–a.

Work is being carried out by the research staff with the cooperation of the Santa Fe and the Chicago & North Western. These tests include experimentation with a 4-bolt 36-in. joint, a possible development which was suggested by the desirability of getting the first bolt hole farther away from the end of the rail. Results are not yet available.

Fatigue tests are under way at the University of Illinois. Special features now being covered include ranges of stress encountered within joint bar limits and the effects of corrosion fatigue, using ordinary tap water.

The Pennsylvania Railroads' 140 PS section is being used for locations of severe service by several railroads in the east, other than the Pennsylvania. The Pennsylvania made stress measurements in track at a location where premature failures of RE 133 rail were occurring, first with the 131 RE rail in track and, second, immediately following the installation of the first 140 PS rail at the same location.

Appendix 12–b reports the results in considerable detail. These results are deemed to be of sufficient general interest to be included in the report of this subcommittee and fit in very closely with the assignment. Charts are included which show a direct comparison of web stresses in track for 131 RE rail worn 1/8 in. versus 140 PS rail new. These charts, Figs. 1, 2 and 3, are given for three classes of heavy freight locomotives. Figs. 4 and 5 show a comparison of stresses in the two rail sections based on laboratory stress measurements.

Table 1 shows the comparison of stress for the new section in new condition versus the oil section with 1/8 in. wear, based on service tests. The reduction varies from 35 percent to 48 percent. The theoretical reduction based on laboratory tests for this condition is 45 percent and 46 percent. The heaviest and most damaging stresses in service were reduced 40 to 42 percent.

Tables 2 and 3 present data of a type which has not been previously reported, namely the number of cycles of stress of each magnitude experienced in a year's time in track. Data of this type are particularly valuable for purposes of comparison with laboratory fatigue results.

In the conclusion of Appendix 12–b it is stated that the reduction in stress which it was sought to make has been realized in track, as shown by service stress measurements. Service experience will, of course, ultimately determine the value of the new section.

The report is presented as information.

Vice-President Schwinn: It will be so recieved.

Chairman Bronson: This Association is spending a considerable sum of money for important research work. While it is a little bit out of line with normal procedure, we decided we would wind up this report work with the presentation of work done at the Battelle Memorial Institute and the University of Illinois.

Incidentally, I want to say this: This work is being conducted and carried on progressively and successfully by a group of relatively young men, and the first man we will call on will be Mr. Manning of Battelle Memorial Institute who will give you an idea of the work that is being conducted there. Mr. Manning!

G. K. Manning (Battelle Memorial Institute): During the past three years Battelle has examined some 200 shelly spots. These shelly spots have been selected by walking along the track, picking out black spots, having the rail removed from track and the specimens sent to Battelle for examination.

It was quite surprising to us to find that all of the defects so selected had only horizontal cracks in them. We had expected that quite a number of them would exhibit vertical components.

What was even more surprising is that we have yet to find among defects so selected by the groups of black spots, any that are bright and unoxidized when laid open. All of them were corroded; all of them had been opened to the surface of the rail at the time they were removed from track.

Furthermore, in examining the gage corner of the rail, we found on almost every rail many small defects. These were found with the use of the microscope; they were all too small to see by the unaided eye. They penetrated the rail only a few thousandths of an inch.

We think these are potential points of origin of the type of defect that is represented by a horizontal crack. We have been forced to come to the conclusion that these horizontal cracks originated at the surface and gradually penetrated into the rail. We do not know that such horizontal cracks never turn downward, but at the present time I think there is very meager evidence that would indicate they do turn down. Obviously, this is not the full story.

Those of you who followed the rails removed by detector car know that very frequently you find small cracks near the gage corner of the rail that are bright and unoxidized and that have both the vertical and horizontal components. You have termed this type of fracture, detail fracture.

It appears at the present time that, very likely, there are two distinct types of fractures that occur near the gage corner of the rail. One is the horizontal crack that starts at the surface and grows inward—very likely continues in a horizontal plane. You see it in the field as a black spot. The other is the detail type of fracture that has both the horizontal and the vertical component. In its early stages you cannot see it in the track with the unaided eye. You pick it up only with the detector car.

Of the two types of fractures, the more hazardous is that which has the vertical component. For that reason, the joint contact committee decided that Battelle should redirect its work and study intensively this type of defect which you term detail fracture.

A number of roads have been requested to send typical examples of detail fractures into Battelle for examination. From these samples we expect to determine more about where the defects originate, perhaps something about the way in which they grow.

We would like, also, to determine whether they are associated with any abnormal condition in the steel, such as nonmetallic inclusions or segregation streaks.

In addition, we will determine the mechanical properties of these rails which develop detail fractures.

A number of roads have also been asked to send in a group of random samples of rail, rails that developed no detail fracture and that were rolled since 1940. Mechanical properties of this rail will also be obtained and will be compared with the mechanical properties of rail that developed detail fractures. Thus we will attempt to establish whether or not rail developing detail fractures is deficient in some respect, in mechanical properties.

Mr. Crane has already mentioned to you that the joint contact committee is at the present time considering doing some additional work directed toward determining the stresses which exist and which develop in the head of the rail.

I hope that by this time next year I may give you a more complete picture of the situation.

Vice-President Schwinn: Thank you, Mr. Manning.

Chairman Bronson: The work being conducted at the University of Illinois will now be presented by Professor Cramer and Mr. Jensen.

(R. E. Cramer and R. S. Jensen, University of Illinois, gave illustrated talks on Assignments 6–a, 8–a and 11–a.)

Chairman Bronson: While this completes the report of the Rail Committee, I would not let this opportunity pass by without expressing my sincere appreciation for the wonderful cooperation I have had from the members of the committee and from the research staff. I know it augurs well for those who are going to take active direction of this from here on.

Vice-President Schwinn: Mr. Bronson, this completes your term as chairman of this committee. On behalf of the Association, I wish to compliment you for your continuing enthusiasm for the work that your committee has been doing.

I also thank all of the members of this committee for their part in this most important work. You are now excused.

Discussion on Wood Bridges and Trestles

(For Report, see pp. 453–456)

(Vice President Schwinn presiding).

Chairman C. V. Lund (Chicago, Milwaukee, St. Paul & Pacific Railroad): The report of this committee will be found in Bulletin 478 beginning on page 453. Your committee is reporting progress this year on three of its assignments, on Revision of Manual, on Assignment 2 dealing with grading rules and classification of lumber for railway uses and specifications for structural timber, and on Assignment 3, Specifications for design of wood bridges and trestles.

Considerable study has been made on the remaining assignments relating to improved design of timber trestles and instructions for inspection of wood bridges and trestles and methods of fireproofing wood bridges and trestles, including fire-retardent paints. We hope next year to offer you some progress on those subjects.

Before proceeding with presentations of the reports, I wish to record the loss to this committee and to the Association during the past year of a valued member, Mr. Alfred Alexander Visintainer, whose memoir appears with the report of this committee.

Mr. Handsaker, the chairman of the subcommittee on Revision of Manual, found himself unable to attend the convention. I will therefore present the report on Revision of Manual.

Your committee is recommending for deletion that material which appears on page 7–64 of Chapter 7, titled Relative Economy of Repairs and Renewals of Wood Bridges and Trestles. The text under that title consists of one sentence only, to the effect that it is economical to repair wood bridges and trestles until such time as the structure requires a new one entirely. Your committee feels that is an accepted practice, and that the material that appears in the Manual serves no useful purpose in its present form.

I move the material appearing under the text of Relative Economy of Repairs and Renewals of Wood Bridges and Trestles be deleted.

(The motion was seconded, put to a vote and carried.)

Chairman Lund: Your committee recommends for readoption, with minor revisions, that material which appears on page 7–69 under the title, Standardization and Simplification of Store Stock and the Disposition of Material Reaching Obsolescence. The following revisions are recommended, some of which are editorial in character.

Under paragraph 4 we revise the language to introduce the words "where suitable" with respect to the use of treated pile butts and other work, including building and frame truss members.

Under paragraph 5 we have made revisions in language, principally.

Under paragraph 8 we have inserted the words "and piling" following the word "timber" with respect to the carrying of emergency stocks at other than general supply yards, recommending that the treated piles also be carried.

I move that this material be reapproved, with the revisions.

(The motion was seconded, put to a vote and carried.)

Chairman Lund: That completes the report of the Subcommittee on Revision of Manual.

Under Assignment 2, Grading Rules and Classification of Lumber for Railway Uses: Specifications for Structural Timber, your committee has given considerable study this year to certain revisions that have been made to Miscellaneous Publications No. 185 of the Forest Products Laboratory as it relates to structural timber. Our present specification, as you know, is based on the recommended working stresses for clear material of the laboratory and during the past year some revisions have been made and issued as a supplement to this publication. Mr. Austill, chairman of the subcommittee will present the report.

H. Austill (Terminal Railroad Association of St. Louis): This subject was first assigned to Committee 7 in 1918. In 1919 the report on Assignment 2 was made in a unified set of specifications for construction timbers and building lumber for use by railroads, showing each kind and quality of lumber and timber which is suitable for each of the different classes of work on a railway.

At that time, there was a special committee on grading of lumber. In 1919, Committee 7 submitted a set of grading rules. In 1920, the committee submitted a set of specifications and classification of grading rules for lumber and timber to be used in the construction and maintenance of railway fixed properties, to which was appended a table of working stresses permissible for structural timbers. In 1921 these grading rules were adopted for the Manual, with amendments, the United States Department of Commerce Simplified Practice Recommendation No. 16 covering American lumber standards becoming effective in 1924. The committee submitted to the Association in 1925 as information, general rules for structural grades of timber and these rules were adopted for the Manual in 1926. In 1935 tentative AREA structural grading specification and stress grades were presented as information and in 1936 specifications for grading structural timbers on the basis of unit working stresses were presented by the committee and adopted for the Manual. With mild changes, these specifications have been in effect since that time. This was a long step forward and while, because of pressure from different sources, the railroad purchasing departments very seldom quoted these specifications in ordering timber, they have served as a helpful guide to engineers, and engineers were quick to adopt stress grading in designing.

The report on this subject is in the nature of a promissory note and is printed on page 455.

When we consider the present condition of many old culverts, highway bridges, and other structures that have been in service up to 100 years (many railroad trestles of treated timber have been in service now over 50 years) it rather amazes me to note how many people consider timber as a temporary structural material. Now, the Forest Products Laboratory at Madison has done some very valuable work recently and this committee intends this next year to present you with a specification that ups working stresses slightly. I will not be on this committee at that time, but I hope to see favorable action when that report comes in. Thank you.

Vice President Schwinn: Thank you, Mr. Austill.

Chairman Lund: We have on our committee Mr. R. P. A. Johnson, who is chief of the Division of Timber Mechanics at the Forest Products Laboratory. In order to acquaint you more fully with the revision that the laboratory has recommended, I will ask Mr. Johnson to elaborate on that matter at this time.

R. P. A. Johnson (U. S. Forest Products Laboratory): Mr. Lund has asked me to give you a rather brief synopsis of the work that we have been doing on working stresses over the last year. I am multiplying that time by three because we have been reviewing them for about three years. Mr. Austill has told you that your working stresses, which are also the working stresses of the ASTM, have been in use for about 30 years and they have been giving, as far as can be determined, highly satisfactory service. Those working stresses were obtained from basic stresses for clear wood determined from tests of small clear pieces, modified to provide for the injurious effects of defects as determined by tests of structural timbers.

The basic stresses for clear wood were obtained by applying a reduction factor to laboratory figures in order to adjust them for the conditions to which timbers are subjected in service.

The reduction factor takes care of the variability in strength, the effect of long continued loading, and the factor of safety. The adjustment for variability is made by reducing average values 25 percent; that is, multiplying them by ¾. The adjustment for long continued load is necessary because wood is a peculiar structural material in that it can sustain a much higher load over a short period of time than it can over a long period of time. To adjust for the difference between the strength obtained in a short-time test in a machine in a laboratory and its strength over the long period load it carries in service, the averages are multiplied by 9/16. Lastly, the averages are multiplied by 3/5 for a so-called factor of safety of 1.66. Multiply all those factors together and the result is a reduction factor of 4. That is the reduction factor applied to average values to obtain the basic stresses for clear wood in bending. I have given in detail the items in the reduction factor because we have been re-evaluating those factors for the past three years.

There came a war and we were suddenly confronted with a shortage of lumber. The Army (to conserve lumber) hiked its stresses for what it called theater operations construction by reducing the assumed loads, by designing for an 1800-lb. grade and using a 1200-lb. grade, and by increasing the working stresses; in some cases the stresses were hiked as much as 85 percent. To further conserve lumber the War Production Board issued Directive 29. That directive prescribed working stresses for timber used in buildings, 20 percent higher than the stresses that had been used in the past. They differed from your working stresses or those of ASTM in that they were mandatory. They applied only to buildings, not to railroad structures. At the end of the war, the authority behind Directive 29 expired and Directive 29 was withdrawn. The question was then raised as to whether the working stresses should remain at the elevated point to which they had been raised by Directive 29 or go back to their prewar level, or to some intermediate level. The Forest Products Laboratory study was made to obtain an answer to that question.

We first attempted to find out what effect the increase in stresses had on several billion dollars worth of wood construction which had been erected by the Army and the Navy. The Army cooperated with us and surveyed and reported on the condition of all buildings erected by it in the United States, listing the failures that had occurred and their cause. We made an airplane survey covering a large number of the Navy structures. We also made a rather general survey of civilian war construction, largely dwellings. Those studies, which were made to try to determine whether the high working stresses used had been satisfactory or had been dangerous, give what you might call a negative result. We found it was impossible to obtain information as to what the actual loadings were where failures had occurred. We therefore were unable to say that the working stresses as such had been responsible for failures.

We did, however, find out a number of things that were helpful. We found out that the principal causes of failure were inadequacy in design, poor fabrication and the use of green lumber of lower grades than were called for by the design. A summation of the entire findings of the surveys indicated that the wood had performed very satisfactorily and no failure had occurred because the working stresses assigned to a grade had been too high.

The next study undertaken was a reanalysis of all of our previous strength data, and in addition an anlysis of the results of some 2500 tests of structural timbers made by the Canadian Forest Products Laboratories which were kindly furnished to us in considerable detail. I told you that we multiplied our average figures by ¾ to take care of variability in the strength of wood. In our analysis of structural timber tests we used an exclusion factor. An exclusion factor of 0.0 would mean that you were basing stresses on the poorest timber tested.

The engineers we contacted agreed that was not necessary. The question was what exclusion factor should be used. It is a question of engineering judgment and opinion. We finally decided on an exclusion factor of 2 percent. Rather peculiarly, we found that an exclusion factor of 2 percent on structural timber tests gave the same result as the 25 percent reduction for variability formerly used on small clear tests.

During the war we made a large number of tests to determine the effect of the duration of load upon the strength of timber. Some of those tests were conducted in 1 sec. Some of them have run over a period of 2 years. In the 1-sec. tests, we got as many as 25 points on the load-deflection curve by the use of a high speed motion picture camera combined with some ingenious equipment. The result of those tests indicated that working stresses could be increased when the period of loading was short. As a result of those tests the Air Forces have been using an increase of 17 percent in working stresses due to the short period the maximum load remains on a plane.

Lastly, we made a study of the so-called factor of safety. The factor of safety is largely a question of engineering judgment. The factor used with wood has to cover a number of things. Among them are slight errors in design, design tolerance, off grade, overloading, and undersize. Some engineers told us "We don't have a design tolerance." If you question them in detail, however, you find they will accept one or two percent tolerance to cover possible errors in grading.

We considered whether provision should be made in the factor of safety for poor workmanship and poor design. Many of the structures inspected, even those built by excellent contractors, had some poor construction. It seems to be almost impossible to build a building without somebody slipping somewhere. We came to the conclusion that it was impractical to make a specific allowance in the working stresses for poor design and poor fabrication. There is no place to draw a line. You can have poor workmanship that will reduce the strength of a structure to half of what it should have been and the same is true with poor design.

We made a study of probable overloading, probable error in grading, and amount of offsize. A questionnaire was sent out by the National Lumber Manufacturers' Association to get engineers' ideas as to the probable frequency and amount of overloading. Graders and members of the lumber industry gave us data on the maximum error to be expected in grading. There was available a study on variations in sawing that furnished data on offsize.

In our study of the factor of safety, we were trying to evaluate certain individual items which are covered by it. After we obtained figures on the size and range of the factors, we tried to find out if we could combine them and obtain what I will call the adequacy of a structural timber; that is, what are the chances that these factors will all occur at once or that any combination of them will combine to cause failure. That meant we had to get some of our high-powered mathematicians to try and figure out what the probability was of a combination of probabilities occurring. One probability is fairly simple mathematically but two of them mixed up together are complicated. They finally made a mathematical analysis which gave us a pretty accurate method of computing the probability of failure of a structural timber. Unfortunately, that mathematical method is only as good as the judgment that goes into the assumptions as to the variation in the items in the factor of safety. The variations of grading, overload, fabrication, and so forth, are a matter of judgment. Our analysis, however, did aid us in arriving at a decision on what factor of safety to use in obtaining working stresses. We hope eventually to develop the method so that you can use your own values for the variability of the factors involving judgment and compute your own probability of failure.

As a result of our studies, we worked out a new set of basic stresses. Then we consulted with the members of AREA Committee 7, with consulting engineers, members of the faculty of the University of Wisconsin, and with the staff of the Canadian Forest Products Laboratories to obtain an over-all judgment on the recommendations which we were making. We modified our findings somewhat, as a result of those conferences, and came out eventually with a recommendation for an increase of 10 percent in the bending and shear stresses, no increase in the compression parallel or perpendicular stresses or the modulus of elasticity. We believe our recommendations are conservative. There are many who believe that the increases could be much higher.

A point I would like to emphasize in closing is that many of the engineers and others contacted seem to feel that a mathematical formula could be worked out into which you could insert data from laboratory tests and come out with a safe working stress.

That, gentlemen, is a fine idea, but I never expect to live to see it accomplished. It is impossible to work out a working stress that will work efficiently and safely in all cases without the use of engineering judgment. You, gentlemen, are engineers; the Lord gave you brains, and we haven't found any mathematical formula that is a substitute for them. Thank you. (Applause)

Vice President Schwinn: Thank you, Mr. Johnson, for a very interesting discussion.

Chairman Lund: I think from Mr. Johnson's remarks, we can appreciate that the preparation of a specification for structural timber for use for this Association is quite a difficult matter, and during the course of the coming year we hope to bring it to a definite conclusion for your approval a year hence.

Under assignment 3 relating to specifications for design, we have abstracted for you what seemed to us to be the highlights on the work by the research staff of the AAR on timber trestles and timber ties. In his address today, Mr. Chapman reviewed briefly the results, and Mr. Johnson has covered them also in his recent remarks. One thing we perhaps want to emphasize is that our concept of impact in timber has changed. The word "impact" is somewhat a misnomer in itself in that in railroad loading we have rather a rapidly applied loading, but a measurable duration and cumulative effect of duration on timber is the same approximately as if the load were continuously applied for a like period of time. The work in testing of timber structures is in its infancy, and we are not any of us in a position at this time to draw any conclusions. The research staff plans additional work during the course of the year.

Mr. Chairman, that concludes the report of Committee 7.

Vice President Schwinn: Thank you, Mr. Lund, for a very interesting and informative report by your committee which is now excused with the thanks of the Association. (Applause)

Concluding Business

(President Mottier presiding).

President Mottier: The first speaker needs no introduction to this audience. In fact, on September 1 he completed 11 years of service on the research staff of the engineering division. I believe there are very few men identified with railway engineering in this country who are as well known.

When we were formulating this program, I asked Mr. Magee if he would give us a talk on the future of research. I asked him if he could prepare a good address on the subject and he replied that he thought he could. So, about a week ago I called him up and asked if he was all set, and he said he was. I asked, "Is the address any good?" and he replied, "Well, I think it is pretty good. I am pretty well satisfied with it."

I am sure Mr. Magee, research engineer, AAR, will give us a good address on the subject, The Future of Research on American Railroads.

The Future of Research in the Railway Industry

By G. M. Magee

Research Engineer, Engineering Division, AAR

Today the railway industry is research minded as never before. This is evident from the interest shown by the railways in our Association research activities, in the substantial increase in appropriations for research work in recent years, and finally by the decision this year to build a $600,000 laboratory in Chicago from which the research work of the Association may be directed.

Research offers the railway industry about the only opportunity to meet all the difficulties with which it faces the future. It is imperative that we organize and plan our research future so that we may take the fullest advantage of this opportunity with all possible means at our disposal.

When we think of our research future, we should not confine our thoughts to research activities of the railways alone or of our Association, important as they are. Our thinking should be broader than that—should embrace every possible research source from which benefits to our industry may ensure—and there are several important agencies which we must include in our plans.

Learn What Others Are Doing

First, the volume of research activity being carried on in all industries today is tremendous. This offers us two opportunities. On the one hand, we must keep in intimate touch with this vast activity so that we may apply new discoveries in our industry for our own benefit and avoid wasteful duplication of research that is being carried on elsewhere—perhaps better and, on a more extensive scale than we would be able to do ourselves. We should actively encourage research by other industries because as users of some 80,000 products, there is not a new discovery by any industry that may not offer possibilities for improvement in railway economy, service or safety. We can offer this encouragement by cooperating with other industries in their research work and by being keenly receptive and willing to try out new materials or equipment that may be developed.

In the past few years, we have had several examples of research developments by other industries working in collaboration with the railways that have resulted in notable benefits to the railway industry. The development of the diesel locomotive has contributed immensely to railway economy and to the attractiveness of railway travel to the public. The diesel locomotive, however, is in its infancy. There is much further development work that needs to be done, in much of which the railway industry may be of help. There are such problems as the treatment of the cooling water, treating the water for heating plants and obtaining sufficient heating capacity, improvement in lubricating oils, etc. The future will see a continuing solution of these problems by industry, using the railways as the "proving ground." In the future development of the diesel, I think it not unlikely that the present 3 and 4-unit locomotives will be replaced by a single or dual unit. Opportunities are offered us in this connection to work with the manufacturers in developing wheel and truck arrangements which will give the best riding condition with minimum maintenance costs on the locomotive and track.

Another noteworthy development of industry has been the new designs of passenger cars. Provision of trucks equipped with long-travel soft springs, snubbers and cross-stabilizers has provided a remarkably smooth ride at speeds of 95 or 100 mph, without requiring an excessively expensive standard of track maintenance. Luxurious seats, attractive and restful decorating, the cleanliness and comfort of good air conditioning, full vision windows, greatly improved toilet facilities—all, as combined in these new passenger cars, provide a riding comfort and pleasure to railway travel never dreamed of before, which will unquestionably result in increased passenger travel and revenue to the industry.

The development of centralized train control is a remarkable research achievement of industry. It has not only effected important economies in railway operating costs by virtue of more intensive use of existing trackage, but has also reduced delays in train operation which are always a source of annoyance to passengers.

Many other examples of industry research developments of great importance to the railways could be cited, but those mentioned serve to show how important a place we must assign to research by other industries in planning our research future.

Research by Universities

Another important place must be assigned to research carried out by universities. In my opinion, we should depend upon universities to contribute largely to the fundamental research in our country. Fundamental research is necessary for the progress of our country and for our industry. The most important requirement for successful fundamental research is the ability and capacity of the research scientist. Next, he must have the proper environment and facilities to carry on his work. He must be directed by men of broad vision who recognize that he is an artist, not a production machine, and who endeavor to provide proper objectives and facilities, but not a schedule. The expense of fundamental research is considerable and the date at which definite results are obtained is uncertain. But it is research that is necessary in our research future, and in my opinion we may well depend upon universities for it. In addition, we may also depend upon universities for carrying out many of our investigations requiring engineering or applied research. This has been our practice for many years past, and I think we should continue it in our research future. It offers the advantages of utilizing existing facilities and selecting personnel specialized in a particular field—both of which are important.

We should also include in our thinking for our research future cooperation with other industries in conducting research on matters of mutual interest. Opportunity for this is afforded by several organizations. One such is the Engineering Foundation, an organization of the five large engineering societies in this country. It is a function of the foundation to establish research councils on engineering matters which are of interest and related to many different industries. Examples are, the Welding Research Council, Research Council on Riveted and Bolted Structural Joints, and the Column Research Council. These councils bring the best qualified engineers from many industries together to collaborate in the direction of the research and provide for sharing its expense. Cooperative investigations of this kind offer an economical and efficient means of progressing research, and I think they have a definite place in our research future.

Our Own Field of Endeavor

In planning the future research activities of our Association, it seems to me there are certain fields of research which are definitely in our province—research which we can either carry on better than others, or which no one else will carry on if we do not. It is our proper field in the railway industry to determine by research investigations just what characteristics are required in the various materials which we use—what tensile, impact, or fatigue strength, ductility, hardness, temperature resistance, corrosion resistance, etc. We are then in a position to inform other industries of these requirements and depend upon them to develop materials to meet our needs, collaborating as may seem advisable. It is also our proper field to study the designs in which the materials are used to determine whether the design assures the most effective use of the material or whether improvements could be introduced which would make for better service life or performance of the product.

With respect to future research work in the Engineering Division, I feel that we have a very sound program established and that in general the projects upon which we are now engaged offer good prospects of producing important benefits to the industry. Our budget this year has been increased to almost $400,000, which provides a substantial scale of research activity. In my opinion, however, the future will see this annual expenditure increased to perhaps as much as 2 million dollars a year for the Engineering Division alone. I believe this rate of expenditure will be required to develop fully all the opportunities and possibilities for improvement which are offered by research. The new laboratory building is, in my opinion, a very constructive step. If, however, the results of our increased scale of research activities materialize, as I fully expect them to, I anticipate in the future to see this building as the nucleus about which have grown up many more buildings and research facilities for our Association to serve the railway industry.

The AREA Committees

The committees of the American Railway Engineering Association have an important part in the research future of the railway industry. These committees are composed of well trained engineers seasoned by years of experience in railway maintenance. Working in collaboration with the research staff, the committee members have provided invaluable counsel in selecting research projects, planning the program, carrying out the work, analyzing the data, and putting the results into effective use. To develop the full possibilities offered by research, I would like to urge our committees to take an especial interest in initiating new research projects. Any major item of maintenance expense offers opportunity for research benefits. The total maintenance of way expense for the railway industry last year was 1350 million dollars. There are lots of possibilities here. Our research staff has been created to work with the Association committees to bring these possibilities into reality. Do not hesitate to call upon our staff for any research assistance required—either research that we can carry out for you, or that we can arrange for other industries or institutions to carry out.

This is the future of railway research in the railway industry as I see it—a fusion of the vast research of industry, the fundamental and applied research of universities, cooperative research with others, and the specialized research of our Association—all combined to maintain a prosperous railway industry, efficiency and economically managed, and to provide the safest and best railway service in the world to keep our nation great.

President Mottier: Thank you very much, Mr. Magee. We are all very interested in our research program and are pleased that we soon will have a new research laboratory. One thing that has pleased us very much recently is the fine cooperation that exists between the AREA and the AAR, primarily as the result of our research program. I spoke just yesterday to Mr. Aydelott and Mr. Faricy about it. This past year, we had several articles in our anniversary series bearing on the joint AAR–AREA research activities. We will furnish the brains, if they will furnish the money. On this basis we should get along very well. I prophesy great things in the next 50 years for the American railroads, growing out of this joint research effort.

President Mottier: At this time we have a pleasant surprise for you. I know you will all enjoy it. Just before we opened this morning, our patriarch from the Pacific Coast asked if he might have two or three minutes to express his appreciation to our Association. By this time you should all know Mr. Campbell. I think the last convention he attended was in '41. He may tell you this, so perhaps I should not detract from his speech, but I have heard him tell how regularly he attended our meetings during his more active life. In recent years, for obvious reasons, he has not been able to attend. But on account of our 50th anniversary, he wanted to come. He is eighty-six years old. He has come all the way from the Pacific Coast. We are glad to honor him and to give him this opportunity to address us and I am sure we will be edified.

It is no reflection on his octogenarian energy to suggest that this may be his last appearance at an annual meeting of the AREA. Mr. Campbell!

(The audience arose and applauded.)

J. L. Campbell (Past President): Mr. President, Members and Guests: Consulting my schedule and the railroad timetable, I find that I should say "Until we meet again."

My last appearance at the annual meeting was in 1941. After this long absence, the generous warmth with which you welcomed me back to this familiar ground impelled me to ask for this opportunity of expressing my deep appreciation.

At this annual meeting, I observed with pleasure the smoothness and precision of the presentation of committee reports. There is a reason for this. The early years of the Association work were devoted mainly to reduction of various standards and practices to some degree of standardization.

Then the Association faced the higher plane of its work in the field of research and testing of the materials, tools and methods of railway transportation. This required collaboration with the technical staffs of universities, institutes of technology, and manufacuring processes. Such community of research has been established.

The work of the Association is growing in precision, distinction and value. This is the reason why there is now little discussion of committee reports on the floor of the convention.

I also observed with admiration the poise, the quiet assurance and the efficiency of the presiding officer in conducting this annual meeting. This prompts me to say that, when President Mottier came into the Association 30 years ago, I marked him as a young man who would rise to eminence such as he has since attained in the service of the Illinois Central Railroad and in this Association. And now, in this golden jubilee year, he has the honor and the satisfaction of bringing to brilliant consummation his able administration of Association affairs.

Finally, I again find that I should say "Until we meet again." I thank you.

(The audience arose and applauded.)

President Mottier: Thank you, Mr. Campbell.

I think Mr. Campbell has given us an excellent preparation for what is to follow. You have all seen our slogan—if you have not, you can look at it now—"A Past of Achievement—A Future of Opportunity."

In the past three days we have given much thought to our past achievements. They were summarized Tuesday night by Mr. Clarke.

In order that we may give proper recognition to the second phase of our slogan, "A Future of Opportunity," we are now going to have Mr. E. M. Hastings a past president address us.

Mr. Hastings! (Applause)

The Future Opportunities of the AREA

By E. M. Hastings

Chief Engineer, Richmond, Fredericksburg & Potomac Railroad

Over on this side of the beautiful banner that is spread out before us is "A Future of Opportunity." I wonder whoever had an idea that anybody could gaze into a crystal ball and see just what lies out ahead of us, particularly having gone through the year 1948 and now entering a third of the way into 1949, when there has been so much confusion everywhere, there has been so much thinking along the lines of what many of us do not like, particularly, and many of us very definitely dislike, specifically.

Before I launch out into some of the material which I have written down, I want to say something to the young men who are here. The work of this Association, as is the work of any great organization of men or women, is never finished.

I used to be irked when I would hear a committee come to this platform and present a report and make a recommendation that a subject be dropped, when it seemed to me that the potentialities of that subject had just been skimmed and only the cream had been taken off. So, do not any of you young men think that, because 50 years have passed—grand years, yes, and magnificent achievements—we have, by any means, plumbed the depths because out ahead of us there are those things of which no one knows the magnitude and no one knows just how much this Association can contribute in the years to come.

You know, we are a peculiarly fitted group of people. We men and women of this American Railway Engineering Association, because of the very training that we have had through the years, and those of you who are just beginning to get your training, because of the educational background that you have had, because of the practices that you have gone through in the years of your experience, are peculiarly fitted to carry on into the days ahead. The thing that worries me about the whole situation that stares us in the face today is that we might become complacent and satisfied and feel that a job is done. It is never done. There is always something that is out in front of us.

A much quoted, probably one of the most unselfish and liberal speeches ever made in the history of this nation, was the utterance of Patrick Henry when on that April day of 1775 he stood in old St. John's Church in my home city of Richmond, Va., and among other things, said, "I have but one lamp by which my feet are guided and that is the lamp of experience. I know no way of judging the future but by the past." Many liberals of today would consider such a statement entirely too narrow and conservative and would contend that no progress could be made if we adhered to such a principle. Let us look at it for a moment in careful appraisement of its real significance. He was a young man looking forward to the making of a new nation; his past experiences were not many, yet each one of them enabled him, by using it as a lamp for his guidance, to form ideas for the future. Some of his experiences were not so good, others were bitter indeed, yet I discern from his utterance that he had plumbed the depth properly—as some writer has said, "We are what we are from what we have experienced and rightly understood. All experiences are good, the bitter ones sometimes best of all." The experience of the days that preceded that April 1775 and those that followed gave the light to guide the man that we quote, and other of the Country's great that lived with him and followed after him, so that down through the years there has been builded the greatest nation the world has ever known.

He chose the hard way, and it was extremely hard in the days in which he lived. Will you and I choose the hard way in 1949? I think one of the finest things that I have ever read, I read just recently, sent to me by a very fine friend of mine, and I am going to read it to you.

Back in 1937, a friend of the late Senator Josiah Bailey, of North Carolina, asked him why he deliberately bucked the New Deal when it would be so much easier and profitable to go long with the tide.

The reply constitutes this thing which I think is the grandest thing that I have ever read. It was reprinted in the Winchester Evening Star on November 3, 1948, showing that it is not anything ancient; it is right down to date. The Winchester Evening Star, as you know—maybe some of you do—is owned and edited by Harry Byrd, Jr., the son of our distinguished Senator from Virginia. Here is Senator Bailey's declaration:

I Remember

"I remember one Pontius Pilate. He pleased his crowd and let them slay their best friend. He went the easy way. So he held the governorship. I do not admire him but he was a smart politician.

"I can remember one Peter, a fisherman, who declared to the people demanding that he agree: We ought to please God rather than men. He went the hard way. They tell me he lost his life on a cross. But I admire him.

"I remember Christopher Columbus, the majority of whose sailors demanded that he turn back, but who nevertheless pressed on. He went the hard way. But he was most unpopular with his crew. But he discovered America.

"I remember Robert E. Lee, who refused the command of the Union Army, and all the rewards of the national gratitude, to do his duty to his State. He went the hard way. There were some who called him a traitor. And there are those to whom he is an inspiration.

"I remember Moses, who chose to dwell in the tents of the wandering tribes of Israel rather than the palaces of the Pharaohs. He went the hard way. He died in the wilderness, but God gave him a mountaintop to die on, and he is still on the mountain.

"I remember Him who said to the Pharisees, 'Your fathers stoned the prophets and you build monuments to them.' He knew the hard way. He died on the instrument of the slave's torture. But all men look to Him on that cross.

"None of these were popular men. They, unlike Pilate, went against the tide of public opinion. None of them was ever governor.

"So, if I have made my choice, you must say that I chose the hard way; that I did not choose it because I was a fool, or wilfully; that I chose it unselfishly, but for the people who have trusted me and honored me."

I commend to you young men, particularly, as you forge forward into the future, that you choose the hard way. It is always the best.

The American Railway Engineering Association has, through the fifty years of its work, been constantly progressing and building upon the foundations of experience and determination to accomplish the things needed for the American Railroads. Consequently should we not use that experience as the lamp to guide our feet in the years ahead of us? How should we start? To ask that question gives the opening for the answer—through education and the full use of capable young men as they come out from our colleges and universities. The future of our profession as it is applied to and used by the American Railroads is dependent to a large degree on the extent that we use the talent that is annually available to us if we will make the effort and convince the executives of our railroads that the trained mind of the engineer is a resource that has great powers of expansion such as will be needed to meet the constantly increasing pressures that are abroad in the land. The Association has this very work under way in the studies that are going on through Committee 24. I do not think we can emphasize too strongly the fact that we must formulate some plans or present the ideas that will bring to us increasing numbers of young college men out of which group the future administrators and executives will develop.

Results of Research

Again we find oil for the lamp that is to guide us in the splendid results that are coming to us through research. Opportunities for the future are almost unlimited if we will use to the fullest those resources that are now ours and project them forcefully into the years ahead, remembering always that there will be many failures along the way and no doubt some reverses and disappointments, but the general movement will be forward if we are determined to make it so. Right here let me say to you that some of the greatest human tragedies I have seen are a few men I have known who, because of some set-back or disappointment, have been unable to reach out over it and gain another hold, hence have slipped back into oblivion; a few others have stayed stationary although the railroad progress through research had passed them and is away out ahead. All of which is said to challenge you not to pass by anything that research and development may bring forth simply because you do not think there is much in it.

Again we find oil for the lamp that is to guide our feet in the experiences that are gained by our younger men as they work at their jobs. Some of the experiences may produce a light that will push us ahead in the practical knowledge of how to do things and do them better than they have been done before. None of us are too old or will ever be too old to profit by the daily experiences of those who are working under us; what I am trying to say to you is that future opportunities can be stymied if we, each of us, do not give encouragement and support to the efforts and ideas of the men that are envisioning the days ahead and how to better the practices of the past.

The road out ahead of us seems to me to be lighted all along the way with many lamps that offer opportunity to this Association through the work of its committees to vastly improve the make-up and maintenance of our railways; one of the bright lights is to found in the development of more and more machines to do the work that through the years has been performed through labor of man; our past experience has shown us that the trend is to do less work and get more pay, therefore if we progress economically we must use less men and more machines. Mechanization is the slogan of the present and the future to me calls for greater mechanization and increasing use of off-track equipment.

A More Permanent Track

We need to be constantly striving in the future to get a permanent track, if possible, but strive to get especially one that does not need such frequent and minor repair; I say this because we are facing the advent of the five-day week in the railroad industry —to meet it we should prepare ourselves to get along with just five days of work in just as many phases of the railroad maintenance as possible. This can come about by the development of things more permanent. Several of our committees can do a great deal to bring this about, particularly the Committees on Track, Roadway and Ballast, Masonry, Steel Structures and others all down the line.

While I have not been too specific about many things bound up in the future of this Association I have endeavored to throw out to you some thinking in the hope it will encourage your vision so that the days ahead will broaden you to the extent that we will be ready for each day that comes and find in it something for tomorrow. Someone has written:

> "For yesterday is but a dream, and tomorrow is only a vision; but today, well lived, will make every yesterday a dream of happiness and every tomorrow a vision of hope."

I commend to you young men that are out here in front of me that there has never been any time, since I have been active and trying to think and to become more familiar with many of the problems of the world, that we need to do something every today that we live, so that tomorrow will be a vision of hope and that the yesterday, when tomorrow comes, will be the dream of happiness. Did it ever occur to you that it is always today? It is always today. Tomorrow, as I am nearing the city of Washington on my way home, is going to be today, yet today I am here with all of you in Chicago.

Young men, make the tomorrow of the American Railway Engineering Association a vision of hope.

Largely, I have pointed to things directly concerning the American Railway Engineering Association. Now, in closing, may I point out to you a wider and to me a more challenging horizon that seems to loom up in our future years, if not already with us. It is the constantly growing power of the state with the diminishing value of the individual. Do you and I want to be submerged in a vast throng that can do only the things that a "benevolent" or dictatorial government tells us to do? In other words, do you and I have a desire to be in the same situation as many of the peoples of what we call the "Old World" find themselves? For myself I say no; and if you, too, say no, then stand up with me and be counted.

We Must Guard Our Liberties

I recently had a vision of an old, old section of the world. Do you realize the privilege that is yours in living in these United States of America, with all the advantages that it offers? Did you know that this great country of ours, with only a sixteenth of the population of the world, has more high school boys and girls and college students in its institutions, high schools and institutions of learning, than all the rest of the world put together? We are on our way, if we are not careful—and I am not pessimistic but I am warning you—to state socialism or something worse if we continue to permit our liberties to be taken from us one by one. David Hume said, I quote: "It is seldom that liberty of any kind is lost all at once." Therefore, we who believe in the right of the individual, liberty for all, and the principles for which our forefathers and, our own sons and brothers fought and died; we who believe that the foundations of this country were well laid should let our views be known and not calmly stand by and see ourselves coddled from the cradle to the grave by those whose motive is political and selfish.

I said a while ago that we are peculiarly fitted, because of our profession and because of our training, to be of great service not only to the engineering profession and to the American Railway Engineering Association but also of great service to the people of this country of ours.

Our greatest future opportunity is to assure ourselves and the coming generations of the greatness of America and the principles of liberty and freedom for which the very name "America" is a symbol throughout the world. I challenge you as I do myself in thinking of the future and its opportunities to further them every day for this great Association of ours, but never forget that each day will provide an experience that will be a lamp to guide our feet tomorrow, remembering always that our foundation is sure as John Clifford wrote, I quote:

"I paused last eve beside the blacksmith's door,
And heard the anvil ring the Vesper Chime,
And looking in I saw upon the floor
Old hammers worn by beating years of time.
'How many anvils have you had?', said I
'To wear and batter all these hammers so?'
'Just one', he answered. Then with twinkling eye:
'The anvil wears the hammers out, you know'.
"And so I thought the anvil of God's word
For ages skeptics' blows have beat upon;
But though the noise of falling blows was heard
The anvil is unchanged, the hammers gone."

May the hammers that are now beating upon the foundations we believe in and have builded upon find them as firm as the anvil, and that fifty years from now we will find the hammers gone.

(The audience arose and applauded.)

President Mottier: We all thank you, Mr. Hastings, for this thought-provoking and very inspirational address.

You all know now why we asked Mr. Hastings to give the last address of the convention.

They have just handed me a record of our final registration. As your president, I hesitate to call attention to the records that have been set up this year.

In the president's address, in order to emphasize our past achievements and to create a proper setting for my predictions as to the future, I mentioned several all-time records which have been established this year. I am referring to them again in the concluding moments of this convention not to satisfy any personal ego but because we all have had a part in establishing these records, and we rejoice together in the successes and achievements of our first 50 years.

I will not repeat any of the records that were mentioned in the president's address. During the convention we have had the opportunity to establish two more records.

Last night I told you of the registration at the banquet which considerably exceeded the registration of any previous banquet. It has been announced during the convention several times that the greatest previous convention registration was 1691. I have just been handed a slip which gives the present registration as 2124, which is a little more than 25 percent greater, if my arithmetic is correct, than the highest previous registration. I think we can all rejoice in this record. (Applause)

This is the last address and the last official act on our program as published. Is there any further business to come before the meeting before we adjourn?

Past President Chinn: Ladies and Gentlemen: Along about this time at every annual convention we have a nice little ceremony in which we tell our retiring president what we think of him and the job he has done for us. Today this pleasant task has been assigned to me.

President Mottier (it won't be long now until it will be past president), your fellow members of the American Railway Engineering Association elected you their president and leader for one of the most important years in the history of the Association, the Golden Anniversary Year. They chose you for this high honor because they were sure that in you they would find those qualities of energy, ability, leadership and vision so necessary during such an important year.

In behalf of the Association, I want to say you have measured up to our every hope and expectation. You have done a magnificent job. We are proud of you and grateful for the splendid leadership you have given us. So that you will know, and be reminded in the years to come that we mean all I have said, we have had our sentiments inscribed in raised letters on a bronze plaque which we hope you will hang in your office or your home. This plaque reads:

> THE AMERICAN RAILWAY ENGINEERING ASSOCIATION, ON THE OCCASION OF ITS GOLDEN ANNIVERSARY, RECORDS ITS GRATEFUL APPRECIATION TO
> CHARLES HELVETIUS MOTTIER
> FOR HIS ABLE ADMINISTRATION OF THE AFFAIRS OF THE ASSOCIATION AS PRESIDENT 1948–1949.

President Mottier, it is a pleasure and a privilege to hand you this token of our high esteem. (Applause)

President Mottier: Thank you, Mr. Chinn. This is a beautiful plaque, and I am deeply and humbly grateful for this token of esteem of the Association.

I received a plaque Monday from the NRAA on the occasion of the luncheon they give each year to our Board of Direction, and I told them that I would hang this plaque on the west wall of the third bedroom, which, incidentally, was originally intended to be the maid's bedroom, but we have no maid. When all of our children were home, there was no place for a den for Dad, or a trophy room. Incidentally, we do not have many trophies. Now that the kids are gone, the third bedroom is set aside as Dad's den.

I know exactly where we are going to put this plaque. It will always be cherished by me and, I am sure, also by my wife as a pleasant reminder of this year of rather intensive activity as the president of the American Railway Engineering Association.

This plaque reminds me of the fact that my term of office will terminate in a very few minutes, and I know of no better time to express to this Association my sense of gratitude at having been given this opportunity to serve it and to serve you.

Strange as it may seem, I am thankful that fate made me your president in this Golden Jubilee year as this circumstance gave me an opportunity to be of greater service to our Association.

I have enjoyed working with you, and I wish again to thank everyone who assisted me or in any way served the Association this year.

There have been very few years in the life of the AREA when greater opportunities for service were presented and when more men responded. What has been accomplished has been the result of the cooperative effort of us all. One man alone, acting as president, would be almost helpless, but with the type of cooperation that I have received, much can be done.

Realizing, as I do, that I am at the end of my term of office and that my next official act will be the induction of the new president into office, I wish to call attention to the fact that this moment marks the termination of service on the Board of Direction of two of our past-presidents, Herbert R. Clarke and Frank R. Layng.

May I ask Mr. Clarke and Mr. Layng to stand and take a bow? (Applause) You gentlemen have contributed greatly to the work of this Association. Your advice and counsel on the Board will be missed.

This moment also marks the end of the term of three directors: Charles H. Blackman, John S. McBride and Sam E. Armstrong. We are going to miss all three of these men very much. It is a matter of personal regret to me that Mr. Armstrong has not been able to be with us this week. Will Mr. Blackman and Mr. McBride please stand? (Applause)

It is now my pleasure to present your new officers, and I would like to do it in a slightly different fashion than has been our past practice.

I wish to invite our newly elected junior vice-president, Henry S. Loeffler, assistant chief engineer, Great Northern, to come to the platform.

I will ask the senior vice-president for next year, George L. Sitton, assistant chief engineer, Southern Railway System, to take a place on the platform.

Ladies and gentlemen, you see before you the men who are being trained for future presidents of this Association. I suggest you give them a hand. (Applause)

It now gives me great pleasure to ask Past-President Miller and Past-President Akers to escort President-Elect Schwinn to the platform.

(President-Elect Schwinn was escorted to the platform.)

President Mottier: Mr. Schwinn, I wish you every success in your new office. I now have the honor and very great pleasure to declare you the newly elected president of the AREA and to present to you, as a gift from this Association, this beautiful gavel. (Applause) It is inscribed:

F. S. Schwinn

President AREA, 1949–1950

I do not wish to detract from the solemnity of this moment. Some of you may remember that last year, when we went through this very solemn ceremony, someone handed Armstrong Chinn a telegram, advising him that a strike had just been called on his railroad and he ran out on us and forgot to give me the gavel. (Laughter) After it was all over, Mr. Lacher slipped me the gavel behind the table.

Mr. Schwinn, I am pleased to present you this gavel. This is given to you as the symbol of your office and the authority vested in you.

Men and women, this is an historic and dramatic moment. It has been my very great privilege and high honor to direct the affairs of this Association during its fiftieth year. I now close the curtain on the first 50 years of the life of the American Railwav Engineering Association.

Mr. Schwinn, you are now given the honor to draw back the curtain and play the first act in the second 50 years. May you and all subsequent actors play your roles well. I now hail you as the new president of the AREA. I congratulate you on your opportunities, and I retire. (Applause)

(President-Elect Schwinn assumed the chair.)

President Schwinn: I thank you, Mr. Mottier

Ladies and Gentlemen, Members of the American Railway Engineering Association and Guests: I find it extremely difficult to express the conflicting emotions which are surging through me—emotions ranging from pardonable pride to deep humility.

This is a great honor, and I appreciate that honor. I appreciate the confidence that you have shown in me. I recognize the responsibilities attending the office of president of this Association. I humbly accept the trust that you are imposing upon me and in me. I will not betray that trust.

We have had a wonderful fiftieth anniversary year, a wonderful jubilee, and this meeting has been a fitting climax to that year. Permit me to pay a word of tribute to the man who is responsible for that successful year and for this successful meeting.

This success was due to a number of things, as he has said. Yes, he has had some committees helping him. He had a very able secretary and the secretarial staff. He had the support of the National Railway Appliances Association and its officers and directors. He had the wholehearted approval of his Board of Direction. But those were not the things that put over this successful year. It was his energy, his vision and imagination, his thought and plans.

I give you your friend and my friend, Charlie Mottier. (Applause)

This is not the time for me to make a speech. It is not so scheduled on the program, and I will not attempt one, but during the past week I have sensed something in the air —I think most of you have, too—and it has left a thought which I am going to take home. It is a thought, a worthwhile thought which we might all take home.

Someone said that the first 100 years are the hardest. We have gone through 50 years, the first half. We know what those 50 years have held—trials, work, success, and everything that has made this Association what it is today.

What do we know of the second 50 years? Where do we go from here? Will it be harder or will it be easier? We hear a great deal and we read a great deal about democracy, and we pride ourselves on being a part of a very great democracy.

Have you ever thought that this Association is, in itself, one of the purest forms of democracy? Here we are, a group or association of individuals, each one an equal, each one having the right to express his thoughts, each one having the right to vote, and we find the youngest member, probably a young man with not over two or three years' practical railroad experience, stands on an equal footing with his chief engineer. Such a condition can exist only under the freedom found in a democracy.

The last half of our slogan, our golden jubilee slogan, is "A Future of Opportunity." Opportunity is not passed around on a silver platter, but we can realize and we can grasp opportunity under the freedom of a democracy.

Our interests as individuals are synonymous with our interests as railroad employees. Our interests are the railroads' interests.

Today we find the railroad industry beset with many dangers. I will not attempt to recount all of them, but the least is not the danger of nationalization; the least is not the threat of socialism.

If we want to continue to have the opportunities during the second 50 years that this Association, that its members, that the railroads in which we are interested, have enjoyed, we must support democratic principles and democratic thoughts during the second 50 years. We must support them wholeheartedly, yes, even noisily.

As we return to our jobs, as we start this fifty-first year in the history of this Association, let us strive to remain individuals. Let us be positive exponents of the American way of life, the way that will insure our future of opportunity, the only way that will insure the future of the railroad industry. (Applause)

It now becomes my privilege to introduce the four new directors whom you have elected to your Board of Direction. I do not know if they are all in the room or not, but I will call them one by one, ask them to stand and take a bow: Mr. A. B. Chapman, assistant chief engineer, lines east, Chicago, Milwaukee, St. Paul & Pacific Railroad. Mr. Chapman! (Applause)

Mr. N. D. Howard, western editor, Railway Age. Mr. Howard! (Applause)

Mr. I. H. Schram, chief engineer, Erie Railroad. (Applause)

Mr. C. B. Bronson, maintenance of way assistant to vice-president, New York Central System. (Applause)

There being no further business to come before this meeting, I declare it now adjourned.

(The meeting adjourned at twelve-ten o'clock.)

PAPERS AND ADDRESSES

A Fifty-Year Look

By William T. Faricy

President, Association of American Railroads

Presented at the Golden Jubilee Dinner on March 16, 1949

It is altogether fitting that you members of the great engineering profession who are engaged in railroad work should celebrate the completion of the first fifty years of service to the industry by your professional society. I am grateful that you permit me, a member of another profession but like you engaged in railroad service, to join in your celebration.

Those who met fifty years ago to form this society devoted to the specialized work of railway engineering, had back of them even at that time a history of seventy years of American railroad engineering. They had seen, and most of them had participated in, the development on this continent of a distinctive American pattern of railroads. It was a pattern adapted to American conditions and needs, under which in the short span of one life time this continent had been laced with tracks, first of iron and then of steel. It was a pattern of railroad building adapted to spanning great distances with minimum expenditure in order that the country might be opened up—built up—unified.

Your society was organized at a turning point in that pattern of American railroad development—the point where the extensive building of railroads into new territories was about over, and where more and more attention was to be devoted to the intensive improvement of existing railroads to fit them to handle heavier traffic and to handle it more efficiently and economically.

A Fifty-Year Look Forward

To try to look ahead for fifty years, or even for five, or for that matter, for a year, is a risky business. Suppose that this task of prophecy had been undertaken at the first meeting of your association, fifty years ago. That was just after the war with Spain, at a time when the United States had begun to assume a place in world affairs. If our engineers then had been called upon to look ahead to future conditions and future demands, I doubt if any one of them would have foreseen that within a span of fifty years the United States would be called upon to put forth its utmost in two World Wars.

The fact is that they were faced with enough immediate problems—chiefly engineering problems with related financial aspects—to keep them busy. The engineers who built and have improved the railroads of this continent have kept in mind the fundamentals of economic location—the balancing of investment costs against operating savings. They have ever been conscious of Wellington's definition of an engineer as a man who could do well with one dollar what any bungler could do after a fashion with two. They have always had to keep in mind the essential relationship between the strength—and the cost—of the roadways they had to build and maintain and the weights and speed of the vehicles which were to run on them. This relationship between roadway and vehicle is equally inescapable in the case of public roads and the loads which roll over them, though it has not always been so recognized. That, perhaps, is because one group is responsible for building, maintaining, and paying for the roads, while others have sought to make that use of the highways most profitable to them, regardless of the effect upon costs of construction and maintenance.

On the railroads, on the other hand, the men who build and maintain the roadway, and the men who decide what weights are to run on it and at what speed, are all part of the same organization, and responsible for overall results as to cost and economy. This fact has clarified and simplified the problem of the engineer. This is not to say that there is, ever was, or ever will be, perfect accord between those responsible for the construction and repair of the track and those responsible for the design and operation of locomotives and cars. But it is a fact that, as one speaker at the first convention of your association put it, railroad men do "not expect track to carry all weights."

It is a cardinal principle of American railroading that track shall be used, whenever and wherever the demand exists, to its fullest extent and capacity, but not to its injury. The application of this principle was one of the problems confronting your membership at the time of the organization of the association. They were concerned about the impact of the 100-ton locomotives which, it was said, were putting the railroads right up "against the limit" of what track could stand in the way of heavy traffic.

It was not given to the engineer of fifty years ago to see that the day of the 100-ton locomotive would pass, and that it would be succeded by the 200-ton, the 400-ton, even the 500-ton locomotive. It was not given to them, either, to see that within the next fifty years the freight traffic per mile would be multiplied by four, and the passenger traffic per mile by 2½. They were familiar with high speeds—already a train had run more than 100 mph. in a short burst of speed—but the idea of sustained average high speeds in the modern sense was still in the future.

But while the men of 1899 probably did not foresee the conditions of 1949, they were at work laying the foundations for meeting those conditions, insofar as construction and maintenance engineering could do so.

The maximum weight of rail in use fifty years ago was 100 lb. to the yard. Today, the average weight of rail in tracks is more than the maximum weight of that time. And that is but the beginning of the measurement of improvement—for as the weight of rail increases, the gain in strength, in wearing quality and in safety, goes up at a far higher rate. Added to these gains as a result of increasing weight of rail, are those flowing from the improved design and proportioning of the rail section, and those which stem from improved metallurgy and manufacture. Then there is the increased life given by rebuilding battered joints and worn spots through in-place welding, coupled with the gains arising from improvements in fastenings, in ballast and track structure, in draining and subgrade conditions, and all the other improvements developed by the research, the study and the experience of the engineer in the past half-century. The result is that today's track structure, called upon to carry a traffic four times as heavy and about twice as fast as the traffic of fifty years ago, handles its job better than did the track structure of that time. And the study and research which produced such results are going on today, on a broader front and at an accelerated pace.

The Example of the Cross Tie

The engineers of fifty years ago were concerned with materials, and with threatened shortages of materials—just as they are today. There was, for example, what one of your members of half a century ago described as the threatened "cross tie famine." Cross ties, in those days, were being put into the track at the rate of about 400 ties per mile per year—almost four times as many per mile per year as are being used now. When the present-day cost of a cross tie in place in the track is considered, it is apparent that in this one feature of maintenance alone savings resulting from half a century of research and study, and from the investment in treated and protected ties, amount to as much as $1000 per mile per year. And, again, the study and the research not only of railroad men but of the cross tie producers and the wood preservers goes on. This research is directed not only to improved preservation against decay but better protection of the tie against mechanical wear and damage—all to the end that we may make better use of better ties, with greater efficiency and at less cost.

It was not given to the men at your first meeting, I am sure, to forsee the enormously expanded practical applications of the internal combustion engine, or its effect not only upon railroads but upon the whole transportation pattern, and indeed the daily life, of the nation. No one then could have foretold that within fifty years, there would be invested in public highways—chiefly for the use of internal combustion powered vehicles—more than four times the investment in railroads at the turn of the century. No one could then have foreseen 37,000,000 motor vehicles on those highways, or fleets of planes in the air, or diesel-powered tugs and tows on the inland waterways. But then no one could have foreseen, either, today's development of the diesel locomotive for railroad use, or the enormously expanded use of off-track work equipment, with all the savings which they have made possible in construction and maintenance work on railroads.

I mention these developments of today which could not have been foreseen fifty years ago as a sort of justification and plea-in-advance for leniency in judgment should anyone chance, fifty years hence, to take a look at the ideas expressed on this day—ideas, no doubt, that will seem quaint to the railroad man of 1999. Just as it was not given to the men of fifty years ago to see ahead all that they and their industry might be called upon to meet, so it is not given to us today to see just what we may be called upon to deal with in the next fifty years.

We can look ahead, however, to some broad fields of certainty. We are justified in accepting the fact that the population of the United States will continue to grow, that production will rise, and that the demand for transportation service will increase.

Only Railroads Can Meet the Demands

If these things be true—and we cannot doubt that they are—then we can assume that railroads must grow in strength and capacity, for only on railroads, in trains of cars on tracks, is it possible to meet now or in the future the tremendous transportation demands of this country. Only on railroads, in trains of cars on tracks, is it possible—or will it be possible—to produce this transportation with the necessary economy in manpower, materials and mechanical power.

There can be no doubt that we shall still have railroads fifty years hence, for there is nothing in existence and nothing in sight which can replace them in doing the mass hauling for this vast and richly productive continent. There can be no doubt, either, that those railroads will be better physically than the railroads of today—just as today's railroads are far different from the railroads of fifty years ago. And there can be no doubt that the railroads of half a century hence will have grown in the ascending line of development from the railroads of today, just as today's railroads have grown out of those of the turn of the century, and those, in turn, grew from the fundamentals of track laid down three-quarters of a century before that. For all we know now, the locomotive of the future may be powered with atomic energy but it still will be a locomotive. It still will pull or push trains of cars, and those cars still will track behind or in front of an engine because their wheels will be guided by parallel raised rails.

The great strides of science in the past fifty years will be dwarfed by what will be done in the next fifty years. Science, ever delving into the unknown, and skeptical of new things until tested out by the great process of trial and error, will develop new and more useful things faster than the old ones will wear out. Far from being a cause of regret to see the old things junked, we should rejoice when science gives us, through invention, things sufficiently valuable to use to be worth more than the unexpired life of the old appliances. That is progress. That is the eternal striving of the American spirit for something better than that which we have.

The real uncertainty of the future is not whether the great basic transportation of the country will be carried in trains of cars on tracks, or whether science and invention will make available new and improved processes. The real uncertainty is as to the conditions under which these trains will be operated, and whether investment funds will be available to use what science and invention give us.

Private Ownership

We in the United States are committed to the principle of private ownership and operation of railroads. It is a principle that has served us well. Under it we have developed the most adequate, the most efficient, the most economical general transportation system the world has ever known.

As to the principle, there is no major disagreement among our people. They have seen both government and private operation of railroads tried, under the stress and strain of war in each case, and the almost universal conviction is that private operation best meets the needs of this country. This conviction stems partly from the observed contrast in the results of government operation of our railroads in the first World War and private operation in the second. It stems partly, and perhaps even more strongly, from the belief of the great majority of our people in the essential idea of freedom of action and opportunity—a freedom which cannot be preserved if the every-day business of the country is conducted by a government which should be the umpire rather than a player in the game.

If government ownership and operation of railroads should ever come to pass in this country, therefore, it would not be because a majority of our people want it. It would be because conditions beyond the control of the railroads might make impossible the continuation of an adequate rail transportation system created and improved by private investment, and managed by private initiative.

The real question there involved is the relationship between expenses and revenues. There have been great changes in these relationships is the past fifty years. Figures are not available as to wage rates in those early days, but just since 1916 the average hourly rate of wages has gone up about five times and the increase since the turn of the century has doubtless been even more. The average annual compensation per employee —which takes no account of the reduction in the number of hours worked—has gone up more than six times since 1916. The average prices which railroads must pay for fuel, materials and supplies have gone up more than four times since 1900. Railroad taxes have gone up, in the last fifty years, from less than $45,000,000 to more than $1,080,000,000—or about 24 times as much.

As against these increases of more than 500 percent in annual compensation per employee, 300 percent in the prices of the things railroads must buy, and more than 2,000 percent in taxes, in the past fifty years, the average charge for hauling a ton of freight one mile on the railroads has gone up less than 80 percent, and the average charge for carrying a passenger one mile has gone up less than 30 percent. On the face of things, and in the absence of some countervailing factor, such a disparity between the many-fold increases in the three major costs of producing rail transportation—wages, purchases and taxes—and the fractional increases in the level of the prices at which railroads sell their services, must long ago have brought about the end of the railroads as self-supporting, privately-operated industries.

Why Hasn't It Happened?

And yet that hasn't happened. Why? It hasn't happened because there have been other factors at work. There has been research, for one thing, with all manner of scientific institutions and laboratories looking into every phase of railroad operation, and with testing going on continually on the whole railroad system as a vast proving ground. There has been investment—investment of private funds on a vast scale, devoted to the installation of new improved plant and equipment.

Fifty years ago the total investment in railroad plant and equipment was less than 10 billion dollars. Now it is more than 28 billion dollars. It is the growth in plant capacity indicated by this increased investment which enabled the railroads to meet the nation's needs in wartime—handling six times as much freight and passenger traffic at the war's peak as they did at the turn of the century.

Nor is the gain in capacity the only gain as a result of the added investment in improved railroads. The gain in efficiency is more difficult to measure, but it is significant that with their 1948 plant the railroads handled five times the freight traffic, and nearly three times the passenger traffic, of fifty years earlier, and did it with 1,350,000 employees—only 45 per cent more than the 930,000 employees that they had fifty years ago. In fact it is likely that the railroad man-hours worked in 1948 were not substantially greater than those of 1899. The output of transportation per man employed in 1948 was more than three times that of 1899—but in the same years, the average pay received by employees increased more than six times.

The story of the past fifty years, then, is one of increasing capacity to meet rising demands, coupled with increasing efficiency to meet rising elements of costs. It is only the combination of these factors—increasing volume of business handled with greater operating efficiency—which has enabled the railroads to meet as well as they have the impact of rises in wages, in the prices of materials, supplies and fuel, and in taxes, which have been many times as great as the increases in the charges received by railroads for hauling freight and passengers. Even with all the great contributions of research, all the magnificient efforts of engineers, all the tremendous investment in improved plant and facilities, all the striking gain in efficiency, it has not been possible to keep the net railway operating income—that is, the return on the capital invested—up to the point where it should be to insure strong and healthy railroads in the future. Fifty years ago the gross operating income of the railroads was less than 1½ billion dollars; last year it was nearly 10 billion. But operating expenses and taxes have increased from less than one billion to nearly 9 billion dollars. The result is that the remainder—the return on investment—has not kept pace with the growth of the railroads, the increase in investment or the needs of the industry.

In this remainder—the difference between what railroads take in and what they pay out—lies the hope of the future of railroading. It is the one basis on which there can be built a structure of investment, and it is only continued investment which can give us the railroads this country will need in the years to come—the railroads, indeed, which it must have to carry its commerce and, supremely important, to serve it in defense. Earnings, for which there is no substitute, can enable you engineers to put into effect the improvements which you have in mind for better and more efficient railroad transportation in the future. Here is the real challenge, not only to railroad men, but to their shippers and to government. Will there be the kind of statesmenship in this field of public endeavor which will rise above temporary selfish advantage and see with clear vision the ultimate good of our country in its ever increasing transportation demands? For the answer, I refer you to the speaker at the one hundredth anniversary dinner of this organization—to the president of the Association of American Railroads of the year 1999.

"A Past of Achievement"

By H. R. Clarke
Chief Engineer, Burlington Lines

"Where there is no vision the people perish." Again and again, through the centuries, history has proved the truth of the idea expressed in this great scriptural verse. We would do well to believe that the statement is as true today as when it was first written, hundreds of years ago.

Conversely stated, where there is vision, an individual, an organization, or a nation may be expected to prosper and progress. The truth of the principle, expressed in this way, has also been demonstrated many times.

But vision alone is not enough. We have also read, "Faith without works is dead," and practical men need no proof of the correctness of that statement. A task without vision is drudgery, a vision without a task is a dream, but a task with a vision is victory.

Period of Expansion Ended Fifty Years Ago

Fifty years ago the period of railroad location and construction, of rapid expansion, was largely past. The pattern of railroad lines in the United States was fairly well developed and set, and this was true to a certain extent in the Dominion of Canada and in Mexico. In the future, development and improvement were to be intensive rather than extensive. The construction of double and multiple tracks, when necessary, the reduction of grades and curvature, the improvement of yards and terminal facilities, the correction of clearances where these were restrictive, the renewal and strengthening of bridges, to carry the heavier power at faster speed, and last, but not least, the great advances in signaling, were to go on at an ever increasing rate, wherever and whenever safety or economy and efficiency in operation could be increased by any or all of these improvements.

Basically, the track of today is similar to that of fifty years ago, but otherwise there is no comparison. The importance and economy of a solid and stable roadbed of adequate dimensions are well understood and great progress has been made in this particular. Ballast is carefully selected and processed to improve the quality and increase its serviceability. Availability and low first cost are no longer determining factors, and every track man and engineer knows that the depth of ballast under the tie must be such as to properly distribute and support the load to be carried.

Fifty years ago comparatively few ties and little timber were treated to retard decay. Today, practically all ties and most exposed timber are treated, and constant progress is being made in the art of timber preservation. Ties are protected against mechanical wear and the entire track structure is strengthened by the use of tie plates; and we have learned a great deal about the advantages of properly anchoring track and made some advance is mastering the technique.

All of the items mentioned are important, in fact, essential, in track construction and maintenance, but to none has been given the intensive study that has been devoted to rail. The rail of today is still the "T" section that was used one hundred years ago, but otherwise the improvements have been many and great. Weight has been increased, design improved, specifications governing manufacture clarified and made more accurate, and there has been great progress in reducing rail failures and detecting them when they occur. Our Association is proud of the large part we have had in all of this.

To some extent, even fifty years ago, uniformity and a certain degree of standardization in motive power and cars had been forced on the mechanical officers by the interchange of equipment between all lines, but except in the gage of track, and to some degree in clearances, there was no such compelling reason existing insofar as the engineering, construction, and maintenance officers were concerned.

Battle of the Gages

Much has been written, and no doubt more was said in the so-called "Battle of the Gages." In the early days of railroad building several gages were in use, from the "broad gage" of 6 ft. to the 3-ft. narrow gage, (in fact there was some mileage of 2-ft. gage) including, of course, the recognized "standard gage" of 4 ft. 8½ in., which varied in some cases from 4 ft. 8 in. to as much as 4 ft. 10 in. on different so-called "standard gage" lines. In at least one case, an unusual gage was adopted to prevent interchange of equipment, the management of the road believing this would be to its advantage.

By the turn of the century, these differences of opinion had been ironed out, all roads had accepted 4 ft. 8½ in. as the standard gage, and most important lines had been converted to this standard. There were, of course, a good many hundred miles of 3-ft. gage track, and even some miles of 2-ft. gage, but these were all either short lines, or light traffic branches of larger systems, generally in territory where converting to standard gage would have been prohibitively expensive.

Except for uniformity in gage, the situation was becoming more confused. There was no generally recognized organization or means through which opinions could be expressed and experiences compared. There was no accepted authority which could even suggest standards or common practices with any hope that they would be accepted. So-called standards and practices varied on every road, and sometimes in the case of the larger lines, even on the same system. As traffic density became greater, speed increased, and the demands of the traveling public and shippers became more exacting, the situation became worse.

The chief engineers of those days, the strong, able, and aggressive men, who had located, built, and were maintaining the greatest railroad plant in the world, were much like the officers of somewhat higher rank, who had financed the plans and made the building possible; they were rugged individualists, each with supreme confidence in his own ability and judgment. A strong organization of unquestioned professional standing was required, if its recommendations were to have any weight.

Genesis of the AREA

In 1898 a small group of men, engaged in railway engineering, construction and maintenance, met in Chicago to consider the situation. They reviewed the advances that had been made in the approximately 75 years since the first railroad was built. They found them to have been great, but they knew that, aside from expansion, progress in the future must be much greater if the railroad industry was to continue to grow and prosper. They saw the need, realized how critical it was becoming, recognized the opportunity and acted. Others caught the inspiration, the American Railway Engineering and Maintenance of Way Association was founded at Buffalo, N. Y., in 1899 and began a half century of achievement, which we are reviewing tonight. It was a "Task with a Vision."

The purpose of the Association, as stated in its constitution as originally written, was: "The object of the association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways." This objective has been adhered to steadfastly through the years and the purpose has never been changed or altered. It is the reason for the existence of the Association today and the source of its continuing strength and vitality.

You are all familiar with the plan of organization of the association and how it works, by and through the standing and special committees. Fourteen standing committees reported at the first annual meeting of the Association. They were:

I—Graduation
II—Ballasting
III—Ties
IV—Rail
V—Track
VI—Buildings
VII—Bridges and Trestles
VIII—Masonry
IX—Signs, Fences, Crossings and Cattleguards
X—Signaling and Interlocking Plants
XI—Reports, Records and Accounts
XII—Uniform Rules, Organization, Titles, Codes, etc.
XIII—Water Service
XIV—Yards and Terminals

As the range of subjects to be studied widened, other committees were set up, and, as time went on, committees have been combined or discontinued as the work to be done demanded. Today there are 21 committees actively at work.

Brief mention of the changes, that is, committees added, combined and discontinued, might be of interest.

Committee 1—Graduation, became Roadway and later Roadway and Ballast were combined.

Committee 7—Bridges, became Wood Bridges and Trestles, and Committee 15—Iron and Steel Structures was added.

Committee 9—Signs, Fences, Crossings and Cattleguards became Highways.

Committee 10—Signals and Interlocking, was discontinued as a duplication of the work of the Signal Section, and Committee 12—Rules and Organization, was also dropped, as it had completed its work, at least, for the time.

Committee 18—Electricity, was added and later discontinued as a duplication of the work of the Electrical Section, and Committees 19—Conservation of Natural Resources, 25—Rivers and Harbors, and 26—Standardization were set up, but later discontinued, having completed their assignments for the present.

Committee 16—Economics of Railway Location, and Committee 21—Economics of Railway Operation, were added and functioned as separate committees for a number of years; but were combined, a few years ago, as Committee 16, Economics of Railway Location and Operation, as it was thought the work could be most effectively handled by one committee.

Committee 23—Shops and Locomotive Terminals, was very active for some years, but later the work assigned to this committee was divided between Committee 6—Buildings, and Committee 14—Yards and Terminals, and Committee 23 was discontinued.

Other committees added and still active are:

17—Wood Preservation
20—Uniform General Contract Forms
22—Economics of Railway Labor
24—Cooperative Relations with Universities
28—Clearances
29—Waterproofing
30—Impact and Bridge Stresses

Special committees, which were most active and which did most valuable work for many years are:

Economics of Bridges and Trestles
Complete Roadway and Track Structure
Stresses in Railroad Track

These, having served the purpose for which they were set up, have been discontinued.

This hurried, and necessarily brief, résumé indicates the care and diligence of the Board of Direction in keeping the organization and assignments of committees up to date and in accord with the work to be done.

Variation in Nature of Work Done

The assignment of work to the various committees varies greatly. In some cases the work done by a committee under its assignment is almost spectacular. In others, the very nature of the assignment is such that the results appear dull and uninteresting to many, yet they are of great importance to the work of the Association and to the railroad industry. Only men deeply interested in their work and devoted to it could carry on year after year on some of the assignments. We recognize the work they have done and pay tribute to them. However, it is the accomplishment of the Association as a whole which we are reviewing, regardless of the committee or group which may have done the work, and thus contributed to progress in the art of railroading.

The statement has frequently been made, by the uninformed, that the railroad industry is not progressive. It is admitted that there has been some advance in equipment, as the difference between the steam locomotive and the diesel is so great that it has been recognized. It is also agreed that the stainless steel or brightly painted, modernly styled, air-conditioned train is an improvement over the older type of equipment. However, it is not generally known or recognized how really great progress and advance has been in economy and efficiency of operation, availability, dependability and safety.

This is even more true in regard to the fixed property. There progress has been fully as great, but necessarily less obvious. To this progress the AREA has contributed much.

Modern construction equipment and methods bear little resemblance to those of fifty years ago. The need for and economic advantages of a well compacted, stable roadbed are now well understood and specifications have been revised and methods improved to provide such a foundation. Geologists and soil specialists are consulted and their advice followed as to material, which will be used, and the methods of handling, which are to be employed to insure the best results. Core borings are made, not only to determine what may underlie bridge and building foundations; but, also, to secure information as to the material to be used in embankments. Soil tests and analyses are used to determine proper construction standards, compaction procedure, etc.

All of these are of great advantage in the construction of new roadbed; but the larger problem now confronting the maintenance officer is the improvement of the already existing embankment, cut or tunnel, in the original construction of which less care was exercised. While the technique is relatively new, the AREA has taken an active part in developing information, and much has been learned in regard to methods and the results to be expected.

The driving of old ties or poles and the installation of drainage to provide a more stable roadbed have been practiced for a good many years, but these methods have been largely superseded. Instead pressure grouting or the use of sand piling is now the more common practice and the results are much more uniform and satisfactory. Our Association has been active in ascertaining and recommending the best procedure.

Improvements in Track

The very early railroad track consisted of wooden stringers, sometimes protected by short iron straps, laid on large stone blocks. This type of construction was of short duration and soon the track structure consisted of iron rails on wooden ties. The ties were small, varying greatly in size, and often not too well made. They were, of course, untreated and the service life of such ties was relatively short. This was not too serious so long as there was an abundant supply of suitable timber, and labor to make, handle and install ties was comparatively cheap. As these conditions changed, that is, good timber began to become scarce and more expensive, and as wages increased, the need for corrective measures became apparent and urgent.

It was recognized that substantial savings could be made if well manufactured ties of proper size and suitable timber were used, and the advantages of standardization to both producer and consumer were apparent. To bring about the desired improvement the AREA developed specifications covering ties, which were generally adopted and which have been almost universally used.

Even a large, well made tie, from the most desirable of timber had a service life of only eight to ten years, and the drain on one of the country's most valuable natural resources, timber, was serious. This led to the development and encouragement of the timber preservation industry, in which the AREA took a leading part, and today almost all ties and practically all exposed timber are treated to retard decay. The railroads are the largest users of treated timber, and today ties made from even inferior species of wood which, untreated, would last only 3 to 5 years, are giving service of 25 to 30 years and even longer. Tie renewals have been reduced from 80,000,000 to 40,000,000 ties per year. The result of this in the conservation of the country's timber resources is apparent, and the saving in labor and expenditure is great.

The railroad of early days was unballasted, that is, the track was surfaced on the earth used in constructing the roadbed, and when ballast began to be used low first cost and availability were usually the governing factors. Engine cinders and pit-run gravel, where available, were the most common materials used, but substitutes, such as burned clay or mine shale were resorted to at times. As weight of rolling stock, density of traffic and speed increased, better and more lasting ballast became necessary, and again the AREA drafted specifications covering crushed stone, processed gravel, and other types of prepared ballast, which now serve as a standard and guide to enable the track maintenance officers to decide the kind and quality of ballast which may be used to best advantage.

The Story of Structures

The story of structures follows somewhat the same pattern. The early drainage openings were generally timber bridges or masonry boxes and arches and some remarkable results were achieved. There were timber trestles, long and high, which required a high degree of skill to design and construct, and the masonry of those days was outstanding. Many of the masonry structures of the early years are a challenge, also a delight to the engineer and builder of today.

It was not long until iron bridges came into use and here also some remarkable work was done; but again, as demand became greater, materials and methods had to changed and steel bridges became common.

Once more the AREA responded to the challenge and, through the years, plans and specifications for both steel and timber bridges have been developed. They have been of great value to the engineers and designers; and the advantages, to both the supplier and the user, in having such standards available have been great.

Concrete has almost entirely supplanted masonry in all structures, both bridges and buildings, and the AREA has taken the lead in developing designs, specifications, and methods, the value of which cannot be overestimated. This includes the waterproofing of structures, which sometimes is difficult, but which at all times is of great importance, and the development of methods and procedure for solidifying masonry structures by internal pressure grouting.

Much time and thought have been devoted to the study of impact and stresses in bridges. Many field tests have been made, using delicate and intricate, but very accurate, instruments. In some cases these tests have confirmed the calculations and in others they have shown where modifications might be made which have resulted in substantial saving to the railroads.

The design, construction, and maintenance of tunnels and transmission lines, both for power and communication, have been studied and reports on recommended practices submitted.

While buildings do not carry the load of traffic as do bridges and track, yet they are essential to successful operation. They range from the section tool house or watchman's shanty, up through the small line depot, roundhouse, and shop building, to the efficient and comfortable general office and the palatial stations in the larger cities, which some think are monuments to civic pride or the rivalry and vanity of the railroads themselves. In any case, they are necessary and our Association has contributed here, also, by studying many outstanding building facilities of all kinds, calling attention to the remarkable results achieved and suggesting where improvements were possible.

Efforts To Obtain Better Rail

No part of the track structure has attracted more attention and been of greater interest to the public, and to none has been given more time, study, and expenditure of money, than the rail itself. The first rail was a timber or stringer, sometimes protected by short iron straps spiked to the top of the timber. Soon an approximately "T" shaped iron rail came into use, and when progress in the art of steel making permitted them to do so, the railroads were quick to see the advantage in the use of steel rails and to adopt steel as standard material for such use. Specifications as to chemistry and method of manufacture varied greatly and the quality of the rail furnished differed, perhaps, even more than the specifications. There was no uniformity in weight, section, length, or drilling. Almost every road had its own standard and these were changed frequently. The results of this condition were very undesirable and correction was imperative.

The first organization or association to attempt to remedy this in any national way was the Roadmasters and Maintenance of Way Association, which found the problem too difficult and referred it to the American Society of Civil Engineers. That association designed rail sections which were generally symmetrical and of several different weights per yard. Probably the most commonly used were 65-lb., 75-lb., and 85-lb.

It will be seen that railroad officers recognized the need for standardization in rail design and had attempted to bring it about, but the situation fifty years ago was one of increasing confusion. The work of the ASCE had only partly reduced the fantastic variety in rail design and there was no agreement on specifications. Rail manufactured at that time was far from satisfactory, and rapidly increasing wheel loads imposed ever greater service demands.

As a result of the work of our Association, in 1908 the ARA adopted sections known as ARA–A and ARA–B, the weights most commonly used being 90-lb., and 100-lb. Later the RE sections were recommended and the success attained is indicated by the fact that during the war years more than 75 percent of new rail tonnage rolled was 112-lb. and 131-lb. RE section.

RE Rail Sections Now Generally Accepted

The Association, through its committees, and assisted by the AAR research engineer and his staff, has continued to study and test rail sections, and as a result of this work, has recently recommended the 115-lb., 132-lb., and 133-lb. RE sections, and again most of the tonnage now being rolled is of these weights and sections.

The keeping of records and the reporting of rail failures by the railroads was sponsored and encouraged. and, as a result of these records, the service performance of rail of each year's rolling by the various rail mills could be studied and compared, and it is possible to detect quickly and accurately unfavorable conditions that may develop. This was most valuable when the Association began the investigation of internal transverse fissures.

One result of this investigation was the development of the detector car, in cooperation with the late Dr. Elmer A. Sperry, which made possible the detection of these internal flaws and the removal of the defective rails from track before actual breakage occurs.

Later, with the cooperation of the AREA, test engineers of the AAR have developed a detector car operating on a principle different from that on which the Sperry car operates. A number of these cars are in service, doing excellent work in locating defective rails, and greatly stimulating a continued advance in the technique of locating defective rails.

A second result of the investigation of internal transverse fissures, already referred to, was the discovery of the cause of the defect and the means of almost entirely preventing its occurrence. This study, carried on at the University of Illinois, was financed jointly by the railroads and the rail manufacturers, and the engineers of the railroads and of the manufacturers cooperated with the scientists at the university in the research work, which extended over a period of several years. The study proved that transverse fissures originated in shatter cracks formed as the rail cooled, and that controlling and regulating the temperature as the cooling progressed would prevent the formation of these shatter cracks, which are the nuclei of the transverse fissures.

The practice of retarding the cooling of rails to prevent formation of shatter cracks was first developed in Canada where it had been introduced by I. C. Mackie, engineer of tests of the Dominion Steel & Coal Corp. We pay tribute to the pioneer work that was done and which our Association, with the cooperation of the rail mills of the United States, continued and perfected.

The standardization and improvement in rail design, the increased safety and efficiency in operation, due to the great reduction in defects, which develop, and the means of detecting flaws before actual breakage occurs, together with the extended service life and improved performance of rail as now manufactured under the specifications, which have been developed, is an achievement of which the AREA is justly proud.

Rail Joints and Other Accessories

Detailed investigation and lengthy field tests have been made to determine the most efficient rail joint assembly for use with the improved rail sections. This included design and length of the bar itself, size and location of bolt holes, bolt tension, involving spring washer design and effectiveness, rail end hardening and lubrication.

Full and detailed plans and specifications for tie plates, spikes, bolts, and other track material have been developed and a most complete portfolio of plans for special track work, such as frogs, crossings, and switches, prepared. A similar portfolio of plans for track tools is available and generally used. This has resulted in more uniform practices, to the great advantage of both railroads and manufacturers.

A railroad, though it might be built and maintained perfectly and to the highest standards, would be a failure, if it was not well located and efficiently operated. Recognizing this, the AREA early gave consideration to the principles governing location, and later, added economics of operation, as they are affected by the fixed property.

Increasing speed and tonnage has been an important problem almost from the day the first railroad was put in operation. Increase in speed became most pronounced some 10 to 12 years ago, and curvature, both lateral and vertical, which had been satisfactory, suddenly became restrictive and improvement was urgently needed. This made necessary the careful review and revision of tables and formulas of superelevation of curves, length of spirals, rate of change of vertical curves, etc. This has been done and the information made available. As a result, curves have been eliminated or reduced and alinement corrected, vertical curves have been adjusted to the higher speeds, and grades reduced to permit more economical operation.

Yards and Terminals

It was found that serious delay occurred at stations, in yards and terminals. This led to the study of these facilities, that is the location and design of yards and terminals, to insure the most efficient and economical operation possible under existing conditions. The studies included not only the type and design of train yards, but all auxiliary facilities. such as engine terminals, shops, roundhouses, fuel and water stations, cinder pits, scales, freight houses and team tracks, all of which were fully covered.

Detailed recommendations have been made regarding passenger stations of various sizes and importance. These reports also include coach yards, service buildings, watering facilities, and sanitation.

The efficient and effective use of labor is highly important in economical operation and here also our association has been active. Reports have been made covering plans and organizations, which have demonstrated their value in increasing efficiency and reducing costs. These reports include recommendations for the use of work equipment, which many maintenance officers have found to be very helpful. The need for and value of proper records of performance and costs have been stressed and suggestions and recommendations made in regard to the preparation and most effective use of such data. The importance of all of this cannot be over-estimated.

Some years ago, the AREA recognized the urgent need for increased and coordinated research work in the railroad industry. While much work of a research nature had been and was being done, it was not organized and directed in any systematic way. Individual railroads and the manufacturers of railroad supplies were doing such work as they thought important, but the results were not recorded and made generally available, and too often much work which was well worth while was not given the properly publicity and attention. Our Association, seeing in this a situation very similar to the confusion in rail design of fifty years ago, undertook to bring this to the attention of the AAR.

AREA Promotes Research

The AREA had long been interested in, and well knew the value of properly directed research. The initial effort was made in 1908 when about $10,000 was collected by individual solicitation from railroads and others and used to conduct an investigation of impact on bridges. This work was done under the direction of Dean F. E. Turneaure of the University of Wisconsin.

In 1910 the AREA and the ARA (predecessor of the AAR) cooperated to employ an engineer of tests for the Rail Committee. In 1913 basic research on stresses in railroad track was first undertaken, under the late Dr. A. N. Talbot, at the University of Illinois. This was financed by the ASCE and later the steel companies and others contributed. In 1920 the ARA became a supporter of the project and the work was carried on for many years, with outstanding results.

The work done in developing improved practices and methods in rail manufacture, especially in determining and correcting the cause of transverse fissures and the locating of internal defects before breakage occurs, has been mentioned. All of this was of great value, but it was not enough.

Knowing the importance of organized and directed research, recognizing the magnitude of the undertaking, and believing that it should be supported by the railroad industry as a whole, the problem was presented to the AAR and in 1937 that association authorized an organization under a research engineer and the direction of the Engineering Division, AAR to carry on the work. The first appropriation, made in 1938, was $78,158. As the value of the work being done became known, the program has been steadily expanded, and in 1948, $291,840 was appropriated, and $372,457 authorized for 1949.

There are now 24 eminently qualified men on the staff of the Research Engineer and the growth and success of the program have culminated in approved plans and a contract with the Illinois Institute of Technology for a $600,000 research laboratory. This laboratory will serve not only the Engineering Division, but also the Mechanical Division and the Container Section of the AAR. We are certain that this important program will continue to grow and expand.

Cooperation With Universities

At one time, almost every young man studying civil engineering planned to enter railroad service. As the active days of great construction passed, this condition changed and there came a time when technical graduates no longer seemed interested in railway work; and the colleges and universities were in some cases no longer offering courses which would provide an opportunity to a young man to prepare himself for such employment. The AREA took note of the seriousness of this situation and has done much to correct it and bring about a better understanding. It was found that the railroad industry did not offer as attractive employment opportunities as did many other industries, and much has been done to change this condition. Frank discussion with representatives of some of the leading schools assisted greatly in bringing this about and there has been a renewed interest in railroad employment on the part of technical graduates and, in the case of many colleges and universities, this is actively encouraged. Here again there is much yet to be done. One important phase of the work is to impress upon railroad management the need for and advantages in a consistent and continued program, which will bring into the service a limited number of technically trained men, and the training and developing of them for greater responsibility.

While much of the time and effort of our Association is directed toward the physical engineering problems, the importance of human engineering is not overlooked, and one of the important accomplishments of the years has been a broader vision, a wider acquaintanceship, and a keener understanding of the problems of our fellow railroad engineers, all of which leads to a more cordial relationship and results in better cooperation among the railroads.

It is difficult to cover the achievement of a half century of an organization such as ours in any reasonable time. I am sure you agree with me that I have already greatly transgressed on your patience and forebearance, but much has been left unsaid.

We have reviewed and are celebrating fifty years of achievement. We look back on the past with pride in what has been accomplished, but we are not satisfied. We know the job is not finished. We carry on, as in the past, "A Task With a Vision," so we review a past of great achievement as a challenge, a guide and an inspiration to a future of even greater service to our members and, through them, to the railroads, which seventy-five years ago made possible and certain the union of our country, from the Atlantic to the Pacific, and from the Canadian Line to the Gulf of Mexico, and, which, ever since, have been and, are today, so vital and essential to the growth, peace, and prosperity of America.

This morning our president expressed firm confidence in the future of the AREA. We all agree with him.

On Thursday Past President Hastings will depict for us the challenging opportunities that lie ahead. We look forward to this address with keen anticipation.

Our motto, a slogan for the year we are now closing so successfully, has been as you all know, "A Past of Achievement—A Future of Opportunity." It has been a challenge to all of us.

With knowledge of the past and full confidence in the future, but knowing that we can achieve our purpose, in the future as we have in the past, only by work and effort, I suggest as a slogan for the coming year

"Hats off to the Past—Coats off to the Future."

Investigation of the Relation Between Track and Equipment

By J. R. Jackson

Mechanical Engineer, Mechanical Division, AAR

In the field of research, the AAR activities are for the most part carried along by separate organizations dealing with the problems relating to the work of the sponsoring division. In the case of the Engineering and Mechanical Divisions, there are numerous problems of common interest, or so interrelated as to make joint sponsorship desirable. In this general category fall studies and investigations dealing with track and equipment. Recognizing the importance of the closely related problems having to do with the operation of motive power and rolling equipment over the track structure, a joint committee composed of members from the Mechanical and Engineering Divisions was appointed in 1938, and reorganized under the present name in 1940. It is under the sponsorship and general direction of this Joint Committee on Relation Between Track and Equipment that the research organizations of the Engineering and Mechanical Divisions of the AAR have carried out a number of important research programs during the past eight or nine years. An account of these joint research assignments, together with a brief history and statement of the present status of each is covered under the following subheadings:

1. Locomotive Counterbalancing

A comprehensive series of road tests was conducted in the fall of 1941 and summer of 1942 on the rails of the Chicago & North Western Railway, out of Harvard, Ill. Three types of locomotives (4–6–2, 4–6–4, and 4–8–2) were tested, a total of 495 test runs being made, with speeds at 5 mph., at diameter speeds, and at speeds as near 100 mph. as could be obtained. Revolving parts were tested on both the dynamic and static basis, with reciprocating compensation ranging from 56 percent to 0, equivalent to a reciprocating unbalance of 2.3 to 6.4 lb. per side, per 1000 lb. of locomotive weight in working order. The results of these tests were published under the title "Counterbalance Tests of Locomotives for High Speed Service" as an AAR Mechanical and Engineering Division joint report in March 1944, and reprinted as AREA Bulletin 447, September–October 1944. Supplemental track tests of 12 additional locomotives were made at the same track location on C. & N. W. rails after completion of the principal counterbalance tests in 1942. These supplemental track tests included four 4–8–4, two 2–8–4, three 2–8–2, and three 2–10–2 type locomotives. The results of the supplemental tests were published as an AAR Mechanical and Engineering Division joint report in September 1944. This program was the basis for a compilation by the Office of the Mechanical Engineer, Mechanical Division, AAR, of a special Manual on Counterbalance for Reciprocating Steam Locomotives, published July 1, 1945, which by letter ballot action of the division, was placed in the Manual of Standard and Recommended Practices of the Mechanical Division during 1947.

2. Proper Relation of Rail and Wheel Gage and Contour for Best Riding Qualities at High Speed

While this was one of the four original joint committee assignments in 1940, a road test program was not carried out by the AAR research organizations until late summer in 1948, when it was combined with a later authorized investigation covering the dynamic balancing of passenger car wheels. These investigations were carried out concurrently, using the Budd Research Car No. 1, operated as a special test train over the main line track on the Pennsylvania Railroad between Coatesville and Parkesburg, Pa. In the interim, some studies of rail and wheel contours as affected by wear were progressed by the Engineering Division research organization.

During the 1948 road tests on Pennsylvania Railroad rails, comparison was made of coned and cylindrical tread wheel contours, nominal and worn condition, operating up to a speed of 100 mph. over stretches of track gaged to 4 ft. 8½ in., 4 ft. 8⅜ in., and 4 ft. 8¼ in. The Budd instrumentation available in their research car and several of the Budd technical personnel were made available to supplement AAR instrumentation and technical personnel. Car riding conditions were determined by accelerometers or oscillograph recordings, along with recordings by mechanical instrumentation. The results of these field tests are now being analyzed and a report is in preparation.

3. Permissible Wheel Load with Relation to Wheel Diameter

This investigation was also one of the four original joint committee assignments and has been progressed since 1941 under a cooperative agreement with the University of Illinois, and is being continued during 1949. A rolling-load machine is being used with various wheel loads and wheel diameters and the effect of bearing pressure on the steel rail is being studied. Progress reports covering this work have been published as monographs in AREA Proceedings, Vol. 45, 1944, and Vol. 47, 1946. The work to date has largely dealt with rail steel material, but it appears probable that the study will be broadened to include comparison of wheel steels.

4. Irregularities in Track Surface and Wheel Circumference

This is the fourth item of the original joint committee assignment in 1940. Two road testing programs have been completed, both investigating the impact effect of flat wheels, as follows:

(a) New York, New Haven & Hartford Railroad, near Boston, Mass.—The results of this series of tests, as completed during August 1942, and published as a monograph in AREA Proceedings, Vol. 45, 1944, were considered as an exploratory investigation dealing with the rail stresses (100-lb. NH section) resulting from a 2½-in. flat spot on a 33-in. diameter wheel, over a speed range from 10 to 60 mph. The report yielded very worthwhile information indicating the procedure to be followed in the later, more complete investigation.

(b) Chicago & North Western Railway, near Harvard, Ill.—The second series of tests was run during May–June 1947. This investigation was broadened to include both 100 and 131-lb. rail in the test track, and instrumentation to record stresses in wheel, axle, and truck frame, as well as in the rail. A total of 354 test runs in 22 schedule variations were completed, during which the wheel circumference was varied from round, 2½, 3½, and 4½ in. flat spots on a 33-in. diameter wheel, with speeds from five to 80 mph., and the load from 60,500 (lightweight), 131,000 (half capacity), and 201,900 lb. (capacity) for the 70-ton flat car used. The report covering the 1947 tests on C. & N. W. rails is in preparation.

5. Lateral Forces from Locomotives with Respect to Track Alinement

During 1946 the Joint Committee was requested to add this item to its program. Measurements of lateral forces exerted by modern steam locomotives of the 4–6–4, 4–8–4, and 2–10–2 axle arrangements on curved track had been shown to be very high, especially at low speeds, on the inner rail of curves. After review of the subject by the Joint Committee, and concurrence by the Mechanical Division Committee on Locomotive Construction, approval of the program to be sponsored jointly by the Engineering and Mechanical Divisions for conducting the necessary test runs on a 4–8–4 locomotive was approved for 1947. Through arrangements made with the Santa Fe Railway a series of road tests was completed during October–November 1947, with 4–8–4 type A. T. & S. F. locomotive No. 3784 near San Bernardino, Calif. The test locomotive was instrumented for recording lateral and vertical accelerations, lateral swing of the engine trucks, and lateral motion of the first driving axle for the purpose of studying the effect of various combinations of truck resistances. Special castings were employed by means of which the engine truck resistance of test locomotive No. 3784 could be set at 10, 20, and 30 percent, and the trailer truck resistance varied in the same values.

The 1947 tests on Santa Fe rails were made at speeds of 5, 20, and 30 mph. on a 10-deg. curve in the eastbound main line, immediately east of Cajon, Calif., where instrumentation for recording the rail stresses and lateral forces produced by the wheels against the rails was installed. Some additional high speed runs up to 100 mph. were made with the test locomotive on tangent track without rail stress instrumentation.

A total of nine schedules where the engine truck and trailer truck resistances were varied through the nine possible combinations, each of 12 test runs at the selected speeds, comprised the main program. Two additional schedules involving other variations in engine and trailer truck resistance and driver lateral control were also run with the 4–8–4 test locomotive.

During the progress with tests of A. T. & S. F. locomotive No. 3784, track records of other locomotives passing over the recording instruments located on a 10-deg. curve at Cajon were taken. These supplementary recordings included both freight and passenger diesel locomotives of different makes, and steam locomotives other than the 4–8–4 type represented by the test locomotive. Track records on the curve were also taken of two Union Pacific and one Southern Pacific 4–8–4 type locomotives, differing in truck resistance distribution and driver lateral motion control from the A. T. & S. F. 4–8–4 type locomotive.

Report covering this series of tests is in preparation.

6. Dynamic Balancing of Passenger Car Wheels

This item was assigned to the Joint Committee during 1947, having originated in a recommendation from a member road that the AAR conduct some research work to determine the effect of wheel unbalance on riding conditions within passenger cars and the maintenance costs of trucks. Acting with a subcommittee of the Mechanical Division Wheel Committee, a program of road tests was formulated and finally approved by the AAR Board as a research activity to be progressed by the research organizations of the Mechanical and Engineering Divisions.

As previously noted under Item (2), this wheel unbalance investigation was combined with previously approved studies of rail and wheel contours and gage in relation to the riding qualities of passenger cars at high speed. The combined road test program was carried out during the summer of 1948 on the main line (152-lb. rail) of the Pennsylvania Railroad between Coatesville and Parkesburg, Pa. The test train consisted of a type G–G–1 electric locomotive, Budd Research Car No. 1, and two PRR P–70 class passenger coaches. The Budd research car is an 85-ft. stainless steel car of post-war Budd design, equipped with basic Commonwealth four-wheel roller bearing trucks. Weight on rail, including extra ballast, was 135,000 lb. when completely instrumented for these road tests. Two car sets of mounted AAR specification multiple wear 36-in. diameter steel wheels were available to effect the variations in wheel finish, balance, and tread contour specified in the test program. Wheel work and changes under the Budd research car, while the road tests were in progress, were carried out at the Wilmington, Del., shops of the Pennsylvania Railroad. A Bear type, 400-lb. dynamic balancer was set up at Wilmington for the wheel balancing measurements. Budd instrumentation available in the research car was supplemented with AAR electronic instrumentation and trained technical personnel of both the Budd Company and the AAR Engineering Division comprised the road testing crew. An experienced machine operator and technician from the Bear Manufacturing Company cooperated in carrying out the test wheel balancing operations at Wilmington.

A total of 15 series of road tests was made over the test track during the period between August 13 and September 27, 1948. The three-car test train was operated on a special schedule. A "series" constituted two runs each at 40, 60, 80, and 100 mph., the total program comprising 120 test runs.

As applying to the question of wheel balance under passenger cars in high speed service, the wheel finish and dynamic balance variation compared during the 15 "series" of test runs were:

Car Set "A"—Starting with road test of a set of conical tread wheels "as received" from the manufacturer, and mounted in accordance with AAR requirements, this set of wheels was modified and tested progressively in the following order: The wheel treads were next road tested concentrically ground, then wheels were dynamically balanced and test repeated. The concentrically ground treads and dynamically balanced wheels were then modified and tested with controlled magnitude and phase of unbalance in 5 and 10 lb. increments. The unbalancing weights were placed in the same circumferential location, or spaced 180 deg. apart on opposite wheels on each axle (four test series). The next step was with the concentrically ground, dynamically balanced wheels with semi and with full cylindrical ground tread contours. The treads of these dynamically balanced wheels were then machined to simulate worn conical tread contours, and finally tested with machined, conical treads of known eccentricity, (total of 11 "series").

Car Set "B"—A second set of conical tread unbalanced wheels "as received" from the manufacturer and mounted in accordance with AAR requirements were road tested, then modified and progressively road tested to provide (1) concentrically ground conical treads with rims and rim fillets machined; (2) hub fillets machined; and finally (3) plates machined, thus providing a set of wheels machined all over, (a total of four "series"). "Unbalance" for each wheel after each progressive finishing operation was recorded.

In all cases the axles, roller bearings and wheels were kept in the same relative location under the car throughout the entire test program.

The results of these series of tests are being analyzed and a report is in preparation.

The following project has been approved and the field work scheduled for this year:

7. Relation of Degree of Track Curvature, Speed, and Equipment Design to Riding Comfort

Present speed limitations on curved track, especially for riding comfort, were established in 1914 by a special committee based upon the personal observation and experience of the committee members. Since that time there have been extensive changes made in truck design, including more flexible springs, snubbers, and stabilizers and reduction in center of gravity height. The availability of accelerometer equipment in combination with laboratory tests to establish riding comfort tolerances makes it desirable to establish these limitations on curved track, especially for the new, low center of gravity equipment, by more scientific methods. It is proposed this year to make tests on track having various degrees of curvature and amounts of superelevation, including various types of equipment and at various operating speeds. From these test data it is expected that suitable recommendations can be made.

The matter of breakage of flanges on chilled iron wheels around curves has been brought to the attention of the Joint Committee by a member road. This subject is being studied as a possible field investigation, but to date no definite program has been formulated, or plan of procedure recommended.

In addition to the above programs carried out, or contemplated as Joint Committee on Relation Between Track and Equipment activities, the AAR research organizations of the Mechanical and Engineering Divisions have at times, when conditions permitted, made the AAR instrumentation and trained technical personnel available to member roads for investigations and studies involving the relation between track and equipment. Typical examples of such projects are:

1. An investigation during March 1945, conducted by the Chicago & North Western Railway covering the determination of lateral outward forces on each rail of the No. 14 turnout in the Chicago Madison Street terminal. Records were taken of 4–6–4 and 4–8–4 type locomotives. This work was preliminary to the later Joint Committee test program carried out as Item (5). The results of the C. & N. W. tests were published in AREA Bulletin 454 and the Proceedings, Vol. 47, 1946.

2. Determination of stresses in eccentric rods on Class "J" reciprocating steam locomotives, conducted for the Norfolk & Western Railway during July 1945.

3. Investigation of the riding qualities of 3400 class locomotives over the Missouri and Illinois Divisions of the Atchison, Topeka & Santa Fe Railway during June 1945, and stress measurements in freight truck side frames under cars in headend service on Santa Fe mail-express trains over the same territory during August 1945.

Freight Truck and Snubber Investigations

As applying to the general subject of relation between track and equipment, it will be of interest to mention here briefly investigations of the riding qualities of freight cars equipped with truck design variations and truck spring snubber arrangements carried out, or in prospect, under the general supervision of the AAR Mechanical Division research office.

Following an investigation including the road testing of truck spring and snubber devices conducted on the Erie Railroad between Avon and Rochester, N. Y., during 1933, a road test program of trucks for high speed freight service was completed during 1939 on the Pennsylvania Railroad between Altoona and Lockhaven, Pa. As a part of this 1939 investigation, measurements of rail stresses at a location on the test track by electronic instrumentation, loaned by the Pennsylvania Railroad, was completed as a cooperative project with the Engineering Division. The results of this rail stress investigation are given as Appendix III, Tests of Trucks for High Speed Service, issued by the AAR Office of Mechanical Engineer, April 1940.

Since the 1933 snubber, and the 1939 freight truck tests, there has been such development in the design of freight trucks for high speed service as to make it desirable to compare the various designs and constructions available. To this end, during 1948 a cooperative research program with the freight truck and snubber manufacturers, under the general direction of the AAR Mechanical Division research office, was approved and a series of road tests made on the Illinois Central Railroad out of Clinton, Ill. The completely instrumented five-car service laboratory, as built for the American Steel Foundries for its own research activities, was leased and ASF trained technical personnel, augmented by AAR personnel, was employed.

During the period between July 27 and November 13, 1948, a total of 78 road tests were run, recording the vertical and lateral shocks within one car equipped progressively with various truck bolster spring, unit snubber, package snubber, and special designs of freight trucks, as compared with a duplicate car under which one set of trucks was maintained throughout the test program. By reason of the fact that the AAR-owned electronic instrumentation was engaged in other activities, no rail stress or other track measurements were taken during the 1948 road tests, as was done during the 1939 tests.

This road testing program was not completed during 1948, but is to be continued during 1949 to complete tests of other snubbers, truck designs, and include trucks having roller bearing journals for comparison with the conventional solid type bearing, under the test train throughout the 1948 tests.

General

By the very nature of things, many problems arising from the operation of the railroads are of common interest to the mechanical and engineering departments. The relation between track and equipment has been studied since railroads were first built, but with the present trend toward faster schedules and the evolution of motive power and rolling equipment designs, the problems are increasing and there is a great deal yet to be accomplished through research to improve passenger comfort and reduce lading damage and maintenance of track and equipment. A question has been raised a number of times during the past several years as to why the railroads do not follow the procedure of the automotive and other industries in setting up central research facilities to study the problems of common interest to all the railroads. For the purpose of solving the many problems relating to track and equipment, for example, the question is frequently asked: Why do not the railroads and equipment manufacturers get together and construct a test railroad plant consisting of an oval, or figure-eight track where tests of motive power and rolling equipment could be run, and improvements in track and equipment developed? It is argued that such an experimental railroad could be used to subject roadbed, rail, fastenings, protective coatings, etc., to service test, and to study motive power and rolling equipment in movement over track under controlled conditions.

The research facilities would include recording instrumentation along the track, and within the test motive power and rolling equipment; together with adequate supplementary office, engineering, operating, and shop equipment and personnel. Such a "proving ground" would no doubt provide facilities for the solution of some problems relating to track and equipment, but could not be expected to give an answer to such problems as are related to tonnage or volume movements of traffic. It appears questionable that the relatively high first cost and the annual cost of operation, maintenance, and depreciation of a non-revenue railroad plant of this general description would justify its relatively limited overall research value to the railroad industry. The quarter of a million miles of existing trackage in service on the railroads of this country make available to the research staff a range of variables for the study of any specific problems which could not be duplicated in a test track of the type suggested.

It is believed that activities of the nature carried on by the AAR Joint Committee on Relation Between Track and Equipment, with field investigations carried out on the lines of member roads under the general supervision of the AAR Mechanical and Engineering Divisions, in cooperation with the technical organizations of the equipment manufacturers, and using available specialized testing equipment and trained personnel whenever available and adaptable, form the basis for a logical procedure and will continue to provide the approach to the solution of those problems common to the railroads which make for progress on a long range basis.

The Future Timber Supply

By C. D. Turley

Engineer of Ties and Treatment, Illinois Central Railroad

One of the major problems before the railroads today is the future supply of timber for cross ties. Dwindling of timber resources is nation wide but since conditions are much more acute in the eastern half of the United States, my remarks will deal very largely with the eastern and southern states where the forests have been greatly depleted and where in the past so little has been done to replenish the supply.

In 1945 and 1946, the United States Forest Service made a re-appraisal of the forest situation in the United States. The volume of saw timber was placed at 1601 billion board feet, a reduction of 14 percent since the previous survey made in 1934, 1935 and 1936. During the same period, pine saw timber decreased in volume, 14 percent in Louisiana, 19 percent in Alabama, 22 percent in Oklahoma, 23 percent in Florida, and 29 percent in Mississippi.

Farmers and small owners own about one-third of the total forest area but practice little or no forest management, and produce less than one-third of what their woodlands are capable of growing. The general trend is toward large ownerships of timberland by the U. S. government, by the woodpulp industry and by other large wood using industries, and this in turn is absorbing small ownerships and gradually reducing the amount and lowering the quality of open market timber on which the railroads must depend for their requirements.

There is the picture of the timber supply which will be available for cross ties in the years ahead, a supply that is gradually decreasing in volume. Due to the many new and diversified uses of wood, for which comparatively higher prices are justified, the quality of the supply remaining for cross ties will gradually be lower and lower.

In contrast, the railroads are facing more exacting public demands, heavy traffic, heavier wheel loads, and ever increasing train speeds, a condition demanding a stronger and more permanent track structure and in turn, of course, calling for larger and better cross ties. Main line tracks over which streamlined trains of today are operated at high speeds, must provide not only safety and comfortable riding conditions, but also increased economy in maintenance.

What are the railroads going to do about it? What can be done? Many times you have heard old timbermen say, "There's no more good virgin timber in the country, it is all gone." It would be just as applicable for the farmers in Iowa and Illinois, after they have gathered their corn crops in the fall to say, there is no more corn, and there wouldn't be unless someone did something about another crop for the following year.

The Answer Is Reforestation

The answer to the whole question is reforestation, proper forest management including necessary planting, fire protection, care of growing timber, pruning, selective cutting, and supervision of all cutting and logging operations.

In the South the once extensive heavy virgin pine forests have been very largely replaced by second growth mixed shortleaf pine, loblolly pine, hardwood forests. Due to the fertile soil, adequate rainfall, favorable climatic conditions and the fact that southern pine and gum grow much faster than most other desirable woods, this territory presents an excellent opportunity for growing a satisfactory supply of timber for railroad cross ties, bridge materials, car lumber, poles and piling.

These mixed pine-hardwood forests in the South are typically, young second-growth forests. There is very little old-growth timber and not much second growth large enough for good sawlogs. In most stands all of the merchantable trees have been cut at least once during the past 30 years and the residual stands have been damaged by repeated fires. In consequence, practically all of the stands are understocked. Small trees are too few and too unevenly distributed to make full stands, and the stock of larger trees is still more inadequate. In the average stand there are less than one fourth as many trees, more than 12 in. in diameter, as there should be, to utilize fully the productive capacity of the forest land. Many of the trees are limby and not straight, fire-scarred, partially decayed, or for other reasons are growing too slowly and not likely to make good timber. What I have said concerning the timber supply and improper care of timber lands in the South applies equally well to the hardwood timber lands in the north and in the New England states.

Fortunately studies of the possibilities of these stands of timber were undertaken by the United States Forest Service several years ago and have now progressed far enough to indicate methods of cutting and management that will enable these forests to grow large and increasing quantities of timber to meet present needs, and by gradually increasing the stands, to yield more and better timber, to safeguard future requirements. A quick look at some of our experimental forests will convince you that it is both practical and economical to grow trees and that the quality of the timber will be far superior to that offered in the open market today. Nature is still the same as when the giant virgin timber grew, and our trained and experienced foresters of today, by creating perfect tree living and growing conditions in the woods, and by providing fire protection, have already demonstrated the possibility of growing timber, rivaling if not equaling or surpassing the original virgin timber, in both quality and yield per acre.

The Recommended Plan

The recommended plan is to start with the existing timber stands and then by forest management and selective cutting methods, build up the total stands to approximately the board feet per acre which will give maximum timber yield in the district for the particular species of wood involved.

In the South these timber lands contain both pine and hardwoods of many different ages and sizes, and ordinarily can be built up from run down stands to provide reasonable returns in from 10 to 15 years. By "run down" is meant stands containing an average of 2500 ft. b. m. per acre in trees 10 in. or more in diameter, and also containing a sizeable growth of small trees from natural seeding, many of which are pine and gum.

The volume of timber to be cut is based on the growing stock, the rate of growth and the length of the cutting cycle. When the stand reaches a volume per acre of approximately 10,000 ft. b. m. of pine and gum it has reached its volume of maximum productivity, and thereafter the cut should equal the growth, approximately 500 ft. b. m. per acre per year indefinitely. Five-year cutting cycles are usually satisfactory for pine and gum timber.

The items of expense of owning land and growing timber under forest management are: Interest on investment, administration, taxes (ad valorem and severance), fire protection, and other risks. This total annual cost varies only slightly from year to year and during periods of intensive business, the difference in the actual cost of growing timber and purchasing it in the open market may vary as much as 25 cents or more per tie.

Experimental tree farms demonstrate emphatically that timber can and should be as much an annual farm crop as corn, potatoes, or cotton. Returns can be made comparable, and timber has important advantages over cultivated crops in that it requires much less attention, is much less subject to weather conditions and can be harvested at the owner's convenience, or (in years of poor prices) left standing until the market is attractive. However, very little improvement is being made or can be expected on small farms since these small owners are unable to finance long term projects. A man's first duty is to see that his family has food, shelter and clothing, even if he does infringe on the rules of timber conservation.

Summary

Investigation and careful study of this important timber problem develop the following facts:

1. Saw timber, trees 10 in. or more in diameter, is being cut annually in the United States at a rate approximately 50 percent faster than it is growing.

2. The general trend is toward large ownership of timber land by the woodpulp and other large wood using industries, and this is gradually reducing the amount and quality of open market timber, on which the railroads must depend for their cross tie requirements.

3. It is both practical and economical to own land and grow timber for railroad use.

4. Industries owning forest managed land not only assure themselves of an ample future timber supply but a better quality of material, and at a cost always materially below open market prices.

5. Unless some unforeseen development takes place (such as occurred 50 years ago, when timber preservation and the use of metal alloys replacing wood, came into common and extensive use, easing the drain on our timber resources), railroad management should understand that in order to secure a satisfactory supply of cross ties at prices they can afford to pay, it may become necessary for them to acquire land and grow their own timber.

In closing I would like to say that second growth forests present a vast opportunity for enterprising forest managament; the dwindling timber supply and the steadily increasing demand and diversified uses of forest products, justify great activity in this field; and that the timber industry has the opportunity. It is good business and it is its duty to make certain that this growing timber is protected and improved and perpetuated, so as not only to meet present day needs but yield more and better timber to safeguard requirements in the future.

Recent Developments in Water Treatment

By R. C. Bardwell

Superintendent Water Supply, Chesapeake and Ohio Railway

Water supply is an essential operating requirement for all railroads using steam locomotives, and water is also necessary in less volume but more refined quality for systems using diesel power. The amount of water used, both in volume and weight, exceeds all other materials used by the railroads. Under such conditions, it can be readily understood that a variation in quality can have a direct effect on operating economy and efficiency. Although the cost for the operation and maintenance of water stations is only about one percent of railroad operating expense, it is still a vital factor which must be given consideration. The selection of sources of supply is limited, as water must be available and delivered at locations determined by operating requirements. This necessitates the installation and operation of facilities and the application of treatment as required at approximately 18,000 individual locations.

The importance of this subject was appreciated by the founders of the American Railway Engineering Association and a standing committee was appointed which has reported the results of its investigations, research and recommendations in the Annual Proceedings of the Association, beginning with the first volume published in March 1900. The membership of this committee has been composed of practical and technical men directly interested and experienced in this activity and the reports of their studies have served not only to keep the Association informed of the progress and development in the equipment and facilities used for obtaining and delivering water supplies, but also in the important field of water conditioning.

It appears appropriate at this time to recall the names of a few of the important members now passed on or retired, who during their tenure of membership, contributed much time and thought in preparing the many important reports on the research and investigations in this activity.

G. M. Davidson, C. & N. W. Ry.
Anthony McGill, Canadian Government
M. H. Wichorst, C. B. & Q. R. R.
E. G. Lane, B. & O. R. R.
C. A. Morse, A. T. & S. F. Ry.
J. L. Campbell, E. P. & S. W.
A. F. Dorley, Mo. Pac. R. R.
C. R. Knowles, I. C. R. R.
R. L. Holmes, T. & P. Ry.
J. H. Davidson, M.-K.-T. Ry.
J. H. Gibboney, N. & W. Ry.
C. H. Koyl, C. M. St. P. & P. R. R.
P. M. LaBach, C. R. I. & P. Ry.
M. E. McDonell, Penna. R. R.
C. P. Van Gundy, B. & O. R. R.
H. H. Richardson, Mo. Pac. R. R.

There are 43 members on Committee 13—Water Service and Sanitation at the present time, representing 27 railroads and 2 consulting engineers, and their activities and contacts, not only with railroad officers but also with technical associations and universities engaged in related investigations, should develop the latest and most authoritative facts in this field for the benefit of the members of the American Railway Engineering Association and its permanent record.

Annual Reports Since 1900

The reports of this committee, published annually since 1900, include description and recommendations for best practice in organization, equipment, installation and operation for railway water stations. Probably the subject which has shown the greatest improvement in over-all results, is the treatment and proper conditioning of boiler feedwater, and more recently the conditioning of water used on diesel power. Although the softening of water was first developed in Scotland and England about 1840, the greatest improvement in practice and efficiency has taken place since 1900 on the railroads in this country which unquestionably now lead the world in the application of this branch of applied science. This has been brought about largely through the efforts of members of Committee 13, working together and in some cases with the assistance and cooperation of the reputable water treatment concerns which have highly developed research laboratories studying many of the intricate details. The accomplishments in this connection as listed in the 1946 Proceedings of the Master Boiler Makers' Association, are quoted here:

1. Made possible long runs of steam locomotives.
2. Permitted use of high power locomotives.
3. Reduced fuel consumption.
4. Saved the railroads not less than $30,000,000 annually.
5. During each war year, saved a substantial tonnage of steel.
6. Contributed very largely to the high availability of steam locomotives which made it possible for about 42,000 locomotives to deliver nearly twice the work done by 64,000 locomotives in World War I.
7. Reduced shopping time of locomotives to the minimum required by machinery repairs.

8. Contributed to a performance record where boiler failures are virtually eliminated.

The efficient operation of steam power is of special importance in railroad service and the proper conditioning of the water supply is a vital factor in this operation. In the 1937 report of the National Resources Committee which was reviewed by G. A. Orrok in the 1937 Proceedings of the American Society of Civil Engineers, the railroads were credited with approximately 60 percent of the steamboiler horsepower in America, embodied in 42,000 locomotives normally in service at that time. Although the number of steam locomotives had decreased to 32,854 as of December 1, 1948, the individual horsepower is much higher and the total ratio should not have changed materially. With this large preponderance of steam boiler horsepower of direct concern to the railroads, it was entirely proper that the railroad water committee direct its best efforts toward the improvement and solution of the problems presented, the satisfactory outcome of which have been listed by the boiler makers.

A Statement of Achievements

A brief summary of the Recent Developments in Water Treatment on railroads might be listed as follows:

1. The practical elimination of internal boiler pitting and corrosion through the research and determination of practical amounts of excess alkalinity to be carried in the boiler water. (Boiler pitting and corrosion were reported as costing the railroads $12,000,000 annually in 1924.)

2. Reduction of scaling matter remaining in water after treatment with lime and soda ash by the use of small amounts of sodium aluminate.

3. Reduction of incrustation and after-precipitation in pipe lines, valves, water columns, branch pipes and injectors by the use of small amounts of recently developed complex polyphosphates and, in some cases, this material mixed with tannins.

4. Reduction and practical elimination in many territories of intercrystalline cracking, (caustic embrittlement) by taking advantage of the recommendations for using small amounts of sodium nitrate or suitable organic materials as developed in the research work at the Bureau of Mines under the direction of the Joint Committee on Boiler Feed Water Research which was largely financed by the Association of American Railroads and in which your Association's representatives were active.

5. Decrease in amount of blowdown required with consequent saving in fuel and increased availability of the motive power with practical elimination of foaming delays by the use of special amide-type antifoam mixtures developed in the research laboratories of the water treatment specialty companies.

6. Development and use of small convenient conductivity sets which are calibrated to read the concentration of boiler water salts direct on the dial, which have proved decidedly advantageous at terminals for checking the road blowing on inbound engines and insure the dispatching of a locomotive with boiler water concentrations within workable limits.

7. The recirculation of sludge in the lime-soda plants, and also the refinements developed in plants of the sludge blanket type, have provided effective means for lowering and controlling the hardness and scaling matter remaining in the treated water.

8. The standardization of methods of water analysis and interpretation of results for raw, treated and boiler waters, has been a decided asset in helping the railroad water chemist control the quality of the water delivered for locomotive use and the conditions in the boiler.

With the diesel locomotive has come water problems somewhat different from those encountered in steam power but fully as important for efficient and economical operation. Water for cooling must be scale free and rendered noncorrosive by treatment with compounds containing chromates, phosphates, soda ash or similar corrosion inhibiting materials. The operating conditions in the flash type heating boilers are particularly severe and distilled or demineralized water with adjustments for protection against corrosion has been found most satisfactory where scale-free, noncorrosive supplies are not available. Although the steam locomotives are reported as still handling over 80 percent of the transportation requirements on American railroads, it is noted that 6201 diesels were in service on December 1, 1948, and with the increasing number, the water problems developed in this power service will be given greater attention.

Methods for proper handling of drinking and culinary water used by the railroads have been given continuous attention since 1920 and your committee has been represented regularly on the AAR Joint Committee on Railway Sanitation. Compliance with the requirements of the Interstate Quarantine Regulations is necessary and conditions are checked in the field by representatives of the United States Public Health Service. These requirements and recommendations for compliance have been incorporated in our committee reports.

Problems of the Future

Future developments and problems to be handled in connection with the conditioning of railway water supplies, will probably be concerned with the improvements in sludge recirculation and sludge blanket lime-soda plants for large capacity installations and improved controls for the smaller wayside plants, particularly with reference to methods to be developed by research for determining and checking the tannin and organic materials used in water treatment which are reported to have given good results in some cases. The new polyamide type of antifoam materials are now undergoing extensive tests with their use being gradually extended, and these developments should be of interest in effecting improved operation with incident economies. Work is progressing and studies are being continued for improving the water conditions on diesel power units which will undoubtedly result in further benefits. Improvement in hydrants and equipment for handling drinking and culinary water to comply with the Public Health Service orders, as well as for waste disposal, are further subjects which are being given serious consideration and developments can be expected in this activity.

The record of water treatment on our railroads is one of great service. Vigilance needs to be exercised by all concerned to maintain the facilities and to continue to obtain the benefits of this program. Because the results of this work are of direct concern to other railroad departments, close cooperation must be maintained with the operating and mechanical forces, as well as the engineering and maintenance officers and employees The fact that four members of our committee have been named as honorary members of the Master Boiler Makers' Association, and that reports have been requested and delivered before meetings of the Railway Fuel and Traveling Engineers Association, as well as many national technical societies, indicates that this cooperation is being achieved The assistance and support given the committee work by the Board of Direction, the executive officers and the secretary have been a material aid in the work, and the broader and more beneficial recognition given the reports due to sponsorship by the American Railway Engineering Association, has served well in the promotion and advancement of railroad water service practice with the resulting economics and improvement in railway operation.

The Achievement of Grade Crossing Protection

By W. J. Hedley
Assistant Chief Engineer, Wabash Railroad

Those of us who are interested in highway-railway crossing problems know something of the value of crossing protection but we are not always sure that the achievement measured in number of lives saved, injuries prevented and property damage avoided is worth the effort, measured in terms of time devoted to design and programming and dollars spent in the installation of new and improved crossing protection devices.

And I don't say this in a spirit of cynicism or callousness. You all know that we still have accidents at protected crossings. You know that some automobile drivers, either through carelessness or just plain cussedness, continue to ignore the warnings provided for their benefit and protection. It is small wonder that we become skeptical; sometimes hypercritical.

Even so, we on the Wabash Railroad have continued to believe that there is at least some value in our efforts to improve grade crossing protection on our lines. We have continued to work cooperatively with those state, county and municipal authorities who are responsible for the safety of vehicular traffic. And may I say that we consider highway-railway grade crossing protection to be in a large measure the obligation of those highway agencies.

Decide to Measure the Results

Having been at this cooperative work for some time now, we decided it would be well to try to find out what our achievements had been. We are fortunate enough to have available a complete record of all the changes made in crossings and crossing protection and of all the accidents which have occurred at highway crossings on Wabash lines since January 1, 1929. Last December 31 completed 20 years of this record and I would like to show you something of what it now contains.

TABLE 1.—NUMBER OF ACCIDENTS AT GRADE CROSSINGS

Year	*Number of Accidents*	*Year*	*Number of Accidents*
1929	279	1939	159
1930	215	1940	159
1931	197	1941	194
1932	157	1942	137
1933	121	1943	143
1934	135	1944	157
1935	169	1945	164
1936	192	1946	149
1937	175	1947	215
1938	126	1948	196
Total number in 20 years			3439

Table 1 shows the total number of accidents which have occurred each year at all of the highway crossings on the 2000 odd miles of line presently owned, maintained and operated by the Wabash Railroad. The statistics I give you in this report do not include any figures accruing from crossings on lines which have been abandoned during the 20-year period. In this report an accident has been recorded for each occurrence involving a collision between a train, engine or cars and a vehicle or a pedestrian, for each occurrence in which a vehicle was damaged or a person injured in the course of avoiding such collision, and for each occurrence in which a person was injured as a result of collision with a crossing gate arm or any other part of a protective device. No account has been taken of the mere breaking of a gate arm or other damage to a protective device unless there was a resultant personal injury. You will note the 1929 figure of 279 accidents and the 1948 figure of 196. These show a reduction of approximately 30 percent in the 20-year period.

Let's look at these figures expressed graphically in Fig. 1. There is considerable variation from year to year. The over-all trend is downward, although that is not too evident. We know that there have been variations in the volume or traffic during the period and it is reasonable to suppose that some of the variations in the accident record may have followed these traffic fluctuations.

We do not have a traffic count each year at each crossing but there are some statistics available which serve very well as a measure of the general traffic fluctuations at these crossings on Wabash lines.

TABLE 2.—TRAIN MILES OPERATED BY THE WABASH RAILROAD

Year	*Train Miles*	*Year*	*Train Miles*
1929	16,273,797	1939	9,931,808
1930	14,127,425	1940	10,105,024
1931	12,347,677	1941	10,846,089
1932	10,179,451	1942	12,534,253
1933	9,244,268	1943	12,597,373
1934	9,434,194	1944	12,552,119
1935	9,648,708	1945	11,973,716
1936	10,377,738	1946	11,180,357
1937	10,702,102	1947	11,237,125
1938	9,565,312	1948	11,112,778

Table 2 is a record of train miles operated by the Wabash Railroad. You will note the maximum figure of more than 16 million in 1929 and the minimum, slightly more than 9 million in 1933, with increases to a level above 12½ million during the war years 1942, 1943 and 1944, and a subsequent decrease to 11 million plus train miles in 1948.

TABLE 3.—HIGHWAY USE OF MOTOR FUEL IN SIX STATES

Year	*1000 Gal.*	*Year*	*1000 Gal.*
1929	3,610,063	1939	5,290,684
1930	3,824,177	1940	5,641,988
1931	4,001,250	1941	6,266,435
1932	3,708,035	1942	5,298,742
1933	3,637,515	1943	4,150,116
1934	3,922,446	1944	4,123,890
1935	4,137,733	1945	4,715,942
1936	4,611,214	1946	6,222,174
1937	4,962,514	1947	6,779,144
1938	4,964,580	1948	

Source: Public Roads Administration, Federal Works Agency.

As a measure of fluctuations in vehicular traffic the record in Table 3 was secured from the Public Roads Administration. The figures show highway use of motor fuel. Such records are accumulated each year from each state and here I have consolidated

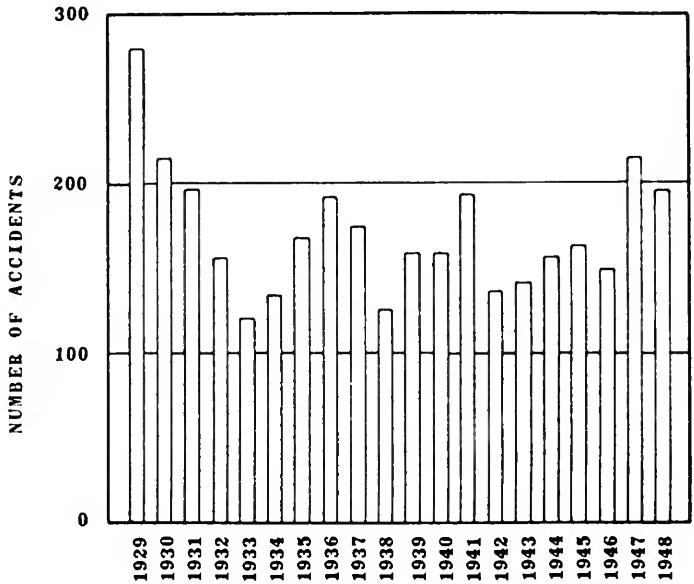


Fig. 1.

the figures for the six states—Michigan, Ohio, Indiana, Illinois, Missouri and Iowa—in which Wabash lines are located. The fluctuations in each individual state follow a quite similar pattern. Variations in the highway use of motor fuel are a good measure of the fluctuations in volume of highway traffic.

The chart in Fig. 2 gives a good picture of these fluctuations in the volume of rail and highway traffic. The rail traffic variations show clearly, down to the low point in 1933, up again through the war years, and again on a downward trend to date. The highway traffic index shows a continual upward trend except for two periods. The depression years of 1932, 1933 and 1934 show a minor dip in the curve and the war years—1942, 1943, 1944 and 1945—show a major dip, the 1943 and 1944 figures being only about 2/3 of those in 1941 and 1946. The trend is now again definitely upward.

Influence of Variations in Traffic

The effect of traffic variations on grade crossing accidents should be measurable. If you run twice the number of trains over a line, it is rather obvious that the accident potentiality is doubled. Likewise, if highway traffic is increased two-fold, the possibility of accident is doubled. If these increases in volume of the two conflicting traffic streams is concurrent, the accident potentiality is increased four times. This analysis may seem over-simplified, but I believe that, upon reflection, you will agree with it as a sound broad principle.

Based upon this principle I have taken the figures representing these volumes of rail and highway traffic each year, multiplied them, and thereby obtained a factor—(train miles) $\times$ (highway motor fuel used) — which should represent the relative accident potential year by year.

This yearly accident potential factor has been plotted to scale on the chart (Fig. 3) showing the number of accidents. You will note that the two—the accident potential

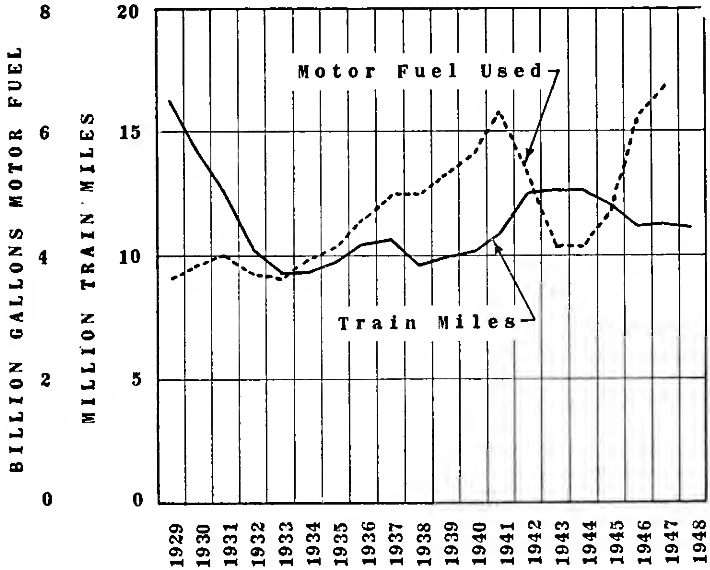


Fig. 2.

factor and the number of accidents—follow the same general pattern. They fall off to a low point in 1933, then rise; dip again in 1938; rise to 1941, dip during the war years and generally rise afterward. However, on careful inspection you will note a general upward trend in the accident potential factor over the 20-year period, while the accident figures have a general trend slightly downward.

It is very reasonable and logical that there should have been a decrease in accidents. During the 20 years we built 77 grade separations, changed protection at 321 crossings and closed 129 crossings which were abandoned, usually in connection with grade separation or crossing protection projects.

The thought then naturally occurred to us: What has been the accident experience with the two groups of crossings; those where changes have been made, and those where no changes have been made.

Table 4.—Accidents at Crossings Where Protection Was Not Changed

Year	*Number of Accidents*	*Year*	*Number of Accidents*
1929	150	1939	97
1930	115	1940	114
1931	114	1941	138
1932	90	1942	96
1933	72	1943	88
1934	81	1944	113
1935	93	1945	110
1936	104	1946	119
1937	116	1947	159
1938	77	1948	159
Total number in 20 years			2205

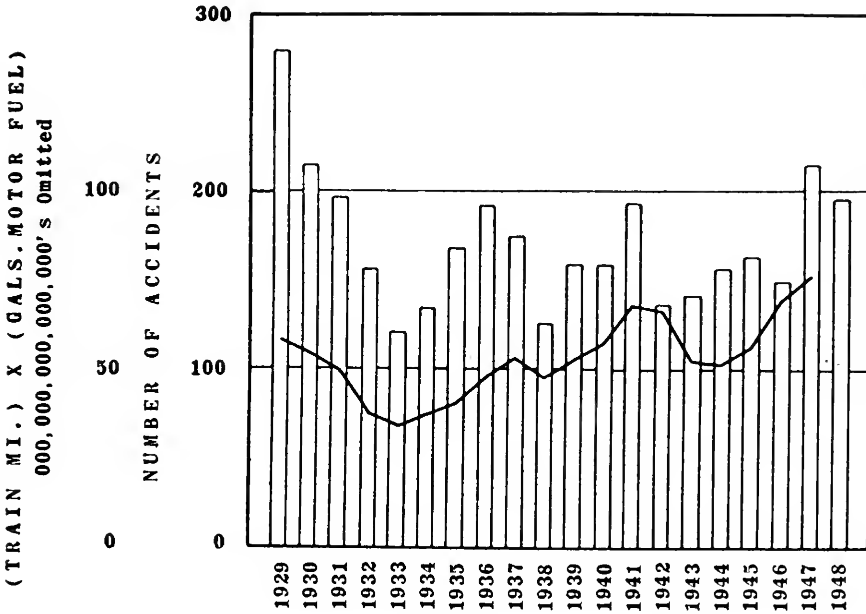


Fig. 3.

First, let's consider the latter group: Those crossings where protection has remained the same throughout the 20-year period. Table 4 shows the number of accidents which occurred at the 2555 crossings in that group. As was the case with the crossings as a whole, the accidents in this group dropped down from 1929 when there were 150 to a low point in 1933 when only 72 accidents occurred. Then there were fluctuations up and down, but you will notice that for each of the last 2 years the number 159 is a figure somewhat higher than the 150 in 1929.

Now, I want to show you something in Fig. 4 which possibly is only natural, yet I consider it rather remarkable: The correlation between the accident potential and the number of accidents which actually occurred at all the crossings in the group where no changes were made in protection. As before, the relative accident potential is shown by the zigzag line. The columns on the chart have been filled in at the base so that the number of accidents which occurred at crossings where protection was not changed is shown by the top of the heavy black part of the column. Note carefully how the number of these accidents fluctuates year by year, following almost exactly the accident potential factor obtained from train miles and highway motor fuel used. I have no doubt that if it were possible to have accident potential factors based on the actual number of train and vehicle movements over these particular crossings, the correlation would be even closer.

Decrease in Accidents

One more significant figure can be obtained at this point. The accidents which occurred at the crossings in the group where changes were made during the 20 years are shown on the upper portion of the columns on the chart. In 1929 this number, the

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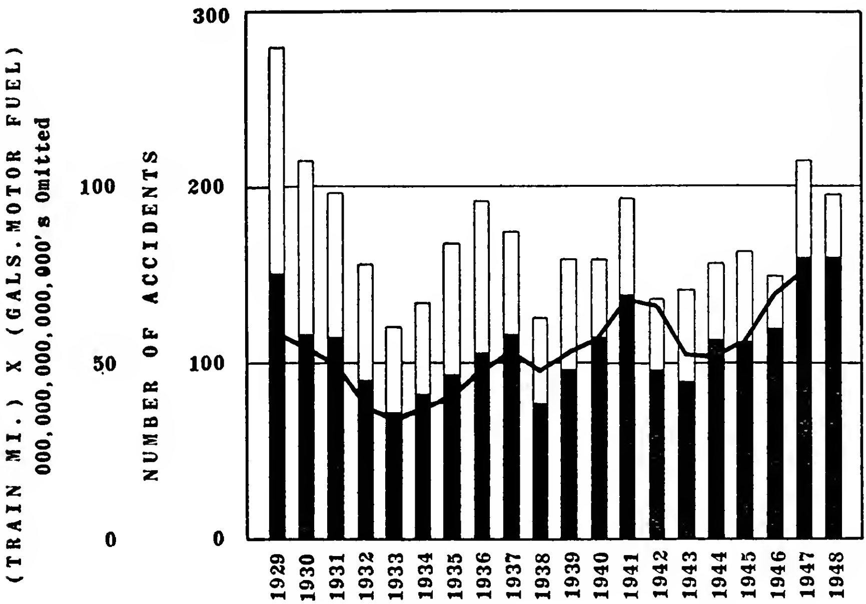

Fig. 4

difference between 279 and 150, was 129; in 1948 the corresponding number, the difference between 196 and 159, was 37. The decrease in accidents in that group was 71.3 percent.

You may say that is not extraordinary. When grades are separated and crossings abandoned, grade crossing accidents no longer occur. That is quite right; and to a very considerable extent the reduction in accidents thus may be accounted for. But, having a desire to determine the effect of crossing protection, I have made a further analysis of the accident records of those crossings where, during the 20-year period, protection was changed from one form to another. That group consists of 321 individual crossings, at 20 of which protection was changed twice during the 20 years. And as I show you the results of this analysis, keep this fact in mind: This group constitutes all of the highway grade crossings on Wabash owned and operated lines at which crossing protection was changed during the 20-year period; it is not a specially selected or hand picked group.

Table 5.—Types of Crossing Protection

Painted crossbuck signs.
Reflector type crossbuck signs—AREA plan.
Reflector type crossbuck signs—required in Michigan.
Automatic bell.
Wig-wag.
Flashing light signals—at single-track crossings.
Flashing light signals—at multiple-track crossings.
Watchman.
Manual gates—part time operation.
Manual gates—full time operation.
Automatic gates.

By inspection of the records, we found that 9 types of protection were used on these crossings. The types are listed in Table 5. There are 11 listings; manual gate installations are subdivided between those operated part time and those operated for the full 24 hours daily, and crossings protected with flashing light signals have been subdivided into two groups, those where the railroad consists of a single track, and those where there are two or more tracks.

First in the list is the painted crossbuck sign, the AREA design or such similar sign as is required by state law.

Next, reflector type crossbuck signs—AREA design; 6-ft. blades at a 50-deg. angle; black letters on a white background.

Third, reflector type crossbuck signs required by the Michigan state law; 4-ft. blades at a 90-deg. angle; black letters on a yellow background.

These first three types of protection are fixed signs only, which indicate to the driver of a vehicle the location of a railroad track or tracks. The other eight types provide, in addition, an indication—in one form or another—of the approach of a train or the presence of a train or cars on the crossing.

The automatic bell, operated by track circuits, gives an audible indication of the approach or presence of a train. The bell installations all include either painted or reflectorized crossbuck signs to give a visual indication of the location of the crossing.

Each wig-wag installation covered by this analysis consists of one swinging unit on a high pole with a single red light showing in each direction along the highway. They are operated by track circuits.

In the flashing light signal installations the aspect at each signal is that of two alternately flashing red lights. Two signals are used at each crossing with additional pairs of lights sometimes used for diverging or intersection routes. Track circuit operation is employed with varying amounts of manual control or manual supervision at locations where irregular switching movements are common. For the purpose of this analysis, flashing light signal installations have been divided into two groups because of the tendency in recent years to differentiate between single-track crossings and multiple-track crossings when selecting the type of protection to be installed.

Watchman protection is afforded by a man on the ground at the crossing equipped with "stop" sign and lantern.

Manual gates consist of the older types of pneumatic or mechanical gates, usually four gates per crossing completely obstructing the highway when in the lowered position. Advance warning is sometimes provided by a manually operated bell. Part time manual gate installations included in this analysis were operated either 16 hours or 20 hours daily.

Automatic gates consist of the modern electrically operated gates with flashing light signals for advance warning and additional warning aspect. The typical installation includes two gates, one located on each side of the tracks on the right hand side of the highway, so that in the lowered position the gate arm extends over the roadway a sufficient distance to cover the lands or lanes used by traffic approaching the crossing. Each gate arm carries three red lights which shine in both directions along the highway, two of them flashing alternately and the other—nearest the tip—burning steadily. Automatic gates are operated by track circuits, some with varying amounts of manual control or manual supervision at locations where irregular switching movements are common.

Table 6.—Summary of Protection Afforded at Crossings Where Changes Were Made

Type of Protection	Number of Crossings
Painted crossbuck signs	226
Reflector crossbuck signs—AREA	38
Reflector crossbuck signs—Michigan	86
Automatic bell	26
Wig-wag	13
Flashing lights—single track	39
Flashing lights—multiple tracks	111
Watchman	36
Manual gates—part time	13
Manual gates—24 hours	20
Automatic gates	54

In the group of crossings where changes have been made, protection of the various types have been in use during some part of the 20-year period at the number of crossings indicated on this list. You will note in Table 6 that painted crossbucks are in the greatest number, 226 crossings. You will also note that 39 single-track crossings and 111 multiple-track crossings were provided with flashing lights and 54 crossings with automatic gates.

For further analysis, we should know how long each of these forms of protection was in use.

Table 7.—Extent of Experience Obtained

Type of Protection	No. of Crossing Years Actual	No. of Crossing Years Equated
Painted crossbuck signs	1812.2	1717.9
Reflector crossbuck signs—AREA	424.7	438.9
Reflector crossbuck signs—Michigan	1057.2	1078.8
Automatic bell	320.5	307.3
Wig-wag	55.5	57.5
Flashing lights—single track	383.8	405.6
Flashing lights—multiple tracks	1308.2	1330.4
Watchman	386.8	368.4
Manual gates—part time	71.1	67.8
Manual gates—24 hours	267.2	263.6
Automic gates	248.7	291.8
Total	6335.9	6328.0

Table 7 shows two columns of figures. The one to the left shows the aggregate length of time these crossings were equipped with each of the various types of protection. For example, the 226 crossings had painted crossbuck signs for an aggregate of 1812.2 years, an average of 8 years per crossing, and the 111 multiple track crossings with flashing lights had that form of protection for an aggregate of 1308.2 years or an average of approximately 12 years per crossing, whereas the 54 crossings with automatic gates had an aggregate of 248.7 years or 4.6 years per crossing.

However, we need some measure of experience other than actual years of use. It was apparent from those annual accident figures and from the charts showing traffic fluctuations, that a year of experience in 1929 or 1948 represented a much greater accident potentiality than a year of experience in 1932 or 1933. Some adjustments are definitely indicated. They might reasonably be based on the accident potential curve obtained from the train mile and highway motor fuel statistics. However, an even more logical adjustment base is available in the accident record on these same lines of railroad at the 2555 crossings where no change was made in protection during the 20-year period.

At those crossings the number of accidents in the year 1929 was equal to 136 percent of the annual average for the 20-year period. Hence, I have concluded that one year of experience at a crossing in 1929 was equivalent to 1.36 years of average experience; or, to express it as has been done in this table, each actual crossing year of experience in 1929 was equivalent to 1.36 equated crossing years of experience. Similarly, each actual crossing year of experience in 1933 was equivalent to only about 0.65 of an equated crossing year of experience. On that basis each actual period of experience with a particular form of protection at each crossing has been converted into equated years of experience. The right hand column shows the summation of these equated crossing years. Equated crossing years are used throughout the remainder of this report. In that manner traffic fluctuations and variable accident potential are recognized and automatically taken into account.

Before leaving this table it is interesting to note that this study and report are based on more than 6300 crossing years of experience, an adequate figure from which to draw some conclusions. The total figure would be 6420 for the 321 crossings for a 20-year period except that grade separations were constructed at some locations and some crossings were abandoned at later dates. Those later changes also give rise to the slight difference between the total actual years and total equated years.

TABLE 8.—SUMMARY OF ACCIDENT RECORD

Type of Protection	*Number of Accidents*	*Average Per Crossing-Year*
Painted crossbuck sign	270	0.1572
Reflector crossbuck signs—AREA	49	0.1116
Reflector crossbuck signs—Michigan	74	0.0686
Automatic bell	79	0.2571
Wig-wag	10	0.1739
Flashing lights—single track	32	0.0789
Flashing lights—multiple tracks	265	0.1992
Watchman	174	0.4723
Manual gates—part time	22	0.3245
Manual gates—24 hours	44	0.1669
Automatic gates	27	0.0925

Now, let's see what happened at the crossings where these various types of protection were used. In Table 8 we have the number of accidents and the average number of accidents per equated crossings year. These average figures have some interest. You will note that at crossings with painted crossbuck signs the average number of accidents per equated crossing year is 0.1572, or about 1 accident per crossing every 6-1/3 years Also, note the figure for automatic gate protection, 0.0925, or about 1 accident per crossing every 10.8 years. Keep this figure 0.0925 in mind. It will be used again. Note also the high figure of 0.4723, or about 1 accident per crossing every 2 years at those having watchman protection.

"But," you may well say, "Is that fair? Traffic conditions may vary at these several crossings. Maybe watchman protection was used only at crossings having heavy traffic and poor visibility." That skepticism is warranted. The answer to it lies in comparing two forms of protection when both have been used on the same identical crossings.

The summary in Table 9 (Part 1) shows the number of crossings at which protection of one specific type was changed to another specific type. This and Table 9 (Part 2) contain a record of all of the changes made in the 20-year period. In some categories only one change was made; in others, a substantial number, as, for example, painted

TABLE 9 (PART 1).—CHANGES MADE IN PROTECTION

Before	*Type of Protection* *After*	*Number of Crossings*
Painted crossbuck signs	Reflector signs—AREA	38
" " "	Reflector signs—Michigan	86
" " "	Automatic bell	1
" " "	Wig-wag	3
" " "	Flashing lights—single track	35
" " "	Flashing lights—mult. tracks	59
" " "	Watchman	3
" " "	Automatic gates	16
Reflector signs—AREA	Flashing lights—single track	3
" " "	Automatic gates	1
Reflector signs—Michigan	Flashing lights—mult. tracks	2
" " "	Automatic gates	5

crossbuck signs were changed to reflector signs of the AREA type at 38 crossings, painted crossbuck signs to reflector signs of the Michigan type at 86 crossings, and painted crossbuck signs to flashing lights at 35 single-track crossings and 59 multiple-track crossings.

TABLE 9 (PART 2).—CHANGES MADE IN PROTECTION

Before	*Type of Protection* *After*	*Number of Crossings*
Automatic bell	Flashing lights—single track	4
" "	Flashing lights—mult. tracks	15
" "	Automatic gates	6
Wig-wag	Flashing lights—mult. tracks	9
"	Automatic gates	4
Flashing lights—mult. tracks	Automatic gates	13
Watchman	Flashing lights—mult. tracks	17
"	Manual gates 24 hours	1
"	Automatic gates	18
Manual gates—part time	Flashing lights—mult. tracks	3
" " " "	Manual gates—24 hours	10
Manual gates—24 hours	Flashing lights—mult. tracks	4
" " " "	Automatic gates	5
Total Number of Changes		361

In Table 9 (Part 2) are listed all of the changes made from one form of automatic or manually operated protection to another such form. In all of these cases the new form of protection consisted of either flashing light signals or automatic gates, except in one instance where watchman protection was changed to full time manual gates and at 10 crossings where manual gate protection was changed from part-time operation to full-time operation.

Now that we know what changes were made, let's see what accidents occurred before the change and after the change. In Table 10 (Parts 1 and 2) we have the 20-year record. The individual figures do not have much significance although it is interesting to note that the totals show 684 accidents before and only 459 after protection was changed.

Again we need to get the years of experience before the change and after the change.

TABLE 10 (PART 1).—NUMBER OF ACCIDENTS

Type of Protection: Before	Type of Protection: After	Accidents: Before	Accidents: After
Painted crossbuck signs	Reflector signs—AREA	43	49
" " "	Reflector signs—Michigan	23	74
" " "	Automatic bell	0	3
" " "	Wig-wag	2	0
" " "	Flashing lights—single track	65	28
" " "	Flashing lights—mult. tracks	93	96
" " "	Watchman	22	9
" " "	Automatic gates	50	5
Reflector signs—AREA	Flashing lights—single track	5	1
" " "	Automatic gates	2	1
Reflector signs—Michigan	Flashing lights—mult. tracks	3	2
" " "	Automatic gates	14	2

TABLE 10 (PART 2).—NUMBER OF ACCIDENTS

Type of Protection: Before	Type of Protection: After	Accidents: Before	Accidents: After
Automatic bell	Flashing lights—single track	16	4
" "	Flashing lights—mult. tracks	16	15
" "	Automatic gates	44	2
Wig-wag	Flashing lights—mult. tracks	8	41
"	Automatic gates	2	1
Flashing lights—mult. tracks.	Automatic gates	59	9
Watchman	Flashing lights mult. tracks	41	48
"	Manual gates 24 hours	6	3
"	Automatic gates	127	17
Manual gates—part time	Flashing lights—mult. tracks	0	9
" " " "	Manual gates—24 hours	22	20
Manual gates—24 hours	Flashing lights—mult. tracks	7	20
" " " "	Automatic gates	14	0
Total		684	459

In Table 11, as before, no conclusion can be drawn from these individual figures, although they are essential to the further calculations. The totals show 2904.9 equated years before and 3823.1 equated years after protection was changed. You may note that the total of these two figures is 400 more than the total equated crossing years of experience for the reason that 20 crossings are duplicated, protection having been changed twice at them during the 20-year period.

TABLE 11—(PART 1).—EQUATED CROSSING YEARS OF EXPERIENCE TABULATED ACCORDING TO CHANGES MADE

Type of Protection: Before	Type of Protection: After	Crossing Years: Before	Crossing Years: After
Painted crossbuck signs	Reflector signs—AREA	268.4	438.9
" " "	Reflector signs—Michigan	553.0	1078.8
" " "	Automatic bell	1.2	18.8
" " "	Wig-wag	43.3	16.7
" " "	Flashing lights—single track	312.4	380.3
" " "	Flashing lights—mult. tracks	418.1	696.4
" " "	Watchman	41.8	18.1
" " "	Automatic gates	173.9	83.6
Reflector signs—AREA	Flashing lights—single track	7.3	32.5
" " "	Automatic gates	4.1	8.2
Reflector signs—Michigan	Flashing lights—mult. tracks	10.1	19.9
" " "	Automatic gates	40.1	33.3

Table 11 (Part 2).—Equated Crossing Years of Experience Tabulated According to Changes Made

Type of Protection Before	After	Crossing Years Before	After
Automatic bell	Flashing lights—single track	54.7	25.3
" "	Flashing lights—mult. tracks	141.4	158.6
" "	Automatic gates	92.4	27.6
Wig-wag	Flashing lights—mult. tracks	29.3	112.8
"	Automatic gates	15.4	34.7
Flashing lights—mult. track	Automatic gates	140.4	85.4
Watchman	Flashing lights—mult. tracks	134.2	172.2
"	Manual gates—24 hours	1.4	8.8
"	Automatic gates	235.2	119.0
Manual gates—part time	Flashing lights—mult. tracks	3.6	56.4
" " " "	Manual gates—24 hours	64.2	135.8
Manual gates—24 hours	Flashing lights—mult. tracks	32.3	47.7
" " " "	Automatic gates	86.7	13.3
Total		2904.9	3823.1

Table 12 (Part 1).—Average Number of Accidents per Equated Crossing Year

Type of Protection Before	After	Accidents per Year Before	After
Painted crossbuck signs	Reflector signs—AREA	0.1602	0.1116
" " "	Reflector signs—Michigan	0.0416	0.0686
" " "	Automatic bell	0.0	0.1596
" " "	Wig-wag	0.0462	0.0
" " "	Flashing lights—single track	0.2081	0.0736
" " "	Flashing lights—mult. tracks	0.2224	0.1379
" " "	Watchman	0.5263	0.4972
" " "	Automatic gates	0.2875	0.0598
Reflector signs—AREA	Flashing lights—single track	0.6849	0.0308
" " "	Automatic gates	0.4878	0.1220
Reflector signs—Michigan	Flashing lights—mult. tracks	0.2970	0.1005
" " "	Automatic gates	0.3491	0.0601

Now, in the set of figures in Table 12 (Part 1) there is some real meat. Here in the left column is shown the average number of accidents per year before protection was changed and, in the right column, the average number of accidents per year after the change was made. Take the top figures as an example. They show that at the crossings where painted crossbuck signs were changed to reflector signs of the AREA type, the accident rate before change was 0.1602 and after change it was 0.1116, a reduction of about 30 percent.

Next, look at the figures in the 8th line showing the change from painted crossbucks to automatic gates. Before the change the accident rate was 0.2875; after, it was 0.0598; a reduction of almost 80 percent.

At the top of Table 12 (Part 2)—the change from automatic bell to flashing lights at single track crossings—the accident rate with bells was 0.2925; and with flashing lights it was 0.1581, a reduction of 46 percent. The next line shows the change from automatic bell to flashing lights at multiple track crossings, where the reduction, from 0.1132 to 0.0946, was only about 16½ percent. Note the overall average, a reduction from 0.2355 before the change to 0.1201 afterward, approximately 49 percent. That, in a sense is a measure of achievement.

TABLE 12 (PART 2).—AVERAGE NUMBER OF ACCIDENTS PER EQUATED CROSSING YEAR

Type of Protection Before	Type of Protection After	Accidents per Year Before	Accidents per Year After
Automatic bell	Flashing lights—single track	0.2925	0.1581
" "	Flashing lights—mult. tracks	0.1132	0.0946
" "	Automatic gates	0.4762	0.0725
Wig-wag	Flashing lights—mult. tracks	0.2730	0.3635
"	Automatic gates	0.1299	0.0288
Flashing lights—mult. track	Automatic gates	0.4202	0.1054
Watchman	Flashing lights mult. tracks	0.3055	0.2787
"	Manual gates—24 hours	4.2857	0.3409
"	Automatic gates	0.5400	0.1429
Manual gates—part time	Flashing lights—mult. tracks	0.0	0.1596
" " " "	Manual gates—24 hours	0.3427	0.1473
Manual gates—24 hours	Flashing lights—mult. tracks	0.2167	0.4193
" " " "	Automatic gates	0.1615	0.0
Average		0.2355	0.1201

However, now that we have these several comparisons obtained from the experience at crossings where protection has been changed from one specific type to another specific type, it would be very desirable to put them all on a comparable basis; to relate them to each other.*

One available medium through which to accomplish this is found in the experience at automatic gate protected crossings. Protection installations of several other types have been changed to automatic gates.

EXAMPLE 1

	Average Accidents per Equated Crossing Year
At all 54 crossings with automatic gates	0.0925
At 16 crossings changed from painted signs to automatic gates:	
Before change	0.2875
After change	0.0598
Accident factor for painted crossbuck signs related to overall average of experience with automatic gates: $\frac{0.2875 \times 0.0925}{0.0598} =$	0.4447

Earlier we found that the average rate of accidents at all of the 54 crossings with automatic gate protection was 0.0925 accidents per equated crossing year. As you will remember, the accident rates at crossings where painted crossbuck signs were changed to automatic gates were 0.2875 before and 0.0598 after the change. Now if these crossings had been of the average at which automatic gates were installed, the accident rate afterward would have been 0.0925 and as this example shows, the rate for painted crossbuck signs at these crossings on a comparable basis would have been 0.4447 accidents per equated crossing year.

Similar calculations were made for the other types of protection which had been changed to automatic gates and the result is shown in Table 13, a fairly direct comparison of the effectiveness of these several types. The column of figures on the left shows figures which I have labeled experience factors. It is axiomatic that the greater the experience, the more reliable the results. In any of these cases where experience with

TABLE 13.—COMPARATIVE EFFECTIVENESS OF VARIOUS TYPES OF CROSSING PROTECTION DETERMINED FROM EXPERIENCE AT 54 CROSSINGS WHERE AUTOMATIC GATES ARE IN USE

Type of Protection	*Experience Factor (Years)*	*Accidents per Crossing Year*
Automatic gates	291.8	0.0925
Painted crossbuck signs	83.6	0.4447
Reflector signs—AREA	4.1	0.3698
Reflector signs—Michigan	33.3	0.5373
Automatic bell	27.6	0.6076
Wig-wag	15.4	0.4172
Flashing lights—multiple tracks	85.4	0.3688
Watchman	119.0	0.3495

either form of protection is limited to only a few years, the results are not as reliable as in cases where the protection experience figures both before the change and after the change aggregate a substantial number of years. Hence, in order to show the relative experience behind each accident rate, an experience factor is recorded, each experience factor being the smallest of the equated years of experience upon which any component accident rate has been determined.

EXAMPLE 2

	Average Accidents per Equated Crossing Year
Accident factor for reflector signs—AREA determined from experience at crossings with automatic gates	0.3698
At 38 crossings changed from painted signs to reflector signs—AREA:	
Before change	0.1602
After change	0.1116
Accident factor for painted crossbuck signs:	
$\frac{0.1602 \times 0.3698}{0.1116} =$	0.5308

Now we have a comparison between painted crossbuck signs and automatic gates and a comparison between reflector signs—AREA and automatic gates, both of which have been reduced to the common denominator of the average accident rate for all crossings having automatic gate protection. We also have comparative accident rates obtained at those crossings where painted crossbuck signs were changed to reflector signs—AREA type. Using these figures we obtain another accident factor for painted crossbuck signs—see Table 14.

TABLE 14.—ACCIDENT QUOTIENT FOR PAINTED CROSSBUCK SIGNS DETERMINED FROM ACCIDENT FACTORS FOR OTHER FORMS OF PROTECTION

Type of Protection	*Experience Factor (Years)*	*Accident Factor*
Automatic gates	83.6	0.4447
Reflector signs—AREA	4.1	0.5308
Reflector signs—Michigan	33.3	0.3258
Flashing lights—single track	85.4	0.5947
Watchman	18.1	0.3700
Accident quotient =		
Weighted average of above factors =		0.4797

Similar calculations produced these several other accident factors for painted crossbuck signs. Experience factors are shown for each and at the bottom is an accident

TABLE 15.—INTERMEDIATE ACCIDENT QUOTIENTS (ACCIDENTS PER CROSSING YEAR)

Type of Protection	*Experience Factor (Years)*	*Intermediate Accidents Quotient*
Automatic gates	291.8	0.0925
Painted crossbuck signs	224.5	0.4797
Reflector signs—AREA	279.8	0.4302
Reflector signs—Michigan	596.4	0.7786
Automatic bell	194.3	0.3928
Wig-wag	44.7	0.2925
Flashing lights—single track	341.8	0.1796
Flashing lights—multiple tracks	675.6	0.3023
Watchman	271.3	0.3475
Manual gates—part time	33.7	0.3511
Manual gates—24 hours	33.7	0.1509

quotient, 0.4797 accidents per year, which is a weighted average of all of the factors shown above it.

Similar calculations produced the intermediate accident quotients in Table 15 for all the other forms of protection. They are called intermediate because they are based on somewhat limited experience factors. Calculations of intermediate accident quotients were made in the following order: Painted crossbuck signs, flashing lights—single track, flashing lights—multiple tracks, reflector signs—AREA, reflector signs—Michigan, automatic bell, wig-wag, watchman, manual gates—24 hours, and manual gates—part time. As soon as an intermediate accident quotient was determined for one form of protection, it, together with its corresponding experience factor, was then used in succeeding calculations in lieu of the accident factor previously developed from automatic gate protected crossings only.

TABLE 16.—FINAL ACCIDENT QUOTIENTS

Type of Protection	*Experience Factor (Years)*	*Final Accident Quotient*
Automatic gates	291.8	0.0925
Painted crossbuck signs	1653.6	0.5038
Reflector signs—AREA	279.8	0.4450
Reflector signs—Michigan	596.4	0.8156
Automatic bell	194.3	0.3941
Wig-wag	44.7	0.2936
Flashing lights—single track	345.0	0.1773
Flashing lights—multiple tracks	850.8	0.3044
Watchman	272.7	0.3581
Manual gates—part time	64.2	0.3520
Manual gates—24 hours	97.9	0.1513

The final accident quotients in Table 16 are the result of another complete set of calculations based upon the intermediate accident quotients and substantially larger experience factors. These calculations were made in the same order as those made for the intermediate quotients and, similarly, final accident quotients were used in succeeding calculations as soon as they were available. These figures are very enlightening.

They are shown graphically in Fig. 5 in preferential order. At the top of the list are automatic gates. Having the smallest accident quotient, they have constituted the most effective form of protection.

Next in order are manual gates operated 24 hours daily. The accident quotient for this type of protection is about 60 percent greater than that for automatic gates. Following these two types of gates come flashing light signals at single track crossings. They are only about 15 percent less effective than full time manual gates.

Following these three, come the other types which give warning of train movements. They rank in order: wig-wags, flashing lights at multiple-track crossings, manual gates—part time, watchman and automatic bell. The range of accident quotients is from about 0.3, or 3¼ times the automatic gate figure for wig-wags and flashing lights at multiple-track crossings, to about 0.4 or 4¼ times the automatic gate figure for an automatic bell. You will note that watchman protection ranks next to an automatic bell as being the least effective form of protection other than fixed signs.

The fixed signs rank in order of effectiveness: Reflector signs—AREA type, painted crossbuck signs and reflector signs of the Michigan type with 4-foot blades and yellow backgrounds.

I think these figures are very interesting and informative. Possibly you will say there is nothing new or startling about the result. They may only confirm what you

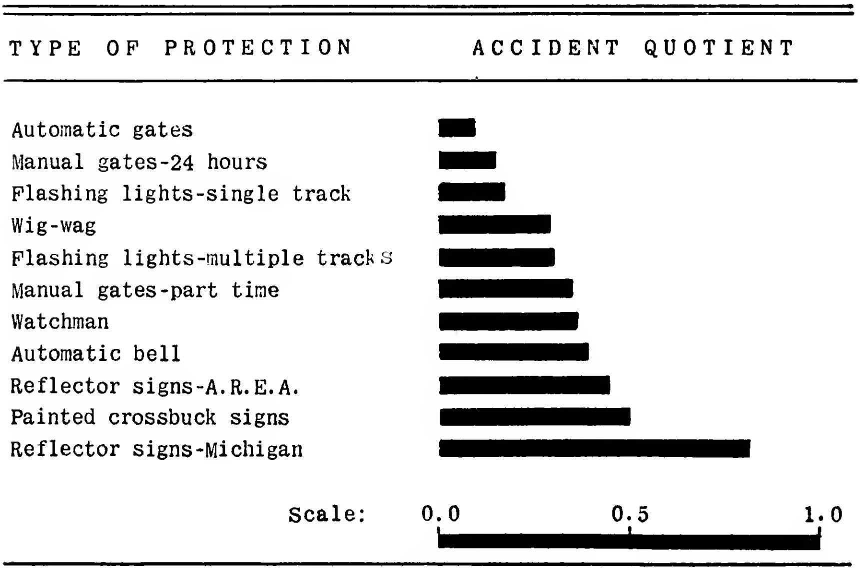

Fig. 5.

already thought you knew. But I think this is the first rational analysis that has been made to measure and determine the relative effectiveness of various forms of crossing protection. If the statistical information is available, I hope other similar studies will be made on other groups of crossings.

Until that is done, I commend these figures to you. Remember they are based on a 20-year record. They are backed by more than 6300 crossing-years of experience. They have been adjusted for fluctuations in accident potential resulting from periodic changes in traffic volume, and the comparisons between types of protection are based fundamentally on the use of two types at the very same crossings.

On these 321 crossings in 1929 we had 83 accidents; in 1948, with somewhat more accident potential, we had only 37. That is a measure of the achievement of grade crossing protection.

Early History and Work Accomplished by Committee 17 —Wood Preservation

By Dr. Hermann von Schrenk*
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At the time of the organization of the Committee on Wood Preservation of the AREA there were two committees involved, namely that committee and the Committee on Ties. In the beginning the work on wood preservation was all done by the members of the Tie Committee. This work consisted in a study of the conditions on American railroads, particularly with reference to the treated ties, bridge materials, piles, etc., then used as a matter of standard practice. This goes back to the year 1899, when the Tie Committee was organized, and specifically to the year 1909, when the Wood Preservation Committee was formed.

In 1899 the treatment of ties and other materials was in its very beginning in the United States. The earliest tie treatments consisted of the use of zinc chloride, employed by the Santa Fe, the Southern Pacific and others, and a little later of the use of creosote, which was then being applied for the first time in this country, particularly on the Louisville & Nashville. Previously the use of creosote had been confined almost exclusively to the treatment of marine structures.

It was soon realized that we on the American railroads could learn much by a study of wood preservation as practiced by European railways. A number of members of the committee made several trips to Europe and studied treating processes, the preservatives used, the installation of ties in track and allied questions that had a bearing on increased service life.

In those days both committees, realized the importance of treated wood, particularly in the shape of ties. They tried to distinguish between problems, which are still of great significance today, namely, getting ties into a fit condition so they could be treated, the chemical treatment, and what could be done after the ties were laid in track to get the maximum life, i.e., how to prevent mechanical wear. This latter question naturally arose after many treated ties had been laid in track and the observation made generally, not only by the AREA committee but by the railroads as well, that maximum life would be seriously affected by mechanical destruction, even though ties were efficiently treated to reduce or prevent decay.

The First Report of Committee 17

The first report of Committee 17—Wood Preservation dealt with the writing of specifications for zinc chloride, and for creosote. Several years were spent in consultation with members of other organizations, such as the American Society for Testing Materials, the American Society of Civil Engineers, etc., which ultimately led to the formulation and adoption by the AREA of a specification for creosote and a process to be used in the treatment of ties, also a specification for zinc chloride and the process to be used.

Because of these studies and the reports which resulted therefrom, great interest was aroused among railroad engineers all over the country. Test tracks of various kinds were installed, using different processes of treatment, different preservatives, different types of tie plates for reducing mechanical wear, etc.

* Read in Dr. von Schrenk's absence by C. S. Burt, chairman of Committee 17.

From time to time, with the increasing use of creosote, all sorts of problems arose, many of which were referred to Committee 17. There was further research and development in the methods for treatment, particularly on problems dealing with the chemical phases of controlling the type of creosote used and with methods for enforcing specifications. It is of interest to note that in the AREA Proceedings of these early years there are repeated references to the highly cooperative spirit manifested by the larger railway systems in developing the specification changes referred to, and particularly to the increasing number of treated ties which made their appearance in the tracks of some of the larger railways.

As a result of the activities of the AREA committee and the experimental work done in cooperation with the various railroads a large amount of information was developed with surprising rapidity so that before very long the practices recommended by the AREA were generally adopted by the railroads that had decided that the use of ties treated with one preservative or another, chiefly creosote, was a good practice.

Treating Processes

The next step was the adoption of specifications for treating processes. Two processes were adopted, which have since been called empty-cell creosoting processes, by which is meant the injection of as much creosote as possible, followed by a subsequent withdrawal of a considerable amount of this creosote, thus accomplishing a maximum penetration with a minimum amount of creosote retention. One of these, the Lowry process, was started on the Big Four in 1905, and the other, the Rueping process, a German invention, was started on a large scale on the Santa Fe in 1906. These processes involved what might be called fundamental changes because they employed methods for getting maximum penetration in the ties at a very large financial saving. In the early days creosote was used to the extent of 10 to 16 lb. per cu. ft. With the introduction of these new processes the amount of preservative was reduced to less than half of the amount previously used, which, as was just stated, resulted in a very great saving because of the smaller amount of preservative retained.

A further step consisted in the investigations which led to the addition of varying percentages of coal tar to distillate creosote. This practice started with the addition of 20 percent coal tar to 80 percent creosote on a number of the western railroads in 1908, which formula was changed rather rapidly by increasing the percent of the coal tar until it became a common practice to have ties treated with 70/30 creosote-coal tar solution, 60/40 creosote-coal tar solution and 50/50 creosote-coal tar solution. The last step in this development consisted in the use of 100 percent coal tar.

Throughout this period the aids in getting maximum penetration were developed, such as adzing and boring and incising of ties. Adzing and boring gave better penetration at the rail seat, the spot most vulnerable to the mechanical destruction of the tie. Furthermore, the adzing gave a better bearing under the rails or tie plates, resulting in lower mechanical destruction.

While the investigations on the part of the committee were going on that related to improved processes and the writing of detailed specifications for preservatives, one of the most important phases of work done, specifically by the AREA committee and its associates, was the study of the toxicity of preservatives. Several reports were written dealing with the changes which take place in creosote or coal tar, either separately or combined, during periods of exposure in the track. Incidentally, these investigations are being continued. Examinations are now being made of test ties treated with 60/40 creosote-coal tar solution and with straight coal tar, after 12 years in track.

Mixture Treatments

As a result of all this research the situation today is that most of the railroads in America are now using coal tar compounds for preserving ties. There are a few roads that are still using distillate creosote, but most of the railroads are using solutions of creosote and varying percentages of coal tar. Some railroads even went to 100 percent coal tar.

At about the time that coal tar began to be added to creosote, the question arose why it would not be practicable to add petroleum to creosote. This followed the finding that petroleum-creosote mixtures were in extensive use on some of the Balkan state railways, particularly in Hungary. Experimental treatments were accordingly carried out and ties treated with mixtures of creosote and petroleum were laid in an experimental track on the Santa Fe. Petroleums of various types were experimented with, such as those coming from the Tampico, Mexico, field, Oklahoma, Bakersfield and from other American sources. A considerable number of ties were treated with petroleum without any creosote. After only a few years, however, it was found that the ties treated with petroleum alone failed almost universally, largely due to the fact that the ties were decayed, demonstrating fully that petroleum by itself had no toxicity which would protect the ties against decay. These early tests led to the adoption by the Santa Fe of creosote-petroleum solutions as its standard treatment for ties. These creosote-petroleum ties showed such evidence of excellent service that this practice gradually spread. It is now used very extensively by some of the leading railroads in the United States. As a result of this wide use the Wood Preservation Committee prepared a specification for creosote-petroleum solution and a specification covering petroleum to be used for mixing with creosote.

At the same time mixtures of petroleum with zinc chloride were employed, known as the zinc-petroleum treatments. Detailed records of all of these treatments, including track installations, frequent inspection results, etc., were published in the AREA Proceedings (Committee 17 reports) over the years.

The committee is also engaged in investigations dealing with the use of various new preservatives which are being advocated from time to time, and are in use at the present time, such as chromated zinc chloride, tanalith, greensalt, pentachlorophenol and copper naphthenate, and new processes such as Celcure and others.

At the present time new methods are being advocated for artificially seasoning wood before treatment. This year's report includes a description of one of these known as the vapor drying process. Another method of artificially seasoning wood, based on the use of high frequency dielectric heating, is being investigated.

Another interesting development concerns the research being conducted by several of the large petroleum corporations looking toward the converting of petroleum fractions into products high in aromatic compounds. These materials have high toxicity and are being investigated for possible use as timber preservatives.

Another subject which has engaged the attention of the committee is the question of making wood fire resistant. This includes the compounds which might be used, the manner of application, method of determining retention and above all, the testing of performance given by these processes and compounds. Several years ago the committee presented a preliminary specification for sampling and testing so-called fire resistive wood. This is becoming a more and more important problem and I want to assure the membership of the Association that our committee is giving this question increased attention.

Results of Treatment

While it is not possible in a short account of the activities of this committee to give detailed data, it is, however, very essential that something should be said about the results of the various types of treatment. Most railroads have kept accurate records of the number of treated, as well as untreated, ties inserted from time to time, and these records have been carefully compiled and published under the auspices of the committee. In general it may be stated that where the treatment was in accordance with AREA specifications as to the preservatives, the processes, the quality of the preservatives and the quantity to be used, the results of the treatment almost always indicated a considerable and often very large increase in the length of life of these treated ties in track, irrespective of whether the railroads were of high traffic or lesser traffic. As the railroads used more and more treated ties the benefits become more and more apparent, as indicated by the reduction of the tie renewals per mile per year. This reduction was due, of course, to a number of factors. One of them was the improved quality of ties laid in track, owing largely to the persistent efforts of the Tie Committee to improve the quality of ties purchased and the degree of care in inspection. A second factor was that a larger and larger percentage of treated ties was laid, and also, of great importance there are the efforts of committees responsible for improving the track structures, such as increasing the mechanical protection due to tie plates and fastenings, heavier rail, improved ballast, etc. By way of a graphic presentation of this reduction in renewals as a result of the efforts of the various committees of the AREA, the following figures will be of interest:

In 1898 an average of 304 cross ties was installed in 262,682 miles of track, or a total of	79,855,328
In 1947 an average of 117 cross ties was installed in 379,025 miles of track, or a total of	44,345,925
Difference in number of cross ties installed, 1898 and 1947	35,509,403
Using 1947 miles of track (379,025) and the rate of renewals that prevailed in 1898, or 304 cross ties per mile, it would have required in 1947 to meet the need	115,232,720
Cross ties installed in 1947	44,345,925
Difference not required in 1947	70,886,795

The Future

One of the most interesting questions now is where are we going from the standpoint of wood preservation, in what direction and what results have we reason to expect will happen in the future? It is, of course, difficult to make a definite prophecy. I visualize, however, that two things are bound to happen, dealing particularly with railroad cross ties. Reference will also be made as to how the cross tie treating practices will correlate with treating practices for marine piling protection.

One of the things that I think will probably happen will be some changes in the chemical composition of the preservatives, particularly of creosote and coal tar, which will further increase the possibility of not only longer preservative service but longer mechanical service. A beginning has already been made. Larger amounts of coal tar are being added to the creosote, and in a number of cases 100 percent coal tar was used, until government restrictions during the war made it impossible to obtain tars suitable for this purpose in sufficient quantities.

One of the biggest problems on the railroads today is how we can decrease the mechanical destruction of our ties. The AAR has already made an appropriation to carry on investigations in this direction. In many cases railroads have been carrying on their own investigations. For example, on the New York Central, the Chesapeake &

Ohio, the Erie and Lackawanna 100-percent coal tar has been used, and one can, by walking along the track, already detect that the ties which display the least mechanical wear are those which show a heavy coating of coal tar on the surface after years of service in track. Such ties can be distinguished from those which were treated with distillate creosote with larger or smaller quantities of coal tar, because the higher the percentage of coal tar in the ties the less the checking and splitting in the ties.

The other result which I visualize will consist in possible increased retention, particularly in ties in which high penetration can be secured. There is no doubt but that coal tar creosote, in the various combinations and quantities as now used, gives every guarantee for long service life, certainly as long as is permitted by the amount of mechanical destruction which occurs. I think that in some form or other we will devise better mechanical protection than we now have, and should this be the case the railroads would be warranted in giving maximum treatment. I would like to have it clearly understood that in making this implied recommendation for increased retention of the preservative, that this is because of the probable increased mechanical protection, and it should be understood that the suggested increased retention is not due to any necessity for increasing preservative protection as used under present practices. This is a big problem, but the most encouraging part of this is that not only the members of the Committee on Wood Preservation but the railroad executives as well are aware of this fact, from a safety standpoint, if I may so call it, as well as from the standpoint of cost.

In the foregoing most of the discussion has referred to treatment of cross ties. This analysis of the AREA activities would not be complete without some reference to the use of these various types of treatment, particularly from the standpoint of preservative, for piles, especially for marine construction. I believe that while we have gone a long way in getting protection from teredo and other marine borers a great deal is still to be found out, specifically what can be done to safeguard not only docks and wharves but also shipping.

In the past treated material has largely been used for ties, piles, poles and bridge timbers; in the near future it is anticipated that the use of wood preservatives is going to be greatly extended to wood products and structures other than the foregoing. In fact, quite a number of railroads have already treated parts of freight cars, and these have been in service long enough to warrant the statement that such treatment is desirable. Railroads are already extensively using wood treated with various preservatives for station platforms, freight house platforms, fences and portions of buildings, particularly foundation timbers where termite attack is anticipated.

The Committee on Wood Preservation is well aware of the problems before it and I think I have every reason to predict some very material improvements in the years to come.

The Future of Soil Mechanics in Railroad Engineering

By R. B. Peck

Research Professor of Soil Mechanics, University of Illinois

It is a little over twenty years ago that soil mechanics first came to the attention of American railroad engineers. At that time several significant articles were published, some of which contained information directly applicable to practice. Most of them, however, assumed that the reader possessed a considerable background in mathematics, physics, theories of elasticity and plasticity, and even in colloidal chemistry. Since most practical engineers did not have such a background, they generally disregarded the subject, although occasionally with the uneasy feeling that perhaps there was something useful in this literature that they should know about.

Neither the railroad engineers nor most of the early practitioners of soil mechanics realized that the infant subject was experiencing severe growing pains. A great deal of basic experimentation had still to be carried out in the laboratory to obtain reliable information concerning the physical characteristics of soils. A great deal more attention had yet to be given to the development of theoretical concepts necessary to explain the behavior of soils.

Attracted Many Investigators

The search for knowledge of this type was a new and promising field of endeavor, and it attracted the attention of many investigators. Most of them felt that eventually it would be possible to design foundations or to select the slopes on embankments and cuts by the same sort of logical procedures that were being used successfully for the design of concrete or steel bridges.

Experience has demonstrated that this expectation was not well founded. Those who made the earliest attempts to apply soil mechanics to practical problems soon became convinced that the results of laboratory tests and theoretical computations were in themselves an insufficient basis for design. The reason was the outstanding influence of the natural variations that occur in the physical properties of every soil deposit and even in soils laid down by man in his construction operations. Eventually, it became apparent that theoretical computations based on soil constants derived from laboratory tests provided no more than a standard against which field performance could be compared. As a result of this comparison, however, it was often possible to get a remarkably clear conception of the real conditions in the soil mass. When this comparison could be made at an early stage of construction, it often led to striking economies in design that could not otherwise have been attained.

Today, the more progressive practitioner in the field of soil mechanics regards the subject as only one of many tools that the civil engineer has at his disposal for solving problems involving soils. I believe that the current emphasis on soil mechanics as such will ultimately disappear and that the most fruitful concepts that have come out of the study of the subject will be incorporated into the general field of civil engineering. Once again, judgment and experience based upon careful personal observation will take their rightful places as the prime requisites for success in dealing with soils. Both judgment and experience will be richer, however, on account of the efforts of students of soil mechanics during the present times.

Soil Mechanics and the Railroads

The demonstrated importance of field observations in dealing with soils warrants the belief that railroad engineers will become among the most successful users of the fruits of soil mechanics. As a group, railroad engineers are in all likelihood the keenest observers of the behavior of natural soil deposits among the ranks of civil engineers. This is due to the fact that a railroad engineer who constructs or inherits a structure or has responsibility for maintaining a stretch of track that involves soil problems must live in intimate relationship with these problems year after year. He learns, for example, to know the characteristics of a given fill. He learns when he may expect it to misbehave and when it is likely to give no trouble. He has notions regarding the cause of its defects. If he learns to supplement his field data with some knowledge of soil mechanics, he will be in a very favorable position to know what the proper treatment may be.

Intelligent field observation is the key to success in all problems involving soils. Soil mechanics has not changed this fact but it has contributed techniques and knowledge that increase the amount of information that can be obtained from such observations. It is worthwhile to consider what these contributions are.

Will Aid in Exchange of Experience

In the first place, soil mechanics has provided a system by which soils can be identified and classified in terms of definite physical properties. Simple tests have been established for determining the values of the appropriate soil properties. As a consequence, any engineer who will take the trouble to learn the significance of the test results can adequately describe the soils with which he deals. He can then make his experience available to other engineers and, conversely, the experience of others is available to him. I believe this is one of the most important contributions of soil mechanics to the railroad engineer. In older days, when soils were inadequately described, one man's experience might be another man's downfall because soils thought to be alike were essentially different. There need no longer be ambiguity regarding the kind of material that an engineer is talking about.

The second contribution lies in certain theoretical concepts, especially those that show the manner in which soils consolidate, the manner in which they fail when overloaded, and the ways in which water influences their behavior. These concepts are usually associated with advanced mathematical theories, but they may be restated in simpler physical terms and they may be used by the engineer to suggest the kind of field observations he should make to determine the seat of existing or potential troubles.

Finally, soil mechanics has already built up a large body of experience that is available to the railroad engineer. Much work has been done to determine the degree of reliability of forecasts made on the basis of theories, soil tests and field observations. This information has been organized in such a way that the engineer faced with a problem today can soon find out whether others have faced similar difficulties, what measures were taken and how well they succeeded.

Turning to the future, I foresee that almost every railroad will possess the simple equipment needed to make subsurface explorations and will have on its payroll a man capable of using it. Each railroad will have at least one small laboratory in which the routine tests for identifying and describing soils can be made. I believe it will be found worthwhile to have in each division at least one man who is assigned the duty of performing the tests to identify the soils occurring in his region and who will then be in a position to know whether the soil conditions in his locality are essentially similar to or different from those in other places. The ability to make these tests is rapidly becoming part of the requirement for graduation in civil engineering from our universities.

A Record of Soils and Behavior

Finally, I foresee the day when the records of every construction job and of many maintenance jobs will contain adequate descriptions of the soils involved and when these job records will be digested and correlated to form a perpetually growing mass of experience available to every railroad engineer. As younger men step into positions vacated by their elders, they will not have to start at the beginning. They will inherit a mass of experience that they can quickly assimilate and to which they can add throughout their own careers. I believe that these digests of experience should be fostered and published in the journals of this Association and that they will constitute one of the most valuable contributions that this organization can make to its own membership and to the civil engineering profession at large.

This view of the future of soil mechanics differs considerably from that held by many of my academic brethren. There are many who believe that studies of soil properties and elaboration of theoretical concepts will ultimately lead to the direct solution of practical problems. I am convinced, however, by my own attempts to apply soil mechanics to actual situations that this approach will be largely sterile. On the other hand, I believe that the incorporation of the many useful concepts of soil mechanics into the working knowledge of keenly observant practicing civil engineers will prove to be a development of the greatest practical value.

What We Know About Impact in Bridges

By A. B. Chapman

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The effects of a locomotive crossing a railroad bridge at various speeds has been of great interest to the bridge designer for many years and numerous tests have been made during the last hundred years to determine these effects. However, it has only been recently that the strains resulting from the passage of high speed locomotives could be reliably measured.

Impact as here used is the additional force produced by a moving load over that produced by the same load at a state of rest. With fast moving trains on short span bridges the increase from zero to maximum occurs in about 0.3 sec. This effect however is very different than that produced by a free falling body on a beam where the maximum effect, also called impact, occurs at least a hundred times faster. It is difficult to talk about impact without referring to stresses so please bear with me if in this discussion they are sometimes used interchangeably.

Strains in steel, timber or concrete bridge members resulting from a locomotive, of known axle weights, standing or moving very slowly over a bridge can be calculated with a fair degree of accuracy, but when the speed of the locomotive increases, the strains also increase and this increase in strain cannot be determined analytically. The increase in strain, over that produced by a slowly moving locomotive, is termed total impact and will vary with the different classes of power, the different lengths and types of bridges as well as the speed of the locomotive.

Total Impact the Result of Several Individual Effects

The total impact effect results from several individual effects; and in this discussion whenever impact is mentioned it will include simultaneous effects, such as produced by roll, speed, track irregularities and hammer blow. Each individual impact effect becomes a maximum at a critical speed for a particular bridge. The critical speed for the roll effect is not necessarily the critical speed for the hammer blow effect; hence, the maximum total impact is usually not a summary of the maximum individual effects, but is a summary of the individual effects that occurred at one locomotive speed.

The "roll effect" results from the locomotive rolling from side to side which increases the wheel loads on one side of the locomotive with a corresponding decrease on the other side. This effect is caused by the spring borne weight of the locomotive oscillating about a horizontal axis. The oscillations of the spring borne weight is caused by the out-of-level track, track joints and soft spots in the track.

The "speed effect" is presumably the result of the centrifugal force developed by the locomotive in following the path of the deflected span and the increased weight on the span resulting from the downward acceleration of the spring borne weight of the locomotive.

The "track effect" is due to the irregularities in the track surface or wheel treads, to the periodic effect of wheel loads coming or going off the span and to a battered rail joint close to the center of the span.

The "hammer blow effect" is one of the most important impact effects and results from the periodic disturbing forces of the resultant unbalanced weights in the driving wheels of the steam locomotives. In short span bridges, where this force can be applied only once, the effect is due to the centrifugal force of the unbalanced weights on the driving wheels and increases with the square of the speed, but in longer spans, where this force can be applied several times, the effect of the centrifugal force is magnified by the spring action of the bridge and hence becomes quite large even though it does occur at a lower speed.

The gages used by the research staff of the Association of American Railroads to measure the strains in the bridge members under the passage of locomotives at various speeds are of two general types, namely, the electromagnetic gage and the SR 4 wire gage. Both types of gages require oscillographs to record the resulting strains on photographic paper or film.

The electromagnetic gage was first developed by the Westinghouse Electric and Manufacturing Company in 1923 and the first tests to employ these gages were rail tests made on the Virginian Railway in 1925, followed by tests on the Great Northern Railway in 1929. Subsequently, the General Electric Company developed gages similar in principle but differing in details of design, for various bridge tests carried out by the Pennsylvania Railroad in 1935.

The SR 4 wire gage was developed by the Baldwin–Southwark Company in 1935 and were first used by the research staff in 1942 during an investigation to determine the effect on a rail of a flat spot on a car wheel.

Short Spans

There are approximately 36,000 short span railroad bridges in the United States today, and up to 1941 the strains had never been reliably measured in any of these bridges. Bridges of this type are subjected to considerable vibrational effect which produced instrumental errors in the mechanical type of strain gage. All previous impact equations for spans of this length have been based on assumptions and were made sufficiently large to be on the safe side.

In 1941 the AAR research staff started tests on short span bridges using electrical gages. The results of tests on seven bridges of this type were published in 1945. The bridges selected for these tests varied in length from 20 ft. to 34 ft. and readings were secured under 900 diesel and steam locomotive crossings over the bridges at speeds varying from 5 mph. up to 85 mph. for steam locomotives and up to 100 mph. for diesels.

The results of these tests were of particular interest to railway bridge engineers generally for the following reasons:

1. The static stresses in short span bridges, under both diesel and steam locomotives were lower than those usually calculated, indicating that as the span deflects, the axle loads are carried to the ends of the spans by the frame action of the locomotive. The static stresses recorded under diesels are only about 60 percent as great as those recorded under modern steam locomotives as the weight of the diesel is spread over a greater length.

2. The maximum stresses in the bridge resulting from the wheel striking a battered rail joint at the center of the span were attained at a speed of 20 to 30 mph. and became smaller as the speed of the locomotive increased. At speeds of 100 mph. the effect of the battered rail joint was negligible.

3. The impact percentages recorded with a battered rail joint at the center of the span are about the same under diesels as those recorded under steam locomotives, however, even with this condition, the maximum recorded stresses under diesels are only about 60 percent of those recorded under steam locomotives on account of the lower static stresses.

4. The maximum recorded stresses under both diesels and steam locomotives resulting from all the individual effects were attained at a speed of about 50 mph. It appears that at the higher speeds, the locomotive is across the bridge before the stress can become very large.

5. The maximum impact percentages resulting from all the simultaneous individual effects were only about 75 percent of the recorded static stresses, instead of values of over 100 percent formerly used by bridge designers.

6. The use of ½-in. rubber fabric pads under regular steel tie plates and placed on top of the bridge or track tie did not reduce the amount of impact in these short span bridges.

7. A welded rail joint at the center of the span can be considered, as far as the bridge stresses are concerned, the same as a continuous rail over the bridge.

Long Girder Spans

With the completion of the investigation of the stresses and impacts in short span bridges, the research staff began its investigation of girder spans on tangent track ranging in length from 40 ft. to 140 ft. Data have been assembled on 31 girder spans under a total of 2900 diesel and steam locomotive runs. Twenty-four individual strains are recorded for each run, making a total of about 70,000 tests. It is planned to test 5 more girder spans and then complete the report on long girder span bridges.

Considerable progress has been made in analyzing the stresses and impacts in these girder spans and the data indicate that:

1. The total maximum impacts as determined by center-line moment are in fair agreement with the revised AREA impact formula which was determined from results of preliminary analysis of then available data. The very large number of tests has fully substantiated it and show that it will give results well above the actual impacts produced.

2. The recorded impacts in the webs at the ends of the girders are somewhat higher than those obtained by center-line moment but from data analyzed to date are within that given by the AREA formula.

3. The stresses in the top flange are about the same as those in the lower flange of symmetrical girders. This however does not hold true for those spans having a poured-in-place concrete floor, where part of the compressive stress is taken by the floor.

4. There is considerable variation between the stresses recorded on the inner and outer sides of the girder flanges, indicating transverse bending.

Truss Spans

A considerable number of the truss spans in service today were built at the beginning of the century and were designed for light locomotives. Many railroads are now operating locomotives weighing about 50 percent more than the locomotives for which the bridges were designed. The research staff has tested a large number of these spans, including the floor system, at the request and expense of the individual railroad, to determine if the stresses resulting from the heavier locomotives exceeded the stresses allowed by AREA rating rules.

The detailed analysis of the data obtained on these truss spans, where the locomotive speed was above crawl speed will be of interest to all the bridge engineers, and reports on three such spans have already been made by your committee in the Proceedings. In general, the tests on truss spans indicated the following:

1. The stresses in the top chords of through spans are greater than the calculated stresses, while those in the lower chord are smaller than the calculated. This appears to be due to the stringers taking part of the stress assumed to be carried by the lower chord, making a corresponding change in the effective depth of the truss. The opposite effect has been found in deck spans.

2. Maximum impacts occur at a relatively low speed. For example, in a 150-ft. truss span the impacts under a modern steam locomotive were maximum at about 35 mph and then decreased with a further increase in speed. This is due to the low speed at which the locomotive drivers synchronize with the natural period of vibration of the span.

3. The impacts in various members of a truss span are not the same. Some members are subject to high impacts while others are low. The reason for this variation in impact has not been definitely determined but since these phenomena do exist, they eliminate the possibility of determining impacts in any truss span by deflection readings, as such readings only indicate the average impact in all the members.

4. The stresses in individual eyebars of any one member usually vary. It has been found that in some members one or two of the bars were not taking any of the load, with a resulting overstress in the other bars.

5. The secondary or bending stresses in some of the older bridges are sometimes so large that compression has been found in one corner of a lower chord tension member with tension in one corner of the end posts. Even in pin-connected trusses where the pins were undoubtedly frozen, a zero stress has been found in one edge of the bar with twice the average stress on the other edge.

The elimination or reduction of these high bending stresses in tension members is very important on account of fatigue failures. Several railroads have recently experienced failures in the tension members of their older bridges which were apparently the result of fatigue from high bending plus direct stresses or from reversal of stress.

6. The eccentricity in some of the compression members has been found greater than we would normally expect and this eccentricity has been found to exist about both axes of the member. The eccentricity in any compression member materially reduces its carrying capacity.

7. The elasticity of the supports for any structure plays a very important part in the amount of impact in the structure. The tests on a 150-ft. truss span, supported on high viaduct columns which seem to act as springs, indicate that impacts in such a span are lower than those in a span supported on rigid bearings.

Impacts in stringers of truss spans, which are supported by elastic floor beams, and floor beams which are supported by elastic hangers, are always lower than these in the same length spans supported by concrete piers or abutments. However floor beam hangers, which are supported by more rigid main chord members of the truss, receive about the same impact as a span with rigid supports.

Bridge Ties

In open deck girder spans, the locomotive wheel loads on the rails are carried to the girders by means of the bridge ties. The rail acts as a continuous beam on elastic supports so that the analytical determination of the amount of wheel load carried by each tie becomes quite complicated. Usually it is assumed that the rail has full bearing on each tie, regardless of the possibility of tight or loose ties. Exploratory tests made on timber bridges ties indicate that some ties get very little of the load while other ties get more than their proportion which may account for the occurrence of broken ties on open deck bridges. A bridge tie carrying a large part of the load would normally be expected to wear down so that more of the load would be carried by the loose ties; it however appears that the loose tie wears faster than the tight tie. The faster wear on the loose ties means that the load taken by the tight tie may continue to increase.

Timber Trestles

A start has been made on the testing of timber trestles and a report covering tests on two open floor trestles and one ballasted floor trestle was presented to the Association this year by your Committee on Impact and Bridge Stresses. The results of these tests are of particular interest to those using timber trestles as the tests seem to indicate the following, although further tests and studies are necessary before definite conclusion can be made.

1. There is some continuous action in stringers having a length equal to two panels. The continuous action reduces the stresses in the stringers at the center of the span, with tension in the top of the stringer over the support.

2. Outside piles in a six-pile bent carry only about half the load carried by each of the four inside piles.

3. Piles of bridge piers outside the girder bearing, even where multiple-chord blocking is used, are of little value in carrying the direct vertical load.

4. Stresses in stringers and piles increase with an increase in locomotive speed and the characteristics of the resulting stress is entirely different from that secured by dropping a weight on a timber beam.

The dynamic stresses in timber bridges have not generally been considered in the design of such structures because laboratory data secured by dropping a weight on a timber beam indicated that the strength of timber under these conditions is about twice what it is under normal test machine loading. The strength of the timber members should be determined under conditions that approach those found in actual bridge structures. The research staff of the U. S. Forest Products Laboratory has indicated its willingness to cooperate with the AAR research staff in developing tests that simulate actual railroad loading conditions.

Concrete Piers

Recent strain gage measurements on two large concrete piers, one pier supporting a 100-ft. and a 75-ft. ballasted girder span and the other pier supporting two 100-ft. ballasted girder spans, have indicated that there is an increase in the soil pressures with an increase in the locomotive speeds. It is common design practice for some engineers to design their piers for full impact on the bearing material while others use only half impact or no impact. Further tests of this type will be required before any recommendation can be made as to the amount of impact which should be used in the design of such structures.

The tests of many types of bridge structures show that actual stresses produced by a complicated locomotive cannot be accurately determined. The aim of your Committee on Impacts and Bridge Stresses is to furnish the bridge engineer information which will aid him in designing the most economical structure and to determining the heaviest locomotive (and at what speed) that can safely operate over existing structures.

The Future of Structural Engineering in Relation to Steel Railway Bridges

By Shortridge Hardesty

Partner, Hardesty & Hanover, Consulting Engineers

While men have been building bridges for more than 2,500 years, progress prior to 1800 was slow, partly because the demands of transportation for bridges were small, and partly on account of the lack of design theory. Some of the basic principles of physics and mechanics, such as the resolution of forces and certain relations between stresses and strains in materials, were developed before 1800; but they had not been applied to bridge building.

The increasing needs of transportation began to call for better bridges toward the end of the eighteenth century, particularly in the United States, where there were many wide waterways. A further powerful impetus came in 1829, when railroads were introduced into America. With their rapid development, many bridges were needed, strong enough to carry the railway loadings.

These requirements were met at first by the ingenuity of bridge builders such as Burr, Wernwag, Palmer, and Howe with various truss and arch forms, largely of timber, and generally of complicated framing. Their designs were based entirely on experience and judgment. Since they were unable to compute the stresses in their structures, long-span railroad bridges, such as were needed for crossing the larger rivers, could not be built.

Beginnings of the Scientific Method

Adequate theory was soon developed. Some data on beams and columns became available about 1830. The greatest advance in design knowledge came in 1847, when Squire Whipple published his "Work on Bridge Building." This was a remarkably complete book for a pioneer work, presenting the calculation of stresses in trusses for both fixed and moving loads, the design of members, and various economic comparisons and practical conclusions, in a simple, direct, correct, concise manner. In 1851, Herman Haupt wrote, independently, his "General Theory of Bridge Construction," which was less complete than Whipple's book.

With these books available, and under the continuing pressure of the needs of the railroads, many truss forms were developed, together with the plate girder bridge and the railway trestle. Construction was generally of timber and wrought iron, or cast iron and wrought iron. The names of Whipple, Howe, Pratt, Latrobe, Bollman, Fink, Post, Carroll, Murphy, and Linville belong to this period. The 1850 bridges of timber, cast iron, and wrought iron gave way by 1870 to all wrought iron construction, which, during the period from 1880 to 1895, was superseded by steel. Bridging of rivers such as the Ohio, Mississippi, and Missouri became possible, and the railroads were enabled to continue extending their lines across the country.

About 1860 the design of railway bridges came into the hands of a group of trained engineers in the employ of railroads and in private practice—men such as Bouscaren, C. Shaler Smith, Eads, Morison, Cooper, and their successors. During the next four decades, railway bridge engineering made important advances, and reached a high plane.

Many Specifications

By the end of the nineteenth century there were many railway bridge specifications. Each important railroad had its own, as did the leading private engineers. While the various specifications produced satisfactory structures, there were vital differences among them. At the same time, railroads were being faced with the problem of overstressed bridges and the need for many replacements, on account of the continuing increase in the weights of locomotives and cars. Some form of cooperative action was needed.

This was the situation 50 years ago, when the American Railway Engineering and Maintenance of Way Association began the development of specifications for steel railway bridges that would receive general acceptance. Many differences had to be resolved: The replacement of soft and medium steels by a single grade of structural steel; the establishment of a standard live loading; the adoption of uniform values for impact and working stresses; and the settling of many detail points. A specification for steel railway bridges with Cooper E–40 as its recommended loading was adopted in 1905, and revised extensively in 1906 and 1910; a revised specification was issued in 1920, with E–60 as its recommended loading; and essentially the current specification, with E–72 loading, appeared in 1935. The specifications did not remain fixed between the various dates, but were revised from time to time as additional data became available or practices changed.

Specifications for movable bridges and turntables, for classifications, rating, and strengthening of bridges, for erection and inspection, and other related subjects were also prepared. The movable bridge specifications were adopted in 1922, and have since had extensive study, a basic revision now being under way. The classification rules were adopted in 1924, and the Rules for Rating Existing Iron and Steel Bridges in 1921. The rating rules have been under extended study and revision during the past year.

With the establishment of the Cooper series of loadings and the adoption of rating specifications for existing bridges, it became feasible for all railroads to rate both their bridges and their locomotives on a common basis. This enabled railroads to check readily their bridges for proposed changes in loadings, and to determine quickly whether they could handle locomotives of other lines.

The development of these specifications has required extended studies by the committee. It has had a diversified membership—railroad bridge engineers, engineering professors, private consulting engineers, public works engineers, and bridge company engineers—so that various aspects of bridge designs and construction have received adequate consideration by men with broad experience in all phases. The railroad bridge engineers have been especially active, on account of their direct interest in and close contacts with the problems involved, and the time allowed them by their managements for committee work.

Committee Sponsored Research

Early in its history, the committee realized that many of the divergencies in practice resulted from deficiencies in engineering knowledge. It therefore sponsored studies, investigations, and tests covering a wide range of topics. These have included comparisons of existing heavy locomotives with the Cooper standard at several different times, impact studies and tests from 1907 to those now under way, studies of column formulas and the making of column tests, studies regarding allowable working stresses, investigations of the bearing values of large and small rollers, studies relative to available higher-strength steels, investigations concerning fatigue of structural parts, studies in connection with the design of movable bridges, consideration of welded construction, studies relative to waterproofing and protection against corrosion, and the detailed review of practically all requirements for design, workmanship, and materials.

With respect to materials, the committee has adopted the general policy of using ASTM specifications where available. There has been close collaboration with the appropriate committees of that society, in order that its specifications might reflect the viewpoint of the railroad engineer.

The research staff of the Engineering Division, of the ARR, under the direction of its research engineer, has been available for the committee's research work during recent years. The personnel of this staff has developed the methods, equipment, and technique necessary for the best test results.

There are still many important problems facing the railway bridge engineer. The future developments in steel railway bridges are largely concerned with the solution of such problems.

While railway loadings showed a steady increase for the first hundred years of American railroad history, this tendency has changed recently on account of the shift, for main line operation, to diesel power, which is at present lighter than steam power and has lower impact effects. On the other hand, heavy steam locomotives are being transferred to branch lines, thus increasing their loadings; and coal-burning steam-turbine locomotives are being tried out, which may become heavier than older steam engines. The diesel loadings may also increase, due to heavier power now under development, and the prospect of more power per diesel unit. While it is difficult to predict the future, it can be said that many main line bridges are now carrying a greater percentage of lighter loads than formerly, due to the use of the diesel engines.

The subject of impact needs further study, as many factors are still to be determined. Research and testing are still continuing, using the newer and improved electric strain gages and other testing equipment now available, which make possible the securing of data formerly not obtainable.

While making impact tests with these gages, stresses have been measured at many points of various members. Such measurements have made it possible to study other effects of live loads, such as longitudinal and lateral effects, secondary stresses, and discrepancies between actual stresses and those computed by conventional methods. Important differences have been observed. Further measurements should be made, and the results analyzed.

The Problem of Fatigue

The problem of fatigue resulting from many repetitions of loading requires further study. There have been enough failures in details of older structures that have been subjected to comparatively high stresses for many years to indicate the importance of the subject. There has been considerable research on this question during the past decade on both riveted and welded work, and the committee is collaborating in further research along similar lines. Recent specifications for welded work make provision for fatigue, and specifications for riveted work need similar clauses.

Floorbeam hangers have shown a good many failures, due to faulty details and fatigue action. A program of research on such members is now under way.

While structural steel makes up most of the tonnage of steel bridges, special materials have many applications. Silicon steel and low-alloy structural steels are examples, also corrosion-resistant steels. The investigation of the possibilities of such materials is an important problem. Fatigue considerations are of especial importance, since many of the steels with yield points and ultimate strengths well above those of structural steel have fatigue strengths little, if any, higher than that of structural steel.

Structural aluminum has been used for bridge construction in a few instances, including one 100-ft. railway deck plate girder span, and may find applications to railway bridges, particularly where saving of weight is important, as in the case of long movable spans. The future price trend of aluminum will be an important consideration.

Welded construction is being employed extensively in the repair of existing bridges. The extent to which it may be used for new bridges is one of the important questions for the future. The subcommittee on the design of welded steel railway bridges has set up an investigation "to ascertain if, and under what conditions, all-welded railroad bridges are: practicable; safe; economical; advantageous structurally, or as to maintenance, or for any other reasons." Basic study of welded bridge design and details is needed, rather than the copying of riveted construction. The control of field welding, the improvement of its technique, and the development of adequate soundness tests are essential. At present, application to girder bridges appears more promising than to trusses.

It seems likely that there will be a greater use of steel H-piles and pipe piles in the future, with considerable savings under some conditions. The research staff of the Engineering Division is at present making tests on cylindrical and tapered pipe piles to determine how their loads are transmitted to the soil along their lengths.

The question of rational column design needs further study. The Association is collaborating in the work of the Column Research Council of Engineering Foundation, the purpose of which is to review existing knowledge, plan and carry out needed research, and develop a consistent group of design formulas or rules. A basic study of our existing knowledge of compression members, under the sponsorship of the council, is nearing completion, and projects for the study of the action of compression members in trusses and frames are now under way.

Another council under Engineering Foundation, that on Riveted and Bolted Joints, is also receiving support from the Association. This council is making tests on joints fabricated with hot-driven rivets, cold-driven rivets, and high-strength bolts, which thus far indicate that the bolts may be superior to the rivets.

A current research project deals with rocker shoe assemblies.

Protection Against Corrosion

A major problem in bridge maintenance is the protection of metalwork against corrosion. Progress is possible along four lines: using metals of greater corrosion resistance; developing better protective coatings; improving the preparation of steel surfaces before applying the protective coating; and improving the technique of applying the coating. Stainless alloys appear particularly promising for expansion bearing details.

An important tendency in current bridge designing is the greater attention given to appearance. Early bridges were mainly utilitarian, and often unsightly. Present-day designers appreciate the fact that, with proper planning, marked improvement in appearance is frequently possible with only a small increase in cost. Proper proportioning, harmonious combinations of substructure and superstructure, and attention to detail are essential. Some of the recent grade-crossing eliminations have been especially noteworthy.

There are not many important railway bridges involving special problems now under way. The replacement of the superstructure of the Illinois Central bridge over the Ohio at Cairo, Ill., on the existing piers is being planned, which is perhaps the first of George S. Morison's large bridges to be rebuilt. Apparently the old structure could have been continued, except for the locking of the expansion bearings due to corrosion, and if the trusses been riveted instead of pin-connected. The new structure will have all-riveted trusses on stainless steel bearings.

There is a tendency, on current projects, to the use of spans of moderate length on tall concrete piers, instead of steel trestles on braced steel towers, for the crossing of deep ravines.

A number of railway movable spans are being rebuilt to afford greater navigation clearances in accordance with the provisions of the Truman–Hobbs Act, under which the railroad pays for betterments, used service life, and certain removal costs, while the United States bears the remainder of the cost. This procedure relieves the railroads of most of the burden of providing for improved navigation facilities. Nearly all the long spans now under way or projected under this program are of the vertical lift type, which is particularly adapted to long movable railway spans.

There are still gaps in our bridge engineering knowledge. These gaps are recognized, and investigations and research are under way or projected to supply the needed information. As these projects are carried out and their results applied to specifications, the present factors of uncertainty can be reduced, and design calculations and detailing brought closer to actual requirements. The result will be better and more economic bridges. This can be expected to be an important aspect of the future developments in railway bridges.

Roadbed Stabilization

By Rockwell Smith

Roadway Engineer, Engineering Division Research Staff, AAR

Reports on roadbed stabilization for this and previous years have covered field procedures and soil conditions on various individual projects. It is not the purpose of this discussion today to cover this ground again but rather to speak in general terms of the conditions that make roadbed stabilization both desirable and necessary.

For this purpose we can put unstable subgrades under two broad categories. The first of these is a pocketed condition of the ballast, containing water, at least during some seasons of the year, usually evidenced by squeezes or push-ups a short distance beyond the ends of the ties. In general the further removed this push-up is from the tie the deeper the pocket. These push-ups involve a lateral movement of the subgrade materials and sometimes the finer ballast from under the track, causing track settlement and requiring lining and surfacing maintenance. This development of pockets is from the surface, that is, it is caused primarily by water falling on the track and penetrating the ballast, wetting the subgrade soils to the point where they will move under load. Where conditions remain conducive to continual soil movements pockets may, and have, developed to a depth of 10 ft. or more. In general it may be said that after development to a depth greater than 6 ft. on fills the instability is likely to take on the character of a slide or slip.

For the purpose of this talk, slides and slips, hereafter used synonymously, can be defined as any movement of the soils in the slopes of a roadbed, of the roadbed itself, or its foundation, from their original position. This definition will cover roadbeds on fills, in cuts, or in cut-fill sections.

Slides may occur in many ways: Slowly and continuing, or rapidly and completely, and with or without any seeming immediate cause. The great majority of slides of concern to the railroads however are of the slow and continuing variety requiring continuous and costly maintenance. Seasonally a number of these sections may accelerate their movements and occasionally this acceleration may be sufficient to impose a definite hazard to operations, requiring immediate and abnormal maintenance. The principal primary cause of slides is water, usually surface water, but in the case of foundation failure or movements of the entire fill the effect of surface water is often augmented by that of ground water or seepage.

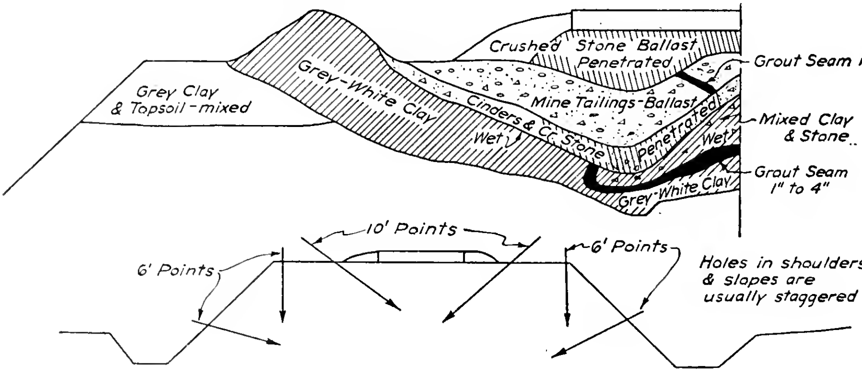


Fig. 1.

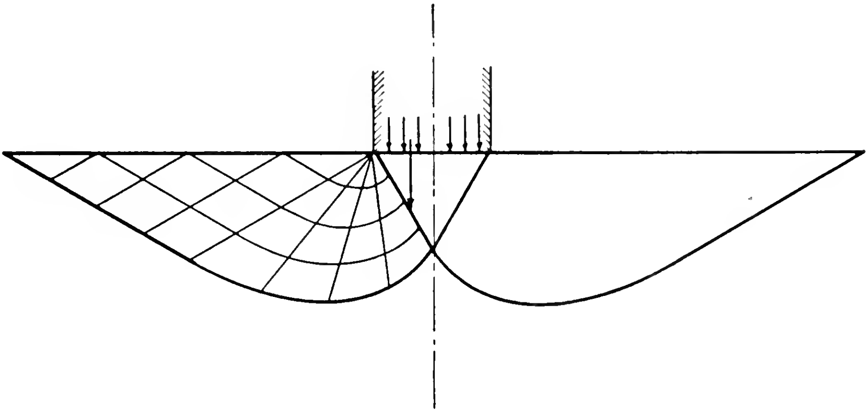


Fig. 2.

Fig. 1 pictures a typical ballast pocket and push-up. Note the lateral flow of the clay subgrade and finer graded ballast material. In conditions of this type the clays of medium to high plasticity are the chief offenders but soils of low plasticity can also be affected under sufficient aggravation of loads and moisture contents. In the investigation of roadbed instability it has been found that the top 1 in. of the subgrade has a higher moisture than the underlying material and it is this wetter soil that moves or furnishes a lubricated base for movement. Grout distribution and scheme of injection are shown. Tbis appreciably bettered the stability of the section.

Fig. 2, taken from Terzaghi and Peck's "Soil Mechanics in Engineering Practice," illustrates the theoretical zone of lateral plastic flow under a continuous footing with a lubricated base. Its similarity to the shape of pockets under tracks is noteworthy. The network on the left indicates the shear pattern.

Fig. 3 shows a pocket that developed to an extent that affected the slope and may be classified as a slide. The grout distribution shows the direct type of correction possible with coarse ballast and rich grout mixtures. The soils in the subgrade for the sections shown are all plastic clays.

Soils may be divided into three main classifications both on the basis of grain size and their action in soil structures: Namely sand, silt, and clay in the order of descending grain size. Also, in general, in the order of decreasing desirability as subgrade materials. Of these three, sands if compact, will cause little or no trouble in railroad subgrades. Under adverse conditions of gradation and moisture a quick condition may result in very loose sands with fine and uniform gradation. This condition could occur, more probably in the foundation of an embankment than in the embankment itself, but it has not been encountered in the course of this investigation.

Silt soils, which can be recognized by a flour-like consistency may also become quick and liquefy, causing sudden movements. Vibrations on silts if wet can be a very disturbing factor.

Fig. 4 shows a slip in silt soils that occurred over a period of about two days. Full investigation would be costly and difficult and might not even reveal the direct cause. From an inspection of the conditions present it is thought that an underground stratum became subject to seepage pressures sufficient to overcome the shear resistance of the

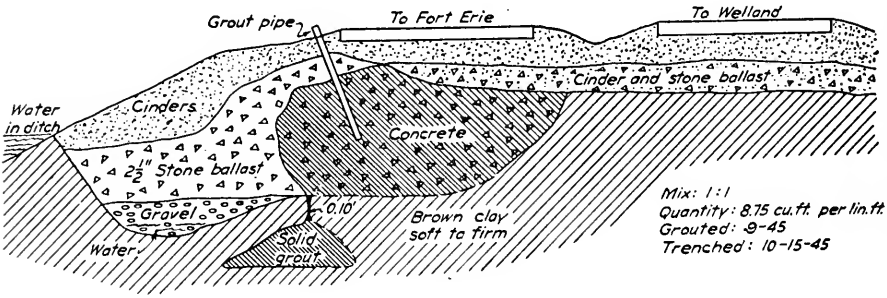


Fig. 3.

soils. A quick draw down of the water could increase the slide tendency. This particular slide occurred in soils in their original position, probably wind deposited and, loosely compacted. This condition, combined with adverse moisture, seepage and vibration would present a situation reducing the strength of the soil structure. In general silts are difficult to compact without close moisture control. Pocketed silts especially in sand are conducive to frost heaving. Conditions as pictured should always be regarded as areas of potential disturbance. Wind deposited silts will often stand on a vertical slope until disturbed.

Fig. 5 depicts a typical slope failure in which the soils comprising the fill have failed in shear. Fills of varying heights and slope angles will separate at different locations along the top of the grade. For this fill the cleavage was approximately at the end of the tie, and the berm in which the grout injection is being made was at the tie level six months prior to this picture. Slides of this type are the most frequent in occurrence on railroad fills. They are caused by the shearing force of the weight of the soil mass overcoming the shearing resistance inherent in the soil. Once this has occurred plastic flow or continued distortion without additional stress sets in.

It may be well to pause a few moments and consider further the causes of this type of slide. Many of them are of long duration, others at new locations develop every year, but in all cases the probability is great that the fill was stable when and as built. If the original design were faulty failure would have occurred during construction. A reasonable explanation for these slides is a decrease in strength of the soil brought on by moisture and vibration. I have never seen it so classified previously but in effect it is fatigue or, better, it may be compared to fatigue in structural material of more definite properties. The hypothesis we have developed in explanation is as follows. Soils in their original position in the ground have developed a structure, probably a type of cohesion, which is broken down when the soils are disturbed and manipulated. This results in a decrease in strength for equivalent condition of moisture and density. In their new position however the soils again develop a structure of sorts if conditions remain constant. Thus, as placed, the soils may have ample strength which may be further increased by a developed structure. Then, in continuing service, moisture contents become greater and this structure is weakened to the shearing point. This hypothesis of structural development goes far to explain why some fills under apparently adverse conditions of height and slope remain stable while others of equal or seemingly more favorable characteristics may slip. Slides of this type are in effect limited to soils of the silt and clay classification with the clays being predominant in most sections coming to our attention.

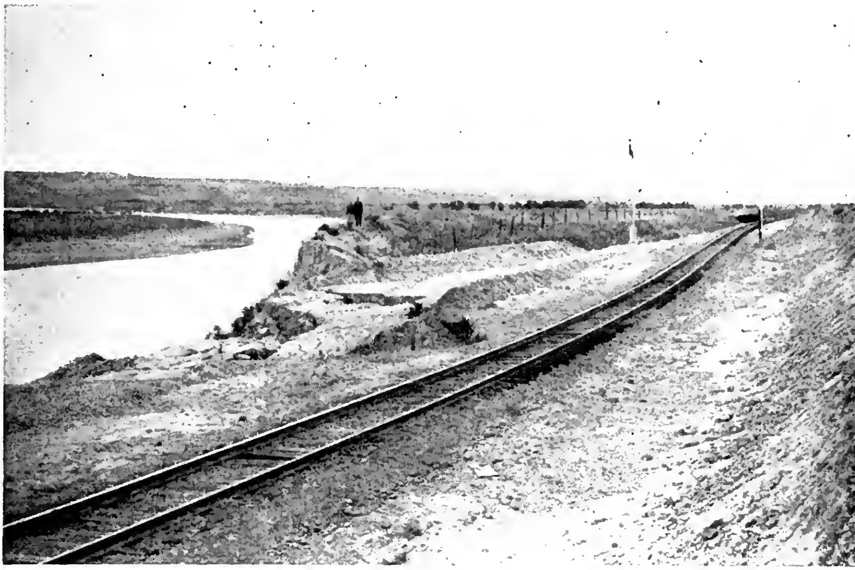


Fig. 4.

Fig. 5.

Fig. 6.

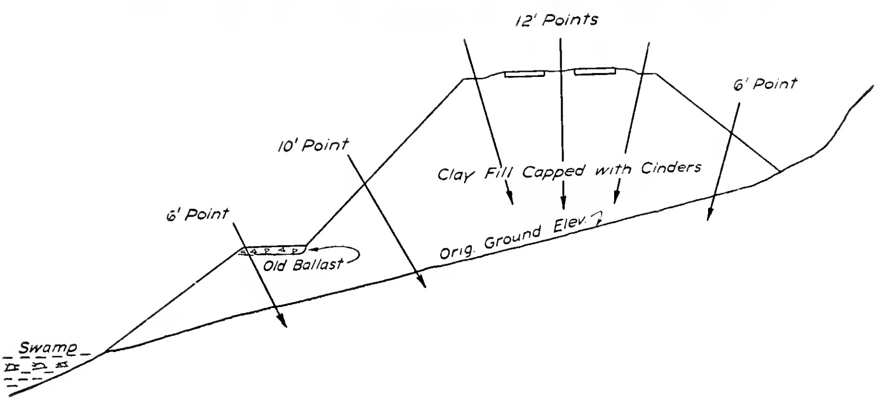


Fig. 7.

There are a number of methods by which moisture contents of the soils can be increased. We have discussed the development of pockets usually water bearing. Under percolation and vibration this moisture can be absorbed into the subgrade. In Fig. 6 is a trench across a fill showing the large voids around the old construction trestle. If the voids accumulate water, a good supply is available for impermeating the subgrade and the consequent weakening of the structure of the soil. For this particular fill pictured a serious slide occurred approximately 22 years after construction.

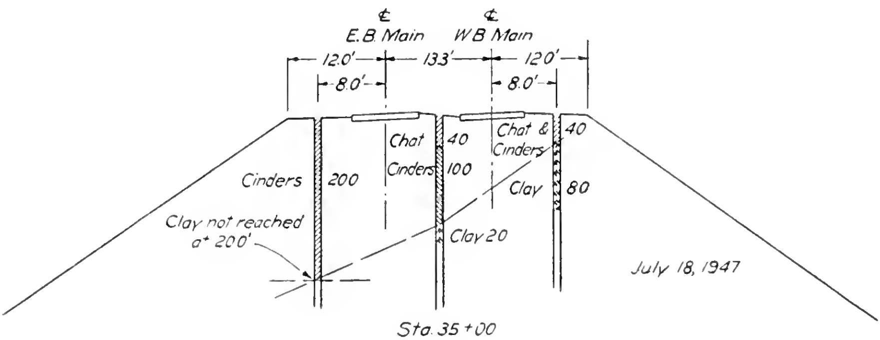


Fig. 8.

It has been indicated that slides can be complex. The diagrammatic sketch in Fig. 7 shows a slide in eastern Iowa that apparently combined pockets, slope failures, and the movement of the entire fill down the original slope. It was aggravated by seepage and soft foundation. In stabilizing this fill the water pockets were grouted from the top of the grade but the following year it was found necessary to grout as indicated. Whether or not the analysis of failure as described was correct the stabilization has been successful during the 2½ years since treatment.

The conditions depicted in Fig. 8 were determined by a power auger. The slip has developed from a slope failure to a movement of that portion of the fill above the inclined clay layer. The presence of granular material above this clay permits to some extent the percolation of water that will keep the slope lubricated. The cinders have been placed when needed to maintain the fill on grade.

There are other properties of some clay soils that apparently have considerable bearing on the action of clays in roadbeds, and which by their action also tend to permit the entrance of moisture and the weakening of the soil structure. These properties are shrinkage and expansion. Shrinkage on drying will open up cracks in the embankment permitting easy access of water. The expansive property will permit the clay to absorb water and swell unless the compaction and original moisture content are controlled between narrow limits, which can be determined only by rather appreciable testing. Even then, there is no record to show that soils controlled in the field placement to obtain the desired moisture content and compaction, will react as predicted by the laboratory determination.

Fig. 9 shows a fill in central Ohio containing clays derived from limestone that are known to have detrimental expansive properties; the open crack probably is the result of expansion and shrinkage.

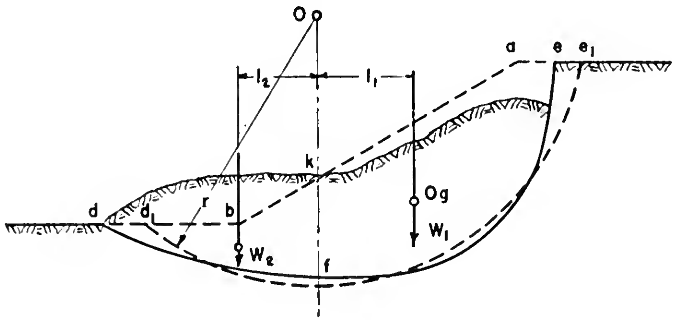
These properties also go far to explain the action of the roadbed in a Texas line revision built in 1944. According to the record this revision was built with controlled moisture and compaction. However, the soils are known to be expansive and apparently no tests were made for this property. In the field the soils were rolled to the degree of compaction shown by the laboratory tests as desirable, but if the moisture content was below that at which least expansion occurs, field exposure could result in a swell with the attendant decrease in density, increase in moisture, weakening of the structure and, if sufficiently aggravated, failure. This apparently occurred, as at present it is the only assumption that will explain the failure of 2½ to 1 slopes on 20-ft. fills.

All computations on the stability of soils are based on the assumption of uniform characteristics. This as we all know is not the case. However, these computations are

Fig. 9.

valuable as will be discussed later. One of the principal problems, now before us in the study of the stability of earth structures is to determine the changes that ensue during the years in service. To quote from the American Society of Civil Engineers' subcommittee on consolidation of materials in earth dams and their foundations as reported in January this year: "Although there is a myriad of results indicating how soils were compacted there exists practically no data indicating the changes in strength, rigidity and permeability of the fill with age." We are acquiring this data. On the railroads we have several projects on which the conditions of construction are known. It is our intent this year to explore these fills and determine the changes that have ensued during the period in service.

Now let us say a few words about the evaluation of subgrade weaknesses as to the possibility of more serious failures. This is in the line of preventive medicine and may be of value to those whose problem it is to select sections for stabilization. I don't believe anybody has received credit for preventing a slide chiefly because no one knew, including himself, that he had prevented one. However, it is common sense to work on those areas most likely to give most serious trouble. The first basis for selection is obvious, that section on which maintenance costs are highest. The next step in our imaginary selection requires an inspection of the various sections and an attempt at analysis of present and incipient failure based on past experience and whatever knowledge of the soils and type of construction that can be obtained from the record. As an example a filled-in trestle may give more trouble than another fill of conventional construction with similar dimensions. A fill widened on an old grade may slip along the original slope. Any seepage apparent and any water bearing strata are also factors promoting instability. Where possible, borings are very valuable, not only in determining soil discontinuities, but also free water and high moisture contents in soils.



$$W_1 l_1 = W_2 l_2 + s r \text{ arc } d_1 e_1$$

$$s = \frac{W_1 l_1 - W_2 l_2}{r \text{ arc } d_1 e_1}$$

Fig. 10.

Another aid is illustrated by the sketch in Fig. 10 showing the method for slope stability analysis. This is especially valuable if a slide of known extent has occurred. From the measurements of this slide statical moments can be taken about the center of the sliding arc and the value of shearing force determined. This at time of movement is equal to the shearing resistance of the soils and any fill of similar soils and comparable conditions will probably exhibit similar strength. The method can be used to evaluate slopes in general but because of lack of knowledge of shear strengths of the soil material in place, its value is limited. Also trial and error are needed to determine the most critical surface.

Let us briefly summarize the results of the investigation of roadbed stability. Water and its effect on susceptible soils are the primary causes of any instability present. This water in the majority of the cases is that which has fallen on the track. It is possible that it can be channeled under the track and into the unstable section, but this is not required as shown by sliding fills between two open deck trestles.

In said piles and sand-filled blast holes there is a tendency to increase soil strength through additional consolidation, but to an extent for which we have no quantitative measure as yet. This type of stabilization will also tend to give relief channels to water. Piling and vertical ties also tend to consolidate the roadbed and where driven into a firm base will supplement the shearing resistance of the soil.

Grouting may also tend to increase compaction, but its main effect appears to be in sealing up channels of moisture movements and restoring or increasing friction and cohesion within the soil mass. Also, where ballast is penetrated to any extent the grouting benefit may be direct in action by spreading loads and reducing unit stress in the subgrade.

These are all generalities. The results of soil pressure cells and further investigation into subgrades should give us the changes that occur in roadbeds resulting in instability and how various methods of stabilization arrest or nullify these changes.

In conclusion, it should be recognized that only 20 years ago soil was considered plain old dirt. In those 20 years great strides have been made in understanding the action of soils as structural material. This is especially true if one considers the time and study devoted to understanding the mechanics of wood and steel materials with much more definite structural properties. There is much yet to be learned about soils. The AREA sponsored investigation, has and will continue to develop information of value to the industry. I know of no other maintenance expenditure that will give a greater return on the dollar than that for roadbed stabilization.

Repairs to Stone and Concrete Masonry Structures

By A. N. Laird

Chief Engineer, Grand Trunk Western Railroad

The subject of repairs to stone and concrete masonry structures might be discussed from various viewpoints, touching on the romantic part these structures have played in the railroad history of our country, or from a statistical standpoint to show the financial savings which have resulted from the improved and ingenious methods which have been developed in making such repairs. However, I propose to confine my remarks rather to the practical engineering viewpoint, outlining some of the causes of deterioration of such structures, the objectives, and some of the methods which have proved effective in carrying out such repairs and restoration.

Railroad companies have been building stone masonry bridges and other structures for more than a century, and there are notable examples of such construction which are giving safe dependable service after 80 or 90 or more years. Concrete, on the other hand, came into general use for such construction about the turn of the century. Thousands of such structures also are still in service, safely carrying heavy freight trains with locomotive axle loads twice the original design loads, and smooth running streamliners which operate at speeds not dreamed of by railroad men in the early days.

I think we should frankly recognize that all structural materials are subject to deterioration when exposed to the elements of nature. In the case of concrete and stone masonry the rate of deterioration is relatively slow. Eventually, after years of service and exposure, repairs and possibly restoration may be required, and at such times it is important that each case be analyzed individually and methods adopted, which will prove most effective and economical.

Causes of Deterioration

It is not my intention to dwell at great length on the specific causes of deterioration of masonry structures, but a brief review of some of the main factors involved is necessary as a background for the selection of the best repair and restoration methods.

In some of the old stone masonry structures, soft stone and lime mortar were susceptible to the action of water and alternate freezing and thawing, resulting in erosion and cracking. Frequently a lowering of the general ground water level, or seasonal fluctuations in stream flow, exposed the originally submerged timber foundation mats and piling, which caused rotting of the timber and settlement, resulting in structural cracks. Also, in many of the large early structures the cut stone blocks were used only on the exterior faces of piers, abutments and arches, and the backing and interior material consisted of man-size irregular stones or spalls laid in random fashion, with little or no attempt to fill the voids with mortar. Large structural cracks frequently developed in such members, which were of such concern to the engineers as to require effective repairs or replacement.

In the case of concrete structures, the problem is more complex. The cause may have been the use of unsound coarse stone or gravel aggregates, or the presence of soft, porous sandstone, shale, chert or organic matter, which when subjected to water and cycles of freezing and thawing or alkaline action results in disintegration, spalling, cracking, and other serious defects. Too, in the early days little attention was paid to the fineness and proper proportioning of fine aggregates, which were combined with the cement paste to form the mortar that would fill the voids in the coarse aggregates and cement the entire mass together. This resulted in a porous or over-sanded concrete which lacked the qualities for durability.

Varying views and construction practices were likewise prevalent, depending on the period. At one period, the inner faces of the forms were plastered with mortar to give a smooth surface finish, and a dry rammed backing of concrete was placed in layers with little regard for the location of construction joints. At another period it was thought that an excess of water was necessary to hydrate the cement, but this practice proved very detrimental to the quality and caused excessive laitance, segregation of aggregates, voids and porous concrete, susceptible to the destructive action of water and of freezing and thawing.

Faulty provision for structure drainage and lack of care in the selection of porous backfill over arches and behind walls and abutments also contribute to progressive disintegration.

Inspection of Structure and Preliminary Work

Before undertaking repairs to a masonry structure, a thorough inspection should be made to determine the nature and extent of the deterioration and defects. In cases where strengthening of the structure is necessary, engineering plans should be carefully prepared. Correction of faulty drainage facilities should be made prior to general repair work to prevent the impounding of water at points where it would damage the masonry. This condition can be taken care of by cleaning out the old drainage lines or by drilling new drainage holes or installing pipe outlets at critical points in the structure. In some cases it may be necessary to open up the back of an abutment or the filling over an arch to install new drainage outlets and apply new waterproofing. Clearly, the repairs can only be partially successful if no attempt is made to eliminate the source of the trouble.

Repair and Restoration Methods

Methods of making repairs and the restoration of deteriorated stone and concrete masonry structures may be broadly classified under the headings of patching, restoration, encasement and internal grouting.

Patching would be generally applicable to the cases where there is local disintegration of the surface, spalling, surface checking or crazing, where sections of the surface material have separated from the main mass or where there is loose, honeycombed or disintegrated concrete or stone on the surface over small areas. Such surface material should be removed to a depth which will expose sound hard materials. Where the purpose of the work is mainly to stop progressive surface disintegration which in time would impair the strength or serviceability of the structure, the depth of the area to be patched may be as little as two inches or it may exceed this by a considerable amount. The edges should be cut approximately square with the surface or slightly undercut so as to avoid thin or feathered edges. Abrupt changes in the depth of such cuts should also be avoided. Where the areas to be patched are small, the work may be accomplished by hand methods if desired but where the area is more extended, other methods, which will be described, are preferable and produce more dependable and uniform results.

Where disintegration has progressed over large areas and to considerable depths and it is desired to restore the structure to its original lines and contours, this may be done by placing ordinary concrete, by the application of shotcrete, or by pressure grouting of concrete aggregates. These methods are also applicable to encasement, both as a means of repair and for the purpose of strengthening.

In all such surface repair work, it is of the utmost importance that the bonding surface of the old structure be thoroughly cleaned and free from oil or a coating of any material which would reduce the bond strength. Loose particles of dust and dirt should be removed and the surface left rough and clean. It should be thoroughly wetted immediately prior to the placing of the new material, preferably for an hour except in freezing temperatures. Suitable metal anchors should be provided of such size, spacing and depth of anchorage as may be determined by the character and condition of the old material and the amount of new material to be applied. Such anchorage should be capable of developing the tensile strength of the anchor rod. The new concrete material should be reinforced with steel bars or mesh of cold drawn steel wire, or a combination of the two, depending on the thickness and type of the surface application. The reinforcement should be rigidly attached to the metal anchorage system and wherever possible the mesh should be stretched tight and lapped between sheets for suitable bond. In each of the repair methods, the quality of portland cement, and of the aggregates, and their grading, storage, handling, proportioning, mixing, placing, compaction and curing must receive the careful attention of the engineer much the same as for new concrete construction. These matters are so fully covered in the current manual of the Association, in the section of Committee 8—Masonry, that reference thereto will suffice.

The placing of ordinary concrete for this purpose may be difficult in many cases, particularly on the underside of a member, or at points which are inaccessible for ordinary concreting operations. There are also problems involving bonding to the old surface of the structure, and shrinkage when the concrete hardens. However, this procedure has been widely used for heavy encasement and for heavy buttresses and facing, and under favorable conditions may be the most economical method.

The Use of Shotcrete

Shotcrete which may be defined as a material consisting of portland cement, sand and water, placed pneumatically by means of equipment which discharges water and premixed cement and sand, under regulated pressure, through pipes or hose and a discharge nozzle, the water being combined with the sand-cement mixture at the nozzle. It has been widely used for many years as a method for restoration and encasement. It is quite fully described in the specifications appearing in the Manual of the Association under recommendations of Committee 8—Masonry. These specifications, however, are now being revised by the committee and when the new recommendations are adopted it is believed that they will outline the best practice for such material and its application.

It is very important that shotcrete be placed by an experienced operator. Poor work will result if the material is permitted to build up too fast or too thick in local areas. The material must be shot approximately perpendicular to the surface to avoid loss of cement due to rebound. Care must also be taken to get thorough embedment and bond of all reinforcement. The application for thick sections should be made in progressive stages, preferably about one inch in thickness, so that no surface will set more than two hours before the next application. By this method a homogeneous mass is built up. Shooting strips should be used to insure true surface and edges. When it is necessary to stop the application before reaching the final contour, such as at the end of the day's work, the surface should be thoroughly wetted and all loose or uncemented particles removed before applying new shotcrete. When shotcrete is used to build up thick sections, multiple layers of steel mesh combined with bars, should be used and these should be thoroughly anchored to the old masonry. Shotcrete surfaces require care in curing and should be kept damp for at least four days after placing.

If a special surface finish is desired over the shotcrete, this may be obtained by applying a flash coat of shotcrete over the entire structure to give it a uniform texture, or it may be rubbed or lightly trowelled if a smoother texture is desired. It is generally considered better practice not to disturb the final surface of the shotcrete any more than necessary. However, there is some difference of opinion among engineers on this point.

Grouting Concrete Aggregates

The third method applicable to restoration work or encasement may be referred to as grouted concrete aggregates. The initial preparation up to and including the erection of the concrete forms is little different for this method than for ordinary concrete, except that grouting pipes are installed, at intervals of three to eight feet or more depending on the form of construction, extending through the face of the forms into the area to be restored. Such grouting pipes should be prepared at the outer exposed end for convenient and rapid attachment and removal of the grouting lines so as to avoid leakage or loss of pressure as the grouting progresses. At this stage, however, the methods differ. After thoroughly flushing out forms and wetting down the old surface, the space between the concrete forms and the surface of the old structure should be filled with well graded coarse concrete aggregates of accepted standard. Such material should be vibrated in the forms to create as compact a mass as possible.

The objective is to completely fill all voids of coarse concrete aggregates with cement grout, applied so as to expel all air or water and form a strong, dense, concrete securely bonded to the old surface and subject to a minimum of shrinkage.

The entire section to be grouted should be thoroughly wetted, including the aggregates in the forms and the surface of the old structure where bonding is desired and the water permitted to drain off if practicable. Immediately following this the grouting operation should be started by pumping the grout into the forms under controlled pressure at the bottom grouting holes. Experience has indicated that a grouting mixture composed of one part of portland cement, three parts of fine graded sand and a suitable admixture of a type which will hold the sand in suspension and prevent separation, and at the same time increase the fluidity of the mixture and counteract mortar shrinkage, is required for best results. Grout may be applied by various means but usually it is pumped, continuing the operation at each hole from the bottom toward the top until grout appears at adjacent holes on the row next above that at which the pumping is taking place. The grouting line would then be moved to the next hole on the same elevation, and the procedure repeated, plugging each grout hole as the grouting at that point is finished and continuing until the entire section scheduled for grouting has been completed. When the grout reaches top surface, a finish may be obtained by placing a layer of ordinary concrete, integrally with the grouted material, before it has taken an initial set, or by placing a quantity of finer graded aggregates in the upper portion of the form to a depth of four to six inches and the grouting continued to the surface, which may be trowelled when it reaches the proper degree of setting. Where the top surface of the grouted material is to become a bearing area for the support of heavy loads, special treatment is sometimes required by carrying the grouting slightly above the finished surface elevation and grinding or dressing this surface down to provide the bearing surface desired. After stripping the forms the desired surface finish could be obtained by following the same methods as would be applicable to ordinary concrete. For heavy construction it is preferable to leave the surface without rubbing or grinding except at form joints and form tee bars, where any cement fins should be removed.

Internal Grouting

As previously mentioned, many structures of stone masonry built in the early days, were built without much attention to the necessity of filling large internal voids and cementing areas between internal stones which were placed at random. Cracks and voids in concrete structure introduce much the same problem. Through the years, the action of the elements and the pressures resulting from the passage of thousands of heavy trains have frequently resulted in cracks in such masonry and local deterioration which has been a source of great concern to the engineering officers of many of the railroads. In a number of cases, structures which in the aggregate would have cost millions of dollars for reconstruction, have been restored to sound condition at only a small fraction of the cost of replacement which would otherwise have been necessary.

The method of repairs which has proved effective in many such cases may be referred to as internal grouting as a means of consolidation. Essentially, this consists of drilling holes at intervals in carefully selected locations from the exterior of the structure, and after suitable preparatory and exploratory work, grouting such holes full of a mixture composed of portland cement, fine sand and an admixture of a type which will improve the fluidity of the grout and prevent separation of the sand and at the same time counteract shrinkage so that the grout will pass through even small cracks to fill internal voids and thoroughly consolidate the entire structure into a single cemented mass. The relative proportions of cement and sand will be determined by the individual job requirements.

Initially, holes should be drilled at critical points to investigate the internal structure. The action of the drilling bit will tell an experienced operator the hardness of the stone or concrete through which the drilling is progressing and whether shattered rock or concrete materials or internal voids have been encountered. This preliminary information is of great value in planning the ultimate treatment. Even inaccessible areas of piers under water and in the footings may be reached by such drilling, and the grouting methods may be extended under favorable conditions to consolidate the foundation material under the structure. Holes for grouting should then be drilled, of ample size to prevent clogging, and these should be of such depth and location that grouting will proceed from the bottom and center toward the outside of the member. Before pumping grout into these holes they should be flushed out with water under pressure and this operation will not only clean out all dirt and drilling dust but will show what effective area each grouting hole will serve by noting the points where the water escapes. The effectiveness of such internal consolidation may be checked by core drilling in critical sections. This has been done on important projects and satisfactory results have been assured.

Illustrations With Photographic Slides

The application of the methods which I have discussed briefly may best be illustrated by an examination of actual structures before and after such repair and restoration work and I will endeavor to bring to you, by means of pictures, what can be accomplished along these lines.

Piers of Steel Viaduct

In Fig. 1 the condition of a concrete pedestal disintegration is clearly indicated. Progressive disintegration of the concrete, spalling and cracking had taken place. The pedestals of this large structure were repaired by removing the unsound concrete of the outer portion of the pier without disturbing the bearing. The new concrete cap or bridge seat extended up and slightly under the bearings. The encasement consisted of reinforced concrete which resulted in restoration to the equivalent of the original construction. The close-up view of the finished piers in Fig. 2 clearly illustrates what can be accomplished by work of this kind.

Concrete Bridge Piers

Restoration in the case of this steel truss structure on concrete piers was undertaken well in advance of the time when there was any serious structural problem involved. A typical view of one of the piers after the disintegrated surface has been removed is shown in Fig. 3. Fig. 4 shows the completed structure in which the surface restoration work by the application of reinforced shotcrete has prevented further deterioration. This kind of work may be considered as normal economical maintenance.

Concrete Arch and Pier With Concrete Deck Slab

Concrete repair work by means of reinforced shotcrete was accomplished on this combination concrete arch and steel truss span with concrete ballast deck slab. Fig. 5 shows the general disintegration which had taken place in the approach filled arch section. Fig. 6 illustrates what was accomplished by the restoration work. The method of repair is quite general in its application and has given sound dependable results.

Stone Piers and Arch Approach

A railroad structure built 90 years ago consisted of 24 dressed limestone masonry piers laid with lime mortar with irregular rock filling bearing on solid rock. Through the successive years the loadings increased to such an extent that the present steel truss spans which were erected about 50 years ago are now transmitting to the piers maximum loads several times original design loads. The lime mortar had gradually lost the lime content and become mainly sand. Also some of the stones had not withstood the weathering and have disintegrated or cracked, particularly at the cut water ends of the piers which are exposed to very heavy ice flow. Large vertical cracks appeared in the piers as shown in Fig. 7. Internal pressure grouting was adopted for the repair of these piers through holes drilled at frequent intervals into the stone work from a point just above the water lines, to the bridge cap. The subsurface portion was grouted through angle holes drilled from above the water surface and some of these holes were extended into the bed of the river and the foundation grouted to insure full bearing of the stone base course. The initial grouting was done at low pressure with cement mortar and this was followed with a neat cement grout at higher pressure to seal any remaining voids. Displaced and disintegrated stones were replaced and broken stones repaired, as shown in Fig. 8.

Stone Piers

An interesting example of what can be accomplished in the repair of underwater portions of bridge piers without the necessity of driving costly cofferdams and unwatering and formwork is illustrated by the typical pier cross section (Fig. 9) of a structure more than 70 years old. Those piers as originally constructed, some of them in 50 ft. of water with a current as swift as 12 mph., consisted of heavy watertight timber

Fig. 1.—Disintegration of a Concrete Pedestal.

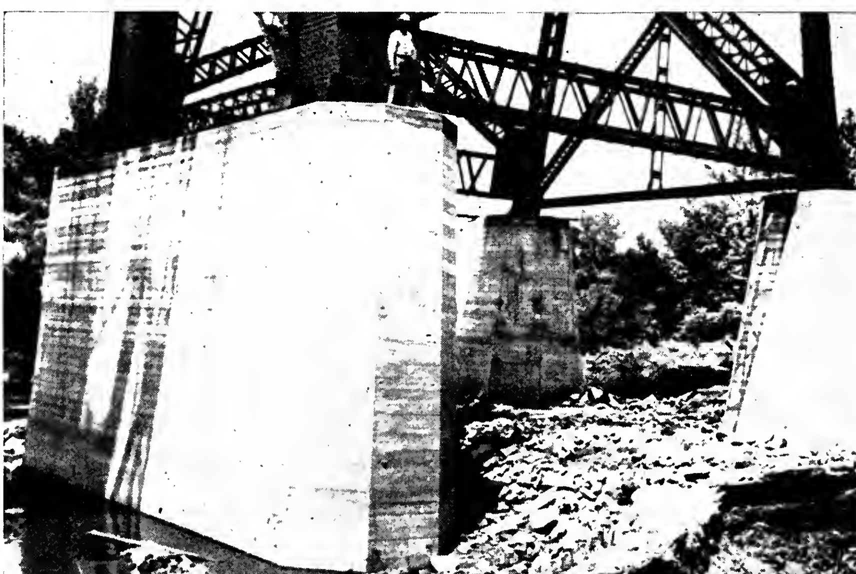


Fig. 2.—An Example of the Encasement of a Deteriorated Substructure.

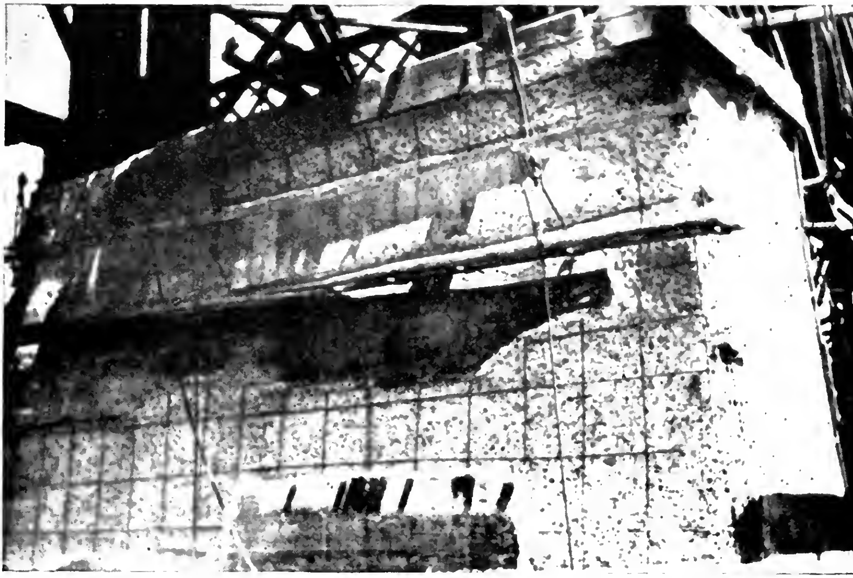


Fig. 3.—Pier with Deteriorated Concrete Removed.

Fig. 4.—Piers Restored by Applying Shotcrete.

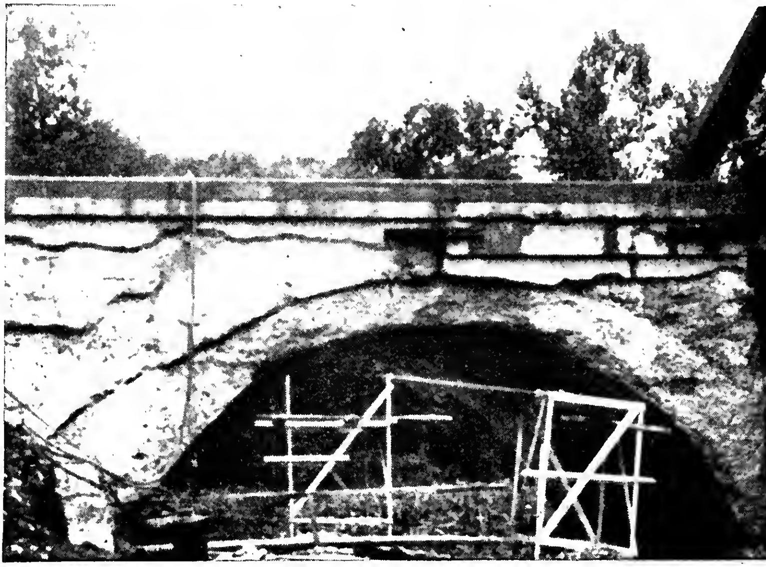


Fig. 5.—An Example of General Disintegration.

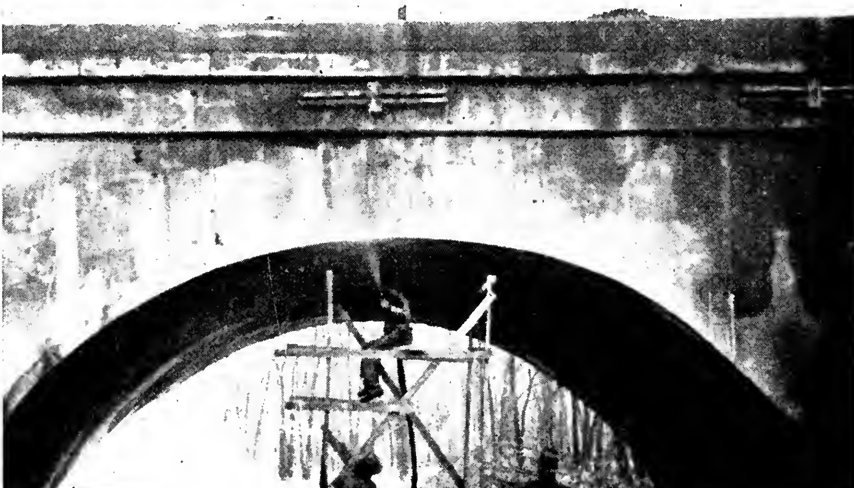


Fig. 6.—Application of Shotcrete in Progress.

Fig. 7.—Vertical Cracks in this Old Pier Due to Progressive Increase in the Live Load.

caissons sunk in place and filled with stone and concrete on which the cut stone pier had been constructed. Around the outer part of the main pier open bottom caissons had been placed and filled with riprap. Deterioration of the outer caisson in later years had allowed much of the riprap to escape and considerable erosion and disintegration of the concrete foundation and underwater cut stone joints had occurred. This structure was repaired from above water by internal pressure grouting the outer caissons and stone riprap, through long drilled diagonal holes in which grouting pipes were inserted so as to force the grout up through the riprap from the bottom. By constructing a heavy protective shield at the nose of the pier, it was possible for divers to make a careful examination of the caisson and guard against grout leakage. When necessary, additional stone was placed in the outer crib through elephant trunks and this likewise grouted. The interior of the pier, including both the original concrete base and the stone work above it, was also consolidated by pressure grouting. This work, completed six or seven years ago, shows every evidence of satisfactory results.

Stone Rib Arch

A three-span skewed four-track stone ribbed arch on a 45-deg. skew built some fifty odd years ago showed considerable disintegration, mainly in the mortar between the ribs, which permitted movement along the longitudinal joints when subjected to live load. The skew ribs are shown in Fig. 10. In this case the spandrel walls were tied

Fig. 8.—Defective Stones Replaced or Repaired after Grouting Interior.

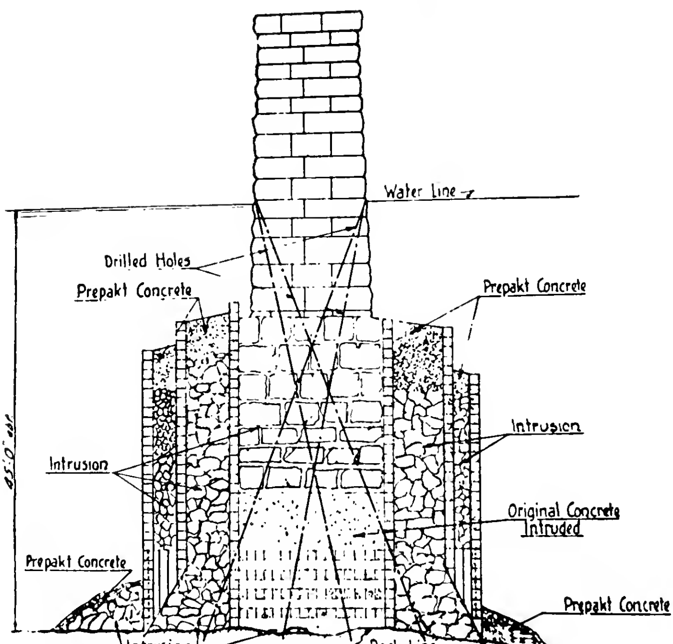


Fig. 9.—Method of Repairing Underwater Portion of a Pier.

Fig. 10.—Opening of Mortar Joints Permitted Movement Between Ribs of this Skew Stone Arch.

Fig. 11.—Grout Was Applied to Interior Through Holes Drilled in Arch Ring Stones.

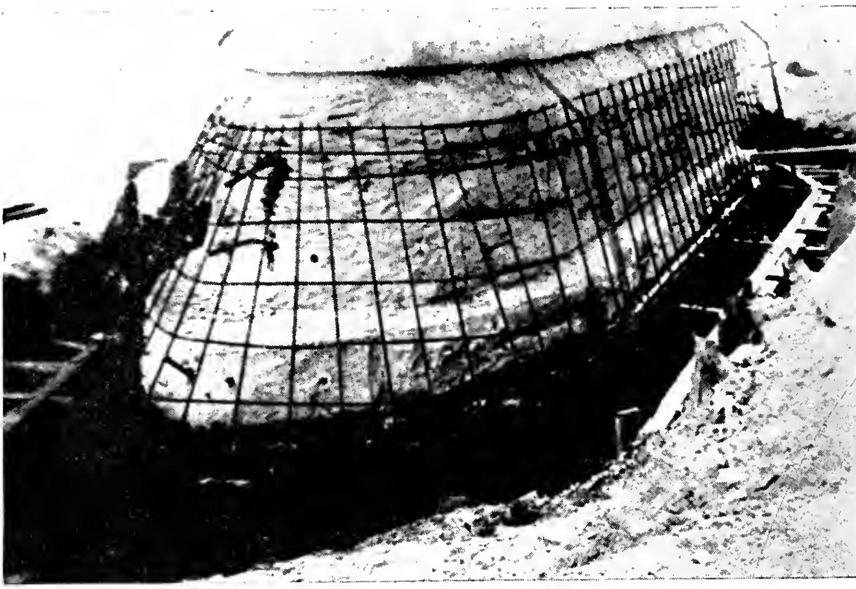


Fig. 12.—Reinforcing in Place After Removal of Defective Concrete.

Fig. 13.—View of the Pier After Completion of the Repairs.

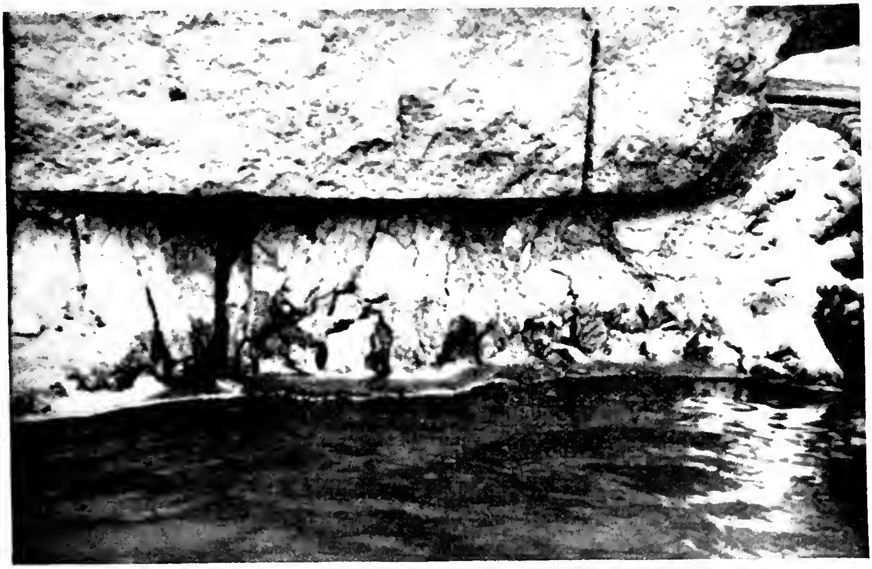


Fig. 14.—Showing Effect of Ice Action and Erosion on a Bridge Pier.

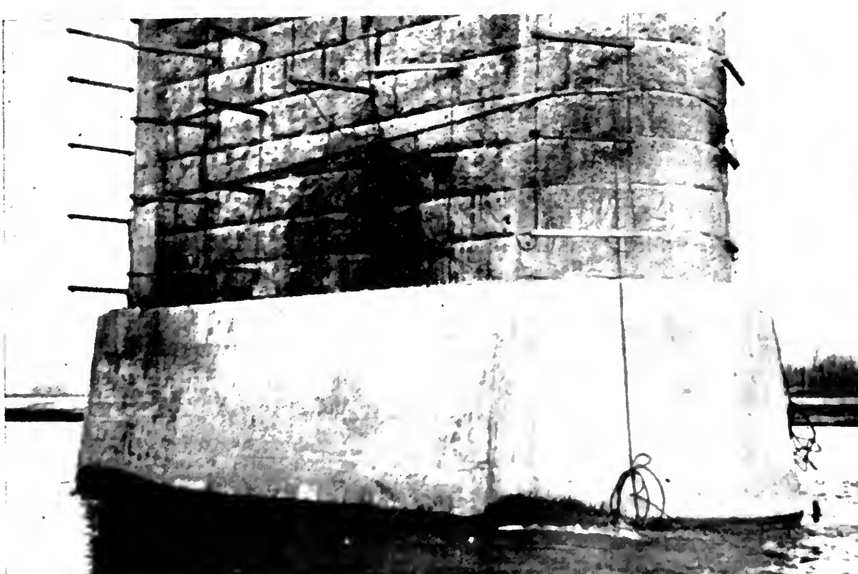


Fig. 15.—Interior of the Pier Was Grouted and the Base Was Encased with Reinforced Concrete.

together with H-beams and tie rods, following which the masonry joints were thoroughly chipped out, sandblasted and washed with water under pressure. The joints were then filled from below to a depth of from 3 to 6 in. witb shotcrete. Cracks and spalled stones were also replaced with reinforced shotcrete. Holes were then drilled through many of the ring stones and pressure grouting was carried out (as shown in Fig. 11) in such a manner that the grout, starting at the spring line and working toward the crown of the arch was applied above the arch ring to insure that the upper parts of the joints were completely filled with grout. The results obtained have proved entirely satisfactory.

Stone Pier on Timber Mat

The engineers faced a somewhat different but not unusual problem in the case of the stone piers of an important structure where there had been a general lowering of the water level in the river. The piers had been constructed on timber mats and it was found that there was considerable scour and these mats were being exposed to alternate wet and dry conditions which would ultimately destroy them. Sheeting was driven around the piers and disintegrated concrete was removed as shown in Fig. 12. Sand was pumped in under and around the mat in progressive stages as a means of keeping the mat moist by capillary action. The base of the pier was then encased (see Fig. 13) by pressure grouting concrete aggregates placed in the forms after a reinforcing with a network of steel bars. The finished encasement protected the timber mat and provided protection against further erosion.

Partial Encasement of Stone Piers

The stone piers of a large bridge structure over one of the large rivers of the middle west, which is subject to extreme fluctuations in water level and carries a high percentage of silt and sand, required repairs to counteract the erosion by water and ice and by freezing and thawing within the range of water level as illustrated in Fig. 14. At this structure it was found necessary to drive temporary steel sheet piling for cofferdams. The timber cribs and caissons extended for a depth of 25 ft. to bed rock and were filled with concrete. The unsound stone work above the timber crib was cut out and the base of the piers encased, as shown in Fig. 15, to a point above high water level with reinforced concrete. The stone work was also repaired and grouted internally above this level. The results have justified the study and care with which this work was carried out.

How To Meet the Increasing Cost of Labor and Material

President Mottier: "How Can the Railroad Construction and Maintenance Engineer Best Meet Increasing Cost of Labor and Material?" I dare say that no one present could think of a more timely question than that. It is a question that we have had in front of us all our lives, but I cannot recall any time in my experience when it was more timely than at the present. Not only are costs of material higher than they have ever been but we are now confronted with increased costs per hour of labor, the five-day week and, at the same time, with a decline in gross revenue.

Realizing these points, the Program Committee arranged for a symposium to discuss the subject from three points of view, three answers to the question: By Heavier Rail; by Increased Mechanization, and by Roadbed Stabilization.

Economies to be Derived from the Use of Heavier Rail and Accessories

By F. R. Layng
Consulting Engineer, Bessemer & Lake Erie Railroad

Generally when we speak of heavy rail we have in mind those sections weighing about 130 lb. per yard and over. It is recognized that there are many miles of track on which, due to character and volume of traffic, future prospects, etc., serious consderation need not be given to increasing the weight of rail. On the other hand, it is my observation that our industry has been ultra-conservative in the introduction of heavier rail. About 1896 the 100-lb. ASCE section was introduced. Up to this time the 85-lb. section was the heavy section generally used. It was not until about 1915 that the sections in the area of 130 lb. per yard were adopted by a few railroads and about 1930 when the Pennsylvania Railroad laid the first 152-lb. rail. The average weight of rail per yard on Class 1 railroads for several periods and by districts is shown in Table 1.

TABLE 1.—AVERAGE WEIGHT OF RAIL

	All Districts	*Eastern*	*Southern*	*Western*
December 31, 1935	92.72	104.64	92.81	86.21
December 31, 1940	95.30	107.00	95.10	89.03
December 31, 1945	98.85	109.92	99.19	92.74
December 31, 1946	99.39	110.43	99.79	93.30

As of December 31, 1946, but 14.2 percent of the main track mileage of all Class I roads was laid with 130-lb. rail and over, and only 0.46 percent was laid with 140-lb. or over.

Much has been accomplished in reducing track maintenance costs in recent years. This has been done by more and better supervision, the use of power driven machines, thus conserving labor, and by increasing the service life of materials such as: The treatment of ties, use of larger tie plates, end hardening of rail, restoring battered rail ends by welding, installing rail lubricators, improving quality of ballast, stabilizing roadbed, providing better drainage, etc.

Before some of the methods mentioned above were developed, the service life of rail was generally determined by end batter and curve wear, especially end batter. Now it is possible to double or even triple the average service life. This change is of great importance in considering the economies of heavier rail.

Since 1940 the cost of track material has increased approximately 60 percent. In this same period the cost of track labor, taking into account time paid for and not worked, has increased considerably over 100 percent. This change of relationship as between the cost of labor and material is an important factor in favor of the heavier rail sections.

The labor used in track maintenance is charged to ICC Account No. 220. In 1946, 29 percent of the total cost of maintenance of way and structures, all class I railroads, was charged to Account No. 220, compared with 25 percent in 1930. Table 2 shows the relationship of the cost of the several operations included in this account.

TABLE 2.—ACCOUNT NO. 220

	Percent
Applying ballast	15
Applying ties	15
Applying rail	10
Applying other track material	5
Track maintenance, lining, surfacing, etc.	55
	100

From what has been said it is clear that further reduction in maintenance costs can be accomplished by the use of materials which will, after installation, reduce labor costs, particularly those materials that are used in the track structure. I believe that this can best be achieved by the replacement of lighter rail sections with heavier sections and accessories.

When rail is purchased we actually buy three qualities that bear directly on maintenance costs; stiffness (the most important), strength, and durability.

As to Stiffness.—As stiffness increases, less labor is required to maintain track to a desired standard of line and surface, because stiffness reduces deflection under traffic and distributes the load over more ties and over a greater area of roadbed and ballast. This reduces the vertical deformation of the track structure with a marked reduction in the labor necessary to maintain line and surface. The reduction in vertical movement also lengthens the service life of all parts of the track, rail, joint bars, ties, ballast, etc. Inasmuch as the stiffer sections are higher, the joint bars are very much more efficient, further reducing the labor necessary to maintain line and surface. The fact that stiffness increases so much more rapidly than the weight should be carefully noted, as indicated in Table 3.

TABLE 3

	Section Weight-lb.	*Height Inches*	*Percent Increase in Weight per Yard*	*M.I. Stiffness*	*Percent Increase*
1.	90 RA	5⅝		38.7	
2.	100 RE	6	9 over 1	49.0	27 over 1
3.	115 RE	6⅝	13 over 2	65.6	34 over 2
4.	132 RE	7⅛	13 over 3	88.2	34 over 3
5.	155 PS	8	17 over 4	129.0	46 over 4

As to Strength.—On the assumption that the rail section in use is strong enough to support the axle loads imposed, additional strength is of less importance than stiffness because its ultimate strength is never expected to be called fully into use. Nevertheless it may be called into use as the rail wears and, to some extent, it adds to the average service life and to safety. Increase of strength is also of value, from the standpoint of safety, as the general experience with the heavier sections show a substantial reduction in rail failures.

As to durability: It is difficult to determine a measure of durability except by actual use of the sections that are to be compared and then under conditions that are as similar as possible. On the B. & L. E. R. R., the average service life of the 100-lb. ASCE section was 6½ years; the 130-lb. PS section was 13 years. These data apply to the period before we adopted end hardening, building up worn rail ends and using rail lubricators. Our experience with the 152-lb. section is too short to determine average service life but we believe there will be a substantial increase over the 130-lb. section, possibly a service life of 20 years. This would increase the service life of 152 lb. compared with 130 lb. by 50 percent. At present this looks to us like a conservative estimate.

Increasing the service life of track materials also results in a reduction in track labor maintenance cost that is substantial due to less frequent need for renewal. The added service life will also have a favorable effect on the life of ties for the reason that less adzing will be necessary.

At present we have in our main tracks, North Bessemer, Pa., to Conneaut Harbor, Ohio, rail of four weights, as follows:

95	track miles	130 lb.
81	" "	131 lb.
89.6	" "	152 lb.
14.5	" "	155 lb.

In 1949 it is planned to replace 23 track miles of 130-lb. rail with 155 lb.

Our average gross ton miles per mile of road southbound is approximately 20,000,000 and northbound is approximately 11,000,000.

Seventy-four percent of our hopper cars are 90-tons capacity (four wheel trucks). Under load this means an axle load of 62,000 lb. The axle load main drivers of our road locomotives (2–10–4) is 75,900 lb. Maximum speed of freight trains 40 mph.

Our experience with the 100, 130, 131, 152 and now the 155-lb. section shows clearly there are substantial savings in the use of the heavier rail sections in both labor and material.

In changing from the 131-lb. section to 152-lb. we add 38.8 net tons of metal (rail and other track material), an increase of 11-6/10 percent. We estimate that this additional cost will be paid for by the saving in labor charged to Account No. 220 alone in from three to four years. In addition to this, we will realize the other savings that have been mentioned as well as a definite saving in wear and tear on equipment.

We are convinced that one of the greatest labor saving devices we can use is the installation of heavy rail. I believe there are many railroads that have certain territory where they can justify its use. The weight of rail to use will, of course, be governed by the conditions in the territory under consideration.

AREA Committee 4—Rail, has a subcommittee studying the economic value of different sizes of rail. This year it reported a test being made by the Illinois Central started in 1945 to study the comparative performance and annual maintenance cost of 112-lb. and 131-lb. rail. In an effort to eliminate as many variables as possible, two 20-mile sections of track were selected on the northward main track between Mattoon and Champaign, Ill. These adjoining sections are located between two terminals and have nearly identical conditions affecting maintenance cost, including tonnage, roadbed, and operation. This test should provide definite information as to the relative costs for these two sections. It is to be hoped that other tests will be made on other railroads, not only for the two sections of rail under test on the Illinois Central, but for other rail sections as well. If a sufficient number of tests are undertaken and they confirm our experience, a much wider use of the heavier sections should result.

Vice-President Sitton: Thank you, Mr. Layng, for that fine information.

This problem will now be discussed from the standpoint of increased mechanization, by Mr. S. R. Hursh, assistant chief engineer, maintenance, Pennsylvania Railroad. Mr. Hursh!

Economies To Be Realized by Increased Mechanization

By S. R. Hursh

Assistant Chief Engineer—Maintenance, Pennsylvania Railroad

The railway maintenance engineer is at present facing a great challenge. Existing trends of labor rates, material prices and traffic returns are seriously threatening the future of the railroads. The Interstate Commerce Commission, aware that deferred maintenance exists in large proportions, has called on the railroads to reduce operating costs. At the same time other governmental agencies are increasing taxes, recommending increases in wages and openly subsidizing competing forms of transportation. Labor regulations are ever becoming more costly, material prices are at high levels, material shortages continue, and requirements of regulatory bodies are ever increasing.

It is appreciated that the railroads must raise passenger and freight rates in keeping with the economic trend of the times. The challenge to the maintenance engineer is—as costs go up, to offset them just as quickly as possible by increasing efficiency of man-hour output.

It is obvious that every attempt must be made to limit maintenance expenditures to aid in keeping the railroads solvent. There are many methods of reducing maintenance expenditures among which are reduced force, lowered maintenance standards increased labor output per man, improved design of track structure and mechanization of hand operations.

However, it is known that to meet competition, we will have to continue to provide a high-speed, heavy duty track structure on our main lines and that trackage reduction is possible only on a few branch lines. We must, therefore, approach the problem in a constructive manner, so that lowered maintenance standards or arbitrary force reduction is not a feasible or practical approach.

Little Hope of Increased Individual Output

Increased labor efficiency considered from the standpoint of individual output is doubtful as present social tendencies and working regulations are ever contributing to diminishing personal output and any expectation of improvement is contrary to foreseeable trends.

In view of the large amount of deferred maintenance now existing on Class I roads any appreciable decrease in work units expended on the properties will be highly injurious. Thus only by improving working methods, abolishing unnecessary work and mechanizing hand operations can we have a reduction in man-hours. This reduction will not be in work units but will be an efficiency saving.

Examining the past record of Class I roads we find that in 1937 it was necessary to expend 376 man-hours of maintenance of way and structures labor per million gross ton-miles, while in 1946 only 307 man-hours were expended—an 18 percent reduction. While it is admitted that due to labor and material shortages and other causes, deferred maintenance was present in both 1937 and 1946 and in even greater proportions during the war years, we believe that most of this reduction was due to improved working methods, mechanization of hand operations and improvements in road and equipment.

Comparing average hourly Group III straight time compensation with investment in roadway machines per mile of main track, we find a close relationship. In the years from 1936 to 1946 compensation increased 96 percent, while investment in roadway machines increased 111 percent.

Only by continuing these trends in future years can we hope to maintain the railroads economically and increase output per man-hour. There is no way to increase individual output commensurate with income other than continued expenditures for labor-saving improvements, constant betterment of working methods, mechanization in ever expanding application and constant application of technological developments.

In the face of recent wage increases and the 40-hour week, the railway maintenance engineers must stop and analyze their present position in regard to mechanization and evaluate approaches to increased application in the future.

At the end of 1948 the investment of Class I roads in maintenance of way equipment of all types is approximately 200 million dollars as represented by road machinery and portions of work and miscellaneous equipment accounts. Undoubtedly a considerable portion of this investment is in obsolete types or in worn out equipment.

Make a Survey of the Equipment

This present investment in maintenance machinery should be analyzed by each individual railroad. All machinery should be checked for condition and obsolescence. Total investment in each type of machine should be compared with work needs for that type to determine if a proper ratio is being maintained. Also, age groups should be worked out for each type of machine so that we do not get in the position of trying to perform a certain operation with a group of obsolete machines and then wonder why our costs increase and the work is not being done. Generally speaking, the usefulness of a machine decreases with age and we must recognize this fact. Immediate purchases should be made of machinery of types that are under-invested as regards quantity of work to be done, machinery age and potential savings. Antiquated machinery should be retired or possibly converted to some other use. I feel that in the past many machinery purchases have been made on a hit-or-miss basis and I urge that future machinery applications be made on a carefully systematized basis with regard to investment, design trend and maximum utility. Purchasing departments must be brought in line with this policy and consider the overall picture, rather than the initial dollar cost of a machine.

Many machines now on hand may be capable of multiple uses which are not utilized or by slight conversion could be adapted to other uses. As an example, crawler compressors may be profitably employed in winter months for gaging and anchor spiking and certain types of mowers can be converted to snow plows or brooms for winter use. Undoubtedly thorough investigation would disclose many other multiple uses for many machines normally worked only in certain seasons and not throughout the year.

Repair programs should be accelerated and staggered so that machinery is not standing idle while awaiting shop space. Mobile repair units should be designated so that working season breakdowns are quickly corrected in the field. Railroads operating in regions of varying weather conditions could transfer machinery between regions for all year utilization. Although generally neglected it is important that full records be kept for each machine showing purchase date and cost, repair dates and possible multiple uses. Working locations should be carefully logged for each machine to insure proper placement of machinery to meet work needs. Occasional field checks are of value to determine if machinery is being properly and sufficiently employed. Perhaps some supervision tends to discount use of machinery and this type of thinking must be overcome to obtain full possible savings from equipment.

Cost and Performance Records Important

Another important field that is virgin territory to most railroads is that of maintaining adequate cost and performance records of comparative hand and machine operation costs for various types of machinery and various jobs. This type of study when made by trained men is most useful in determining future machinery applications for maximum economy, in revising inefficient working methods and devising improved machinery, in preparing budgets, in preparing requests for machinery expenditures. This field offers rewards of substantial savings from thorough and informed cost research.

Machinery officers and supervision must be chosen for alertness, ingenuity and ability, and incentives must be provided in advancement and salary to insure their continued interest in the problem. The machinery officer is a valuable trained specialist and this important work must not be delegated to untrained and disinterested personnel.

These varied considerations all reflect on obtaining maximum efficiency from our present investment in maintenance of way machinery and only until our position is thus consolidated do I suggest the next approach to the problem which might be entitled "Future Requirements and Designs."

In order to keep abreast of technological advances and fully develop maximum efficiency from mechanization the railroads must utilize constant ingenuity. From the previously mentioned cost studies and from field observation, we should know where we are failing to eliminate costly hand operations. Even by casual thought many operations come to mind that offer ample opportunity for improvement.

Some Examples

On any railroad there are many such examples, a few of which I might mention:

1. Generally speaking, the section gangs are under-mechanized. There has not been sufficient adoption of spot surfacing machinery, possibly because some developments in this line were poorly suited to the needs. Mowing and brush cutting still involve too much hand labor due to insufficient investment and a high rate of mechanical failure in present machinery. Spot tie renewals are costly and involve considerable digging and handling. Splice, spike and bolt renewals by local gangs offer room for improvement. Local rail changing operations are uneconomical; perhaps something could be worked up in the line of an especially equipped truck to move rail from mile posts and fitted with compressor to pull and drive spikes and take care of bolt changing. This would be most useful in handling broken rails either day or night.

2. Although we have made good progress we still do not have the final answer to crib cleaning. On some railroads this is probably the most important operation needing improvement. You cannot maintain satisfactory track conditions with foul cribs and much of the present intertrack and border cleaning is failing due to foul cribs. Crib cleaning demands concentrated study and research to achieve satisfactory results both from quality and cost standpoints. Future hand cleaning has been priced out of the picture.

3. Considerable hand labor is wasted leveling ballast, dressing shoulder, moving cinders and sloping banks. Further progress in equipment to deliver ballast in proper

quantities to the proper place, and equipment to then level and dress it is essential. This is a fertile field for investigation.

4. Although rail operations are fairly well mechanized, there is still room for improvement, especially in the matter of distributing material and picking up scrap, both wasteful hand operations. Parceling of material in bundles for each rail and delivery by magnet is a possibility. Modern ingenuity certainly can provide an answer for us in the matter of picking up scrap after the rail is laid and sorting it for disposition.

5. The use of off-track machinery and operations by the aid of trucks, using widened berms, is also of major importance. Many work trains could be eliminated by truck delivery of material with considerable saving. Thousands of man-hours are lost each year by gangs having to walk to the point of work from the nearest road crossing or set-off. Your improvement program should certainly provide for the scheduling of berm widening to achieve this goal and free the tracks for revenue traffic. Specialized truck designs would lower cost of transporting machinery and many of our present machines could be truck mounted. Properly equipped trucks for welders, grinders, painters, bolt tightening gangs and many other appropriate outfits would result in great savings.

6. Delivery of ties involves large amounts of hand labor and is a source of many accidents. Perhaps it is possible to palletize tie shipments, transfer by crane to a properly designed truck and deliver in position one at a time by some contrivance. There is no reason for present wasted labor. Similarly, disposal of ties released from track is usually a wasteful hand operation as well as a source of annoyance to every one concerned. This operation also should be mechanized.

Hundreds of Operations Need Correction

These are only examples of outstanding difficulties and possible cures. There are literally hundreds of such operations needing correction. Many of them can be corrected by existing machinery properly applied, but someone must make the effort to find these weaknesses and devise a mechanized approach. Suggestions from field supervision should be encouraged and freed from all possible red tape. Many of us lose touch with field problems and become engrossed with daily difficulties, but we must avoid mental lethargy and be ever alert for improvements. This is our job as maintenance engineers and the results depend on our resourcefulness.

The equipment manufacturers deserve high praise for their research and products, but they cannot do all the creative work. We are closer to the problem and after we find the operation to be improved and line up possible solutions, I am sure that they will cooperate in development and manufacture. They always have, and I am sure they always will.

Developments in other industries should be closely followed by the maintenance engineer. Many improvements in other fields can be adapted to railroad use with a little ingenuity, and considerable research can be saved by watching the man who builds the better mousetrap. As an example, we can learn much about low cost earth moving and grading from the contractor and mining engineer, who specialize in this work and have devised many cost-saving methods well worth investigation. Similar parallels are to be found in many fields, but we must be sufficiently alert to follow them and use imagination to apply them.

I can hear the representatives of smaller railroads saying, "All that is fine but where can we get the money to buy these machines or find the time to investigate and develop them?"

Naturally, conditions vary greatly among railroads, but it is certain that ingenuity is not confined to any one group. Along this line, perhaps joint ownership of machinery can be worked out by two or three roads, or railway contractors can be interested in purchasing these machines for rental. There are many possible approaches to the problem and it can be solved.

This Association must pioneer in development. Its committees must be more creative minded and not confine themselves to a rehash of previous happenings. Many of these problems are naturally common to all roads and should be worked out by cooperation in committee. Cost research studies and improvement developments should be correlated by committees for the benefit of all and by mutual contribution.

Above all, this is no time for complacency or resting on our past record. The difficulties ahead of us are grave but not insurmountable. We must approach them with open mind, confidence and resolution to achieve our goal.

Vice-President Sitton: Thank you, Mr. Hursh.

Mr. Hursh has given us a lot of food for thought. One thought that impressed me is that we cannot get far toward accomplishing the desired results without a lot of work on our part. We cannot assume that we need a certain machine and ask for it and get it. We have to prove that we need it and that we can save money by buying it. We have to prove that we need this machine worse than some others.

Mr. T. A. Blair, chief engineer of the Santa Fe System, will now discuss our problems from the standpoint of roadbed stabilization. Mr. Blair.

Economies To Be Realized from Roadbed Stabilization

By T. A. Blair

Chief Engineer System, Atchison, Topeka and Santa Fe Railway

One of the fields that merits investigation by the maintenance engineer is the operating saving that can result from investigation and application of stabilization of roadbed to cure soft track.

Heavier rail, improved and greater depth of ballast, and longer ties give a better distribution of loads and minimize the effect of soft track, but the only sure cure is stabilization of roadbed.

This year's report by Committee 1 on roadbed stabilization establishes the economy of grouting. Seventeen roads have reported their costs of stabilization, together with maintenance savings in spotting track, on projects from one to ten years old. There are 35 projects for which this full information has been reported. I have eliminated one project that would require 93 years to repay the cost of installation. Considering the 34 remaining projects, the cost of installation is returned through maintenance savings, in an average of 3.6 years. The repayment period for these 34 projects varies from a maximum of 14 years to a minimum of 4 months. Six of these projects reported by the New York Central give this return in 1.1 years; 8 of the 34 projects pay back in less than 1 year; 18 pay back in 2 years or less.

Because of my familiarity with the Santa Fe stabilization program, I quote from the statements regarding that property appearing in the report of Committee 1. For the nine projects reported, the cost of stabilization is paid back through savings in section labor, spotting track, in an average of 3.5 years, as compared with the average for the 34 projects on the 17 railroads of 3.6 years. A survey of soft track on the Santa Fe indicates that for 7600 miles of ballasted, high speed main track, 900 miles or approximately 12 percent of the total, may be classed as soft track requiring more than normal maintenance. A total of 570 miles of this track have already been grouted.

In addition to the direct section labor savings resulting from stabilization, there are other savings difficult to assess, such as elimination of temporary slow orders, and in some cases permanent slow orders, extension of rail and tie life, savings in ballast, and increase of the period between out-of-face resurfacings. Where all track requiring excess maintenance due to soft subgrade is grouted, as is being done on the Santa Fe, it is my conviction that operating savings, including all of the above features, pay for the stabilization in two years' time. If only squeezes and critical soft spots are treated, the payment period is much shorter. I have quoted these figures because I believe that an investigation by the individual railroads will prove that not only should "squeezy" track be stabilized, but that it is worth while to stabilize any soft track where there is excess maintenance.

Although this year's report by Committee 1 gives statistics for grouting, I have purposedly used the term stabilization. Stabilization can be accomplished in several ways, the more usual of which are subdrainage, pole driving, forming sand piles, grouting, the replacement of the subgrade material and the construction of supporting .berms for embankment. My experience indicates that for certain projects success can be expected by the use of only one of these methods but, in general, it may be expected with two or more of these methods—and the engineer's problem is to determine the one that will accomplish the result at least cost. My own conclusion is that for our own territory and for our particular method of grouting, that grouting is most economical for curing soft track due to water pockets. I have no doubt that as more history is made with sand piles, they will prove most economical for certain conditions. We have one test section of grout in a low fill across swamp land where the soil below the grout is saturated and plastic, and the results to date cause us to believe that for such a location, pole driving will result in economy. Our experience leads us to believe that, in cuts where there is an excess of ground water, this water must be disposed of through drainage.

Sliding fills are being stabilized by all of the above-mentioned methods. Any solution to this problem is expensive and I have not seen enough history made to draw any definite conclusions.

The construction engineer's work is now largely confined to line changes, but even here he should apply the principles of soil mechanics. There have been numerous instances in recent years where line changes have been made in plastic clay territory and where the subgrade has been properly compacted and yet water pockets and soft track developed within a few months after the line was placed in operation. In some cases the new line has had to be "slow-ordered" for a year or more until stabilized, and, in some cases, to lower speeds than on the old line that had heavier curvature. By classifying soils as to type, in borrow pits, the engineer can often specify suitable borrow mixtures to give a stable embankment. Where this is not feasible, sand and gravel can be hauled in and mixed with the top layers of the embankment and for subgrade in cuts, to give a mechanically stable mixture. To do this it is necessary for the construction engineer and inspectors to educate themselves in soil mechanics and to acquaint themselves with the procedure followed by some of the state highway departments in securing a mechanically stable mixture.

Vice-President Sitton: Mr. Blair has also given us a lot of food for thought. Sometimes one method of roadbed stabilization might be superior to another, depending on conditions. One of our problems is to find out what will work best under the conditions we have.

On our railroad we have had some experience in grouting, some experience in sand blasting, some in sand piles. We still do not know which is best.

At the present time we are inclined to believe that, in most of our conditions, if we can get sand into our roadbed we have solved our problem. We got that idea from the Santa Fe. We read about their grouting and got the idea that they were not trying to put real grout into their roadbed but they were using cement and sometimes asphalt as a lubricating agent for the sand that they really wanted to get in there. We did not have any sand like that, so we started just using sand by itself, and we have been successful. That may work somewhere else, I don't know.

A. A. Miller (Missouri Pacific): Mr. Blair did touch on roadbed construction, but our difficulties today in maintenance come from the lack of proper methods in the days of construction.

At the turn of the century, I think you will find in the records made at that time covering some experiments sponsored by the International Railway Congress that met in Switzerland, some statement like this: In the days of construction, the amount of ballast that should be used for the distributing material between the roadbed and the tie should be about a meter; in other words, say, 40 in. We are doing that on our railroad on some of our new work—and we have not had any slow orders on it and we do not expect to put any on.

I think we should use such ballast sections when we construct our railroads, and then I do not believe we are going to have much trouble in maintenance because of unstability. I remember that meter so well. At that time I was only a cub but I did assemble some material for the American delegate to that Congress. They made very elaborate tests, scale tests, as to what the depth should be to properly distribute the load on a new fill, but we have not used it.

Somebody said here this morning that we should be alert. Definitely, I think that is one of the things that might be a committee subject for a new committee of the AREA, to be alert to things that ought to be done from time to time. But I can say to your positively that what they developed then is usable now from the viewpoint of construction where, particularly, the higher fills are involved, and we wait for seasoning and settlement, and what-not.

If we get a proper distribution of the load, with materials other than dirt under the tie, I do not think we would have these unstable roadbed conditions to take care of by the maintenance forces at enormous cost.

I wanted to add that, Mr. Blair, because I really think we ought to develop some construction ballast sections. Those that we have are for maintenance, after our railroad has been in use for a long period of time. I think we could do the railroad industry a lot of good by having some construction sections of ballast. (Applause)

Vice-President Sitton: Thank you, Mr. Miller. We are glad to get that information.

When we come to talking about ballast sections for construction, we must also consider what we are going to put the ballast on. If a fill is made out of sand, that is one thing. If it is made out of clay, that is another.

I heard recently—I believe Mr. Blair made a reference, it may be the same piece of railroad—where the roadbed had been compacted in thin layers, about 6 in., the track was sub-ballasted on 12 in. of stone screenings and later ballasted on 8 in. of stone, and, in six months, water pockets developed. So, there is something more to be done.

We thought, when we were following the method of building roadbed in layers and compacting each layer thoroughly with a sheepfoot roller, we were solving that problem, but there is a recent instance—I do not know where it was, Mr. Rockwell Smith told me about it—in which a lot of water pockets developed in the particular piece of track. He did say that, where they had the water pockets, the roadbed material was fine clay. He said they had to use it because there wasn't anything else there.

If some sand could have been mixed with that clay by some means, it might have been too expensive, but we all know that water pockets are very expensive, and perhaps the sand would have solved the problem. We still have a long way to go in finding what to do in this connection.

Effect of Diesel Operation on the Fixed Properties of the American Railroads

By J. B. Akers

Chief Engineer, Southern Railway System

Diesel-electric locomotives have been in general use on American railroads for only a few years, but are found to have characteristics which make them especially adaptable to railway operation, both passenger and freight.

The diesel is a highly efficient prime mover, carrying a fuel supply adequate for long distance runs. It requires only a small quantity of water for cooling purposes on freight and switch power and just enough additional water on passenger type locomotives to supply steam for heating and air conditioning purposes on the passenger cars handled. This eliminates, to a great extent, the costly operation of supplying fuel and disposing of cinders in coal burning locomotive territories as well as the furnishing of large quantities of water in all steam operated areas. Idling and standby losses are low as compared with coal burning locomotives on which steam pressure must be maintained. It has a smooth flow of tremendous starting power which minimizes the usual starting shocks created by steam power and eliminates track pounding that results from out-of-balance wheels of steam power.

It is possible to operate diesels with multiple units connected, and subject to control from a cab at either end so that turning is unnecessary. Multiple units being articulated will take curves much better than the usual steam locomotive with its long rigid wheel-base. Multiple units are operated with a single crew, whereas multiple steam locomotives require an engine crew for each unit. With multiple units these locomotives will handle trains up to 140 or 150 cars depending on grade and track conditions. This hauling capacity calls for immediate extension of selected passing tracks and the provision for longer yard tracks on which to make up or receive such trains.

It is manifestly impossible for any railroad to make an immediate change over from steam to diesel power, or vice versa. The acquisition of diesel power is gradual and it becomes necessary for the railroad to provide for the transition gradually. Since the requirements for maintenance and operation of the two types of locomotives are so different, a problem immediately arises as to its accomplishment.

The history of the change over up to the present time indicates that the first diesels are used on long passenger runs and next on long freight runs. As the number of locomotives increases there comes on effort to dieselize by territories or areas. While this is in progress, diesel switch engines are taken on as they have a high degree of availability for service throughout the 24 hours of the day, and are not subject to the requirement for frequent servicing and taking on of coal and water.

The conventional roundhouse, due to its peculiar type of construction, does not ordinarily lend itself to conversion for the maintenance of diesel locomotives, except possibly where the diesels are limited to switchers or single units. Generally the roundhouse stalls are not long enough to accommodate more than one diesel unit. In some cases the roundhouse is being extended by moving the back wall, but in that case a capacity of two units per stall is a practical limit. The working pits and drop pits in the roundhouse are inadequate as to depth and general arrangement.

A serious objection to the use of a converted roundhouse is that its only means of ingress and egress is by way of the turntable. Uncoupling of diesel units would be frequently necessary and this results in costly delays.

The machine tolerances in diesel maintenance are much closer than are required for steam locomotives. Therefore scrupulous cleanliness must be observed so that dirt and dust are kept out. This requirement alone may call for extensive alterations of the roundhouse before it can be successfully used for mixed maintenance of the two types of power. Protection from fire becomes an important consideration.

Notwithstanding the difficulty of converting the roundhouse for diesel maintenance, it is sometimes found to be a necessity. Economy may dictate it. The answer is found only by a careful analysis of the construction cost and the probable operating costs. If a great many locomotives, including both steam and diesel, are to be maintained at a given point adequate provision must be provided for both, and a determination can only be made after detailed study.

Essential Characteristics

Where a great many diesels are maintained, the pits should be approximately 4 ft. 6 in. deep; the working floor usually 2 ft. 9 in. to 3 ft. below top of rail on running repair tracks; and at the same time level with top of rail on heavy repair tracks. A drop table should be provided to enable the dropping of either the entire truck, or a single pair of wheels and traction motor. A working platform at deck level should be provided at a height of about 4 ft. 7 in. above top of rail on pits. A track must be provided either with or without a pit on which released wheels or trucks are placed for repair work. An overhead crane of 30 tons capacity is required for handling a complete truck, a diesel engine or other heavy parts.

The installation just described must be sufficiently extensive to handle repairs on the number of diesels anticipated, and with space provided for extension or enlargement. Suitable working space is required for cleaning filters and the necessary fuel oil and lubricating oil supplies.

For smaller operations a transfer table can be used to remove trucks laterally after the frame has been elevated with large synchronized jacks. Working pits as described are necessary, with jacking blocks properly placed, a track for storage of wheels and trucks and an overhead crane of approximately 10 tons capacity.

At locations where only a few pairs of wheels must be changed per month, the working pits I have described can be eliminated. Four high-lift jacks are used to lift the entire diesel locomotive so that the trucks may be rolled out at the end. A small work pit of suitable length should be provided with jacking blocks and an overhead crane of about ten tons capacity for the removal of wheels.

A shop for heavy repair work should include work room or space for reconditioning of parts, a well ventilated room for filter cleaning, space for battery overhaul, radiator core cleaning, wash and locker rooms and office space. Such facilities should be kept scrupulously clean and that is another reason for separating the maintenance facilities for steam and for diesel locomotives.

Adequate capacity is required for fuel oil and other kinds of oil. A wash track on concrete foundation is very desirable. Special sanding facilities are necessary, and it is customary to place more than one outlet on each side of each track on which diesels are serviced. Cooling water for diesels should be treated. Water for steam generators on passenger diesels must be given special attention, and some railroads have installed demineralizing plants.

If standby steam power has to be held for operation in emergencies, those locomoties must comply with all government regulations as to periodical inspection and for testing of stay bolts, flue changes and matters of that character. It seems obvious that the trend is to dieselize by territories or areas simply to obviate the provision of facilities for repair and maintenance of both types of power. When an area is converted to diesel operation, all the steam facilities can be eliminated, including coaling facilities and wayside watering facilities. Substantial economies result from this alone. In a dieselized territory, it is usually found that some passing tracks must be lengthened, and others can be removed entirely because of the lesser number of trains operated. What is done in this respect must be carefully studied with relation to grades, important cities and terminals. If longer trains are operated signals must be spaced at greater intervals.

Effect on Tracks and Bridges

In the effect on track and bridge structures there are many advantages in the diesel, and at the same time some things which seem now to be disadvantages. The speed of diesel trains, either passenger or freight, in many cases is greater than with steam power. Diesel electric drive is of the rotary type, whereas conventional steam is of reciprocating type and this alone has a definite effect in rail bending stresses, and surely minimizes what we know as track pounding.

Most diesel locomotives have a wheel load approximately 29,000 to 31,000 lb. as compared with 37,500 lb. maximum for steam locomotives, plus dynamic augment. In considering contact pressures and internal bearing stresses in the rail head we know that they are a function of the diameter of the wheel as well as of the load itself. Even with the dynamic augment on steam locomotive drivers in addition to their heavier wheel load, the internal bearing stresses in the rail head are well below those for diesel locomotives which have relatively small wheel diameter. High contact pressures and high internal bearing stresses are expected to influence rail end batter, flow of metal on curves, and aggravate the development of transverse fractures within the rail head. It seems therefore that diesels may not effect an improvement in these respects. The increased speed of diesel operation may modify the effects produced on track by the wheels of the cars in the train. It may even be that the over-all effect will be less favorable than with our present modern, heavy steam locomotives, properly counterbalanced.

The lighter wheel loading of diesels would itself have a favorable influence on rail bending stresses, but apparently most of this advantage is lost due to the wheel spacing. Steam locomotive wheels are spaced relatively close together which fact tends to reduce the bending stresses under adjoining wheels. The net result seems to be that bending stresses in rail under diesels are not much less than for a modern steam locomotive properly counterbalanced.

Measurements recently made on 132-lb. rail show that the range of stresses in the upper web and fillets is only about half as great under the diesel as they are with modern heavy steam locomotives on tangent track. This is a definite advantage. Measurements made on the inner and outer rail on a 10-deg. curve indicate even further reductions of extreme localized stresses under diesels.

No measurements have been made as yet of the comparative lateral forces exerted on tangent track by diesel and steam locomotives. Measurements have been made of the comparative lateral forces exerted on a 10 degree curve. These lateral forces under long wheel-base steam locomotives are severe, but they are found to be much less under diesel locomotives. The effect as regards lateral forces on curves is found by measurement to be very pronounced indeed, and that seems borne out by observation. These lateral forces are at the root of much of our trouble in maintaining gage and alinement, and in the tie plate cutting of cross ties. It will bear on the general subject of eccentricity of tie plates.

Lessening of Wear and Tear Not Too Pronounced

It seems true that track damage, or what we know as wear and tear resulting from use, is primarily a result of gross tons of traffic moved over the track, and that the proportion of this so-called track damage that may result from the character of locomotives used may be confined to 10 percent or less of the total. We speak of the pounding of track from steam power, but our observation is that more damage is often done to rail and track by flat wheels or out-of-round wheels than by well maintained and properly counterbalanced steam locomotives. For instance, tests have shown that a 4-in. flat spot on a coal car wheel increases rail stress 150 percent, or to 2½ times normal stress (AREA Proceedings, Vol. 42, 1941, page 754). This is mentioned merely to show that we may not expect too pronounced a lessening of wear and tear in the track structure as a result of operation of diesels. We still have the gross weight of the train and of all the traffic, and the locomotive itself is only a small portion of it. At the same time, I do not minimize the advantage to track maintenance under diesel operation.

The relative effect of diesel and steam locomotives on railway bridges is pronounced and clearly to our advantage as long as the weights are approximately what we have at present. While the total weight of the 4-unit diesel and the heaviest steam locomotive is about the same, the load per foot of the diesel is only 56 percent of that for the steam. The axle load of the diesel is 82 percent of the axle load of the steam locomotive. The net result is that in general, the Cooper equivalent of the diesel locomotive on spans 50 ft. to 200 ft. or longer varies from 44 percent to 63 percent of that of the steam locomotive. For spans as short as 10 ft., the Cooper equivalent of the diesel is 82 percent of that of the steam locomotive.

Impacts under diesel locomotives recorded in spans varying from 30 ft. to 110 ft. in length range from 53 percent to 74 percent of the impacts under steam locomotives and this is recognized in the reports of Committee 15. Traction stresses in the longer spans will be higher for diesels than for steam locomotives, and this effect must be carefully considered. This is particularly true for the older and longer spans and high viaducts. It is seen that stresses in railway bridges under diesel operation (except for traction stresses, and bridges of very short span length) are in general only about 60 percent as large as those produced by steam locomotives.

I am indebted to Mr. Magee and his research group for the information I have used regarding stresses in track and bridges. They will, of course, report further findings as their work progresses. We must keep in mind that the figures used are based on present designs. We can speculate on changes that may be made as the diesel is developed. It could easily be that we will have heavier wheel loads and longer wheel-base engines. If that occurs, it may be that some of these things that we view now as advantages may be lost.

The railroads have enormous capital investments in shop facilities and locomotives, and it is seen that the transition from steam to diesel power will hasten the ultimate retirement of property. As extraordinary obsolescence occurs there is a charge-off of unusual magnitude. The members of Committee 11 have done excellent work in the application of actuarial methods to service life studies, and they know better than most of us how difficult it is to make proper allowance for extraordinary obsolescence. The abandonment of shop facilities does not dispose of the financial and accounting difficulty which then faces us. The values are still reported in the inventory and accounts. A portion of the service loss may be recovered under a procedure permitted by the Bureau of Internal Revenue in the case of extraordinary obsolescence. Accelerated amortization is allowed and is covered by Bulletin "F" issued by the U. S. Treasury Department, Bureau of Internal Revenue, revised January 1942. A careful study of this bulletin is recommended.

This subject as a whole is new to us. What I have said should be viewed more or less as a progress report.

The operation of diesels has resulted in outstanding efficiency and economy, and their use must grow until something better is found. Our research group will doubtless have much more to say as to their effect on fixed property. I do not mean to detract from their importance.

President Mottier: Thank you very much. I am sure we all wish to thank Mr. Akers for his interesting and very able presentation of this subject. I do not wish to put him on the spot, but if any of you would like to ask him a question or say something, you can do so.

Mr. Akers: Bear in mind, the president intimates that I know something about the subject, which I do not. (Laughter) It is brand new, as I say.

President Mottier: What I am interested in relates to the argument our managements will have for reducing our allowance for maintenance, when we all start to using diesel engines.

Mr. Akers: I did not touch on that much, but I did touch on the obsolescence, which I think is a subject to which we as a group must pay very much more attention for the benefit of our own managements. We have these enormous capital investments, and someone—I don't know who shall do it other than the engineering department—must find a means to recover some of that capital investment, if possible to do so. It is possible through the tax procedure described generally in which the depreciated values are permitted to be charged off to operating expense accounts. Then the prevailing tax rate applies.

This, gentlemen, is something from which the railroads can get substantial help. It is a big thing. We have one case where an entire roundhouse and shop layout were wiped off the map, although built only about 22 years ago. If we do not find some way of getting back some of the money invested, a big financial burden results. We owe it to our managements to work it out.

President Mottier: Thank you very much, Mr. Akers.

This is a problem which many of us are facing. It is very interesting. One thing that bothers us is the effect that the future operation of diesels should have on what we do with our facilities now. If we have an old coal chute ripe for replacement—using that as an illustration—should we nurse it along and make heavy charges to maintenance and let Uncle Sam help pay the bill, or should we replace it and make a heavy charge to A and B? That is a problem we all face.

I might mention several other problems but will only refer to one. From our point of view the ideal program of dieselization would be to pick out a particular operating district and then overnight replace all the steam power with diesel power. You would then save the maintenance of all the fixed property that is required for steam operation but, unfortunately, that procedure is not usually followed because diesels cost so much money that they must be operated where they will produce the greatest operating economy.

Historical Exhibit

Of all the plans conceived for the purpose of recognizing the historical significance of the Association's 50th anniversary during the course of the convention, none involved more painstaking effort and none proved more outstanding in its results than that for an historical exhibit. Many ideas were advanced for implementing this idea, including the display of actual physical elements of the fixed properties of the railroads, but as the plan was eventually evolved, it took the form of a pictorial display—largely photographs, but including also charts, diagrams and line drawings, and in each case the fundamental idea was the same, that of depicting the condition "then and now."

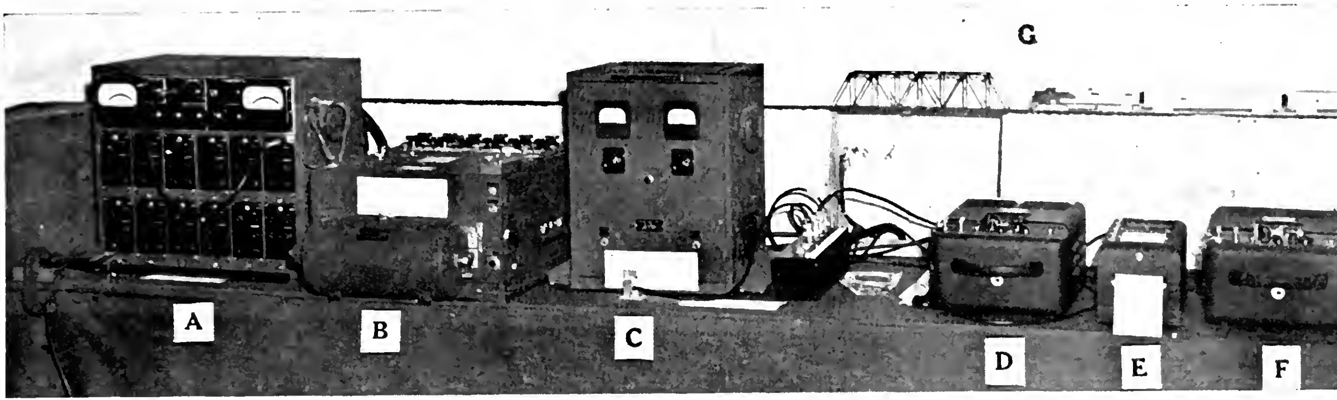
The various pictures were grouped in panels 4 ft. by 4 ft., mounted on easels, separate panels or groups of panels being assigned to individual subjects roughly approximating the scope of responsibility of the various committees, as indicated in the table. The panels were set up in the aisles to the east and west of the foyer on the fourth floor of the Palmer House as well as in the east and west public corridor. The pictorial material used in the exhibit was obtained through the AREA committees and the company members of the National Railway Appliances Association. However, the success of the exhibit must be ascribed almost entirely to the initiative, persistance, and untiring efforts of J. de N. Macomb, who served as the representative of President Mottier, and G. E. Johnson, advertising manager of the P & M Company, who served as the representative of President M. K. Ruppert of the NRRA.

The re-photographing and mounting of the material for the exhibit was done at the expense of the NRAA which has retained the panels with the thought that other opportunities for displaying them will be presented.

This main exhibit was augmented by several supplementary features, including two panels embracing photographs of all of the past presidents of the AREA, a model of the laboratory now under construction for the Association of American Railroads on the campus of the Illinois Technological Institute and an exhibit of stress and vibration measuring equipment used by the research staff of the Engineering Division, AAR.

List of Pictorial Panels in Historical Exhibit

1.	Grading	21.	Lubrication
2 & 3.	Ballasting	22.	Stabilization
4.	Cross Ties	23.	Snow removal
5.	Rail sections	24.	Weed control
6.	Rail design	25 & 26.	Bridges
7.	Rail manufacture	27 & 28.	Bridges and stresses
8 & 9.	Rail ends	29.	Highways
10 & 11.	Transverse fissures	30 & 31.	Buildings
12.	Rail joints	32.	Fuel service
13.	Joint bar design	33 & 34.	Water service
14.	Tie plates	35.	Waterproofing
15.	Track accessories	36 & 37.	Wood preservation
16.	Anchoring track	38, 39 & 40.	Work equipment
17.	Special track work	41 & 42.	Motor cars
18.	Yards	43 & 44.	Economics of railway location
19 & 20.	Laying rail	45 & 46.	Records and accounts



RESEARCH STAFF EQUIPMENT EXHIBIT FOR FIFTIETH ANNIVERSARY MEETING OF THE AMERICAN RAILWAY ENGINEERING ASSOCIATION

A—Twelve-Channel Amplifier Unit—Carrier-Wave Type.

B—Twelve-Channel Magnetic Oscillograph for Recording Dynamic Stresses and Vibrations.

C—Power Supply for Twelve-Channel Amplifier Units.

D and F—Two-Carrier Wave Type Amplifiers for Pen Writing Magnetic Oscillograph.

E—Two-Channel Magnetic Pen Writing Oscillograph for Recording Moderate-Frequency Dynamic Stresses and Vibrations.

G—Model Train on Railroad and Bridge. Wire Resistance Strain Gages Were Applied to the Rail and Bridge and the Stresses Were Indicated on the Oscillographs as the Train Ran Back and Forth Automatically.

MEMOIRS

MEMOIR

John Robert William Ambrose

Died June 29, 1948

John Robert William Ambrose, son of Mortimer C. and Lidia (Bushell) Ambrose was born in Watertown, Wis., on June 13, 1878, and died at his home in Toronto, Ont. on June 29, 1948.

He was educated at Berlin (Wis.) high school, Ripon college and the University of Minnesota, graduating with a degree in mining engineering. In February 1906 he married Alphield Nyborg, who died in October 1947. A daughter, Mrs. K. A. B. Degen, a son, H. G. B. Ambrose, and two grandchildren survive him.

In 1898 Mr. Ambrose became engineer for the electric light plant at Berlin, Wis., and in 1900 entered railway service as assistant engineer in charge of field engineering and maintenance work for the Minneapolis & St. Louis Railroad. In 1904 he became bridge inspector on the Minneapolis, St. Paul & Sault Ste. Marie Railway, and in 1905 was promoted to resident engineer on construction on the same railway. In 1906 he returned to the Minneapolis & St. Louis as resident engineer on construction and in 1907 became assistant engineer, special work, on the Grand Trunk Railway of Canada.

In 1910 he became engineer of grade separation for the Grand Trunk, and in this position was in charge of extensive highway–railway grade crossing elimination work in and beyond the west end of the City of Toronto, Ont. In 1914 he was appointed chief engineer of the Toronto Terminals Railway, in which position he was in charge of highway–railway grade crossing elimination along the Toronto waterfront and the completion and placing in service of the Toronto union station building, trackage and train shed. He was appointed superintendent of the Toronto Terminals Railway in 1935, which position he held until his retirement from active railway work in June 1944.

Mr. Ambrose became a member of the American Railway Engineering Association in 1908 and a life member in 1943. He was so greatly interested in the Association that throughout most of his professional career he contributed both time and effort to its basic work. From 1910 to 1923 he was a member, and from 1920 to 1922 chairman, of Committee 1—Roadway. From 1923 to 1946 he was a member, and from 1924 to 1927 chairman, of Committee 14—Yards and Terminals. From 1920 to 1946 he was a member, and from 1920 to 1937 vice-chairman, of Committee 26—Standardization. From 1925 to 1927 he was a member of the Special Committee on Clearances. He was appointed chairman of the Committee on Convention Arrangements when that committee was first organized as a continuing committee in 1925, and was a member of the committee for many years. He served on the Board of Direction of the Association from 1923 to 1926.

He had been a member of the Signal Section of the Association of American Railroads, and of the American Standards Association, and was a life member of the Engineering Institute of Canada, a member of the Canadian Institute of Mining and Metallurgy and a member of the Association of Professional Engineers of Ontario. He was a member of the Toronto Transportation Club and of the Toronto Railway Club, and served as president of the latter in 1935. He was a fellow of the Royal Society of Arts, a member of the Toronto Board of Trade, a member of the Canadian Club and a member and past secretary of the Ontario Club. He was a member of the Lambton Club, of the Boulevard Club, of the Toronto Anglers Association, of the Royal Canadian Yacht Club, and a member and past vice-commodore of the Parkdale Canoe Club. He was a member of the Delta Upsilon fraternity.

Prior to his retirement in 1944, Mr. Ambrose was active in both the professional and social spheres of life. After retirement he did not lose interest in professional matters but placed more emphasis on his social contacts until stricken by failing health some 18 months prior to his death. In both spheres and in the American Railway Engineering Association he has a host of friends who will long cherish their memory of him.

JOHN E. ARMSTRONG, *Chairman*,
J. DE N. MACOMB
R. T. SCHOLES
Committee on Memoir.

MEMOIR

Clarence Richard Knowles

Died August 5, 1948

Clarence Richard Knowles was born at La Porte, Ind., July 7, 1879, the son of Michael and Mary (Inman) Knowles. On June 5, 1919, he married Ella J. Nelson. A daughter, Katherine Helen, survives. His early boyhood was spent in western Kentucky and there he attended Farrill's School for Boys at Hopkinsville, graduating from high school in 1897. Later he took special courses in civil engineering from private and correspondence schools. During summer vacations or other spare time, he worked in machine shops and foundries, obtaining experience which later was invaluable in his water service and mechanical work. He studied a great deal by himself, was a wide reader and a keen observer and these traits, combined with his active mind and unbounded energy, gave him a broad self-education.

Clarence Richard Knowles

Mr. Knowles entered railway service in 1900 as a water service repairman on the Kentucky division of the Illinois Central. In 1902 he was promoted to division water service foreman, and thereafter his duties were gradually increased until 1912, when he became superintendent of water service for the entire Illinois Central System, serving in that capacity until April 30, 1942, when ill health compelled his retirement from active service. In 1930, his duties were extended to include supervision of work equipment

In addition to his regular assignments, he handled special work for the chief engineer at various times, and from 1927 to 1930 he participated in the Mississippi river flood control investigations, particularly in the district served by the Illinois Central. As a result of his efforts during these serious floods, the data collected were of great value to the railroad and that particular section of the country. Undoubtedly, the information showing monetary losses resulting from the periodical innudation of the area had much to do with the formation of definite plans for control projects that have been of lasting benefit.

Mr. Knowles became a member of the American Railway Engineering Association in 1915, at which time with his characteristic enthusiasm he became an ardent worker on the Committee on Water Service and Sanitation, serving as chairman from 1923 to 1930. He was also chairman of the committee on Maintenance of Way Work Equipment from 1930 to 1937, a member of the AREA Convention Arrangements committee for many years, and a director of the Association from 1930 to 1933. He joined the American Railway Bridge and Building Association in 1912 and gave much time and energy to promoting its welfare. He was president in 1921–1922 and treasurer from 1942 until his death.

He was a member of the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the American Water Works Association. In the latter, he was chairman of its Illinois Section in 1928–1929, and served as a national director in 1930–1933. He was also a member of the Western Society of Engineers, the Maintenance of Way Club of Chicago, and the Indiana Society of Chicago.

Clarence Knowles was one of the pioneers in the conditioning of water for locomotive boilers and was widely known as a leader in this sphere. While this was always his major interest, his attention was not limited to this field; his work in charge of power tools and equipment and his pioneering in this phase of railroading at a time when it was relatively new and not well organized, was outstanding. With characteristic zeal and a knowledge gained in his early training in mechanical matters, he not only organized the department on his own railway but wrote prolifically for engineering magazines on details of what was then a new field. In any undertaking, he studied the problems with willingness and thoroughness and had the capacity to instill a like interest in his associates. His writing was constructive and absorbing. His genial personality will be missed at many a meeting or convention at which he always contributed to the advancement of railway engineering.

He was a 32nd degree Mason, member of Garden City Lodge No. 141, A.F.& A.M., Woodlawn Commandery K. T., and Medinah Temple, A.A.O.N.M.S., and he valued highly the inspiration he derived from these organizations.

E. M. Grime, *Chairman,*
G. R. Westcott
G. E. Martin
Committee on Memoir.

MEMOIR

Fred Lawrence Thompson

Died February 27, 1948

Fred Lawrence Thompson was born on February 1, 1872, on a farm near Grandview, Edgar County, Ill., the son of Edward Taylor and Mima J. (McDonald) Thompson. His boyhood days were spent on his father's farm. He attended preparatory school at DePauw University and in 1892 entered the College of Engineering at the University of Illinois, from which he was graduated on June 10, 1896, with the degree of Bachelor of Science in Civil Engineering.

True to his instincts of service, Fred Thompson learned railroading the hard way. Six days after graduation he entered the service of the Illinois Central Railroad in Chicago as a laborer in a gang working on track depression and grading between Randolph and Twelfth Streets. For his labor he received the then-current pay of 12½ cents

Fred Lawrence Thompson

per hour, or $1.25 a day for a 10-hour day. From his first day of employment until his retirement more than 45 years later, he worked continuously for the Illinois Central. From laborer he was soon advanced to earth inspector and then to chainman. His next advancement was to rodman on the removal of a tunnel south of Vicksburg, Miss., and the construction of a freight house in that city.

Next the rising young engineer was engaged in grade reduction between Fulton, Ky., and Memphis, Tenn. Then as his qualities of leadership were recognized he was placed in charge of grade reduction and second-track work from Cairo, Ill., to Fulton and of second-track work from Centralia, Ill., to Carbondale, Ill. He was in the chief engineer's office in Chicago for a year and then from 1903 to 1907 served as roadmaster on the Illinois and Kentucky divisions.

In 1907 Mr. Thompson was promoted to assistant engineer of bridges and buildings and in 1910 to engineer of bridges and buildings. In 1913 he became engineer of construction and the next year assistant chief engineer. In 1918 he became chief engineer, in 1925 vice-president in charge of Chicago terminal improvement and in 1931 vice-president in charge of engineering. In addition to his duties as vice-president, he again assumed the chief engineer's duties from May 1, 1938 until July 1, 1941. He retired on February 28, 1942, having reached the retirement age of 70.

Mr. Thompson served the Illinois Central through its greatest period of expansion as well as through some of its hardest trials. His was a leading part in many notable engineering projects, including the Chicago terminal improvement, involving the reconstruction of a large part of the terminal, track elevation, track depression, numerous grade separations and the electrification of the suburban service. It was also while he was head of the engineering department that the Illinois Central had to meet the exigencies of the great depression by conducting the severest retrenchment of its history. His working career closed in the midst of World War II which had revived activities on the railroad to another record-breaking peak. Throughout these fluctuating tides of expansion and contraction, Mr. Thompson displayed a notable capacity for calm and analytical leadership that inspired confidence and endeared him to his associates.

As an alumnus of the University of Illinois, Mr. Thompson always retained an active interest in its affairs and activities. He was especially alert to the needs of the University's sports and recreational affairs, having been a catcher on the university baseball teams of 1895 and 1896. In evidence of Mr. Thompson's influence as an alumnus of the university, and as an engineer, he was chosen a member of the committee of three that supervised the design and construction of the Memorial Stadium at Champaign. A feature of the first game played in that stadium was the award of the letter "I" to various former athletes among the alumni, including Mr. Thompson, who then obtained the award he earned in 1895 and 1896 before such letters were instituted.

As a further recognition of the services performed by Mr. Thompson in connection with the construction of the stadium, he became the holder of a gold life pass, entitling him to admission to all athletic contests of the University of Illinois. Only three such passes have been awarded by the athletic association of the university.

Mr. Thompson married Maude Nellie Martin of Terre Haute, Ind. on November 21, 1900. To them were born two daughters, Donna (Mrs. D. D. Wilson) and Ruth (Mrs. W. E. Dee, Jr.)

Mr. Thompson joined the American Railway Engineering Association (then the American Railway Engineering and Maintenance of Way Association) in 1909. He was a member of the Committees on Masonry, on Rail and on Economics of Railway Operation. He was chairman of the Committee on Masonry from 1916 to 1918. He served as a director in 1919, 1920 and 1921. He was also a member of the American Society of Civil Engineers, the Western Society of Engineers, the American Railway Bridge and Building Association, the Chicago Engineers Club and the South Shore Country Club of Chicago, serving the latter as president in 1939–1941. He was a trustee of the Woodlawn Methodist Church in Chicago.

Mr. Thompson was an outstanding engineer and a capable executive. His high integrity, keen sense of justice and unfailing sympathy endeared him to all his associates.

C. H. Mottier, *Chairman*,
G. J. Ray,
Albert Reichmann,
Committee on Memoir.

MEMOIR

Arthur Montzheimer

Died May 20, 1948

Arthur Montzheimer, a life member of the American Railway Engineering Association, passed away May 20, 1948, at the age of 79 years.

Mr. Montzheimer was born in Sharpsburg, Pa. He attended high school in Webster City, Iowa, and Dixon College of Civil Engineering in Dixon, Ill. In 1893 he married Julia McClellan Mosher of Racine, Wis. A son and two daughters were born of this marriage.

He was employed by the Chicago & North Western Railway from 1887 to 1903 as roadmaster's clerk, rodman, instrumentman, assistant engineer and superintendent of bridges and buildings. In 1903 he became chief engineer of the Elgin, Joliet & Eastern Railway and continued at that post until his retirement in 1938.

Mr. Montzheimer joined the AREA in 1905 and became a life member in 1940. He served on the Yards and Terminals committee from 1906 until 1931 when impairment of his health made it necessary for him to become inactive in the affairs of the Association. During his period of membership on the Yards and Terminals committee he was vice-chairman for two years and chairman for three years. He was also a member of the Committee on Standardization for three years. In 1927 he was elected to a three-year term as director of the Association and during that term he served for one year as chairman of the Finance committee.

Mr. Montzheimer also engaged in several other activities connected with the railway and engineering fields. He invented a railway mail crane device and a side clearance device for bridges. He was president of the American Railway Bridge and Building Association in 1903–1904. He served as a director of the Railway Signal Association and was a member of the American Society of Civil Engineers, the Western Society of Engineers, the American Wood-Preservers' Association and the Chicago Engineers' Club. His biography for a number of years was included in Who's Who in Engineering and Who's Who in Railroading.

Mr. Montzheimer interested himself in and participated in the religious, social and civic life of the community in which he resided.

Those persons whose good fortune it was to know Mr. Montzheimer will always treasure the memory of a cheerful, kindly, helpful man who always sought to perform well the tasks assigned to him.

F. E. Morrow, *Chairman,*
F. H. Masters,
F. G. Campbell,
Committee on Memoir.

Report of the Secretary

To the Members: March 1, 1949.

This report covers the affairs of the American Railway Engineering Association for the year ending March 17, 1949. However, because this year completes the Association's first half century and because President C. H. Mottier launched a plan designed to give full and appropriate recognition to this significant turning point, the year now coming to a close has been marked by a number of noteworthy records.

On February 1, 1949, the membership of the Association totaled 3008, the greatest number in its history, while the increase in the number of members during the year was the greatest in any 12-month period.

Both the receipts and the disbursements in the calendar year of 1948 were greater than in any previous year, while the balance on hand at the end of the year, $106,-205.53, has been exceeded only once. On December 31, 1945 the balance on hand amounted to $107,356.17.

The number of members on the rosters of the standing committees, effective as of the close of the annual meeting in March 17, 1949, will be 911, representing the greatest committee personnel on record.

The Association is now the beneficiary of the largest appropriation for research work of the Engineering Division ever to be provided as a result of the cooperative arrangement with the Association of American Railroads, $372,457 having been allotted for this purpose for the calendar year of 1949.

In addition, there is every assurance that the annual meeting which will mark the end of the Association's first 50 years will be by far the largest in point of attendance.

Constitution Amended

During the last year the members ratified amendments of the constitution. Amendments of Article II, clarifying the requirements for admission and making consulting engineers and their qualified engineering employees eligible for full membership, were approved by a vote of 803 to 30. Amendments of Articles V and VI, increasing the number of directors on the Board of Direction from 9 to 12 and reducing the number of past presidents thereon from 5 to 2, were approved by a vote of 822 to 14.

Finances

The financial statement for the calendar year of 1948, which appears in full on following pages, may be summarized as follows:

Receipts	$57,740.50
Disbursements	53,061.54
Excess of receipts over disbursements	$ 4,678.96

As will be observed in the table of receipts and disbursements over a 14-year period, both the receipts and the disbursements were greater than in any previous year, but because the receipts in 1948 included the entrance fees of a large number of new members and the expenditures embraced outlays incurred in preparation for the Golden Jubilee convention, both totals are abnormally high and nonrepetitive, except to the extent that both influences have been carried over into the present year.

For this reason the financial operations for 1948 can not serve as a valid test of the judgment of the Board of Direction in proposing an increase of $5 in the membership dues as the means of overcoming the Association's financial difficulties. It will probably be necessary to withhold judgment in this matter until the end of 1950 to get a measure of the results in what might be termed a "normal" Association year. Except for the semicentennial activities, the disbursements covered substantially normal operations. The expenditures for the Manual necessarily vary rather widely from year to year. During 1948 the outlay was somewhat above the average because of the need for replenishing the stocks of printing paper and binders.

Comparison of Receipts and Disbursements for a 14-Year Period

	Receipts	*Disbursements*	*Net Gain*
1935	$29,001	$30,110	$1,109*
1936	28,643	34,662	6,019*
1937	36,523	32,200	4,323
1938	28,422	23,394	5,028
1939	28,189	23,847	4,342
1940	28,272	26,451	1,821
1941	32,433	29,384	3,049
1942	31,500	26,692	4,808
1943	28,736	23,809	4,927
1944	30,492	26,534	3,958
1945	32,305	29,305	3,000
1946	28,836	34,583	5,747*
1947	46,993	46,989	4
1948	57,741	53,062	4,679

* Deficits.

Membership

The membership record for the period from February 1, 1948 to February 1, 1949 was as follows:

Members on rolls February 1, 1948			2334
New Members (including 91 applications in process)			852
Reinstatements			27
			3213
Deceased	38		
Resigned	52		
Dropped	102		
Juniors transferred or dropped	13		205
			3008
Net gain		674	
Membership as of February 1, 1949			3008

The total membership on February 1, 1949, was the largest in the history of the Association and is to be compared with 2856 for March 1, 1929, the highest previous total. It also represents a progressive increase from 1880 members on March 1, 1940, the lowest level of membership in any recent year. However, as shown by the statement above, the present total of 3008 is to be accounted for primarily by the increase that was effected during the last year as the result of the well organized efforts of the Committee on Membership Development of which Vice-President F. S. Schwinn was chairman. Through the efforts of his committee and of the engineering officers who were asked to recruit applicants on the individual railroads, the number of applications filed with the secretary during the 12 months ending with February 1, 1949, exceed the experience of any previous year by a wide margin. The record in detail is as follows.

APPLICATIONS FOR MEMBERSHIP, FEBRUARY 1, 1948 TO FEBRUARY 1, 1949

	Juniors	*Others*	*Total*
February–May, incl.	4	101	105
June	5	83	88
July	37	182	219
August	23	112	135
September	13	63	76
October	12	61	73
November	4	28	32
December	4	20	24
January	11	39	50
	113	689	802

As could be expected, the receipt of applications for membership in such numbers seriously disrupted the routine of the secretary's office, since the processing of each application calls for at least a score of separate and distinct clerical operations, including a minimum of six letters. It was only because of the adoption of an abridged form for the presentation of the qualifications of the candidates to the Board of Direction and the institution of other short cuts suggested by members of the staff that it was possible to keep up with the job.

The aggregate membership of the Association as of February 1, 1949, was adversely affected by the shrinkage resulting from the action of the Board of Direction on November 16, 1948, in requiring that all members who had not paid their 1948 dues, or who had not asked for an extension of time in which to pay them, be removed from the rolls at the end of the year, rather than on April 1 of the following year, as has been the practice heretofore.

The classification of the membership as of February 1, 1949, compared with the corresponding dates in four previous years is shown below. This illustrates the effect of the amendment of Article II of the constitution, in requiring the reclassification of consulting engineers and their qualified engineering employees. It resulted in a definite decrease in the number of members classified as Associates.

One of the heartening by-products of the membership drive, as disclosed by this table is the increase in the number of Junior members. The current total of 145 compares with a previous high of 38, and places this group in a category that demands specific attention.

	1945	*1946*	*1947*	*1948*	*1949*
Life	197	246	277	294	325
Member	1515	1564	1618	1686	2263
Associate	259	262	287	317	275
Junior	33	35	34	37	145
	2004	2107	2216	2334	3008

Deaths during the year ending February 1, 1949 totaled 38, as listed in the roll of deceased members appearing at the end of this report. Among these were four former members of the Board of Direction, J. R. W. Ambrose, C. R. Knowles, Arthur Montzheimer and F. L. Thompson. Special mention is warranted also of H. A. Cassil, a former committee chairman, G. E. Boyd and J. M. Farrin, who gave unselfishly of their time and talents to the work of committees for many years, and C. Frank Allen, a pioneer member, the mark of whose influence on the work of the Committee on Uniform General Contract Forms remains to this day.

Publications

The seven bulletins ending with Bulletin 479 for February 1949 contained a total of 890 text pages, compared with 848 pages in the seven preceding bulletins and with 1014 pages two years ago. Vol. 49 of the Proceedings issued during the summer of 1948, contained 866 pages, or 174 pages less than in Vol. 48, but 80 pages more than in Vol. 47.

The volume of the committee reports for the past year, including reports on research work carried on in the interest of specific assignments, totaled 694 pages, compared with 656 pages a year ago and 818 pages two years ago. As in previous years, the February bulletin is still the largest. Containing the reports of the committees on Roadway and Ballast, on Rail and on Track, this bulletin always includes a considerable volume of data accumulated during the year in the research work done for these committees. Although the Board has requested that so far as possible, the results of research work be covered in reports published in the summer bulletins, only limited progress has been made to this end.

Contents of Bulletin 474, June–July 1948

Design of Tie Plates—Advance report on Assignment 6 of Committee 5—Track
Tie Renewal Statistics—Advance report of Committee 3—Ties
Butt Welded Rail in Australia—a monograph

Contents of Bulletin 475, September–October 1948

Eight Reports on Impact Tests—Presenting data on tower columns and bracing, pile and frame trestles, ballasted and open-deck floors, longitudinal forces, lateral bracing and concrete bridge piers.
Cathodic Protection of Buried Metalic Structures Against Corrosion

The Manual

The Manual supplement for 1948 called for the insertion of 135 new sheets and the withdrawal of 132, or a net gain of 3 sheets. Expenditures for other Manual needs during the year covered the purchase of paper and a new stock of binders. No extraordinary disbursements on account of the Manual are anticipated during 1949, and with the leveling off of the demand for the Manual or parts thereof, no reprinting should be necessary for several years. However, there is evidence of a growing need for the re-arrangement of the material in the individual chapters, which if carried out will result in a rather pronounced increase in the size and cost of the supplements in the years in which these drastic changes are made.

Under the paging system to which the AREA Manual is committed, new material is presumed to be added only at the end of the chapter, in other words, in chronological order. To introduce new matter according to the dictates of some topical plan or according to a "Complete Outline Of Work," entails resort to the use of decimal fraction paging. Both plans are objectionable, and what is more unfortunate—rearrangement and reprinting serve only as temporary expedients, since they do not correct the basic fault. One means of correction, adopted when Chapter 11—Records and Accounts, was reprinted in 1943 and Chapter 17—Wood Preservation, in 1946, is to leave gaps in the numerical sequence of the paging at places where it is anticipated that more material *may* be added in the future. Another scheme, proposed by the Committee on Masonry, is to set up an entirely new system of paging that embodies some of the elements of the Dewey decimal system. The problem is a complex one and must be studied from all angles.

Record of Manual Supplements

Supplement	*New Sheets Issued*	*Old Sheets Withdrawn*	*Net Increase*
1937	110	69	41
1938	151	121	30
1939	128	95	33
1940	185	139	46
1941	148	120	28
1942	144	149	—5
1943	176	158	18
1944	131	109	22
1945	44	45	—1
1946	127	147	—20
1947	167	184	—17
1948	135	132	3
Total	1646	1468	178

AREA News

In laying the plans for the semi-centennial celebration, President Mottier sought to direct such activities along constructive lines so that the Association would be strengthened, its prestige enhanced, its membership increased, its contribution to the railroads more fully recognized and confidence in its future opportunities established. As a means of accomplishing this purpose and to win the enthusiastic support of the members by keeping them informed currently on the celebration plans, he prepared a series of articles which appeared each month in the AREA News beginning with the April 1948 issue. Five of these issues were sent with a personal letter from him to the presidents and operating vice-presidents of the railroads of the United States and Canada so that railroad management might have a clear picture of the AREA and the services it is rendering to its members and to the railroad industry. Because of the inclusion of these articles, which were received with wide interest and because of the appearance of other material relating to the plans for the Golden Jubilee, the AREA News attained a prominence that it had not previously enjoyed.

Work of the Committees

No change was made during 1948 in the number of the committees, in their names, or in the general character of their assignments. On the other hand, the personnel of the committees was not only entirely reorganized but was also expanded to the largest aggregate committee membership in the history of the Association. This reorganization came about as the consequence of the increase in membership, which resulted in an unusual demand for places on committees. This demand was met in two ways, (1) by increasing the number of places on the committees (but limiting the committees to a maximum of 60 members each) and (2) by imposing certain limitations on committee service, for example by restricting affiliation with more than one committee. These limitations were implemented through a set of rules governing committee personnel adopted by the Board of Direction which appear under the heading of Personnel of Committees in the General Rules for the Preparation, Publication and Consideration of Committee Reports, published elsewhere in this volume.

The number of persons serving on committees was increased from 736 to 911, while the number of places on the committees was increased from 885 to 1003. However, because the application of the rules required 155 withdrawals, it was necessary to make 273 new appointments to effect a net increase of 118. Another feature of this reorganization that merits a place in the record is the fact that all these changes were made in no more than one-third of the time that is normally allotted to this task, because of the decision to issue the pamphlet of assignments and personnel before the end of the year, instead of withholding its publication until after the conclusion of the convention. The change in the schedule added tremendously to the difficulty of the task, but made it possible for the committees to proceed with the new year's work three months earlier than in previous years.

Committee activity, measured in terms of meetings held, corresponded closely with that of 1947. Four committees held one meeting each, eight had two meetings, eight others had three meetings and one had four, or a total of 48, which compares with 46 meetings in 1947. As an index of the effect of the earlier publication of the committee roster and assignments is the fact that five committees held meetings in January 1949.

As previously stated, the material in the committee reports exceeded that produced in the previous year by 38 pages, and in general it represented a greater diversification of content. This fact is brought out in the tabular classification of the material, but in studying this table it is necessary to note that, while the total number of subjects for 1947 is 170, compared with 151 for 1948, the 1947 total includes 59 items of minor revisions and reapprovals of the Manual, compared with only 28 such items in 1948. In other words, as the committees have succeeded in carrying out the major share of the task imposed on them by the mandate to make a detailed review of their chapters of the Manual, they have been able to devote more time to other assignments.

Classification of Material in the Committee Reports

	1944	*1945*	*1946*	*1947*	*1948*	*1948*
Revisions of the Manual—minor	6	6	10	13	36	21
Revisions of the Manual—major	6	..	7	11	22	16
Reapproval of Manual material	..	..	..	..	23	7
New Manual material—minor	..	1	..	2	1	2
New Manual material—major	10	2	3	3	4	2
New Manual material—tentative	2	2	1	5	7	2
Information	45	33	32	33	29	35
Reports on research work	12	12	14	15	16	19
Reports on service tests	2	4	5	6	3	7
Statistical data	5	3	2	2	3	4
Analytical studies	2	2	2	2	8	14
Bibliographies	3	2	2	2	2	2
Brief report of progress	18	7	7	13	16	20
War emergency provisions and reports	4	4	1	..	..	..
	115	76	86	107	170	151

Engineering Division Allotments for Research

	1947 Budget	*1948 Budget*	*1949 Budget*
Committee on Rail			
Transverse Fissure Investigation	$ 5,000	$ 5,000	$ 5,500
Investigation of Shelly Spots	13,000	13,000	13,500
Rail Investigation Committee	7,713	8,996	9,808
Service Tests of Joint Bars	3,200	8,500	9,076
Rolling Load Tests of Joint Bars	7,000	8,500	9,000
Investigation of Driver Burns	6,000	6,000	3,000
Rail Design Investigation	15,000	15,800	18,545
Total	$ 56,913	$ 65,796	$ 68,429
Committee on Track			
Stresses in Tie Plates	$ 10,000	$ 10,620	$ 11,028
Bolt Tension and Joint Lubrication	4,500	4,800	5,000
Corrosion from Brine Drippings	1,000	1,000	10,000
Stresses in Manganese Frogs	5,000	5,380	5,245
Tests of Rail Anchorage	3,000	3,180	5,000
Tie Plate Fastenings	10,000	10,800	10,688
Total	$ 33,500	$ 35,780	$ 46,961
Relation Between Track and Equipment			
Rail and Wheel Gage and Contour	$ 10,000	$ 10,400	$ 8,000
Relation Wheel Load to Wheel Dia.	5,000	5,500	5,500
Flat Spot Investigation	10,000	0	0
Lateral Forces from Locomotives	25,000	10,700	2,000
Relation of Wheel Pressures to Track Curvature	0	0	15,000
Total	$ 50,000	$ 26,600	$ 30,500
Structural Projects			
Impact Investigation	$ 45,000	$ 79,500	$ 97,792
Riveted and Bolted Struct. Joints	5,000	5,000	10,000
Strength of Floor Beam Hangers	5,000	10,000	10,000
Rocker Shoe Assemblies	0	0	4,000
Column Research Council	0	0	4,000
Fatigue Strength of Butt Welded Beams	0	2,000	0
Waterproofing Investigation	10,000	10,000	15,343
Total	$ 65,000	$106,500	$141,135
Roadway and Ballast			
Roadbed Stabilization	$ 15,000	$ 20,000	$ 26,496
Ballast Tests	0	0	6,700
Total	$ 15,000	$ 20,000	$ 33,196
Miscellaneous			
Research Office	$ 13,015	$ 16,164	$ 31,236
Electrolitic Corrosion of Steel in Concrete	1,000	1,000	1,000
Wear and Splitting of Ties	0	20,000	20,000
Total	$ 14,015	$ 37,164	$ 52,236
GRAND TOTAL	$234,428	$291,840	$372,457

Research Work

For the seventh consecutive year, the appropriations of the Association of American Railroads for the research work of the Engineering Division have been increased markedly, compared with the allotment of the previous year. The essential facts covering the work embraced in the research program for the last two years and the allotments for the present year are presented in the large table. Except for the allotments for "Relation Between Track and Equipment," "Research Office" and "Electrolysis Study," the funds provided are for studies proposed by AREA committees and carried out under arrangements providing for committee collaboration.

In the table of total allotments from 1938 to 1949, incl., it will be observed that the appropriation for 1949 is more than five times as much as it was in 1940.

Total Allotments for Research Work, Engineering Division, 1938–1949

1938	$78,158	1944	$109,050
1939	77,650	1945	138,110
1940	69,250	1946	159,510
1941	95,150	1947	234,428
1942	87,932	1948	291,840
1943	98,445	1949	372,457

W. S. Lacher,
Secretary.

Deceased Members

C. Frank Allen
88 Montview St., West Roxbury, Mass.

J. R. W. Ambrose
Retired Superintendent, Toronto Terminals Railway, Toronto, Ont.

A. J. Anderson
Division Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Spokane, Wash.

W. H. Bettis
Assistant Engineer, Norfolk & Western Railway, Portsmouth, Ohio

G. E. Boyd
Retired Associate Editor, Railway Age, Chicago, Ill.

J. C. Bradley
Special Representative, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

W. J. Cable
Division Engineer, Minneapolis, St. Paul & Sault Ste Marie Railway, Stevens Point, Wis.

A. W. Carpenter
Retired Engineer of Bridges, New York Central System, Johnstown, N. Y.

H. A. Cassil
Armond Cassil, Inc., Detroit, Mich.

C. O. Congdon
4150 Hardee Road, Miami, Fla.

F. H. Cothran
President, Durham & Southern Railway, Piedmont & Northern Railway, Charlotte, N. C.

J. R. Derrick
Manager Roadway Maintenance, Norfolk & Western Railway, Roanoke, Va.

Clark Dillenbeck
Retired Chief Engineer, Reading Company, Mount Dora, Fla.

L. J. Drumeller
Engineer of Track, Chesapeake & Ohio Railway, Cleveland, Ohio

J. M. Farrin
Retired Special Engineer, Illinois Central Railroad, Lake Worth, Fla.

W. R. Ganser
Division Engineer, Pennsylvania Railroad, Chicago, Ill.

R. M. Hailey
Assistant Auditor Capital Expenditures, Chicago & North Western Railway, Chicago, Ill.

F. S. Hewes
Office Engineer, Atchison, Topeka & Santa Fe Railway, Chicago, Ill.

F. C. Knight
Valuation Engineer, Canadian National Railways, Toronto, Ont.

C. R. Knowles
Retired Superintendent Water Service, Illinois Central Railroad, Chicago, Ill.

H. T. Livingston
Chief Engineer Maintenance of Way and Structures, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

Arthur Montzheimer
Retired Chief Engineer, Elgin, Joliet & Eastern Railway, Aurora, Ill.

C. H. Morse
Assistant Engineer Maintenance of Way-System, New York Central System, New York, N. Y.

R. J. Needham
Retired Mechanical and Electrical Engineer, Canadian National Railways, Toronto, Ont.

J. H. O'Brien
Executive Vice-President, Petroleum Heat and Power Company, New York, N. Y.

D. W. Richards
Retired Superintendent Telegraph and Signals, Norfolk & Western Railway, Salem, Va.

H. L. Robertson
Assistant Signal Engineer, Missouri Pacific Lines (N. O. T. & M. Ry.), Houston, Tex.

W. H. Rochester
Chief Engineer, Gulf, Colorado & Santa Fe Railway, Galveston, Tex.

R. L. Schmid
Chief Engineer, Nashville, Chattanooga & St. Louis Railway, Nashville, Tenn.

O. W Swenson
Chairman of Board, Foley Brothers, Inc., Pleasantville, N. Y.

F. L. Thompson
Retired Vice-President and Chief Engineer, Illinois Central Railroad, Chicago, Ill.

R. L. Turner
Consulting Engineer, Industrial Development and Grade Crossing Elimination Work, Buffalo, N Y.

H. D. Van Vranken
Chief Engineer, Jacksonville Terminal Company, Jacksonville, Fla.

A. A. Visintainer
Engineer of Structures, Erie Railroad, Cleveland, Ohio

William Walker
Retired Bridge Engineer, Canadian National Railways, Winnipeg, Man.

R. N. Warnock
President, Chas. Warnock & Company, Ltd , Montreal, Que.

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1948

Balance on hand January 1, 1948			$101,526.57
RECEIPTS			
Membership Account			
Entrance Fees	$ 6,860.00		
Dues	33,679.75		
Binding Proceedings	222.00		
		$ 40,761.75	
Sales of Publications			
Proceedings	$ 1,409.42		
Bulletins	1,799.63		
Manuals	4,093.30		
Specifications	1,963.65		
Track Plans	824.10		
Hand Books	359.50		
		$ 10,449.60	
Advertising			
Publications		$ 2,758.10	
Interest Account			
Interest on Investments	$ 2,455.74		
Less Interest Paid on Bonds Purchased	13.23		
		$ 2,442.51	
Profit From Sale of Securities		1,156.99	
Miscellaneous		171.55	
Total		$ 57,740.50	
DISBURSEMENTS			
Salaries	$15,775.02		
Proceedings	7,338.83		
Bulletins	6,767.39		
Stationery and Printing	2,518.49		
Rents, Lights, etc.	780.00		
Supplies	261.40		
Postage	1,177.46		
Refund of dues, etc.	148.40		
Audit	300.00		
Pension	1,200.00		
Social Security and Unemployment Taxes	477.48		
Manual	6,575.39		
Track Plans	1,811.80		
Committee and Officer's Expense	123.60		
Annual Meeting Expenses	1,280.91		
News Letter	2,015.90		
50th Anniversary	2,945.81		
Hand Books	900.00		
Miscellaneous and Extraordinary	663.66		
Total		$ 53,061.54	
Excess of Receipts over Disbursements			$ 4,678.96
Balance on hand December 31, 1948			$106,205.53

REPORT OF THE TREASURER

To the Members:		
Balance on hand January 1, 1948		$101,526.57
Receipts during 1948	$ 57,740.50	
Paid out on Audited Vouchers	53,061.54	
Excess of Receipts Over Disbursements		4,678.96
Balance on hand December 31, 1948		$106,205.53
Consisting of		
Bonds at Cost	$ 98,385.50	
Cash in Northern Trust Company Bank	7,795.03	
Petty Cash	25.00	
		$106,205.53

We have made an audit of the accounts of the American Railway Engineering Association for the year ending December 31, 1948 and find them to be in accordance with the foregoing statements.

Paul Mitchell,
C. A. Bick
Auditors

GENERAL BALANCE SHEETS

December 31, 1948

	1948	*1947*
Assets		
Due from Members	$ 361.00	$ 857.50
Due from Sale of Publications	81.00	97.75
Due from Advertising	127.50	266.00
Furniture and Fixtures	863.16	570.18
Publications on hand (estimated)	504.00	630.00
Investments (Cost)	98,385.50	95,162.64
Interest on Investments (accrued)	567.41	616.44
Cash in Northern Trust Company Bank	7,995.03	6,338.93
Petty Cash	25.00	25.00
Manuals on hand	9,630.50	9,220.00
Track Plans	2,722.00	400.00
Paper Stock	1,502.00	305.10
Total	$122,764.10	$114,489.54
Liabilities		
Members' dues paid in advance	$ 539.25	$ 263.50
Surplus	122,224.85	114,226.04
Total	$122,764.10	$114,489.54

American Railway Engineering Association

CONSTITUTION

Revised to June 15, 1948

Article I

NAME, OBJECT AND LOCATION

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Standing and Special Committees.

(b) Meetings for discussion of reports and papers.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions reached shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Illinois.

Article II

MEMBERSHIP

1. Classes

The membership of this Association shall be divided into five classes: Members, Life Members, Honorary Members, Associates and Junior Members.

2. Qualifications

A. GENERAL

(a) An applicant to be eligible for membership in any class other than that of Junior Member shall be not less than twenty-five (25) years of age.

(b) To be eligible for membership in any class, or for retention of membership as a Member, an Associate or a Junior Member, a person shall not be engaged directly or primarily in the sale to the railways of appliances, supplies, patents or patented services.

(c) The right to membership shall not be terminated by retirement from active service.

(d) In determining the eligibility for membership in any class, graduation in engineering from a school of recognized standing shall be considered as equivalent to three years of active practice, and satisfactory completion of each year of work in such school without graduation shall be considered as equivalent to one-half year of active practice.

B. Member

A Member shall be:

(a) An engineer or officer in the service of a railway corporation that is a common carrier, who has had not less than five years' experience in the location, construction, operation or maintenance of railways.

(b) A Professor of Engineering in a university or college of recognized standing.

(c) An Engineer or Member of a public board or commission who in the discharge of his regular duties deals with railway problems.

(d) An editor of a trade or technical magazine who in the discharge of his regular duties deals with railway problems, and who has had the equivalent of five years' engineering or railway experience.

(e) A consulting engineer, engaged in private practice, or an engineer in his employ, who has had the equivalent of five years' engineering experience.

C. Life Member

A Life Member shall be a Member who has paid dues for thirty-five (35) years, or who has been retired under a recognized retirement practice and has paid dues for not less than twenty-five (25) years.

D. Honorary Member

(a) An Honorary Member shall be a person of acknowledged eminence in railway engineering or management.

(b) The number of Honorary Members shall be limited to ten (10).

E. Associate

An Associate shall be:

(a) An Engineer of a railway which is essentially an adjunct of an industry or which is used primarily to transport the products and materials of an industry to and from a railway which is a common carrier.

(b) A person qualified by training and experience to co-operate with Members in the object of this Association but who is not qualified to become a Member.

F. Junior Member

(a) A Junior Member shall be not less than twenty-one (21) years of age and shall be an engineering employee of a railway corporation who has had not less than three (3) years of experience in the location, construction, operation or maintenance of railways.

(b) His membership in this Association shall terminate at the end of the calendar year in which he becomes thirty (30) years of age.

(c) He may make application for membership other than as a Junior Member at any time when he becomes eligible to do so.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members and Life Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates and Junior Members shall have all the rights and privileges of the Association, except those of voting and holding elective office.

Article III

Admission, Resignation, Expulsion and Reinstatement

1. Charter Membership

The Charter Membership of this Association consists of all persons elected to membership before March 15th, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form provided by the Board of Direction. In the event that Junior Membership is desired, the application shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of such Members shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(c) If an applicant is not personally known to three Members of this Association, the names of at least three well known persons engaged in railway or allied professional work to whom personally known shall be given instead. Each of such persons shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with all the information obtained, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible and the admission of the applicant shall be canvassed by letter ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

(d) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (c) of this Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

A person elected to membership in this Association shall subscribe to its Constitution on the form prescribed by the Board of Direction. If this provision has not been complied with within six months of notice of election the election shall be considered null and void.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fully met.

7. Expulsion

Charges may be preferred in writing by ten or more Members against a person holding membership in the Association. The person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be required for expulsion.

8. Reinstatement

(a) A person having been a Member, an Associate or a Junior Member of this Association and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member, an Associate or a Junior Member of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

Article IV

Dues

1. Entrance Fee

(a) An entrance fee of ten dollars ($10.00) shall be payable to the Association with each application for membership other than Junior Membership. This sum shall be returned to an applicant not elected.

(b) No entrance fee shall be payable to the Association on account of Junior Membership.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be fifteen dollars ($15.00).

(b) The annual dues for each Junior Member shall be seven dollars and fifty cents ($7.50).

(c) Life Members and Honorary Members shall be exempt from the payment of dues.

3. Arrears

A person whose dues are not paid before April 1st of the current year shall be notified by the Secretary. If the dues are still unpaid on July 1st further notice shall be given and a delinquent Member shall lose the right to vote. If the dues remain unpaid October 1st the person shall be notified on the form prescribed by the Board of Direction, and shall no longer receive the publications of the Association. If the dues are not paid by December 31st, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, Associate or Junior Member who, for good reason, is unable to pay them.

Article V

Officers

1. Officers

(a) The officers of the Association shall be a President, two Vice-Presidents, twelve Directors, a Secretary and a Treasurer.

(b) The President, the Vice-Presidents and the Directors, together with the two latest living Past-Presidents continuing to be members, shall constitute the Board of Direction, in which the government of the Association shall be vested; they shall act as the trustees and have the custody of all property belonging to the Association. The President, the Vice-Presidents and the Directors shall be members.

(c) The Secretary and the Treasurer shall be appointed by the Board of Direction.

(d) Provided, however, that in the first Association year following the amendment of the Constitution by the inclusion of this paragraph, the Board of Direction shall include ten Directors and the four latest living Past-Presidents continuing to be members, and that in the second Association year it shall include eleven Directors and the three latest living Past-Presidents continuing to be members.

2. Term of Office

The term of office of the President shall be one year, of the Vice-Presidents two years and of the Directors three years. The term of each shall begin at the close of the Annual Convention at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position during the pleasure of the Board of Direction.

3. Officers Elected Annually

(a) There shall be elected at each annual convention a President, one Vice-President and four Directors.

(b) The candidates for President and for Vice-President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election. Vice-Presidents and Directors shall not be eligible for re-election to the same office until at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) When a vacancy occurs in the office of President the duties shall be performed by the senior Vice-President.

(b) When a vacancy occurs in the office of either Vice-President the Board of Direction shall select a Vice-President from the members or past members of the Board of Direction. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) A vacancy in the office of Director shall be filled by the Board of Direction.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provisions of Article V, Section 4.

6. Vacation of Office

(a) When an elected officer ceases to be a Member of the Association, as provided in Article II, the office shall be vacated.

(b) In case of the disability of or neglect in the performance of duty by an officer, the Board of Direction, by a two-thirds affirmative vote of the entire Board, shall have the power to declare the office vacant.

Article VI

Nomination and Election of Officers

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not Past-Presidents shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past-President who is a member of the Committee shall be the Chairman of the Committee. In the absence of the senior Past-President from a meeting of the Committee the Past-President next in seniority present shall act as Chairman.

2. Method of Nominating

(a) Prior to December 1st of each year the Chairman shall call a meeting of the Committee at a convenient place, at which nominees for the several elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee.*	*Number of Candidates to be elected at the Annual Election of Officers.*
President	1	1
Vice-President	1	1
Directors	8	4
Nominating Committee	10	5

(b) The Chairman of the Nominating Committee shall send the names of the nominees to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the members of the Association on a printed slip not later than January 1st following.

(c) At any time between January 1st and February 1st any ten or more Members may send to the Secretary additional nominations for any elective office for the ensuing year signed by such Members.

(d) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, the name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than thirty days prior to each Annual Convention, the Secretary shall issue a ballot to each voting member of record in good standing, listing the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate, his record of membership and activities in this Association.

4. Substitution of Names

Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw a ballot, and cast another, at any time before the polls close.

(c) Ballots not endorsed or from persons not qualified to vote shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by tellers appointed by the Presiding Officer.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

(c) The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article.

Article VII

Management

1. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio a member of all committees, except the Nominating Committee.

2. Vice-Presidents

The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and shall discharge the duties in case of a vacancy in the office.

3. Treasurer

The Treasurer shall receive all monies, deposit the same in the name of the Association, receipt to the Secretary therefor and invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. The Treasurer shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction.

4. Secretary

The Secretary, shall be under the direction of the President and Board of Direction, the Executive Officer of the Association and shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. The Secretary shall see that the monies due the Association are collected and without loss transferred to the custody of the Treasurer, and shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. The Secretary is to conduct the correspondence of the Association, keep proper record thereof, and perform such other duties as the Board of Direction may prescribe.

5. Auditing of Accounts

The accounts of the Treasurer and of the Secretary shall be audited annually by an approved accountant under the direction of the Finance Committee of the Board of Direction.

6. Board of Direction

(a) The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution.

(b) The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(c) Seven members of the Board of Direction shall constitute a quorum.

(d) At the first meeting of the Board of Direction after the Annual Convention, the following committees, each consisting of not less than three members, shall be appointed by the President from the Board of Direction and they shall report to and perform their duties under the supervision of the Board of Direction.

Finance
Publication
Outline of Work of Committees
Personnel of Committees
Membership
Manual

7. Duties of the Committees of the Board of Direction

(a) Finance Committee

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of monies and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(b) Publication Committee

The Publication Committee shall have general supervision of the publications of the Association. The Publication Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(c) Committee on Outline of Work of Committees

The Committee on Outline of Work of Committees shall prepare and present to the Board of Direction a report of the subjects to be investigated, considered and reported upon by the standing and special committees of the Association during the ensuing year.

(d) Committee on Personnel of Committees

The Committee on Personnel of Committees shall prepare and present to the Board of Direction a list of chairmen, vice-chairmen and members of the standing and special committees of the Association for the ensuing year.

(e) Membership Committee

The Membership Committee shall make investigation of applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(f) Manual Committee

The Manual Committee shall study and recommend to the Board of Direction as to the manner in which the material adopted for addition or deletion from the Manual shall be handled.

8. Standing Committees

The Board of Direction may appoint standing committees to investigate, consider and report upon questions pertaining to railway location, construction, operation and maintenance.

9. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

10. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

11. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual convention of the Association shall be deemed to be the act of the Association.

Article VIII

Meetings

1. Annual Convention

(a) The Annual Convention of the Association shall be held in the City of Chicago, Illinois. The convention shall open on a Tuesday in the month of March to be determined by the President.

(b) The Secretary shall notify all members of the Association of the time and place of the Annual Convention at least thirty (30) days in advance thereof.

(c) The order of business at the Annual Convention of the Association shall be:

- Reading of the Minutes of the last meeting
- Address of the President
- Reports of the Secretary and the Treasurer
- Reports of Committees
- Unfinished Business
- New Business
- Installation of Officers
- Adjournment

(d) This order of business may be changed by a majority vote of Members present.

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

(f) Discussions shall be limited to members and to those others invited by the Presiding Officer to speak.

2. Special Meetings

Special meetings of the Association may be called by the Board of Direction and special meetings shall be so called by the Board of Direction upon written request of thirty Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten (10) days in advance and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five (25) Members shall constitute a quorum at all meetings of the Association.

Article IX

Amendment

1. Amendment

Proposed Amendment of this Constitution shall be made in writing, shall be signed by not less than ten Members and shall be acted upon in the following manner:

The amendment shall be presented to the Secretary who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes the matter shall be submitted to the Association by letter-ballot.

The Board of Direction shall canvass the ballots which have been received within sixty days after the date of issue of the letter-ballot and if two-thirds (⅔) of the votes so received are in the affirmative the amendment shall be declared adopted and shall become immediately effective.

The result shall be announced at the next Annual Convention.

GENERAL INFORMATION

(Revised to November 16, 1948)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS

(A) Appointment of Committees and Outline of Work

Standing Committees

1. The following are Standing Committees:

1. Roadway and Ballast.
3. Ties.
4. Rail.
5. Track.
6. Buildings.
7. Wood Bridges and Trestles.
8. Masonry.
9. Highways.
11. Records and Accounts.
13. Water Service and Sanitation.
14. Yards and Terminals.
15. Iron and Steel Structures.
16. Economics of Railway Location and Operation.
17. Wood Preservation.
20. Uniform General Contract Forms.
22. Economics of Railway Labor.
24. Cooperative Relations with Universities.
27. Maintenance of Way Work Equipment.
28. Clearances.
29. Waterproofing.
30. Impact and Bridge Stresses.

Special Committees

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Section 9, of the Constitution.

Outline of Work

The Board of Direction will assign to the committees subjects which in its judgment should preferably be considered during the succeeding year, provided, however, that such assignments may be subject to revision when necessary until the close of the annual convention. *Such assignments should not be deviated from except in extreme cases and then not until approved by the Committee on Outline of Work.*

Personnel of Committees

3. The personnel of all committees shall be revised annually. It is desirable that 10 percent of the membership be changed each year. Members who do not attend meetings of the committee during the year or render no service by correspondence will be replaced. The terms of chairmen and vice-chairmen shall be three years in each position.

(a) Chairmen completing their three-year term shall recommend to the Board Committee on Personnel two or more nominees for the chairmanship and vice-chairmanship, with assurance of acceptance from such nominees if appointed by the Board Committee.

(b) The total membership of any committee shall be limited to 60.

(c) In determining membership of a committee, roads having no more than 50 Association members may have two members per committee; railroads having 51 to 100 members may have 3 members; railroads having more than 100 members may have not more than 4 members on any one committee.

(d) No member who has retired from active service shall serve on a committee more than 3 years following his retirement.

(e) No company will be permitted to have more than one Associate representative on any committee; company representation shall not necessarily be continuing.

(f) Membership of Associates on a committee shall be limited to 10 percent of the total membership of the committee. However, committees are not required to reduce the number of Associates immediately for the purpose of complying with this rule, but no Associates may be added as long as the proportion exceeds 10 percent.

(g) No member of the Association shall serve on more than one committee, except that a member may serve on two committees if one or both of the committees are among the following—Committee 3—Ties; Committee 7—Wood Bridges and Trestles; Committee 17—Wood Preservation; Committee 20—Uniform General Contract Forms; Committee 24—Cooperative Relations with Universities; Committee 28—Clearances; Committee 29—Waterproofing; Committee 30—Impact and Bridge Stresses.

(B) Preparation of Committee Reports

General

5. The objectives of the Association are advanced through the work of the committees in two ways—(1) the development of useful information pertinent to their assignments to be presented to the Association "as information," and (2) the formulation of recommended practices to be submitted for adoption and publication in the Manual.

(a) Whether the report on any particular assignment should take the form of "information" or a "recommended practice," depends largely on the nature of the assignment. Some assignments will be fulfilled completely by the presentation of information; others call for information in support of appended recommendations that are submitted for adoption. In still other cases, the primary objective is a comprehensive statement of recommended practices, but the development of these recommended practices may entail investigation or research work, the results of which are of such importance as to warrant their presentation as information prior to the submission of the recommendations. In some cases, also, it may be advisable to submit as information matter in the form of recommended practice, with a view to inviting suggestions and criticisms that may serve as the basis for revisions prior to the resubmission of the matter for adopton a year later.

Planning the Work

6. In pursuing the work on any assignment, the first step is necessarily one of fact finding, including (a) a study of available literature on the subject, particularly reports of previous investigations, (b) a compilation of current practice, especially recent changes in practice, and (c) resort to original tests or experimentation, after a canvass of all other sources of information indicates that research work is necessary.

Collection of Data

(a) Committees are privileged to obtain data or information in any proper way. If desired, the secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blueprint.

(b) Requests for appropriations for the conduct of research work should be sent to the secretary with a supporting statement setting forth: (a) the nature of the information sought; (b) how the railroads are adversely affected by the lack of this information; (c) the estimated cost of the investigation; (d) the estimated time to complete the work; (e) the basis for assuming that the investigation will produce the data desired; and, (f) an estimate of the savings to be realized or other advantages to accrue from the successful completion of the investigation. A request for funds to continue or complete an investigation shall include a statement of the results obtained to date.

Reports

7. Committees should pursue their investigations on all assignments but are expected to present progress or final reports for publication only on those assignments regarding which pertinent information has been developed.

(a) Committees are privileged to present the results of any special study or investigation they may be engaged upon in connection with their assignments that may be considered of sufficient importance to warrant presentation.

(b) Reports of information, supplementing previous reports of progress, may include a brief review of matter previously presented, but should avoid extended repetition of such matter.

(c) Matter offered for adoption and publication in the Manual should be submitted in full, regardless of its publication in previous years unless the matter being offered appeared in substantially identical form not more than one year before being submitted for adoption.

(d) Illustrations accompanying reports should, when possible, be prepared so that they can be reproduced on one page. The use of inserts should be avoided.

(e) One of the most important duties of each committee is to examine its own subject matter in the Manual each year and submit such revisions of or supplements to the Manual as are deemed necessary to keep it up to date. New matter for publication in the Manual and revisions thereof must be submitted in the form and manner specified in the General Rules for Publication of the Manual.

(f) Committees are required to resubmit all items in their respective chapters of the Manual at intervals of not less than 10 years, either with desired revisions or with a request for reapproval without change.

Form of Reports

8. Committee reports shall be prepared in accordance with the Style Standards for Committee Reports.

(C) PUBLICATION OF REPORTS

Dates for Filing and Publication of Reports

9. For the convenience of those attending the convention, the reports of committees to be presented at any session of the annual convention will be published, so far as possible, in the same bulletin. To carry out this plan requires a careful scheduling of the filing of reports and the publication of bulletins, and the arrangement of the convention program. It is of utmost importance that chairmen file complete reports of their committees on or before the dates specified on the schedule furnished them.

Written Discussions

10. Written discussions of published reports will be transmitted to the chairman of the interested committee who will read or present them by title or in abstract at the convention. Written discussions will be published in the Proceedings as a part of the discussion of the committee reports.

Verbal Discussions

11. When necessary to insure accuracy, the speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

(D) CONSIDERATION OF COMMITTEE REPORTS

Sequence

12. The sequence in which committee reports will be considered by the convention will be determined by the Board of Direction.

Method

13. Reports offered as information will be presented by title or by a brief outline of the contents. Comments or criticisms may be offered from the floor upon invitation from the presiding officer.

14. Matter submitted for adoption and publication in the Manual may receive consideration by one of the following procedures:

(a) Reading by title.
(b) Reading, discussing and acting upon each conclusion separately.
(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

Action on Reports

15. No formal action is to be taken by the convention on matter submitted as information, whether in the form of a progress or final report.

Action on matter submitted for adoption and publication in the Manual will be one of the following:

(a) Adoption as a whole as presented.
(b) Affirmative action on the amendment of a part or parts of the matter presented, followed by adoption as a whole, as amended.
(c) Adoption of a part, complete in itself, and referring of remainder back to the committee.
(d) Recommittal with or without instructions.

NOTE.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the committee considers affected.

The Chair will decline to entertain amendments which in his opinion are primarily a matter of editing.

(E) PUBLICATION OF ABSTRACTS BY TECHNICAL JOURNALS

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the bulletin; provided, application therefor is made in writing and proper credit be given the Association, authors or commttees presenting such material.

GENERAL RULES FOR PUBLICATION OF THE MANUAL

Title

1. The title of the volume will be "Manual of the American Railway Engineering Association."

2. The Board of Direction shall have the authority to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Contents

3. The matter adopted by the Association for publication in the Manual shall be considered Recommended Practice, but shall not be binding on the members. Recommended Practice, as defined by the Board of Direction (May 20, 1936) is a material, device, plan, specification or practice recommended to the railways for use as required, either exactly as presented or with such modifications as may be necessary or desirable to meet the needs of individual railways, but in either event, with a view to promoting efficiency or economy, or both, in the location, construction, operation or maintenance of railways.

Requisites for Adoption

4. The Manual will include only such matter as has been made the subject of a special study by a standing or special committee and embodied in a committee report after it has received a two-thirds majority in a letter ballot of all Members of the committee (Associate members are not entitled to vote), and shall include only such matter as has been published not less than 30 days prior to the annual convention, and submitted by the committee to the annual convention, and which, after due consideration and discussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction shall be reviewed by the Association of American Railroads, may be referred to that association before being published in the Manual.

5. When and as required, recommendations for the adoption or revision of Manual material shall be submitted to letter ballot of the Members of the Association under the following limitations:

(a) That the letter ballot shall be taken only after the Board of Direction has recognized the necessity for such emergency action, and

(b) That the propositions submitted by the committee shall have the approval of a special committee of the Board of Direction appointed by the President for that purpose, both as to the substance of the material offered and also as to the circumstances attending the consideration of the material by the committee.

6. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the committee report and subsequent discussion and the final action of the Association.

Revision

7. Any matter in the Manual may be amended or withdrawn either by vote at any subsequent annual convention or by letter ballot, provided such changes are proposed in time for publication not less than 30 days prior to the annual convention, and in the following manner: (a) upon recommendation of the committee in charge of the subject; (b) upon recommendation of the Board of Direction; (c) upon request of five members made to the Board of Direction.

8. Revisions of or additions to the Manual authorized by action at each convention will be published annually in the form of loose-leaf sheets which will be made available to all holders of the Manual. These supplemental sheets will be accompanied by instructions for insertion of the new sheets and the withdrawal of sheets that have been superseded, as well as those that have been withdrawn by action of the Association.

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