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Page 125: Section modulus shown in fourth line of first full paragraph should be 61.2 $in.^3$ instead of 62.2 $in.^3$

Page 116: In plate, Series 44 J a, cross section shows 12″ I @ 318, instead of 12″ I @ 31.8.

In discussion, Van Hovenberg: Under Non-Metallic Coatings, page 228, change first line of last paragraph to read: Probably the coating which will give the longest underground protection is portland cement mortar, which forms a film of alkaline solution in contact with the iron pipe to inhibit corrosion.

Page 405: Change second line on page to read $T =$ Throw in feet of equipment measured from an "at rest" position.

Page 447: Between twentieth and twenty-first lines, insert dash line to indicate separation of the material on Blast and Fume Protection and the introductory paragraph to the material on Specifications for Movable Railway Bridges.

Tests of Steel Girder Spans on the Chicago & North Western Railway

Advance Report of Committee 30—Impact and Bridge Stresses

1. Digest

This report embraces a description and analysis of the test data secured on 3 deck plate girder spans varying in length from 70 ft. ¼ in. to 78 ft. on the Chicago and North Western Railway. Two of the bridges had an open timber floor while the other bridge had a ballasted precast concrete floor. The tests were made under regular scheduled trains, using both diesel and steam locomotives operating over a complete range of speeds from 5 mph. up to the maximum operating speed of 100 mph. for the diesels and 85 mph. for the steam locomotives. Stresses were measured under 100 diesel locomotives and 386 steam locomotives, or a total of 486 locomotive test runs on the 3 spans.

The stresses were measured by means of electromagnetic strain gages, with oscillograph recordings, in various parts of the bridges, such as:

Bottom flanges at the center of the span
Top flanges at the center of the span
Web plates at the end of the span
Web plates at the quarter point of the span
Columns of the viaduct bent supporting the girders
Transverse bracing in the viaduct bent
Lateral bracing and crossframes of the girder spans

The tests were conducted as part of the research program to determine the static and dynamic effects in plate girder bridges and the final conclusions will be based upon the results obtained in 32 plate girder bridges varying in length from 40 ft. to 140 ft.

The data secured during these tests were analyzed for the purpose of determining the static and total impact effects as well as the individual effects which contribute to the total impacts. A brief summary of the analysis of the data is as follows:

1. There was considerable variation between the static stresses recorded in the lower flanges of the girders at the center of the span and those calculated by the usual method, as shown in Tables 3, 5 and 7. The ratio of the recorded stress to the calculated stress varied from 1.14 to 0.84.

2. A comparison of the recorded and calculated static stresses in the web plates of the girders close to the end of the span is shown in Tables 3, 5 and 7, and it can be seen that this ratio varied from 1.39 to 0.84.

3. The recorded and calculated static stresses in the web plates of the girders at the quarter point of the span were in fair agreement, as shown in Tables 5 and 7. The ratio of recorded to calculated stress varied only from 1.13 to 0.90.

4. The recorded stresses in the top flanges are only slightly greater than those recorded in the bottom flanges, see Tables 6 and 8, except in the south girder of the 71-ft. 10-in. span where the stresses in the top flanges are considerably larger.

5. A comparison of the recorded and calculated static stresses in the columns of the viaduct bent is shown in Table 4. It can be seen that the ratio of recorded to calculated stresses in the bottom of the column, section F–F or C–C, varied from 1.11 to 0.89.

6. There was considerable variation in the simultaneous stresses measured at the four corners of the columns of the viaduct bents and the bending stresses and derived eccentricities are shown in Table 10. The derived eccentricities exceed the allowance in the current AREA design specification.

7. The recorded simultaneous stresses across the section of the lower girder flanges are shown in Table 9. The stresses on the edges of the flange are slightly lower than the stress at the center of the flange and the same variation occurs for all locomotive speeds.

8. An increase in the average mean stress of both girders by an increase in speed over the slow-speed runs has been termed "speed effect" and this effect was found throughout these tests, as shown in the upper left diagrams of Figs. 9, 10 and 11 for the diesel locomotives and Figs. 12 to 20 incl. for the steam locomotives.

The speed effect generally amounted to about 10 percent of the static stress under the diesel locomotives and about 15 percent under the steam locomotives.

9. The simultaneous stress measurements usually indicated an increase in stress in the steel girder under one rail with a corresponding decrease under the other rail. This change in stress is termed "roll effect" and this effect on the three girder spans is shown in the lower left diagrams of Figs. 9, 10 and 11 for the diesel locomotives and in Figs. 12 to 20 incl. for the steam locomotives.

The roll effect generally amounted to about 15 percent of the static stress under both the diesel and steam locomotives.

10. The test measurements showed that vibrations were induced in the test spans by the diesel locomotives even though their wheels had no unbalanced counterweights. This impact effect has been termed "track effect" and is presumably caused by irregularities in the track surface, flat spots or out-of-round wheels. The track effects under the diesel locomotives are shown on the right diagrams of Figs. 9, 10 and 11.

11. The combined track and hammer blow effects recorded under the passage of the steam locomotives are shown in Figs. 12 to 20 incl. This vibrational effect is considerably greater than that recorded under the diesel locomotives.

GIRDER FLANGES AT CENTER

Span	*Locomotive Class*	*Total Impacts—Percent*			*Maximum Stresses—Ksi.*		
		Area Design	*Maximum Recorded*	*Average Recorded (6 Highest)*	*Area Design*	*Maximum Recorded*	*Average Recorded (6 Highest)*
	2-Axle Diesel	43.8	41.9	26.9	4.11	4.94	4.17
	3-Axle Diesel	43.8	21.4	19.2	4.66	4.72	4.57
70 ft. ¼ in.	Class J	63.1	50.6	44.4	6.70	7.53	6.49
	Class E 4	63.1	39.1	25.8	7.81	7.97	6.94
	Class H	63.1	62.1	39.5	8.55	8.42	8.18
	2-Axle Diesel	46.0	31.6	26.2	6.12	6.87	6.18
	3-Axle Diesel	46.0	23.3	20.1	7.31	6.65	6.47
71 ft. 10 in.	Class J	65.4	50.2	46.8	10.91	10.07	9.76
	Class E 4	65.4	38.3	32.9	12.68	11.69	10.82
	Class H	65.4	29.1	25.6	14.21	11.23	10.90
	2-Axle Diesel	41.4	27.3	17.5	5.28	4.42	4.24
	3-Axle Diesel	41.4	18.4	13.7	6.80	4.92	4.76
78 ft.	Class J	60.7	50.2	45.7	9.68	8.64	8.19
	Class E 4	60.7	37.2	33.8	11.69	8.78	8.24
	Class H	60.7	38.6	39.9	12.80	9.52	9.16

12. The total impact effects and recorded maximum stresses in the girder flanges, produced by each of the diesel and steam locomotive classes, are shown in the diagrams of Figs. 21, 22 and 23 for the diesel locomotives and in Figs. 24 to 32 incl. for the steam locomotives. A comparison of the values determined by the current AREA design specification with the maximum recorded values and the average of the six highest recorded values are shown in the preceding tabulation:

13. The total impact effects and recorded maximum stresses in the girder webs at the end of the three spans, produced by each of the diesel and steam locomotive classes, are shown in the diagrams of Figs. 33, 34 and 35 for the diesel locomotives and Figs. 36 to 44 incl. for the steam locomotives. A comparison of the values determined by the current AREA design specification with the maximum recorded values and the average of the six highest recorded values are shown in the following tabulation:

GIRDER WEBS AT END

Span	*Locomotive Class*	*Total Impacts—Percent*			*Maximum Stresses—Ksi.*		
		Area Design	*Maximum Recorded*	*Average Recorded (6 Highest)*	*Area Design*	*Maximum Recorded*	*Average Recorded (6 Highest)*
70 ft. ¼ in.	2-Axle Diesel	43.8	37.8	22.3	2.78	3.49	3.18
	3-Axle Diesel				3.64	3.49	3.21
	Class J	63.1	58.2	42.7	4.57	5.42	4.82
	Class E 4	63.1	43.1	28.7	5.03	5.45	5.14
	Class H	63.1	55.7	45.9	5.71	6.03	5.60
71 ft. 10 in.	2-Axle Diesel	46.0	38.6	32.3	4.82	6.57	6.13
	3-Axle Diesel	46.0	29.1	24.5	5.86	6.72	6.54
	Class J	65.4	54.7	46.4	8.13	8.91	8.58
	Class E 4	65.4	43.8	31.6	9.80	10.39	10.18
	Class H	65.4	30.5	25.4	10.15	11.17	10.71
78 ft.	2-Axle Diesel	41.4	24.9	17.5	3.99	3.20	3.01
	3-Axle Diesel	41.4	12.1	8.0	5.22	3.87	3.69
	Class J	60.7	50.6	42.8	7.58	5.33	5.23
	Class E 4	60.7	37.7	32.1	8.12	6.57	6.22
	Class H	60.7	53.0	37.4	9.09	8.08	7.02

14. The total impact effects and recorded maximum stresses in the girder webs at the quarter point of two of the spans, produced by each of the diesel and steam locomotive classes are shown in the diagrams of Figs. 45 and 46 for the diesel locomotives and Figs. 47 to 52 incl. for the steam locomotives. A comparison of the values determined by the current AREA design specification with the maximum recorded values and the average of the six highest recorded values are shown in the following tabulation, page 4.

15. The total impacts in the columns of the viaduct bents supporting the 70-ft. ¼-in. girder spans are shown on the right diagram of Fig. 53 for the diesel locomotives and Fig. 54 for all three classes of steam locomotives. The current AREA design allowance appears to be ample for the impact in these columns.

16. The maximum recorded direct live load plus impact stresses in the columns of the viaduct bent supporting the 70-ft. ¼-in. girder spans are shown on the left diagram of Fig. 53 for the diesel locomotives and Fig. 54 for the steam locomotives. The highest recorded stresses were in close agreement with the calculated stresses, using the current AREA design allowance.

17. The recorded stresses in the bracing of the viaduct bent were quite low and were about the same for all classes of locomotives, as shown in Fig. 55.

GIRDER WEBS AT QUARTER POINT

Span	Locomotive Class	Total Impacts—Percent			Maximum Stresses—Ksi.		
		Area Design	*Maximum Recorded*	*Average Recorded (6 Highest)*	*Area Design*	*Maximum Recorded*	*Average Recorded (6 Highest)*
71 ft. 10 in.	2-Axle Diesel	46.0	62.8	48.8	2.86	3.42	3.13
	3-Axle Diesel	46.0	31.0	25.1	3.39	3.34	3.12
	Class J	65.4	56.8	54.1	4.35	4.51	4.43
	Class E 4	65.4	50.4	44.6	5.20	5.09	4.89
	Class H	65.4	38.8	37.4	5.31	4.99	4.82
78 ft.	2-Axle Diesel	41.4	33.3	24.1	2.57	2.28	2.14
	3-Axle Diesel	41.4	17.4	10.1	3.25	2.95	2.72
	Class J	60.7	93.2	68.2	4.26	4.79	4.74
	Class E 4	60.7	49.1	42.2	4.02	4.62	4.27
	Class H	60.7	48.0	42.8	4.89	5.38	4.72

18. The maximum direct stresses recorded in the angles of the lateral bracing and crossframes of the 78-ft. deck girder span with the ballasted concrete floor are shown in Figs. 56 and 57 for both the diesel and steam locomotives. The stresses in the bottom lateral were larger than those recorded in the top laterals and all the stresses in these members are somewhat smaller than those recorded in the 71-ft. 10-in. span with the open timber floor.

19. Since the readings were secured under practically all the trains passing over the bridge during the test period, valuable data were secured on the frequency of occurrence of the maximum stresses. A summary of the maximum stresses recorded in one girder of each span and data on the frequency of the maximum stresses are shown on Figs. 58 to 63 incl. The average of the 6 girders on the 3 bridges indicates that only about 7 percent of the trains passing over the bridge produce stresses in the higher range.

2. Foreword

The bridge impact tests analyzed in this report were conducted in 1946 for AREA Committee 30—Impact and Bridge Stresses and were carried out under the direction of G. M. Magee, research engineer, Engineering Division, Association of American Railroads. The funds necessary for the tests were provided by the 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, assisted by A. A. Sirel, assistant structural engineer.

The second assignment of Committee 30 is Steel girder spans with open decks and with ballasted decks, and to secure data for this assignment the research staff arranged to conduct tests of various lengths and types of girder spans on several railroads where both diesel and steam locomotives are operating at high speeds.

An effort was made to select four girder spans of the same length consisting of one open-track span of light design, one open-track span of present-day design, one ballasted-track span of light design and one ballasted-track span of present-day design. Since these requirements could not be met and still have the bridges in high-speed territory, it was necessary to select bridges of various span lengths and capacity.

The three bridges tested on the Chicago and North Western Railway and analyzed in this report are on the main line between Chicago and Omaha where several diesel locomotives as well as high-speed steam locomotives are operating each day. All three of the bridges are in double-track territory. The first bridge tested is a 71-ft. 10-in deck girder span with an open timber floor, close to Rochelle, Ill. The second bridge is a

Fig. 1. General views of 70-ft. ¼-in. girder viaduct near Jefferson, Iowa.

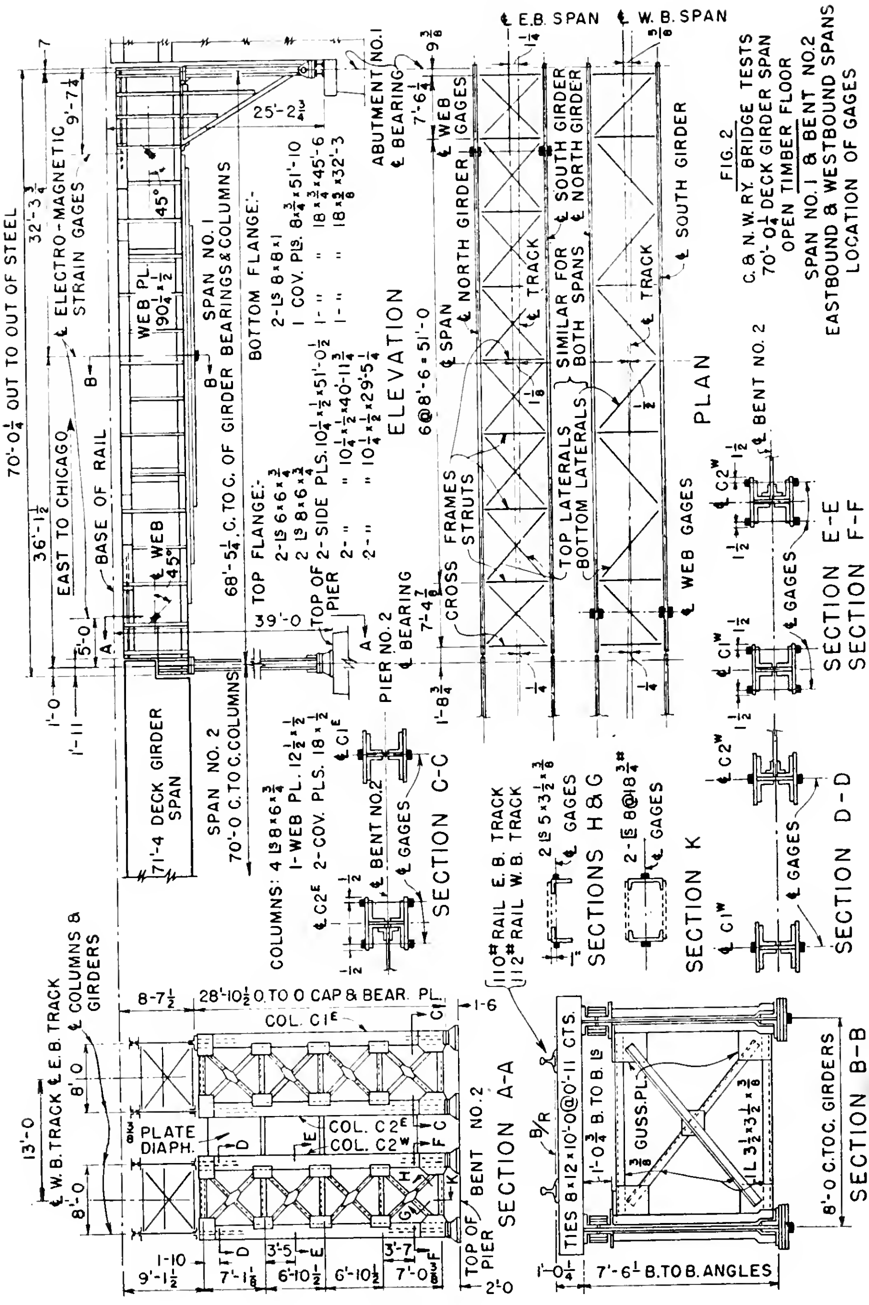


FIG. 2

C. & N. W. RY. BRIDGE TESTS
70'-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR
SPAN NO. 1 & BENT NO. 2
EASTBOUND & WESTBOUND SPANS
LOCATION OF GAGES

78-ft. deck girder span with a ballasted precast reinforced concrete floor, close to Morrison, Ill. The third bridge is a 70-ft. ¼-in. deck girder span viaduct with an open timber floor, close to Jefferson, Iowa.

The tests were conducted under regular scheduled trains since the effect on the stresses of any variation in the tender loads was quite small and easily adjusted. Arrangements were made with the operating department of the railway to have the trains cross the test bridge at various speeds, ranging from 5 mph., which is considered the same as static loading, to the maximum operating speed of the locomotive. Telephone service was provided between the bridge and the dispatcher by placing a telephone in the test building.

The general procedure in conducting the tests was first to erect the 6-ft. by 8-ft. sectional test building at one end of the bridge. The instruments were then placed in the test building, special care being taken to place the recording oscillographs and power unit on sponge rubber pads to eliminate any damage to the equipment from vibrations. The electromagnetic gages were individually calibrated and then erected on the steel. Recordings were then secured under both diesel and steam locomotives at all speeds, with the track in normal operating condition. No effort was made to determine the effect of a battered rail joint.

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 a maximum of 24 simultaneous stresses were recorded for each test run of the locomotive.

In order to secure readings on both the eastbound and westbound spans, gages were mounted on both spans and a system of switches employed whereby the oscillographs recorded the effects of the trains on either track.

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, such as the location for maximum stress in the flanges or in the webs, 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, for these tests a 1-in. deflection of the light trace on the film indicated a strain in the steel of 0.001 in. for the 2-in. gage length, which is equivalent to a unit stress of 15,000 psi., assuming a modulus of elasticity of 30,000,000 psi.

4. Test Spans and Location of Instruments

70-ft. ¼-in. Deck Girder Viaduct—Open Timber Floor: This structure, built in 1929 near Jefferson, Iowa, consists of six double track spans having two girders per track. The test girders in the end span are 70 ft. ¼ in. overall and 68 ft. 5¼ in. center to

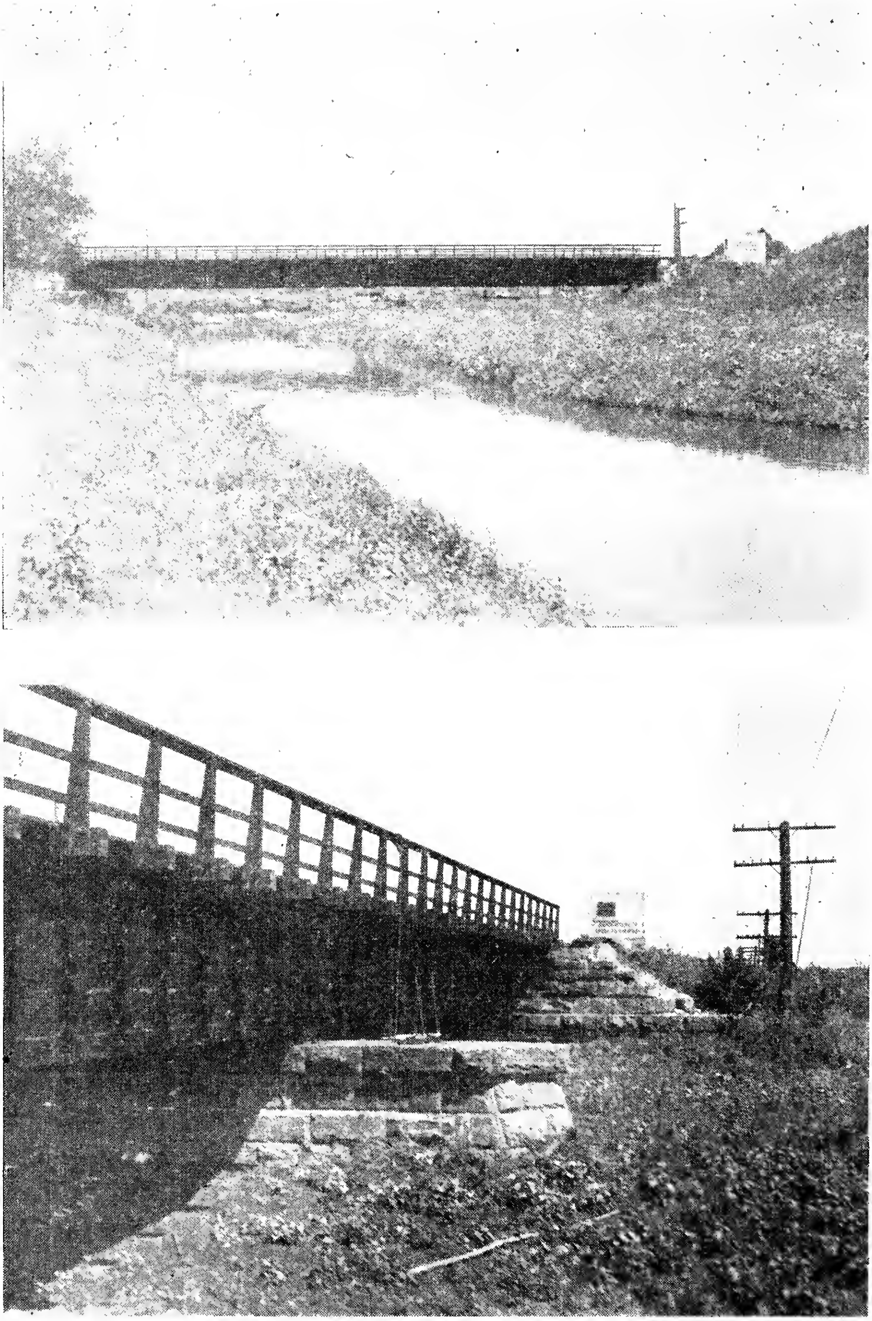


Fig. 3. General views of 71-ft. 10-in. deck girder span near Rochelle, Ill.

center of bearings, spaced at 8 ft. center to center of webs, as shown in Figs. 1 and 2. The girders are resting on viaduct columns and the distance from base of rail to top of pier is 39 ft. at the west end of the test span and 25 ft. 2¾ in. at the east end. The capacity of the girder spans, with the present open timber floor using gross section and the present AREA design stresses and impacts would be Cooper E 125. The girders were designed for a ballasted concrete floor, which accounts for the high rating. The center line of track on the eastbound span was off center 1⅛ in. to the south at the center of the span so that the south girder was carrying 51.2 percent of the total load and the north girder 48.8 percent. The center line of track on the westbound span was off center ½ in. to the south at the center of the span so that the south girder was carrying 50.5 percent of the total load and the north girder 49.5 percent.

The floor was of the open type, that is, the 8-in. by 12-in. by 10-ft. timber ties supporting the rail, rested directly on the top flanges of the girders and spaced at approximately 11-in. centers. The eastbound track was laid with 110-lb. rail and the westbound with 112-lb. Double-shoulder tie plates were used in both tracks.

The viaduct bents consist of four built-up columns spaced directly under the four girders, with the two center columns diaphragmed together for practically the entire height of the columns—see Fig. 2.

The electromagnetic strain gages were erected on various parts of the structure, such as the lower flanges of the girders close to the center of the span, the web plates at the ends of the spans, the viaduct columns, and bracing between the columns. The locations of the gages are shown in Fig. 2.

71-ft. 10-in. Deck Girder Span—Open Timber Floor: This structure, built in 1905 near Rochelle, Ill., consists of two double-track spans having two girders per track, as shown in Figs. 3 and 4. The girders under each track are 71 ft. 10 in. overall and 70 ft. 10 in. center to center of bearings spaced at 6 ft. 6 in. center to center of webs, and are supported by stone piers and abutments, as shown in Fig. 3. The capacity of the spans, using the gross section and the present AREA design stresses and impact would be Cooper E 75.3. The center line of track on the eastbound span was off center 9/16 in. to the north at the center of the span so that the north girder was carrying 50.7 percent of the total load and the south girder 49.3 percent. The center line of track on the westbound span was off center 1½ in. to the south at the center of the span so that the south girder was carrying 51.9 percent of the total load and the north girder 48.1 percent.

The floor was of the open type, that is, the 8-in. by 10-in. timber ties supporting the rail rested directly on the top flange of the girders. The rails were 112-lb., joined with four-hole angle bars, and rested on double-shoulder tie plates.

The strain gages were erected on various parts of the structure, such as the lower and top girder flanges close to the center of the span, and the web plates at the end and quarter-points of the span, as shown in Fig. 4. The gages were also placed on the angles comprising the top and bottom lateral bracing and the end and center cross frames, but the results of these tests have been previously reported in the Proceedings, Vol. 50, 1949.

It is recognized that the strains on a section through the rivet holes are not uniform across the section so the gages on the flanges were placed between the rivets, as shown, in views C–C and D–D, Fig. 4, to avoid any strain concentrations. The practice of placing the gages between the rivets was followed for all three structures.

78-ft. Deck Girder Span—Ballasted Concrete Floor: This structure, built in 1916 near Morrison, Ill., consists of one double-track span having two girders per track,

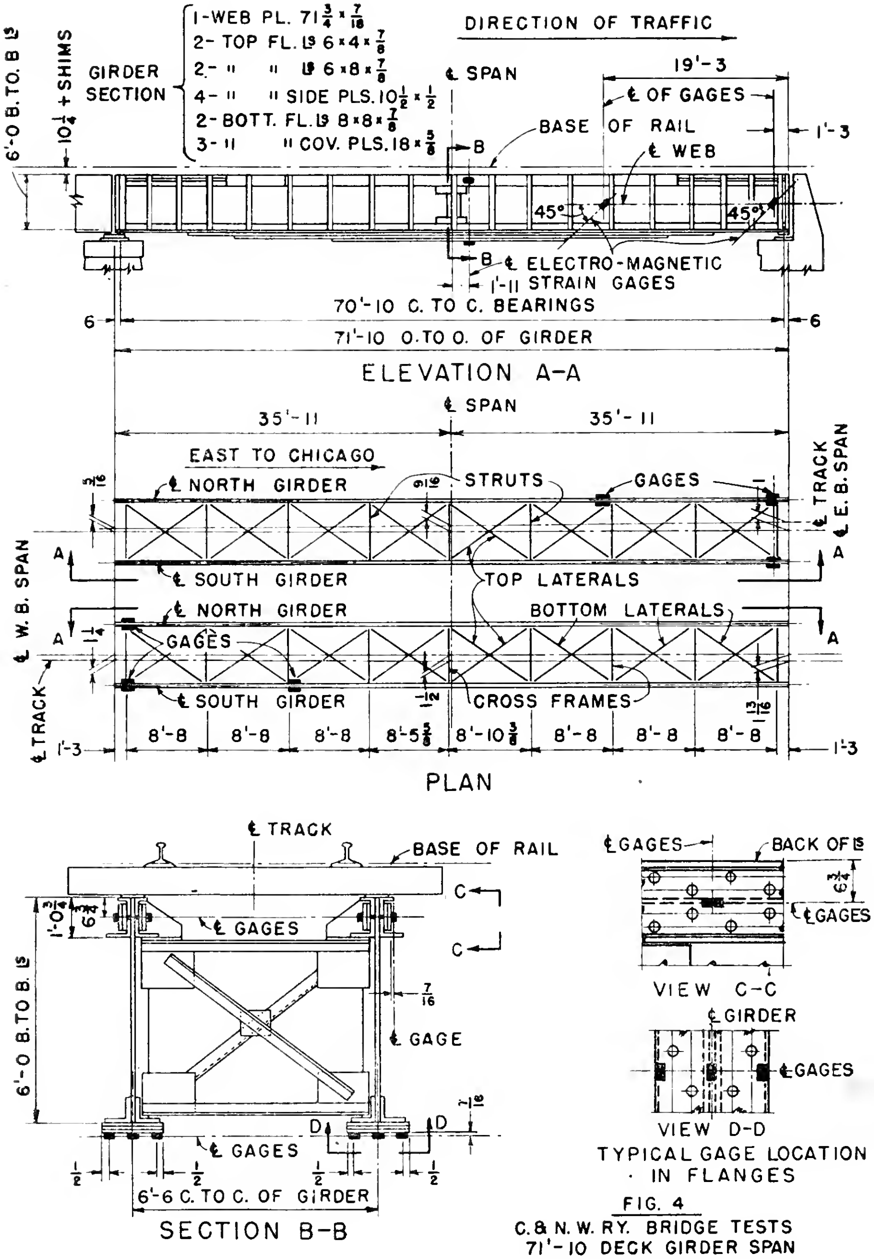


FIG. 4

C. & N. W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR

SPAN NO. 1
EASTBOUND AND WESTBOUND SPANS
LOCATION OF GAGES

112-LB. RAIL
4-HOLE ANGLE BARS
DOUBLE-SHOULDER TIE PLATES
8×10 TIES

Fig. 5. General view of 78-ft. deck girder span near Morrison, Ill.

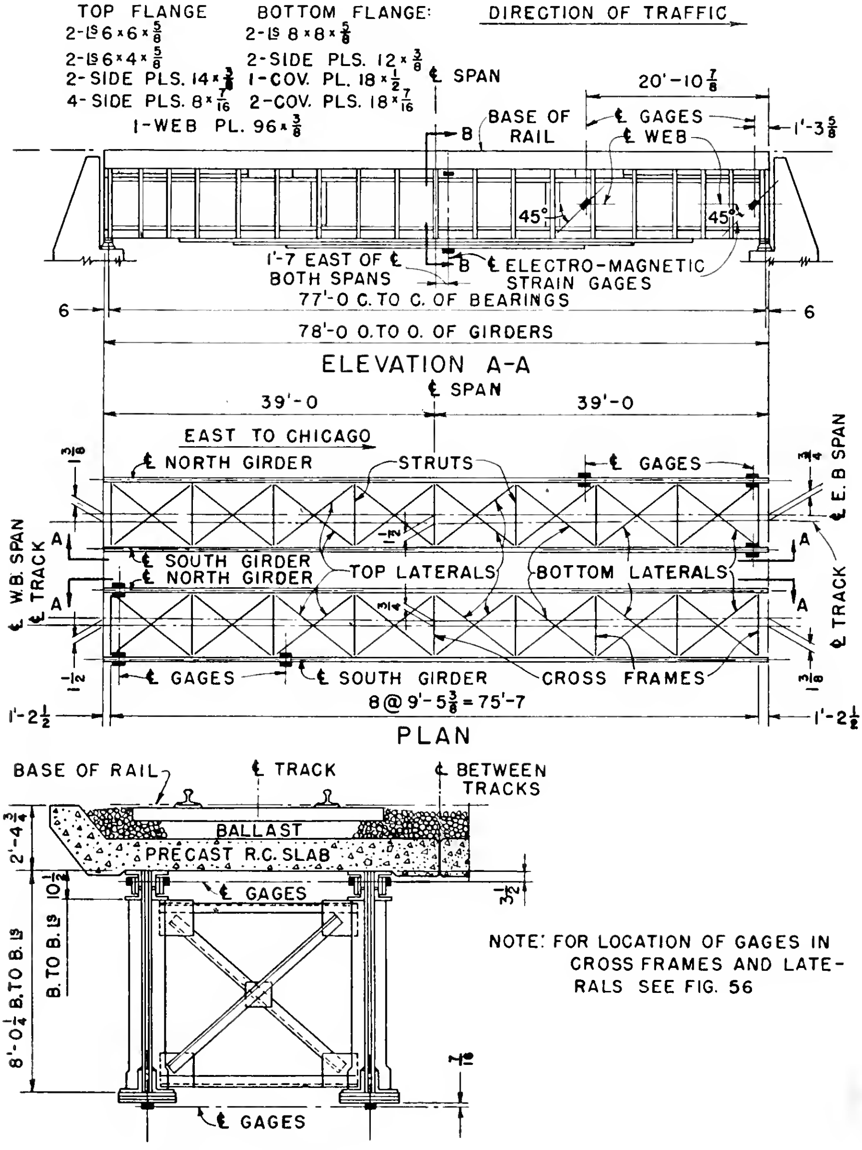
as shown in Figs. 5 and 6. The girders under each track are 78 ft. overall and 77 ft. center to center of bearings, spaced at 8 ft. center to center of webs, and are supported by stone abutments, as shown in Fig. 5. The capacity of the span, using the gross section and the present AREA design stresses and impact, would be Cooper E 66.3. The center line of track on the eastbound span was off center 1½ in. to the south at the center of the span so that the south girder was carrying 51.6 percent of the total load and the north girder 48.4 percent. The center line of track on the westbound span was off center ¾ in. to the north at the center of the span so that the north girder was carrying 50.8 percent of the total load and the south girder 49.2 percent.

The floor was of the ballasted type, that is, the track ties supporting the rail rested on 6 in. of gravel ballast. The ballast was supported by precast concrete slabs resting directly on the top flanges of the girders. Both tracks were laid with 112-lb. rail on double-shoulder tie plates.

The stain gages were erected on various parts of the structure, such as the bottom and top flanges close to the center of the span and the web plates at the end and quarter points of the span, as shown in Fig. 6. The gages were also placed on the angles comprising the cross frames and lateral bracing, as shown on Fig. 56.

5. Test Trains

The tests were conducted, as previously stated, under regularly scheduled trains. The locomotive numbers were recorded as the train passed over the bridge and the locomotives were then grouped for analysis of data, according to their classes. A record was maintained of the amount of coal and water required to fill the tender at the next



NOTE: FOR LOCATION OF GAGES IN CROSS FRAMES AND LATERALS SEE FIG. 56

112-LB. RAIL
DOUBLE-SHOULDER TIE PLATES

FIG. 6
C.& N.W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
EASTBOUND AND WESTBOUND SPANS
LOCATION OF GAGES

service stop past the bridge, but the corrections to the calculated stresses for a partially filled tender were negligible for these lengths of spans.

The necessary information regarding all the locomotives used in these tests, such as axle weights, axle spacing, nominal wheel diameters, and all information required to calculate the components and resultant unbalanced weights on the driving wheels of the steam locomotives was furnished by the mechanical department of the railroad. The diagrams of all the locomotives used in these tests, except the Mikado type 2–8–2, have been shown in past reports, but in order to facilitate the study of this report, the locomotives axle weights and axle spacings are shown on each diagram of impact effects.

A general description of all the locomotives under which test records were obtained is as follows:

Diesel-Electric—2400 hp.:—The locomotives of this class are used in passenger service and their diagram can be found in the Proceedings, Vol. 44, 1943, page 52. The rating of the locomotives of this class, in terms of Cooper loading for moment at the center of the spans, varies from E 31.7 to E 36.8, as shown in Table 1.

Diesel-Electric—4000 hp.:—The locomotives of this class are used in passenger service and their diagram can be found in the Proceedings, Vol. 44, 1943, page 52. The rating of the locomotives of this class, in terms of Cooper loading for moment at the center of the spans, varies from E 38.4 to E 39.6, as shown in Table 1.

Steam Locomotive—Hudson Type 4–6–4 (Class E4):—The locomotives of this class are used in passenger service and their diagram and counterbalancing data can be found in the Proceedings, Vol. 46, 1945, page 238. The rating of these locomotives, in terms of Cooper loading for moment at the center of the spans, varies from E 58.1 to E 58.8, as shown in Table 1.

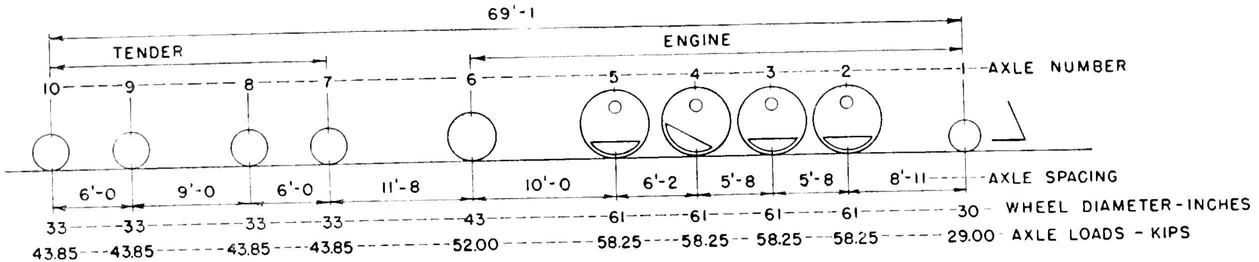
These locomotives have an average reciprocating unbalance per side per ton of locomotive weight in working order of 5.96 lb. and an average reciprocating compensation of 38 percent. The main drivers are crossbalanced while the front and rear drivers are straight balanced. The average calculated hammer-blow stresses in the three test spans, based on the gross section at the center of the span, at one revolution per second, are shown in Table 2.

Steam Locomotive—Northern Type 4–8–4 (Class H):—The locomotives of this class are used in freight service and their diagram and counterbalancing data can be found in the Proceedings, Vol. 46, 1945, page 239. The ratings of these locomotives, in terms of Cooper loading for moment at the center of the spans, varies from E 63.6 to E 65.9, as shown in Table 1.

These locomotives have an average reciprocating unbalance per side per ton of locomotive weight in working order of 6.76 lb. and an average reciprocating compensation of 29 percent. The main and intermediate drivers are crossbalanced while the front and rear drivers are straight balanced. The average calculated hammer-blow stresses in the three test spans, based on the gross section at the center of the span, at one revolution per second, are shown in Table 2.

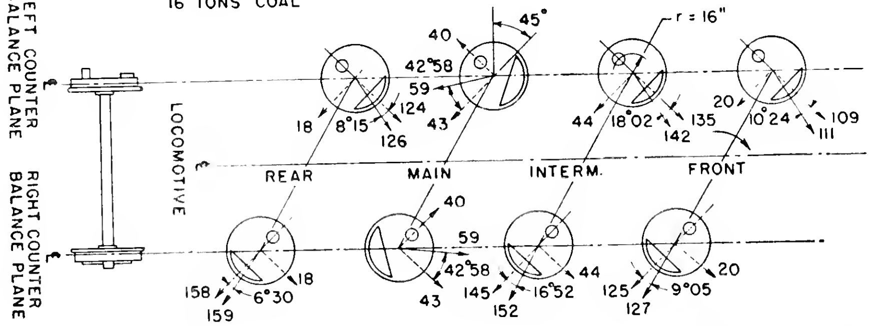
Steam Locomotive—Mikado Type 2–8–2 (Class Js):—The locomotives of this type are used in freight service and all general data regarding them are shown in Fig. 7. The ratings of these locomotives, in terms of Cooper loading for moment at the center of the spans, varies from E 49.5 to E 50.3, as shown in Table 1.

These locomotives have an average reciprocating unbalance per side per ton of locomotive weight in working order of 6.28 lb. and an average reciprocating compensation of 24 percent. These locomotives were originally purchased with all the drivers straight balanced, with about 66 percent reciprocating compensation, but within recent years the main drivers were crossbalanced and the reciprocating compensation materially



TENDER CAPACITY:
8265 GALS. WATER
16 TONS COAL

TOTAL WEIGHT OF LOCOMOTIVE IN WORKING ORDER - POUNDS	489,000
AVERAGE RECIPROCATING WEIGHT PER SIDE - POUNDS	2,022
AVERAGE RECIPROCATING COMPENSATION PER SIDE-POUNDS	483
AVERAGE RECIPROCATING UNBALANCE PER SIDE - POUNDS	1,539
AVERAGE RECIPROCATING UNBALANCE PER SIDE PER 1000 LB. OF LOCOMOTIVE WEIGHT IN WORKING ORDER - POUNDS	6.28
AVERAGE RECIPROCATING COMPENSATION	.024



COMPONENTS AND RESULTANT UNBALANCED WEIGHTS IN POUNDS

HAMMER BLOW AT ONE REVOLUTION PER SECOND

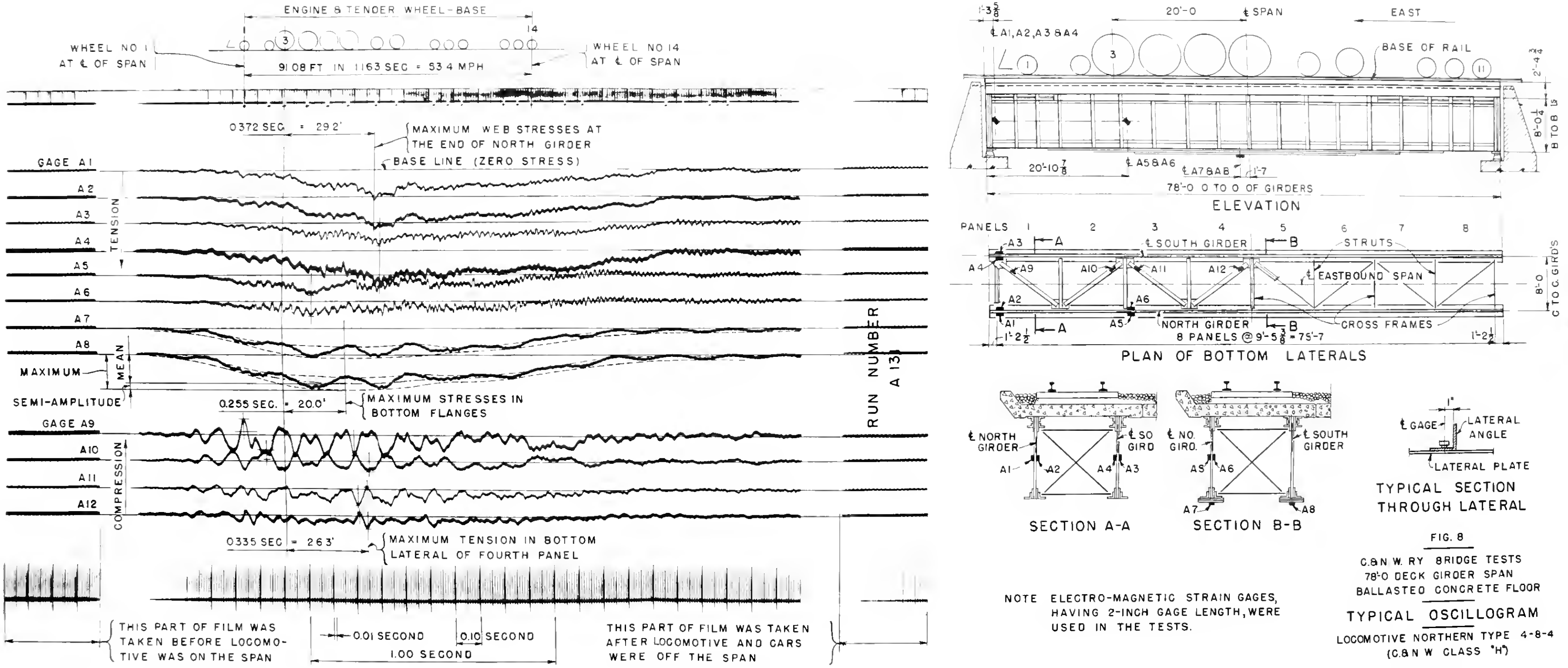
	LEFT SIDE	RIGHT SIDE
FRONT DRIVER	181	207
INTERM. DRIVER	231	248
MAIN DRIVER	96	96
REAR DRIVER	206	259

RECIPROCATING COMPENSATION

	LEFT SIDE	RIGHT SIDE
FRONT DRIVER	129	145
INTERM. DRIVER	179	189
MAIN DRIVER	3	3
REAR DRIVER	142	176
TOTAL	453	513
AVERAGE	483	

RECIPROCATING WEIGHTS
AVERAGE FOR ONE SIDE
TOTAL = 2022

FIG. 7
C. & N. W. RY. BRIDGE TESTS
LOCOMOTIVE DATA
MIKADO TYPE 2-8-2
C. & N. W. RY. CLASS JS
LOCOMOTIVE NO. 2517



NOTE ELECTRO-MAGNETIC STRAIN GAGES, HAVING 2-INCH GAGE LENGTH, WERE USED IN THE TESTS.

FIG. 8

C.&N.W. RY BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR

TYPICAL OSCILLOGRAM

LOCOMOTIVE NORTHERN TYPE 4-8-4
(C.&N.W. CLASS "H")

CHICAGO AND NORTH WESTERN RAILWAY BRIDGE TESTS
TABLE 1
RATING OF TEST LOCOMOTIVES

LOCOMOTIVE CLASS	DECK GIRDER SPANS		
	70'-0$\frac{1}{4}$ OPEN TIMBER FLOOR	71'-10 OPEN TIMBER FLOOR	78'-0 CONCRETE FLOOR BALLASTED
2-AXLE DIESELS	E-36.8	E-31.8	E-31.7
3-AXLE DIESELS	E-38.8	E-38.4	E-39.6
CLASS-J	E-49.5	E-50.3	E-49.7
CLASS-E4	E-58.1	E-58.5	E-58.8
CLASS-H	E-63.6	E-65.3	E-65.9

TABLE 2
CALCULATED HAMMER BLOW STRESSES

LOCOMOTIVE CLASS	DECK GIRDER SPANS		
	70'-0$\frac{1}{4}$ OPEN TIMBER FLOOR	71'-10 OPEN TIMBER FLOOR	78'-0 CONCRETE FLOOR BALLASTED
CLASS - J	0.0162	0.0247	0.0222
CLASS - E4	0.0229	0.0359	0.0306
CLASS - H	0.0221	0.0394	0.0306

NOTE: HAMMER BLOW STRESSES AT 1.0 RPS. ARE GIVEN IN KIPS PER SQUARE INCH

reduced in all the drivers. The average calculated hammer-blow stresses in the three test spans, based on the gross section at the center of the span, at one revolution per second, are shown in Table 2.

6. Analysis of Field Records

Test Records

The test records or oscillograms were photographed on sensitized paper 10 in. wide and 200 ft. long. Each oscillogram was marked with the name of the railroad, bridge number and date. The oscillograph and run number, which is protographed 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 inclusion of all the test records, consisting of 972 oscillograms for the 486 test runs, would have made this report too voluminous, so only a typical oscillogram is included, as shown in Fig. 8. All of the oscillograms are now on file in the AAR Central Research Laboratory, at Chicago.

Reading of Oscillograms

For an analysis of the oscillograms it was first necessary to find the base lines representing zero stress. As shown on the typical oscillogram for the steam locomotive (see Fig. 8), the first 2 or 3 in. of the record were taken before the locomotive reached the span; the oscillographs were then started just as the locomotive reached the test span and continued until the locomotive and tender were off the span. The final 2 or 3 in. of oscillogram were then taken after the entire train had passed over the span. Base lines, representing zero stress, were then drawn from one side of the light trace for all the gages connecting the two "no load" parts of the record. Light dash pencil lines were drawn on the records indicating the upper and lower envelope curves through the peaks of the oscillations on the traces from the gages on the center of the lower flanges and on the web plates. The mean stress curves for the slow locomotive speeds represent the static stress at the gage location for the different positions of the locomotive as it passes over the span. Hence, the average of the greatest mean stresses for the slow-speed runs of 10 mph. and under was used in arriving at the recorded static stresses.

The semi-amplitudes of stress or the difference between the upper envelope curve and the mean stress curve (see Fig. 8), are produced by irregularities of the track and the effect of the locomotive hammer blow. At slow speeds of about one revolution per second of the steam locomotive drivers, the effect of the hammer blow in producing oscillations is negligible so that the semi-amplitudes of stress are almost entirely due to the track or wheel condition. At higher speeds the effect of the hammer blow in producing oscillations in the structure increases rapidly. At or near synchronous speed the oscillations keep building up until they reach a maximum, which usually occurs at the time of maximum mean stress. It has been interesting to note from the oscillograms that the frequency of these oscillations coincides with the speed of the locomotive drivers in revolutions per second as the theory predicts.

Stress Corrections

The center of gravity of the "air gap" on the magnetic strain gage being 0.44 in. from the base, the strains were correspondingly recorded on a plane 0.44 in. from the surface of the steel. The stresses recorded in the lower flanges of the girders were corrected by assuming that the stress is proportional to the distance from the neutral axis. The stresses recorded by the gages on the web plates were not corrected as the average of the maximum simultaneous stress was used for these readings, thus eliminating all bending effects in the web plates from the test results. It was not necessary to correct the stresses in the lateral bracing as the gages were placed on the inside of the angles close to the neutral axis, hence, only the direct stresses were recorded. The only correction required to the stresses recorded in the columns of the viaduct was that resulting from the bending of the members.

Tabulation of Stresses

The mean, semi-amplitude and maximum galvanometer deflections from the gages on the lower flanges and the web plates, and only the maximum deflections from the remaining gages were scaled from the oscillograms and tabulated. The stresses were then determined for each gage by multiplying the galvanometer deflections by the individual stress factor determined from the calibration of the gages and based upon a modulus of elasticity of 30,000,000 psi. The locomotive's speed and the position of the first driver on the bridge at the instant of recorded stress are also shown on the tabulation sheets.

Tables were then prepared for each test member showing the various static and dynamic effects in the member. The effects were tabulated according to locomotive classes and in order of speeds for each test span.

The tables containing all the data taken from the film and entitled "Tabulation of Recorded Stresses" and "Analysis of Strain Gage Readings" are on file in the AAR Central Research Laboratory.

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 static stresses in the lower flanges and web plates of the girders and in the columns of the viaduct were determined from the maximum mean stresses secured under slow-speed runs of approximately five mph. for each locomotive class. The static stress in the girder flanges was the greatest mean stress recorded by the one gage on the lower flange of each girder, while the static stress in the girder webs was the average of the greatest mean stresses recorded by the two gages on the web plate at each location. The static stress in the columns of the viaduct near Jefferson, Iowa, was the average of the greatest mean stresses recorded by either the two or four gages on the columns at each location.

The static stresses in the flanges, webs and columns under the different locomotive classes 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 stress. Concentrated wheel loads were used in computing the bending moment and the stresses are based upon the gross moment of inertia of the section.

70-ft. ¼-in. Deck Girder Span—Open Timber Floor:—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 in the lower flanges of the girders close to the center of the span and in the web plates of the girder close to the end of the span, is shown in Table 3. The static stresses recorded in each girder and the average of the two girders are shown in Columns 5, 6 and 7 of this table, while the calculated static stresses are shown in Column 8. The recorded static stresses in the lower flanges of the girders under the westbound track are about 8 percent greater than those calculated; but under the eastbound track, the recorded stresses are about 11 percent lower than the calculated. The difference in the calculated static stresses between the westbound span and the eastbound span under the same locomotive classes is due to a slightly different locomotive position producing maximum recorded stresses, indicating some unequal distribution of the axle loads.

The recorded and calculated static live-load stresses in the web plates close to the end of the span are shown in the lower part of Table 3, and are the maximum tensile stresses occurring at the center height of the web on a 45-deg. angle with the horizontal,

CHICAGO AND NORTH WESTERN RAILWAY BRIDGE TESTS
70'-0$\frac{1}{4}$ DECK GIRDER SPAN - OPEN TIMBER FLOOR
TABLE 3
COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES-GIRDERS, SPAN NO. 1

TYPE OF STRESS	SPAN	TEST LOCOMOTIVE		RECORDED STATIC STRESS			AVERAGE CALCULATED STATIC STRESS	STRESS FACTOR = RECORDED / CALCULATED	
		CLASS	NUMBER	NORTH GIRDER	SOUTH GIRDER	AVERAGE			
COL. 1	2	3	4	5	6	7	8	9	10
BENDING MOMENT AT CENTER OF SPAN	WEST BOUND TRACK	2-AXLE DIESEL	CO-06	2.76	3.45	3.11	2.86	1.09	1.09
		J	2386 2461	3.98 3.46	5.45 4.45	4.72 3.96	4.08	1.16 0.97	1.08
		E-4	4005	4.89	5.68	5.29	4.82	1.10	
		H	3027	5.41	6.11	5.76	5.38	1.07	
	EAST BOUND TRACK	J	2414	3.37	3.80	3.59	4.14	0.87	0.89
		E-4	4003	3.81	4.59	4.20	4.74	0.89	
		H	3024	4.15	5.25	4.70	5.09	0.92	
WEB SHEAR AT END OF SPAN	WEST BOUND TRACK	2-AXLE DIESEL	CO-06	2.43	2.50	2.47	1.93	1.28	1.28
		J	2386 2461	3.56 2.96	3.62 2.71	3.59 2.84	3.01	1.19 0.94	1.10
		E-4	4005	4.20	3.77	3.99	3.34	1.19	
		H	3027	3.90	3.98	3.94	3.61	1.09	
	EAST BOUND TRACK	J	2414	2.89	3.65	3.27	2.68	1.22	1.21
		E-4	4003	3.10	3.81	3.46	2.81	1.23	
		H	3024	3.52	4.43	3.98	3.38	1.18	

NOTE: STRESSES SHOWN ARE TENSION VALUES IN KIPS PER SQUARE INCH.

TABLE 4
COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES-COLUMNS, BENT NO. 2

SEE FIG. 1		TEST LOCOMOTIVE		RECORDED STATIC STRESS			AVERAGE CALCULATED STATIC STRESS	STRESS FACTOR = RECORDED / CALCULATED	
MEMBER	SECTION	CLASS	NUMBER	OUTSIDE COLUMN	INSIDE COLUMN	AVERAGE			
COL. 1	2	3	4	5	6	7	8	9	10
WEST BOUND COLUMNS C1^W & C2^W	F-F	2-AXLE DIESEL	—	1.93	1.87	1.90	1.71	1.11	1.11
		J	2386 2461	2.40 2.60	2.45 2.58	2.43 2.59	2.99	0.81 0.87	0.87
		E-4	4005	3.86	3.40	3.63	4.03	0.90	
		H	3027	3.87	3.51	3.69	4.14	0.89	
	D-D	J	2461	3.00	3.00	3.00	2.99	1.00	1.08
		E-4	4005	4.05	4.42	4.24	3.81	1.11	
		H	3027	4.75	4.48	4.62	4.10	1.13	
	E-E	J	2386	2.39	1.61	2.00	2.66	0.75	0.75
EAST BOUND COLUMNS C1^E & C2^E	C-C	J	2414	3.23	2.54	2.89	2.92	0.99	1.01
		E-4	4003	4.82	3.76	4.29	3.94	1.09	
		H	3024	4.50	3.34	3.92	4.08	0.96	

NOTE: STRESSES SHOWN ARE COMPRESSON VALUES IN KIPS PER SQUARE INCH.

The recorded stresses were greater than those calculated in both the eastbound and westbound spans. The difference in the calculated static stresses between the westbound span and the eastbound span under the same locomotive classes is due to the different location of the gages on the two spans (see Fig. 2).

The recorded and calculated static live-load direct stresses in the viaduct columns of bent 2 are shown in Table 4. There is fair agreement between the recorded and calculated stresses in these columns, except at Section E–E where the effect of the diaphragm in reducing the stresses in the inside column is very pronounced.

The recorded and calculated static stresses in this structure are quite low since it has a capacity rating, as previously mentioned, of Cooper E 125, and any variation in the recorded stresses has a marked influence in the stress factors.

71-ft. 10-in. Deck Girder Span—Open Timber Floor:—The comparison of the recorded and calculated live-load static stresses and the stress factors in the lower flanges

TABLE 5
CHICAGO AND NORTH WESTERN RAILWAY BRIDGE TESTS
71-FT. 10-IN. DECK GIRDER SPAN-OPEN TIMBER FLOOR
COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES

TYPE OF STRESS	SPAN	TEST LOCOMOTIVE		RECORDED STATIC STRESS			AVERAGE CALCULATED STATIC STRESS	STRESS FACTOR = RECORDED / CALCULATED	
		CLASS	NUMBER	NORTH GIRDER	SOUTH GIRDER	AVERAGE			
COL. 1	2	3	4	5	6	7	8	9	10
BENDING MOMENT AT CENTER OF SPAN	EAST BOUND TRACK	2-AXLE DIESEL		5.43	4.49	4.96	4.20	1.18	1.14
		3-AXLE DIESEL		6.10	5.00	5.55	5.01	1.11	
		R 1	936	5.20	4.24	4.72	4.68	1.01	0.98
		J	2523	6.56	5.90	6.23	6.61	0.94	
			2512	7.24	5.91	6.58	6.61	0.99	
		J 4	2802	8.15	6.55	7.35	8.03	0.92	
		E	1653	5.88	5.26	5.57	5.55	1.00	
		E 4	4004	8.36	7.18	7.77	7.58	1.03	
		H	3002	8.59	7.44	8.02	8.58	0.93	
			3016	8.59	7.96	8.28		0.97	
	WEST BOUND TRACK	2-AXLE DIESEL		4.46	4.00	4.23	4.18	1.01	1.05
		3-AXLE DIESEL		5.28	5.09	5.19	4.72	1.10	
		J	2561	6.68	5.81	6.25	6.59	0.95	0.96
		J 4	2812	7.93	7.09	7.51	7.98	0.94	
		E 4		7.65	7.08	7.37	7.73	0.95	
		H	3006	9.19	8.18	8.69	8.59	1.01	
WEB SHEAR AT END OF SPAN	EAST BOUND TRACK	2-AXLE DIESEL		4.59	4.74	4.67	3.37	1.39	1.39
		3-AXLE DIESEL		5.27	5.49	5.38	3.85	1.39	
		R 1	936	4.63	5.00	4.81	3.45	1.39	1.32
		J	2523	6.59	6.72	6.65	4.64	1.43	
			2535	5.16	6.79	5.98		1.29	
		J 4	2802	7.26	6.92	7.09	5.90	1.20	
		E	1653	5.65	6.17	5.91	4.67	1.27	
		E 4	4004	7.81	7.94	7.87	5.99	1.32	
		H	3002	8.25	8.77	8.51	6.32	1.35	
			3016	7.81	8.65	8.23	6.32	1.32	
	WEST BOUND TRACK	2-AXLE DIESEL		3.08	3.35	3.22	3.23	1.00	0.99
		3-AXLE DIESEL		3.85	4.21	4.03	4.18	0.97	
		J	2561	4.83	5.47	5.15	5.20	0.99	1.08
		J 4	2812	5.54	6.44	5.99	5.83	1.03	
		E 4	4005	5.46	6.52	5.99	5.83	1.03	
		H	3006	6.93	7.96	7.45	5.94	1.25	
WEB SHEAR AT QUARTER POINT OF SPAN	EAST BOUND TRACK	2-AXLE DIESEL		2.10			2.08	1.01	1.07
		3-AXLE DIESEL		2.55			2.28	1.12	
		R 1	936	2.11			1.77	1.19	1.10
		J	2523	2.77			2.70	1.03	
			2535	2.85				1.05	
		J 4	2802	3.10			2.63	1.18	
		E	1653	2.70			2.15	1.26	
		E 4	4004	3.45			3.20	1.08	
		H	3002	3.37			3.34	1.01	
			3016	3.37				1.01	
	WEST BOUND TRACK	2-AXLE DIESEL			2.10		1.83	1.15	1.10
		3-AXLE DIESEL			2.50		2.36	1.06	
		J	2561		2.88		2.56	1.12	1.09
		J 4	2812		3.03		3.20	0.95	
		E 4	4005		3.19		3.08	1.04	
		H	3006		3.79		3.07	1.24	

NOTE: STRESSES SHOWN ARE TENSION VALUES IN KIPS PER SQUARE INCH

TABLE 6

CHICAGO AND NORTH WESTERN RAILWAY BRIDGE TESTS

71-FT. 10-IN. DECK GIRDER SPAN-OPEN TIMBER FLOOR

COMPARISON OF TOP AND BOTTOM FLANGE RECORDED STRESSES

SPAN	TEST LOCOMOTIVE			NORTH GIRDER				SOUTH GIRDER			
	CLASS	NUMBER	SPEED MPH.	TOP FLANGE	BOTTOM FLANGE	VARIATION FROM BOTTOM FLANGE		TOP FLANGE	BOTTOM FLANGE	VARIATION FROM BOTTOM FLANGE	
						STRESS	PERCENT			STRESS	PERCENT
COL. 1	2	3	4	5	6	7	8	9	10	11	12
EAST BOUND TRACK	2-AXLE DIESEL		28.2	-5.62	+5.73	-0.11	-1.9	-5.72	+4.81	+0.91	+18.9
			42.0	-6.04	+5.73	+0.31	+5.4	-6.36	+5.07	+1.29	+25.4
	3-AXLE DIESEL		27.7	-6.30	+5.73	+0.57	+10.0	-6.36	+4.93	+1.43	+29.0
			72.2	-7.14	+6.18	+0.96	+17.1	-7.19	+5.32	+1.87	+35.2
	J	2416	13.5	-7.80	+7.56	+0.24	+3.2	-8.40	+6.49	+1.91	+29.4
		2513	37.4	-9.11	+9.39	-0.28	-3.0	-8.72	+7.79	+0.93	+11.9
		2535	47.1	-9.28	+8.70	+0.58	+6.7	-8.90	+7.14	+1.76	+24.7
	J4	2808	43.5	-10.86	+8.70	+2.16	+24.8	-11.16	+8.70	+2.46	+28.3
		2807	44.2	-10.62	+10.08	+0.54	+5.4	-10.86	+8.96	+1.90	+21.2
	E	1648	72.2	-8.84	+8.47	+0.37	+4.4	-7.64	+6.10	+1.54	+25.2
	E2B	2901	77.5	-9.05	+7.78	+1.27	+16.3	-8.45	+6.75	+1.70	+25.2
	E4	4004	3.2	-8.70	+8.70	0.0	0.0	-8.98	+7.53	+1.45	+19.3
	H	3002	2.4	-9.18	+8.93	+0.25	+2.8	-9.54	+7.66	+1.88	+24.7
		3009	63.0	-11.81	+11.00	+0.81	+7.4	-11.78	+9.48	+2.30	+24.2
		3005	76.6	-11.28	+10.78	+0.50	+4.6	-10.80	+9.48	+1.32	+13.9

NOTE: STRESSES SHOWN ARE IN KIPS PER SQUARE INCH

COLS. 5, 6, 9, AND 10. THE STRESSES RECORDED AT THE GAGE POSITIONS HAVE BEEN CORRECTED FOR THE DISTANCE FROM THE NEUTRAL AXIS TO ARRIVE AT THE EXTREME FIBER STRESSES SHOWN.

COLS. 7, 8, 11, AND 12. A POSITIVE SIGN IN THESE COLUMNS MEANS THAT THE TOP FLANGE STRESS IS GREATER THAN THE BOTTOM FLANGE STRESS BY THE AMOUNT SHOWN.

COLS. 8 AND 12. THE CALCULATED TOP FLANGE STRESS IS 9.6 PERCENT GREATER THAN THE BOTTOM FLANGE STRESS BECAUSE OF THE LOCATION OF THE NEUTRAL AXIS.

of the girders close to the center of the span, in the web plates of both girders close to the end of the span and in the web plate of one girder close to the quarter point. are shown in Table 5.

The difference between the recorded and calculated static stresses in the lower flanges is quite small for this bridge, especially for the heavier steam locomotives where there is only 2 percent difference in the eastbound span and 4 percent in the westbound span.

The static live-load stresses recorded in the web plates at the east end of the eastbound span are appreciably greater than those calculated for both the diesel and steam locomotives; being 39 percent greater for the diesels and 32 percent for the steam. The recorded stresses in the westbound span are about the same as those calculated.

The stresses in the web plates close to the quarter point were measured in only one girder of each span, so the data is not complete on the shears at this location; however, it can be seen from the lower part of Table 5 that there was good agreement between the recorded static stresses and the calculated stresses in the one girder of each span. The low recorded and calculated static stresses in the web plates at the quarter points are the result of using the same thickness of web plate for the entire girder, which is common practice.

CHICAGO AND NORTH WESTERN RAILWAY BRIDGE TESTS
78'-0 DECK GIRDER SPAN – BALLASTED CONCRETE FLOOR
TABLE 7

COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES

TYPE OF STRESS	SPAN	TEST LOCOMOTIVE		RECORDED STATIC STRESS			AVERAGE CALCULATED STATIC STRESS	STRESS FACTOR RECORDED / CALCULATED	
		CLASS	NUMBER	NORTH GIRDER	SOUTH GIRDER	AVERAGE			
1	2	3	4	5	6	7	8	9	10
BENDING MOMENT AT CENTER OF SPAN	EAST BOUND TRACK	2-AXLE DIESEL	CD07	3.67 3.85	3.04 3.84	3.36 3.84	3.73	0 90 1.03	0.93
		3-AXLE DIESEL	927	4.19	4.10	4.15	4.80	0.87	
		J	2496	5.42	5.04	5.23	6.04	0 87	0.85
		E-4	4009	6.11	6.23	6.17	7.26	0 85	
		H	3004 3032	6.81 6.81	6.88 6.61	6.85 6.71	8.02	0 85 0 84	
	WEST BOUND TRACK	J	2499	4 68	5.76	5.22	6.00	0.87	0 84
		H	3012	5.80	6.79	6 30	7.90	0 80	
WEB SHEAR AT END OF SPAN	EAST BOUND TRACK	2-AXLE DIESEL	CD07	2.12 2.38	2.51 2.85	2.32 2.62	2.82	0.82 0 93	0.87
		3-AXLE DIESEL	927	2.81	3.45	3.13	3 69	0 85	
		E-4	4009	4 08	4 75	4 42	5.05	0.88	0.84
		J	2496	3.14	4.00	3.57	4 63	0.77	
		H	3032	4.63	5.28	4.96	5 69	0 87	
	WEST BOUND TRACK	J	2499	4.22	3.91	4 07	4 80	0 85	0.86
		H	3012	4.82	4 90	4 86	5 62	0 87	
WEB SHEAR AT QUARTER POINT OF SPAN	EAST BOUND TRACK	2-AXLE DIESEL	CD07	1.71 1.42			1.82	0.94 0 78	0.90
		3-AXLE DIESEL	927	2.24			2 30	0 98	
		J	2496	2 40			2 67	0.90	0.99
		E-4	4009	2 69			2.50	1 08	
		H	3032	3 00			3.07	0.98	
	WEST BOUND TRACK	J	249C	—	2.98		2.62	1.14	1.13
		H	3012	—	3.36		3.01	1 12	

NOTE: STRESSES SHOWN ARE TENSION VALUES IN KIPS PER SQUARE INCH.

The simultaneous stresses recorded in the top and bottom flanges of each girder under various locomotive classes are shown in Table 6. The top flange stresses are the average of two gage readings on each girder after correcting for the distance of 6¾ in. from the gage position to the back of the angle to arrive at the stress in the extreme fiber of the flange. The average of all the readings in this table indicates that the top flange of the north girder is stressed 6.9 percent greater than the lower flange, while the top flange of the south girder is 23.8 percent greater than the lower flange, an average of 15.3 percent for both girders. It can be seen from Fig. 4 that the flanges of these girders are not symmetrical so the calculated stress in the top flange in flexure should be 9.6 percent greater than the bottom flange. It appears that the top flange is stressed slightly more than the calculated amount.

The small increase in the top flange stresses over the bottom flange stresses could be the result of frictional restraint against movement of the end bearings resulting in some such action of the span.

78-ft. Deck Girder Span—Ballasted Concrete Floor:—The comparison of the recorded and calculated live-load static stresses and the stress factors in the lower flanges of the girders close to the center of the span, in the web plates of both girders close to the end of the span, and in the web plate of one girder close to the quarter point are shown in Table 7.

TABLE 6

COMPARISON OF TOP AND BOTTOM FLANGE RECORDED STRESSES

SPAN	TEST LOCOMOTIVE			NORTH GIRDER				SOUTH GIRDER			
	CLASS	NUMBER	SPEED MPH.	TOP FLANGE	BOTTOM FLANGE	VARIATION FROM BOTTOM FLANGE		TOP FLANGE	BOTTOM FLANGE	VARIATION FROM BOTTOM FLANGE	
						STRESS	PERCENT			STRESS	PERCENT
COL. 1	2	3	4	5	6	7	8	9	10	11	12
EAST BOUND TRACK	2-AXLE DIESEL	CD07	5.8	- 3.65	+ 3.67	- 0.02	- 0.5	- 3.27	+ 3.17	+ 0.10	+ 32
		"	31.1	- 3.58	+ 3.67	- 0.09	- 2.5	- 3.51	+ 3.31	+ 0.20	+ 6.0
		"	38.6	- 3.90	+ 4.01	- 0.11	- 2.7	- 3.58	+ 4.23	- 0.65	- 15.3
		5402	45.0	- 4.54	+ 4.36	+ 0.18	+ 4.1	- 4.29	+ 4.38	- 0.09	- 2.1
	3-AXLE DIESEL	904	30.2	- 4.38	+ 3.85	+ 0.53	+ 13.8	- 3.81	+ 4.23	- 0.42	- 9.9
		5009	79.5	- 4.47	+ 4.19	+ 0.28	+ 6.7	- 4.21	+ 4.38	- 0.17	- 3.9
		5009	90.0	- 4.79	+ 4.37	+ 0.42	+ 9.6	- 4.68	+ 4.63	+ 0.05	+ 1.1
		926	100	- 4.71	+ 4.72	- 0.01	- 0.2	- 4.14	+ 4.63	- 0.49	- 10.6
	E	1648	48.7	- 6.00	+ 6.12	- 0.12	- 2.0	- 5.37	+ 5.69	- 0.32	- 5.6
		1647	67	- 6.41	+ 6.11	+ 0.30	+ 4.9	- 5.14	+ 5.56	- 0.42	- 7.5
		1648	78	- 5.99	+ 5.41	+ 0.58	+ 10.7	- 5.13	+ 5.69	- 0.58	- 9.9
	E-2B	2909	61.8	- 6.16	+ 6.11	+ 0.05	+ 0.8	- 5.15	+ 5.96	- 0.81	- 13.3
		2904	78.0	- 7.23	+ 6.29	+ 0.94	+ 15.0	- 6.00	+ 6.75	- 0.75	- 11.1
	E-4	—	12.8	- 7.13	+ 6.30	+ 0.83	+ 13.2	- 6.54	+ 6.23	+ 0.31	+ 5.1
		4004	37.8	- 7.23	+ 6.48	+ 0.75	+ 11.6	- 6.79	+ 6.36	+ 0.43	+ 6.8
		4009	62.2	- 8.20	+ 7.51	+ 0.69	+ 9.2	- 7 32	+ 7.28	+ 0.04	+ 0.6
		4008	86.0	- 7.80	+ 7.15	+ 0.65	+ 9.1	- 6.86	+ 7.42	- 0.56	- 7.6
	J	2521	17.3	- 5.44	+ 5.07	+ 0.37	+ 7.3	- 4.93	+ 5.18	- 0.25	- 4.8
		2535	35.9	- 5.93	+ 5.76	+ 0.17	+ 3.0	- 4.99	+ 5.43	- 0.44	- 8.1
		2423	36.8	- 7.47	+ 6.65	+ 0.82	+ 12.3	- 6.70	+ 6.50	+ 0.20	+ 3.1
		2536	46.3	- 8.36	+ 7.34	+ 1.02	+ 13.9	- 6.80	+ 7.16	- 0.36	- 5.0
	H	3032	16.4	- 6.74	+ 6.99	- 0.25	- 3.6	- 6.67	+ 6.88	- 0.21	- 3.1
		3021	43.4	- 8.01	+ 8.39	- 0.38	- 4.5	- 7.46	+ 7.55	- 0.09	- 1.2
		3024	59.9	- 8.62	+ 8.73	- 0.11	- 1.3	- 7.65	+ 8.21	- 0.56	- 68
		3004	72.1	- 8.37	+ 8.20	+ 0.17	+ 2.1	- 7.72	+ 7.81	- 0.09	- 1.2
	Z	1869	35.8	- 61.9	+ 5.94	+ 0.25	+ 4.2	- 5.46	+ 5.56	- 0.10	- 1.8

NOTE: STRESSES SHOWN ARE IN KIPS PER SQUARE INCH

COLS. 5,6,9 & 10: THE STRESSES RECORDED AT THE GAGE POSITIONS HAVE BEEN CORRECTED FOR THE DISTANCE FROM THE NEUTRAL AXIS AT THE EXTREME FIBER STRESS SHOWN.

COLS. 7,8,11 & 12: A POSITIVE SIGN IN THESE COLUMNS MEAN THAT THE TOP FLANGE STRESS IS GREATER THAN THE BOTTOM FLANGE BY THE AMOUNT SHOWN.

COLS. 8 & 12: THE CALCULATED TOP FLANGE STRESS IS 6.5 PERCENT GREATER THAN BOTTOM FLANGE BECAUSE OF THE POSITION OF THE NEUTRAL AXIS.

The recorded static stresses in both the eastbound span and the westbound span were below those calculated under all locomotive classes by stress factors as low as 0.80 for the class "H" locomotives on the westbound span. In general, the recorded stresses were about 15 percent below the calculated static stresses. As previously mentioned, this structure has a ballasted track with a precast concrete floor and it would appear from these low stress factors that the ballast and concrete floor were acting as part of the top flange. A study of Table 8, Comparison of Top and Bottom Flange Recorded Stresses, indicates that the top flange is stressed about the same as the bottom flange, even under the locomotives operating at high speeds.

The stresses shown in Table 8 for the top and bottom flanges are simultaneous stresses in each girder. The top flange stresses are the average of two gage readings on each girder after correcting for the 3½-in. distance from the gage positions to the back of the angles to arrive at the stress in the extreme fiber of the flange. With perfect freedom of movement of the end bearings, the top flange stresses should be 6.5 percent greater than the lower flange stresses because of the location of the neutral axis; however, the average of all the readings shown in this table indicates that the top flange stress of the north girder is 5 percent greater than the lower flange stress, while the top flange stress of the south girder is 4 percent smaller than the bottom flange.

Speed Effects

The increase in the average mean simultaneous stresses recorded in the two girders of each span resulting from the locomotive passing over the bridge at increasing speeds has been termed speed effect. This speed effect could be due to the centrifugal force resulting from the loaded axles running over the deflected span or to the variation of axle loads resulting from the accelerations of the unsprung weight of the locomotive during its vertical oscillations.

The measured speed effects, in percent of the measured static stresses, secured at crawl speeds, are shown in the upper left diagrams of Figs. 9 to 20 incl. In general, the speed effects for the diesel locomotives, shown on Figs. 9, 10 and 11, are smaller than those for the steam locomotives.

Roll Effect

An increased mean stress in one girder with a corresponding decrease in the mean stress in the other girder is undoubtedly due to the spring-borne weight of the locomotive oscillating about a longitudinal axis. This rolling action is probably set up, not only by track inequalities, but also by the locomotive weaving or nosing from side to side. This increase in the mean stress in one girder is called roll effect.

The magnitude of the increase in stress in one girder was found by subtracting the average simultaneous mean stress of both girders from the maximum mean stress. The increase in pressure on the rail which would produce the recorded difference in stress, in percentage of the recorded static stress, is shown in the lower left diagrams of Figs. 9 to 20 incl. for all the test locomotives. For example, when the two-axle westbound diesel locomotive passed over the 70-ft. ¼-in. deck girder span at 41 mph., see Fig. 9, the mean stress in the south girder was found to be 9.6 percent greater than the average stress in both girders, due to an increase in pressure on the south rail of 15.4 percent for this particular run.

There is considerable variation in the rolling effects as found in these three girder-type bridges and this effect does not appear to bear any relation to locomotive speed. The roll effect appears to be about the same for both diesel and steam locomotives, and only one value, see Fig. 14, out of a total of 486 test runs, exceeded the present AREA allowance.

(text continued on page 79)

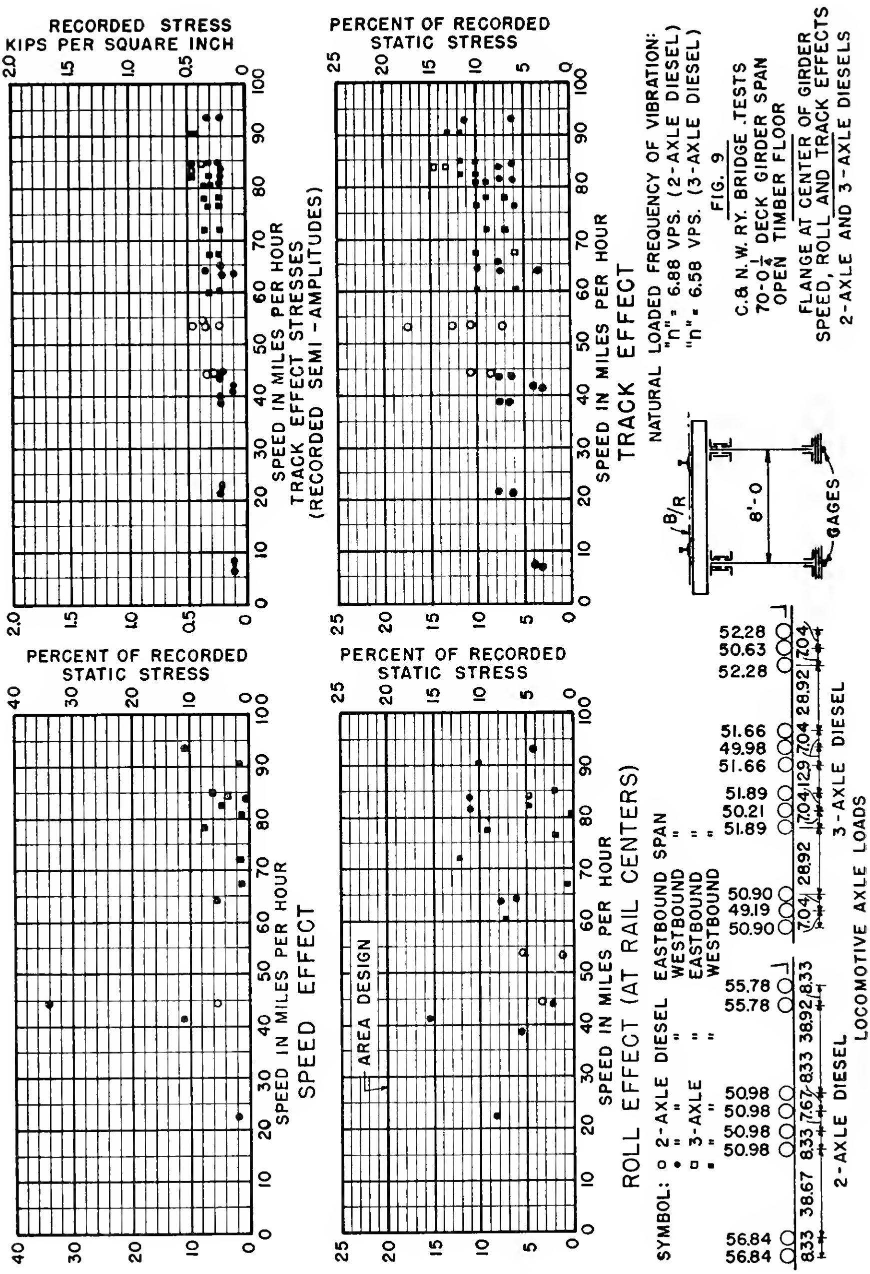


FIG. 9

C.& N. W. RY. BRIDGE TESTS
70-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR

FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK EFFECTS
2-AXLE AND 3-AXLE DIESELS

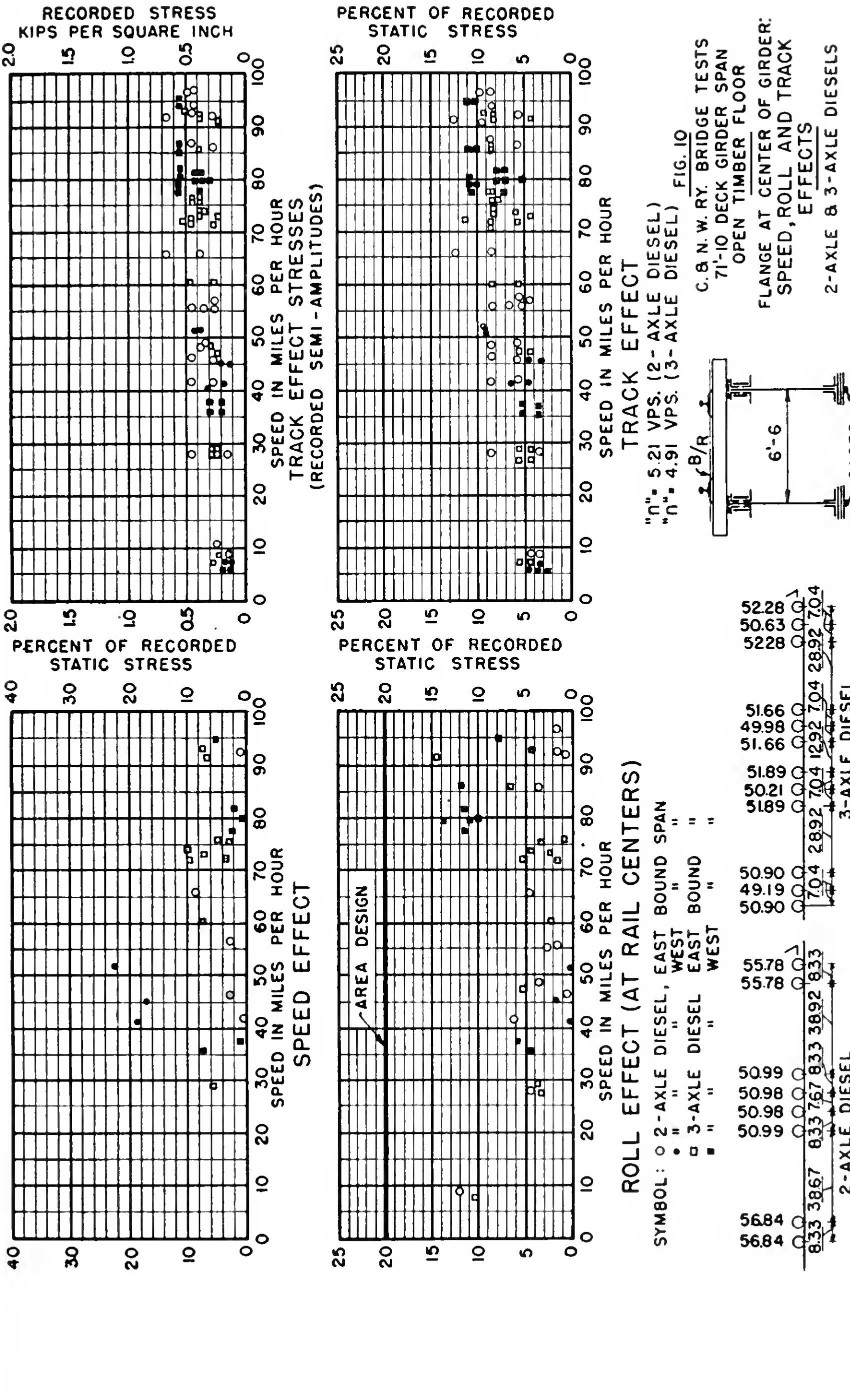


FIG. 10
C. & N. W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER:
SPEED, ROLL AND TRACK
EFFECTS
2-AXLE & 3-AXLE DIESELS

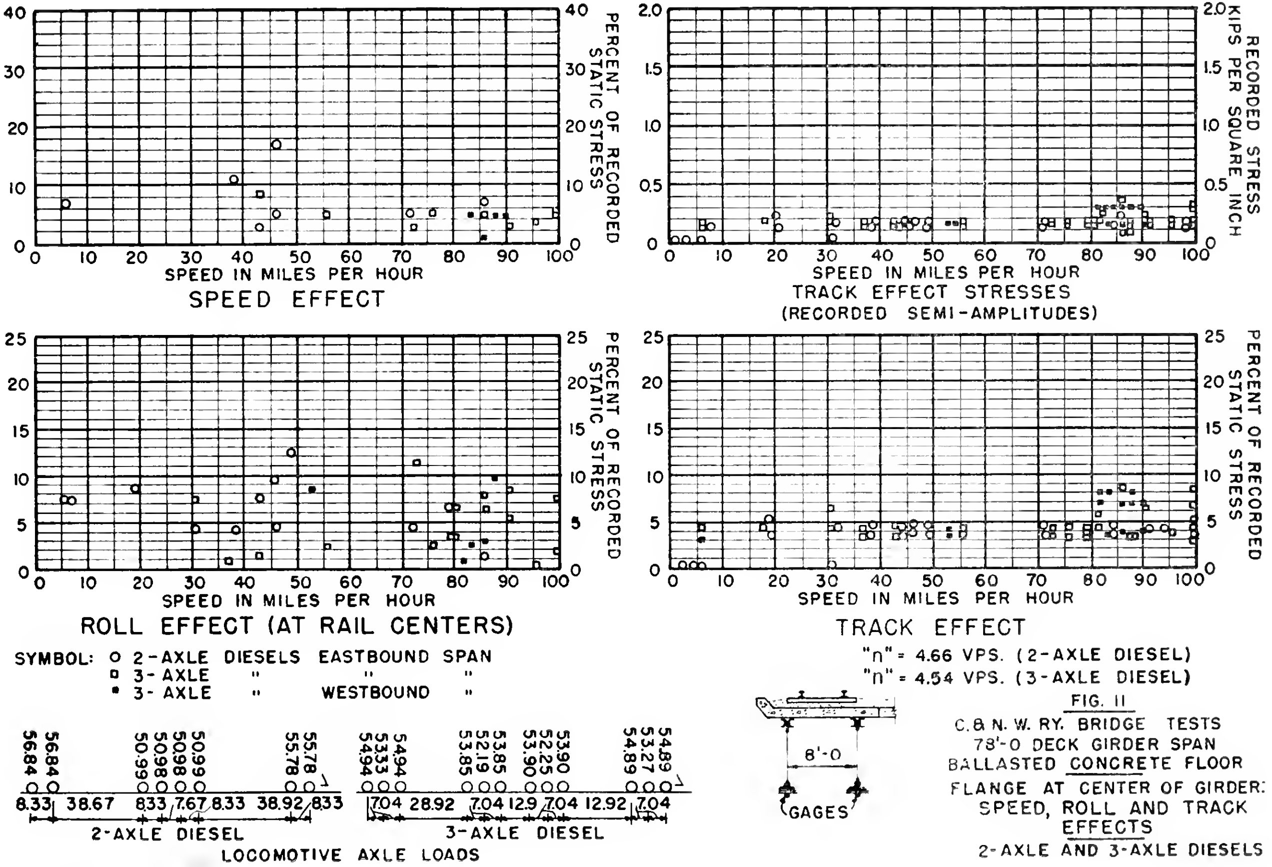


FIG. 11

C. & N. W. RY. BRIDGE TESTS
73'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR

FLANGE AT CENTER OF GIRDER:
SPEED, ROLL AND TRACK
EFFECTS
2-AXLE AND 3-AXLE DIESELS

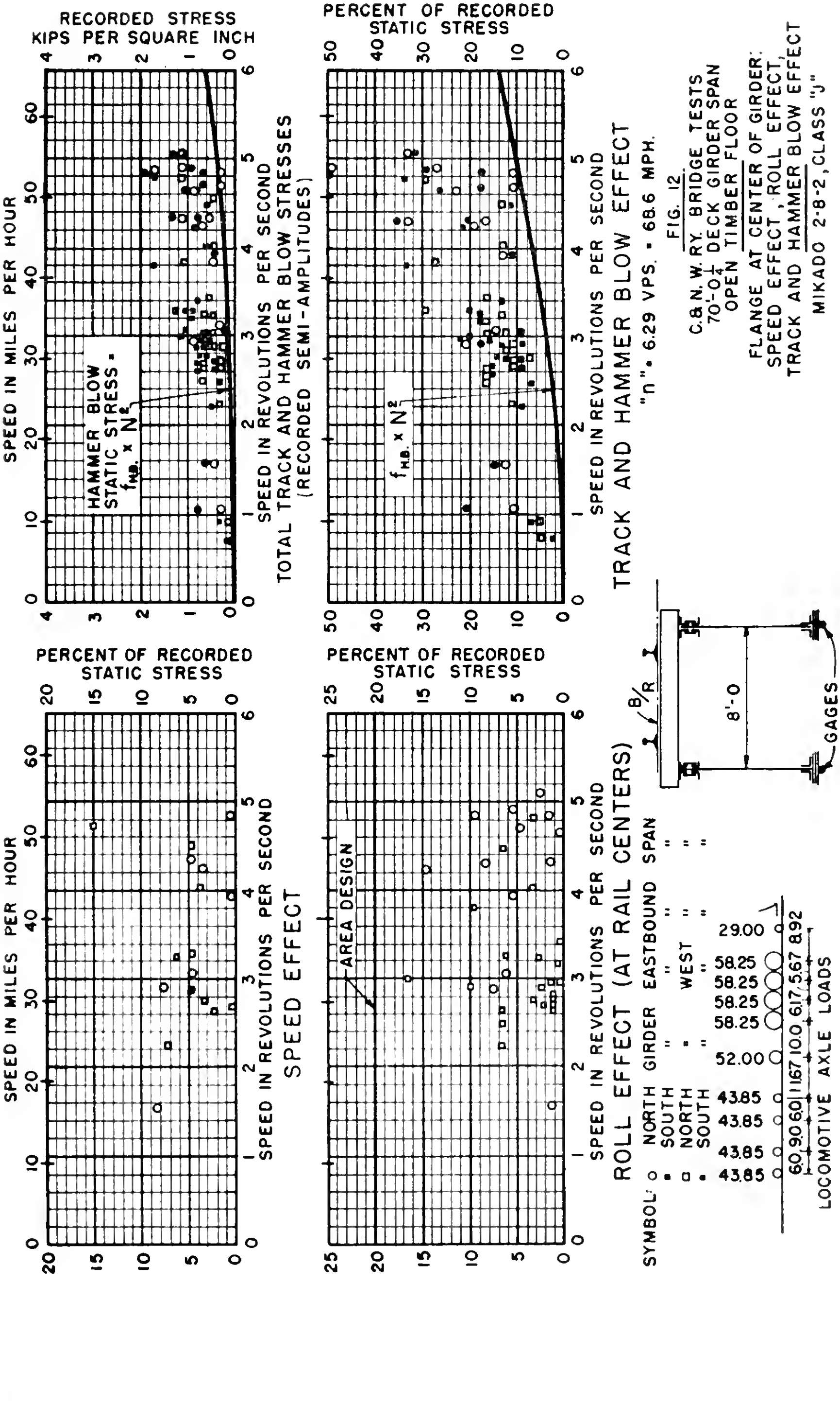
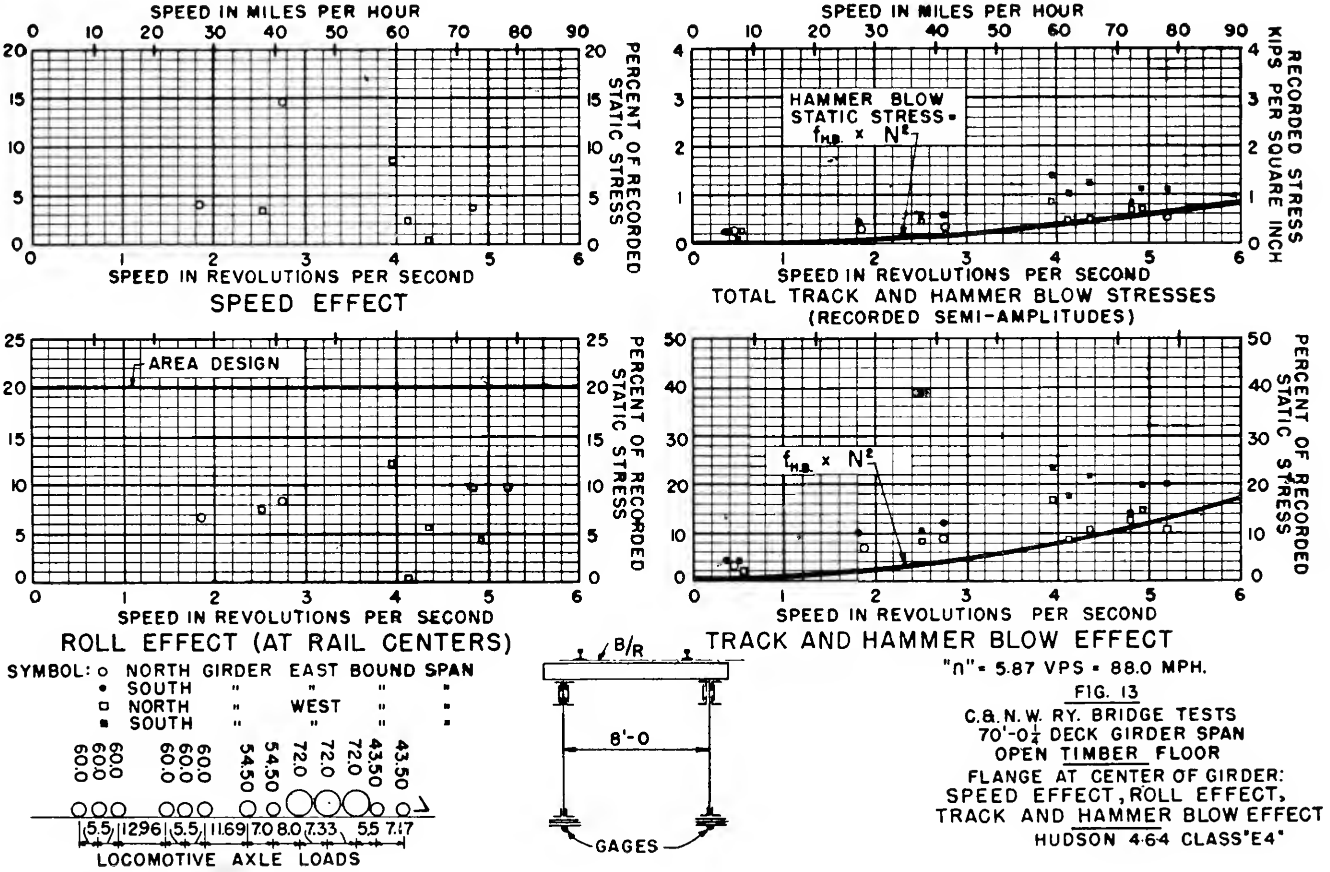


FIG. 12

C.&N.W. RY. BRIDGE TESTS
70'-0¼" DECK GIRDER SPAN
OPEN TIMBER FLOOR

FLANGE AT CENTER OF GIRDER:
SPEED EFFECT, ROLL EFFECT,
TRACK AND HAMMER BLOW EFFECT

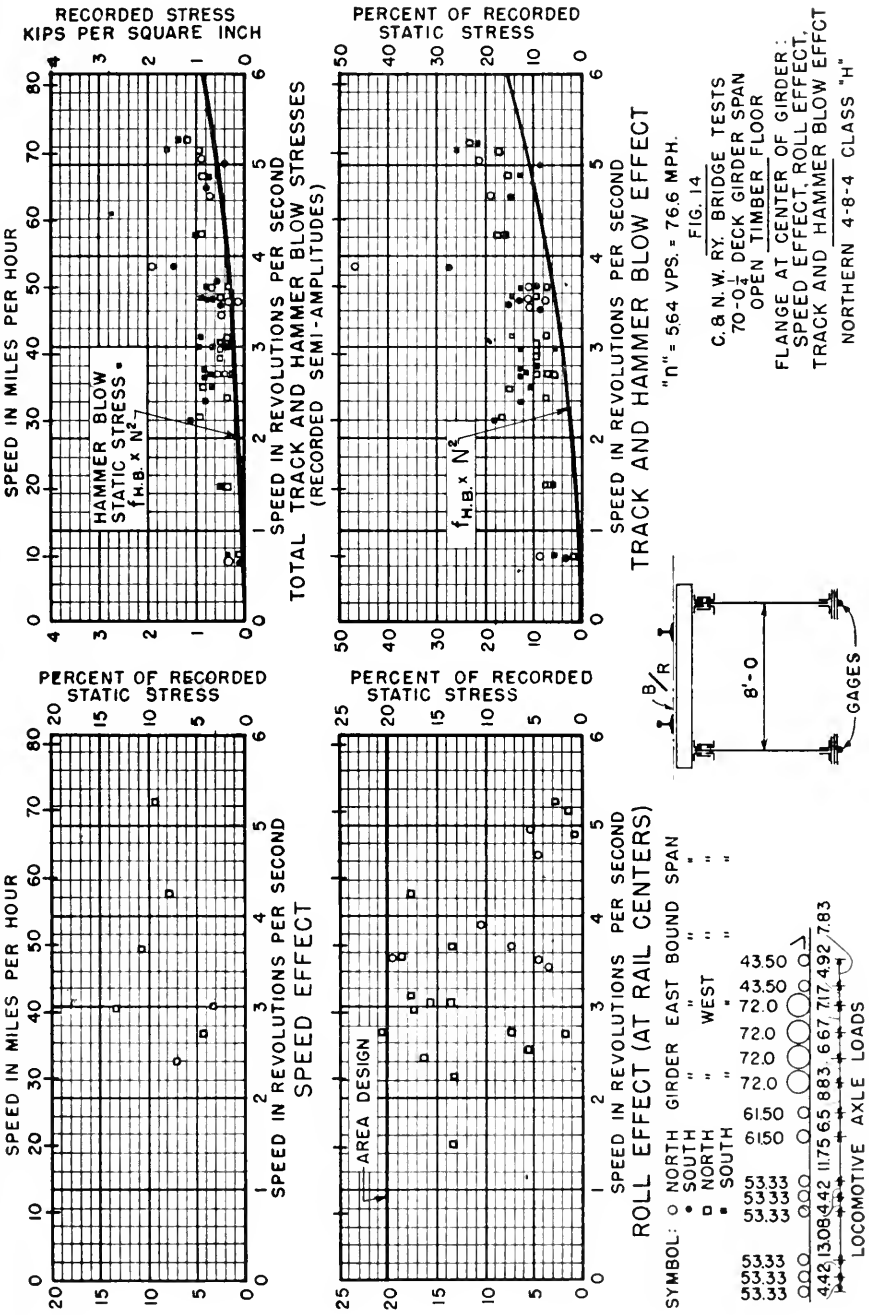
MIKADO 2-8-2, CLASS "J"



"n" = 5.87 VPS = 88.0 MPH.

FIG. 13

C.& N. W. RY. BRIDGE TESTS
70'-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER:
SPEED EFFECT, ROLL EFFECT,
TRACK AND HAMMER BLOW EFFECT
HUDSON 4-6-4 CLASS "E4"



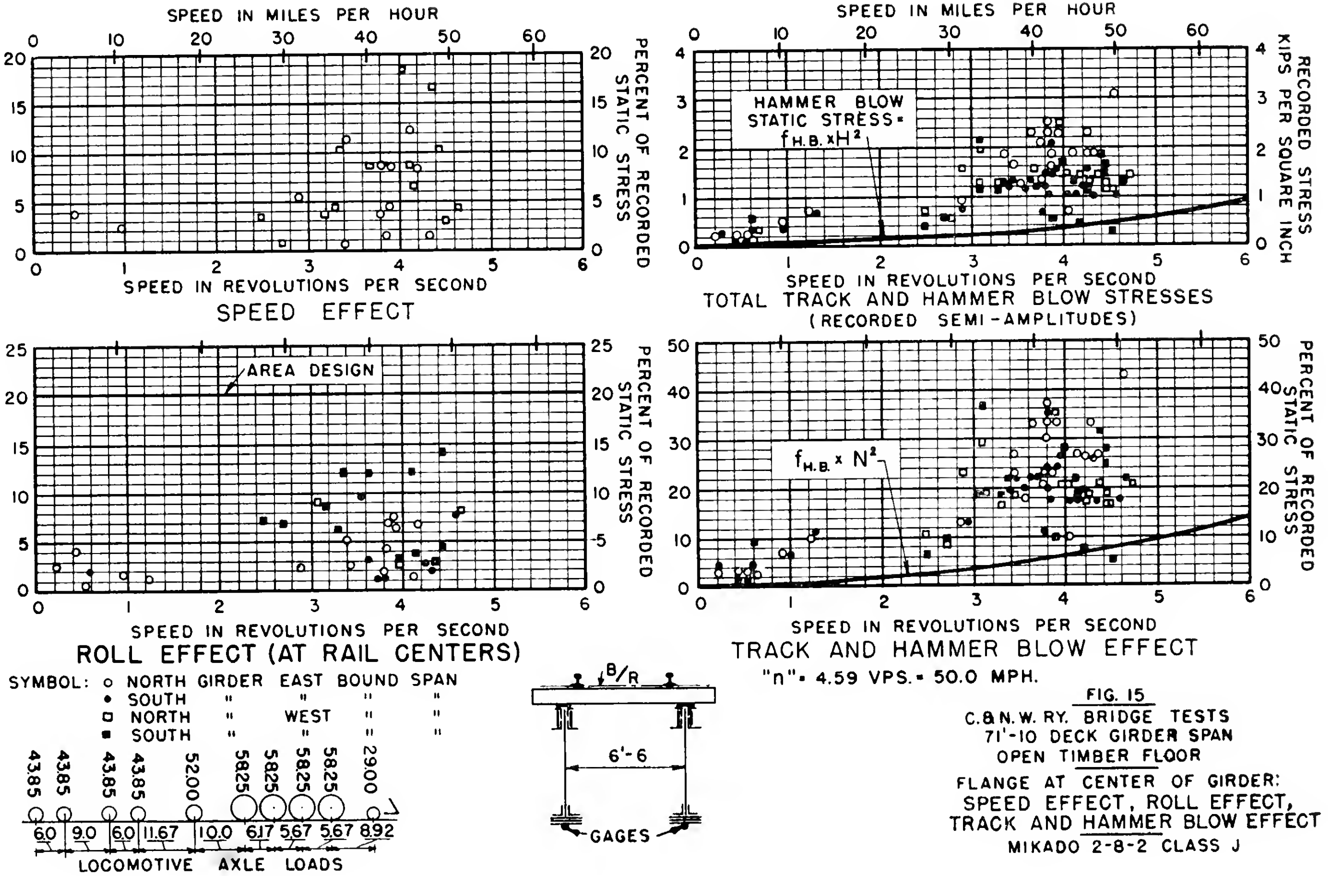
"n" = 5.64 VPS. = 76.6 MPH.

FIG. 14

C. & N. W. RY. BRIDGE TESTS
70-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR

FLANGE AT CENTER OF GIRDER:
SPEED EFFECT, ROLL EFFECT,
TRACK AND HAMMER BLOW EFFCT

NORTHERN 4-8-4 CLASS "H"



SPEED EFFECT

TOTAL TRACK AND HAMMER BLOW STRESSES (RECORDED SEMI-AMPLITUDES)

ROLL EFFECT (AT RAIL CENTERS)

TRACK AND HAMMER BLOW EFFECT

"n"= 4.59 VPS.= 50.0 MPH.

FIG. 15

C.& N.W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR

FLANGE AT CENTER OF GIRDER:
SPEED EFFECT, ROLL EFFECT,
TRACK AND HAMMER BLOW EFFECT
MIKADO 2-8-2 CLASS J

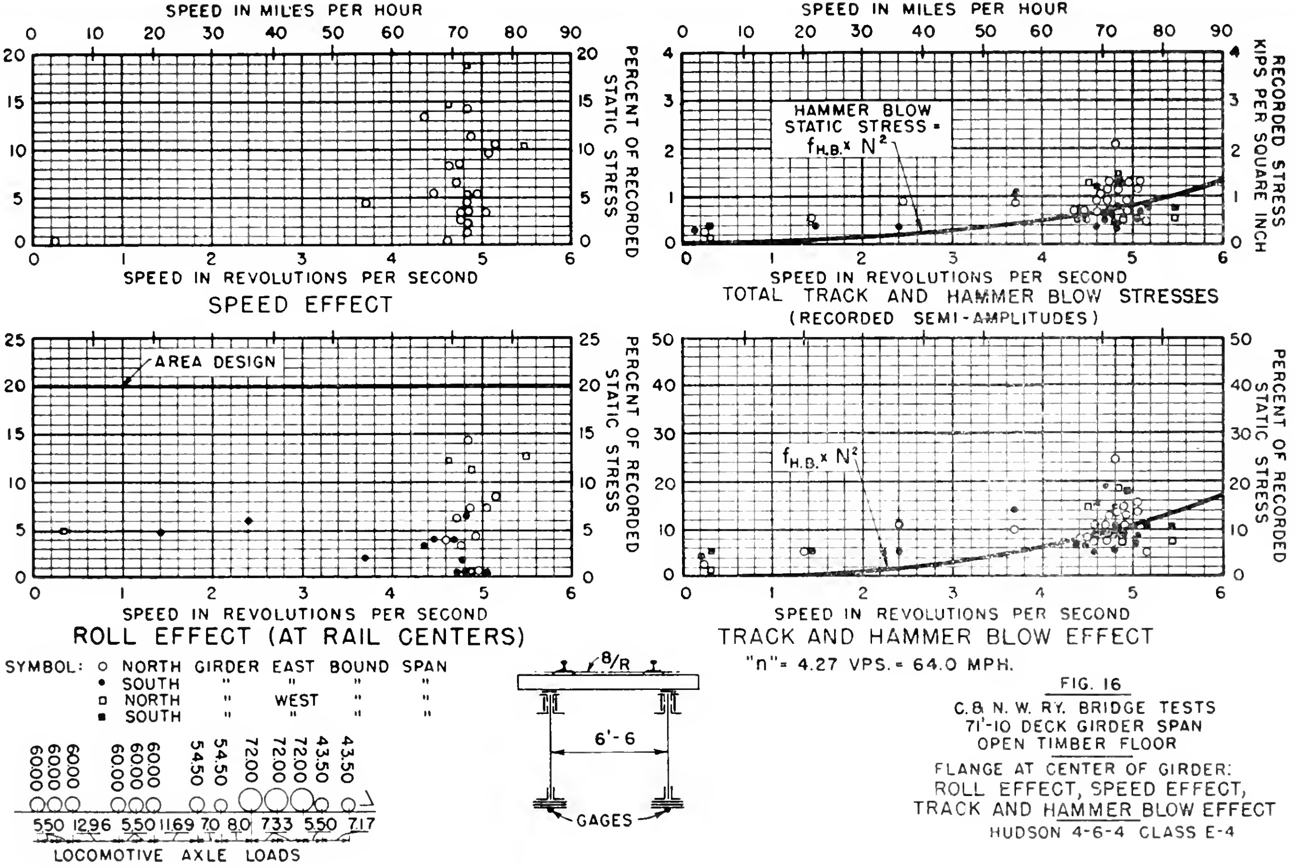


FIG. 16

C. & N. W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR

FLANGE AT CENTER OF GIRDER:
ROLL EFFECT, SPEED EFFECT,
TRACK AND HAMMER BLOW EFFECT
HUDSON 4-6-4 CLASS E-4

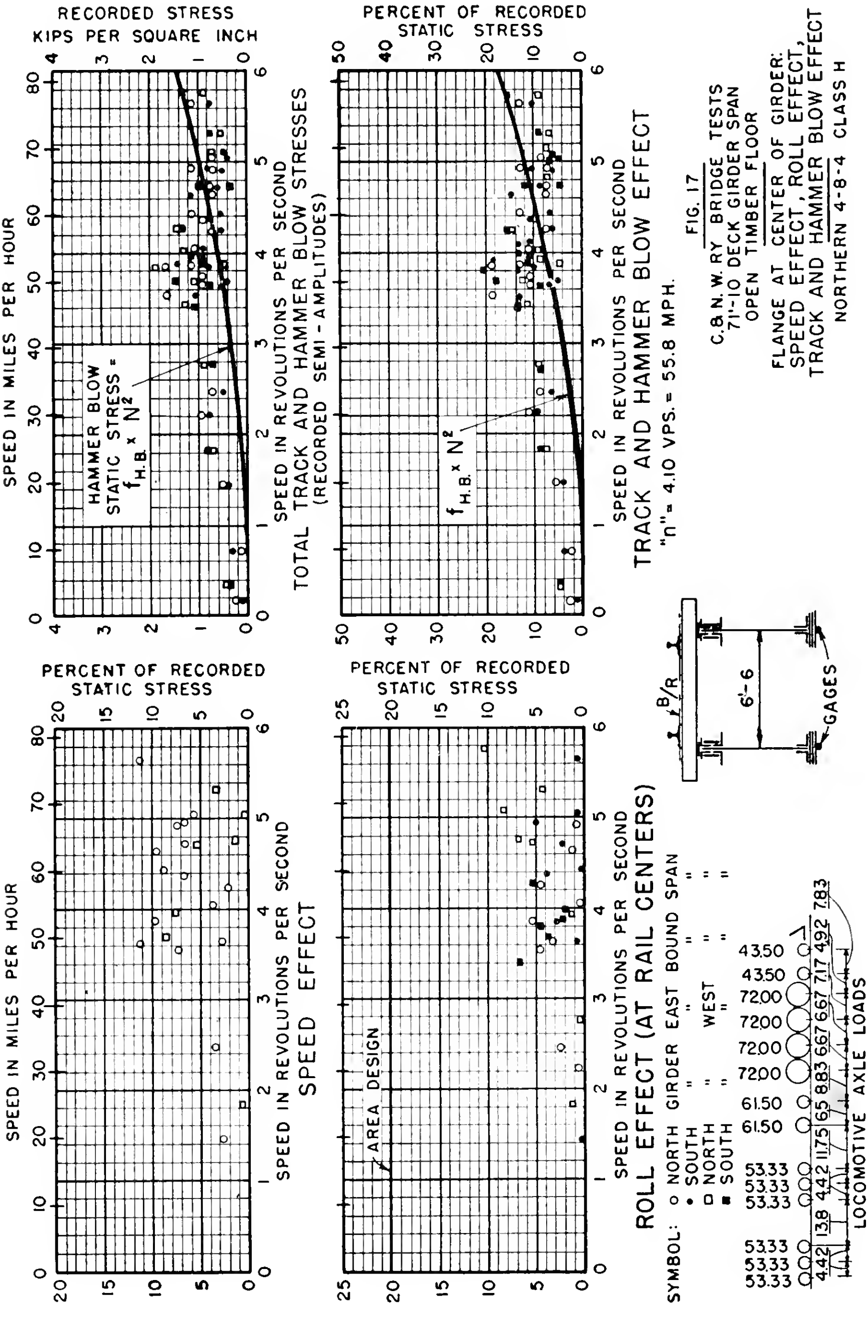
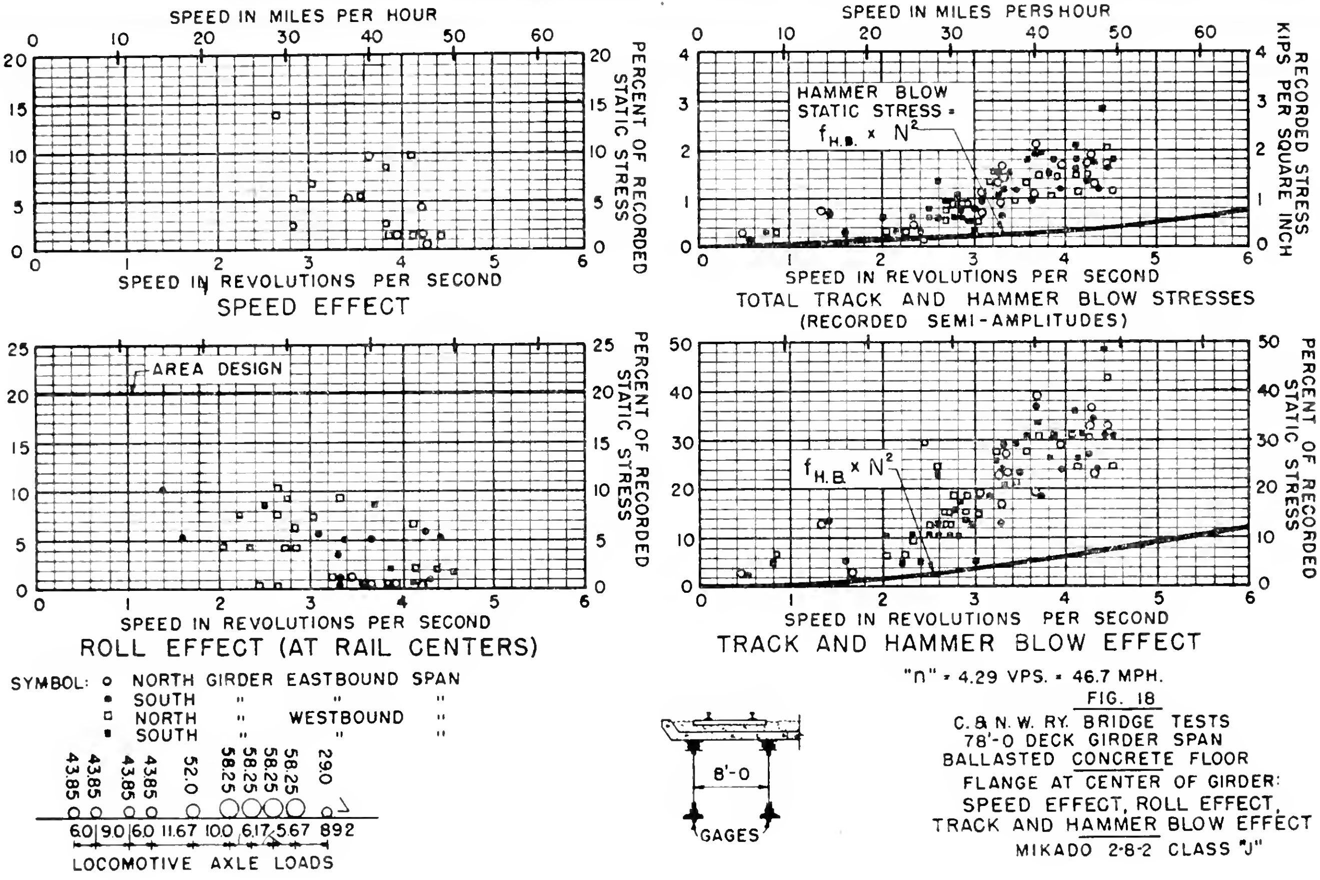


FIG. 17
C.& N.W. RY BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER:
SPEED EFFECT, ROLL EFFECT,
TRACK AND HAMMER BLOW EFFECT
NORTHERN 4-8-4 CLASS H


SPEED EFFECT

ROLL EFFECT (AT RAIL CENTERS)

TOTAL TRACK AND HAMMER BLOW STRESSES (RECORDED SEMI-AMPLITUDES)

TRACK AND HAMMER BLOW EFFECT

"n" = 4.29 VPS. = 46.7 MPH.

FIG. 18

C. & N. W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
FLANGE AT CENTER OF GIRDER:
SPEED EFFECT, ROLL EFFECT,
TRACK AND HAMMER BLOW EFFECT
MIKADO 2-8-2 CLASS "J"

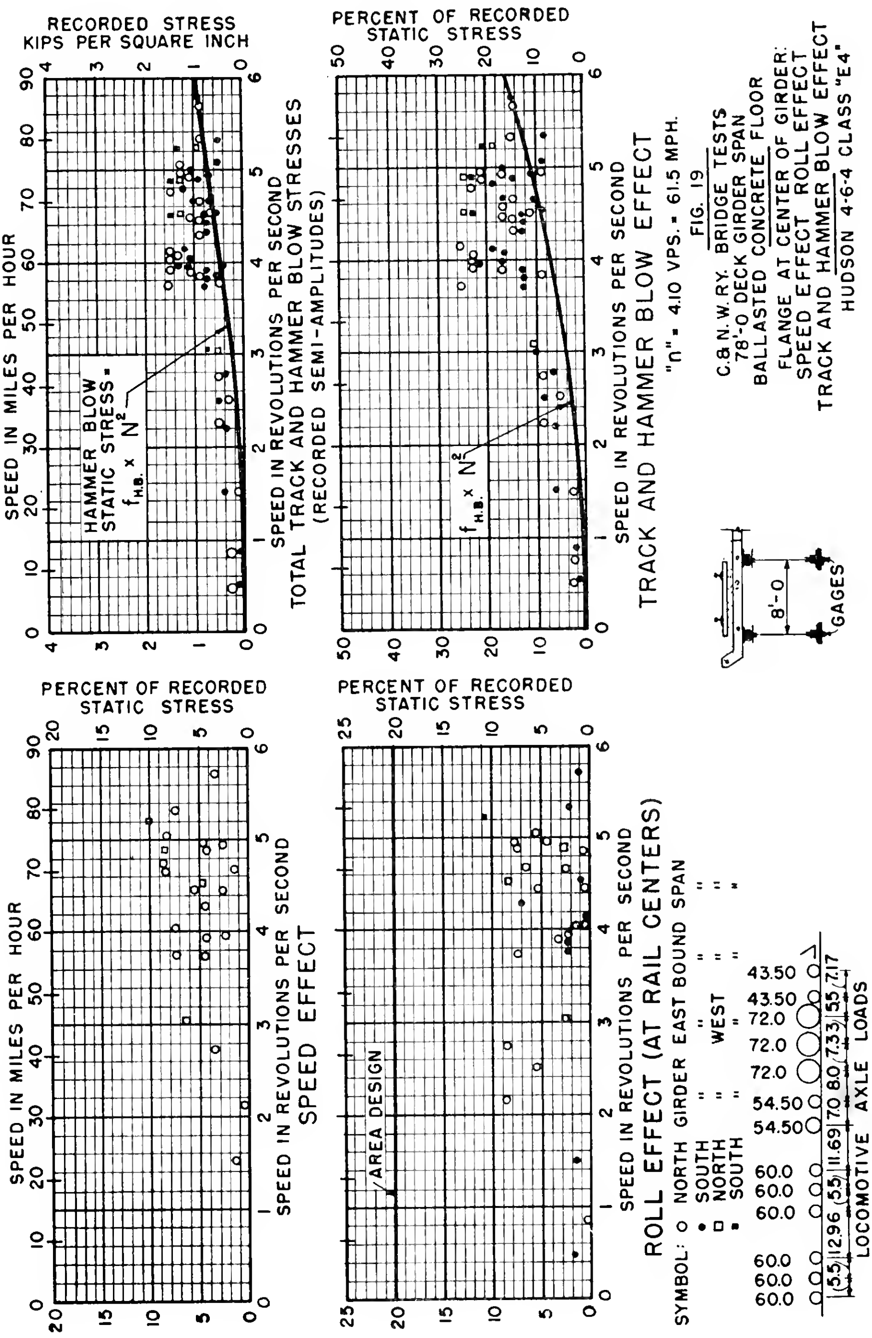
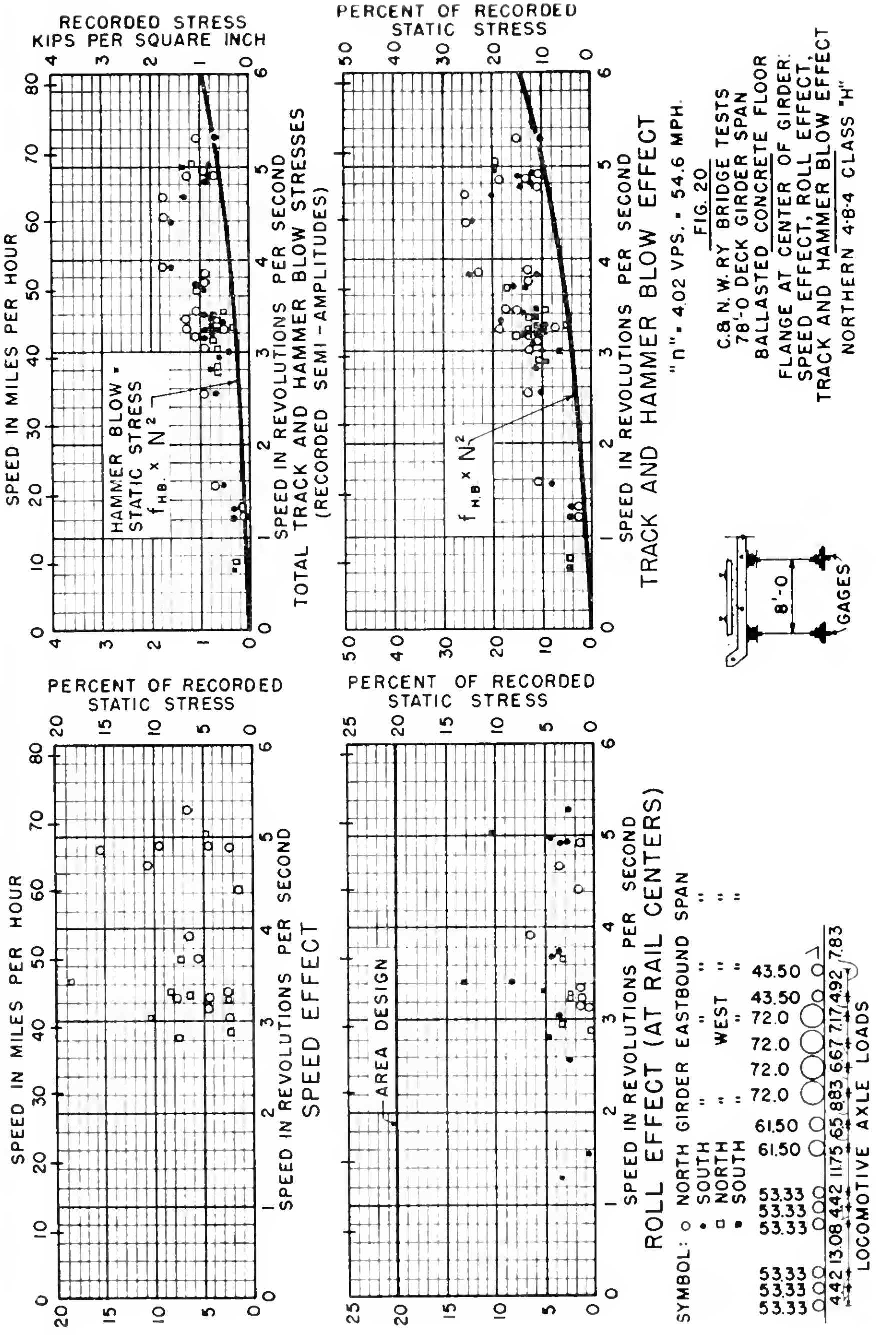


FIG. 19

C.&N.W.RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
FLANGE AT CENTER OF GIRDER:
SPEED EFFECT ROLL EFFECT
TRACK AND HAMMER BLOW EFFECT
HUDSON 4-6-4 CLASS "E4"


TOTAL TRACK AND HAMMER BLOW STRESSES (RECORDED SEMI-AMPLITUDES)

TRACK AND HAMMER BLOW EFFECT

"n" = 4.02 VPS. = 54.6 MPH.

SPEED EFFECT

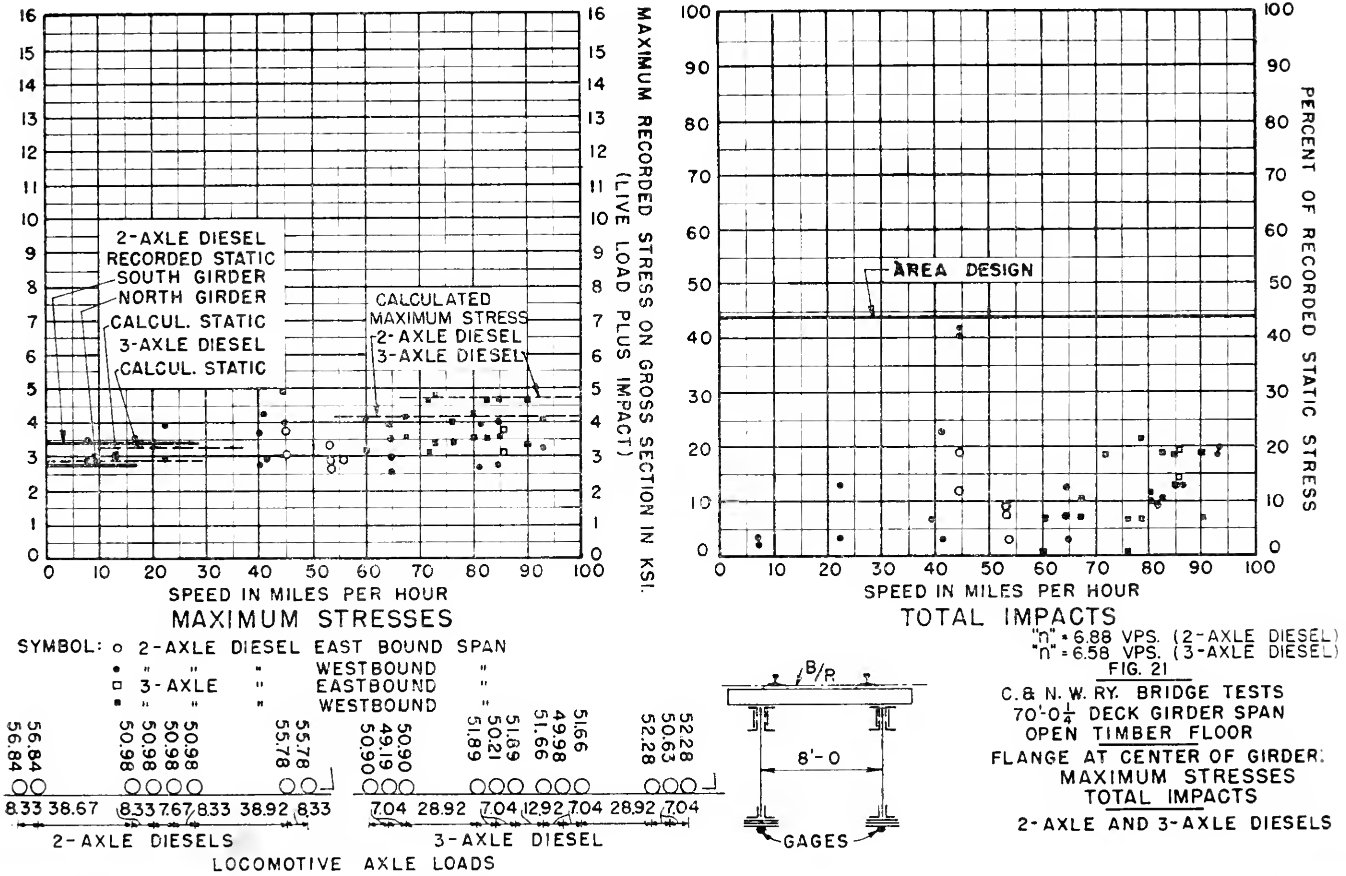
ROLL EFFECT (AT RAIL CENTERS)

SYMBOL: ○ NORTH GIRDER EASTBOUND SPAN
• SOUTH " " "
□ NORTH " WEST "
■ SOUTH " " "

LOCOMOTIVE AXLE LOADS

FIG. 20

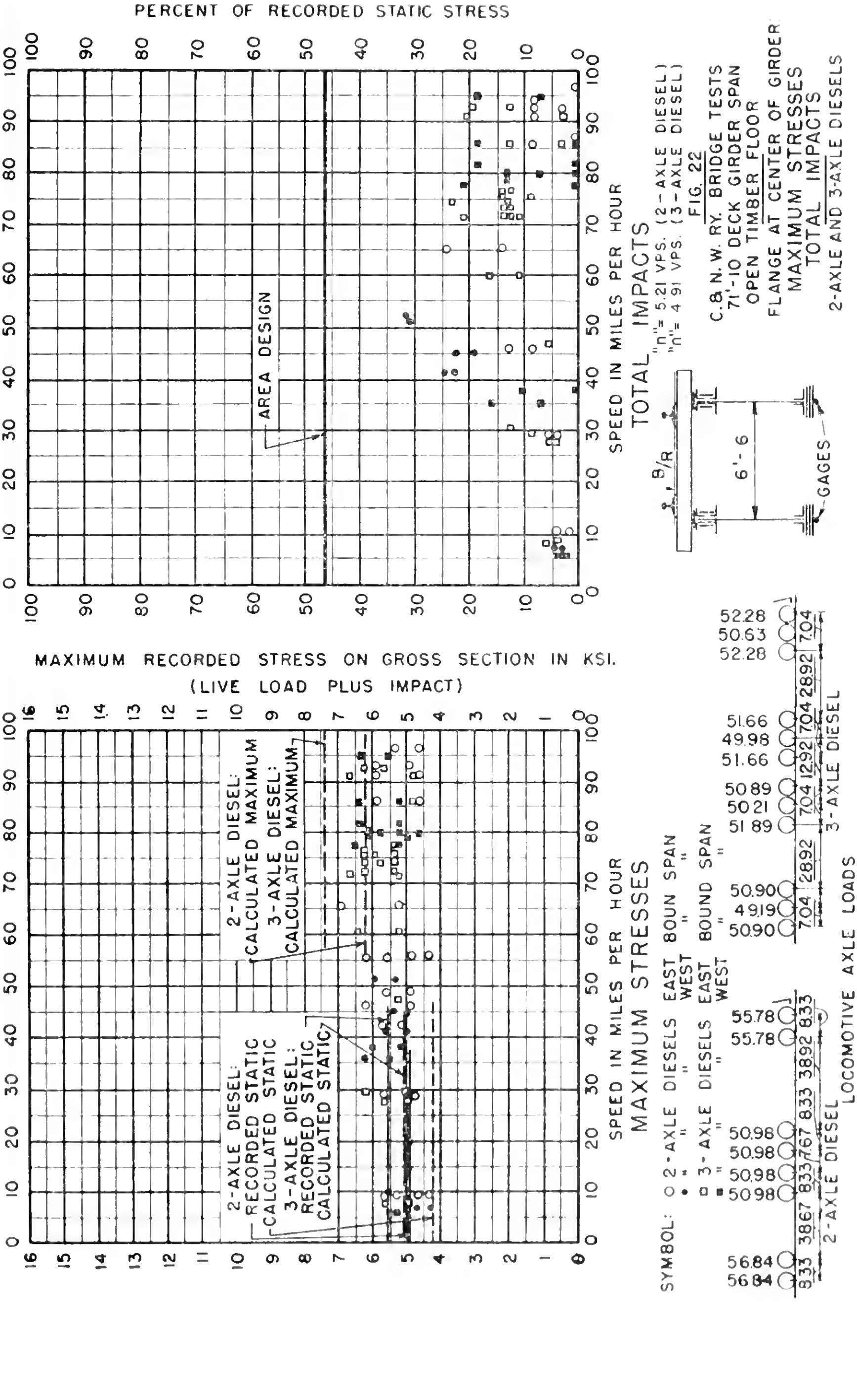
C.& N.W. RY BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
FLANGE AT CENTER OF GIRDER:
SPEED EFFECT, ROLL EFFECT,
TRACK AND HAMMER BLOW EFFECT
NORTHERN 4-8-4 CLASS "H"



"n" = 6.88 VPS. (2-AXLE DIESEL)
"n" = 6.58 VPS. (3-AXLE DIESEL)

FIG. 21

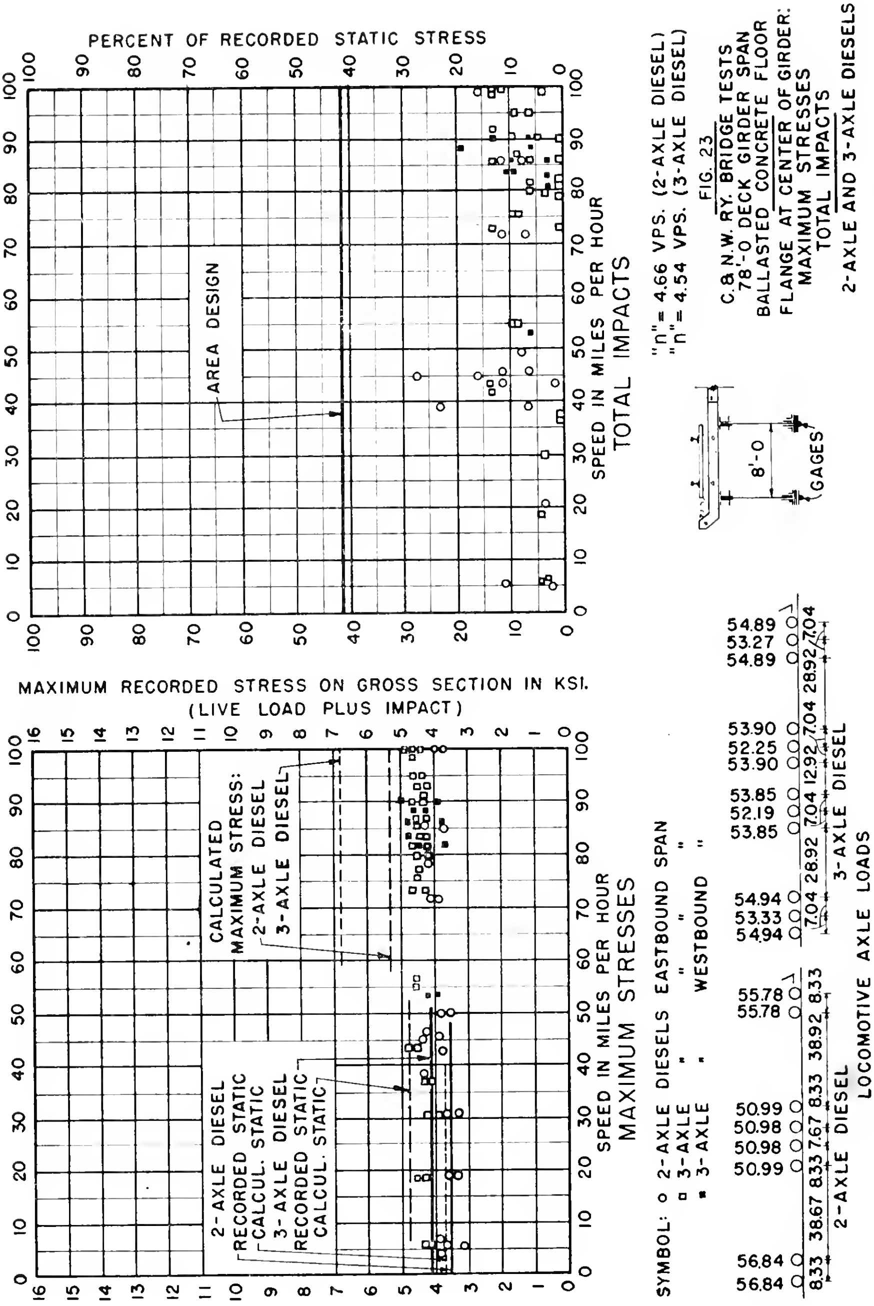
C. & N. W. RY. BRIDGE TESTS
70'-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
2-AXLE AND 3-AXLE DIESELS



"n" = 5.21 VPS. (2-AXLE DIESEL)
"n" = 4.91 VPS. (3-AXLE DIESEL)

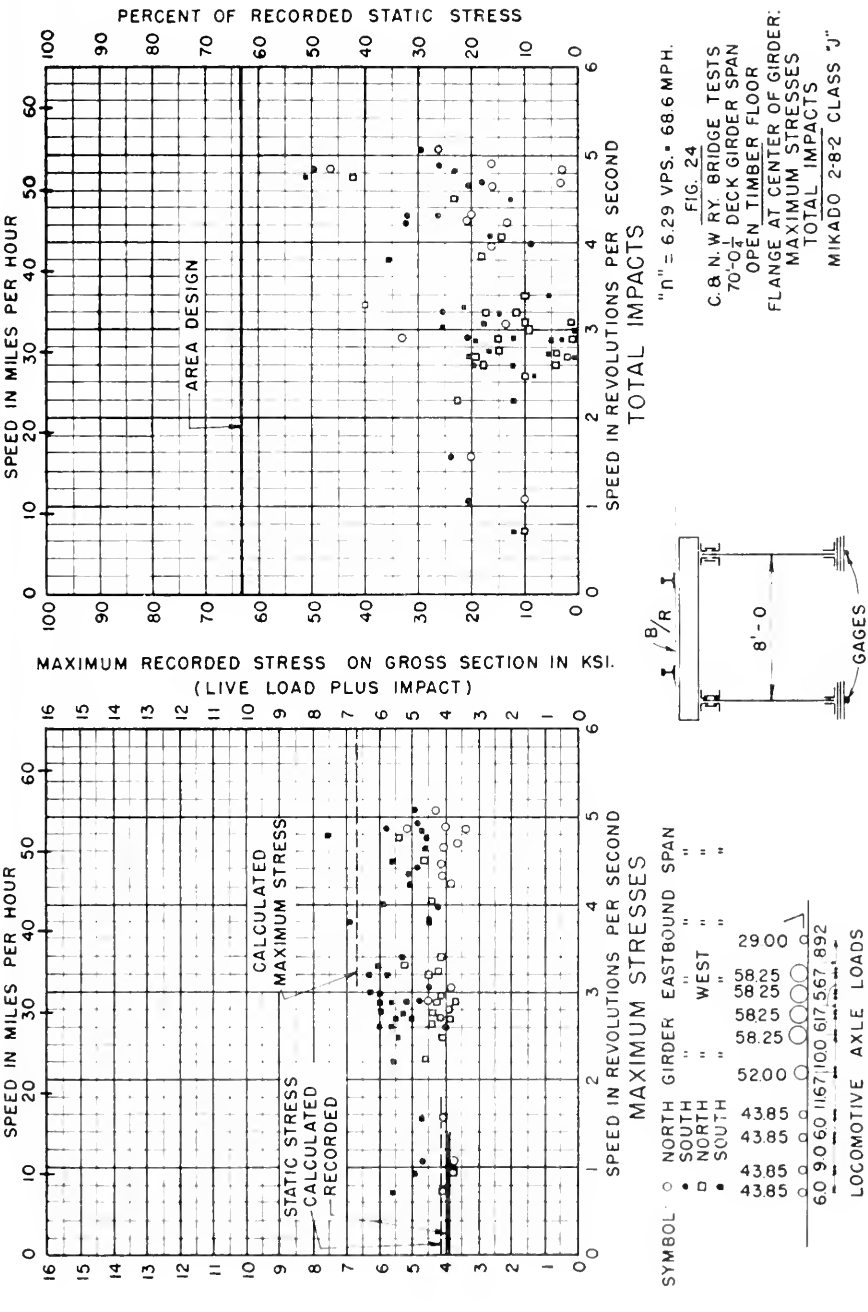
FIG. 22

C.& N.W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
TOTAL IMPACTS
2-AXLE AND 3-AXLE DIESELS



"n" = 4.66 VPS. (2-AXLE DIESEL)
"n" = 4.54 VPS. (3-AXLE DIESEL)

FIG. 23
C.& N.W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
FLANGE AT CENTER OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
2-AXLE AND 3-AXLE DIESELS



"n" = 6.29 VPS. = 68.6 MPH.

FIG. 24

C.&N.W. RY. BRIDGE TESTS

70'-0¼" DECK GIRDER SPAN

OPEN TIMBER FLOOR

FLANGE AT CENTER OF GIRDER:

MAXIMUM STRESSES

TOTAL IMPACTS

MIKADO 2-8-2 CLASS "J"

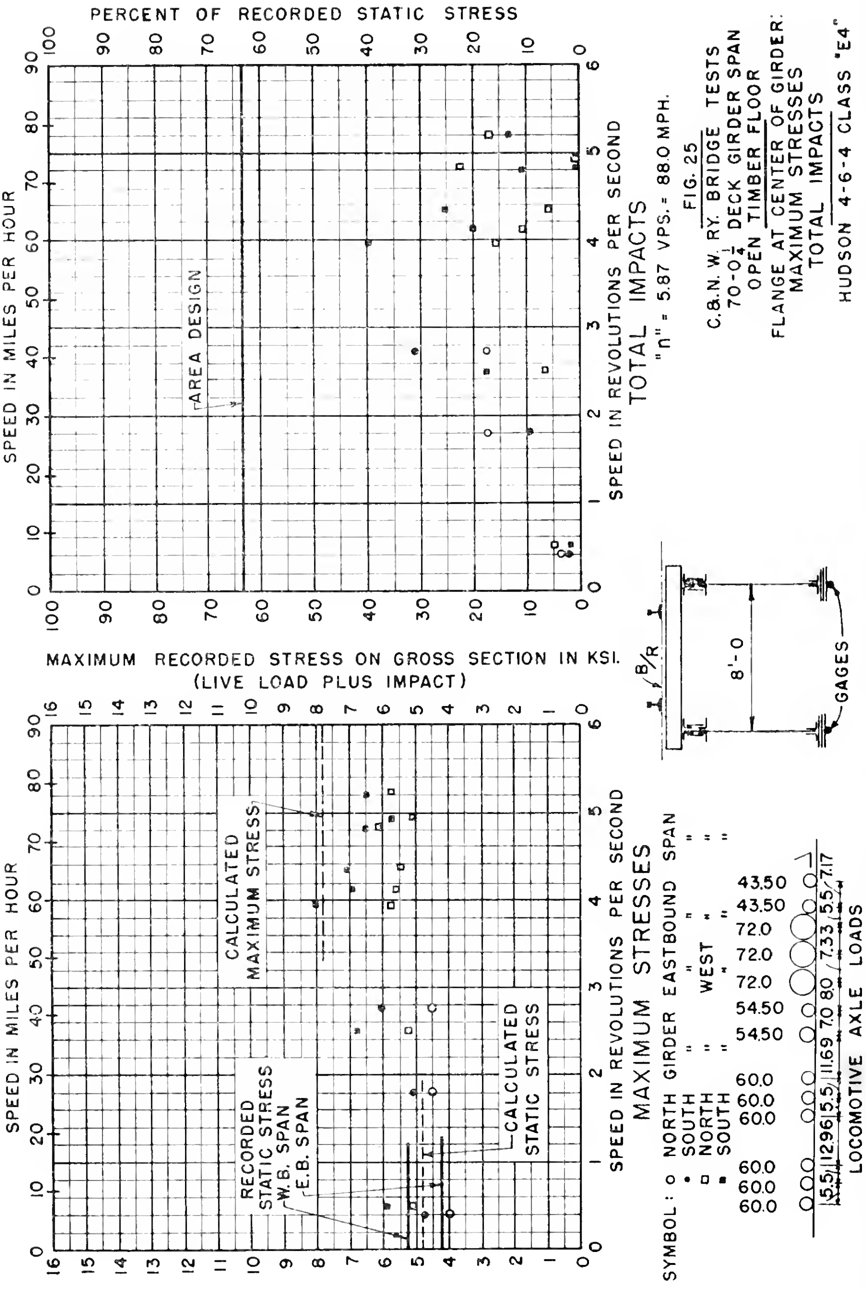
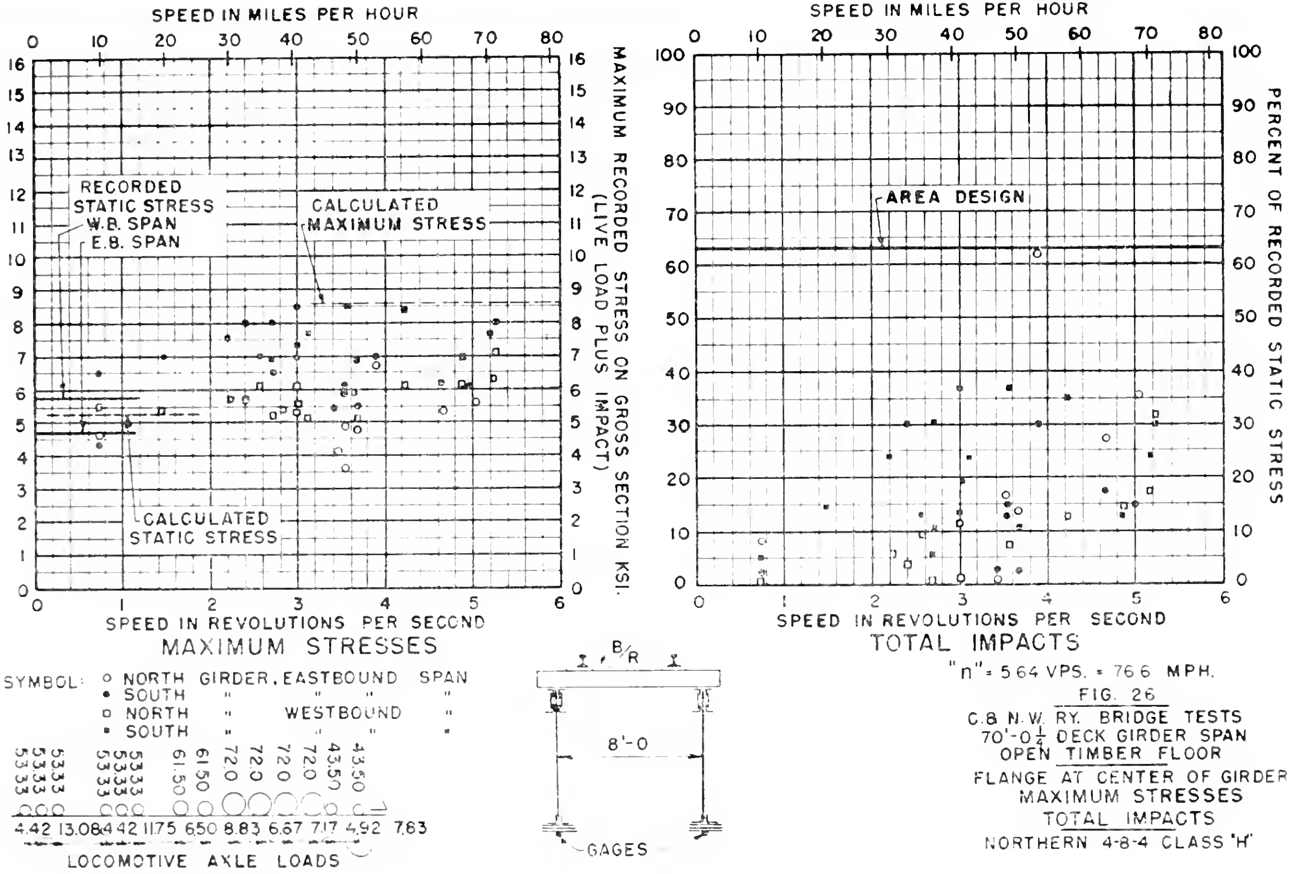


FIG. 25
C.&N.W. RY. BRIDGE TESTS
70-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
HUDSON 4-6-4 CLASS "E4"



"n" = 5.64 VPS. = 76.6 MPH.

FIG. 26

C.& N.W. RY. BRIDGE TESTS
70'-0$\frac{1}{4}$ DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
TOTAL IMPACTS
NORTHERN 4-8-4 CLASS 'H'

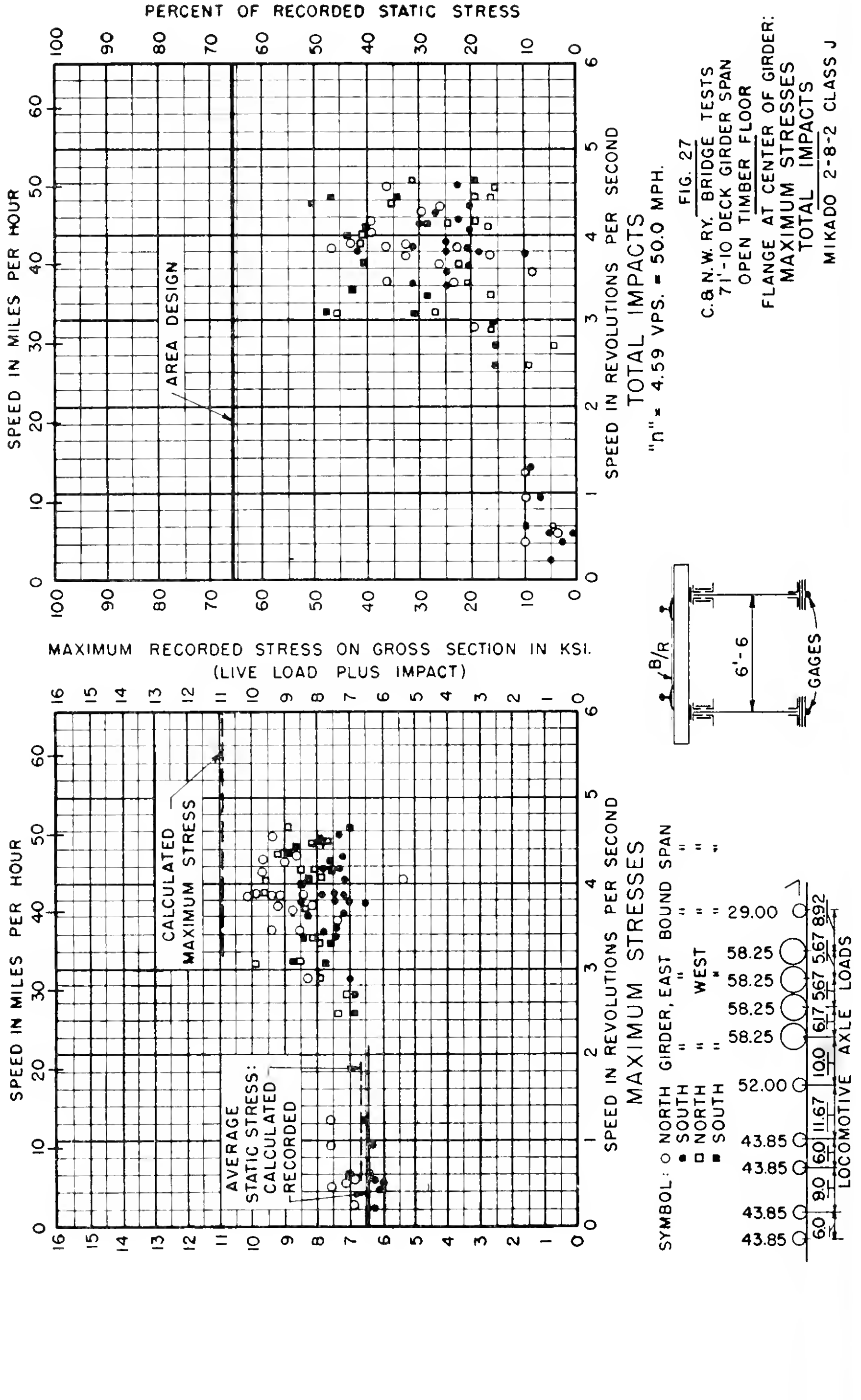


FIG. 27
C.& N.W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
MIKADO 2-8-2 CLASS J

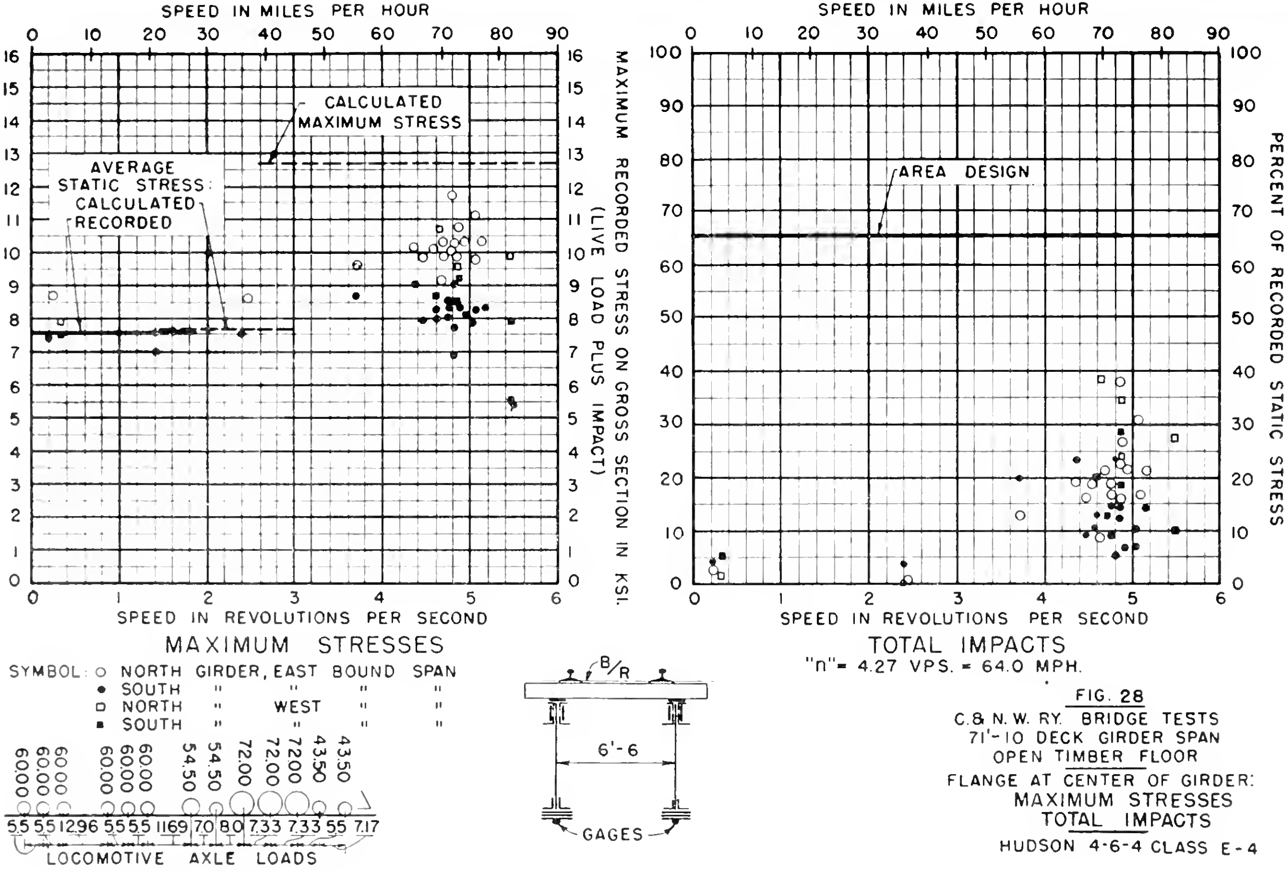
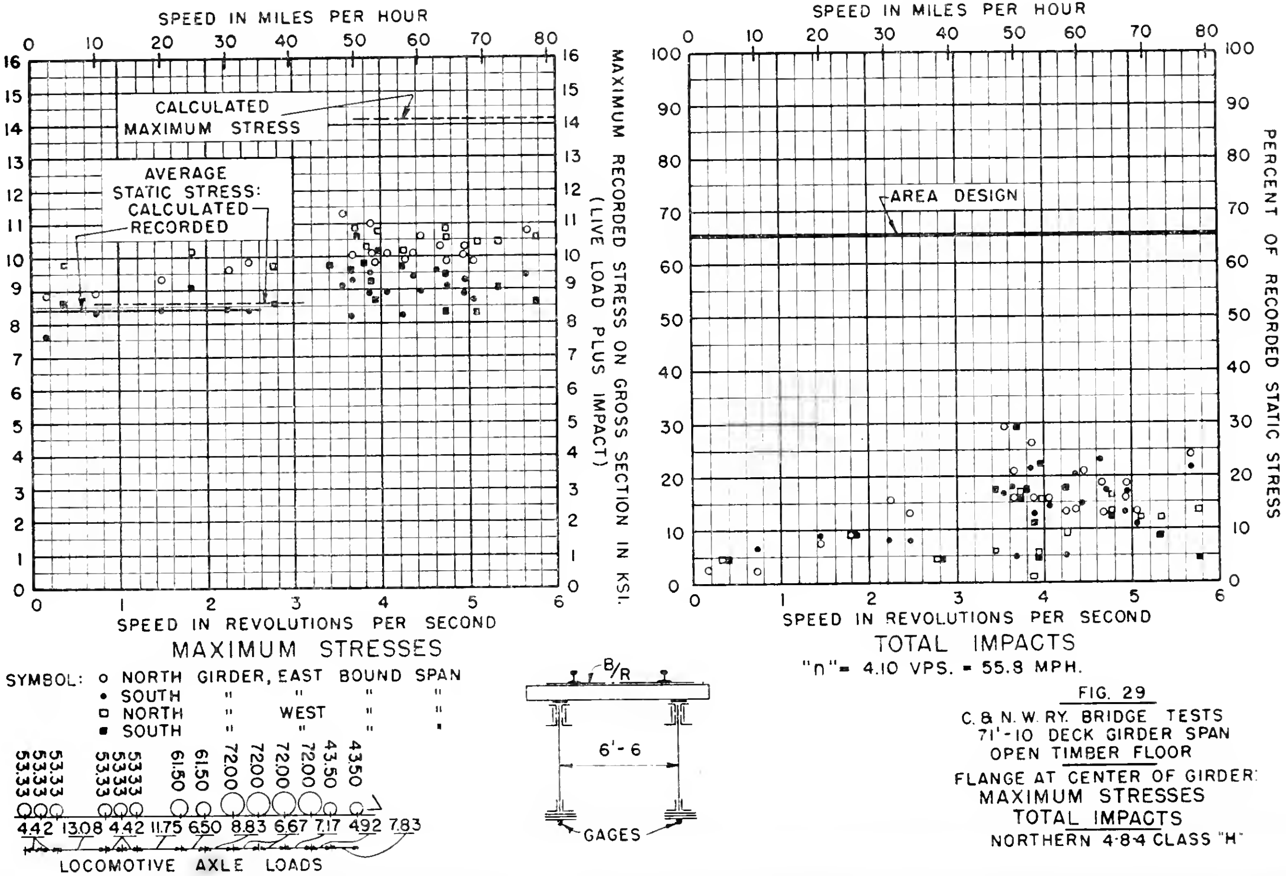


FIG. 28

C. & N. W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
HUDSON 4-6-4 CLASS E-4



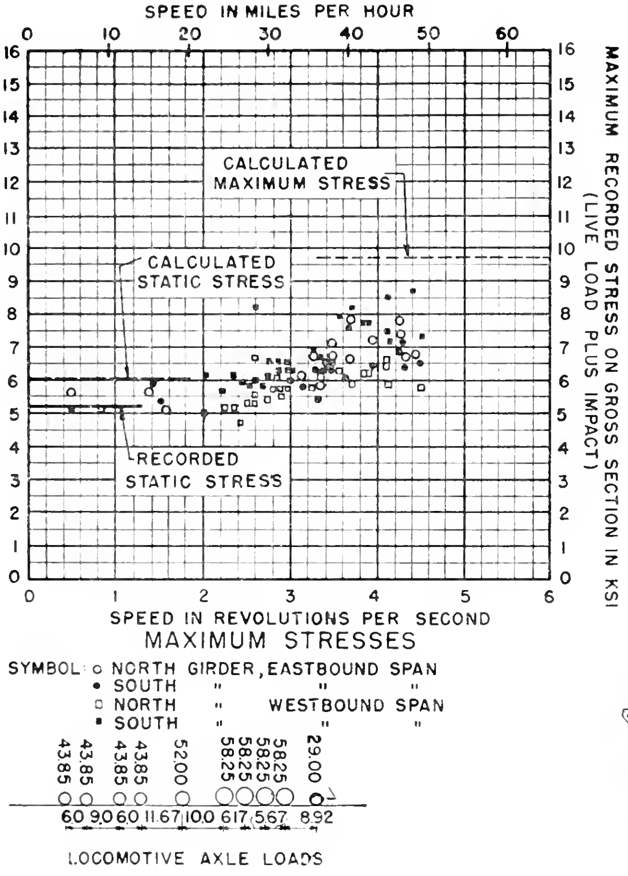
MAXIMUM STRESSES

TOTAL IMPACTS

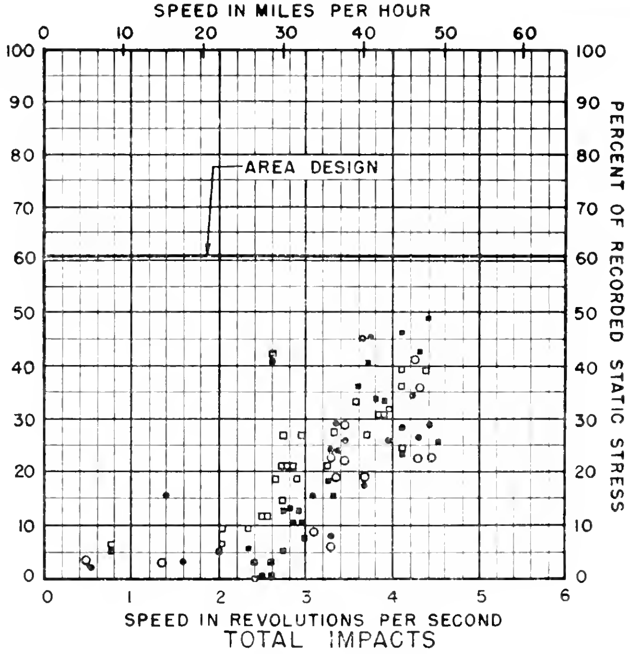
"n" = 4.10 VPS. = 55.8 MPH.

FIG. 29

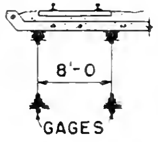
C. & N. W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
NORTHERN 4-8-4 CLASS "H"



MAXIMUM STRESSES



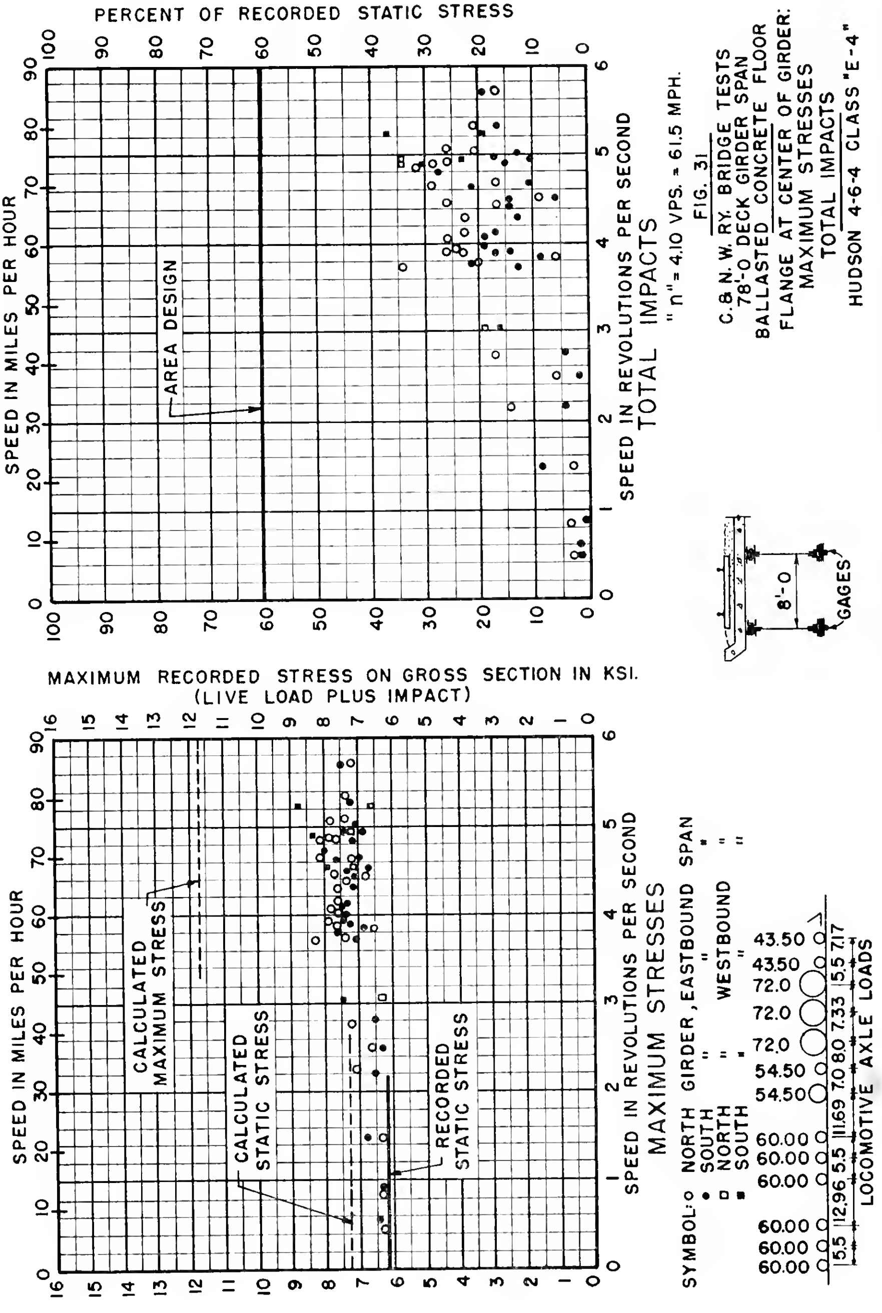
TOTAL IMPACTS



"n" = 4.29 VPS. = 46.7 MPH

FIG. 30

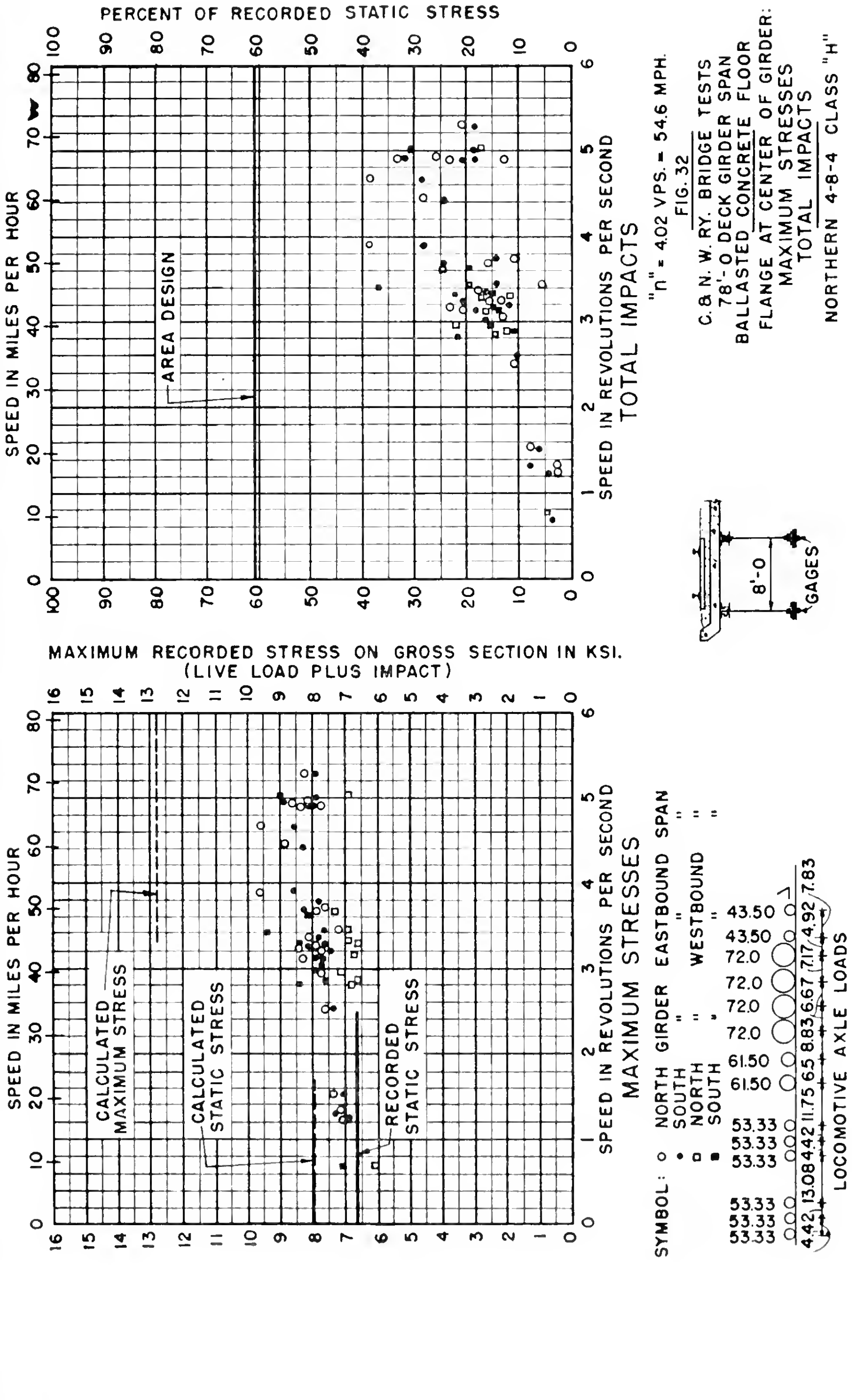
C. & N. W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
FLANGE AT CENTER OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
MIKADO 2-8-2 CLASS "J"



"n" = 4.10 VPS. = 61.5 MPH.

FIG. 31

C. & N. W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
FLANGE AT CENTER OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
HUDSON 4-6-4 CLASS "E-4"



"n" = 4.02 VPS. = 54.6 MPH.

FIG. 32

C.& N. W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
FLANGE AT CENTER OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
NORTHERN 4-8-4 CLASS "H"

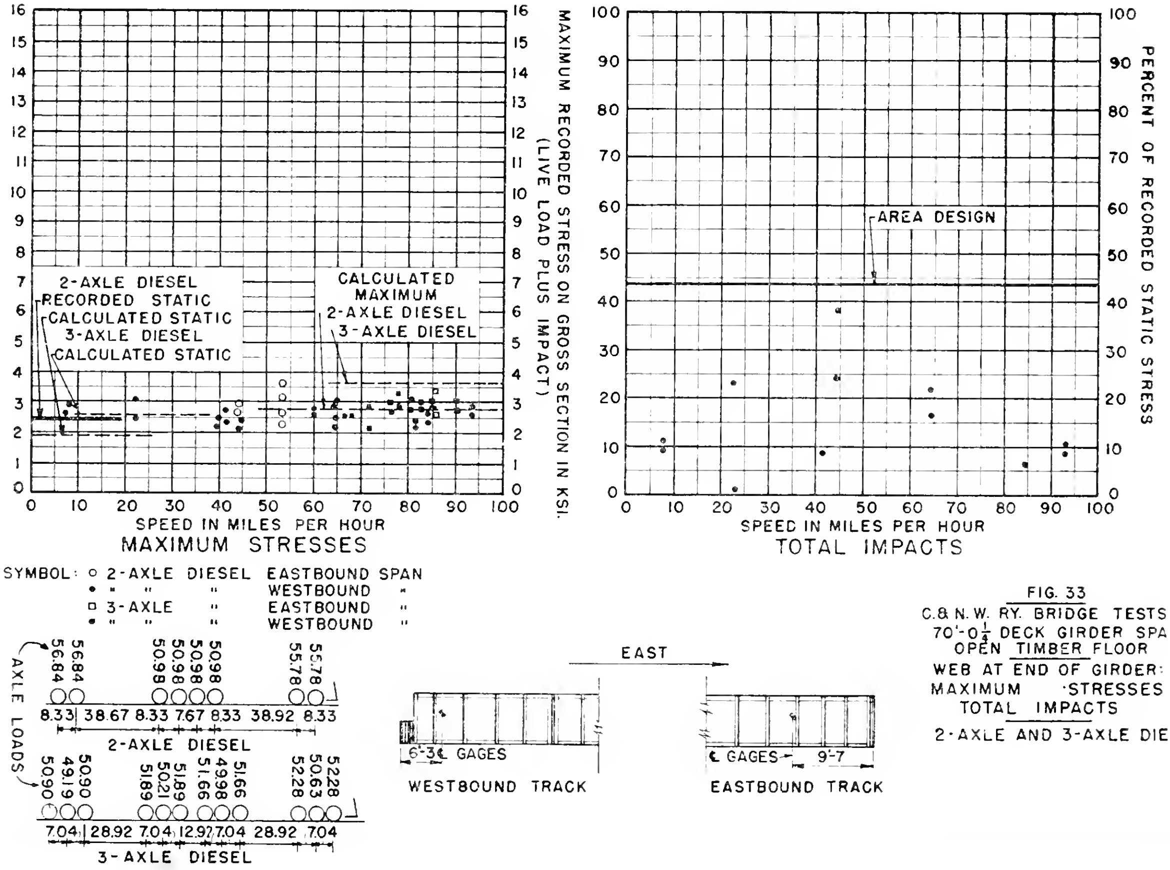


FIG. 33
C.& N.W. RY. BRIDGE TESTS
70'-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
2-AXLE AND 3-AXLE DIESELS

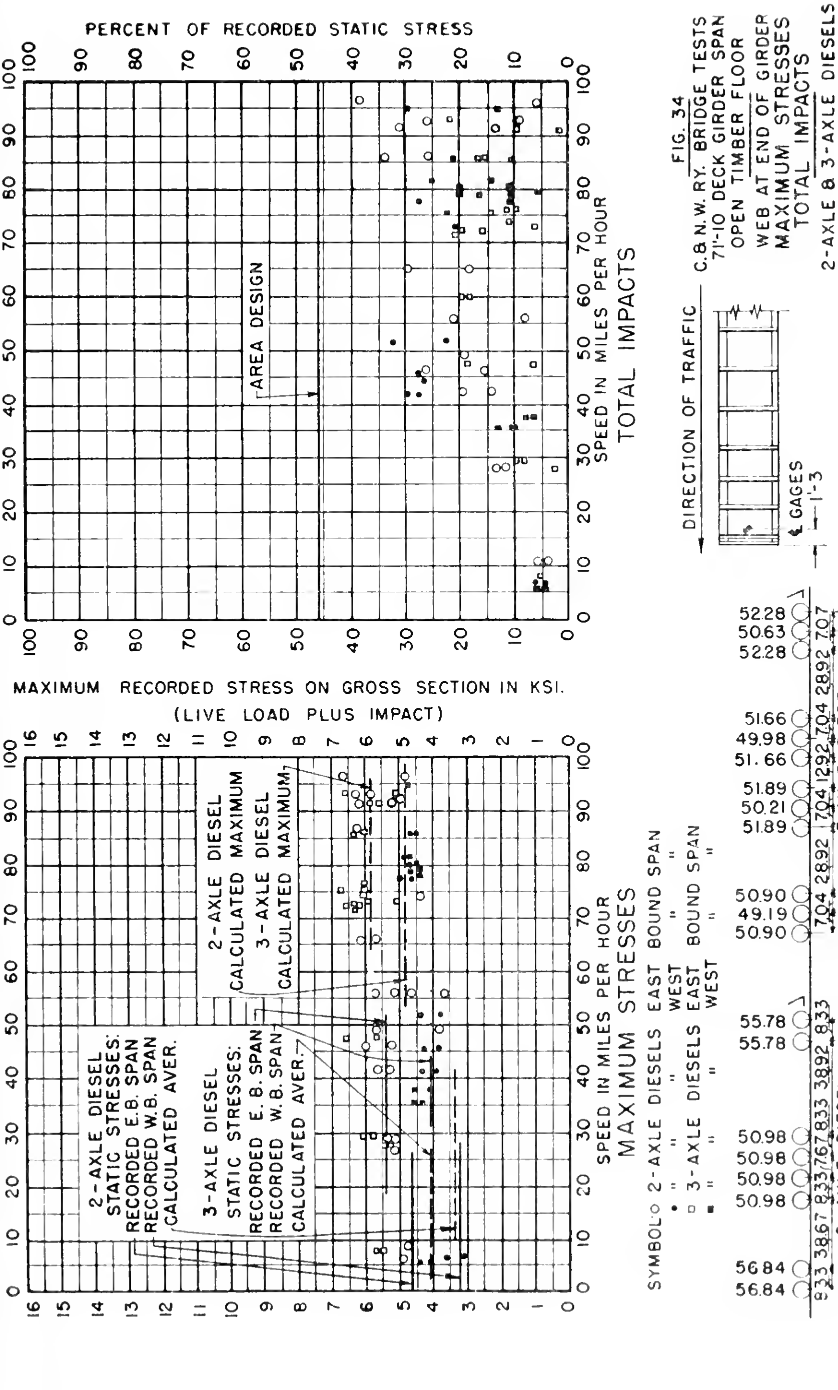


FIG. 34
C.& N.W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
MAXIMUM STRESSES
TOTAL IMPACTS
2-AXLE & 3-AXLE DIESELS

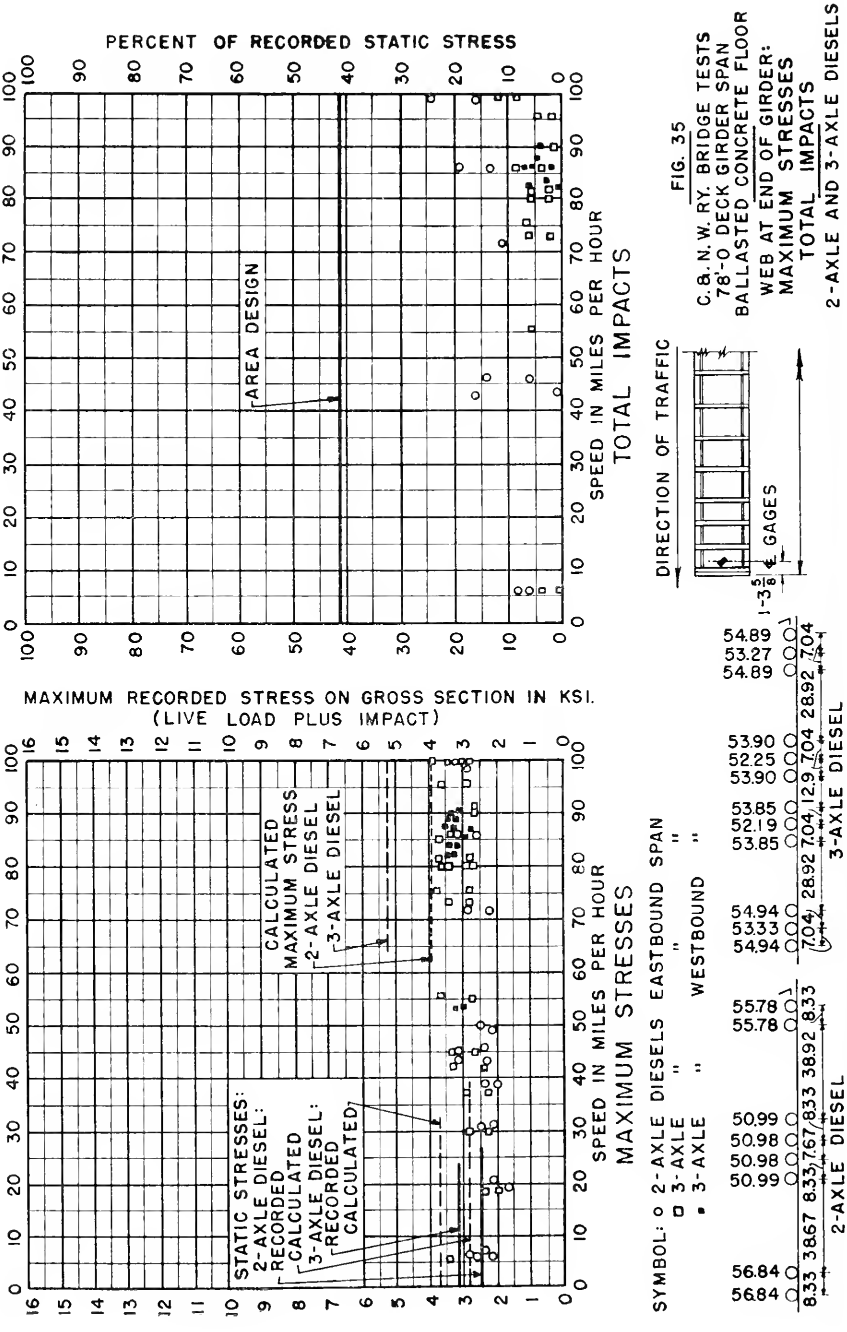


FIG. 35
C.&N.W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
WEB AT END OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
2-AXLE AND 3-AXLE DIESELS

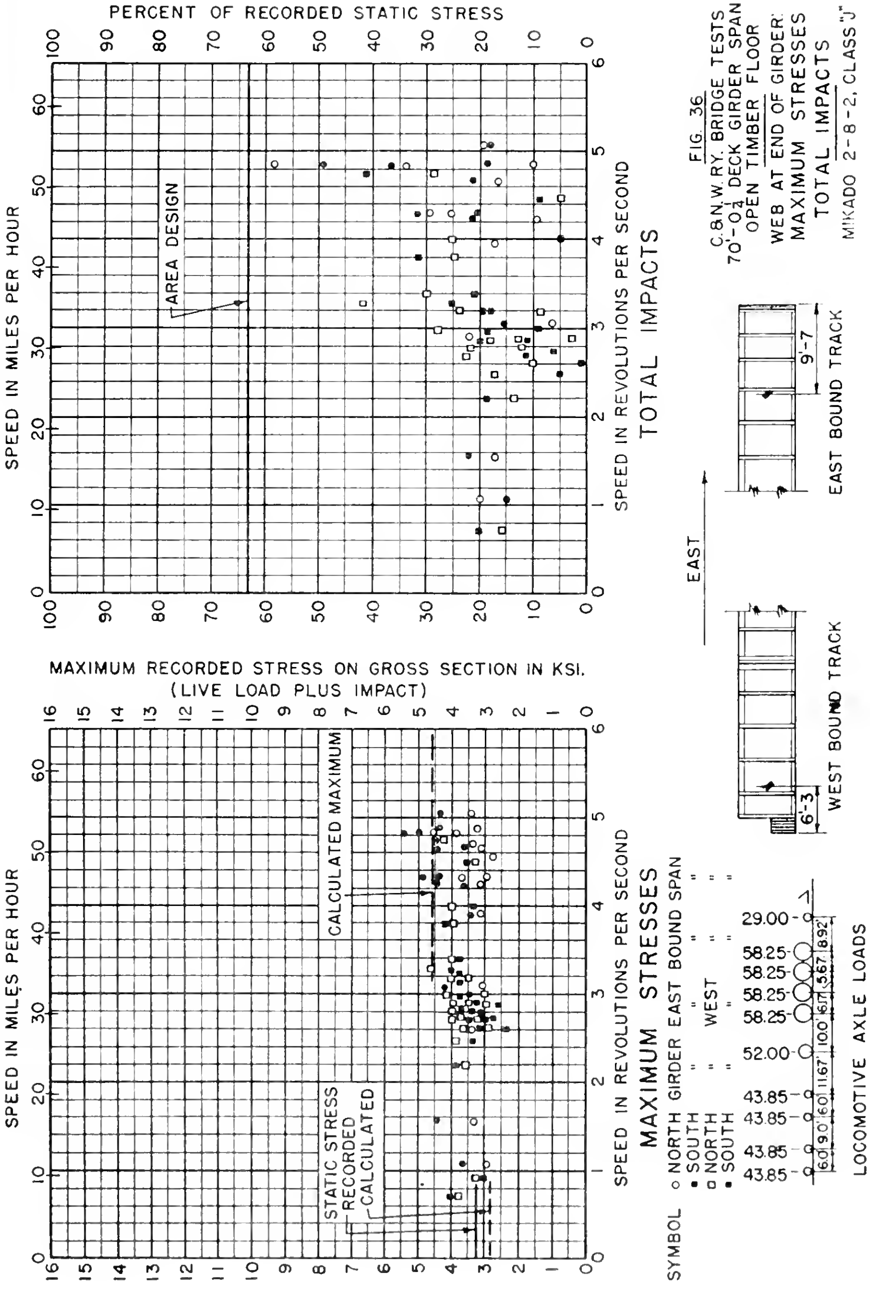


FIG. 36
C.&N.W. RY. BRIDGE TESTS
70'-0½ DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
MIKADO 2-8-2, CLASS "J"

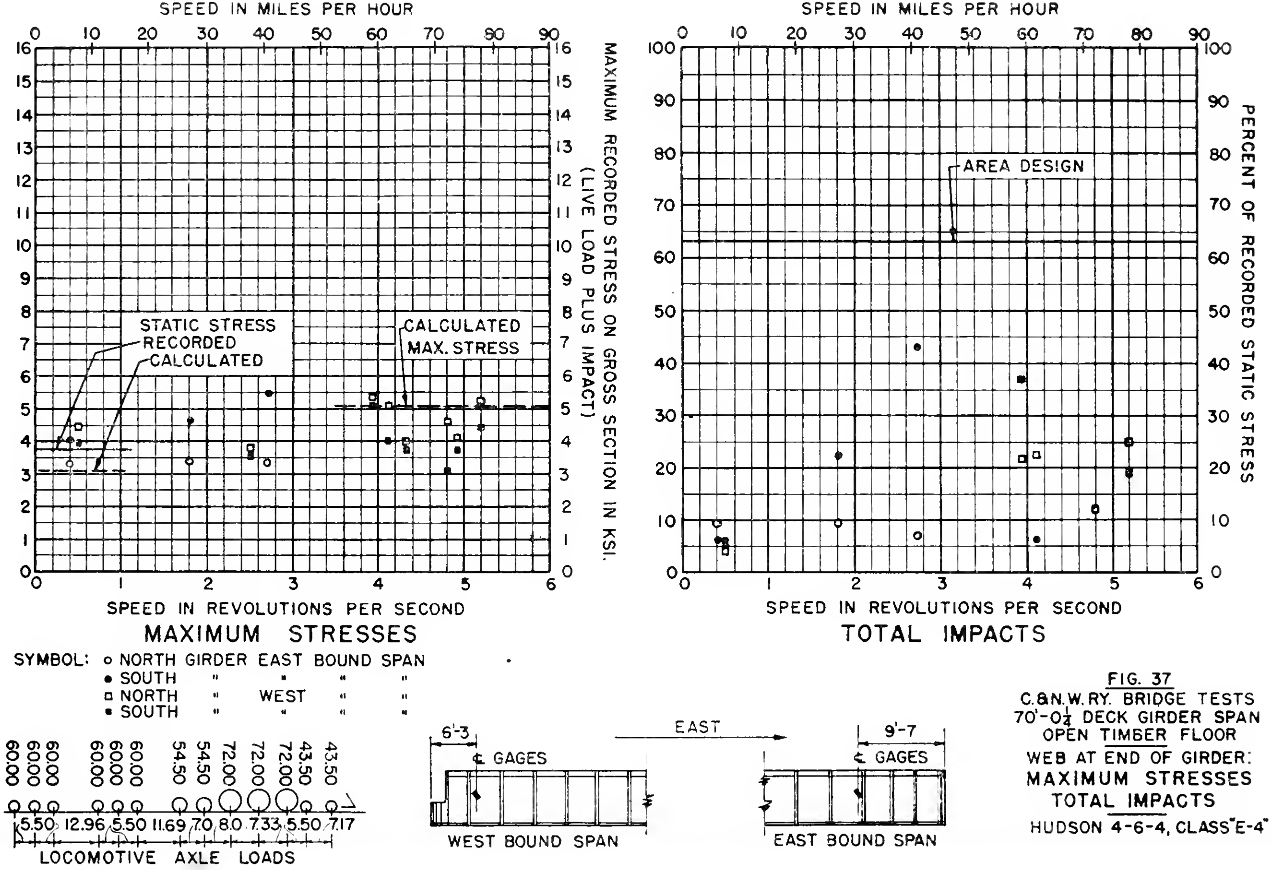


FIG. 37
C.&N.W.RY. BRIDGE TESTS
70'-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
HUDSON 4-6-4, CLASS "E-4"

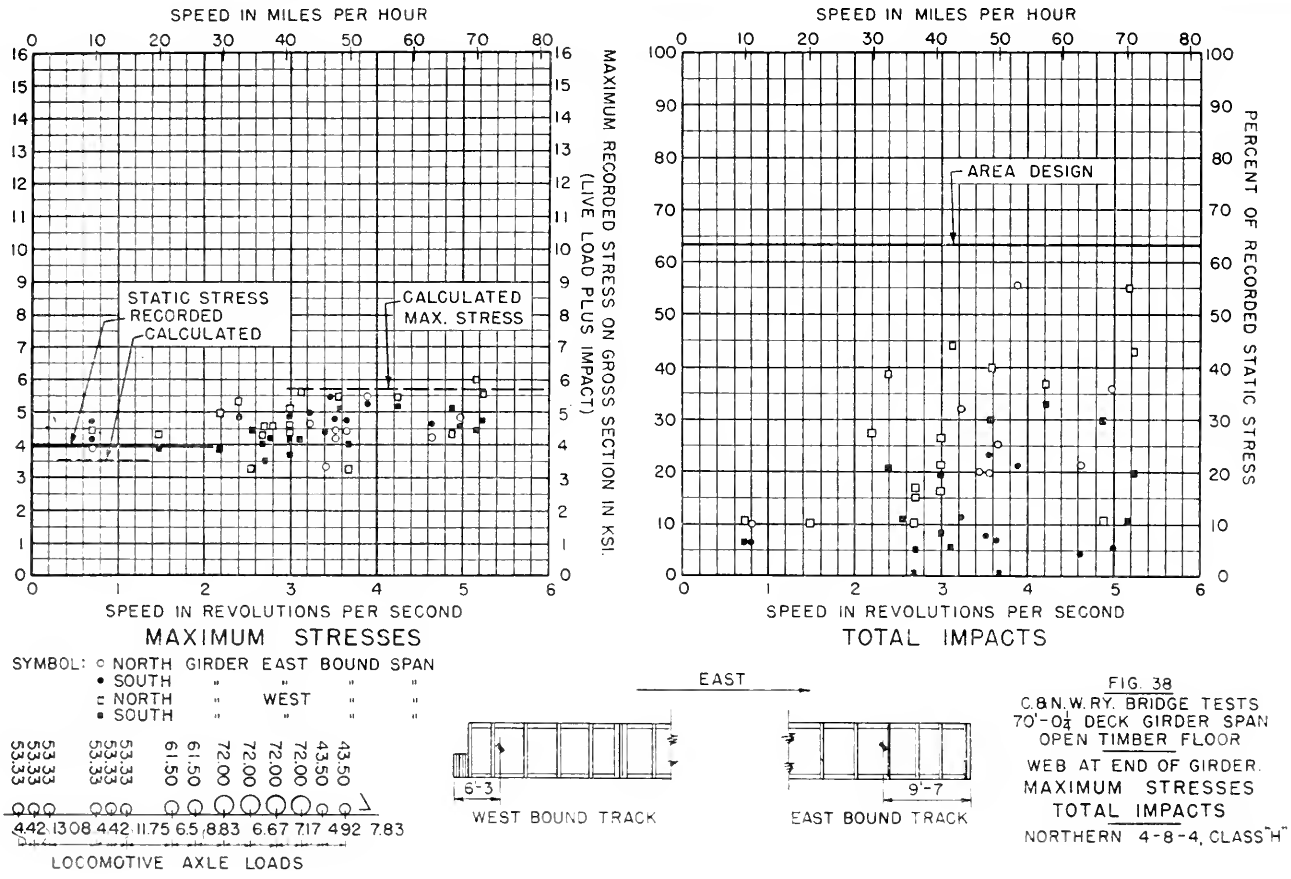


FIG. 38

C.&N.W.RY. BRIDGE TESTS
70'-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER.
MAXIMUM STRESSES
TOTAL IMPACTS
NORTHERN 4-8-4, CLASS "H"

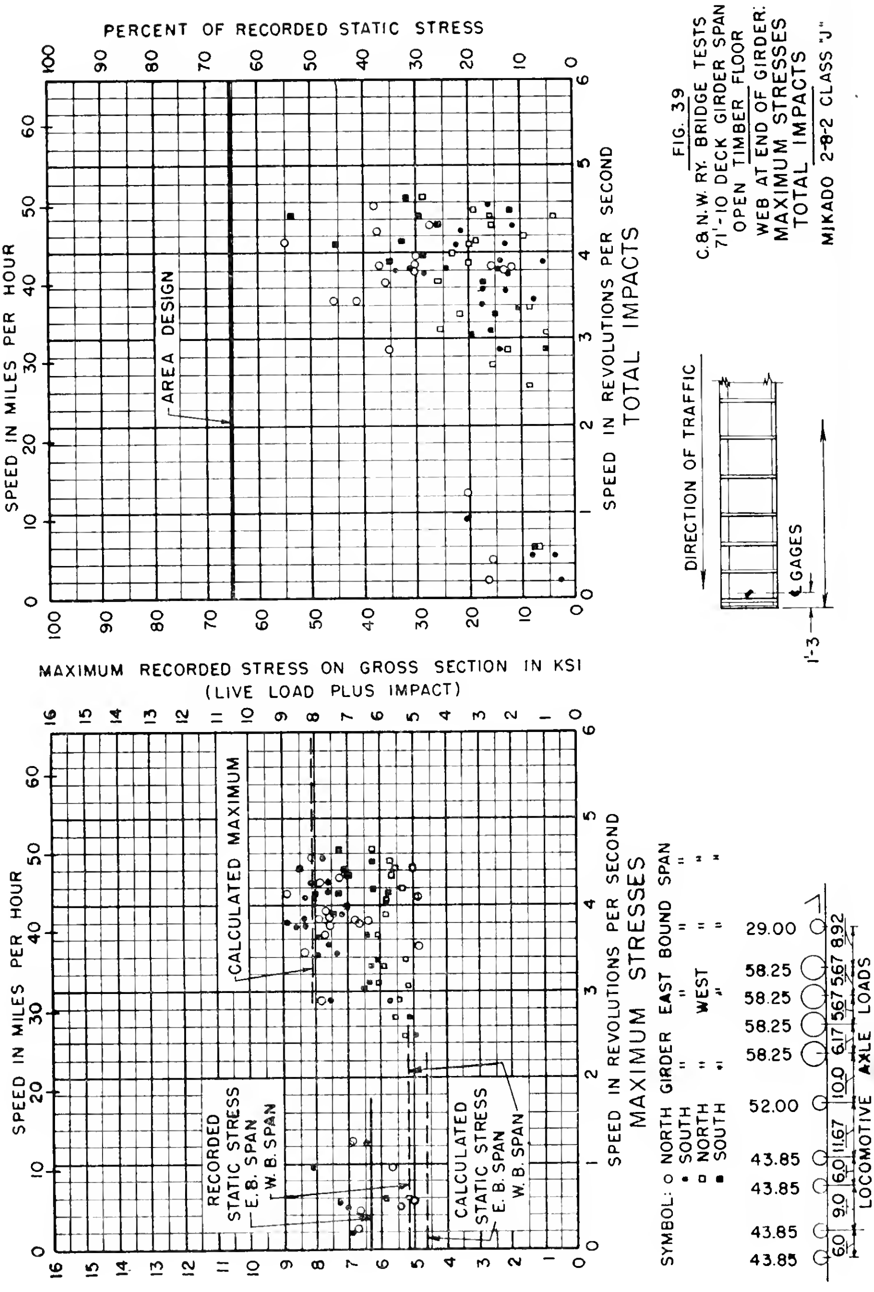


FIG. 39
C.&N.W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
MIKADO 2-8-2 CLASS "J"

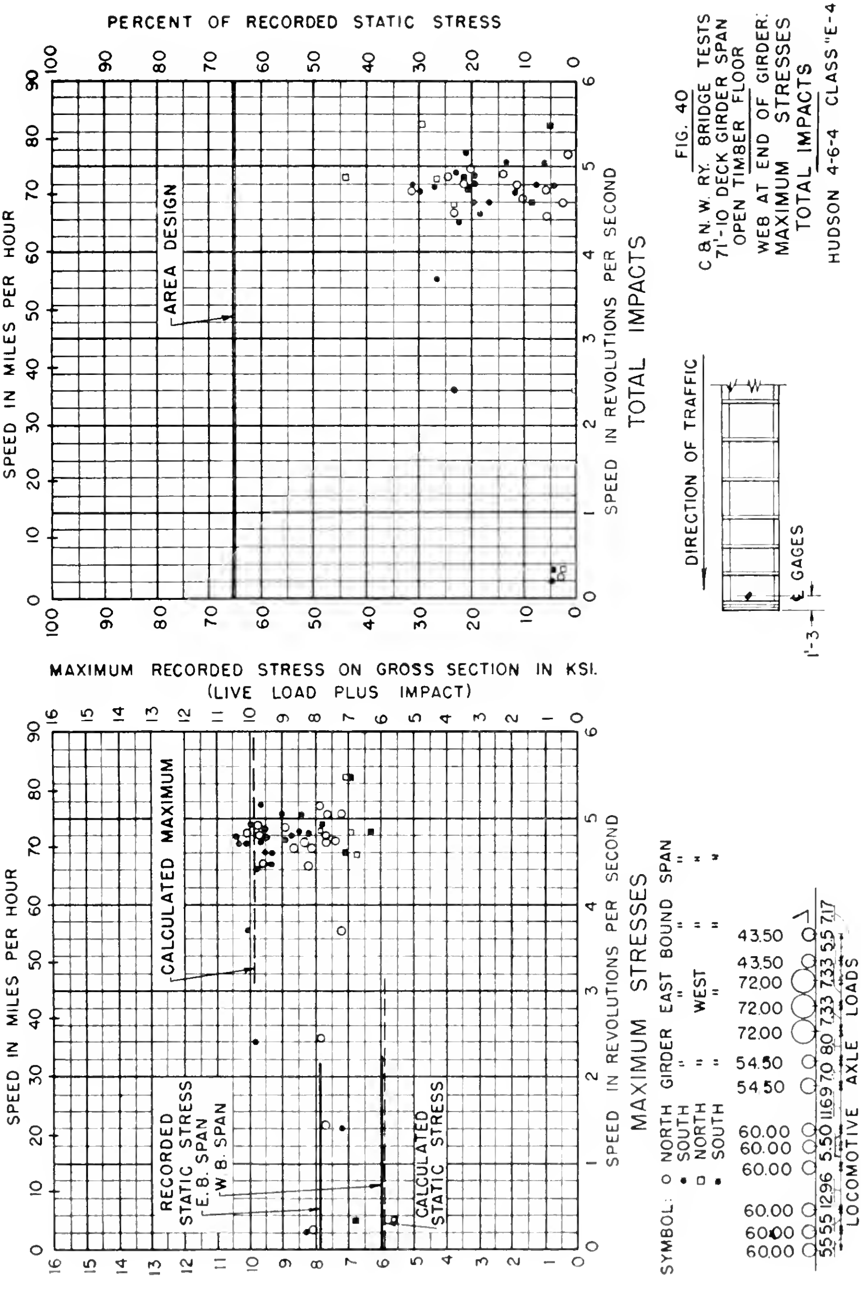


FIG. 40
C & N. W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
HUDSON 4-6-4 CLASS "E-4"

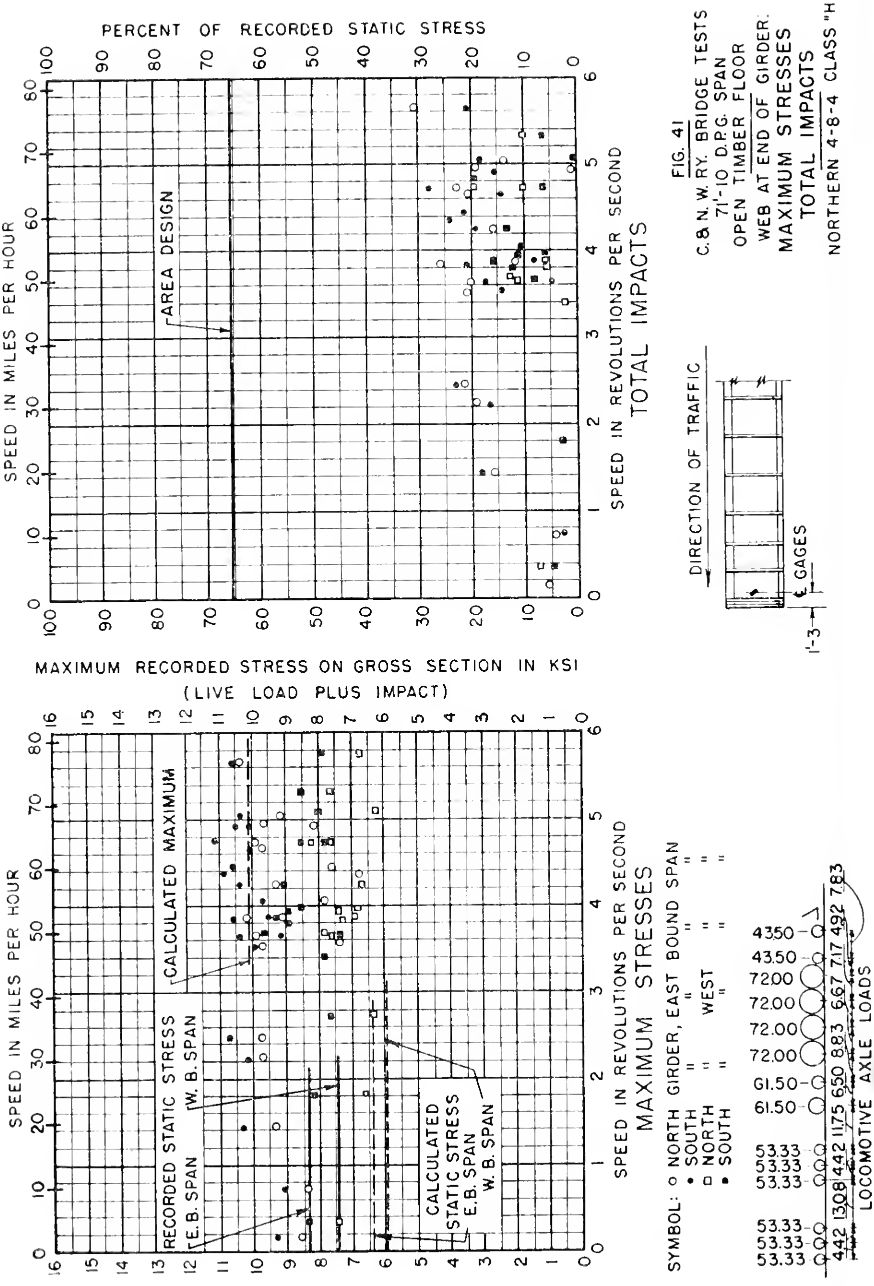


FIG. 41
C.& N.W. RY. BRIDGE TESTS
71'-10 D.P.G. SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
NORTHERN 4-8-4 CLASS "H"

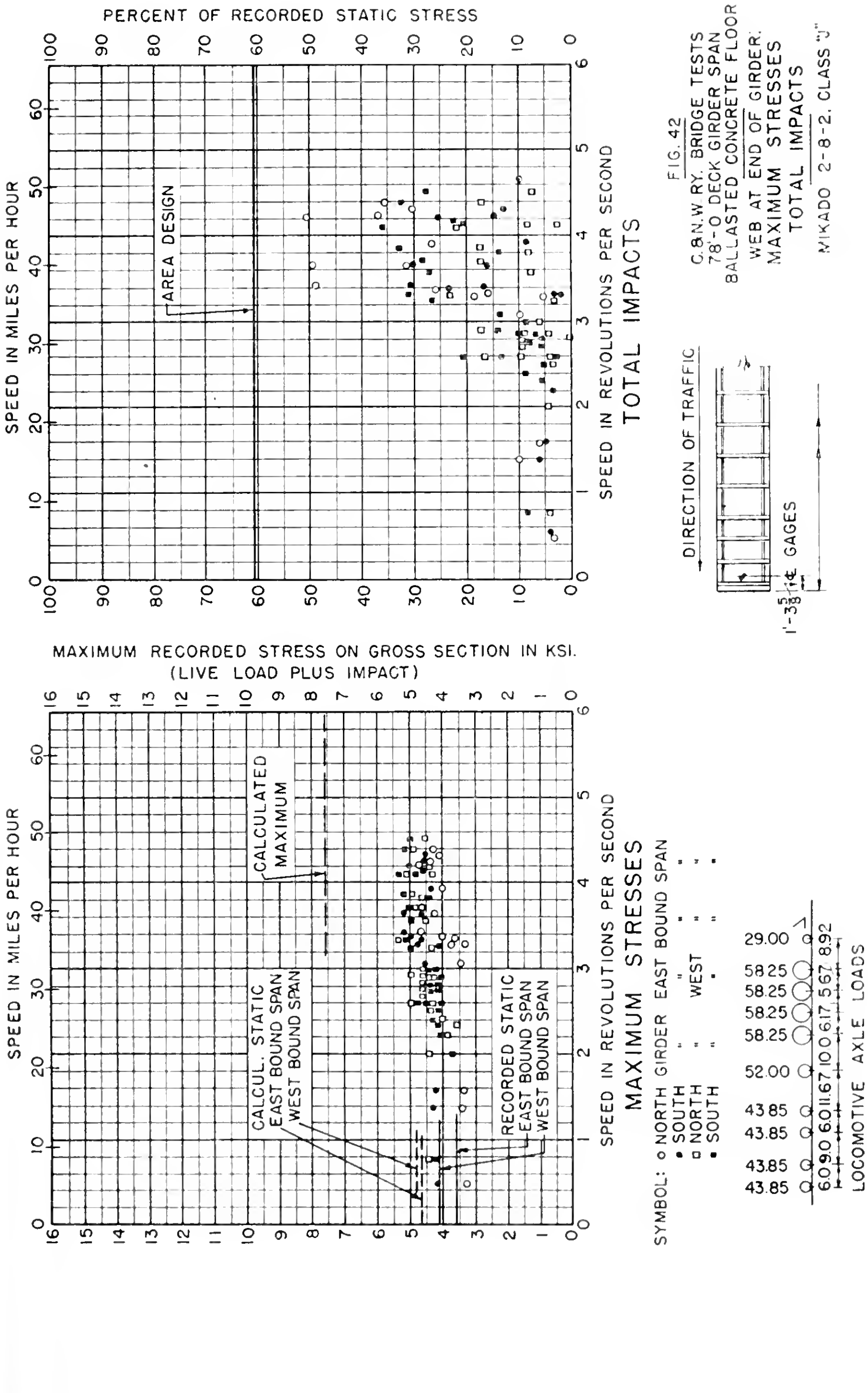


FIG. 42
C.&N.W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
WEB AT END OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
MIKADO 2-8-2, CLASS "J"

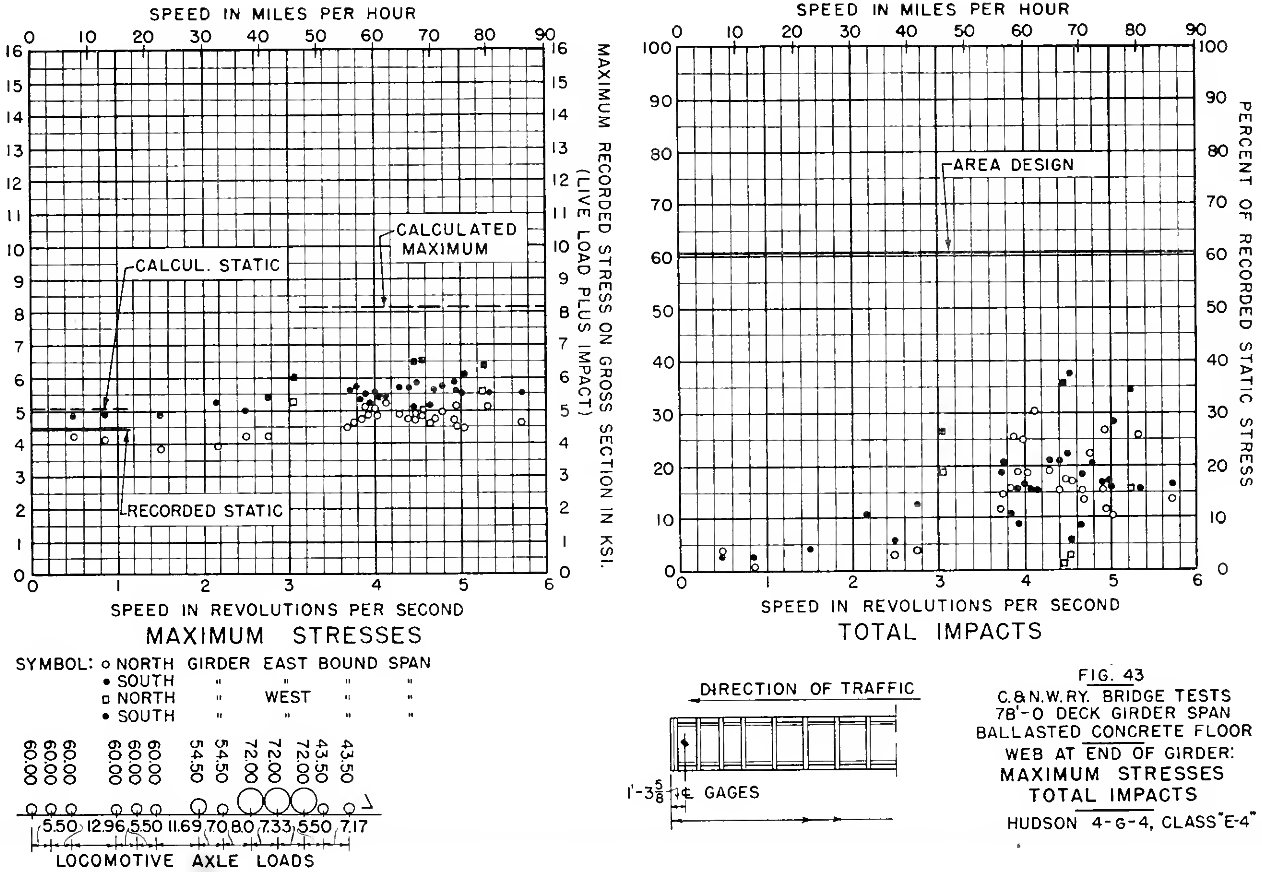


FIG. 43

C.&N.W.RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
WEB AT END OF GIRDER:
MAXIMUM STRESSES
TOTAL IMPACTS
HUDSON 4-6-4, CLASS "E-4"

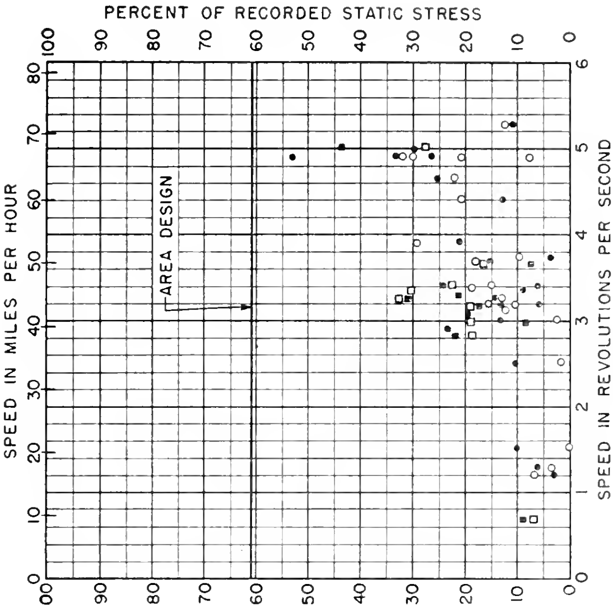
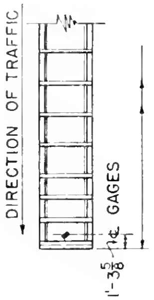
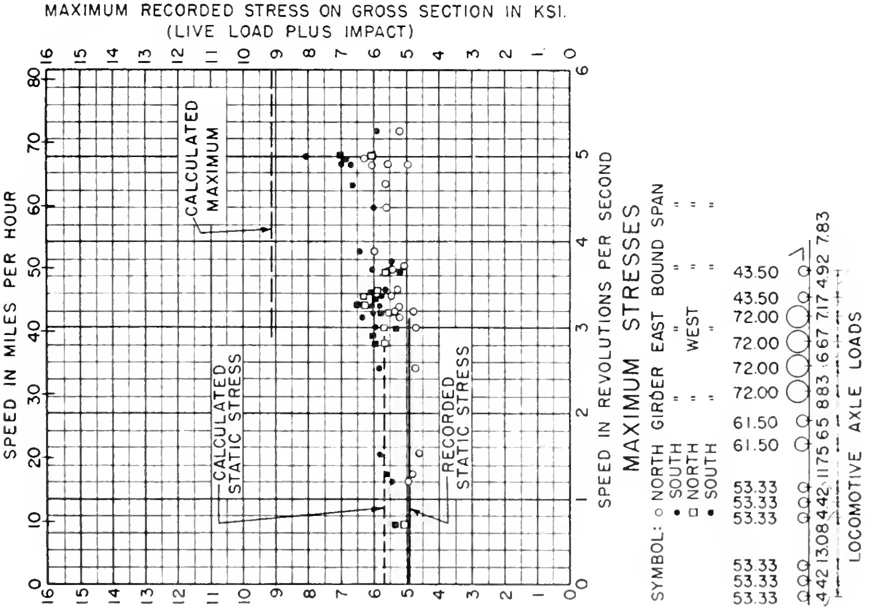


FIG. 44
C.& N.W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
WEB AT END OF GIRDER
MAXIMUM STRESSES
TOTAL IMPACTS
NORTHERN 4-8-4, CLASS "H"





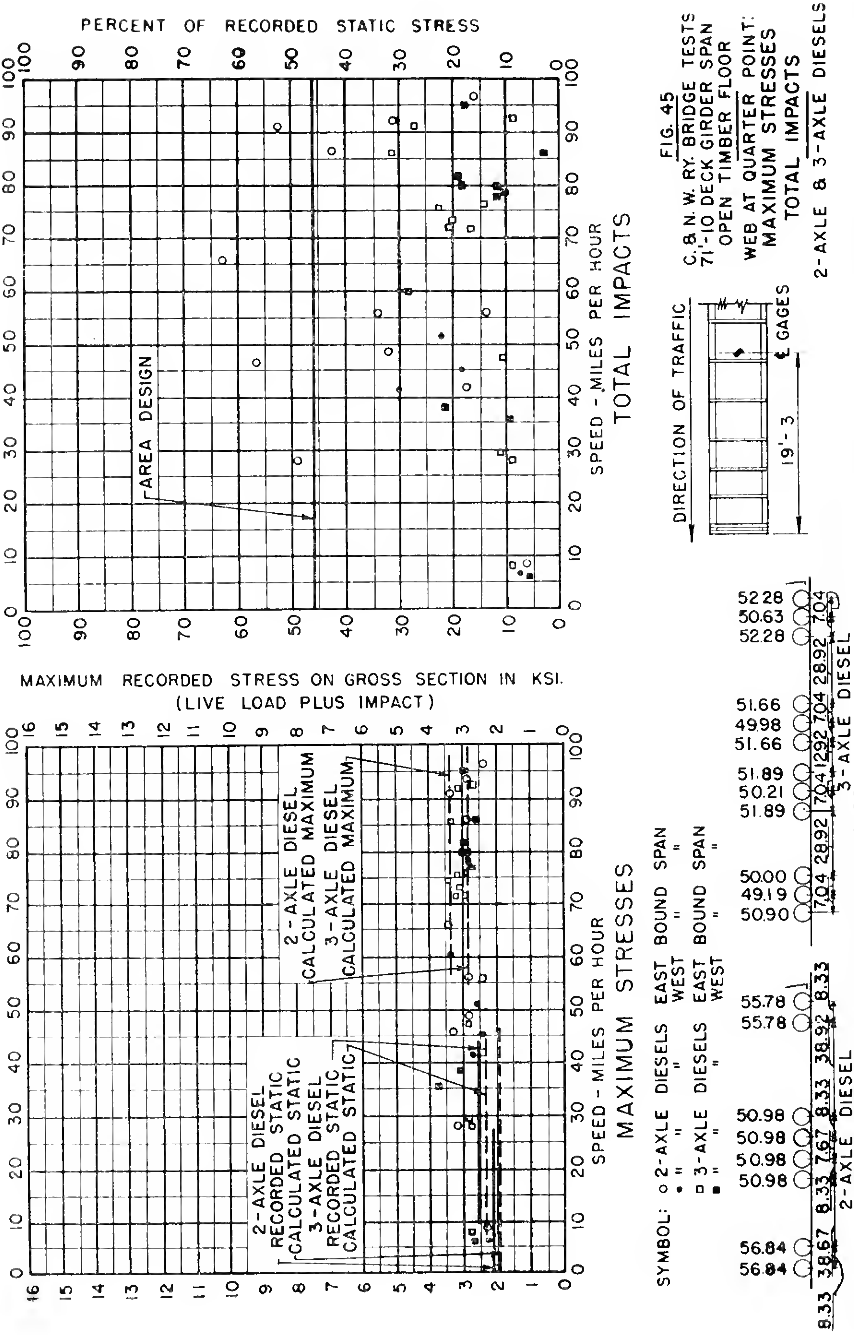


FIG. 45
C. & N. W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT QUARTER POINT:
MAXIMUM STRESSES
TOTAL IMPACTS
2-AXLE & 3-AXLE DIESELS

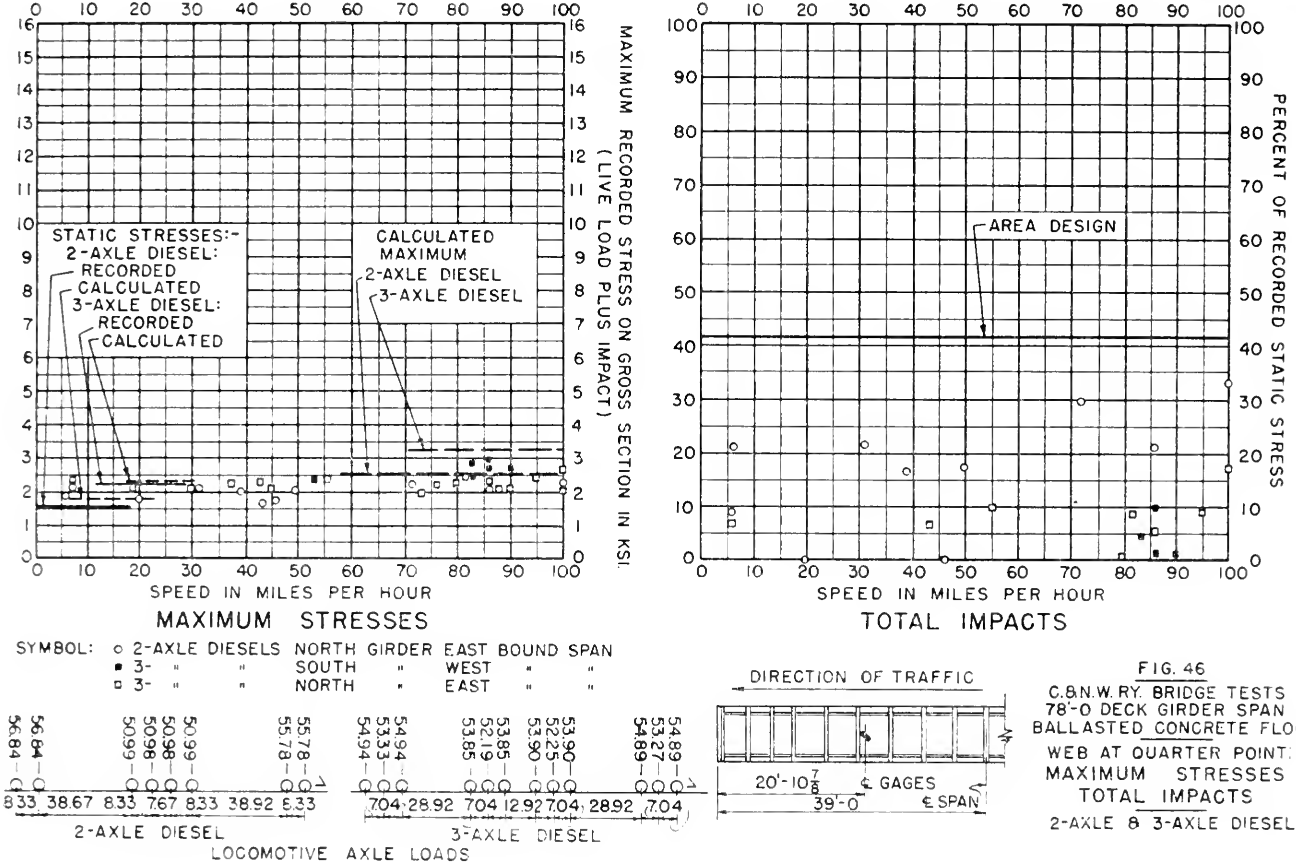


FIG. 46

C.&N.W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
WEB AT QUARTER POINT:
MAXIMUM STRESSES
TOTAL IMPACTS
2-AXLE & 3-AXLE DIESELS

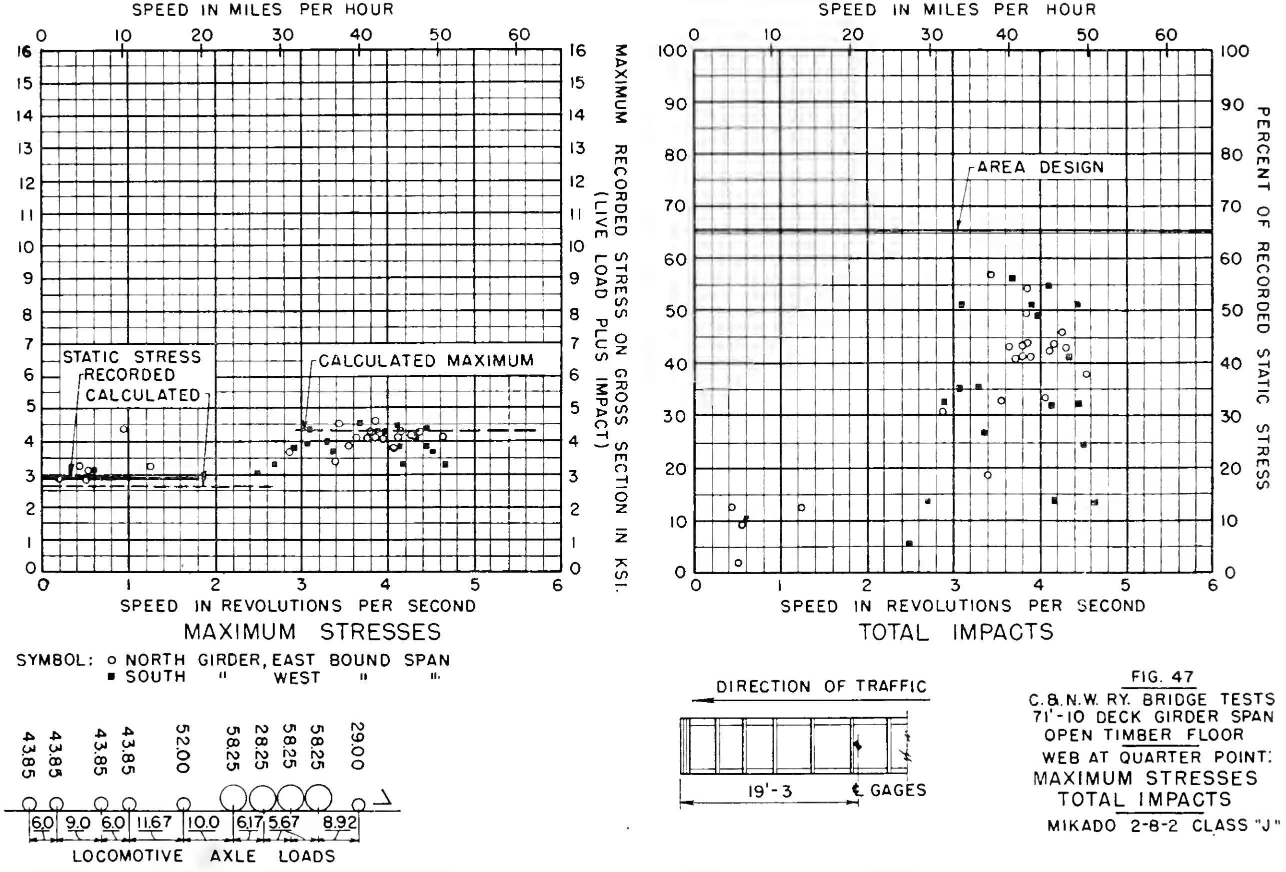


FIG. 47

C.&N.W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT QUARTER POINT:
MAXIMUM STRESSES
TOTAL IMPACTS
MIKADO 2-8-2 CLASS "J"

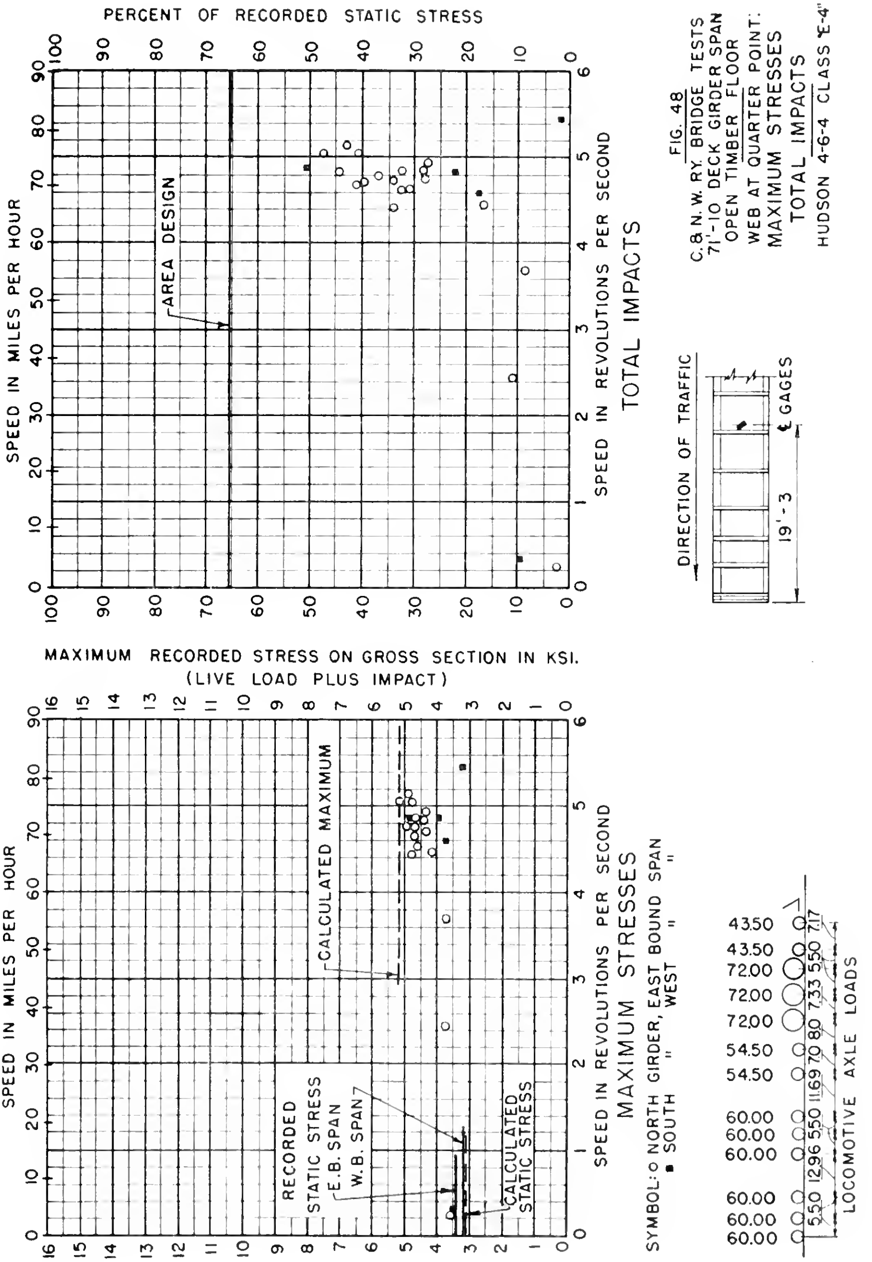


FIG. 48
C. & N. W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT QUARTER POINT:
MAXIMUM STRESSES
TOTAL IMPACTS
HUDSON 4-6-4 CLASS 'E-4'

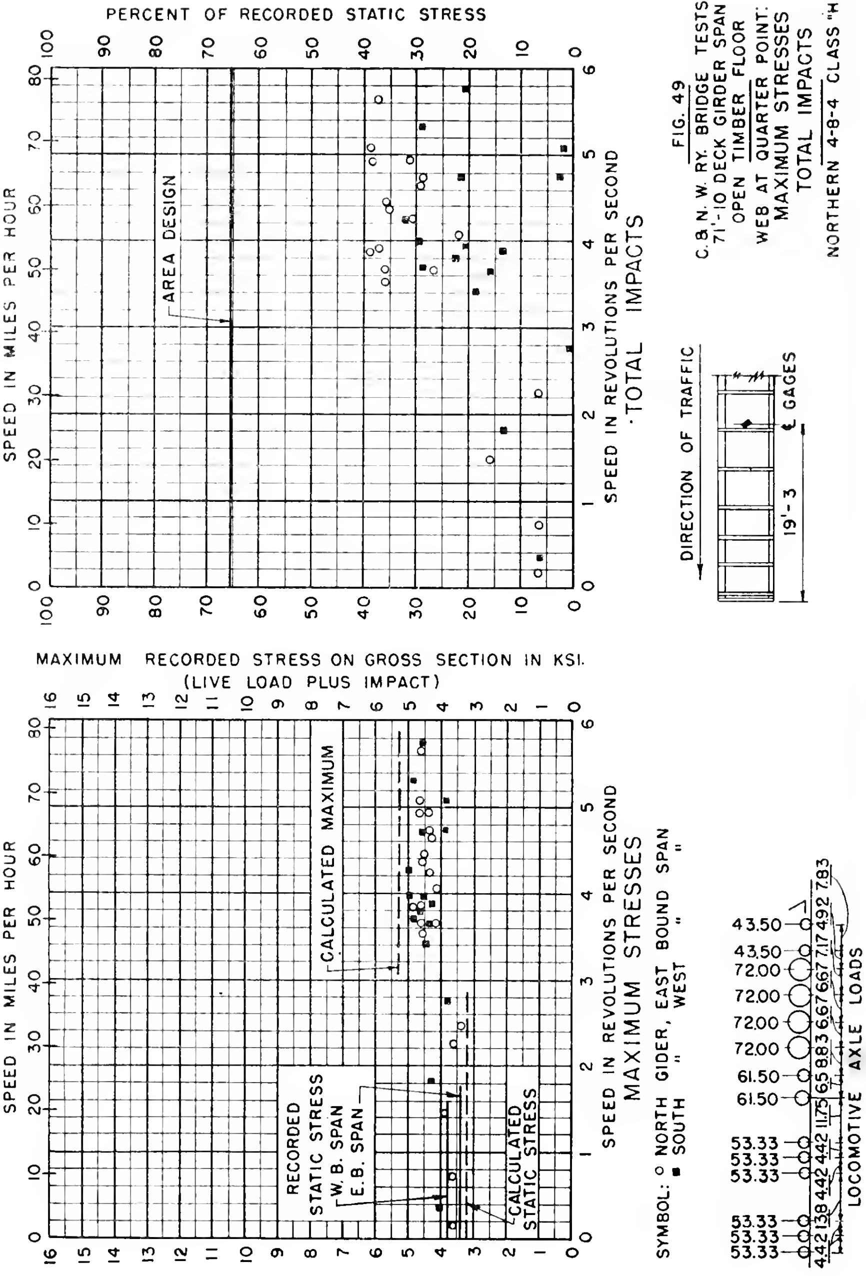


FIG. 49
C.&N.W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT QUARTER POINT:
MAXIMUM STRESSES
TOTAL IMPACTS
NORTHERN 4-8-4 CLASS "H"

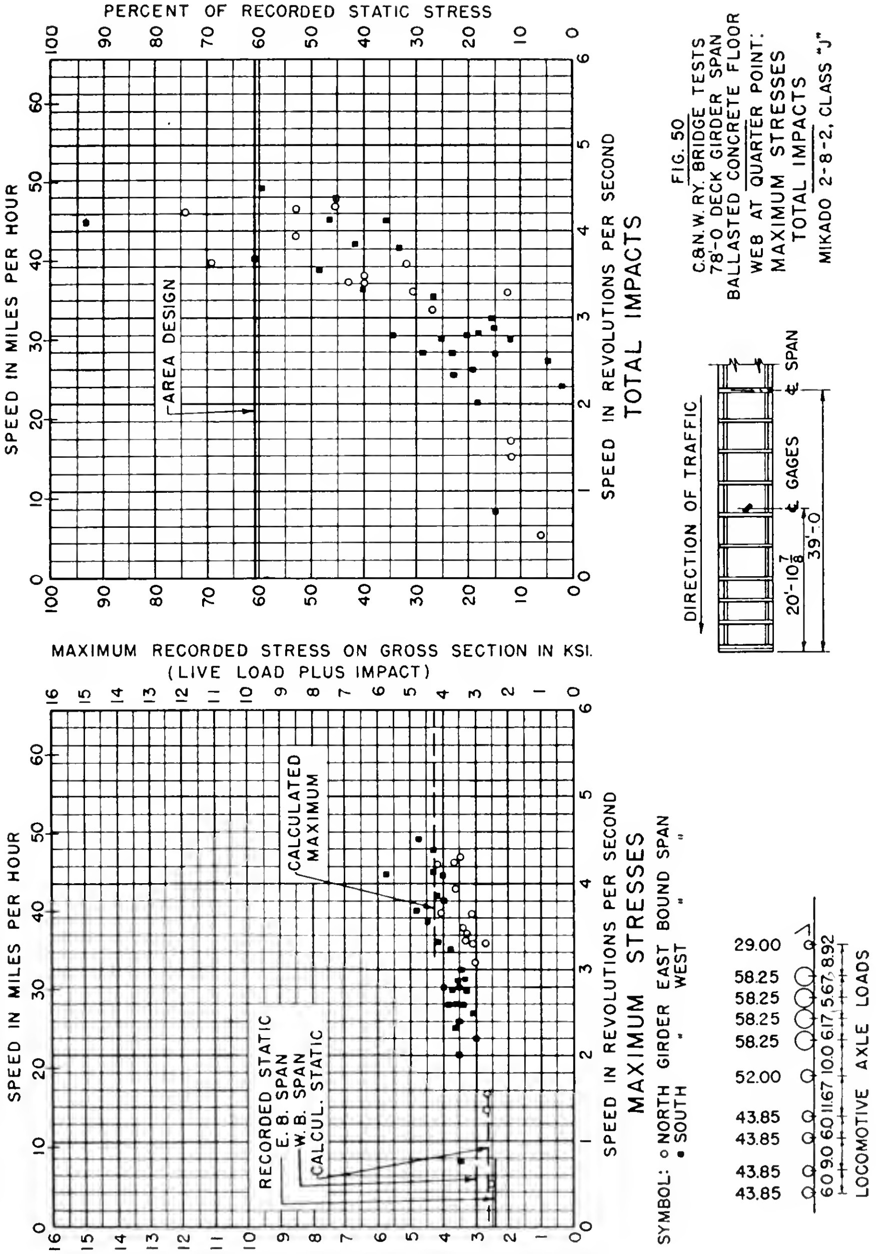


FIG. 50
C.&N.W.RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
WEB AT QUARTER POINT:
MAXIMUM STRESSES
TOTAL IMPACTS
MIKADO 2-8-2, CLASS "J"

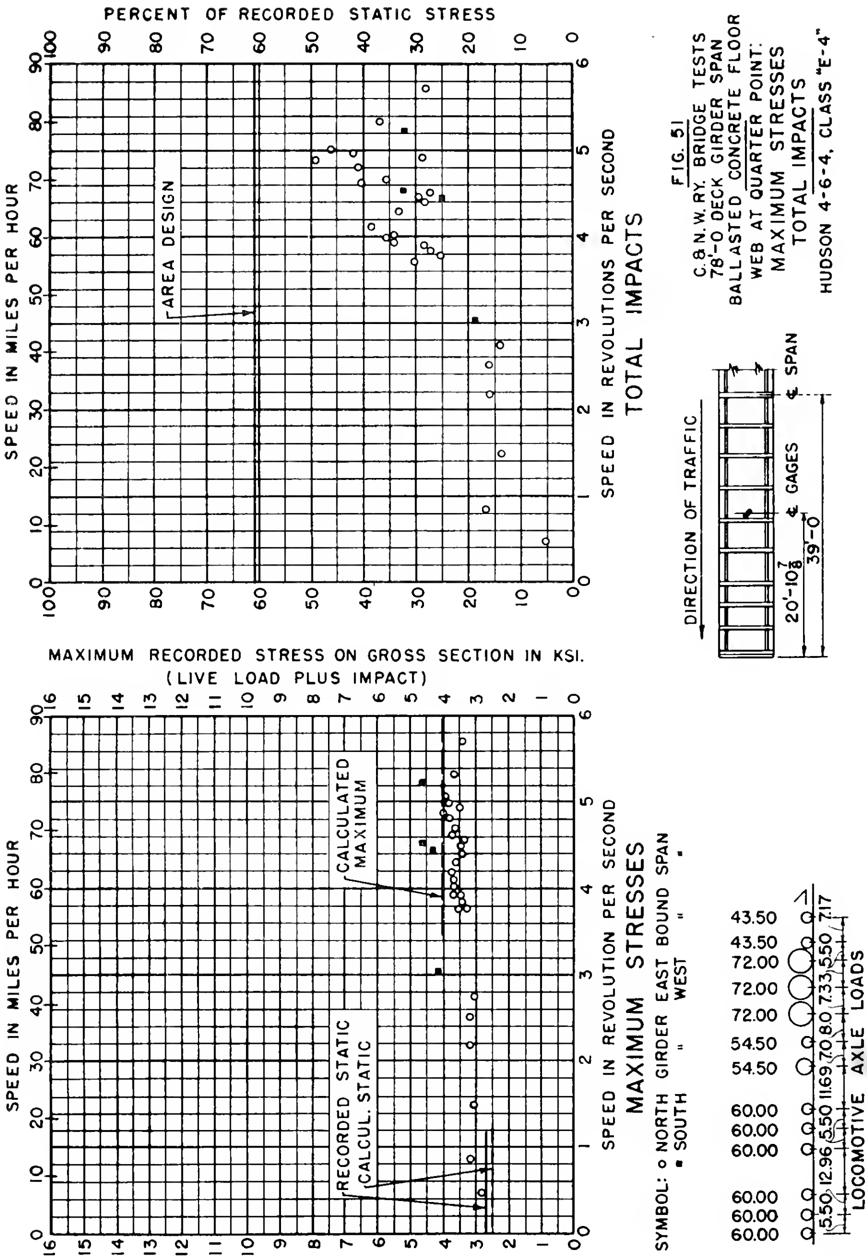
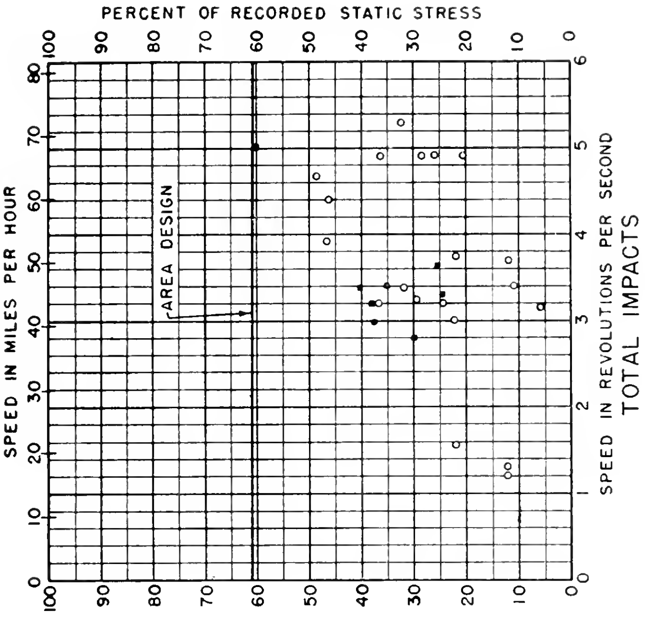
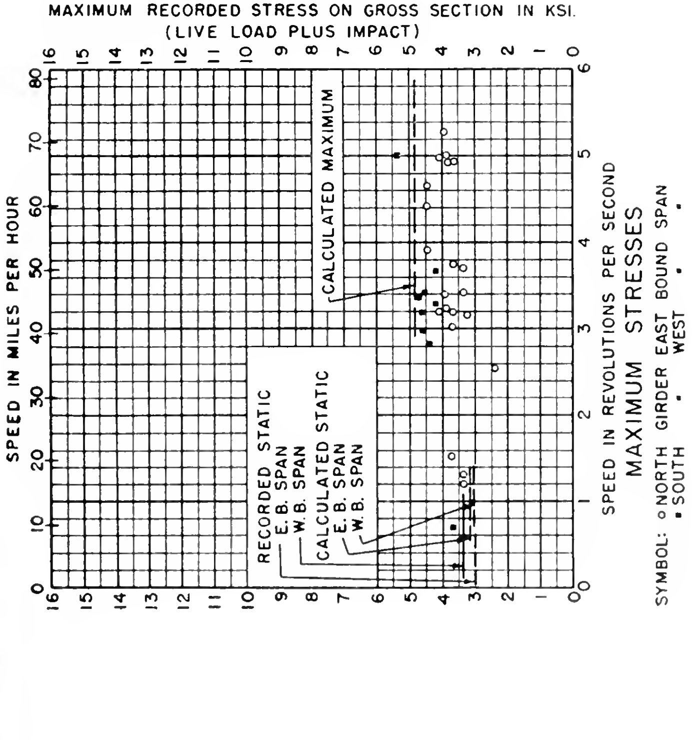
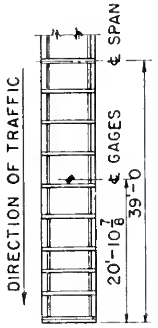


FIG. 51
C.& N.W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
WEB AT QUARTER POINT:
MAXIMUM STRESSES
TOTAL IMPACTS
HUDSON 4-6-4, CLASS "E-4"







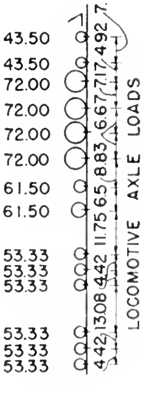


FIG. 52
C.& N.W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
WEB AT QUARTER POINT:
MAXIMUM STRESSES
TOTAL IMPACTS
NORTHERN 4-8-4, CLASS "H"

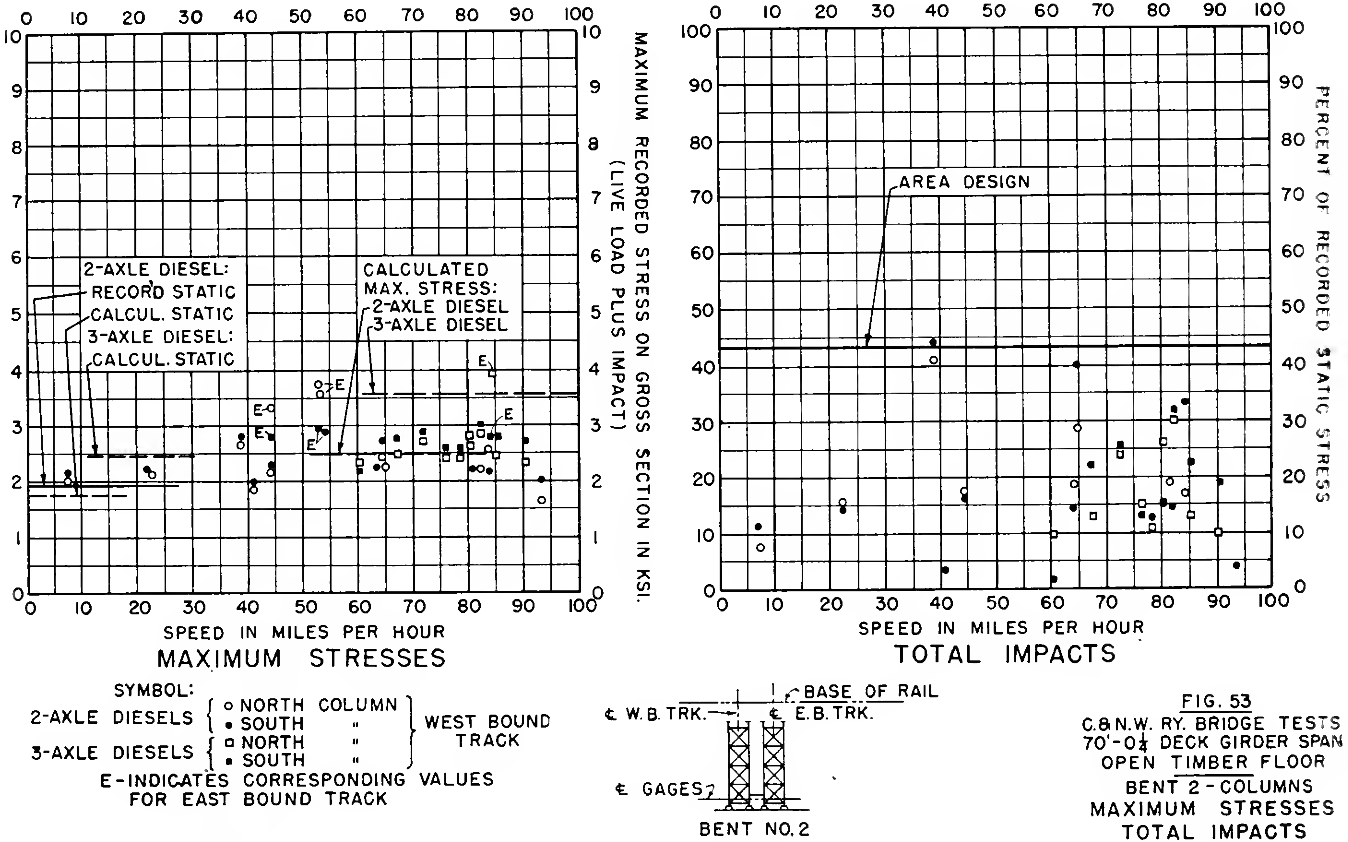


FIG. 53
C.& N.W. RY. BRIDGE TESTS
70'-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR
BENT 2-COLUMNS
MAXIMUM STRESSES
TOTAL IMPACTS
DIESEL LOCOMOTIVES

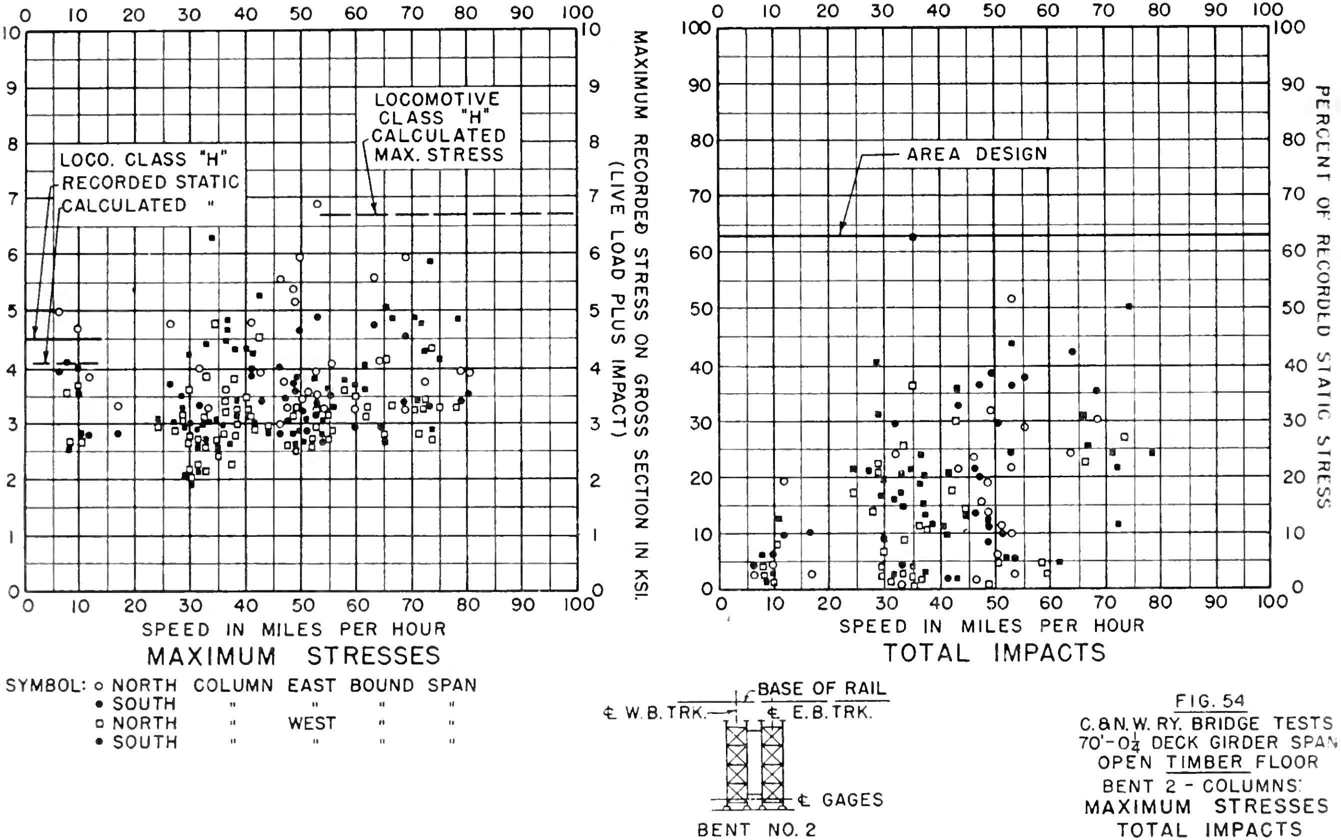


FIG. 54
C.&N.W. RY. BRIDGE TESTS
70'-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR
BENT 2 - COLUMNS:
MAXIMUM STRESSES
TOTAL IMPACTS
STEAM LOCOMOTIVES

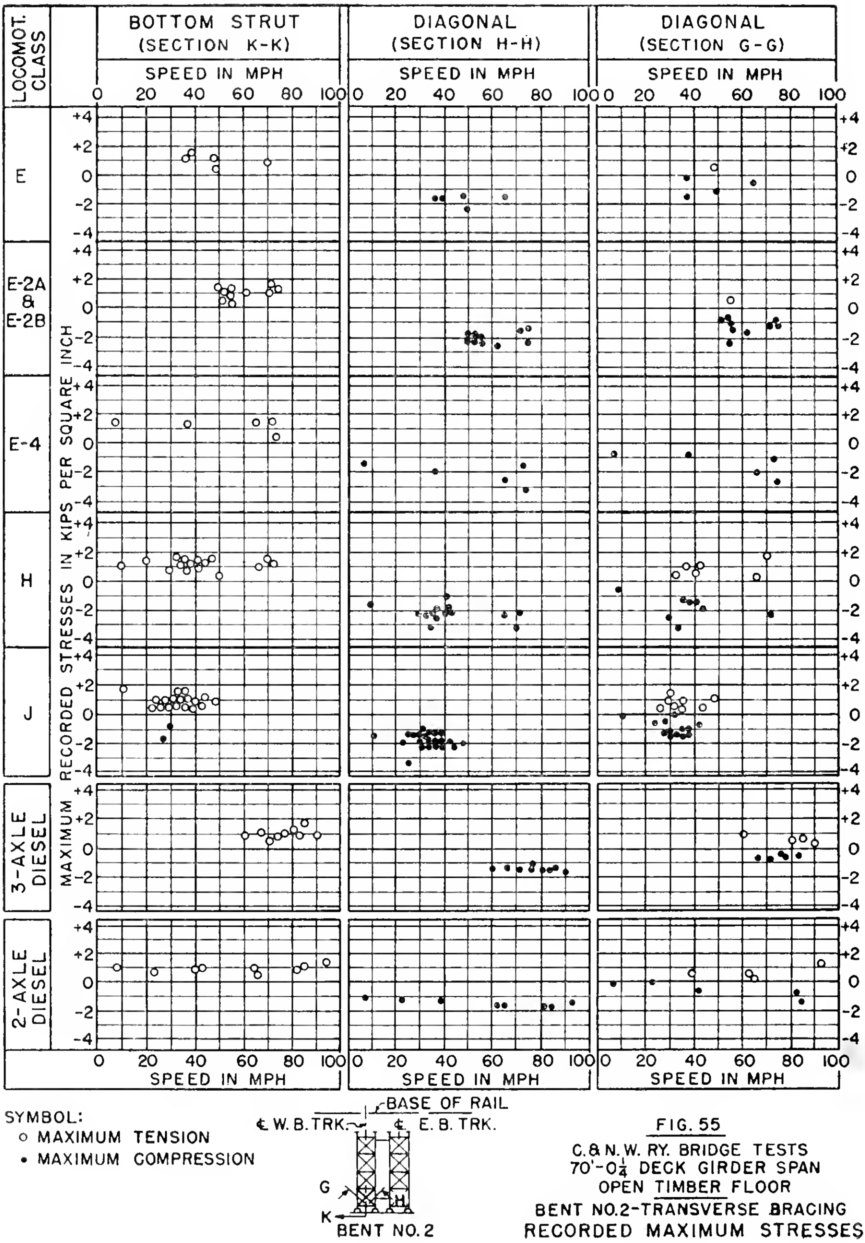
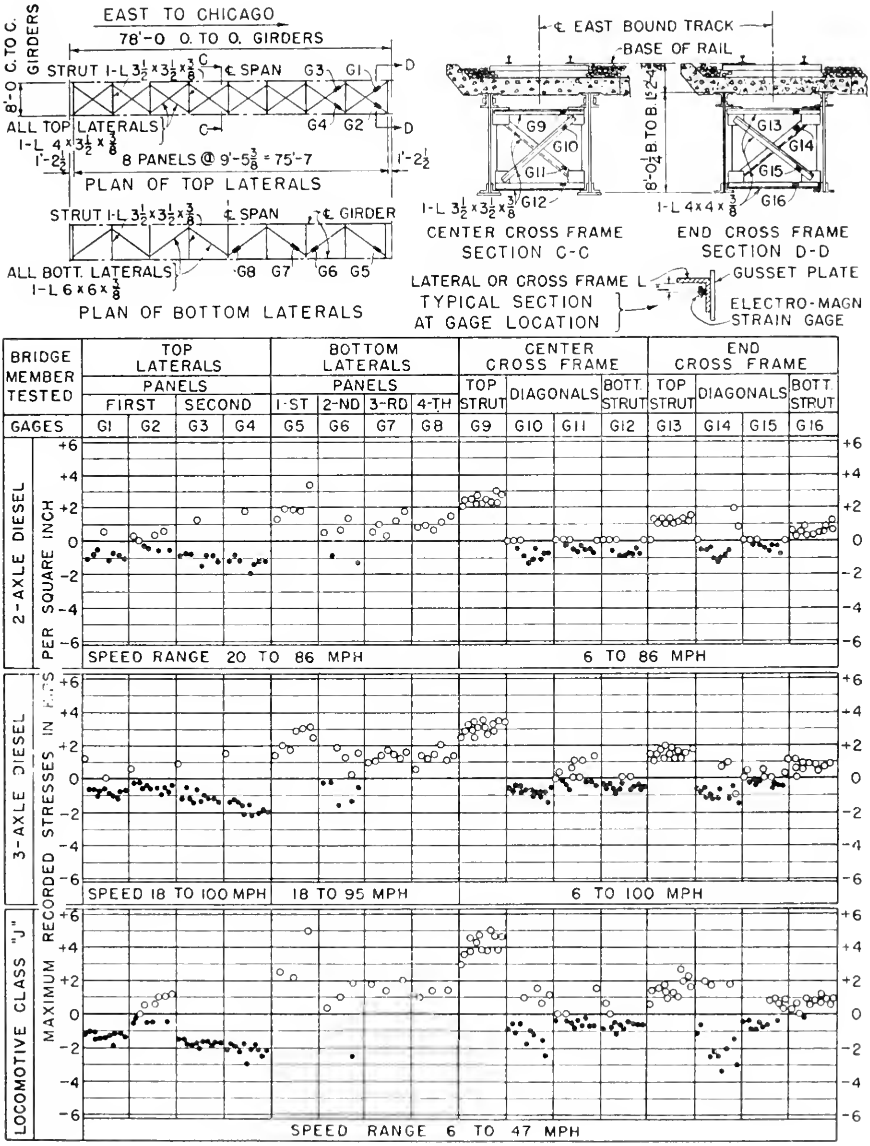


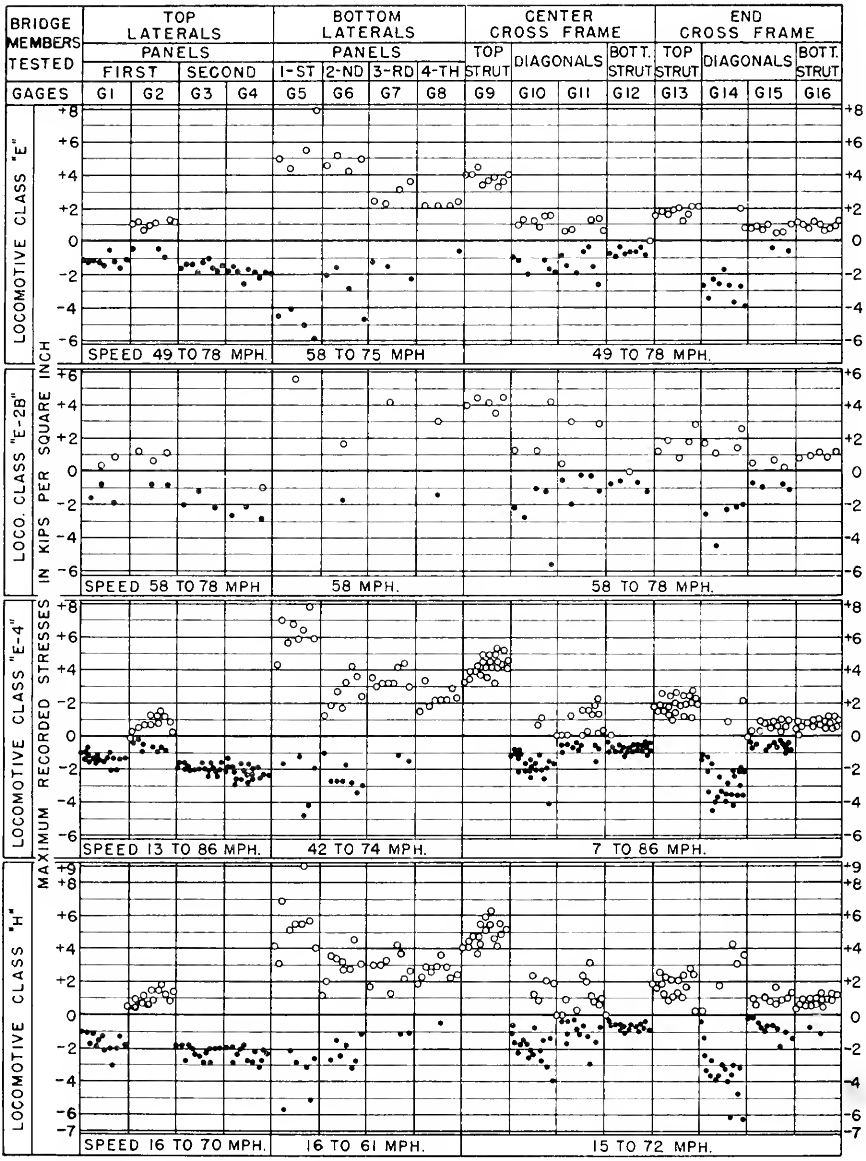
FIG. 55

C.& N.W. RY. BRIDGE TESTS
70'-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR
BENT NO.2-TRANSVERSE BRACING
RECORDED MAXIMUM STRESSES



SYMBOL:
- • MAXIMUM COMPRESSION
- ○ MAXIMUM TENSION

FIG. 56
C.&N.W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
RECORDED MAXIMUM STRESSES
IN LATERALS AND CROSS FRAMES
DIESELS AND LOCO. CLASS "J"

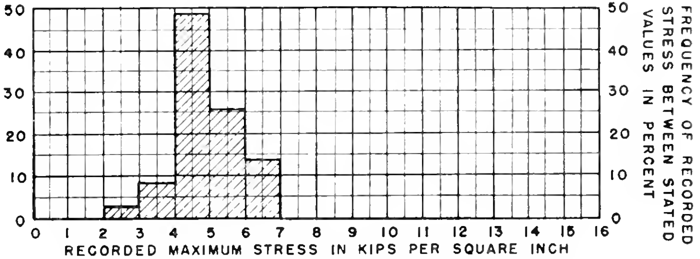


SYMBOL:
- • MAXIMUM COMPRESSION
- ○ MAXIMUM TENSION

FIG. 57
C. & N. W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
RECORDED MAXIMUM STRESSES
IN LATERALS AND CROSS FRAMES
LOCOMOTIVE CLASSES "E", "E-2B", "E-4" & "H"

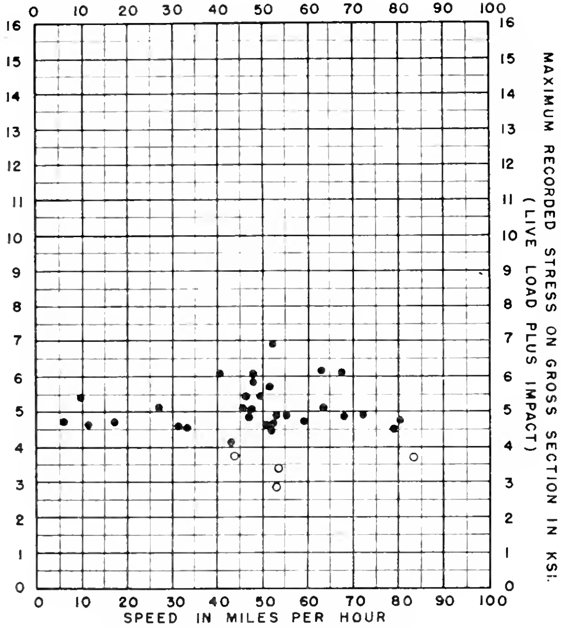
STRESS RANGE DISTRIBUTION

STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI.	NUMBER OF READINGS FOR EACH STRESS RANGE									PERCENT OF TOTAL READINGS								
	DIESELS		STEAM LOCOMOTIVES						TOTAL	DIESELS		STEAM LOCOMOTIVES						TOTAL
	2 AXLES	3 AXLES	RI	J	E	E-2A E-28	E-4	H		2 AXLES	3 AXLES	RI	J	E	E-2A E-28	E-4	H	
6.0 TO 7.0							1	4	5							2.9	11.4	14.3
5.0 " 6.0				3		1	1	4	9				8.6		2.9	2.8	11.4	25.7
4.0 " 5.0				11	3	2	1		17				31.3	8.6	5.7	2.9		48.5
3.0 " 4.0	2	1							3	5.7	2.9							8.6
2.0 " 30	1								1	2.9								2.9
TOTAL READINGS	3	1	—	14	3	3	3	8	35	8.6	2.9	—	39.9	8.6	8.6	8.6	22.8	100



FREQUENCY OF MAXIMUM STRESSES

(SOUTH GIRDER)



RECORDED MAXIMUM STRESSES

(SOUTH GIRDER)

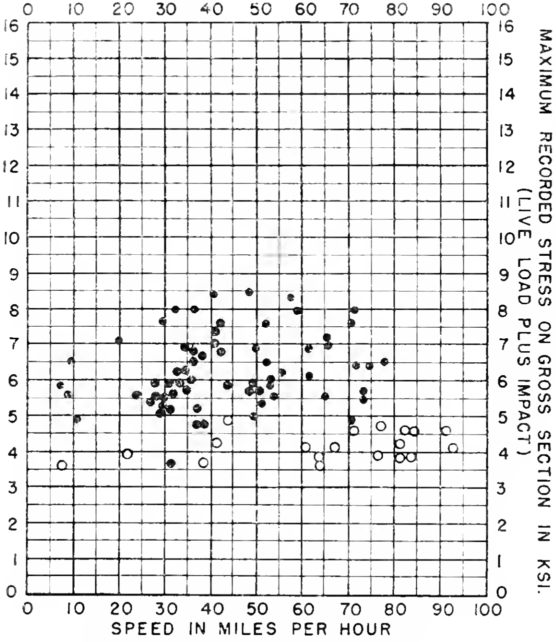
SYMBOL: ● STEAM LOCOMOTIVES
○ DIESEL LOCOMOTIVES

FIG. 58

C. & N. W. RY. BRIDGE TESTS
$70'-0\frac{1}{4}''$ DECK GIRDER
OPEN TIMBER FLOOR
FREQUENCY OF MAXIMUM STRESSES
EASTBOUND SPAN, SOUTH GIRDER

STRESS RANGE DISTRIBUTION

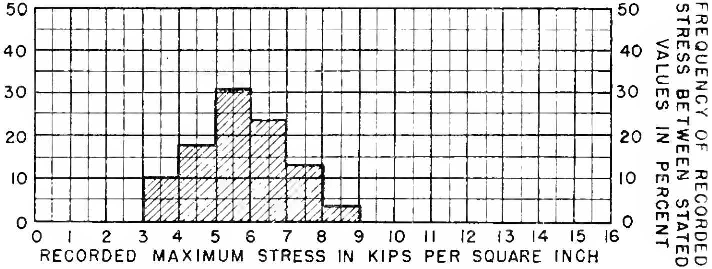
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI.	NUMBER OF READINGS FOR EACH STRESS RANGE									PERCENT OF TOTAL READINGS								
	DIESELS		STEAM LOCOMOTIVES						TOTAL	DIESELS		STEAM LOCOMOTIVES						TOTAL
	2 AXLES	3 AXLES	RI	J	E	E-2A E-2B	E-4	H		2 AXLES	3 AXLES	RI	J	E	E-2A E-2B	E-4	H	
8.0 TO 9.0								3	3								3.6	3.6
7.0 " 8.0				1			2	8	11				1.2			2.4	9.5	13.1
6.0 " 7.0				4		5	4	7	20				4.8		5.9	4.8	8.3	23.8
5.0 " 6.0	1			17	2	4	2		26	1.2			20.2	2.4	4.8	2.4		31.0
4.0 " 5.0	2	8		1	3	1			15	2.4	9.5		1.2	3.5	1.2			17.8
3.0 " 4.0	7	1	1						9	8.3	1.2	1.2						10.7
TOTAL READINGS	10	9	1	23	5	10	8	18	84	11.9	10.7	1.2	27.4	5.9	11.9	9.6	21.4	100.0



RECORDED MAXIMUM STRESSES

(SOUTH GIRDER)

SYMBOL: ● STEAM LOCOMOTIVES
○ DIESEL LOCOMOTIVES



FREQUENCY OF MAXIMUM STRESSES

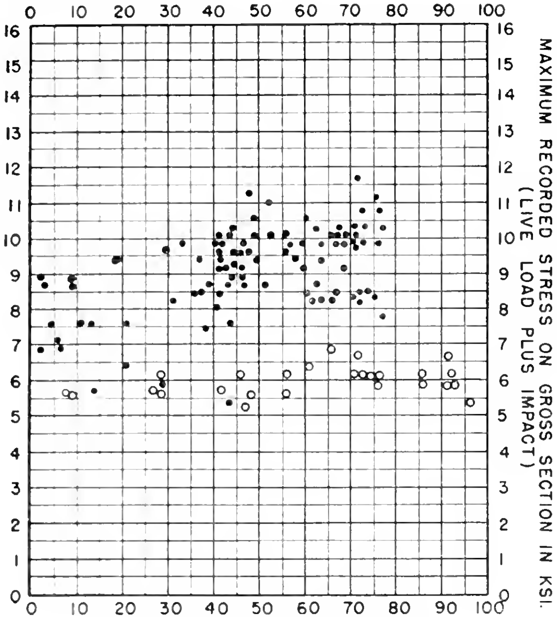
(SOUTH GIRDER)

FIG. 59

C.& N.W. RY. BRIDGE TESTS
70'-0¼ DECK GIRDER SPAN
OPEN TIMBER FLOOR
FREQUENCY OF MAXIMUM STRESSES
WESTBOUND SPAN, SOUTH GIRDER

STRESS RANGE DISTRIBUTION

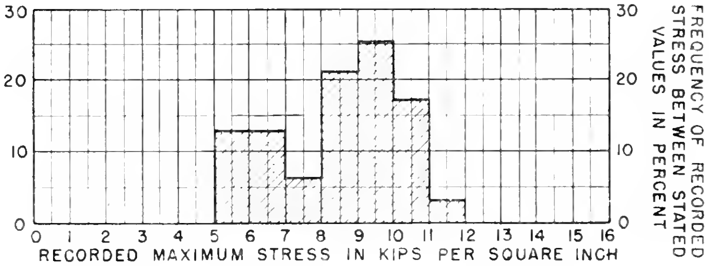
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI.	NUMBER OF READINGS FOR EACH STRESS RANGE										PERCENT OF TOTAL READINGS									
	DIESELS		STEAM LOCOMOTIVES							TOTAL	DIESEL		STEAM LOCOMOTIVES							TOTAL
	2	3	RI	J	J-4	E	E2A E28	E-4	H		2	3	RI	J	J 4	E	E2A E28	E-4	H	
	AXLES										AXLES									
11.0 TO 12.0								2	2	4								1.6	1.6	3.2
10.0 " 11.0				1	2			9	9	21				0.8	1.6			7.4	7.4	17.2
9.0 " 10.0				8	6	3		7	7	31				6.6	4.9	2.4		5.8	5.8	25.5
8.0 " 9.0				7	3	8	4	2	2	26				5.8	2.5	6.6	3.3	1.6	1.6	21.4
7.0 " 8.0			1	5			1	1		8			0.8	4.1			0.8	0.8		6.5
6.0 " 7.0	3	10		2		1				16	2.5	8.2		1.6		0.8				13.1
5.0 " 6.0	9	4	2	1						16	7.3	3.3	1.7	0.8						13.1
TOTAL READINGS	12	14	3	24	11	12	5	21	20	122	9.8	11.5	2.5	19.7	9.0	9.8	4.1	17.2	16.4	100.



RECORDED MAXIMUM STRESSES

(NORTH GIRDER)

SYMBOL: ● STEAM LOCOMOTIVES
○ DIESEL LOCOMOTIVES



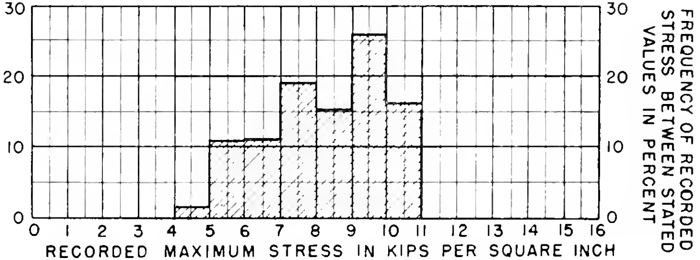
FREQUENCY OF MAXIMUM STRESSES

(NORTH GIRDER)

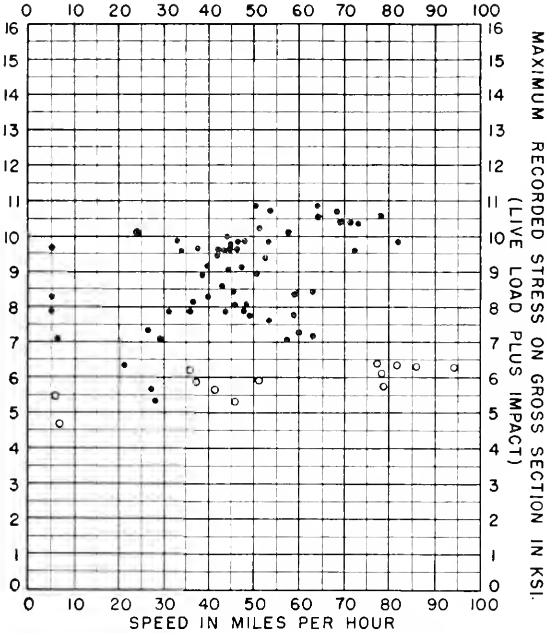
FIG. 60

C. & N. W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FREQUENCY OF MAXIMUM STRESSES
EASTBOUND SPAN, NORTH GIRDER

STRESS RANGE DISTRIBUTION																				
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE										PERCENT OF TOTAL READINGS									
	DIESELS		STEAM LOCOMOTIVES							TOTAL	DIESELS		STEAM LOCOMOTIVES							TOTAL
	2 AXLES	3 AXLES	RI	J	J-4	E	E2A E-28	E-4	H		2 AXLES	3 AXLES	RI	J	J-4	E	E2A E2B	E-4	H	
10.0 TO 11.0								2	10	12								2.7	13.7	16.4
9.0 10.0				4	8			2	5	19				5.5	11.0			2.7	6.8	26.0
8.0 9.0				7	2	1	1			11				9.6	2.7	1.4	1.4			15.1
7.0 8.0				8			5	1		14				11.0			6.8	1.4		19.2
6.0 7.0		7				1				8		9.6				1.4				11.0
5.0 6.0	3	3	2							8	4.1	4.1	2.7							10.9
4.0 5.0	1									1	1.4									1.4
TOTAL READINGS	4	10	2	19	10	2	6	5	15	73	5.5	13.7	2.7	26.1	13.7	2.8	8.2	6.8	20.5	100



FREQUENCY OF MAXIMUM STRESSES
(NORTH GIRDER)



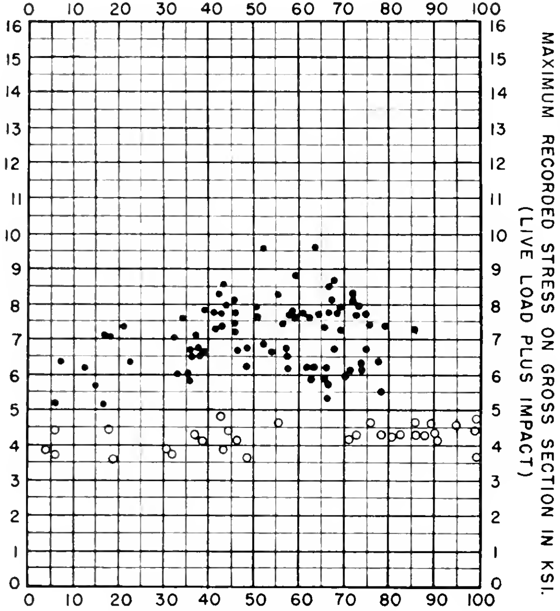
RECORDED MAXIMUM STRESSES
(NORTH GIRDER)

SYMBOL: • STEAM LOCOMOTIVES
○ DIESEL LOCOMOTIVES

FIG. 61

C & N.W. RY. BRIDGE TESTS
71'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR

FREQUENCY OF MAXIMUM STRESSES
WESTBOUND SPAN, NORTH GIRDER

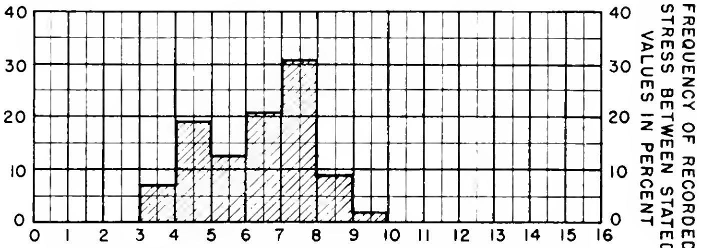


RECORDED MAXIMUM STRESSES
(NORTH GIRDER)

SYMBOL: ● STEAM LOCOMOTIVES
○ DIESEL LOCOMOTIVES

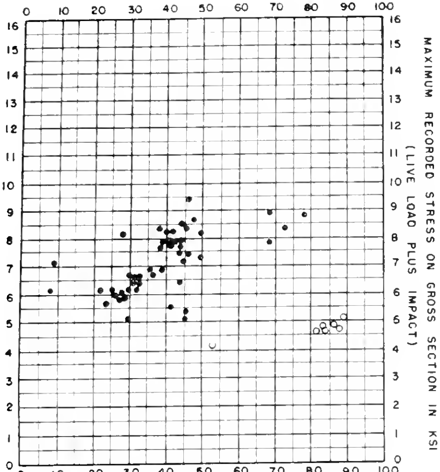
STRESS RANGE DISTRIBUTION

STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE									PERCENT OF TOTAL READINGS								
	DIESELS		STEAM LOCOMOTIVES						TOTAL	DIESELS		STEAM LOCOMOTIVES						TOTAL
	2 AXLES	3 AXLES	Z	J	E	E-2A E-2B	E-4	H		2 AXLES	3 AXLES	Z	J	E	E-2A E-2B	E-4	H	
10.0 TO 9.0								2	2								1.8	1.8
9.0 " 8.0							2	8	10							1.8	7.0	8.8
8.0 " 7.0				5			19	11	35				4.4			16.6	9.6	30.6
7.0 " 6.0				6	6	5	6		23				5.3	5.3	4.4	5.2		20.2
6.0 " 5.0			1	5	7	1			14			0.9	4.4	6.1	0.9			12.3
5.0 " 4.0	5	17							22	4.4	14.9							19.3
4.0 " 3.0	7	1							8	6.1	0.9							7.0
TOTAL READINGS	12	18	1	16	13	6	27	21	114	10.5	15.8	0.9	14.1	11.4	5.3	23.6	18.4	100.0



FREQUENCY OF MAXIMUM STRESSES
(NORTH GIRDER)

FIG. 62
C.&N.W. RY. BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
FREQUENCY OF MAXIMUM STRESSES
EASTBOUND SPAN, NORTH GIRDER



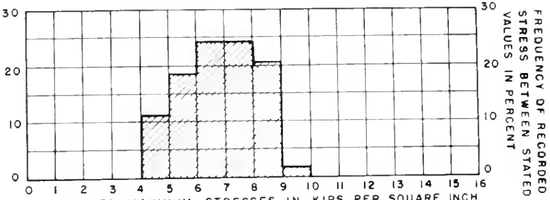
RECORDED MAXIMUM STRESSES

(SOUTH GIRDER)

SYMBOL: ● STEAM LOCOMOTIVES
○ DIESEL LOCOMOTIVES

STRESS RANGE DISTRIBUTION

STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI.	NUMBER OF READINGS FOR EACH STRESS RANGE								PERCENT OF TOTAL READINGS							
	DIESELS	STEAM LOCOMOTIVES						TOTAL	DIESELS	STEAM LOCOMOTIVES						TOTAL
	3-AXLES	J	J-4	E	E-2A E-2B	E-4	H		3-AXLES	J	J-4	E	E-2A E-2B	E-4	H	
10.0 TO 9.0							1	1							1.8	1 8
9 0 " 8.0		4	1			2	4	11		7.4	1 9			3.7	7 4	204
8.0 " 7.0		6				2	5	13		11 1				3.7	9 3	24 1
7.0 " 6.0		11		1	1			13		204		1.8	1.9			24 1
6.0 " 5.0		6		1	3			10		11.1		1 9	5 5			18 5
5 0 " 4 0	6							6	11.1							11 1
TOTAL READINGS	6	27	1	2	4	4	10	54	11.1	500	19	37	74	74	18 5	100



FREQUENCY OF MAXIMUM STRESSES

(SOUTH GIRDER)

FIG 63

C & N W RY BRIDGE TESTS
78'-0 DECK GIRDER SPAN
BALLASTED CONCRETE FLOOR
FREQUENCY OF MAXIMUM STRESSES
WESTBOUND SPAN, SOUTH GIRDER

(text continued from page 23)

Track Effect—Diesel Locomotives

The vertical vibrations produced in a railroad bridge by the passage of a diesel locomotive are undoubtedly caused by the wheel or track irregularities. The wheel irregularities are usually the flat spots, out-of-round wheels and eccentric mountings, while the track irregularities usually result from hard and soft spots in the ballast or irregular bridge tie wear.

The stress semi-amplitudes of vibrations as read from the oscillograms for the three girder spans are plotted on the upper right diagram of Figs. 9, 10 and 11 for the two-axle and three-axle diesels for a complete range of speed from 5 mph. up to over 90 mph. The calculated natural loaded frequency of vibration of these spans, in vibrations per second, is shown on these figures. It can be seen that there is no particular critical speed for the diesel locomotives where the track effect stresses become a maximum, but the stresses appear to increase somewhat with an increase in speed. It should be kept in mind that since the wheels on the diesel locomotives do not have any unbalanced weights, the force to excite vibrations must be produced by the uneven track, flat spots or out-of-round wheels.

The track effects, expressed as a percentage of the recorded static stresses, are shown in the lower right diagrams of Figs. 9, 10 and 11. The track effect percentages on the two girder spans with the open timber floor, Figs. 9 and 10, are somewhat greater than those recorded in the girder span with the ballasted concrete floor, Fig. 11.

Track and Hammer-Blow Effect—Steam Locomotives

The vertical vibrations produced in a railroad bridge by the passage of a steam locomotive are undoubtedly caused by a combination of wheel and track irregularities and the periodic disturbing force of the counterweights. This disturbing force or hammer blow of the steam locomotives is due to the centrifugal force of the unbalanced weights on the revolving driving wheels. It is quite possible that in some cases the condition of the track would tend to counteract the vibrations due to the hammer blow. In other cases, the vibrations due to the track conditions might be additive to the vibrations caused by the hammer blow. Since for these tests there is no way to determine the separate effects, the only alternative is to report their combined effect.

The stress semi-amplitudes of vibration, as read from the oscillograms for the three girder spans, are plotted on the upper right diagrams of Figs. 12 to 20 incl. for the three classes of steam locomotives for a complete range of speed varying from 5 mph. up to over 80 mph. for the Class E 4 locomotives.

The calculated stresses in the girder flanges caused by the resultant weights producing dynamic augment or hammer blow of the locomotive drivers, without magnification, are shown by the solid curved line on these figures. For example, the calculated maximum stress in the girder flanges of the 70-ft. ¼-in. span produced by the vertical components of the resultant unbalanced weights in the drivers of the Class J locomotives, see Fig. 7, with the crank pins at 45 deg. with the vertical, is 0.0162 kips per sq. in. when the locomotive is operating at 1 rps. and 0.5832 kips per sq. in. when operating at 6 rps., see Table 2 and Fig. 12. These static hammer-blow stress curves, as indicated by the solid line on each diagram, are the average of the north and south girders, and are based upon the gross steel section.

The calculated natural loaded frequency of vibration of these spans, in vibrations per second and in miles per hour for the nominal driver diameters, is shown on each diagram for the particular locomotive class and span. As previously mentioned, the 70-ft. ¼-in. girders have a high Cooper rating so that their natural loaded frequencies are considerably higher than those of the other girders. It can be seen from the diagrams that synchronous speed was not attained on the 70-ft. ¼-in. span, but that synchronous speed or higher was reached on the other spans.

The track and hammer-blow effects, expressed as a percentage of the recorded static stresses, are shown in the lower right diagrams of Figs. 12 to 20 incl. It can be seen from these diagrams that the track and hammer-blow effects recorded under the Class J locomotives are considerably higher than those recorded under the Class E 4 and H locomotives. In general, there does not appear to be much difference in the track and hammer-blow effects recorded in the three spans under the same locomotive class, even though synchronous speed was not attained on the shorter span.

Total Impacts

The total impacts recorded in the lower flanges of the girders close to the center of the span, in the web plates close to the end of the girders, in the web plates close to the quarter point of the girders, and in viaduct columns of the 70-ft. ¼-in. span, under the various locomotive classes at a full range of speeds, are shown in the right diagrams of Figs. 21 to 54 incl. The total impact percentage for each test run at a particular speed is the increase in the stress in the member over that occurring at a slow speed for the same locomotive class. 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.

Flanges at Center of Girder

The total impact percentages resulting from the diesel locomotives crossing the three girder spans, as determined from the tests on the lower flanges of the girders close to the center of the span, are shown on the right diagrams of Figs. 21, 22 and 23. These diagrams also show the impact percentage as computed by the current AREA design specification, and it can be seen that the recorded values are considerably below the specification values, except for two runs under the two-axle diesel over the 70-ft. ¼-in. span (Fig. 21), where high values were recorded at a speed of about 45 mph.

The diagrams of total impacts show that there is considerable scatter of the impact values, even at the same speeds, indicating that not all of the impact effects are a maximum at the same time. In general, these diagrams indicate that the maximum impacts under the diesels occurred at a speed of 40 to 50 mph. and then decreased with a further increase in speed. The total impacts in the girder span with the ballasted concrete floor, appear to be somewhat smaller than those in the girder spans with the open timber floor.

The total impacts resulting from the steam locomotives crossing the three girder spans, as determined from the tests on the lower flanges of the girders close to the center of the span, are shown on the right diagrams of Figs. 24 to 32 incl. The current AREA design specification allowance is also shown on these diagrams and the recorded values are at least about 15 percentage points below the specification values, except for one run on the 70 ft. ¼ in. span under a Class H locomotive at about 53 mph.

It can be seen from these diagrams that the maximum recorded total impacts did not necessarily occur at the synchronous speed as determined by the calculated natural loaded frequency of the spans but, in general, occurred at a speed of 40 or 50 mph. For example, the calculated natural loaded frequency of the 71-ft. 10-in. span loaded with the Class H locomotive is 4.10 vibrations per second, but the maximum impacts were recorded at a locomotive speed of about 3.6 revolutions per second, or about 50 mph., see Fig. 29. It can be seen from Fig. 17 that while the greatest track and hammer-blow effect occurred at a speed of 3.8 rps., the greatest speed effect occurred at 3.6 rps., thus the combination of separate effects of roll, speed track and hammer blow produced the greatest total impact at about 50 mph.

The maximum recorded total impacts resulting from the steam locomotives crossing over the three girder spans range, in general, from 40 to 50 percent of the recorded static stresses, and the percentages are about the same in the girder span with the ballasted concrete floor as those in the two girder spans with the open timber floor.

Web at End of Girder

The total impact percentages resulting from the diesel locomotives crossing the three girder spans, as determined from the tests on the girder webs close to the end of the span, are shown on the right diagrams of Figs. 33, 34 and 35. These diagrams also show the impact percentage as computed from the current AREA design specification, and it can be seen that while the recorded total impacts are below the design allowance, the values are somewhat greater than those measured on the lower flanges at the center of the spans.

The total impact percentages resulting from the passage of the steam locomotives over the three girder spans, as determined from the tests on the girder webs close to the end of the spans, are shown on the right diagrams of Figs. 36 to 44 incl. The current AREA design specification allowances, shown on these diagrams, are above the recorded values. It appears that higher total impact values were recorded in the webs at the ends of the girders than those recorded in the girder flanges, with very little difference between the girders with the ballasted concrete floor and the girders with the open timber floor.

Webs at Quarter Point

The total impact percentages resulting from the diesel locomotives crossing the 71-ft. 10-in. and 78-ft. girder spans, as determined from the tests on the girder webs close to the quarter point of the span, are shown on the right diagrams of Figs. 45 and 46. It can be seen that several recorded total impact values under the two-axle diesels on the 71-ft. 10-in. span exceeded the current AREA design specification allowance. The total impacts recorded in the span with the ballasted concrete floor are smaller than those recorded in the span with the open timber floor; however, a greater number of runs were secured on the span with the open floor.

The total impact percentages recorded by the gages on the girder webs close to the quarter points of the 71-ft. 10-in. and 78-ft. spans under the steam locomotives are shown on the right diagrams of Figs. 47 to 52 incl. The total impact values in the 78-ft. span under the Class J locomotive were quite high—see Fig. 50—but the impacts under the other locomotive classes were below the current AREA design specification allowance. The impacts recorded in the 78-ft. span with the ballasted concrete floor appear to be greater than those in the 71-ft. 10-in. span with the open timber floor.

Viaduct Columns

The total impact percentages recorded in the viaduct columns supporting the 70-ft. ¼-in. girder spans are shown in the right diagram of Fig. 53 for the diesel locomotives and Fig. 54 for the steam locomotives. The agreement between the recorded values and the AREA design allowance is very good for both the diesel and steam locomotives, with only one value exceeding the design allowance, as shown on Fig. 53 under the three-axle diesel at about 40 mph. As usual, there was a considerable scatter of the test results under both the diesel and steam locomotives with high and low values recorded under the same locomotive class at the same speed.

Maximum Stresses

The maximum live load plus impact stresses recorded in the girder flanges, webs, viaduct columns and tower bracing of the 70-ft. ¼-in. span and the lateral bracing of the 78-ft. span under the various locomotive classes at a full range of speeds are shown in Figs. 21 to 57 incl.

Flanges at Center of Girder

The maximum stresses recorded in the lower flanges of the girder close to the center of the span, under the passage of the diesel locomotives, are shown on the left diagram of Figs. 21, 22 and 23. These diagrams also show the maximum live load plus impact stresses, using the current AREA design impact allowance, and it can be seen that most of the recorded values are below the calculated maximums, although a few values are above.

The maximum stresses resulting from the steam locomotives passing over the three girder spans, as determined from the readings on the lower flanges close to the center of the span, are shown on the left diagrams of Figs. 24 to 32 incl. The calculated maximum live load plus impact stresses, using the current AREA design impact allowance, are also shown on these diagrams, and it can be seen that a few of the recorded values exceed or equal the calculated values—see Figs. 24, 25 and 26. It is interesting to note from these diagrams that there is considerable scatter to the recorded stresses, even at the same speeds, and it is not unusual to record stresses at the higher speeds which are lower than those recorded at the very slow speeds. This phenomena is undoubtedly the result of a heavy rolling to one side, accompanied by a very small speed, track and hammer-blow effect.

Web at End of Girder

The maximum live load plus impact stresses resulting from the diesel locomotives crossing the three girder spans, as determined from the readings on the girder webs close to the end of the spans, are shown on the left diagrams of Figs. 33, 34 and 35. These diagrams also show the calculated maximum stresses, using the current AREA design impact allowance, and it can be seen that the recorded values in the webs of the girders having the open timber floor are above the calculated values, Figs. 33 and 34. The fact that the recorded maximum stresses are higher than the calculated values, even though the recorded impacts are lower than the AREA design allowance, is due to the larger recorded static stresses in the spans with the open timber floor—see Tables 3 and 5. The recorded static stresses in the ballasted floor span are lower than the calculated stresses, see Table 5, so it is reasonable to expect lower maximum stresses in this span.

The maximum live load plus impact stresses produced by the steam locomotives in the girder webs at the ends of the three girder spans are shown on the left diagrams of Figs. 36 to 44 incl. The calculated maximum values, using the current AREA design impact allowance, are also shown on these diagrams, and a considerable number of the recorded values in the webs of the girders with the open timber floor exceed the calculated values. It can be seen from the diagrams of total impacts and the tables of recorded static stresses that the high recorded maximum stresses are due to the high recorded static stresses. The recorded web stresses in the ballasted floor span are all below the calculated values, although those recorded under the Class H locomotive, see Fig. 44, are only slightly below.

Web at Quarter Point of Girder

The maximum live load plus impact stresses produced by the diesel locomotives in the girder webs close to the quarter point of the 71-ft. 10-in. and the 78-ft. spans, as well as the calculated values, are shown on the left diagrams of Figs. 45 and 46. In general, there is fair agreement between the recorded and calculated maximum values, with only a few recorded values exceeding the calculated stresses.

The maximum live load plus impact stresses produced by the steam locomotives on these two spans, and the calculated values, are shown on Figs. 47 to 52 incl. There is fair agreement between the recorded and calculated values on the girder span with the open timber floor, but the recorded values on the span with the ballasted concrete floor are appreciably higher than those calculated for this span. However, it can be seen that the maximum recorded values under all the locomotives are much lower than those recorded at the ends of the span, as would be expected.

Viaduct Columns

The maximum direct live load plus impact stresses recorded in the viaduct columns supporting the 70-ft. ¼-in. girder spans are shown in the left diagram of Fig. 53 for the diesel locomotives, and Fig. 54 for all three classes of steam locomotives. The calculated maximum values shown on these diagrams are based on the three-axle diesel and the Class H locomotive, with the current AREA design impact allowance, which is the same as that used in calculating the maximum stresses in the girder webs and flanges.

The recorded maximum stresses under the diesels are well below the calculated maximum stresses, but there is closer agreement between the recorded and calculated stresses under the steam locomotives, with one value recorded under a Class H locomotive at about 53 mph. exceeding the calculated maximum.

It should be kept in mind that the maximum stresses in these columns, as shown in Figs. 53 and 54, are the direct stresses without bending, and were determined by averaging the simultaneous readings of either the two or four gages on the column at the particular section. It can be seen from Table 10 that there was considerable bending in these columns, which would have to be considered in determining the allowable stresses in the columns.

Transverse Bracing of Viaduct Bent

The recorded maximum direct stress in the transverse bracing of the viaduct bent No. 2 under the various diesel and steam locomotives passing over the girders is shown in Fig. 55. For example, the maximum stress recorded in the bottom strut, section K–K, was about 1.90 ksi. in tension, and occurred under a Class J locomotive at about 10 mph. In general, the stresses in this bottom strut are about the same for all the diesel and steam locomotives and remain about the same for all locomotive speeds.

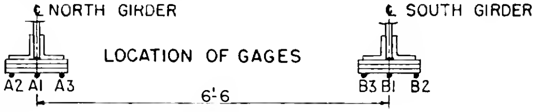
The strain gages on the diagonal member, section H–H, indicated that this member remained in compression during the passage of the locomotives, as shown in Fig. 55, but the diagonal member, section G–G, reversed from tension to compression as shown. However, the stresses generally did not exceed 2 ksi. in either direction. It should be kept in mind that these diagonal members would be subjected to some compressive stresses due to the compression in the columns, so that the stresses shown on Fig. 55 do not necessarily represent those entirely produced by the lateral forces at the top of the bent.

TABLE 9

CHICAGO AND NORTH WESTERN RAILWAY BRIDGE TESTS

71 FT. 10 IN. DECK GIRDER SPAN OPEN TIMBER FLOOR

VARIATION OF RECORDED STRESSES ACROSS LOWER FLANGE

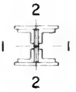


SPAN	TEST LOCOMOTIVE			NORTH GIRDER						SOUTH GIRDER					
	CLASS	NUMBER	SPEED	GAGE A1	GAGE A2	GAGE A3	AVER. A2&A3	VARIATION FROM AVER.		GAGE B1	GAGE B2	GAGE B3	AVER. B2&B3	VARIATION FROM AVER.	
								STRESS	%					STRESS	%
COL 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
EAST BOUND TRACK	2-AXLE DIESEL		9.3	5.73	4.38	5.88	5.13	+0.75	+14.6	4.68	4.49	4.87	4.68	+0.19	+4.1
			9.3	5.27	4.63	5.15	4.89	+0.26	+5.3	4.28	3.91	4.08	4.00	+0.08	+2.0
			55.6	6.18	5.82	6.62	6.22	+0.40	+6.4	4.80	4.78	4.71	4.74	−0.03	−0.6
			91.7	5.95	5.67	6.07	5.87	+0.20	+3.4	4.68	4.64	4.87	4.76	+0.11	+2.3
			925	5.95	5.22	6.07	5.64	+0.43	+7.6	4.93	4.64	4.23	4.44	−0.21	−4.7
	3-AXLE DIESEL		7.7	6.42	5.97	6.25	6.11	+0.14	+2.3	5.19	4.93	5.02	4.98	+0.04	+0.8
			73.2	6.18	6.12	6.25	6.18	+0.07	+1.1	5.32	5.51	5.33	5.42	−0.09	−1.7
			75.4	5.96	6.12	6.43	6.28	+0.15	+2.4	5.32	5.36	5.49	5.42	+0.07	+1.3
			76.0	6.18	5.83	6.25	6.04	+0.21	+3.5	5.33	4.93	5.33	5.13	+0.20	+3.9
			91.6	6.63	6.12	6.07	6.10	− 03	−0.5	4.81	4.93	4.55	4.74	−0.19	−4.0
	J	2535	5.7	7.10	6.42	6.98	6.70	+0.28	+4.2	5.97	5.79	5.80	5.79	+0.01	+0.2
		2515	10.4	7.56	6.87	7.72	7.30	+0.42	+58	6.36	6.37	6.27	6.32	−0.05	−0.8
		2513	37.0	8.47	8.51	9.01	8.76	+0.25	+2.8	7.41	7.97	7.69	7.83	−0.14	−1.8
		2505	388	——	7.32	7.54	7.43	+0.11	+1.5	7.40	7.39	7.37	7.38	−0.01	−0.1
		2528	41.3	9.16	8.36	9.74	9.05	+0.69	+7.6	7.40	7.83	6.90	7.36	−0.46	−6.2
		2496	41.4	9.15	8.51	9.20	8.86	+0.34	+3.8	7.01	6.96	6.28	6.62	−0.34	−5.1
		2562	42.1	8.47	8.21	9.19	8.70	+0.49	+5.6	7.79	7.68	7.53	7.60	−0.07	−0.9
		2532	45.4	9.61	8.66	10.66	9.66	+1.00	+10.4	7.27	8.40	7.53	7.96	−0.43	−5.4
		2567	46.4	8.93	9.26	9.74	9.50	+0.24	+2.5	7.54	7.39	7.69	7.54	+0.15	+2.0
	J4	2808	40.1	9.84	9.40	10.66	10.03	+0.63	+6.3	8.83	8.70	8.63	8.66	−0.03	−0.3
		2809	44.6	10.31	9.70	10.30	10.00	+0.30	+3.0	8.44	8.40	8.94	8.67	+0.27	+3.1
		2808	46.5	9.16	8.81	9.19	9.00	+0.19	+2.1	8.44	8.70	8.79	8.75	+0.04	+0.4
	E	1653	21.4	6.41	6.42	7.36	6.89	+0.47	+6.8	5.58	5.80	5.81	5.80	+0.01	+0.2
		1646	58.4	9.39	7.91	8.64	8.28	+0.36	+4.3	5.97	5.79	5.64	5.72	−0.08	−1.4
		1642	60.3	8.46	7.91	8.28	8.10	+0.18	+2.2	5.97	6.08	5.81	5.94	−0.13	−2.2
		1633	62.0	8.24	7.46	8.83	8.15	+0.68	+8.3	6.63	6.67	6.12	6.40	−0.28	−4.4
		1648	64.0	8.25	7.46	9.01	8.24	+0.77	+9.3	6.11	6.52	6.27	6.40	−0.13	−2.0
		1623	72.2	8.24	7.16	9.56	8.36	+1.20	+14.4	6.36	7.10	5.81	6.46	−0.65	−10.1
	E4	4009	21.2	7.56	7.31	8.27	7.79	+0.48	+6.2	7.02	7.10	6.91	7.00	−0.09	−1.3
		——	65.8	10.08	9.70	10.31	10.00	+0.31	+3.1	8.96	8.84	9.25	9.04	+0.21	+2.3
		4005	69.0	9.15	8.96	10.12	9.54	+0.58	+6.1	8.18	8.40	7.06	7.73	−0.67	−8.7
		4005	70.8	10.30	9.41	11.59	10.50	+1.09	+10.4	8.18	8.70	8.47	8.58	−0.11	−1.3
		4005	70.9	10.31	9.56	11.41	10.48	+0.93	+8.9	8.57	9.13	8.63	8.88	−0.25	−2.8
		4007	71.3	9.84	9.85	10.12	9.98	+0.14	+1.4	7.92	7.97	7.22	7.60	−0.38	−5.0
		4009	71.7	10.32	10.00	11.04	10.52	+0.52	+4.9	7.66	7.97	7.84	7.90	−0.06	−0.8
		4001	73.1	10.77	10.31	11.41	10.86	+0.55	+5.1	8.31	8.40	8.46	8.43	+0.03	+0.4
		4007	74.0	10.31	9.40	11.40	10.40	+1.00	+9.6	8.18	8.41	8.32	8.36	−0.04	−0.5
		4004	77.2	10.32	9.85	11.60	10.72	+0.88	+8.2	8.31	8.55	8.94	8.74	+0.20	+2.3
	H	3016	9.6	8.93	8.51	9.01	8.76	+0.25	+2.8	8.32	7.97	8.16	8.06	+0.10	+1.2
		3006	19.6	9.39	8.81	9.93	9.37	+0.56	+6.0	8.44	7.97	8.47	8.22	+0.25	+3.0
		3011	49.3	10.54	10.16	11.41	10.78	+0.63	+5.8	9.23	8.98	8.63	8.80	−0.17	−1.9
		3024	49.7	10.08	9.55	10.12	9.84	+0.28	+2.8	8.18	8.26	8.15	8.20	−0.05	−0.6
		3033	60.2	10.53	9.55	11.05	10.30	+0.75	+7.3	8.96	8.98	9.73	9.36	+0.37	+4.0
		3003	67.1	10.08	9.85	11.04	10.45	+0.59	+5.6	8.83	8.98	9.25	9.12	+0.13	+1.4
		3009	67.4	10.30	9.70	11.60	10.65	+0.95	+8.9	9.22	9.56	9.10	9.33	−0.23	−2.5
		3004	68.5	9.85	9.26	9.92	9.59	+0.33	+3.4	8.70	8.99	9.41	9.20	+0.21	+2.3

NOTE: STRESSES SHOWN ARE TENSION VALUES IN KIPS PER SQUARE INCH.
A POSITIVE SIGN IN THE COLUMNS 9, 10, 15 AND 16 MEANS THAT THE STRESS ON THE INNER EDGE OF THE FLANGE IS GREATER THAN THE AVERAGE BY THE AMOUNT SHOWN.

CHICAGO AND NORTH WESTERN RAILWAY BRIDGE TESTS
$70'\text{-}0\frac{1}{4}$ DECK GIRDER SPAN – OPEN TIMBER FLOOR
TABLE 10

SECONDARY STRESSES IN COLUMNS OF BENT NO. 2



$$\text{RATIO OF } \frac{\text{DEPTH}}{\text{LENGTH}} = \begin{cases} \text{AXIS (1-1)} = 0.0414 \\ \text{AXIS (2-2)} = 0.2135 \end{cases}$$

TRACK	SECTION SEE FIG. 2	COLUMN	TEST LOCOMOTIVE		SPEED IN MPH.	MAXIMUM DIRECT STRESS	BENDING													
			CLASS	NUMBER			AXIS (1-1)					AXIS (2-2)					BOTH AXIS		
							STRESS	STRESS IN PERCENT		DERIVED ECCENTRICITY INCHES		STRESS	STRESS IN PERCENT		DERIVED ECCENTRICITY INCHES		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
WESTBOUND TRACK	SECTION F-F	$C1^{W}$	2-AXLE DIESEL	CD-06 5402	7.4 39.1 93.5	2.15 2.78 2.01	1.36 0.94 0.80	63.3 33.8 39.8	45.6	2.71 1.45 1.71	1.62	0.05 0.28 0.26	2.3 10.1 12.9	8.4	0.05 0.22 0.28	0.18	1.48 1.03 1.09	68.8 37.1 54.3	53.4
			3-AXLE DIESEL	— — —	602 82.6 904	2.32 3.00 2.71	1.11 1.24 0.93	47.8 41.3 34.3	41.1	2.05 1.77 1.43	1.42	0.17 0.27 0.35	7.3 9.0 12.9	97	0.16 0.20 0.28	0.21	1.15 1.38 1.10	49.6 46.0 406	45.4
			J	2386 2537 2492	7.9 28.6 50.2	254 3.51 2.63	1.56 1.54 1.00	61.4 43.9 38.0	47.8	2.63 1.88 1.63	2.05	023 0.46 0.35	9.1 13.1 13.3	11.8	0.20 0.29 0.29	0.26	1.70 1.85 1.32	66.9 52.8 50.2	56.6
			E-4	4005 — 4004	7.5 65.3 78.3	4.12 5.04 4.70	1.08 1.65 1.26	26.2 32.7 26.8	28.6	1.12 1.41 1.15	1.23	0.43 0.50 0.02	10.4 9.9 0.1	6.6	0.23 0.22 0.01	0.15	1.39 2.02 1.29	33.7 401 27.5	33.8
			H	3027 3008 3009 3006	9.9 34.8 424 714	402 6.30 5.28 472	1.34 1.66 1.33 1.00	34.3 26.4 251 21.2	26.8	1.44 1.13 1.08 0.91	1.14	0.32 0.39 0.55 054	8.0 6.2 10.4 11.4	12.0	0.17 0.14 0.23 0.25	0.20	1.49 2.04 1.78 134	37.1 32.4 33.7 28.4	32.9
		$C2^{W}$	2-AXLE DIESEL	CD-06 5402	7.4 39.1 93.5	2.01 2.65 1.65	0.03 0.09 0.15	1.5 3.4 9.1	4.7	0.06 0.14 0.39	0.20	0.04 0.04 0.05	20 1.5 30	2.2	0.04 0.03 0.07	0.05	0.12 0.18 0.18	6.0 6.8 10.9	7.9
			3-AXLE DIESEL	— — —	60.2 82.6 90.4	2.36 2.80 2.36	0.03 0.03 0.09	1.3 1.1 3.8	2.1	0.05 0.05 0.16	0.09	0.08 0.12 0.01	3.4 4.3 0.4	2.7	0.07 0.09 0.01	0.06	0.12 0.21 0.12	5.1 7.5 5.1	5.9
			J	2386 2537 2492	7.9 28.6 50.2	2.59 3.03 2.65	0.32 0.44 0.32	12.3 14.5 12.1	13.0	0.53 0.62 0.52	0.56	0.13 0.06 0.21	5.0 2.0 7.9	5.0	0.11 0.04 0.17	0.11	0.37 0.49 0.53	14.3 16.2 20.0	16.8
			E-4	4005 — 4004	7.5 65.3 78.3	3.54 4.20 3.36	0.14 0.06 0.18	4.0 1.4 5.4	3.6	0.17 0.06 0.23	0.19	0.29 0.29 0.15	8.2 6.9 4,5	6.5	0.18 0.15 0.10	0.14	0.40 0.40 0.30	11.3 9.5 8.9	99
			H	3027 3008 3009 3006	9.9 34.8 42.4 71.4	3.58 4.79 4.55 3.47	0.11 0.11 0.02 0.29	3.1 2.3 0.4 8.4	4,7	0.13 0.10 0.02 0.36	024	0.11 0 0.27 0.03	3.1 0 5.9 0.9	2.5	0.07 0 0.13 0.02	0.06	0.14 0.21 0.58 060	3.9 4.4 12.8 17.3	96
	SECTION E-E	$C1^{W}$	2-AXLE DIESEL		44.3	1.95	0.33	16.9	16.9	0.73	0.73	0.02	1.0	1.0	0.02	0.02	0.66	33.9	33.9
			J	2386 2492	7.9 50.2	2.58 2.55	0.16 0.46	6.2 18.0	12.1	0.27 0.77	0.52	0.14 0	5.4 0	2.7	0.12 0	0.06	0.32 0.93	12.4 36.5	24.5
			E-4	4006 4002	59.4 61.9	4.10 4.19	0.14 0.23	3.4 5.5	4.5	0.15 0.24	0.20	0.47 0.26	11.5 6.2	8.9	0.25 0.14	020	1.03 051	25.1 12.2	18.7
			H	3005 3032	48.7 57.8	3.41 4.21	0.25 0.16	7.3 3.8	5.6	0.32 0.16	0.24	0.15 0.52	4.4 12.4	8.4	0.10 0.26	0.18	0.50 1.06	14.7 25.2	20.0
		$C2^{W}$	2-AXLE DIESEL		44.3	1.48	0.60	40.6	40.6	1.74	1.74	0.10	6.8	6.8	0.15	0.15	0.89	60.1	60.1
			J	2386 2492	7.9 50.2	1.75 2.06	0.55 0.92	31.4 44.6	38.0	1.35 1.92	1.64	0.12 0.01	6.8 0.5	3.7	0.15 0.01	0.08	0.76 1.28	43.4 62.2	57.8
			E-4	4006 4002	59.4 61.9	2.41 1.96	0.67 0.48	27.8 24.5	26.2	1.09 1.05	1.07	0.17 0.12	7.1 6.1	6.6	0.16 0.13	0.15	107 0.81	44.4 41.3	42.9
			H	3005 3032	48.7 57.8	2.42 2.72	0.87 0.71	35.9 26.1	31.0	1.54 1.12	1.33	0.10 0.15	4.1 5.5	4.8	0.09 0.12	0.11	1.34 1.18	55.4 43.4	49.4
EASTBOUND TRACK	SECTION C-C	$C2^{E}$	2-AXLE DIESEL	5402 5402	44.8 53.6	2.72 2.88	0.22 0	8.1 0	4.1	0.35 0	0.18	0.12 0.26	44 9.0	6.7	0.10 0.20	0.15	023 0.45	8.5 156	12.1
			3-AXLE	924	84.6	2.79	0.23	8.2	8.2	0.35	0.35	0.11	3.9	3.9	0.09	0.09	0.30	10.8	10.8
			J	2414 2431 2414	11.8 47.1 55.3	2.79 3.46 3.50	0.31 0.72 0.76	11.1 208 21.7	17.9	0.48 0.89 0.93	077	0.19 0.35 0.34	6.8 10.1 9.7	8.9	0.15 0.22 0.21	0.19	0.32 0.96 1.08	11.5 27.7 30.9	234
			E-4	4003 4003 4006	6.2 27.2 41.4	3.90 3.32 3.81	0.57 0.79 1.04	14.6 23.8 27.3	21.9	063 1.01 1.17	0.94	0.29 0.44 0.31	7.4 13.3 8.1	9.6	0.16 0.29 0.18	021	068 1.10 1.10	17.4 33.1 28.9	26.5
			H	3024 3008 3031 3001	10.0 53.0 634 67.9	3.56 4.80 503 453	0.76 1.08 0.42 078	213 22.5 8.3 172	17.3	0.92 097 0.36 0.74	0.75	0.31 0.86 067 0.45	8.7 17.9 13.3 9.9	12.5	0.19 0.39 0.29 0.22	0.27	0.86 076 079 1.04	24.2 15.8 15.7 23.0	19.2

NOTE: STRESSES SHOWN ARE COMPRESSION VALUES IN KIPS PER SQUARE INCH

$$\left.\begin{matrix} C_1 = 713'' & r_1 = 569'' \\ C_2 = 900'' & r_2 = 406'' \end{matrix}\right\} \quad \frac{C_1}{r_1^2} = 022 \qquad \frac{C_2}{r_2^2} = 055$$

Lateral Bracing of Girder Spans

The maximum stresses recorded in the lateral bracing and crossframe angles of the 78-ft. deck girder span with the ballasted concrete floor under the various diesel and steam locomotives, according to speed, are shown on Figs. 56 and 57. As previously explained, the gages were located close to the neutral axis of the angles so that the stresses shown on these diagrams represent only direct stress. It would appear logical to expect, from the results of previously reported tests with three gages on each angle at the same section, that the stresses on the corners of the angles would be two or three times greater than the direct stresses shown on the diagrams. The maximum compressive stresses are shown by the solid circles on these diagrams, while the maximum tension stresses are shown by the open circles.

In general, the maximum stresses recorded in the bottom laterals were greater than those recorded in the top laterals; the stresses ranging from only about 2 kpi. tension to 3 ksi. compression in the top laterals, but ranging from about 8 ksi. tension to 6 ksi. compression in the bottom laterals. The stresses in the end and center crossframes were about the same with a range of about 6 ksi. tension to 6 ksi. compression. There is an indication that the stresses in some of the lateral and crossframe members increase with an increase in locomotive speed, but in other angles the stresses remain about the same for all speeds.

The shortening of the top flange of the girders tends to produce a compressive stress in the top laterals and, conversely, the lengthening of the lower flange tends to produce a tension stress in the bottom laterals, and this is quite evident from the preponderance of compressive stresses in the top laterals and tension stresses in the bottom laterals.

The maximum stresses recorded in the lateral and crossframes of the 71-ft. 10-in. deck girder span were previously reported in the Proceedings, Vol. 50, 1949, page 134. It is interesting to note that, in general, the stresses in the top and bottom laterals of this bridge, which had an open timber floor, were larger than the stresses recorded in the 78-ft. span with the ballasted concrete floor.

Secondary Stresses—Girder Flanges

The simultaneous stresses in the lower flanges of each girder of the 71-ft. 10-in. span were recorded at three locations, as shown in Fig. 4, Section B–B, and the variations in these stresses are shown in Table 9 under the various locomotive classes at speeds ranging from crawl to 92.5 mph.

The average stresses recorded in the edges of the flanges are shown in Columns 8 and 14 of this table, and in most cases the stresses recorded at the center of the flange, gages A1 and B1, are slightly greater than the average stress on the edges, indicating that the stress is not uniform across the section. The differences between the maximum inner or outer flange stresses and the average flange stresses are shown in Columns 9 and 15, with the percent variation shown in Columns 10 and 16. For example, the passage of the two-axle diesel over this span at 9.3 mph. produced a stress of 4.38 ksi. in the outside edge of the lower flange of the north girder and 5.88 ksi. in the inner edge, with an average value of 5.13 ksi. The stress on the inner edge was + 0.75 ksi or + 14.6 percent greater than the average stress, see Columns 9 and 10, Table 9. In general, the stress in the inner edge of the north girder was never greater than 15 percent above the average stress, while the variation in the edge stresses of the south girder was considerably smaller.

Secondary Stresses—Viaduct Columns

The determination of the direct stresses in the viaduct columns by securing the stresses at the four corners of each column afforded an opportunity for the study of the secondary stresses and derived eccentricities in these members under the diesel and steam locomotives at various speeds. The summary of this study is shown in Table 10.

The maximum direct stresses shown in Column 7 of Table 10 were determined in the same manner as those shown for the static stresses, except that the simultaneous maximum stresses recorded by the four gages on the edges of each column were used instead of the simultaneous mean stresses.

The bending stresses about the axis transverse to the center of the track, axis 1–1, shown in Column 8 of Table 10, were determined by subtracting the maximum direct stress in Column 7 from the average of the two gages on the cover plate. The bending stresses about the axis parallel to the center of the track, axis 2–2, shown in Column 13, were determined by subtracting the maximum direct stress from the average of the two gages on one side of the member. The bending stresses shown in Column 18 were determined by subtracting the maximum direct stress from the maximum recorded value on one of the four corners. The values shown in Columns 9, 14 and 19 of this table are the percentages of the direct stress for each run which would produce the bending stresses, while those in Columns 10, 15 and 20 are the average percentages for each locomotive class.

The derived eccentricities shown in Columns 11 and 16 of Table 10 were determined by solving for e_{1-1} and e_{2-2} in the following equations:

$$f_1{}^b{}_{-1} = \frac{P \times e_{1-1} \times c_{1-1}}{I_{1-1}} \quad \text{.......} \quad (1)$$

$$f_2{}^b{}_{-2} = \frac{P \times e_{2-2} \times c_{2-2}}{I_{2-2}} \quad \text{.......} \quad (2)$$

where

$f_1{}^b{}_{-1}$ = the bending stress about axis 1–1.
P = the maximum direct stress times the area of the column.
e_{1-1} = the eccentricity about axis 1–1.
c_{1-1} = the distance from axis 1–1 to the extreme fiber.
I_{1-1} = the moment of inertia about axis 1–1.
$f^b{}_{2-2}$ = the bending stress about axis 2–2.
e_{2-2} = the eccentricity about axis 2–2.
c_{2-2} = the distance from axis 2–2 to the extreme fiber.
I_{2-2} = the moment of inertia about axis 2–2.

The bending stresses and derived eccentricities shown in Table 10 are shown for three or four 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 column at all speeds for the same locomotive class. However, there is considerable variation in these values between the columns. For example, the average total bending stress about both axis of the south Column $C1^W$ of the westbound track under the Class H locomotive was 32.9 percent of the maximum direct stress (Column 20), while a bending stress of only 9.6 percent was recorded in the north Column $C2^W$ under the same locomotive class.

The coefficient 0.25 in the denominators of the secant formulas for compression members, appearing in the current AREA design specification, is an empirical value selected to provide for the inherent crookedness and unknown eccentricity, and is equivalent to an eccentricity of 1.13 in. producing bending about axis 1–1 for these particular columns. It is apparent from the values of derived eccentricities shown in

Table 10, especially about axis 1–1 which is the weak axis of this structure on account of the low depth divided by length ratio, that the present allowance of 0.25 is not sufficient to provide for the unknown eccentricity.

The maximum direct stresses recorded in the north Column $C2^W$, the westbound track at the mid-height of the bent, Section E–E, are of interest as they are appreciably lower than the stresses recorded in the south Column, $C1^W$ at the same section, as well as in the same column at the base, Section F–F, indicating that the heavy plate diaphragm between bents was carrying part of the load.

Frequency of Maximum Stresses

The strain gage readings, as previously mentioned, were secured under regular trains with the speed reduced on only a few of the trains for the slow speed runs, so that the stresses recorded during these tests actually indicate the frequency of occurrence of the maximum stresses on the bridges tested.

The maximum stresses recorded in one girder of each span for the three bridges tested under all the locomotives are shown on the left diagram of Figs. 58 to 63 incl. The maximum stresses recorded under the diesel locomotives are shown by the open circles, while those under the steam locomotives are shown by the solid circles. These diagrams are a summation of the maximum stresses shown on Figs. 21 to 32 incl. for the individual locomotive classes.

The data shown under the table of "Stress Range Distribution" in Figs. 58 to 63 incl., indicate the number of stresses at any one stress range which were recorded under each locomotive class for the particular girder being considered. For example, the Class H locomotive produced two stresses between 11 and 12 ksi. in the north girder on the eastbound span of the 71-ft. 10-in. deck girder span, and the Class E 4 also produced two stresses within this range in the same girder for a total number of four within this range, see Fig. 60. Since there were 122 trains across the bridge during the test period and only four of these produced stresses within the range of 11 to 12 ksi., it appears that only about 3.2 percent of the trains crossing this bridge will produce the higher stresses, provided the same distribution of power between the various locomotive classes is maintained; and the average of the six spans indicates that only about 7 percent of the trains passing over the bridge produce stresses in the higher range. On this basis, it can be seen that 17.2 percent of the trains crossing this bridge will produce stresses within the range of 10 to 11 ksi.

The data tabulated in the tables of "Stress Range Distribution" are shown graphically in the lower right diagrams of Figs. 58 to 63 incl.

8. Conclusions

The tests on these three girder spans afforded an opportunity to measure and compare the static and dynamic effects on the same spans of diesel and steam locomotives operating over a wide range of speeds. A great deal of interesting and valuable data was obtained, but it must be kept in mind that these tests represent but 3 girder spans out of a total of 33 girder spans to be reported, so that any conclusions must be considered as applying only to these 3 definite spans.

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

1. Static Stresses

The recorded static live load stresses in the lower flanges of the girders at the center of the span were, in some cases, 14 percent greater than the calculated stresses and, in other cases, 16 percent smaller than those calculated.

The recorded static live load stresses in the web plates at the ends of the girders were greater than the calculated stresses by as much as 39 percent and, in other cases, below the calculated by as much as 16 percent.

There was fair agreement between the recorded stresses in the top and bottom flanges of the girders at the center of the span. This agreement was about the same at high speeds as at low speeds.

2. Secondary Effects

The stresses across the section of the lower flanges were quite uniform, although the stresses at the center under the web were slightly higher than those on the edges. The uniformity of stress was about the same for all locomotive speeds.

The bending stresses and derived eccentricities in the columns of the viaduct bents were quite high, exceeding the allowance in the current AREA dsign specification by a considerable amount.

3. Speed Effects

The speed effect under the diesel locomotives generally amounted to about 10 percent of the static stress with a few values considerably higher.

The speed effect under the steam locomotives was usually not greater than 15 percent of the static stress.

The speed effects under both diesel and steam locomotives did not appear to increase with an increase in speed but attained their maximum values at about 40 or 50 mph.

4. Roll Effects

The roll effect was about the same for both the diesel and steam locomotives and amounted to about 15 percent of the static stresses as compared with the AREA design allowance of 20 percent.

The roll effect was generally about the same at the low speeds as that occurring at the high speeds.

5. Track Effects—Diesel Locomotives

The track effects under the diesel locomotives were about 15 percent of the static stresses in the two bridges with the open timber floors and about 10 percent in the one bridge with the ballasted concrete floor.

The track effects were generally about the same for all speeds.

6. Track and Hammer-Blow Effects—Steam Locomotives

There was considerable variation in the track and hammer-blow effects resulting from the Class J locomotives and those resulting from the Class E 4 and Class H locomotives. The effect under the Class J locomotives was about 40 percent of the static stress while those under the Class E 4 and Class H locomotives were generally below 30 percent.

The track and hammer-blow effects were about the same in the girder span with the ballasted concrete floor as those in the spans with the open timber floor.

7. Total Impacts—Diesel Locomotives

The total impacts measured in the lower flanges at the center of the span under the diesel locomotives were considerably below the current AREA design allowance.

The total impacts measured in the girder webs at the ends of the span were larger than those measured in the flanges but the values were still below the design allowance.

The total impacts measured in the girder webs at the quarter point of the span were higher than those measured at the ends of the span with several values above the design allowance.

The total impacts measured in the viaduct columns were in close agreement with the design allowance.

8. Total Impacts—Steam Locomotives

The total impacts measured in the lower flanges at the center of the span under the steam locomotives were about 15 percentage points below the current AREA design allowance.

The total impacts measured in the girder webs at the ends of the span were about the same as those measured in the lower flanges and were below the design allowance.

The total impacts measured in the girder webs at the quarter point were in fair agreement with the design allowance, with the exception of the Class J locomotive on the 78-ft. span where several values exceed the design allowance.

There was close agreement between the total impacts measured in the viaduct columns and the design allowance.

The maximum total impacts did not necessarily occur at the synchronous speed but usually attained a maximum at 40 or 50 mph.

The total impacts in the one span with the ballasted concrete floor were about the same as those recorded in the spans with the open timber floor.

9. Maximum Stresses—Diesel Locomotives

The maximum stresses recorded in the lower flange at the center of the span under the diesel locomotives were usually below the calculated stresses, using the current AREA design allowance.

The maximum stresses recorded in the web plates at the ends of the spans with the open timber floor were higher than the calculated stresses by a considerable amount.

The maximum stresses recorded in the web plates at the quarter points of the spans were in fair agreement with the calculated stresses.

The maximum recorded stresses in the viaduct columns were well below the calculated stresses.

10. Maximum Stresses—Steam Locomotives

The maximum stresses recorded in the lower flanges at the center of the span under the steam locomotives were in fair agreement with the calculated stresses, using the current AREA impact allowance although several values exceeded the calculated stresses on the spans with the open timber floor.

The maximum stresses recorded in the web plates at the ends of the spans with the open timber floor were greater than the calculated stresses.

There is fair agreement between the recorded and calculated stresses in the web plates at the quarter point of the span with the open timber floor but the recorded stresses in the span with the ballasted concrete floor were above the calculated values.

The recorded maximum stresses in the viaduct columns were in close agreement with the calculated stresses.

11. Bracing Stresses

The stresses in the bracing members of the viaduct bent were quite low and were about the same under the diesel locomotives as under the steam locomotives.

The stresses in the bottom lateral bracing of the girder span, with the ballasted concrete floor were larger than those recorded in the top lateral bracing.

The stresses in the end crossframe of the girder span were about the same as those in the center crossframe.

There is some indication that part of the stresses in the top and bottom lateral bracing is a result of the shortening and lengthening of the girder flanges.

The stresses in the lateral bracing of the girder span with the ballasted concrete floor were appreciably lower than those in the bracing of the girder span with the open timber floor.

12. Frequency of Maximum Stresses

About 7 percent of the trains passing over the girder spans produced stresses varying from 90 percent of the maximum to the maximum.

9. Acknowledgment

The Committee on Impact and Bridge Stresses is indebted to the officers of the Chicago and North Western Railway for their cooperation in conducting these tests.

Preliminary Report of Committee 3—Ties

B. D. Howe, *Chairman,*
R. S. Belcher
C. S. Burt
W. J. Burton
R. F. Bush
R. E. Butler
G. B. Campbell
C. M. Coates
E. L. Collette
W. P. Conklin
B. S. Converse
R. L. Cook
R. W. Cook
T. Crawford
B. E. Crumpler
W. T. Donoho
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H. R. Duncan
W. F. Dunn, Sr.
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W. E. Fuhr
L. E. Gingerich
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W. J. Kernan
L. W. Kistler
C. R. Lapeza
J. R. Latimer
C. M. Long
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W. O. Nelson
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L. H. Powell
M. H. Priddy
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W. C. Reichow
H. S. Ross
E. F. Salisbury
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H. W. Seeley, Jr.
F. S. Shinn
Stuart Shumate
E. F. Snyder
J. G. Sutherland
P. V. Thelander
S. Thorvaldson
R. H. Timmins
C. D. Turley
B. J. Worley

Committee

Report on Assignment 4

Tie Renewals and Costs Per Mile of Maintained Track

The statistics compiled annually to provide information regarding the number and cost of the cross ties laid in replacement are supplied for 1949 in Tables A and B. These are compiled by the Bureau of Railway Economics, AAR. The number of ties applied in 1949 in the United States was slightly over 30,000,000, the smallest number for many years. The average cost per tie in 1949 was $0.16 above the 1948 average.

The Committee on Ties,
B. D. Howe, *Chairman.*

Sheet 1 of 2 sheets

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1949

	Cross ties laid in replacement					Miles of	Estimated total	Average number of cross	Number of	Number of equated gross	New wooden cross ties replacement averages			
	New	New	Total all	Ties							Per	Number	Renewal	Renewal

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1949

Road	Cross ties laid in replacement							Total ties applied	Miles of main-tained tracks (item 25)	Estimated total cross ties in all maintained tracks (item 24)	Average number of cross ties per mile of main-tained track	Number of equated gross ton-miles a (thousands)	Number of equated gross ton-miles per mile of main-tained track (thous.)	[illegible] replacement [illegible]			
	New wooden ties untreated (U)		New wooden ties treated (T)		Total all new wooden ties laid		Ties other than wood(S) & second-hand(•) reapplied ties							Per cent renewal to all ties in main-tained track	Number laid per mile of main-tained track	Renewal cost per mile of main-tained track	Renewal cost per 1,[illegible]
	Number	Aver-age cost	Number	Aver-age cost	Number	Aver-age cost											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NEW ENGLAND REGION:																	
Bangor & Aroostook	172 585	$1.52	12 687	$2.86	185 272	$1.61	-	185 272	[illegible].79	2 389 331	2 876	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Boston & Maine	-	-	137 395	3.18	137 395	3.18	-	137 395	2 801.75	8 265 162	2 950	14 879 988	5 311	[illegible]	49	[illegible]	
Canadian Nat.Lines in New Eng.	637	1.43	17 499	2.28	18 136	2.25	-	18 136	233.62	740 150	3 168	[illegible]	[illegible]	[illegible]	78		
Canadian Pacific (lines in Me.)	1 986	1.82	19 710	2.50	21 696	2.44	-	21 696	216.23	628 039	2 904	[illegible]	[illegible]	[illegible]	100	[illegible]	
Canadian Pacific (lines in Vt.)	518	1.76	6 491	2.26	7 009	2.23	-	7 009	121.49	377 163	3 099	[illegible]	[illegible]	1.9	58	126	[illegible]
Central Vermont	-	-	24 103	3.02	24 103	3.02	• 244	24 347	494.77	1 465 167	2 961	2 119 [illegible]	4 284	1.6	49	147	
Maine Central	57 089	1.56	71 546	3.84	128 635	2.83	• 14 928	143 563	1 168.62	3 555 725	2 941	[illegible]	440	[illegible]	[illegible]	[illegible]	
New York Connecting	-	-	2 398	3.98	2 398	3.98	-	2 398	25.90	81 641	[illegible]	[illegible]	12 299	[illegible]	[illegible]	[illegible]	
New York,New Haven & Hartford	-	-	163 567	3.28	163 567	3.28	-	163 567	[illegible]	11 509 257	[illegible]	[illegible]	5 752	1.4	44	246	
Rutland	-	-	27 590	3.03	27 590	3.03	• 809	28 399	465.77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	
Total	232 815	1.53	482 986	3.22	715 801	2.67	15 981	731 782	10 060.77	30 522 035	3 028	48 756 [illegible]	4 837	[illegible]	[illegible]	[illegible]	
GREAT LAKES REGION:																	
Ann Arbor	-	-	47 752	3.09	47 752	3.09	-	47 752	402.[illegible]	1 220 893	[illegible]	1 565 380	949	[illegible]	[illegible]	56	
Cambria & Indiana	-	-	1 556	3.17	1 556	3.17	-	1 556	56.54	163 032	[illegible]	91 214	1 61[illegible]	[illegible]	[illegible]		
Delaware & Hudson	-	-	155 566	3.25	155 566	3.25	(S) 44	155 610	1 353.59	4 269 344	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Delaware,Lackawanna & Western	-	-	196 860	3.44	196 860	3.44	• 6 000((S) 137(	202 997	2 163.35	6 555 787	[illegible]	[illegible]	7 16[illegible]	[illegible]	[illegible]	[illegible]	
Detroit & Mackinac	9 169	1.32	28 150	2.34	37 319	2.09	-	37 319	[illegible]	828 973	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Detroit & Toledo Shore Line	-	-	9 053	3.19	9 053	3.19	• 49	9 102	149.65	451 562	3 017	[illegible]	[illegible]	[illegible]	[illegible]	1	
Erie	-	-	373 900	3.26	373 900	3.26	-	373 900	4 705.01	13 869 364	2 948	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Grand Trunk Western	-	-	191 269	2.68	191 269	2.68	-	191 269	1 654.06	[illegible] 875 931	3 149	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lehigh & Hudson River	64	1.78	5 998	1.78	6 062	1.75	• 1 026	7 088	111.64	300 000	2 688	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lehigh & New England	-	-	26 854	3.20	26 854	3.20	-	26 854	242.39	[illegible]	3 026	742 099	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lehigh Valley	-	-	221 104	3.27	221 104	3.27	-	221 104	2 564.30	7 664 297	2 989	13 382 027	5 219	[illegible]	[illegible]	[illegible]	[illegible]
Monongahela	-	-	10 994	3.35	10 994	3.35	-	10 994	240.15	[illegible]	[illegible]	[illegible]	4 261	[illegible]	[illegible]	[illegible]	[illegible]
Montour	20	2.35	4 887	3.91	4 907	3.90	• 2 692	7 599	72.54	[illegible]	2 880	227 617	135	[illegible]	[illegible]	[illegible]	[illegible]
New York Central	-	-	1 219 194	3.27	1 219 194	3.27	• 2 396	1 221 590	21 040.65	60 975 754	2 898	[illegible]	7 764	[illegible]	[illegible]	[illegible]	[illegible]
New York,Chgo.& St.L.(Inc.W&LE)	-	-	398 337	3.01	398 337	3.01	• 1 354	399 691	3 398.96	10 579 667	3 113	27 705 800	8 151	[illegible]	117	[illegible]	[illegible]
New York,Ontario & Western	-	-	-	-	-	-	• 5 350	5 350	684.79	1 954 510	2 854	[illegible]	2 244	-	-	-	
New York,Susquehanna & Western	-	-	14 460	3.36	14 460	3.36	-	14 460	212.62	617 621	2 905	355 883	1 674	[illegible]	[illegible]	[illegible]	[illegible]
Pittsburgh & Lake Erie	-	-	86 533	3.18	86 533	3.18	-	86 533	810.77	2 480 502	3 059	4 029 426	[illegible]	[illegible]	107	[illegible]	[illegible]
Pittsburg & Shawmut	-	-	12 123	3.15	12 123	3.15	• 155	12 478	116.35	330 608	2 841	298 928	[illegible]	[illegible]	106	[illegible]	[illegible]
Pittsburgh & West Virginia	-	-	14 170	3.54	14 170	3.54	• 5 489	19 659	181.36	550 999	3 038	898 024	4 952	[illegible]	78	276	
Wabash	-	-	299 986	2.98	299 986	2.98	-	299 986	3 178.19	9 899 525	3 115	[illegible]	7 372	[illegible]	94	261	
Total	9 253	1.33	3 318 946	3.18	3 328 199	3.17	24 692	3 352 891	43 813.63	130 230 584	2 972	313 709 519	7 160	2.6	76	241	
CENTRAL EASTERN REGION:																	
Akron,Canton & Youngstown	33 010	2.83	-	-	33 010	2.83	• 5 071	38 081	220.00	648 878	2 949	607 508	2 761	5.1	150	[illegible]	
Baltimore & Ohio	-	-	461 237	2.60	461 237	2.60	-	461 237	10 391.92	29 601 767	2 849	35 041 714	[illegible] 200	1.6	44	[illegible]	[illegible]
Bessemer & Lake Erie	-	-	13 473	3.93	13 473	3.93	-	13 473	486.56	1 513 963	3 112	3 947 435	8 114	0.9	28	109	1.34
Central R.R.of New Jersey	-	-	59 785	3.06	59 785	3.06	-	59 785	910.38	2 559 402	2 811	4 862 010	5 341	2.3	66	[illegible]	
Central R.R.of Pennsylvania	-	-	35 864	3.59	35 884	3.59	-	35 884	467.26	1 313 678	2 811	2 971 462	[illegible]	[illegible]	77	[illegible]	[illegible]
Chicago & Eastern Illinois	-	-	61 489	2.87	61 489	2.87	-	61 489	1 314.98	4 001 905	3 043	6 221 007	4 731	[illegible]	47	[illegible]	[illegible]
Chicago & Illinois Midland	-	-	16 323	3.33	16 323	3.33	-	16 323	166.00	501 448	3 021	1 196 136	7 206	3.3	98	327	4.54
Chicago,Indpls.& Louisville	-	-	102 709	2.69	102 709	2.69	-	102 709	729.29	2 263 822	3 104	3 560 688	4 882	[illegible]	141	378	7.7
Detroit,Toledo & Ironton	8 330	.40	53 065	2.75	61 395	2.43	-	61 395	596.95	1 719 216	2 880	2 037 346	3 413	3.6	103	250	[illegible]
Elgin,Joliet & Eastern	-	-	59 125	2.82	59 125	2.82	• 8 794	67 919	845.02	2 613 084	3 092	3 166 622	3 747	[illegible]	70	197	[illegible]
Illinois Terminal	1 388	1.81	56 541	2.48	57 929	2.47	• 213	58 142	634.25	1 902 750	3 000	1 116 329	1 760	3.0	91	225	12.80
Long Island	-	-	67 826	3.93	67 826	3.93	-	67 826	782.91	2 249 109	2 873	4 575 522	5 844	3.0	87	340	
Missouri-Illinois	406	1.35	36 888	2.28	37 294	2.27	-	37 294	215.86	[illegible]	3 136	366 898	1 700	5.5	173	392	[illegible]
Pennsylvania	-	-	1 842 086	3.15	1 842 086	3.15	-	1 842 086	21 412.16	61 193 170	2 858	191 539 567	8 945	3.0	86	271	[illegible]
Penna.-Reading Seashore Lines	-	-	47 640	3.65	47 640	3.65	-	47 640	617.34	1 678 015	2 718	1 651 229	2 675	2.8	77	282	[illegible]
Reading Co.	-	-	180 656	3.34	180 656	3.34	-	180 656	2 792.84	7 793 151	2 790	17 240 641	6 173	2.3	65	[illegible]	[illegible]
Staten Island Rapid Transit	-	-	5 877	3.43	5 877	3.43	-	5 877	93.19	238 560	2 560	141 005	1 513	2.5	63	217	14.31
Western Maryland	683	2.22	70 333	3.14	71 016	3.13	-	71 016	1 163.37	3 375 105	2 901	7 641 610	[illegible]	2.1	61	[illegible]	2.91
Total	43 817	2.31	3 170 937	3.06	3 214 754	3.05	14 078	3 228 832	43 840.28	125 843 947	2 871	338 055 [illegible]	7 725	2.6	[illegible]	[illegible]	[illegible]
POCAHONTAS REGION:																	
Atlantic & Danville b	2 740	2.00	1 625	2.76	4 365	2.28	-	4 365	220.91	664 550	3 008	91 513	414	[illegible]	[illegible]	45	[illegible]
Chesapeake & Ohio	-	-	608 073	2.92	608 073	2.92	-	608 073	7 942.50	24 115 918	3 036	70 731 053	8 905	2.5	77	224	[illegible]
Norfolk & Western	-	-	539 630	2.81	539 630	2.81	• 2 175	541 805	4 330.11	13 423 341	3 100	41 999 624	9 699	4.0	125	[illegible]	[illegible]
Richmond,Fred.& Potomac	-	-	17 968	2.97	17 968	2.97	• 1 198	19 166	410.95	1 201 600	2 924	5 699 061	13 868	1.5	44	[illegible]	[illegible]
Virginian	-	-	113 594	2.56	113 594	2.56	-	113 594	938.35	2 883 451	3 073	7 445 308	7 934	[illegible]	121	[illegible]	[illegible]
Total	2 740	2.00	1 280 890	2.85	1 283 630	2.84	3 373	1 287 003	13 842.82	42 288 860	3 055	125 966 359	9 100	[illegible]	[illegible]	[illegible]	[illegible]
SOUTHERN REGION:																	
Alabama Great Southern	-	-	96 625	3.22	96 625	3.22	-	96 625	546.46	1 657 817	3 034	4 159 995	7 613	5.8	177	[illegible]	[illegible]
Atlanta & St.Andrews Bay	-	-	16 498	3.02	16 498	3.02	-	16 498	113.30	341 344	3 013	402 153	[illegible]	4.8	[illegible]	440	[illegible]
Atlanta & West Point	112	0.81	22 254	2.89	22 366	2.88	-	22 366	146.37	437 542	2 989	895 132	6 116	5.1	[illegible]	441	[illegible]
Atlantic Coast Line	47 877	1.65	988 290	2.72	1 036 167	2.67	-	1 036 167	7 348.55	22 339 592	3 040	36 450 277	4 960	[illegible]	141	377	[illegible]
Central of Georgia	-	-	295 527	2.45	295 527	2.45	-	295 527	2 134.35	6 693 531	3 136	9 605 608	4 500	[illegible]	[illegible]	[illegible]	[illegible]
Charleston & Western Carolina	22	1.00	66 850	2.99	66 872	2.98	-	66 872	426.87	1 233 527	2 890	1 059 257	[illegible] 481	[illegible]	157	468	[illegible]
Cin.,New Orleans & Tex.Pac.	-	-	136 381	3.21	136 381	3.21	-	136 381	768.06	2 272 369	2 959	9 010 484	11 731	6.0	178	570	4.86
Clinchfield	36 838	1.59	82 177	2.83	119 015	2.44	-	119 015	419.54	1 275 405	3 040	3 871 429	9 228	9.3	284	693	[illegible]
Columbus & Greenville	-	-	33 448	2.24	33 448	2.24	-	33 448	204.59	648 141	3 168	242 743	1 187	[illegible]	[illegible]	[illegible]	[illegible]
Florida East Coast	17 405	1.77	139 205	2.99	156 610	2.86	• 8 912	165 522	1 151.09	3 348 464	2 909	6 231 811	5 414	4.7	136	389	[illegible]
Georgia	1	1.88	56 595	2.72	56 596	2.72	-	56 596	440.57	1 338 439	3 038	1 805 798	[illegible]	4.2	128	[illegible]	[illegible]
Georgia & Florida	102 639	1.49	-	-	102 639	1.49	-	102 639	460.81	1 244 187	2 700	651 003	1 413	8.2	223	[illegible]	[illegible]
Georgia,Southern & Florida	77 181	2.07	18 226	3.10	95 407	2.26	-	95 407	466.58	1 468 108	3 147	1 994 989	[illegible]	[illegible]	204	[illegible]	[illegible]
Gulf,Mobile & Ohio	4 711	1.65	500 799	2.56	505 510	2.55	• 6 985	512 495	3 742.30	11 642 534	3 111	16 391 215	4 380	4.3	[illegible]	344	
Illinois Central	-	-	1 540 987	2.67	1 540 987	2.67	(S) 32	1 541 019	9 808.47	29 901 100	3 048	61 842 871	6 310	[illegible]	[illegible]	[illegible]	
Louisville & Nashville	-	-	701 469	2.63	701 469	2.63	-	701 469	6 753.63	19 332 595	2 863	45 543 325	6 744	[illegible]	104	[illegible]	[illegible]
Mississippi Central	-	-	29 163	1.84	29 163	1.84	-	29 163	173.87	552 225	3 176	319 733	1 839	[illegible]	168	[illegible]	[illegible]
Nashville,Chatt.& St.Louis	-	-	142 993	2.51	142 993	2.51	-	142 993	1 447.12	3 959 320	2 736	7 930 310	5 480	3.6	[illegible]	248	[illegible]
New Orleans & Northeastern	-	-	57 126	3.34	57 126	3.34	-	57 126	289.06	850 991	2 944	2 415 962	8 358	6.7	198	[illegible]	
Norfolk Southern	95 614	1.53	69 688	2.72	165 302	2.03	• 1 154	166 456	821.21	2 401 000	2 924	1 557 888	1 897	6.9	201	[illegible]	
Seaboard Air Line	775	1.69	864 329	2.65	865 104	2.65	-	865 104	5 367.38	16 229 275	3 024	33 366 48[illegible]	6 217	5.3	161	[illegible]	
Southern Ry.	8 427	2.02	730 024	3.04	738 451	3.02	-	738 451	8 319.85	25 783 961	3 099	50 171 139	6 030	[illegible]	[illegible]	[illegible]	
Tennessee Central	36 119	1.53	4 911	2.25	41 030	1.62	-	41 030	342.65	1 037 544	3 028	712 557	2 080	4.0	[illegible]	[illegible]	
Western Ry.of Alabama	106	2.46	23 745	2.90	23 851	2.90	-	23 851	188.14	563 871	2 997	1 005 705	[illegible]	[illegible]	[illegible]		
Total	427 827	1.66	6 617 310	2.72	7 045 137	2.66	17 083	7 062 220	51 860.82	156 552 904	3 018	297 741 916	5 739	[illegible]	[illegible]	[illegible]	

Table A

Sheet 2 of 2 sheets

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1949

	Cross ties laid in replacement						Estimated	Average number of		Number of equated	New wooden cross tie replacement averages			
											Per	Number	Renewal	Renewal

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1949

Road	Cross ties laid in replacement								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			
	New wooden ties untreated (U)		New wooden ties treated (T)		Total all new wooden ties laid		Ties other than wood (S) & second-hand (*) reapplied ties	Total ties applied						Per cent renewal to all ties in maintained track	Number laid per mile of maintained track	Renewal cost per mile of maintained track	Renewal cost per 1,000 equated gross ton-miles
	Number	Average cost	Number	Average cost	Number	Average cost											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NORTHWESTERN REGION:																	(cents)
Chicago & North Western	12 160	$1.33	805 245	$2.54	817 405	$2.52	-	817 405	11 173.50	33 148 825	2 967	45 392 078	4 063	2.5	73	$154	4.5[illegible]
Chicago Great Western	24 587	1.95	354 506	3.49	379 093	3.39	-	379 093	1 861.71	5 531 985	2 971	8 715 301	4 681	6.9	204	690	14.[illegible]
Chicago, Milwaukee, St. Paul & Pac.	48 756	.41	822 347	2.77	871 103	2.63	-	871 103	13 547.91	41 892 407	3 092	61 183 059	4 516	2.1	64	169	3.7[illegible]
Chicago, St. Paul Minpls. & Omaha	745	1.41	170 955	2.86	171 700	2.85	-	171 700	2 149.84	6 374 281	2 965	7 730 456	3 596	2.7	80	226	5.34
Duluth, Missabe & Iron Range	1 331	1.70	100 781	2.58	102 112	2.57	-	102 112	1 081.26	3 221 065	2 979	6 441 890	5 958	3.2	94	24[illegible]	4.[illegible]
Duluth, South Shore & Atlantic	13 761	1.47	73 677	2.71	87 438	2.51	-	87 438	538.99	1 610 257	2 988	1 306 379	2 427	[illegible].4	162	400	16.[illegible]
Duluth, Winnipeg & Pacific	3 996	1.63	41 766	2.38	45 762	2.31	-	45 762	206.00	607 564	2 949	815 680	3 960	7.5	2[illegible]2	513	12.9[illegible]
Great Northern	14 465	1.35	1 195 343	2.68	1 209 808	2.66	* 19 219	1 229 027	10 259.24	31 657 577	3 086	54 131 218	5 276	3.8	118	314	5.74
Green Bay & Western	5 638	1.77	27 276	3.39	32 914	3.11	-	32 914	273.40	792 374	2 898	589 085	2 155	4.[illegible]	120	375	17.4[illegible]
Lake Superior & Ishpeming	21 260	1.51	11 181	3.14	32 441	2.07	-	32 441	236.18	708 540	3 000	167 988	711	4.6	127	264	39.99
Minneapolis & St. Louis	68 299	1.37	236 941	2.73	305 240	2.43	-	305 240	1 559.00	4 696 788	3 013	3 909 764	2 508	6.5	196	476	18.76
Minneapolis, St. Paul & S.S. Marie	16 474	1.33	447 810	2.45	464 284	2.41	-	464 284	4 799.67	14 490 387	3 019	15 527 594	3 235	3.2	[illegible]7	2[illegible]4	7.22
Northern Pacific	1 534	1.38	569 743	2.48	571 277	2.48	-	571 277	9 242.94	26 831 146	2 903	42 216 234	4 567	2.1	62	153	3.35
Spokane International	54 112	1.54	754	2.00	54 866	1.55	-	54 866	176.78	514 787	2 912	336 015	1 901	10.7	310	461	25.30
Spokane, Portland & Seattle	2 298	.63	84 121	2.70	86 419	2.63	-	86 419	1 139.56	3 512 861	3 083	6 156 869	5 403	2.5	76	200	3.69
Wisconsin Central							Included in report of Minneapolis, St. Paul & S.S. Marie										
Total	289 416	1.30	4 942 446	2.69	5 231 862	2.62	19 219	5 251 081	58 245.98	175 590 844	3 015	254 122 013	4 371	3.0	90	235	5.38
CENTRAL WESTERN REGION:																	
Atchison, Topeka & Santa Fe	-	-	1 346 716	2.65	1 346 716	2.65	-	1 346 716	19 337.04	61 743 169	3 193	146 330 256	7 567	[illegible].2	70	185	2.44
Chicago, Burlington & Quincy	-	-	755 433	2.60	755 433	2.60	* 89 304	844 737	11 866.87	36 644 895	3 088	61 644 438	5 195	2.1	64	166	3.19
Chicago, Rock Island & Pacific	-	-	810 602	2.35	810 602	2.35	-	810 602	9 594.83	28 637 859	2 985	51 140 181	5 330	[illegible].5	84	199	3.73
Colorado & Southern	-	-	55 860	2.96	55 860	2.96	* 2 621	58 481	822.36	2 463 922	2 996	3 663 015	4 454	2.3	60	[illegible]01	4.52
Colorado & Wyoming	-	-	4 257	3.14	4 257	3.14	-	4 257	105.7[illegible]	312 904	2 [illegible]	31 512	298	1.4	40	127	42.48
Denver & Rio Grande Western	-	-	191 667	3.46	191 667	3.46	* 45 345	237 012	3 404.33	10 609 000	3 116	18 233 903	5 356	1.5	56	19[illegible]	3.64
Fort Worth & Denver City	-	-	75 985	2.77	75 985	2.77	* 421	76 406	1 036.28	3 084 199	2 976	4 240 684	4 092	2.5	73	203	4.97
Northwestern Pacific	14 588	2.24	63 665	2.63	78 253	2.56	-	78 253	422.68	1 221 569	2 890	1 522 606	3 602	6.4	185	473	13.14
Sacramento Northern	32 961	2.47	2 315	2.66	35 276	2.48	-	35 276	313.86	947 507	3 019	115 315	367	3.7	112	279	75.91
Southern Pacific Co.- Pac. Lines	5 813	2.02	882 587	2.75	888 400	2.74	* 1 624	890 024	11 801.51	[illegible]6 46[illegible] 0[illegible]2	3 [illegible]0	117 [illegible]11 412	[illegible] 540	2.4	75	207	2.08
Toledo, Peoria & Western	-	-	10 439	2.37	10 439	2.37	-	10 439	278.28	[illegible]81 591	3 1[illegible]	79[illegible] [illegible]91	2 [illegible]71	1.2	38	89	3.10
Union Pacific	2 212	1.61	841 555	2.72	843 767	2.72	-	843 767	13 160.26	37 180 733	2 825	126 311 854	9 598	[illegible].3	64	174	1.32
Utah	4 990	1.99	4 935	3.80	9 925	2.89	* 12	9 937	71.31	200 394	2 810	372 904	5 229	5.0	139	402	7.69
Western Pacific	102 129	2.22	217 506	3.15	319 635	2.85	* 333	319 968	1 537.46	4 574 207	2 975	11 535 216	7 503	7.0	208	593	7.90
Total	162 693	2.25	5 263 522	2.68	5 426 215	2.67	139 660	5 565 875	73 752.80	224 969 041	3 050	543 252 189	7 366	2.4	74	196	2.67
SOUTHWESTERN REGION:																	
Beaumont, Sour Lake & Western	-	-	20 507	2.85	20 507	2.85	-	20 507	109.37	428 200	3 915	1 512 598	13 830	4.8	188	533	3.80
Burlington-Rock Island	-	-	13 958	2.82	13 958	2.82	-	13 958	179.37	561 428	3 130	1 094 132	6 100	2.5	78	220	3.60
International-Great Northern	-	-	176 877	2.83	176 877	2.83	-	176 877	1 421.89	4 261 400	2 997	8 037 455	5 653	4.2	124	352	6.22
Kansas City Southern	-	-	71 623	2.65	71 623	2.65	-	71 623	1 287.80	4 076 265	3 165	10 247 647	7 957	1.8	56	148	1.85
Kansas, Oklahoma & Gulf	-	-	36 047	2.67	36 047	2.67	-	36 047	352.40	1 046 698	2 970	1 467 763	4 165	3.4	102	274	6.57
Louisiana & Arkansas	-	-	39 4[illegible]	2.35	39 488	2.35	-	39 488	[illegible]2.49	2 [illegible]	3 2[illegible]	3 97[illegible]	4 [illegible]	1.4	4[illegible]	105	2.33
Midland Valley	-	-	28 081	2.52	28 081	2.52	-	28 081	355.12	1 051 154	2 960	446 782	1 258	2.7	79	199	15.86
Missouri-Kansas-Texas Lines	-	-	307 931	2.72	307 931	2.72	-	307 931	3 916.16	12 308 900	3 143	19 664 980	5 021	2.5	79	214	4.25
Missouri Pacific	4 497	.59	900 519	2.41	905 016	2.41	-	905 016	8 853.10	27 305 624	3 084	48 171 241	5 441	3.3	102	246	4.52
New Orleans, Texas & Mexico	-	-	12 88[illegible]	2.84	12 883	2.84	-	12 88[illegible]	221.[illegible]	696 800	3 0[illegible]	1 500 076	6 585	4.7	144	410	6.22
Oklahoma City-Ada-Atoka	-	-	26 461	2.40	26 461	2.40	-	26 461	136.89	394 243	2 [illegible]	98 670	721	6.7	193	465	64.48
St. Louis, Brownsville & Mexico	-	-	81 244	2.81	81 244	2.81	-	81 244	776.19	2 348 000	3 025	3 302 307	4 255	3.5	105	294	6.92
St. Louis-San Francisco	308	1.66	791 869	2.35	792 177	2.35	-	792 177	6 232.57	19 631 881	3 150	29 152 947	4 679	4.0	127	299	6.40
St. Louis, San Fran. & Texas	-	-	17 876	2.40	17 876	2.40	-	17 876	150.97	472 899	3 132	749 279	4 963	3.8	118	284	5.73
St. Louis Southwestern Lines	-	-	2[illegible]	2.64	[illegible]	2.64	* 1 [illegible]24	24[illegible] 25[illegible]	[illegible]861.[illegible]	5 [illegible] 4[illegible]4	3 090	14 240 [illegible]14	[illegible] 648	4.6	143	377	4.93
San Antonio, Uvalde & Gulf	-	-	38 242	2.50	38 242	2.50	-	38 242	355.48	1 025 200	2 884	705 207	1 984	3.7	108	269	13.56
Texas & New Orleans	-	-	601 233	2.51	601 233	2.51	-	601 233	5 558.45	15 337 126	2 759	30 897 057	5 559	3.9	108	271	4.88
Texas & Northern	-	-	1 337	1.75	1 337	1.75	-	1 337	10.76	42 986	3 995	29 375	2 730	3.1	124	217	7.97
Texas & Pacific	-	-	329 680	2.69	329 680	2.69	-	329 680	2 254.27	6 591 550	2 924	16 654 408	7 388	5.0	146	394	5.33
Texas Mexican	204	.56	17 246	2.39	17 450	2.37	-	17 450	232.28	736 035	3 169	235 752	1 015	2.4	75	178	17.55
Total	5 009	.65	3 799 029	2.52	3 804 038	2.52	1 324	3 805 362	35 155.32	106 943 154	3 042	192 196 749	5 467	3.6	108	273	4.99
Grand Total - United States	1 173 570	1.64	28 876 066	2.79	30 049 636	2.74	235 410	30 285 046	[illegible]30 612.42	992 941 367	3 003	2 114 906 295	6 397	3.0	91	249	3.90
CANADIAN ROADS:																	
Canadian National	643 809	1.18	3 167 585	2.26	3 811 394	2.08	-	3 811 394	26 902.00	78 767 255	2 928	c	c	4.8	14[illegible]	295	c
Canadian Pacific	179 211	1.56	2 836 922	2.35	3 016 133	2.30	-	3 016 133	21 089.00	60 714 534	2 879	100 388 291	4 760	5.0	143	329	6.92
Ontario Northland	168 070	1.60	21 268	2.85	189 338	1.92	-	189 338	693.60	1 [illegible]	2 841	1 529 865	2 206	9.6	273	524	13.74

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 The Atlantic & Danville became a Class I railroad August 1, 1949; figures shown for 1949 are for last five months of year.

c 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 1, 1950.

Table B

NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOOD 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 1945 to 1949, inclusive

Note: All figures are exclusive of bridge and switch ties

	Number of new wood cross tie renewals	Aggregate cost of new wood cross tie renewals	Per cent new wood cross tie renewals

Table B

NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOOD 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 1945 to 1949, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wood cross tie renewals per mile of maintained track						Aggregate cost of new wood cross tie renewals per mile of maintained track						Per cent new wood cross tie renewals to all ties in tracks					
	1945	1946	1947	1948	1949	5 year average	1945	1946	1947	1948	1949	5 year average	1945	1946	1947	1948	1949	5 year average
NEW ENGLAND REGION:																		
Bangor & Aroostook	110	201	163	187	223	177	$231	$449	$365	$297	$359	$340	3.8	7.0	5.7	6.5	7.8	6.2
Boston & Maine	42	47	62	61	49	62	101	124	185	181	156	149	1.4	1.6	2.1	2.1	1.7	1.8
Canadian Nat.Lines in New England	126	88	108	109	78	102	211	157	208	229	175	196	4.0	2.8	3.4	3.5	2.5	3.2
Canadian Pacific (lines in Me.)	82	80	100	106	100	94	154	172	214	242	244	205	2.6	2.6	3.2	3.6	3.5	3.1
Canadian Pacific (lines in Vt.)	86	93	68	55	58	72	168	184	145	110	128	147	2.9	3.1	2.3	1.8	1.9	2.4
Central Vermont	21	41	52	49	49	42	42	92	126	139	147	109	0.7	1.4	1.8	1.7	1.6	1.4
Maine Central	124	84	123	135	108	115	299	205	324	353	306	297	4.1	2.8	4.1	4.5	3.6	3.8
New York Connecting	132	39	125	117	93	101	400	123	431	470	369	359	4.2	1.2	4.0	3.7	2.9	3.2
New York, New Haven & Hartford	77	100	83	81	44	77	190	261	225	240	146	212	2.5	3.2	2.6	2.6	1.4	2.5
Rutland	39	51	39	45	57	46	83	120	97	117	172	118	1.2	1.6	1.2	1.4	1.8	1.4
Total	72	85	86	88	71	80	169	211	225	230	190	205	2.4	2.8	2.8	2.9	2.3	2.6
GREAT LAKES REGION:																		
Ann Arbor	97	104	100	103	119	105	213	249	275	296	366	280	3.2	3.4	3.3	3.4	3.9	3.4
Cambria & Indiana	177	110	82	34	28	86	416	303	235	100	87	228	6.2	3.8	2.8	1.2	1.0	3.0
Delaware & Hudson	110	134	123	123	115	121	294	386	368	384	373	361	3.5	4.3	3.9	3.9	3.6	3.8
Delaware,Lackawanna & Western	71	77	86	100	91	85	171	202	241	308	313	247	2.5	2.7	3.0	3.5	3.0	2.9
Detroit & Mackinac	93	88	131	175	136	125	101	124	249	365	284	225	3.1	2.9	4.4	5.8	4.5	4.1
Detroit & Toledo Shore Line	72	53	68	49	60	60	170	138	208	153	193	172	2.4	1.7	2.2	1.6	2.0	2.0
Erie	71	62	62	77	79	70	177	160	176	237	259	202	2.4	2.1	2.1	2.6	2.7	2.4
Grand Trunk Western	142	140	116	113	103	123	327	365	271	292	276	306	4.5	4.4	3.6	3.6	3.3	3.9
Lehigh & Hudson River	98	99	99	93	54	89	288	303	328	295	204	284	3.7	3.7	3.7	3.4	2.0	3.3
Lehigh & New England	59	60	75	97	111	80	159	171	238	332	354	251	1.9	2.0	2.5	3.2	3.7	2.7
Lehigh Valley	74	89	93	99	86	88	189	251	286	334	282	268	2.5	3.0	3.1	3.3	2.9	3.0
Monongahela	96	91	76	70	46	76	220	237	220	211	154	208	3.3	3.1	2.6	2.4	1.6	2.6
Montour	100	78	87	11	68	69	213	172	285	36	264	194	3.5	2.7	3.0	0.4	2.3	2.4
New York Central	118	100	73	99	58	90	288	262	206	309	190	251	3.9	3.2	2.4	3.2	2.0	2.9
New York,Chgo.& St.Louis (Incl.W&LE)	140	136	126	107	117	125	326	363	351	312	353	341	4.5	4.4	4.0	3.4	3.8	4.0
New York,Ontario & Western	2	-	-	-	-	-	4	1	-	-	-	1	0.1	-	-	-	-	-
New York,Susquehanna & Western	32	33	41	57	68	46	62	79	109	179	228	131	1.1	1.1	1.4	2.0	2.3	1.6
Pittsburgh & Lake Erie	93	102	99	112	107	103	233	234	258	346	340	282	3.1	3.4	3.4	3.7	3.5	3.4
Pittsburg & Shawmut	164	175	153	223	106	164	507	524	476	679	333	504	5.8	6.2	5.4	8.0	3.7	5.8
Pittsburgh & West Virginia	105	110	80	64	78	87	325	343	260	212	276	283	3.5	3.6	2.6	2.1	2.6	2.9
Wabash	111	103	100	96	94	101	238	252	269	286	281	265	3.6	3.3	3.2	3.1	3.0	3.2
Total	106	97	83	97	76	92	255	252	232	298	241	256	3.2	3.2	2.7	3.2	2.6	3.0
CENTRAL EASTERN REGION:																		
Akron,Canton & Youngstown	221	269	182	176	150	200	428	563	411	468	424	459	7.7	9.3	6.3	5.8	5.1	6.8
Baltimore & Ohio	144	123	100	106	44	103	312	277	255	284	115	249	5.1	4.3	3.5	3.7	1.6	3.6
Bessemer & Lake Erie	30	30	28	27	28	29	92	97	97	95	109	98	1.0	1.0	0.9	0.9	0.9	0.9
Central R.R.of New Jersey	84	132	82	89	66	91	204	323	212	250	201	238	3.0	4.7	2.9	3.2	2.3	3.2
Central R.R.of Pennsylvania a	-	68	113	101	77	*	-	176	343	336	275	*	-	2.4	4.0	3.6	2.7	*
Chicago & Eastern Illinois	116	142	60	84	47	90	256	324	145	212	134	214	3.7	4.6	2.0	2.8	1.5	2.9
Chicago & Illinois Midland	329	34	114	180	98	151	1070	94	357	586	327	487	11.1	1.2	3.9	6.0	3.3	5.1
Chicago,Indpls.& Louisville	51	72	124	169	141	111	94	156	299	455	378	276	1.6	2.3	4.0	5.4	4.5	3.6
Detroit,Toledo & Ironton	47	60	72	76	103	72	90	127	178	200	250	169	1.6	2.1	2.5	2.7	3.6	2.5
Elgin,Joliet & Eastern	90	99	61	82	70	80	192	218	146	202	197	191	2.9	3.2	2.0	2.7	2.3	2.6
Illinois Terminal	89	81	73	89	91	85	159	158	159	210	225	182	3.0	2.7	2.4	3.0	3.0	2.8
Long Island	123	87	116	139	87	110	361	270	401	535	340	381	4.3	3.0	4.1	4.9	3.0	3.9
Missouri-Illinois	175	191	219	261	173	204	310	393	496	562	392	431	5.6	6.1	7.0	8.3	5.5	6.5
Pennsylvania	109	92	89	97	86	95	252	229	256	293	271	260	3.8	3.2	3.1	3.4	3.0	3.3
Penna.-Reading Seashore Lines	78	92	108	113	77	94	222	276	379	385	282	309	2.9	3.4	4.0	4.1	2.8	3.4
Reading Co.	122	111	128	116	65	108	292	289	350	346	216	299	4.4	4.0	4.6	4.1	2.3	3.9
Staten Island Rapid Transit	65	108	75	65	63	75	182	270	206	197	217	214	2.7	4.2	2.9	2.6	2.5	3.0
Western Maryland	75	72	77	57	61	68	171	183	213	172	191	186	2.6	2.5	2.7	2.0	2.1	2.4
Total	115	102	94	101	73	97	261	245	258	292	224	256	4.0	3.5	3.3	3.5	2.6	3.4
POCAHONTAS REGION:																		
Atlantic & Danville b	-	-	-	-	20	*	-	-	-	-	45	*	-	-	-	-	0.7	*
Chesapeake & Ohio (Inc.P.M.)	108	93	88	94	77	92	235	226	233	289	224	241	3.6	3.0	2.9	3.1	2.5	3.0
Norfolk & Western	68	86	114	134	125	105	144	191	273	361	351	264	2.2	2.8	3.7	4.3	4.0	3.4
Richmond,Fred.& Potomac	215	98	52	46	44	91	469	231	132	129	130	218	7.4	3.4	1.8	1.6	1.5	3.1
Virginian	89	81	100	121	121	102	158	152	205	295	310	224	2.9	2.6	3.2	3.9	3.9	3.3
Total	97	90	96	107	93	97	208	210	241	308	264	246	2.9	3.0	3.1	3.5	3.0	3.1
SOUTHERN REGION:																		
Alabama Great Southern	214	227	219	191	177	206	525	594	608	580	569	575	7.1	7.5	7.2	6.3	5.8	6.8
Atlanta & St.Andrews Bay c	-	-	103	131	146	*	-	-	303	353	440	*	-	-	3.4	4.3	4.8	*
Atlanta & West Point	278	214	132	152	153	186	611	506	340	403	441	460	9.0	6.9	4.3	5.1	5.1	6.1
Atlantic Coast Line (Inc.AR&C)	271	288	254	207	141	232	588	701	617	551	377	567	9.3	9.6	8.4	6.8	4.6	7.7
Central of Georgia	144	154	149	131	138	143	240	298	305	296	339	296	4.9	5.2	5.3	4.5	4.4	4.9
Charleston & Western Carolina	270	197	187	167	157	196	600	539	430	453	468	498	9.3	6.8	6.5	5.8	5.4	6.8
Cincinnati,New Orleans & Tex.Pac.	74	93	96	144	178	117	180	241	265	458	570	343	2.5	3.2	3.3	4.9	6.0	4.0
Clinchfield	151	173	212	227	284	209	277	340	433	526	693	454	5.0	5.7	7.0	7.5	9.3	6.9
Columbus & Greenville	174	154	181	183	163	171	364	344	414	442	366	386	5.5	4.9	5.4	5.8	5.2	5.4
Florida East Coast	156	178	195	132	136	159	383	450	503	343	389	414	5.4	6.2	6.7	4.5	4.7	5.5
Georgia R.R.	200	128	112	130	128	140	400	287	275	320	349	326	6.5	4.2	3.7	4.3	4.2	4.6
Georgia & Florida	195	253	201	221	223	219	258	396	307	312	331	321	7.2	9.4	7.5	8.2	8.2	8.1
Georgia,Southern & Florida	143	195	209	211	204	192	238	334	393	452	463	376	4.6	6.2	6.7	6.7	6.5	6.1
Gulf,Mobile & Ohio (Inc.Alton)	238	228	234	187	135	204	505	545	559	451	344	481	7.7	7.4	7.5	6.4	4.3	6.7
Illinois Central (Inc.G&SI and Y&MV)	203	208	198	19	157	192	424	472	471	469	420	451	6.6	6.8	6.5	6.3	5.2	6.3
Louisville & Nashville	134	130	134	127	104	126	272	287	334	326	273	298	4.7	4.5	4.7	4.4	3.6	4.4
Mississippi Central	136	98	161	153	168	143	297	211	424	326	308	313	4.3	3.1	5.1	4.8	5.3	4.5
Nashville,Chattanooga & St.Louis	178	123	85	77	99	112	383	288	182	186	248	257	6.5	4.5	3.1	2.8	3.6	4.1
New Orleans & Northeastern	250	239	234	226	198	229	680	651	710	680	661	676	8.7	8.3	8.2	7.9	6.7	8.0
Norfolk Southern	224	255	229	244	201	231	419	511	471	498	409	462	7.7	8.8	7.8	8.3	6.9	7.9
Seaboard Air Line	186	175	171	168	161	172	388	404	417	426	427	412	6.1	5.8	5.7	5.6	5.3	5.7
Southern Ry.	136	136	129	122	89	122	327	380	379	367	268	344	4.4	4.4	4.2	3.9	2.9	4.0
Tennessee Central	139	137	152	157	120	141	257	275	298	295	194	264	4.6	4.5	5.0	5.2	4.0	4.7
Western Ry.of Alabama	235	183	124	135	127	161	485	416	321	358	367	389	7.7	6.0	4.1	4.5	4.2	5.3
Total	187	187	178	164	136	170	398	443	437	419	361	412	6.2	6.2	5.9	5.5	4.5	5.7

Sheet 2 of 2 sheets

Table B

NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOOD 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 1945 to 1949, inclusive

Note: All figures are exclusive of bridge and switch ties

	Number of new wood cross tie renewals	Aggregate cost of new wood cross tie renewals	Per cent new wood cross tie renewals

Table B

NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOOD 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 1945 to 1949, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wood cross tie renewals per mile of maintained track						Aggregate cost of new wood cross tie renewals per mile of maintained track						Per cent new wood cross tie renewals to all ties in tracks					
	1945	1946	1947	1948	1949	5 year average	1945	1946	1947	1948	1949	5 year average	1945	1946	1947	1948	1949	5 year average
NORTHWESTERN REGION:																		
Chicago & North Western	143	121	106	110	73	111	$267	$240	$238	$268	$184	$239	4.8	4.1	3.6	3.7	2.5	3.7
Chicago Great Western	127	155	134	181	204	160	266	370	329	495	690	430	4.3	5.2	4.5	6.1	6.9	5.4
Chicago,Milwaukee,St.Paul & Pacific	157	109	145	102	64	115	297	213	323	248	169	250	5.1	3.5	4.7	3.3	2.1	3.7
Chicago,St.Paul,Minpls.& Omaha	142	112	116	115	60	113	307	253	281	309	228	276	4.8	3.8	3.9	3.9	2.7	3.8
Duluth,Missabe & Iron Range	66	64	56	70	94	70	134	133	120	172	243	160	2.2	2.2	1.9	2.4	3.2	2.4
Duluth,South Shore & Atlantic	148	142	138	150	162	148	258	273	293	338	408	314	4.6	4.7	4.7	5.1	5.4	4.9
Duluth,Winnipeg & Pacific	347	295	263	251	222	276	609	521	523	582	513	550	11.8	10.0	9.0	8.5	7.5	9.4
Great Northern	149	96	124	123	118	122	286	177	269	284	314	266	4.8	3.1	4.0	4.0	3.8	3.9
Green Bay & Western	225	142	110	141	120	148	490	318	240	378	375	360	7.2	4.9	3.6	4.4	4.2	4.9
Lake Superior & Ishpeming	171	151	149	170	137	156	293	310	271	348	284	301	5.7	5.0	5.0	5.7	4.6	5.2
Minneapolis & St.Louis	144	111	151	189	196	158	256	209	338	447	476	345	4.8	3.7	5.0	6.3	6.5	5.3
Minpls.,St.Paul & S.S.Marie (Inc.Wis.C.)	92	104	111	110	97	103	178	201	234	254	234	220	3.1	3.5	3.7	3.7	3.2	3.4
Northern Pacific	90	61	66	69	62	70	154	109	131	151	153	140	3.1	2.1	2.3	2.4	2.1	2.4
Spokane International	342	294	308	305	310	312	405	358	456	433	481	427	11.8	10.1	10.6	10.5	10.7	10.7
Spokane,Portland & Seattle	233	119	169	111	76	142	438	253	430	294	200	323	7.7	3.8	5.6	3.6	2.5	4.6
Total	136	104	117	110	90	111	257	203	257	262	235	243	4.5	3.4	3.9	3.6	3.0	3.7
CENTRAL WESTERN REGION:																		
Atchison,Topeka & Santa Fe	100	80	88	89	70	85	173	147	172	200	185	175	3.3	2.6	2.9	2.9	2.2	2.8
Chicago,Burlington & Quincy	169	126	75	80	64	103	319	258	161	184	166	218	5.5	4.1	2.4	2.6	2.1	3.3
Chicago,Rock Island & Pacific	140	109	72	108	84	103	292	236	159	234	199	224	4.7	3.6	2.4	3.6	2.8	3.4
Colorado & Southern	103	103	94	86	68	91	205	222	210	220	201	212	3.4	3.4	3.1	2.9	2.3	3.0
Colorado & Wyoming	56	40	28	38	40	40	169	117	79	139	127	126	2.0	1.4	1.0	1.3	1.4	1.4
Denver & Rio Grande West.(Inc.D&SL)	40	35	39	40	56	42	83	77	104	112	195	114	1.3	1.1	1.3	1.3	1.8	1.4
Fort Worth & Denver City	114	153	123	103	73	113	235	329	280	264	203	262	3.8	5.1	4.1	3.5	2.5	3.8
Northwestern Pacific	237	142	115	137	185	163	413	251	305	359	473	360	6.2	4.9	4.0	4.7	6.4	5.6
Sacramento Northern d	-	-	-	180	112	*	-	-	-	429	279	*	-	-	-	6.0	3.7	*
Southern Pacific Co.- Pac.Lines	160	77	94	75	75	96	283	141	237	193	207	212	5.1	2.5	3.0	2.4	2.4	3.1
Toledo,Peoria & Western	*	*	30	53	38	*	*	*	58	112	89	*	*	*	1.0	1.7	1.2	*
Union Pacific	140	70	75	49	64	80	232	123	152	121	174	160	4.9	2.5	2.7	1.7	2.3	2.8
Utah Ry.	66	85	162	154	139	121	157	214	396	463	402	326	2.3	3.0	5.8	5.5	5.0	4.3
Western Pacific	264	123	348	208	208	230	468	247	777	435	593	504	8.8	4.1	11.6	7.0	7.0	7.7
Total	135	90	86	81	74	93	246	175	187	190	196	199	4.5	3.0	2.9	2.7	2.4	3.1
SOUTHWESTERN REGION:																		
Beaumont,Sour Lake & Western	157	182	161	224	188	182	309	395	367	581	533	437	5.3	6.1	5.4	7.5	4.8	5.8
Burlington-Rock Island	84	137	169	138	78	121	133	292	388	360	220	279	2.7	4.4	5.4	4.4	2.5	3.9
International-Great Northern	123	142	138	136	124	133	247	315	298	330	352	308	4.1	4.7	4.6	4.5	4.2	4.4
Kansas City Southern	83	56	70	65	56	66	161	113	154	156	148	146	2.6	1.8	2.2	2.1	1.8	2.1
Kansas,Oklahoma & Gulf	36	55	71	74	102	68	67	116	166	184	274	161	1.2	1.9	2.4	2.5	3.4	2.3
Louisiana & Arkansas	130	25	130	46	45	75	255	51	272	103	105	157	4.0	0.8	4.0	1.4	1.4	2.3
Midland Valley	34	61	64	77	79	63	62	126	145	181	199	143	1.2	2.1	2.2	2.6	2.7	2.2
Missouri-Kansas-Texas Lines	157	92	109	93	79	106	323	196	258	235	214	245	5.0	2.9	3.5	3.0	2.5	3.4
Missouri Pacific	90	110	159	164	102	125	159	226	371	380	246	276	2.9	3.6	5.1	5.3	3.3	4.0
New Orleans,Texas & Mexico	113	137	142	154	144	138	222	300	320	394	410	329	3.7	4.5	4.6	5.0	4.7	4.5
Oklahoma City-Ada-Atoka	233	248	190	198	193	212	433	522	401	511	465	466	8.1	8.6	6.6	6.9	6.7	7.4
St.Louis,Brownsville & Mexico	146	157	147	130	105	137	276	334	329	307	294	308	4.8	5.2	4.8	4.3	3.5	4.5
St.Louis-San Francisco	107	111	129	119	127	119	172	212	270	270	299	245	3.4	3.5	4.1	3.8	4.0	3.8
St.Louis,San Fran.& Texas	61	122	117	125	118	109	97	226	247	290	284	229	2.0	3.9	3.8	4.0	3.8	3.5
St.Louis Southwestern Lines	196	158	184	164	143	169	389	338	423	407	377	387	6.2	5.1	5.9	5.3	4.6	5.4
San Antonio,Uvalde & Gulf	114	145	124	101	108	118	210	319	285	241	269	265	4.0	5.2	4.3	3.5	3.7	4.1
Texas & New Orleans	122	115	112	114	108	114	197	221	235	279	271	241	4.4	4.1	4.0	4.2	3.9	4.1
Texas & Northern e	-	-	-	-	124	*	-	-	-	-	217	*	-	-	-	-	3.1	*
Texas & Pacific	192	181	172	171	146	172	370	325	367	432	394	378	6.6	6.2	5.9	5.9	5.0	5.9
Texas Mexican	144	79	81	165	75	109	266	170	174	391	178	236	4.5	2.5	2.5	5.2	2.4	3.4
Total	124	115	135	130	108	122	224	230	301	310	273	268	4.1	3.8	4.4	4.3	3.6	4.0
Grand Total, United States	132	113	112	111	91	112	269	251	270	286	249	265	4.4	3.8	3.7	3.7	3.0	3.7
CANADIAN ROADS:																		
Canadian National	159	154	143	135	142	147	240	246	247	257	295	257	5.4	5.3	4.9	4.6	4.8	5.0
Canadian Pacific	149	149	146	144	143	146	228	251	267	291	329	273	5.2	5.2	5.1	5.0	5.0	5.1
Ontario Northland	200	205	167	263	273	222	294	252	228	459	524	351	6.6	7.1	5.7	9.1	9.6	7.6

* Not reported.

a The Central R.R.of Pennsylvania started operations August 5, 1946; formerly part of Central R.R.of New Jersey.

b The Atlantic and Danville became a Class I road August 1, 1949; figures shown for 1949 are for last five months of year.

c The Atlanta & St.Andrews Bay became a Class I road January 1, 1947; formerly a Class II road.

d The Sacramento Northern became a Class I road January 1, 1948; formerly a Class I Electric road.

e The Texas and Northern became a Class I road November 30, 1948.

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 1, 1950.

Lateral Forces Exerted By Locomotives on Curved Track

Synopsis of a Report Prepared by the Joint Committee on Relation Between Track and Equipment of the Mechanical and Engineering Divisions, AAR*

Introduction and Acknowledgment

The Joint Committee on Relation Between Track and Equipment of the Mechanical and Engineering Divisions of the AAR has as Assignment 5: Lateral Forces from Locomotives with Respect to Track Alinement. In November 1947, tests were made with a 4–8–4 modern Northern passenger-type steam locomotive with various amounts and combinations of front and trailer truck lateral resistances on a sharp curve, to determine what arrangement gave the most favorable lateral force distribution on the curve. Since truck resistances have a bearing on the relative stability and riding qualities of a locomotive, the riding conditions of the engine were also tested on tangent track at high speed to determine the effect of each variation of resistance studied. Besides the complete series of tests on the committee locomotive, measurements were also made of the lateral and vertical forces produced on the sharp curve by three other classes of 4–8–4 modern steam locomotives covering a wide range of truck resistances, one 2–10–4 modern steam locomotive, and one class of diesel locomotive. The investigation was outlined and directed by the Committee on Locomotive Construction of the Mechanical Division AAR. The necessary coordination between the Engineering and Mechanical Divisions has been afforded through the AAR Joint Committee on Relation Between Track and Equipment. Funds for the investigation were provided by the Association of American Railroads.

The tests were carried out under the direction of J. R. Jackson, mechanical engineer, Mechanical Division, AAR, and G. M. Magee, research engineer, Engineering Division, AAR, assisted by E. E. Cress, assistant research engineer, Engineering Division, AAR, who analyzed the data, derived the comparison between measured and nominal wheel loads and the lateral force distribution at wheels, and prepared the report.

The conduct of the test, including the design and operation of the complicated electrical and mechanical testing equipment, was by Randon Ferguson, electrical engineer, H. E. Durham, track engineer, M. K. Smucker, assistant electrical engineer, of the AAR research staff, and G. U. Moran, former assistant mechanical engineer, research staff, AAR.

Special amounts of lateral resistances in the trucks of the test locomotive necessitated special castings and changes in other truck parts. These design changes, the preparation of the locomotive for test, and the actual operation of the engine on test were in charge of S. L. Smith, assistant mechanical engineer, Atchison, Topeka & Santa Fe Railway.

The success of the project was in large measure due to the assistance and close cooperation given by the officers and personnel of the several railroads involved. The committee and the Association greatly appreciate these services, and are indebted to the following railroads:

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* Only selected illustrations are used in this synopsis, and bear the numbers of the original report. Report to be published in full, in mimeograph form, by the AAR.

Fig. 1. Santa Fe locomotive of the 4–8–4 type.

The Atchison, Topeka & Santa Fe Railway System for providing the committee test locomotive and designing and making the special changes in its truck resistances; also for providing a test car, passenger equipment, the test tracks and other facilities, and the assistance of various employees.

The Union Pacific Railroad for providing two test locomotives.

The Southern Pacific System for providing one test locomotive.

Test Locomotive

The committee test locomotive was a 4–8–4 type Santa Fe steam passenger locomotive built in 1941 by the Baldwin Locomotive Works (Fig. 1). This locomotive, No. 3784, had Timken roller bearings on all axles and on main and side rods, with Timken lightweight rods. The drivers were 80 in. in diameter, all drivers having flanged tires The first driving axle had a Franklin lateral motion device which allowed a total lateral movement of 1⅜ in., or a movement of 11/16 in. each way from its center. The device required 5600 lb. to produce lateral motion of the axle and had a constant resistance throughout its 11/16-in. travel. There was no free lateral in the first driving axle. The Franklin lateral motion device is specifically a gravity-type centering device designed for the purpose of providing flexibility for curving the long wheel base locomotive. When a heavy lateral thrust is exerted at the first driving axle because of curvature or nosing on tangent, the lateral motion device will deflect with a predetermined constant resistance, thus distributing the lateral thrust instead of allowing it to concentrate on a single pair of drivers. The road mileage, since shopping, at the beginning of the test was 14,000 miles. Fig. 1 shows the test locomotive on the test curve. The nominal axle loads and wheel spacings are shown in Fig. 2.

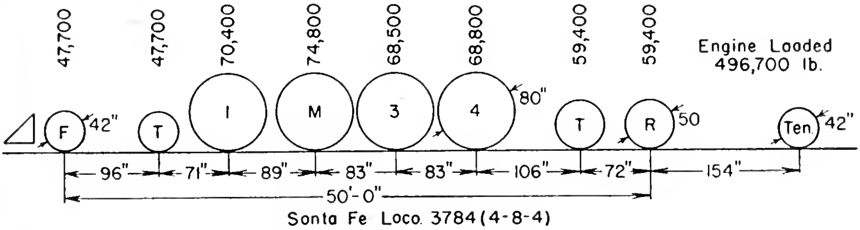

Fig. 2. Axle loads and wheel spacing of the Santa Fe 4–8–4–type test locomotive.

The 4-wheel Batz swing-motion type front truck had inside roller bearings. The truck swing was produced on a double rocker resistance mechanism with a maximum travel of 6¼ in. either side of center. The radial trailer truck was the 4-wheel Delta type manufactured by General Steel Castings Corporation. The axles were equipped with outside roller bearings. The truck resistances normally used in this locomotive have 20 percent initial and constant lateral resistance in the front truck and 15 percent initial and constant in the trailer truck. For the purpose of studying the effect of various combinations of truck resistances, special castings were obtained, by means of which the front truck resistance could be set at 10, 20 or 30 percent, as desired, and the trailer truck resistances varied by the same values. The three resistances available in each truck, therefore, provided nine different combinations of lateral resistances of the trucks of the test locomotive.

When a series with given front and trailer truck resistances had been completed, the test locomotive was returned to the San Bernardino, Calif., shops for changes in truck resistances. The test series was as follows:

	Truck Resistances—Percent	
	Front	*Trailer*
Series 1	30	20
2	30	10
3	30	30
4	10	30
5	10	20
6	10	10
7	20	10
8	20	30
9	20	20
10	20	20 (½ in. lateral at 1st dr.)
11	20	15 (Only tested on curve.)

Each series consisted of the following test runs:

A.—On the 10-deg. test curve, locomotive pulling forward up the 2.2 percent compensated grade; test apparatus on both the locomotive and track recording.

Speeds Mph.	*Runs*	*Load on Engine*
5—forward	3 or more runs	pulling —720 tons
5—backing	3 " " "	coasting—720 tons
20—forward	3 " " "	pulling —720 tons
30—forward	3 " " "	pulling —470 tons

B.—On tangent high-speed level track; test apparatus on locomotive only recording. The locomotive was pulling a test train consisting of 8 passenger cars weighing 550 tons. Two runs with a recorded record for each run at 30, 40, 60, 80 and 100 mph.; each speed on tangent maintained at a marked sign post. Immediately following the 100-mph. stretch there were 2 curves, 1 deg. to the right and 1 deg. to the left; the test train operated over these curves at the time-table speed of 80 mph.

Four other steam locomotives were used to pull the test train for a series of tests on the 10-deg. test curve. The apparatus recording the rail stress, lateral force on the track, and the movements of the rail heads, operated under these locomotives. Test apparatus was not provided on these locomotives, so they were not operated on the tangent track at high speed.

Test Equipment on Locomotive

To determine the relative stability and the riding qualities of Santa Fe locomotive No. 3784, with the various changes in lateral resistances of both trucks, in the 11 series of tests, 5 accelerometers and 3 lateral movement instruments were applied to the locomotive. Two accelerometers were attached to the center of the front end of the engine bed; one measured vertical and the second measured lateral accelerations of the front end of the engine bed. Two additional accelerometers were attached to the left side of the rear end of the engine bed, under the cab, to measure vertical and lateral accelerations at this position. A fifth accelerometer was mounted at the center of the engine frame, between the main and third driving axles, to measure the fore-and-aft accelerations of the frame.

Potentiometers were connected between the engine frame and both the front and trailer trucks to measure the lateral movemnts of each truck with respect to the frame. A third potentiometer was connected between the engine frame and the lateral motion device on the first driving axle to measure the lateral movement of the first driving axle with respect to the frame. Leads from the instruments on the engine were carried into a test car directly behind the tender. The test car housed the recording apparatus, which included a magnetic oscillograph with a 10-in. record, on which the accelerations and movements were recorded. A magnet and coil were attached to the right cross-head and guide, so that the position of the piston was recorded on the record in relation to accelerations of the frame and the swing of the trucks.

Test Equipment on 10-Deg. Curve

The 10-deg. curve selected as the best suited for test purposes was on the eastbound main Santa Fe track through the pass at Cajon, Calif. Both Santa Fe and Union Pacific traffic from Southern California is carried over this track. The curve has a length of 888 ft. between points of spirals, and the test instruments were placed in the track near the middle of the curve. Fig. 4 shows a view of the curve; the test house near the middle of the curve housed the electrical recording apparatus attached to the track instruments. Traffic is up the 2.2 percent compensated grade. The rails were of 131 RE section, laid less than a year before the test. The outer rail was only slightly flange worn and the head of the inner rail was of almost full contour, without lateral flow. The tie plates were double shoulder, 7¾ in. by 12 in. in size. There were two line and two anchor spikes per tie plate. The 7-in. by 9-in. creosoted oak ties ranged in length from 8 to 9 ft., and there were 25 to the rail length. There were gage rods on the curve at about 4 tie space intervals, but during the test those rods within 50 ft of the track instrument locations were loosened so they had no effect.

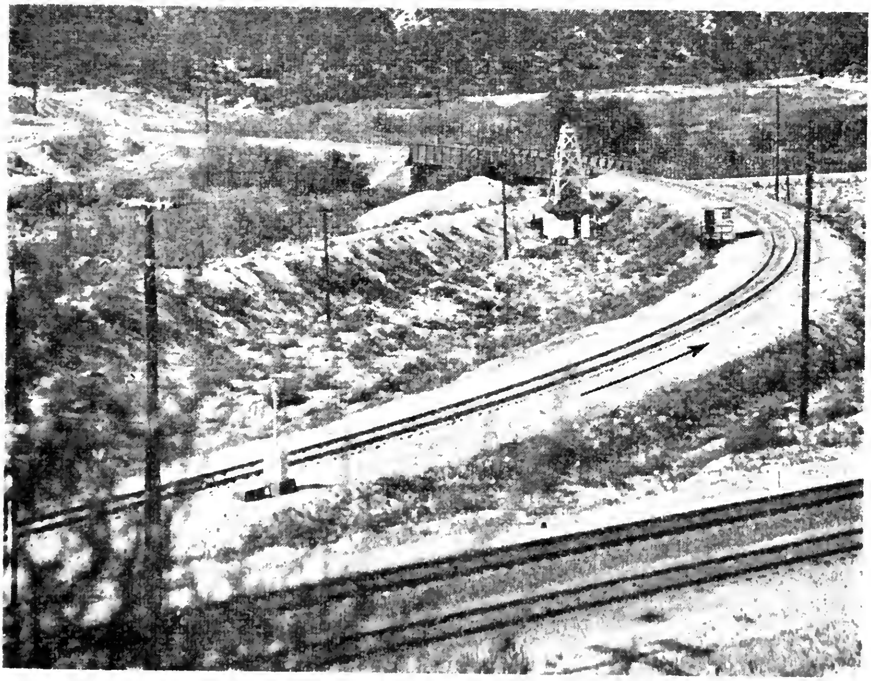

Fig. 4. The 10-deg. test curve—A. T. & S. F. Ry., Cajon, Calif.

A

The test location was on a 10-ft. fill. The ballast was Los Angeles crushed rock, about 16 in. deep, with a very high sand content blown in from the wayside and dropped by locomotives. The track gage was 4 ft. 9 in. at the test locations. The superelevation was 3 in., which corresponds to an equilibrium speed of 20½ mph. The speed for 3-in. unbalanced elevation was 30 mph., which was the maximum allowable speed on the curve. Before the tests, the curve was lined to engineer's stakes and spot surfaced. As the tests progressed, moderate irregularities in line and surface developed. Generally the curve could be considered to be representative of main-line track conditions.

Strain gages were placed in position on the rail cross section where it was known from experience that the most significant stresses would be determined under the variety of loading conditions existing on the curve. On the inner rail a gage was placed on each face of the upper portion of the rail web, at a height of 4⅞ in. above the base, to measure strains in a vertical direction (gages No. 3 on the inner face and No. 13 on the outer face). The average of these vertical strains is closely proportionate to the amount of vertical wheel load. Gage 17a was placed in the lower outer web fillet of the rail (for gage locations see Fig. 34). Strains at this gage are indicative of the outward lateral force from the wheel loads. Similar gages were attached to the outer rail directly across the track. All gages were directly over the middle of the tie plates. All rail stress measurements were made with Baldwin–Southwark SR–4 electrical wire resistance strain gages with an effective length of ¼ in.

At the same cross section, two potentiometers were attached to the tie outside the tie plates, and to a flexible cable attached to the outside of each rail head to measure the lateral movement of each rail head as the wheels passed. The 6 rail stress records and the 2 records of lateral movement of the rail head were recorded on one 10-in. magnetic oscillograph located in a test house beside the track. The stress records were amplified so that a + 1 in. recorded deflection was equivalent to a tensile stress of 40,000 psi., and a — 1 deflection was a compressive stress of the same magnitude. A 0.30-in. movement of a rail head was magnified on the record to a deflection of 1 in. Fig. 6 shows a record of the measured rail stresses and lateral movements of rail heads under Santa Fe locomotive 3784 operating at 5 mph.

Eight special roller-bearing tie plates of new and improved design were used to measure the outward and inward lateral forces exerted by individual wheels at the ties on each rail separately. The eight special lateral force recording tie plates are shown in Fig. 7. They were located on four consecutive ties, one rail length beyond the rail stress gages. The assembled special tie plates were attached to sawn ties with four through bolts.

As shown in Fig. 8, the roller-bearing tie plate consists principally of a nest of roller bearings resting on a base plate, and supporting a movable top plate on which the rail rests. At either end of the nest of rollers is a simple beam 3¼ in. by 2½ in. by 6 in. (with an SR–4 stress gage attached to it), with reactions on the base plate and loaded at its midlength by a lateral movement of the top plate. An outward lateral thrust on the rail is transmitted from the rail base to the top movable plate, and strains weigh bar (A) at the outer end of the tie plate, or an inward thrust strains the other weigh bar (B) at the opposite end of the tie plate. Stress gages on the two weigh bars are connected together in one electrical circuit to measure inward or outward lateral forces on the rail. The magnitude of the lateral thrust or force of the rail upon the special tie plate is determined by the bending stress in the one weigh bar of the pair that is loaded.

The records of lateral forces at each of the 4 special tie plates on both the inner and outer rails of the curve were recorded on the second 10-in. magnetic oscillograph.

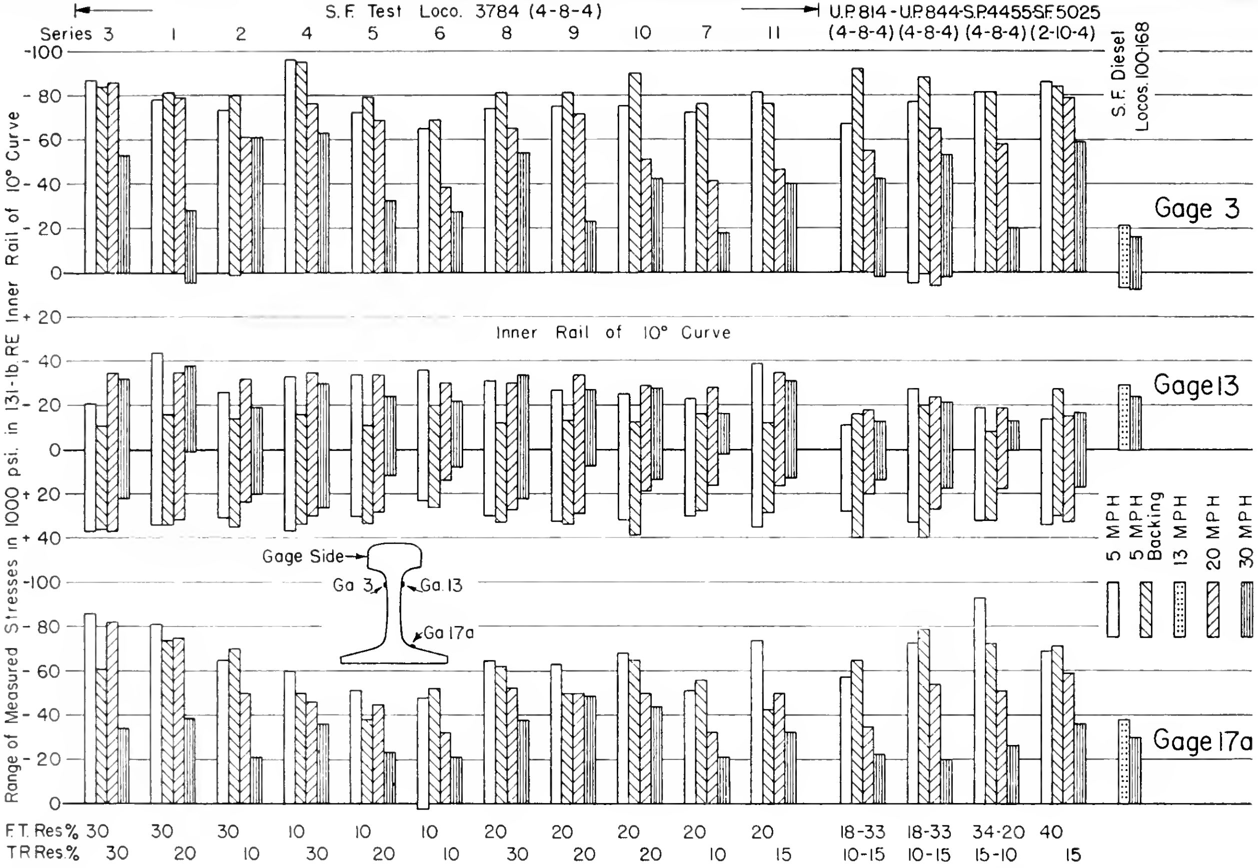

Fig. 34. Range of measured vertical web and lower outer fillet stresses in 131 RE inner rail of 10-deg. Curve, Cajon, Calif. Five long wheelbase steam locomotives and one diesel class locomotive.

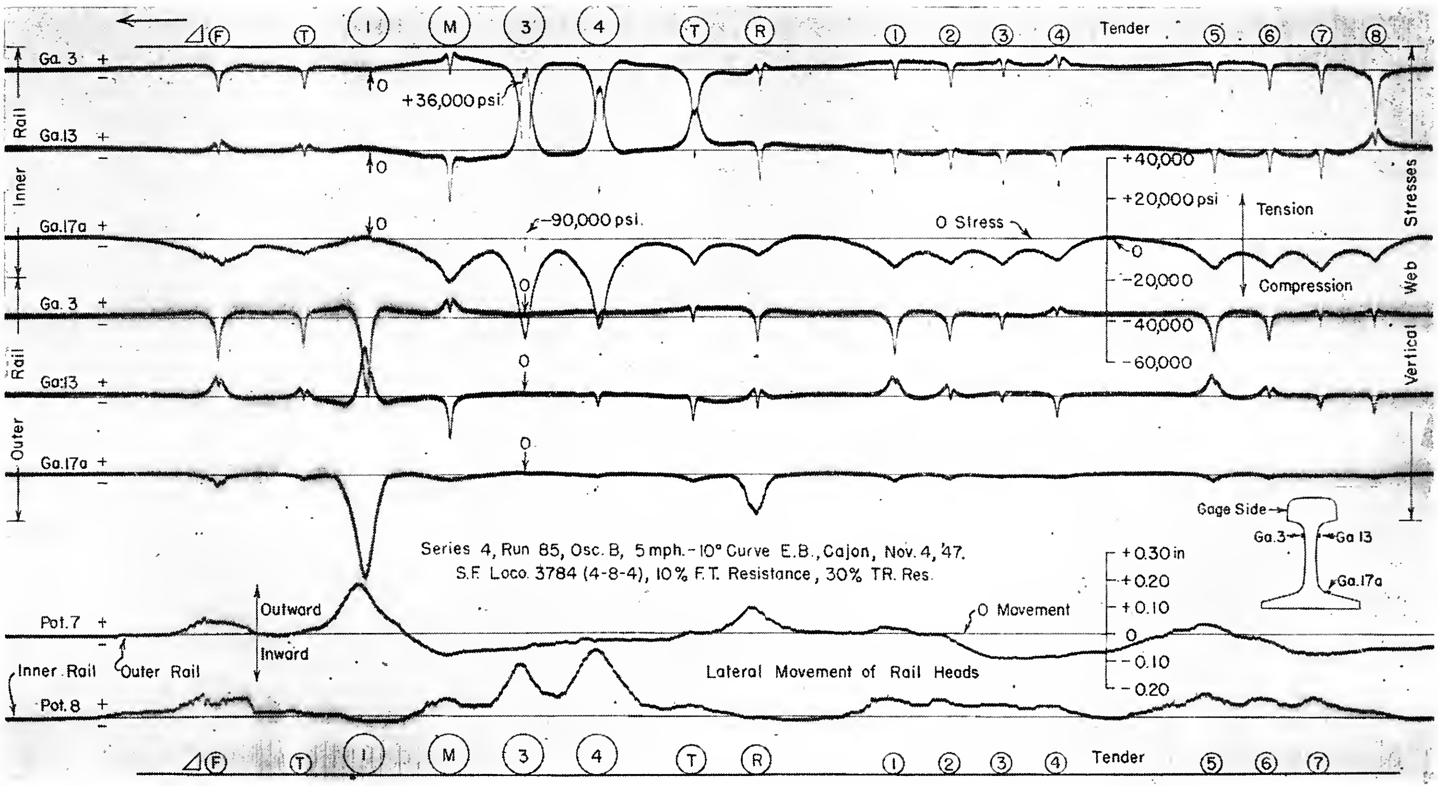

Fig. 6. Rail stress record.

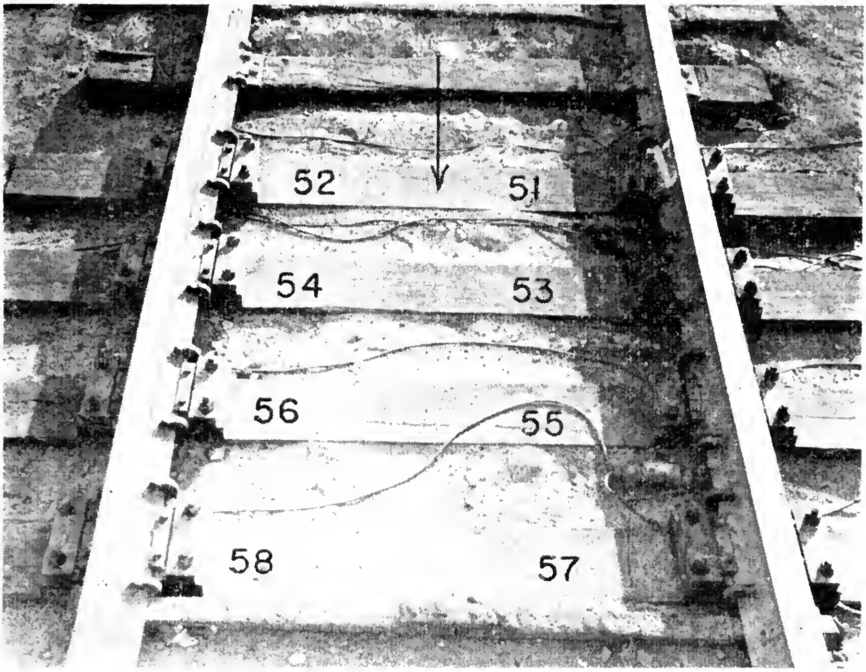

Fig. 7. Eight special lateral force recording-type plates in the 10-deg. curve.

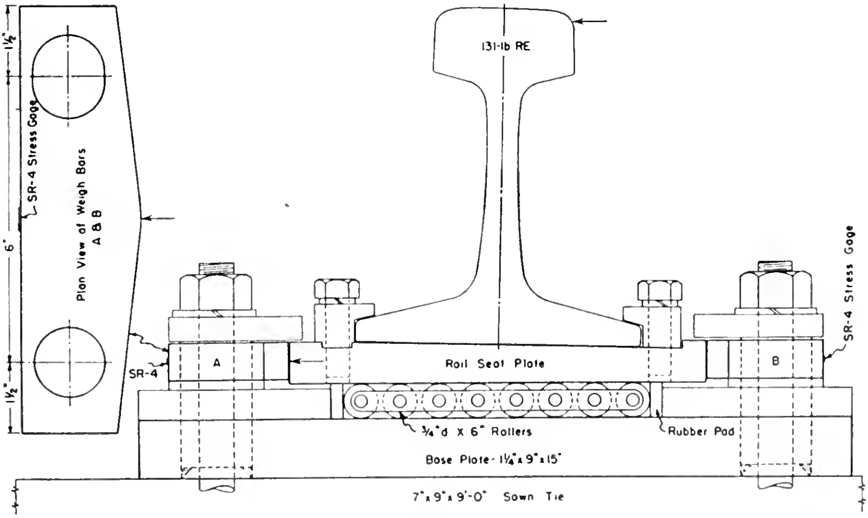

Fig. 8. Details of special lateral force recording tie plate.

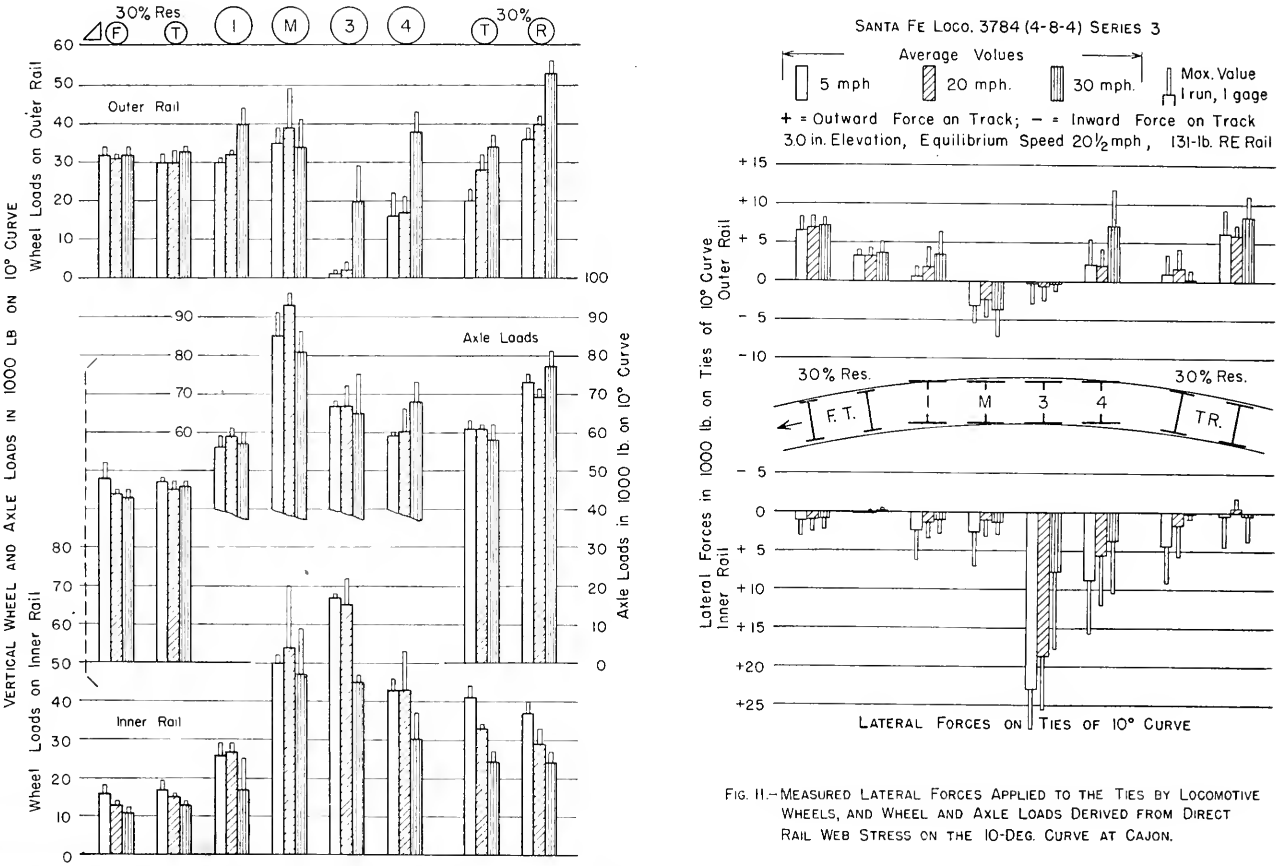

Fig. 11.—Measured Lateral Forces Applied to the Ties by Locomotive Wheels, and Wheel and Axle Loads Derived from Direct Rail Web Stress on the 10-Deg. Curve at Cajon.

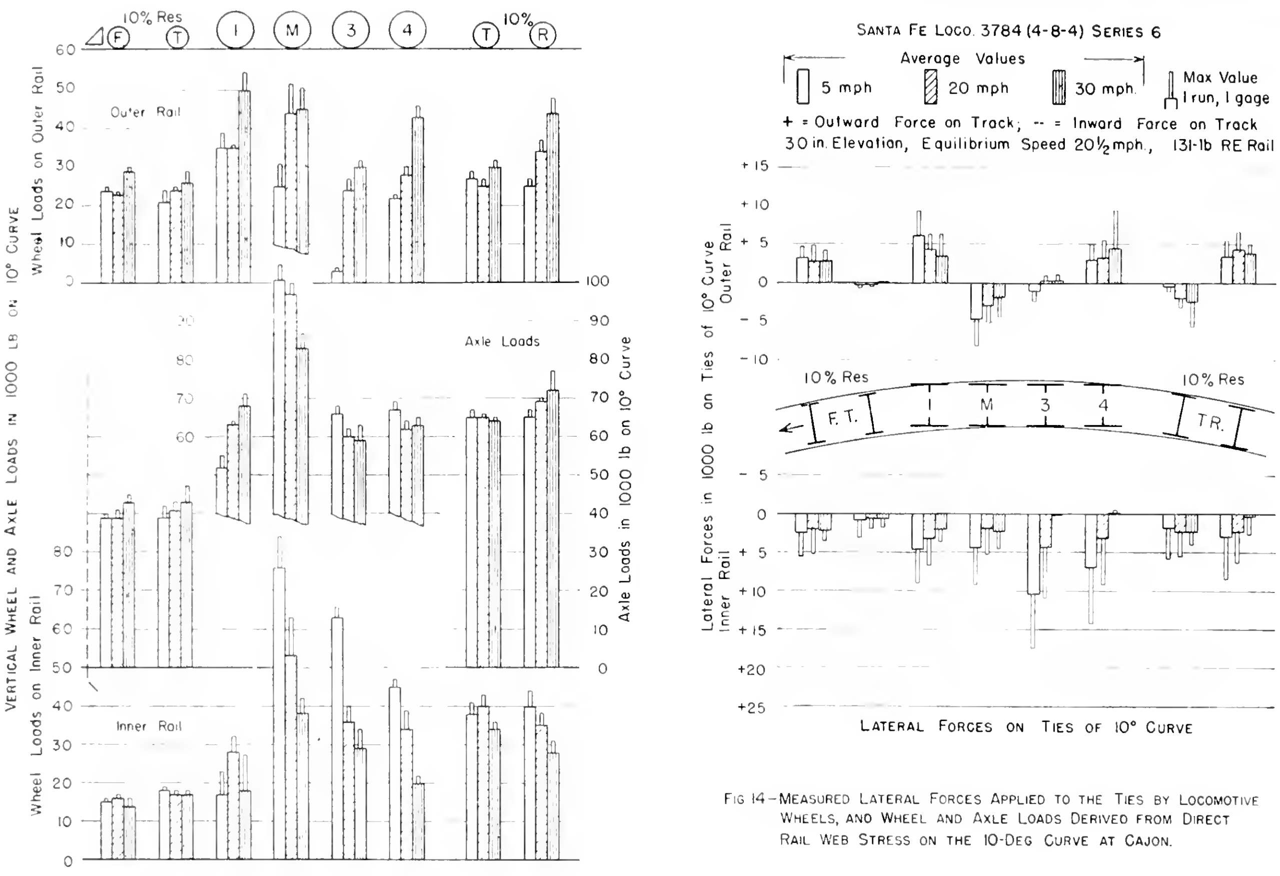

Fig 14—Measured Lateral Forces Applied to the Ties by Locomotive Wheels, and Wheel and Axle Loads Derived from Direct Rail Web Stress on the 10-Deg Curve at Cajon.

A ninth record was made by a rail web fillet stress gage located directly over one special tie plate, so that the exact location of an individual wheel could be determined for any magnitude of recorded lateral force. The weigh bars were so designed that a lateral force of 10,000 lb. against the special tie plate produced a tensile stress of 20,000 psi., and amplification was set so that these values produced a record deflection of 1 in. On the record, a deflection to the right of zero denotes an outward force on the track, while a deflection to the left of zero denotes an inward force.

The results obtained from the test measurements definitely point to several interesting and worthwhile features of steam locomotive design with respect to stability and ease of traversing sharp curves.

Lateral Forces Exerted by Locomotive on Curve

It was found in these tests that very severe outward lateral forces were exerted on the inner rail at slow speed by the third driving wheel. When both trucks had 30 percent lateral resistance (Fig. 11), this wheel exerted lateral forces of 39,000 lb., 32,000 lb., and 13,100 lb. against the inner rail at speeds of 5, 20 and 30 mph., respectively. These lateral forces were found to be substantially reduced by decreasing the amount of lateral resistance in the trucks, and with only 10 percent lateral resistance in the front and trailer truck (Fig. 14), these forces were reduced to 18,000 lb., 4300 lb., and 0.0 lb., respectively. When the locomotive was backing at slow speed, the position of highest lateral forces on the inner rail changed from the third driver to the second (main) driver.*

At all other locomotive wheels, on both the inner and outer rails (Fig. 14), the lateral forces produced were not unduly high for any of the combinations of lateral resistance of 20 percent or less when the locomotive was going forward.

Therefore, the high lateral forces exerted against the inner rail of a 10-deg. curve at low or balanced speed are of considerably more concern than are the wheel forces against the outer rail, even at the highest allowable speed. This suggests that it may be more important in the design of long-wheelbase locomotives to provide a flexibility that will reduce lateral forces at the inner rail, even if this means some increase in forces at the outer rail at high speed.

Vertical Wheel Loads on Curve

The vertical wheel loads that were applied by certain of the driving wheels to the rail were found to be unexpectedly high. Generally speaking, at all forward speeds the main driving axle load was very high, ranging in some instances to almost 100,000 lb. This high load on the main driving axle was evidently due principally to the added vertical component from the main rod thrust which calculations indicate may range from 15,000 to 33,000 lb. during a driver revolution. On the third driving axle with the truck arrangements that gave the very high lateral forces, the effect of the lateral force was to throw almost the entire axle load on the inner rail, no load whatever being carried on the outside third driving wheel. The effect of this high wheel load of over 60,000 lb. on the inner rail was to produce localized rail web stresses beyond the fatigue strength of the steel, as well as to contribute towards flow of the top bearing surface (Fig. 34). In certain of the test series, when the first driving wheel gave the highest lateral force against the outer rail at the 30-mph. speed, a similar weight transfer was found, almost the entire axle load being carried by the first driving wheel on the outer rail.

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* The values of the lateral forces plotted in these and other figures are the recorded forces at the special tie plates; when these tie forces are greater than 5000 lb. they must be multiplied by 1.70 to obtain the total lateral thrust of a wheel against the rail.

The only method that can be employed to obtain a reasonable distribution of vertical load between the two wheels of the third driving axle of 4–8–4 locomotives operating at slow or medium speeds on sharp curves is to reduce the high outward lateral force of the wheel against the inner rail. Either of two methods, or a combination, might be employed to reduce this lateral force; (a) reduce the lateral resistance of the front and trailer trucks to 15 percent, or preferably 10 percent; and (b) install a lateral motion device on the third driving axle, with a total travel of at least 1 in., with a total lateral resistance of not over 5000 lb.

Guiding Action of Engine Trucks on Curve

It was found in the tests that the lateral resistance of the front truck relative to the trailer truck had a great influence on the guiding characteristics of the 4–8–4 locomotive. For example, with the resistance in the front truck higher than in the trailer truck, the front truck performed all of the guiding and turning of the locomotive on the curve and the first driving axle did not contribute to this action. The effect of the relatively low resistance in the trailer truck in this combination was to permit the rear driving wheels to bear rather heavily against the outer rail of the curve. When the relation of the truck resistances was reversed and a low resistance was provided in the front truck, with a high resistance in the trailer truck, the first driver bore heavily against the outer rail and performed a major part in turning the locomotive. On the other hand, the stiff trailer truck tended to hold the rear driving wheel of the locomotive away from the outer rail.

Best performance in guiding a locomotive of this type can apparently be obtained with the lateral resistance in both front and trailer trucks either the same, or with that of the trailer only slightly less than for the front truck.

Distribution of Wheel Load of Trucks on Curves

The test furnished interesting data on the distribution of the wheel loads of the four-wheel engine trucks to the outer and inner rail. On the front truck the lateral swing of the truck as the engine traversed the curve was found to be a principal factor in load distribution and accounted for much of the transfer of the load to the outer rail. The force couple set up from the lateral resistance in the truck produced still additional transfer of load to the outer rail. A low resistance in the front truck was here again found to be of advantage as it helped provide a more equal distribution of load between the outer and inner rails of the curve. On the other hand, the distribution of load between outer and inner rails from the four-wheel trailer truck was principally determined by the speed of operation, the division of load to the outer or inner rail depending upon whether the operating speed was above or below the speed of superelevation, respectively.

Lateral Motion on First Driving Axle on Curve

The test locomotive had a lateral motion device on the first driving axle which permitted a lateral movement of 11/16 in. in either direction. In the test with the relatively higher resistance in the four-wheel front truck, it was found that the lateral motion device was not called upon to function at all on the sharp curve. In the test with relatively lower resistance in the front truck the lateral motion device did function but not to the full extent of the amount of motion provided. With approximately the same lateral resistance in the front and trailer trucks there seems to be little need for any lateral motion device on the first driving axle.

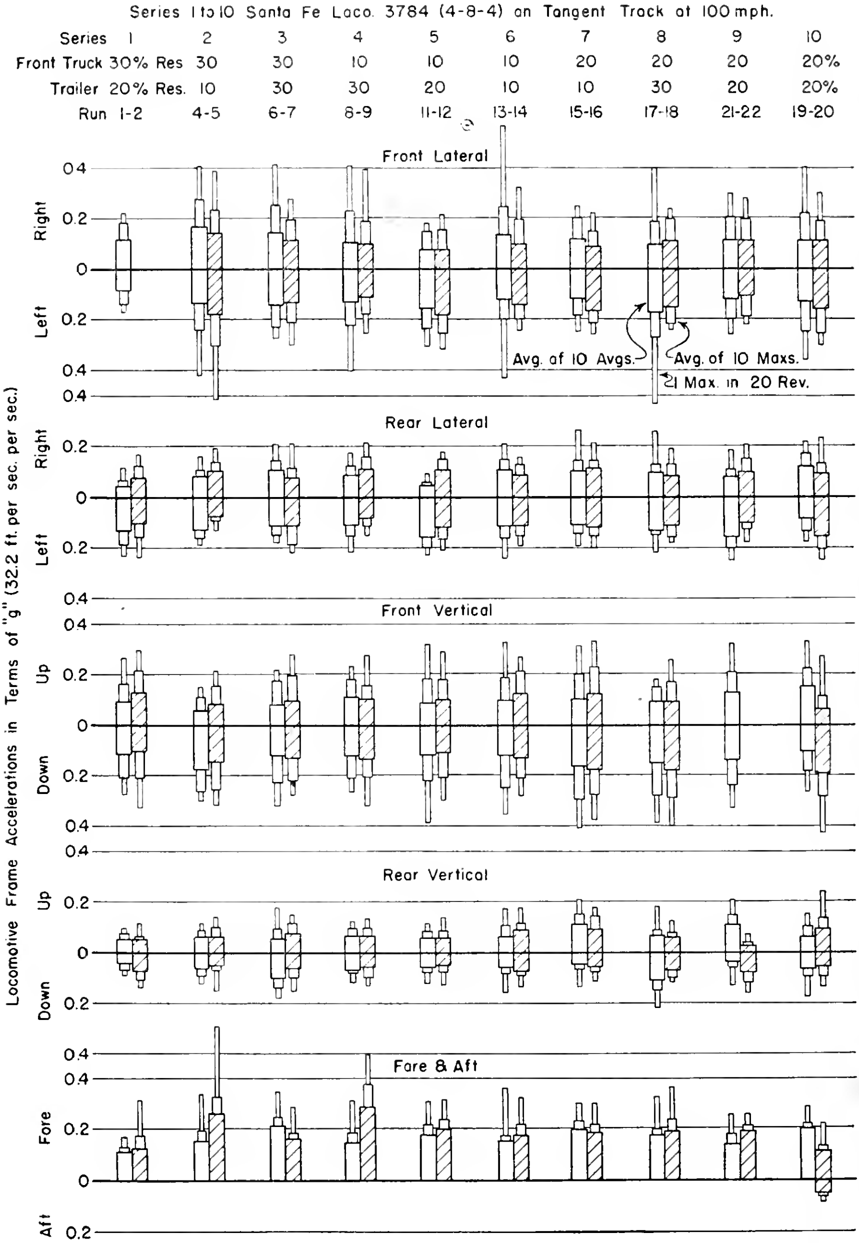


Fig. 51. Accelerations of Santa Fe locomotive 3784 frame in 20 driver revolutions (418.8 ft.) on tangent track at 100 mph. Series 1 to 10.

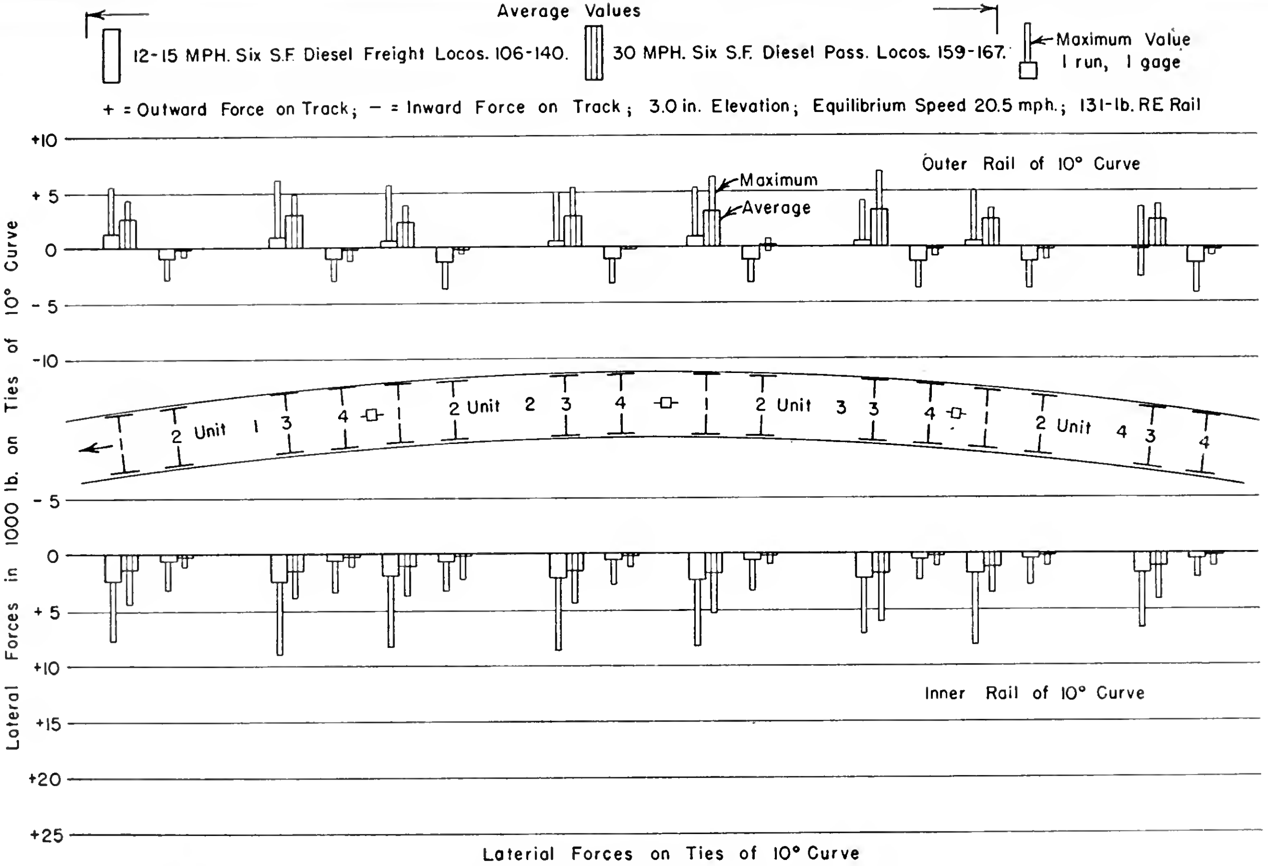


Fig. 58. Measured lateral forces applied to ties by locomotive wheels on the 10-deg. curve at Cajon, Calif. Santa Fe diesel 100–158 class locomotives at 13 and 30 mph.

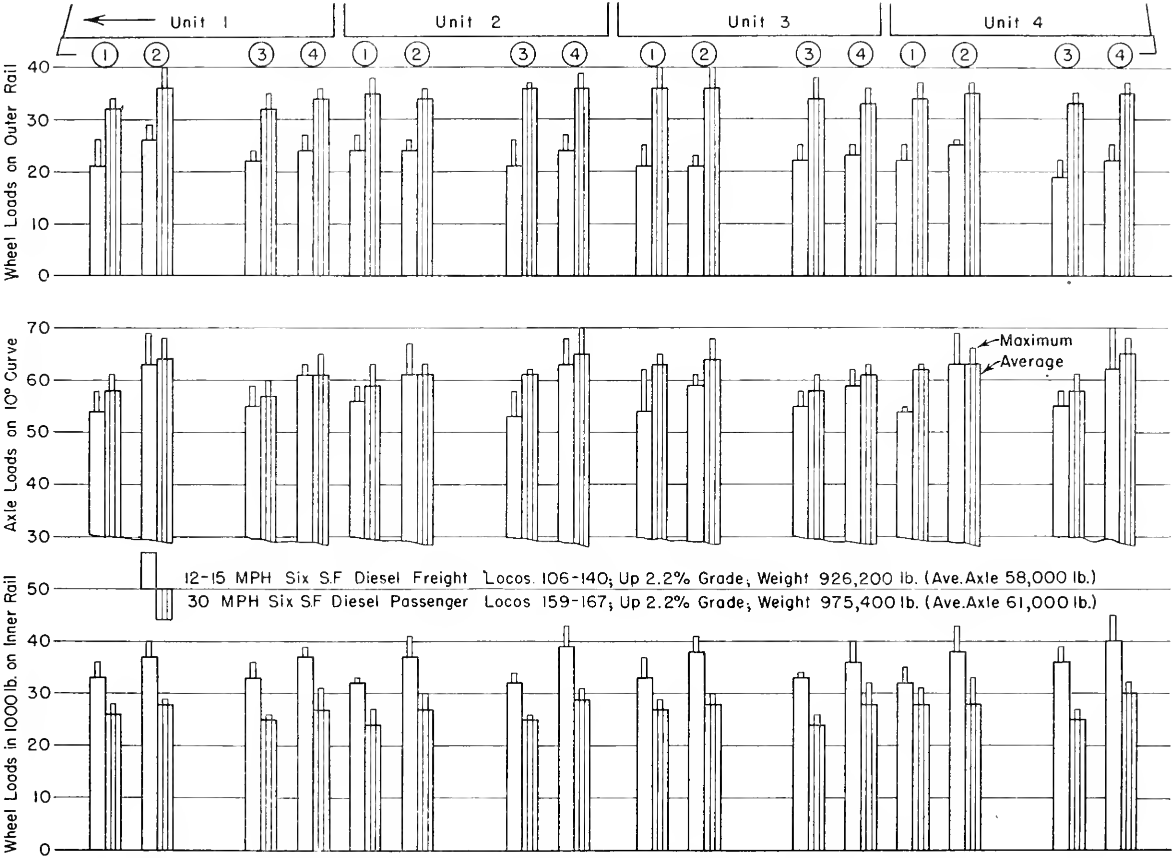


Fig. 59. Wheel and axle loads derived from direct rail web stress on the 10-deg. curve. Santa Fe diesel 100–158 class locomotives at 13 and 30 mph.

Locomotive Stability on Tangent Track

Studies of the measured accelerations of the locomotive bed, and of the lateral movements of the front truck, first driving axle, and trailer truck at speeds up to 100 mph. on tangent track (Fig. 51), did not indicate that the change in lateral resistances of the engine trucks provided in the test series had any appreciable effect on the stability of the 4–8–4 locomotive. With the lowest amount of resistance provided in both trucks, the measurements indicated somewhat greater front truck motion and lateral accelerations of the front end of the locomotive bed, particularly at one rough spot in the track, but this was judged to be of minor consequence.

Measurements Under Diesel Locomotives on Curve

The results obtained and presented in the report of the lateral forces and vertical wheel loads exerted on the track structure of the 10-deg. curve by the diesel locomotives are very gratifying compared to the effects obtained with the steam locomotives. Only very low lateral forces—less than 4000 lb.—were produced by the diesel wheels against the rails of the curve (Fig. 58). Also, no vertical wheel load in excess of 40,000 lb. was found in the measurements (Fig. 59), and the localized rail web stresses were found to be well below the fatigue strength of rail steel. Due to the traction of the locomotive when pulling a heavy train at 13 mph., a transfer of load from the front axle to the rear axle of each truck, of approximately 3500 lb., was obtained, but this could not be considered to be of particular concern.

Recommendations

Based upon the results obtained with the Santa Fe test locomotive and those obtained with the other locomotives tested, having certain differences in the truck arrangements and lateral motion devices on driving wheels, it is believed that the most satisfactory operating condition for locomotives of this 4–8–4 type may be obtained by providing approximately 10 percent lateral resistance in the front and trailer trucks of these modern long wheelbase steam locomotives. A lateral motion device on the first driving axle, requiring a force of not to exceed 5000 lb. to produce a motion of ½ in. in each direction, appears to be sufficient. If practical to do so, it would seem well to give consideration to the provision of a lateral motion device on the third driving axle, which would also provide for a motion of at least ½ in. in either direction from a lateral force not exceeding 5000 lb. If this is found to transfer too much lateral force to the second (main) driving wheel on the inner rail, then consideration should be given to making a similar provision for lateral motion at the main axle. Whether or not the lateral motion devices on the third and main driving axles are practical, it seems evident from the test results that the recommended reduction in lateral resistances of the front and trailer trucks will go far towards relieving track of sharp curvature from the excessive forces now imposed, and that this reduction in lateral resistances of the front and trailer trucks will not result in any unsatisfactory condition of locomotive stability while running at high speed on tangent track.

Fatigue Tests of Beams in Flexure

Advance Report of Committee 15—Iron and Steel Structures

1. Digest

This report embraces a description and a summary of the results of fatigue tests conducted by Professor W. M. Wilson of the University of Illinois on various types of beams similar to those used in actual structures and subjected to repeated cycles of loads.

The tests consisted essentially of subjecting various types of beams to repeated loads varying from a small load on the beam to the maximum in the cycle. This load cycle was repeated at about 150 cycles per minute until failure developed at some location in the beam. The stresses in the beams were calculated from the known loads, and the fatigue strengths at 100,000 cycles and 2,000,000 cycles of load were determined from an empirical equation.

Fatigue data were obtained on 27 different types of beams and a total of 104 specimens were tested. A description of each series or types, with the average fatigue strength obtained for each series at 100,000 cycles and 2,000,000 cycles, is shown in Table 1, and a comparison of the carrying capacities of typical types is shown in Table 2.

The results of these tests are of particular interest to the bridge engineer constructing and maintaining stringers and beams subjected to a large number of cycles of stress, for they indicate the following outstanding features:

1. The carrying capacity of a rolled beam is considerably higher than that obtained with a fabricated beam of equivalent section modulus.

2. The carrying capacity of a beam with cover plates cannot be increased indefinitely with an increase in cover plate thickness, as there is some economic relation between the cover plate area and the flange area of the beam.

3. The use of cover plates on rolled beams appears to be limited to reinforcement jobs where the beam is already in place. In such cases an increase in carrying capacity can be obtained, but this increase in capacity will not increase as rapidly as the calculated section modulus.

4. Cover plates on beams should be full length or extended past the theoretical cut-off point a sufficient distance, so that the stress in the beam at the end of the plate is only about 40 percent of the stress at the center.

5. The stress-raising effect of welding across the ends of partial length cover plates is about the same as that of the longitudinal welds along the edges of the cover plates.

6. The stress-raising effect of continuous fillet welds when used to attach cover plates to beams is smaller than that of intermittent fillet welds or rivets.

7. The carrying capacity of a beam is always reduced whenever intermediate stiffeners or lateral plates are welded to the tension flanges.

8. It is impossible to splice a beam by butt welding or riveting, and attain a load carrying capacity equal to that of a continuous rolled beam of equal section modulus.

9. It is doubtful if fatigue failures will occur in the longer girder spans, as the fatigue strength at 100,000 cycles of stress range for the various types of specimens is fairly high.

2. Foreword

The fatigue tests of beams in flexure summarized in this report were conducted at the University of Illinois under the direction of Professor W. M. Wilson, research professor of structural engineering, and the details of all the test results have been published in the University of Illinois Engineering Experiment Station Bulletins 377 and 382.

The tests were sponsored by the American Welding Society and the American Institute of Electrical Engineers, under the general supervision of the Committee on Fatigue Testing (structural) of the Welding Research Council. The tests were planned by a Subcommittee on Flexural Fatigue Tests, with G. M. Magee, research engineer, AAR, as chairman. Several members of AREA Committee 15—Iron and Steel Structures were members of the subcommittee. This summary report was prepared by E. J. Ruble, structural engineer, research staff, AAR.

The principal purpose of the investigation was to determine the relative fatigue strength of various types of bridge members subjected to flexure. It was realized by bridge engineers that the stringers and beam spans of some bridges are subjected to a considerable number of cycles of stress, varying from a very small dead load stress to a maximum stress. It was realized also, that these stringers and beam spans usually have geometrical stress-raisers, such as partial length cover plates, lateral plates welded or riveted to the flanges, intermediate stiffeners welded to the flanges and web, and welded or riveted full length cover plates, and that very little information was available on the effect of these stress-raisers.

The actual number of stress cycles and the range of the stresses occurring in any bridge are usually variable quantities, except in crane girders where the magnitude and number of the loads are fairly well known. Railroad and highway bridges are usually subjected to loads of various static weights and, in addition, the dynamic effects are not always the same, so that the magnitude of the stress cycle cannot be accurately determined.

It has been generally agreed in the past that in short span bridges, where the stresses produced by heavy car and tender axles are about the same as those produced by the locomotive axles, the number of stress cycles attained could reach about 2,000,000. In the longer span bridges, where the maximum stresses are produced under the locomotive and tender together, the number of stress repetitions could reach 100,000 during the life of the structure. During the past few years, the research staff of the AAR has secured strain gage readings on railroad bridges of all lengths under actual operating conditions, and a considerable range in the actual stresses has been found with only a small percentage of the loads producing maximum stresses in the structures. Considerably more field work must be done before the frequency of occurrence of the maximum stresses can be determined, as well as laboratory work to determine the effect on the fatigue strength of various stress ranges on the same specimen.

3. Method of Testing

The srtuctural beams were tested in flexure under cycles of stress varying from a small tensile stress of about 500 psi., to the maximum tensile stress by means of the fatigue machine shown in Fig. 1. The force that produced the bending stress in the beams originated in the variable-throw eccentric that raised and lowered the loading lever, thereby subjecting the loading column to cycles of load. The magnitude of the force at the end of the loading lever was measured by the calibrated dynamometer or proving ring.

In operation, the specimens were placed in the machine and supported on rollers resting in cylindrical grooves. The grooves were somewhat larger in diameter than the rollers, to prevent the rollers from introducing a horizontal restraint. The machine was then cranked by hand while the eccentric was being adjusted to give the desired load. The machine was then started and run at a speed of approximately 150 cycles of load per minute, but was stopped from time to time for load adjustment as required. The stresses in the beams were not measured but were computed by the usual flexural formula from the load in the loading column as indicated by the dynamometer.

A static test was made on one specimen each of several types of beams, which was identical with the fatigue specimen of the corresponding series. The specimen was loaded and supported in the same manner for the static tests as for the fatigue tests. The compression flange had no lateral support except that afforded by the loading head of the testing machine.

4. Test Specimens

The general details of the 27 different types of beams tested are shown in Figs. 2 to 5, incl., and a brief description of each series follows:

The specimens in Series 44A consisted of a 12 in. I at 31.8 lb. without reinforcement, and the results of the tests on these specimens form the base for comparing the results of the tests on the remaining types. A total load of 16,000 lb. on the specimen at the center of the span was required to produce a calculated unit stress of 10,000 psi. in the flanges under the loading pins.

The specimens in Series 44Ba, A1–A3 and A4–A6 consisted of three slightly different types, the principal difference being in the thickness of the full length cover plates The three different types were selected to determine whether the carrying capacity of a beam with cover plates subjected to repeated cycles of load increased directly with the increased section modulus. The beams in Series 44Ba had a 6 by ⅜-in. cover plate on the lower flange, with a 4 by 9/16-in. cover plate on the upper flange. The different width cover plates were used to simulate field practice whereby overhead welding is eliminated. The beams of Series A1–A3 had two 6 by ½-in. cover plates while two 6 by ⅝-in. cover plates were used to fabricate the beams of Series A4–A6. The use of the same width cover plates on the upper and lower flanges required a different welding technique than that used in Series 44Ba, but since all failures occurred in the lower flange, the results were considered comparable for all three series.

A total load of 34,500 lb. was required on the specimen of Series A4–A6 at the center of the span to produce a calculated unit stress of 10,000 psi. in the 6 by ⅝-in. cover plates under the loading pins, with a resulting calculated unit stress of of 2980 psi. in the 3/16-in. continuous fillet welds.

The specimens of Series 44EA consisted of a 12 in. I at 31.8 lb. beam reinforced with two 6 by ⅜-in. cover plates attached with ¾ in. round rivets. The section modulus of the gross section was 61.0 in.^{3} while the section modulus of the net section was only 45.3 in.^{3} resulting in an efficiency of 74.3 percent. The tests on the specimens of this series were made so that the results could be compared with those secured on specimens having cover plates fastened with welds.

Series 44Ga and Series 44Gb were identical, except for the size of the continuous fillet welds fastening the 7 by ⅝-in. flange plates to the 12 by 7/16-in. web plate. The beams were reinforced with 3 by ⅜-in. stiffener plates welded to the web plate only. The end stiffeners were welded to the web plate their full length, but the intermediate stiffeners were welded only to the compression half of the web. The corners of the stiffeners were clipped so that the fillet welds fastening the flange plates to the web plate could be continuous.

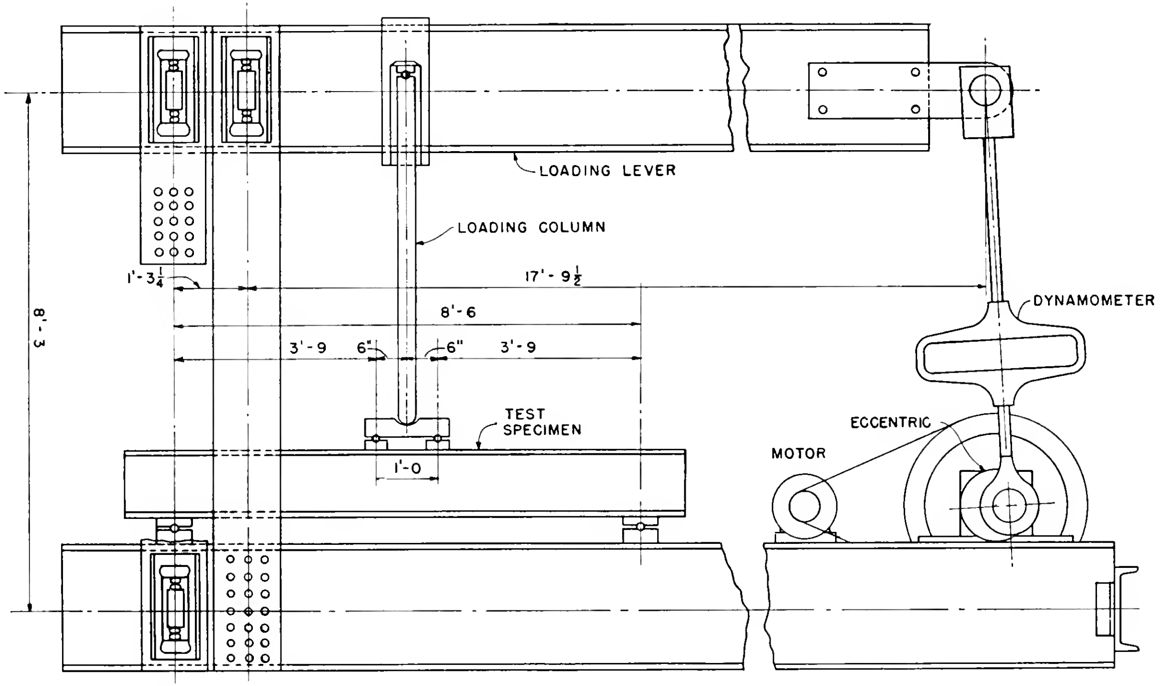


Fig. 1. Fatigue testing machine.

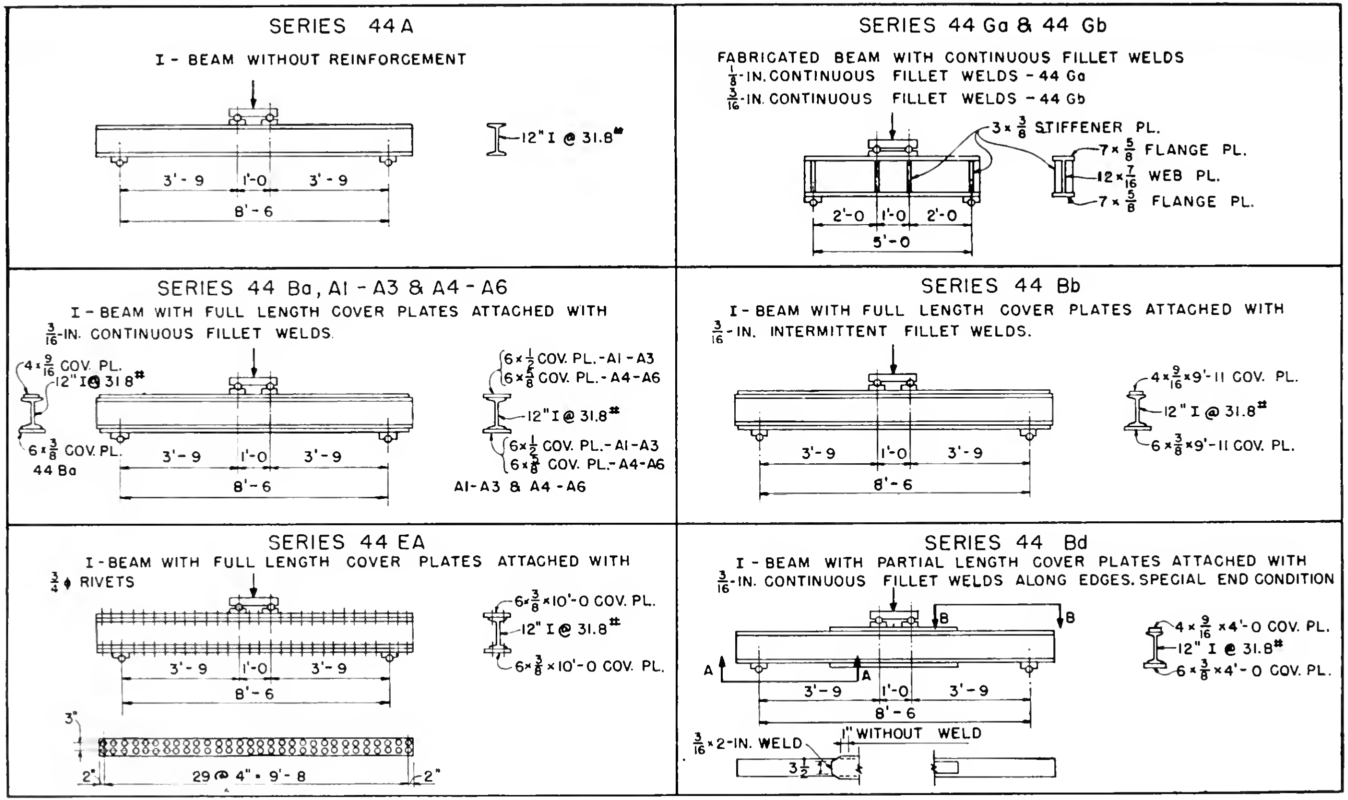
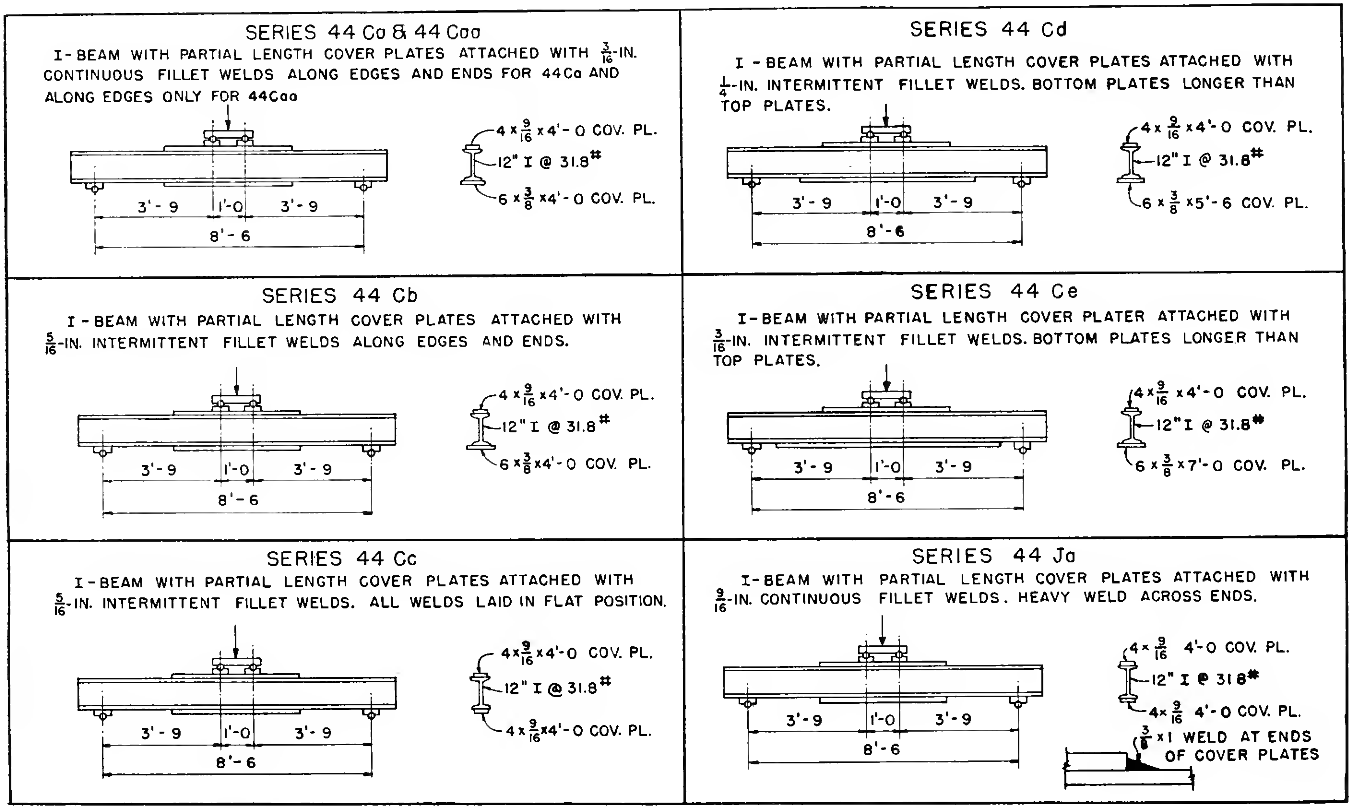


Fig. 2. Details of various types of beams tested in flexure.



SERIES 44 Ca & 44 Caa

I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELDS ALONG EDGES AND ENDS FOR 44Ca AND ALONG EDGES ONLY FOR 44Caa

SERIES 44 Cd

I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{1}{4}$-IN. INTERMITTENT FILLET WELDS. BOTTOM PLATES LONGER THAN TOP PLATES.

SERIES 44 Cb

I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{5}{16}$-IN. INTERMITTENT FILLET WELDS ALONG EDGES AND ENDS.

SERIES 44 Ce

I-BEAM WITH PARTIAL LENGTH COVER PLATER ATTACHED WITH $\frac{3}{16}$-IN. INTERMITTENT FILLET WELDS. BOTTOM PLATES LONGER THAN TOP PLATES.

SERIES 44 Cc

I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{5}{16}$-IN. INTERMITTENT FILLET WELDS. ALL WELDS LAID IN FLAT POSITION.

SERIES 44 Ja

I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{9}{16}$-IN. CONTINUOUS FILLET WELDS. HEAVY WELD ACROSS ENDS.

Fig. 8. Details of various types of beams tested in flexure.

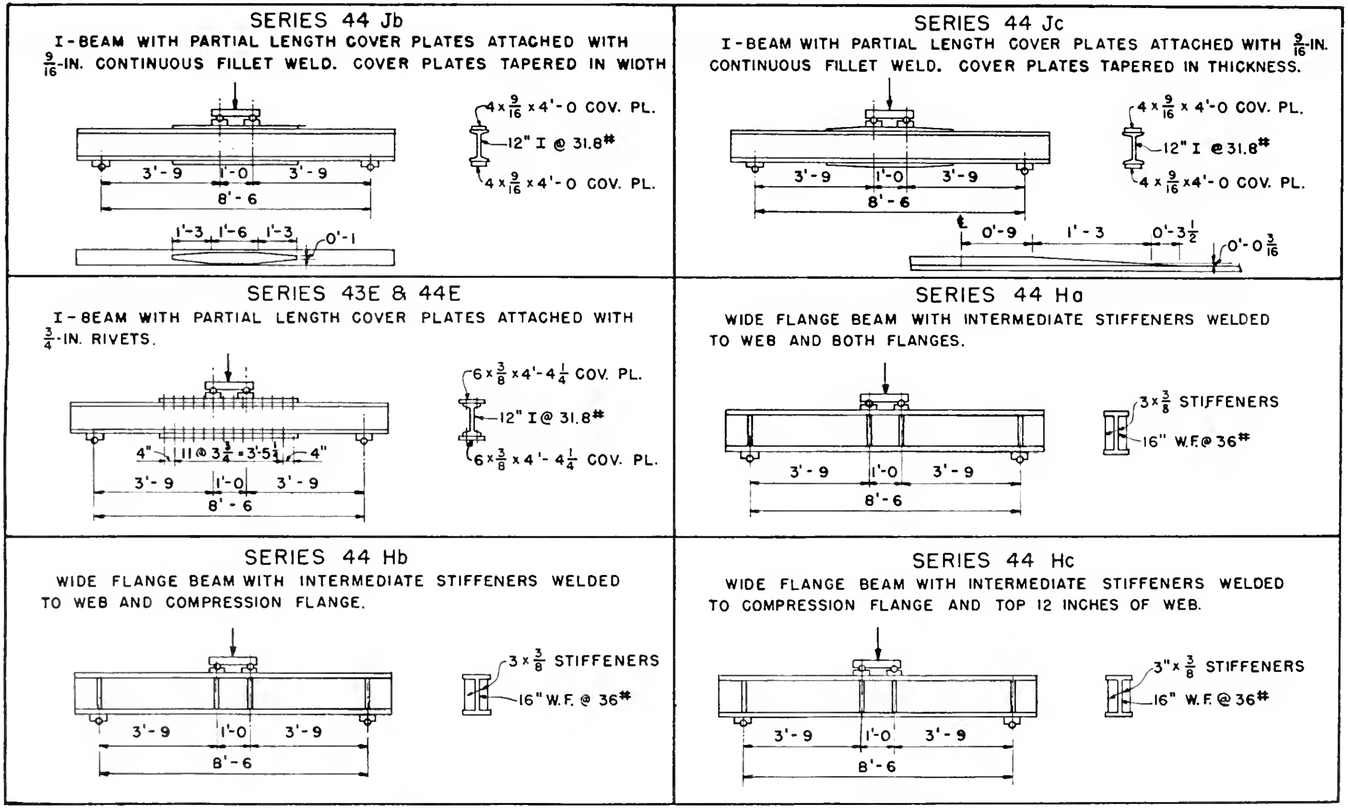


Fig. 4. Details of various types of beams tested in flexure.

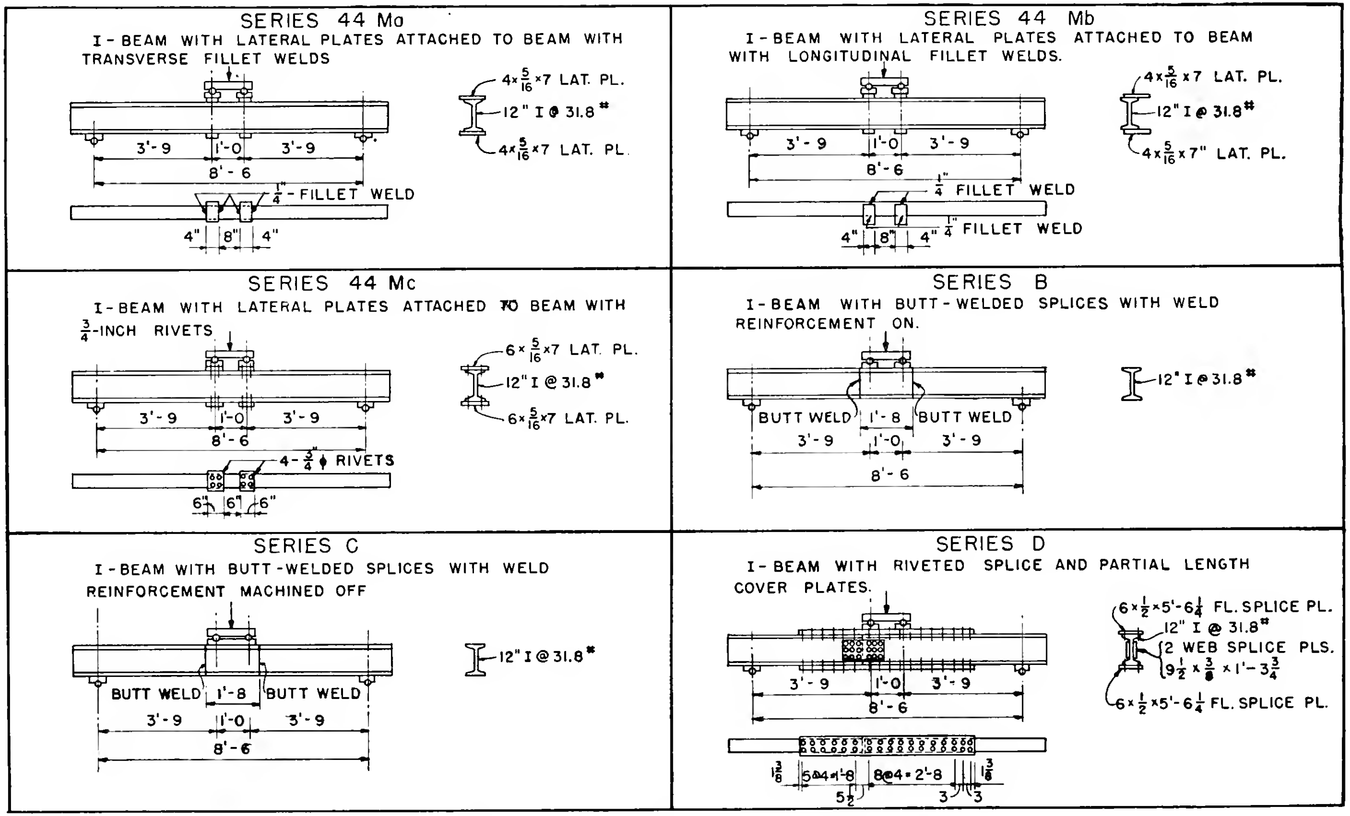


Fig. 5. Details of various types of beams tested in flexure.

In an effort to produce fatigue failures in the welds fastening the flange plates to the web, the span length for this series was reduced to 5 ft. However, the plan was not effective as no failures occurred in these welds. The flange plates of Series 44Ga were welded to the web plate by continuous fillet welds and then reduced to ⅛-in. welds by machining off the surplus. The specimens of Series 44Gb were fabricated with 3/16-in. continuous fillet welds.

A unit stress of 9850 psi. was calculated in the ⅛-in. fillet welds from a total load of 51,900 lb. on the specimen at the center, which also produced a unit flange stress of 10,000 psi. under the loading pins. This same total load on the specimens of Series 44Gb produced a calculated unit stress of 6580 psi. in the 3/16 in. fillet welds.

The full length cover plates on the specimens of Series 44Bb were fastened to the beams with 3/16-in. intermittent fillet welds. The welds were 2¼ in. long and were spaced at 6-in. centers. A total load of 26,600 lb. on the specimen at the center of the span produced a calculated unit stress of 10,000 psi. in the cover plates under the loading pins and a calculated stress in the 3/16 by 2¼ in. fillet welds of 4.810 psi.

The specimens of Series 44Bd consisted of I beams reinforced with partial length cover plates. The cover plates were fastened to the beams with 3/16-in. continuous fillet welds along their edges, with special weld conditions at the ends of the bottom cover plate. The cover plates were cut off at the theoretical points so that the stress in the beam flanges at these points was about the same as the stress in the cover plates between the loading pins. The cover plates were cut off at this point so that the full stress-raising effect could be determined.

The 3/16-in. fillet welds fastening the 4 by 9/16-in. top cover plate to the beam were run continuous around the ends of the plate. The corners of the bottom cover plate were clipped to produce a 3½-in. width plate and then 3/16 by 2-in. welds were placed along the ends of the plate. The 3/16-in. continuous welds along the plate edges were stopped 1 in. from the clipped corners.

The partial length cover plates reinforcing the specimen of Series 44Ca were fastened to the I beams with 3/16-in. continuous fillet welds along the edges, around the corners and across the ends of the plates. The top cover plates were 4 by 9/16 in., while 6 by ½-in. plates were used on the bottom flange.

The specimens of Series 44Caa were identical to those of Series 44Ca, except for the welds across the ends of the cover plates. The continuous welds on the sides of the specimens of Series 44Caa were stopped at the corners and did not extend across the beams at the ends of the cover plates. The specimens of this series were fabricated and tested to determine the effect of welding transverse to the line of stress in a member.

The partial length cover plates reinforcing the specimens of Series 44Cb consisted of a 4 by 9/16-in. top plate and a 6 by ⅜-in. bottom plate. The cover plates were attached to the beams with 5/16-in. intermittent fillet welds on the sides, the welds each being 2¾ in. long, spaced at 6-in. centers, and with 5/16-in. continuous fillet welds across the ends of the cover plates. The calculated stress in the beam flanges at the ends of the plates was about the same as that in the cover plates between the loading pins.

The partial length cover plates reinforcing the specimens of Series 44Cc were fastened to the I beams with 5/16-in. intermittent fillet welds along the edges and 5/16-in. continuous fillet welds across the ends of the cover plates. Both top and bottom cover plates were 4 by 9/16 in. and all the welds were laid in the flat position by turning over the specimens during welding. The intermittent fillet welds along the edges of the cover plates were 2¾ in. long and were spaced at 6-in. centers. The calculated stress in the beam flanges at the ends of the plates was the same as that in the cover plates between the loading pins.

The specimens of Series 44Cd consisted of I beams reinforced with a partial length cover plate on the top flange and a longer plate on the lower flange. The cover plates were attached to the beams with ¼-in. intermittent fillet welds on the sides, the welds being 2¾ in. long, spaced at 6-in. centers, and with ¼-in. continuous fillet welds across the ends of the cover plates.

In order to produce failure in the top flange, the cover plate on the lower flange was extended past the theoretical cut-off point so that the stress in the beam flange at the end of the plate was only 67.5 percent of the stress in the cover plate between the loading pins. The calculated compressive stress in the top flange of the beam at the end of the cover plate was 92.3 percent of the stress in the cover plate under the loading pins.

The specimens of Series 44Ce consisted of I beams reinforced with a partial length cover plate on the top flange and a much longer plate on the lower flange. The lower flange cover plate on these specimens was extended past the theoretical cut-off point until the stress in the beam flange at the end of the plate was only 34 percent of the stress in the cover plate between the loading pins. The longer cover plate was used on the specimens of this series, as one specimen of Series 44Cd failed at the end of the lower cover plate, even though the stress at this point was only 73.3 percent of that at the end of the top plate.

The cover plates were attached to the beams with 3/16-in. intermittent fillet welds—the welds being 2¾ in. long, spaced at 6-in. centers—and with 3/16-in. continuous welds across the ends of the cover plates.

The partial length cover plates reinforcing the specimens of Series 44Ja were fastened to the I beams with 9/16 by ½-in. continuous fillet welds on the edges of the plates and with heavy welds across the ends. Both the top and bottom cover plates were 4 by 9/16 in., and all the welds were laid in the flat position by turning over the specimens during welding. The partial length cover plates resulted in the calculated stress at the ends of the plates being about the same as the stress in the plates between the loading pins.

The continuous welds along the edges of the cover plates were 9/16 in. high but the 5-in. flange width of the beam only permitted the welds to be ½ in. wide. Three of the specimens were fabricated with ⅜ by ⅜-in. welds at the ends of the cover plates and three were fabricated with ⅜ by 1-in. welds at the ends.

The specimens of Series 44Jb consisted of I beams reinforced with partial length tapered cover plates. The cover plates were fastened to the beams with 9/16-in. continous fillet welds along the edges and ends of the plate. The welds along the full width of plate were only ½ in. wide as permitted by the 5-in. beam flange width.

The top and bottom cover plates were tapered in width only from 4 in. to 1 in. and the calculated stress in the beam flange at the end of the cover plate was the same as that in the cover plates between the loading pins. The tapered cover plates were used for this series in an effort to reduce the abrupt change in section at the ends of the plates.

The partial length cover plates reinforcing the specimens of Series 44Jc were reduced in thickness from 9/16 in. to 3/16 in. in an effort to eliminate the abrupt change of section at the ends of the plates. The 4-in. width of plate was maintained for its entire length.

Both top and bottom cover plates were fastened to the beam with 9/16-in. continuous fillet welds along the edges of the plates for their center portion, and the vertical legs of the welds were then reduced along the tapered edges of the plate. The welds on the ends of the plates were tapered by grinding from 3/16 in. down to a feather edge as shown.

The stress in the beam at the end of the 3½-in. welds was only about 87 percent of the stress in the cover plates between the loading pins.

The partial length 6-in. by ⅜-in. cover plates reinforcing the specimens of Series 43E and 44E were fastened to the I beams with ¾-in. dia. rivets. The section modulus of the gross section of the reinforced member was 61.0 in.,^{3} while the net section modulus was 48.9 in.^{3} The net section modulus of the beam at the end of the cover plate was 26.9 in.^{3} The tests on the specimens of this series were conducted so that the results could be compared with those secured on specimens having partial length cover plates fastened with welds.

The specimens of Series 44Ha. 44Hb and 44Hc consisted of a 16 WF beam at 36 lb., with the web reinforced with 3-in. by ⅜-in. stiffeners on both sides of the web at the points of loading and bearing. The corners of the stiffeners were clipped to clear the fillets of the beams.

The intermediate stiffeners under the loading pins for Series 44Ha were welded to both the tension and compression flanges, and to the full depth of the web, with contínous fillet welds. The intermediate stiffeners of Series 44Hb were welded to the compression flange only, and to the full depth of the web, with continuous fillet welds. The intermediate stiffeners of Series 44Hc were welded to the compression flange only, and to the top 12-in. of the web, with continuous fillet welds.

The end stiffeners of all three series were ground to fit the lower flange but cleared the top flange. The stiffeners were welded to the web only with continuous fillet welds.

The specimens of Series 44Ma, 44Mb and 44Mc consisted of I beams with small plates attached to the top and bottom flanges under the loading pins. The specimens of these three series were representative of actual practice, whereby lateral plates and angles are attached to the flanges of stringers.

The 4 by 5/16 by 7-in. plates in Series 44Ma were placed symmetrically on the beam flanges and attached to the beam with ¼-in. continuous fillet welds transverse to the beam. The 4 by 5/16 by 7-in. plates in Series 44Mb were placed unsymmetrically on the beam flange so that the plates could be attached to the beam with ¼-in. continuous fillet welds longitudinal to the beam. The 6 by 5/16 by 7-in. plates in Series 44Mc were placed symmetrically on the beam flange and were fastened to the flange with 4¾-in. dia. rivets.

Each specimen of Series B and C was fabricated from three short beam sections butt-welded together. The tests were planned to simulate conditions encountered in long continuous beam spans where it becomes necessary to splice the beams. The ends of the beam flanges and webs were chamfered and for all specimens, except one, the web was welded first and then the flanges. A series of tiedown clamps was used to hold the three short lengths of beams forming a specimen in line during welding.

The specimens of Series B and Series C were identical, except that the specimens of Series B were tested in the as-welded condition, while the weld reinforcement on the specimens of Series C was ground flush with the base metal.

The specimens of Series D were fabricated from two beam sections with a riveted splice, and were planned so that the results could be compared with the results obtained on the butt-welded specimens. The specimens were designed for fatigue failure on a section through the inside row of rivets in both the cover plates and the web splice plates. To make the specimens fail at this section, the cover plates were extended far enough so that failure would not occur at the ends of the plates.

The gross section modulus of the plain beam was 36 in.,^{3} while the gross section modulus of the splice plates was 44.4 in.^{3} The net section, modulus of the beam was 26.9 in.,^{3} compared with a net section modulus of 33.4 in.^{3} for the splice plates.

TABLE 1.—STATIC AND FATIGUE STRENGTH OF VARIOUS TYPES OF BEAMS IN FLEXURE

TEST SERIES	DESCRIPTION OF TEST SPECIMEN	STATIC STRENGTH KIPS PER SQ. IN.		AVERAGE FATIGUE STRENGTH KIPS PER SQ. IN.	
		YIELD POINT	ULTIMATE	AT 100,000 CYCLES	AT 2,000,000 CYCLES
44A	I-BEAM WITHOUT REINFORCEMENT	35.9	43.8		31.2
44Ga	FABRICATED BEAM WITH $\frac{1}{8}$-IN. CONTINUOUS FILLET WELDS		55.0	49.8	17.2
44Gb	FABRICATED BEAM WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELDS		54.8	45.2	16.6
44Ba	I-BEAM WITH FULL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELDS ($\frac{3}{8}$-IN. BOTTOM PLATE)	42.2	59.3	41.1	22.8
A1-A3	I-BEAM WITH FULL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELDS. ($\frac{1}{2}$-IN. BOTTOM PLATE)				23.4
A4-A6	I-BEAM WITH FULL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELDS. ($\frac{5}{8}$-IN. BOTTOM PLATE)				20.3
44Bb	I-BEAM WITH FULL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. INTERMITTENT FILLET WELDS.	37.5	49.2	42.4	16.5
44EA	I-BEAM WITH FULL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{4}$-IN. DIAMETER RIVETS.				15.8 *
44Bd	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELDS ALONG EDGES. SPECIAL END CONDITIONS.			22.1	10.0
44Ca	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN CONTINUOUS FILLET WELDS ALONG EDGES AND ENDS.	37.5	45.8	19.4	9.3
44Caa	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELDS ALONG EDGES.				8.9
44Cb	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{5}{16}$-IN INTERMITTENT FILLET WELDS ALONG ENDS AND EDGES		39.3	19.0	8.4
44Cc	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{5}{16}$-IN. INTERMITTENT FILLET WELDS. ALL WELDS LAID IN FLAT POSITION	32.9	44.8	21.8	9.4
44Cd	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{1}{4}$-IN. INTERMITTENT FILLET WELDS. BOTTOM PLATE LONGER THAN TOP PLATE.		38.9	16.5	11.5 †
44Ce	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. INTERMITTENT FILLET WELDS. BOTTOM PLATE LONGER THAN TOP PLATE			22.0	8.2 ‡
44Ja	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. INTERMITTENT FILLET WELDS. HEAVY WELD ACROSS ENDS			22.8	12.0
44Jc	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{9}{16}$-IN. CONTINUOUS FILLET WELDS. COVER PLATES TAPERED IN THICKNESS				14.2
43E 44E	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{4}$-IN. DIAMETER RIVETS.	38.5	46.5	26.8*	12.4*
44Ha	WIDE FLANGE BEAM WITH INTERMEDIATE STIFFENERS WELDED TO WEB AND BOTH FLANGES.	42.3	47.2		18.4
44Hb	WIDE FLANGE BEAM WITH INTERMEDIATE STIFFENERS WELDED TO WEB AND COMPRESSION FLANGE				26.6
44Hc	WIDE FLANGE BEAM WITH INTERMEDIATE STIFFENERS WELDED TO COMPRESSION FLANGE AND TOP 12-IN. OF WEB				32.7
44Ma	I-BEAM WITH LATERAL PLATES ATTACHED TO BEAM WITH TRANSVERSE FILLET WELDS.			19.2	12.2
44Mb	I-BEAM WITH LATERAL PLATES ATTACHED TO BEAM WITH LONGITUDINAL WELDS			24.4	13.6
44Mc	I-BEAM WITH LATERAL PLATES ATTACHED TO BEAM WITH $\frac{3}{4}$-IN DIAMETER RIVETS.		48.7*	26.4*	14.6 *
B	I-BEAM WITH BUTT WELDED SPLICES WITH WELD REINFORCEMENT ON.				16.0
C	I-BEAM WITH BUTT WELDED SPLICES WITH WELD REINFORCEMENT MACHINED OFF.				16.7
D	I-BEAM WITH RIVETED SPLICE AND PARTIAL LENGTH COVER PLATES.				18.0 *

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* Based on gross area of section.
† Six failures in compression flange; one failure in tension flange.
‡ All three failures in compression flange.

5. Results of Tests

A summary of the results obtained from the static and fatigue tests of the various types of beams in flexure is shown in Table 1. The values shown in this table are the results of one static test on a specimen of each series, and the average of several results for the fatigue tests of each series.

The yield point and ultimate static strength values shown in Table 1 were calculated from the maximum load which the specimen would carry, applying the flexual equations used in engineering design. However, it must be kept in mind that the values shown are not the true stresses, inasmuch as the stress-strain relation changes at the proportional limit. Plastic flow was limited to a relatively short length of the flange, and the yield point was not so apparent as for the same steel under a static tension test. For some specimens there was a definite drop in the beam; for others there was none, but there was a definite slowing down in the rate of loading with the testing machine running at a uniform speed. The corresponding loads have been reported as the yield point. For other specimens, no yield point was detected with the method of testing used.

The yield point of the various specimens tested varied from 32,900 psi. to 42,300 psi., but the ultimate strength of the specimens, which varied from 38,900 psi. to 59,300 psi., was reduced by the unsupported top flange.

The average fatigue strengths shown in the last two columns of Table 1 are the average of the result obtained from tests on at least three specimens for each series. In general, the fracture occurred on the lower or tension flange, except for those specimens designed especially to produce failure in the compression flange, such as 44Cd and 44Ce.

The tests were planned to produce failure in some specimens at 100,000 cycles of load and failure in others at 2,000,000 cycles, but the specimens usually failed after a variable number of cycles of stress. The fatigue strength at 100,000 cycles, designated as F100,000, was then computed by means of an empirical equation, from tests in which the actual number of cycles of stress to produce failure was less than 600,000. The fatigue strength at 2,000,000 cycles, designated as F2,000,000, was computed from tests in which the actual number of cycles of stress to produce failure was greater than 300,000. The values of F100,000 and F2,000,000 were both computed from the tests in which the actual number of cycles of stress to produce failure was between 300,000 and 600,000.

Because of the small number of specimens tested of each type, the values reported for F100,000 and F2,000,000 must be considered as more or less approximate. However, it is believed that the values are sufficiently accurate to indicate the relative fatigue strengths of the various types tested.

The relative fatigue strength and moment resisting capacities of various types of beams normally used in short beam spans and stringers of bridges are shown in Table 2. The section moduli of the various specimens are shown in Col. 3 of this table, while the ratios of the section modulus to that of the plain beam are shown in Col. 4. The fatigue strengths determined for each series are shown in Col. 5. The bending moment capacity of each series at 2,000,000 cycles, as determined from the fatigue strength and section modulus of the specimen, is shown in Col. 6, while the ratios of the bending moment capacity to that of the plain beam are shown in Col. 7.

6. Significance of Test Results

A study of the fatigue strengths determined for the various types of specimens subjected to repeated cycles of stress clearly indicates the following significant features:

a) The carrying capacity of the various types of beams does not increase directly with an increase in the section modulus of the beam. For example, it can be seen from

TABLE 2.—RELATIVE FATIGUE STRENGTH OF VARIOUS TYPES OF BEAMS IN FLEXURE

TEST SERIES	DESCRIPTION OF TEST SPECIMEN	SECTION MODULUS INCHES CUBED	SECTION MODULUS RATIO TO PLAIN BEAM	FATIGUE STRENGTH AT 2,000,000 CYCLES KIPS PER SQ. IN.	BENDING MOMENT CAPACITY AT 2,000,000 CYCLES KIP - FT.	CAPACITY RATIO TO PLAIN BEAM
COL. 1	2	3	4	5	6	7
44 A	I-BEAM WITHOUT REINFORCEMENT.	36.0	1.00	31.2	93.6	1.00
44 Ga	FABRICATED BEAM WITH $\frac{1}{8}$-IN. CONTINUOUS FILLET WELD.	62.0	1.72	17.2	88.9	0.95
44 Gb	FABRICATED BEAM WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELD	62.0	1.72	16.6	85.8	0.92
44 Ba	I-BEAM WITH FULL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELD. ($\frac{3}{8}$-IN. BOTTOM PLATE)	61.2	1.70	22.8	116.3	1.24
A1 - A3	I-BEAM WITH FULL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELD ($\frac{1}{2}$-IN. BOTTOM PLATE)	75.2	2.09	23.4	146.6	1.57
A4 - A6	I-BEAM WITH FULL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELD. ($\frac{5}{8}$-IN. BOTTOM PLATE)	85.8	2.38	20.3	145.4	1.56
44 Bb	I-BEAM WITH FULL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. INTERMITTENT FILLET WELD	61.2	1.70	16.5	84.4	0.90
44 EA	I-BEAM WITH FULL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{4}$-IN. DIAMETER RIVETS	61.0	1.69	15.8	80.5	0.86
44 Bd	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{16}$-IN. CONTINUOUS FILLET WELD ALONG EDGES. SPECIAL END CONDITION	61.2	1.70	10.0	51.0	0.54
44 Cb	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{5}{16}$-IN. INTERMITTENT FILLET WELD ALONG EDGES AND ENDS	61.2	1.70	8.4	42.8	0.46
43 E 44 E	I-BEAM WITH PARTIAL LENGTH COVER PLATES ATTACHED WITH $\frac{3}{4}$-IN. DIAMETER RIVETS	61.0	1.69	12.4	66.9	0.67

Table 2 that while the section modulus of a rolled beam reinforced with cover plates fastened to the beam with 3/16-in. continuous fillet welds (Series 44Ba) increased 70 percent over that of a plain beam (Series 44A), the bending moment capacity was only increased 24 percent over that of the plain beam.

b) The carrying capacity of a beam with full length welded cover plates is increased by using heavier cover plates, but there appears to be a limit to this increase in the carrying capacity. For example, it can be seen from Table 2 that the ½-in. cover plates on the specimens of Series A1–A3, increased the section modulus from 62.2 in.^{3} for the specimens of Series 44Ba with the ⅜-in. plates, to 75.2 in.,^{3} or an increase of 23 percent. The carrying capacity increased from 116.3 kip. ft. to 146.6 kip. ft., or an increase of 26 percent. However, the increase in the carrying capacity of the specimens of Series A4–A6 with the ⅝-in. cover plates was only 25 percent over that for Series 44Ba, while the section modulus increased 40 percent, indicating that there is some economic relation between the cover plate area and the flange area of the beam.

c) The carrying capacity of a beam with partial length cover plates is decreased tremendously over that for a beam fabricated with full length cover plates. A comparison of the carrying capacity of the two types with welded cover plates is shown in Table 2 for Series 44Ba and Series 44Bd. The section moduli of the specimens of the two series are the same and the specimens would normally be expected to carry the same static load, but their carrying capacity, when subjected to repeated loads, is entirely different. The capacity of the beam with the full length cover plate is 116.3 kip. ft., while that for the beam with the partial length cover plate is only 51.0 kip. ft., indicating that the cutting off of the plate reduced the capacity by 56 percent.

The reduction in the carrying capacity of beams with riveted cover plates, due to cutting off the plates, is not as great as that occurring for welded cover plates, as can be seen by comparing the value for Series 44EA and 43E, Table 2. The bending moment capacities for the two series indicate that the cutting off of the plates reduced the carrying capacity by only 17 percent.

It is evident from the results of these tests that whenever it becomes necessary to attach cover plates to beams, the plates should be extended past the theoretical cut-off point at least a sufficient distance so that the stress in the beam at the end of the cover plate is below the fatigue strength. A method of calculating the correct cover plate lengths for a 50-ft. beam span is shown in Fig. 6, and for a 100-ft. girder span in Fig. 7. The resisting moment of the 36-in. beam and two 12-in. by ½-in. continuously welded cover plates, when subjected to repeated cycles of stress of 22,800 psi., is calculated as 2320 ft. kip., as shown in Fig. 6. Under static loading conditions, the cover plates could be stopped at the calculated cut-off point, but under repeated loading it is necessary to extend the plates 10 ft. past this point, or to a point where the stress in the beam is only 9100 psi. It is evident that a heavier 36-in. beam would be more economical; in fact, the carrying capacity of the same weight beam without cover plates is greater than the reinforced beam on account of the higher fatigue strength.

The method of calculating the cover plate lengths on riveted spans, when subjected to repeated cycles of load, is shown on Fig. 7. It can be seen from the moment diagram that it becomes necessary to extend the outside cover plates a considerable distance past the theoretical cut-off point, but the distance decreases for the other plates. It should be kept in mind that the unit stress of 12,400 psi., used on Fig. 7, was for ready identification taken from Test Series 43E and 44E, Table 2. In the actual design of a long girder span, it would be necessary to consider, 1) that because of its dead load, the actual stress cycle affecting fatigue strength is somewhat less than zero-to-maximum tension; 2) the probable repetitions of maximum loading would never attain 2,000,000; and

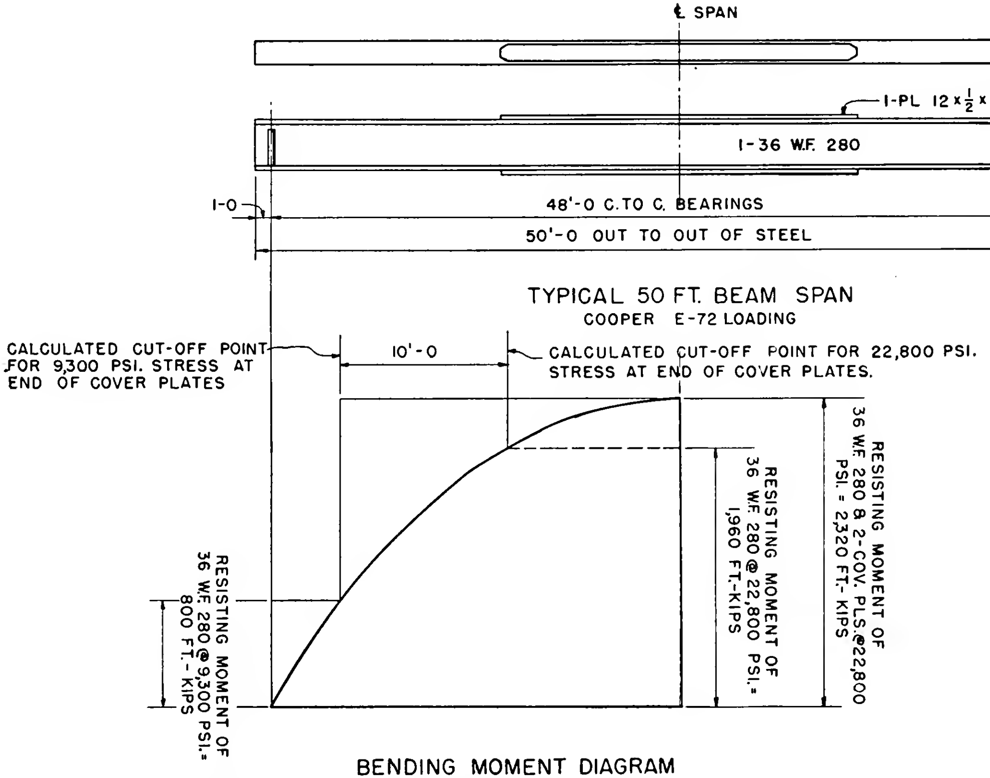

Fig. 6. Determination of cover plate lengths. 50-ft. welded beam span. Ballasted timber floor.

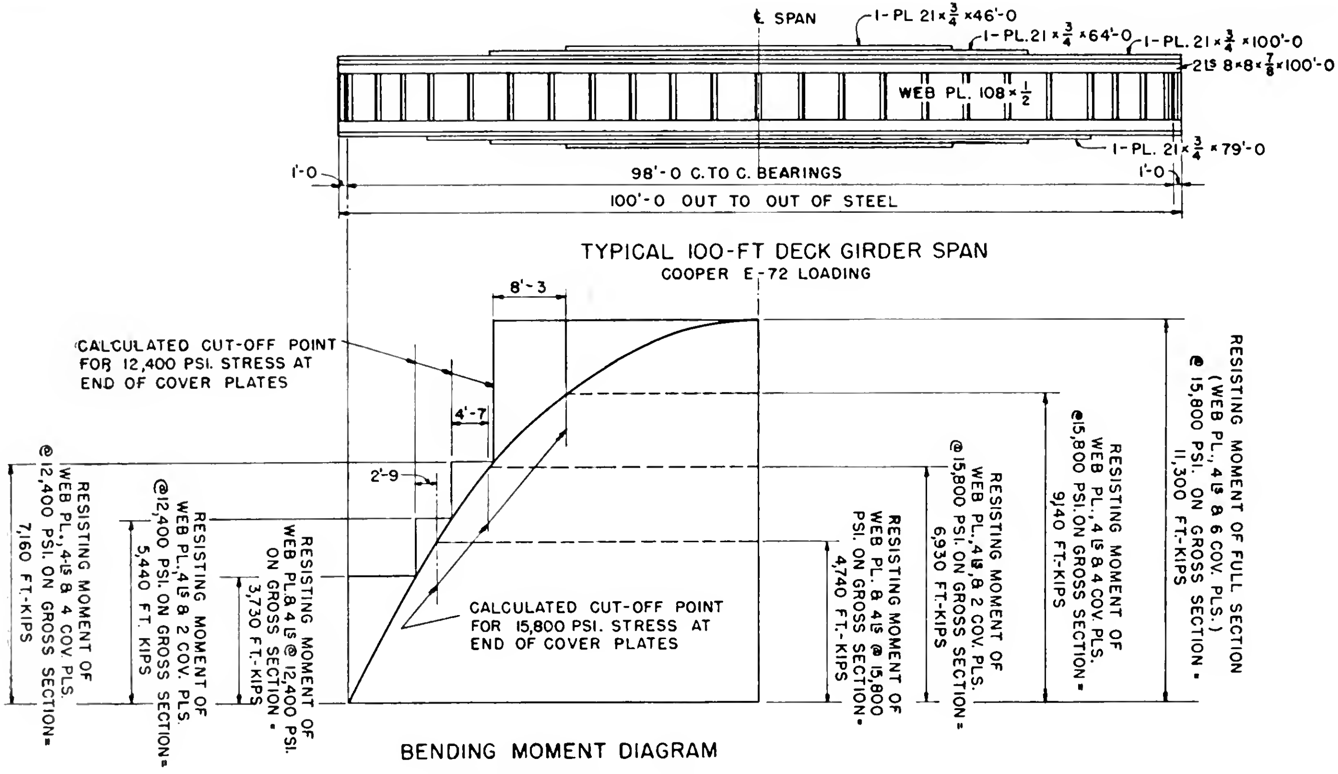

Fig. 7. Determination of cover plate lengths. 100-ft. riveted deck girder span. Ballasted timber floor.

3) conversely, the unit stress of 12,400 psi. represents failure and does not contain any safety margin. The scant data from these tests would need to be interpreted and applied with judgment.

d) The various tests conducted on specimens with partial length cover plates fastened to the beams with welds but with different plate and weld end conditions, indicate that there is no practical method to increase the fatigue strength of beams with partial length cover plates. The only significant increase in fatigue strength was obtained by tapering the cover plates in thickness and then fastening the plates to the beam with tapered welds on the edges, and with long tapered welds at the ends of the plates, but even for this method the fatigue strength was only increased to 14,200 psi., see Table 1, Series 44Jc.

The tests conducted on the specimens of Series 44Ca and 44Caa indicate that the welds across the ends of the cover plates do not reduce the fatigue strength of the specimens. The average fatigue strength at 2,000,000 cycles for four specimens with welds across the ends of the plates was determined as 9300 psi., while the average value for three specimens without welds across the ends of the plates was only 8900 psi.

e) The results of the tests conducted on the specimens of Series 44Cd and 44Ce indicate that the fatigue strength of the compression flanges of beams is about the same as that of the tension flange.

f) The fatigue strength at 100,000 cycles is about the same for specimens fabricated with continuous fillet welds as that for intermittent fillet welds, see Table 1, Series 44Ba and 44Bb. However, the intermittent fillet welds materially reduce the fatigue strength at 2,000,000 cycles, with failure occurring at the end of the weld bead.

g) The results of the tests on beams with butt-welded splices, Series B and C, Table 1, indicate that the fatigue strength at 2,000,000 cycles is only about half that of a plain beam, Series 55A. It appears that the reduction in the fatigue strength is due principally to the slag inclusions in the butt welds, as the strength was only slightly increased by machining off the weld reinforcement flush with the base metal.

h) The efficiency of a riveted spliced beam can be secured by comparing the results obtained on the spliced specimens of Series D with those obtained on the unspliced specimens of Series 44A. The carrying capacity of the unspliced beam was 93.6 kip. ft., while that for the spliced beam was 66.4 kip. ft., indicating that a riveted splice reduces the carrying capacity by about 29 percent. However, the splicing of a beam already reinforced with riveted cover plates should not reduce its carrying capacity, as can be seen by comparing the fatigue strengths of Series 44EA and Series D, Table 1.

j) The carrying capacity of beams is greatly reduced by the attachment of lateral plates to the flanges by either welding or riveting. For example, the fatigue strength of a plain beam was determined as 31,200 psi., see Table 1, Series 44A, but when lateral plates were fastened to the flanges the fatigue strength was reduced to 12,200 psi., or about 39 percent of the original strength, see Series 44Ma. The method of attaching the lateral plates to the beam flanges did not have much effect on the fatigue strength. In Series 44Mb, the plates were fastened with longitudinal fillet welds instead of transverse fillet welds, and in Series 44Mc the plates were riveted to the flanges, and for both methods the increase in strength was small.

k) The carrying capacity of beams having the webs reinforced with vertical stiffeners at the points of maximum stress depended upon the method of attaching the stiffeners to the beam. In Series 44Hc the stiffeners were welded to the compression flange and to the top 12 in. of the web without any apparent reduction in the carrying capacity of the beam. In Series 44Hb the stiffeners were welded to the compression flange and to the full depth of web, with a reduction of about 19 percent in its carrying capacity. In

Series 44Ha the stiffeners were welded to both the compression and tension flanges and to the full depth of web, with a reduction of 44 percent in its carrying capacity.

l) It is evident from the results of tests obtained on the fabricated beams of Series 44Ga and 44Gb that the carrying capacity of these beams is appreciably lower than the capacity of a rolled beam. For example, it can be seen from Table 2, that while the section modulus of the fabricated beam with 3/16-in. continuous fillet welds, Series 44Gb, increased 72 percent over that for a rolled beam, Series 44A, the bending moment capacity reduced to 92 percent of that of the rolled beam.

m) The results of the tests indicate that the welds have exceptionally high fatigue strengths when transmitting loads by horizontal shear. For example, the calculated stress in the welds connecting the flange plates to the web plate of one specimen of Series 44Ga was 27,600 psi., and still this specimen failed in the lower flange plate after 563,900 cycles of stress varying from about zero to 28,000 psi. However, it should be kept in mind that the calculated weld stress is based upon the throat area and does not include any of the weld area resulting from the under-cutting.

n) The fatigue strengths shown in Table 1 for the various series at 100,000 cycles of stress indicate that, in general, fatigue failures will not occur in the longer girder span bridges where the dead load stress comprises a fairly large percentage of the total stress. In addition, data are now available indicating that only a small percentage of the trains passing over railroad girder bridges produces stresses as large as the fatigue strength of these members.

7. Conclusions

Although these tests were too few in number, and too restricted in stress-cycle patterns, to afford a basis for close estimating of the fatigue life of bridge members under service conditions, they do lead to certain qualitative conclusions.

The customary working stresses and methods of design of reinforcements are adequate for flexural members designed to withstand not over 100,000 cycles of maximum stress range. For flexural members to be subjected to more than 100,000 cycles, the following precautions are recommended, and increasingly so as the probable number of cycles increases:

a) Any plain rolled beam without attachments or flange holes will have a greater fatigue life than any cover-plated beam, or any built-up beam, of the same or somewhat greater section modulus.

b) If lack of depth dictates cover-plating of beams in new work, or if existing beams are cover-plated for reinforcement, the cover plates should preferably be of full length, and in any case long enough so that the stress in the main material ahead of the plates does not exceed for welded beams, 40 percent of the normal design stress for flanges, or for riveted beams, 70 percent.

c) Continuous fillet welds afford the best means of attaching full length cover plates to beams; followed by rivets and by intermittent welds, in that order.

d) Splices in continuous beams should be placed where they will be subjected to the lowest practicable bending moment. Flange splices in simple-span beams should not be permitted.

e) Any attachment, riveted or welded, to a tension flange at a point of considerable bending moment will reduce the fatigue life. If such attachments to the flange cannot practicably be avoided, the allowable flange stress at such points should be reduced below usual working values. This precaution applies to stiffeners, lateral plates, diaphragm flanges, etc.

f) For flexural members subjected to stresses of opposite sign, the loss of fatigue life due to any of the stress-raising conditions discussed herein would be still more serious.

Effect of Wheel Unbalance, Eccentricity, Tread Contour and Track Gage on Riding Quality of Railway Passenger Cars

Synopsis of a Report Prepared by the Joint Committee on Relation Between Track and Equipment of the Mechanical and Engineering Divisions, AAR*

The primary objective of the tests described herein was to obtain information on the effect of wheel unbalance on riding quality of railway passenger cars. Other objectives were to determine the effect of wheel tread eccentricity and contour, and track gage on riding quality of railway passenger cars.

A modern passenger car was subjected to variations in wheel unbalance, wheel tread eccentricity and contour. and track gage during tests made over a 3-mile section of Pennsylvania Railroad track near Philadelphia in the fall of 1948. Preparations for the tests included a survey of 108 wheels to obtain data on unbalance and tread eccentricity in wheels as normally manufactured. The preparations also included the re-gaging of the three 1-mile sections of test track to specified gages. Accelerations of the car body were recorded and analyzed to evaluate the importance of the various conditions tested on riding quality.

Comparisons of riding quality are made on the basis of values of a "Ride Index"—a term introduced in this report, which is a quantitative measure of the physical sensation of a passenger based on the characteristics of vibration to which the passenger is subjected. The method used to convert vibration data to values of Ride Index was derived from literature based on extensive laboratory experiments. Sensations as actually experienced during the tests are shown to be consistent with those derived through the use of the Ride Index.

Conclusions

The conclusions in this report are with respect to the passenger car employed, the construction of which is typical of that of modern passenger cars. The findings are, therefore, considered applicable, within limits, to modern passenger cars, and are listed as follows:

1. Effect of Wheel Unbalance and Machining of Wheels

The detrimental effect of wheel unbalance on the riding of the test car was inconsequential when the total unbalance per wheel was below two pounds. The investigation of the effect of wheel machining shows that the above limiting condition of wheel unbalance can be met by the semi-finish machining of wheels.

2. Effect of Wheel Tread Eccentricity

Wheel tread eccentricity (up to 0.035 in.) had no important effect on the riding of the test car.

3. Effect of Wheel Tread Contour

Both with the full-cylindrical tread contour wheels and with the standard conical tread contour wheels machined to simulate a selected worn condition, the riding of the test car was slightly poorer than with the AAR standard conical tread contour wheels.

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* Only selected illustrations are used in this synopsis, and bear the numbers of the original report. Report is published in full, in mimeograph form, by the AAR, and may be obtained from G. M. Magee, research engineer, upon request.

4. Effect of Variation in Track Gage

Narrowing of the track gage by ⅛ in. had no effect on the riding of the test car, but the ¼ in. narrower gage (4 ft. 8¼ in.) resulted in a slight improvement in the ride.

Purpose of Tests

The tests partially reported herein—run from August 13 through September 27, 1948—combined two assignments to the Committee on Relation Between Track and Equipment, for which separate provision had been made in the AAR budget. These assignments called for similar instrumentation and testing procedure, and the grouping of the projects together permitted a special train to be used, with consequent closer control of speed and other factors.

The ultimate aim of all the tests was to determine the effect of the various test factors on the quality of the ride in the car. The specific objectives were to determine:

(1) The effect of unbalance and tread eccentricity in passenger car wheels on the riding quality of the car. This subject has currently been a matter of considerable controversy and of increased importance because of the higher speeds and improved riding comfort standards of the newer passenger equipment.

(2) The effect of wheel and track gage on riding quality. There has been some contention that a tighter gage decreases lateral forces on the equipment and passengers, and some railroads use for tangent track a gage less than standard. For the tests, the gage of the track was varied rather than the wheels. Three sections of track, approximately 1 mile in length each, with gages 4 ft. 8½ in., 4 ft. 8⅜ in., and 4 ft. 8¼ in., respectively were specially prepared for the tests.

(3) The effect of wheel contour on riding quality. The AAR standard conical tread was used for most of the tests, but one series had a cylindrical tread for comparison. The cylindrical tread has been advocated in some cases as a means of reducing lateral oscillations of the track and car body.

(4) The effect of worn wheels on riding quality. For this series, the wheels were machined to simulate worn conditions.

It is realized that the action of a set of trucks, the car body, and the track are very complex. There are many types of trucks and variations in a given type of truck so that it is difficult to generalize from tests of one car and a given set of conditions. However, it was considered impracticable to introduce into such a test as here reported any additional variations of equipment and track and keep the test program within reasonable limits of time and cost. Considerable study was given to making these tests representative and the conclusions as generally applicable as possible.

The Test Car and Apparatus

The test train consisted of a GG–1 electric locomotive and two P–70 passenger cars, with the research car of the Budd Company between the passenger cars. This arrangement simulated the positioning of most passenger equipment in that the test car was neither next to the locomotive nor on the rear end of the train. A view of the test train is shown in Fig. 1.

The research car was used both to carry the instrumentation and to test the effect of the factors involved in the program. The car is a modern-type stainless steel coach with the usual interior fittings removed and fitted out to mount and operate the various instruments used for testing. Basic four-wheel trucks with 8-ft. 6-in. wheel spacing were used. The length of the car was 85 ft. and the truck spacing 59 ft. 6 in., as shown in Fig. 3.

Fig. 1. View of the test train; test car is the middle car.

The trucks had Houde shock absorbers for the restraint of vertical oscillations and a rubber-cushioned tie rod for longitudinal restraint of the bolster with respect to the truck frame. The journals were 5½ in. by 10 in. and were fitted with Timken roller bearings. The pedestal openings were 13⅜ in. Rubber insulating pads were used at top and bottom of equalizer and bolster springs and between the journal box and the equalizer seat, and there was a Thermoid center plate liner. There were no roll or pitch stabilizers and no lateral shock absorbers. The pedestal clearance was 1/16 in., and frequent checks were made to see that the journal boxes were not binding in the pedestals. Budd basic spring hangers were used.

The deflection of the bolster springs was 5.28 in. and of the equalizer springs 3.78 in., making a total spring deflection of 9.06 in. under the car as tested.

The total car weight, including trucks and test equipment, was 120,000 lb. The test truck was under the non-vestibule end of the car (the leading end in all tests). The loads and other data are given in Fig. 3.

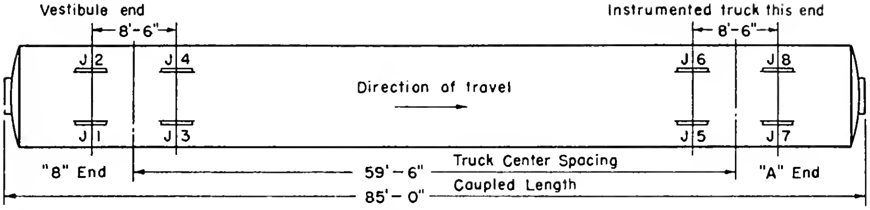
The recording equipment was placed in the car as shown in Fig. 4. The equipment in the foreground on both sides of the car is on two of the ballast boxes that contained the weights used to load the car. The principal items of the measuring equipment were one 24-channel and two 12-channel magnetic oscillographs, one 6-channel and two 12-channel sets of amplifiers, all with power supplies, and one eight-channel mechanical recorder.

Measurements

Certain of the measurements were of quantities directly indicative of the riding quality of the car, while others were a means of showing the cause of the variation and manner of action of the truck and car body. Only those measurements (car body accelerations) which indicate the riding quality are analyzed in this report.

The car body measurements indicated the final effect of the various test factors on riding quality. They consisted principally of accelerations indicated by 1.5 g and 2 g range Statham resistance-type accelerometers. In the forward end of the car (the non-vestibule end) three accelerometers were mounted at the car floor on the centerplate

Fig. 3 — Plan of the Test Car



Weight data:

Weight of 1 truck	16,700 lb.
Ctr. plt. load, "A" end	44,600 lb.
Ctr. plt. load, "B" end	42,000 lb.
Total wt. on rails	120,000 lb

Spring data:	Bolster springs	Equalizer springs
Free height	20.39 in.	16.21 in.
Loaded height	15.11 in.	12.43 in.
Deflection	5.28 in.	3.78 in.
Total deflection, bol. and equal. springs		9.06 in.

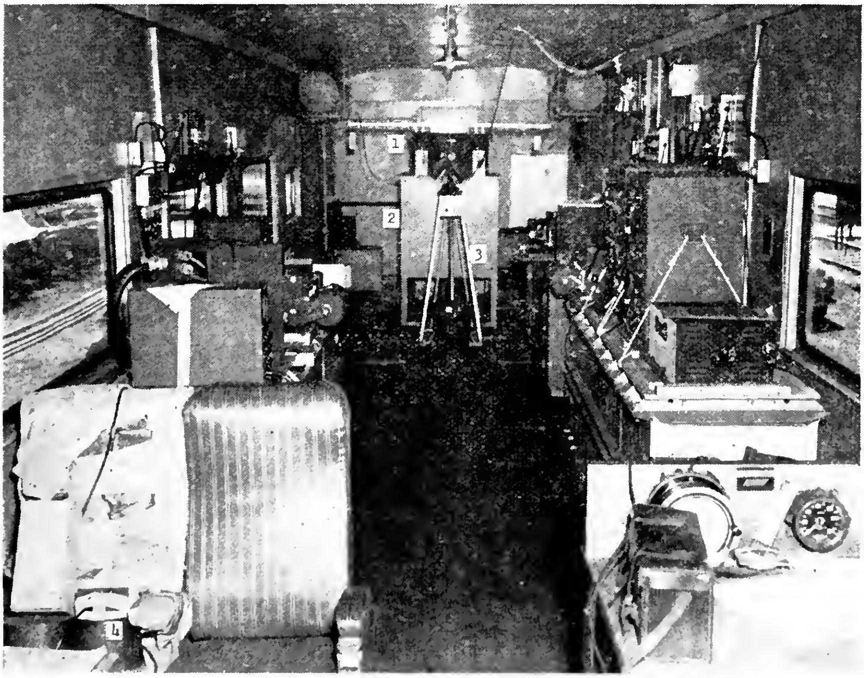


Fig. 4. View of forward end of test car.

(1) Mechanical recorder.
(2) Car roll indicator.
(3) Vertical displacement indicator.
(4) Seat accelerometer.

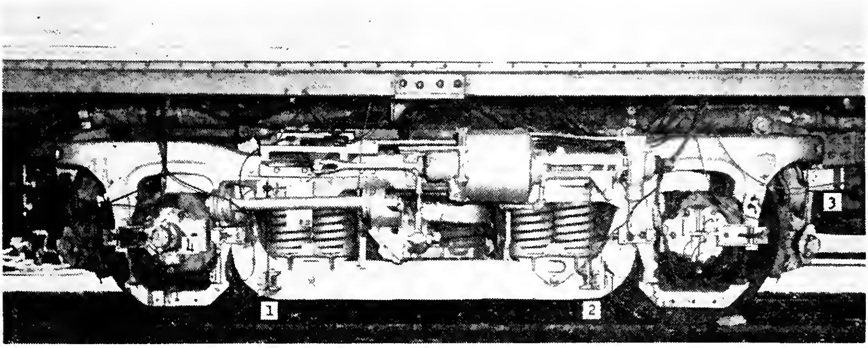


Fig. 8. View of the test truck.

(1) Mechanical recorder connection, equalizer spring at J5.
(2) Mechanical recorder connection, equalizer spring at J7.
(3) Mechanical recorder connection, end transom at J7.
(4) Phase indicator at J5.

to measure the vertical, lateral and fore-and-aft acceleration of the car. In the rear end at the same relative location the vertical and lateral accelerations were measured.

The journal box movements in the fore-and-aft and lateral or transverse directions relative to the frame were measured by microformers and were recorded on an oscillograph.

When the unbalance was checked in the wheels, its angular position was marked on the wheels. To correlate this position with the other records, a phase indicator was attached to each of the two axles of the test truck. (See Fig. 8)

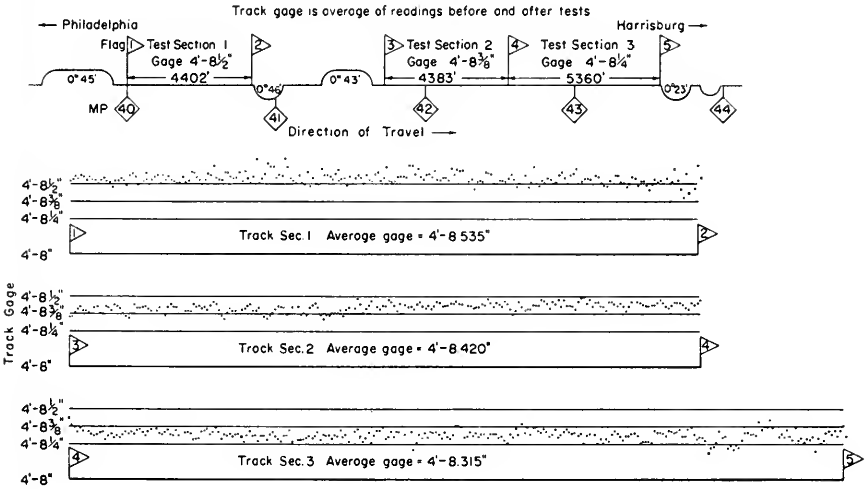
The Track

The prime consideration in the selection of the test track was to obtain a sufficient length of high-speed track, without curves or other conditions that would introduce irrelevant actions. Three stretches were selected on the Philadelphia division about 20 miles west of Philadelphia, Pa., near Coatesville. These stretches of track were each almost one mile in length, two were contiguous and the third separated by two short curves of slightly more than 40 min. curvature. There were no turnouts or crossovers. There was an ascending grade of 0.57 percent. The electric locomotive easily attained 100 mph. with three cars on this grade, requiring only about 2½ miles from a standing start.

The track selected was the No. 4 westbound passenger track, laid with 152-lb. PS rail on a deep bed of rock ballast.

Each section of track was gaged to the required gage over the whole length, Section 1 being 4 ft. 8½ in., Section 2, 4 ft. 8⅜ in., Section 3, 4 ft. 8¼ in. Gage readings were taken to one hundredth of an inch at every half rail length before and after the tests. Averages of these readings at each point are shown in Fig. 11. The track gage measurements were taken with a special gage designed to read to 0.01 in., in conformance with recommended practice of the AREA. At some locations there was an appreciable lip of flowed metal on the inner corner of the head of one or both rails. A track gage that did not clear this lip would give a smaller reading of gage than one that reads ⅝ in. down from the top of the rail, as does the gage used.

Fig 11 – Track Profile and Gage



Markers were placed along the track to indicate the start and finish of the test sections. These positions were indicated on the record by a manual control as the test car passed the marker.

Test Procedure

The tests were grouped into 15 series, each series comprising 6 to 8 "runs." Each series represented a variation in wheel balance, eccentricity or tread contour. Each run was made at a constant train speed over the three test sections of track. In most cases two runs were made at the same speed, and speeds of 40, 60, 80 and 100 mph. were used for each series. When a resonance was noted at a speed other than the nominal speed, an additional run was made at the speed that produced the resonant action.

Two car sets of wheels were used in the tests: Car set "A", with which the effects of wheel unbalance and tread variations were compared; and car set "B", with which the effects of wheel machining operations were compared.

Wheel variations for all test series are summarized as follows:

Series No.	*Date*	*Wheels*	*Condition of Wheels*
1	Aug. 13, 1948	A	As received
2	Aug. 18, 1948	A	Treads ground
3	Aug. 21, 1948	A	Treads ground, wheels balanced
4	Aug. 26, 1948	B	As received
5	Aug. 30, 1948	A	10 lb. unbal., 180 deg. phase
6	Aug. 31, 1948	A	5 lb. unbal., 180 deg. phase
7	Sept. 2, 1948	A	10 lb. unbal., 0 deg. phase
8	Sept. 3, 1948	A	5 lb. unbal., 0 deg. phase
9	Sept. 8, 1948	B	Treads ground, rims machined
10	Sept. 10, 1948	A	(Slid flat)
11	Sept. 14, 1948	A	Cylindrical tread, balanced
12	Sept. 16, 1948	B	Treads grd., rims and hubs mach'd
13	Sept. 22, 1948	A	"'Worn" tread, balanced
14	Sept. 24, 1948	B	Treads ground, fully machined
15	Sept. 27, 1948	A	"Eccentric" treads, balanced

Riding Quality Evaluation

Comparisons of riding quality are made on the basis of values of a "Ride Index"—a term introduced in this report, which is a quantitative measure of the physical sensation of a passenger based on the characteristics of vibration to which the passenger is subjected. The method used to convert vibration data to values of Ride Index was derived from literature based on extensive laboratory experiments. The composite Ride Index chart used for these tests is shown in Fig. 16. Sensations as actually experienced during the tests are shown to be consistent with those derived through the use of the Ride Index.

Effect of Wheel Unbalance on Riding Quality

One of the aims of the work preliminary to the actual running of the tests was to make a survey of representative wheel and axle assemblies to determine the range of unbalance and eccentricity likely to be found under the usual conditions of service and shop practice. A survey of 54 assemblies (108 wheels) was made. These wheels were manufactured by four companies in accordance with AAR Specification M–107–47, Section 14, Manual of Standard and Recommended Practice.

A dynamic balancing machine, furnished by the Bear Manufacturing Company, was used to determine amounts of unbalance of the wheels in the survey and of the wheels as tested. These amounts are shown in Fig. 13, and are summarized as follows:

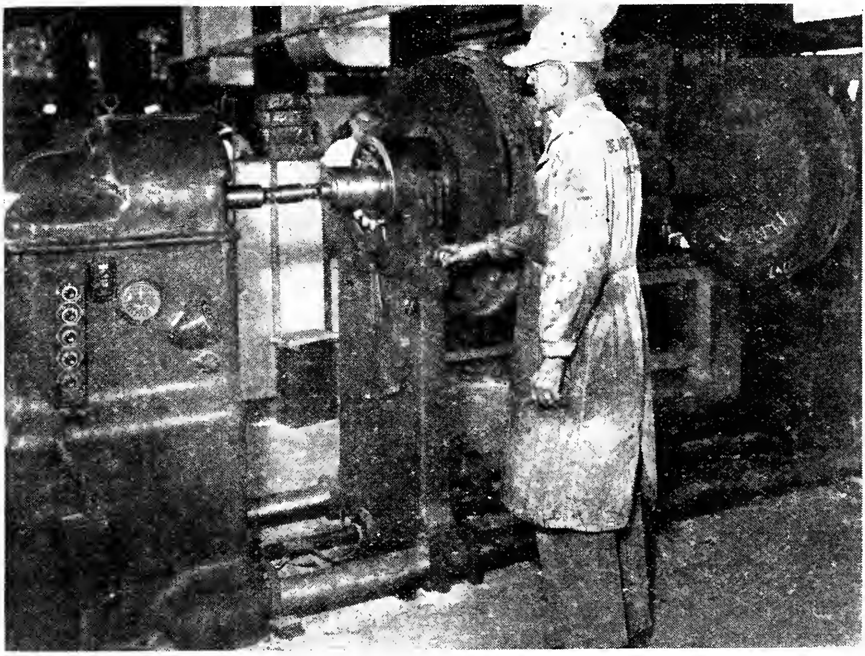


Fig. 12. View of the wheel balancing machine and a wheel assembly.

108 Wheels Surveyed

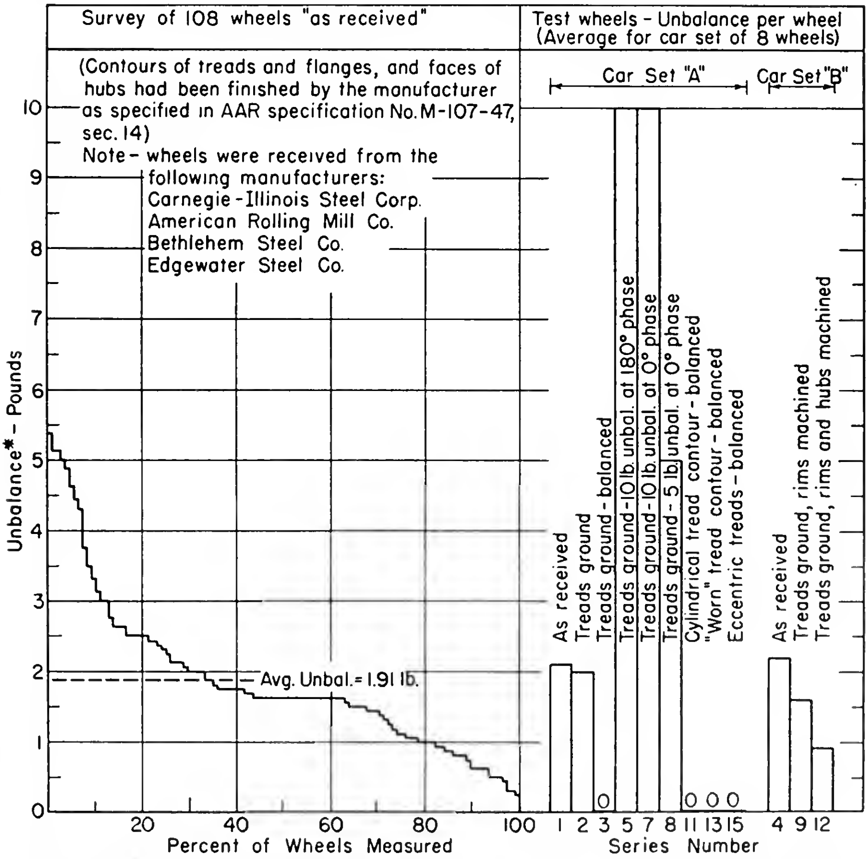
Range of Unbalance—Lb.	*Percent of Wheels*
0 through 0.9	17.6
1 through 1.9	49.1
2 through 2.9	20.4
3 through 3.9	5.5
4 through 4.9	3.7
5 through 5.4	3.7
Avg. 1.91	

Test Wheels

Series	*Avg. Unbalance Per Wheel—Lb.*
1	2.09
3	0.00
4	2.13
5	10.00
7	10.00
8	5.00
12	0.90

In each case the unbalance is the total weight, effective at the rim of a wheel, by which that wheel is unbalanced. The wheels were mounted on axles when checked, and the phase angle between the unbalance in two wheels is not shown, but varied from 0 deg. to ± 180 deg. because the wheels were mounted at random. The phase angle between the effective positions of unbalanced weights in the mounted wheels is shown to be of major importance in riding quality. If this angle is 0 deg.. the unbalance is termed "static"; if this angle is 180 deg. the unbalance is termed dynamic. The static unbalance can be measured by a static test; dynamic cannot.

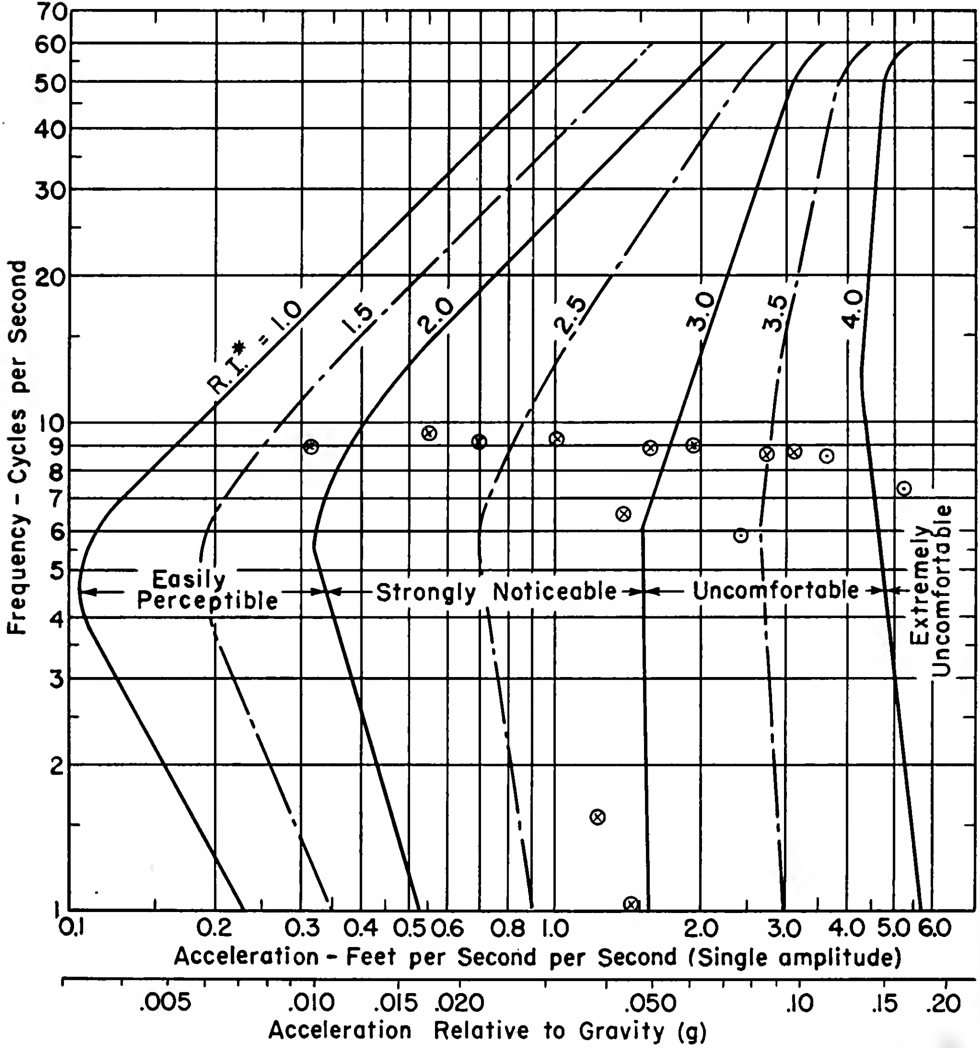
Fig. 13 - Unbalance in Wheels, As Received and As Tested



*"Unbalance" is the weight, effective at the rim of a wheel, by which that wheel is unbalanced

Fig. 16 — Composite Ride Index Chart

Based on F.J. Meister's tests as reported in the Forschung (V.D.I. Berlin), May-June '35



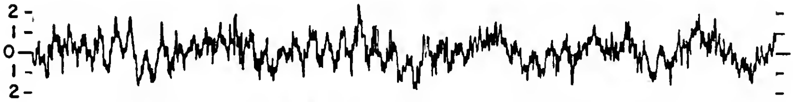
Legend: Each of the fourteen plotted points represents a vibration obtained during the tests. The sensation for each vibration as noted by recorder is given as follows: ⊗ "noticeable", "annoying"; ⊙ "very bad", "terrific".

R.I.* = Ride Index - a term chosen for reference purposes, to which numerical values have been assigned. A Ride Index of 1.0 corresponds to a relationship of acceleratio and frequency which would be "easily perceptible", in some direction relative to the human body, to sensitive persons.

Fig. 21.-Vibration Records Showing Effect of Unbalance

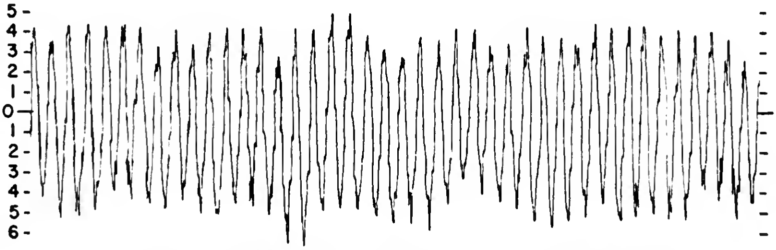
Vertical vibration at wheel frequency.

Series 1 - "A" wheels as received.
Accel. 1.31 ft./sec.^{2}; Freq. 9.10 cps.; R.I. 2.82

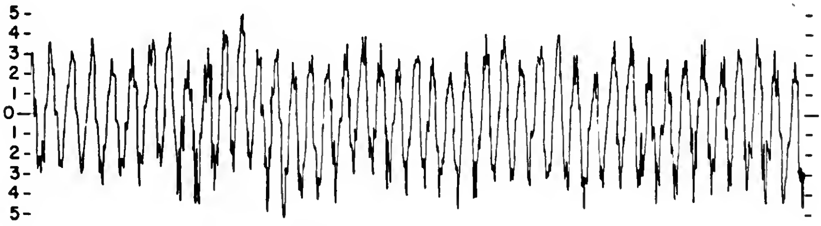


Series 3 - "A" wheels, treads ground, balanced.
Accel. 0.56 ft./sec.^{2}; Freq. 9.50 cps.; R.I. 2.24

Series 5 - "A" wheels, 10 lb. unbal. at 180 deg. phase.
Accel. 1.01 ft./sec.^{2}; Freq. 9.20 cps.; R.I. 2.64



Series 7 - "A" wheels, 10 lb. unbal. at 0 deg. phase.
Accel. 3.65 ft/sec.^{2}; Freq. 8.50 cps.; R.I. 3.78



Series 8 - "A" wheels, 5 lb. unbal. at 0 deg. phase.
Accel. 2.73 ft./sec.^{2}; Freq. 8.55 cps.; R.I. 3.48

Note: Lengths of record between scales are 5 second periods of maximum vibration.

Fig. 21 is a reproduced tracing of the oscillograph records of vertical car body acceleration at the car floor on the forward center plate for test Series 1, 3, 5, 7 and 8 at speeds of 60 mph., all with "A" wheels, but with various amounts of wheel unbalance. The length of each record between scales is for a 5-sec. period selected along the record at positions of maximum accelerations. The frequency and acceleration of each 5-sec. interval of vibration were plotted on Fig. 16, the composite Ride Index Chart, to obtain the value of Ride Index for that vibration. The values of Ride Index are shown below each record in Fig. 21 and in bar-graph form in Fig. 26.

Fig. 26 shows the effect of wheel unbalance on riding quality in the vertical and lateral directions at the car floor on the forward center plate. Wheel frequency vibrations are shown at 60 mph., the speed at which they were found to produce maximum Ride Indices. Low-frequency vibrations are shown at 100 mph., the speed at which they were found to produce maximum Ride Indices. The riding quality based on wheel frequency vibrations is shown not to be affected materially by dynamic unbalance (Series 1 versus 5) in both the vertical and lateral directions. Low-frequency vibrations in both the vertical and lateral directions are shown not to be affected by wheel unbalance.

Fig. 25 shows the effect of wheel unbalance on riding quality in the fore-and-aft direction at the car floor on the forward center plate. Wheel frequency vibrations are clearly shown to be a maximum at 60 mph. Even the residual unbalance in Series 3 (wheel balanced) apparently produces its maximum effect at 60 mph. One significant fact is clearly shown in this figure—that the riding quality in the fore-and-aft direction is a function of the static unbalance (unbalance at 0-deg. phase in a wheel-axle assembly) and is not materially affected by dynamic unbalance (180-deg. phase). The relative importance of static versus dynamic unbalance is shown by comparison of Series 1 and 5; Series 1 proved to produce higher Ride Indices than did Series 5, although the average total unbalance per wheel was 2.09 lb. and 10 lb., respectively. The essential difference between the two conditions was that the static unbalance per wheel was 1.13 lb. and 0.00 lb., respectively. The effect of dynamic unbalance is shown to be practically isolated from the car body in the fore-and-aft direction.

The following conclusions are with respect to the passenger car employed, the construction of which is typical of that of modern passenger cars. The conclusions are, therefore, considered applicable, within limits, to modern passenger cars.

(1) Wheel unbalance is a positive, controllable factor in riding quality. It is a positive factor because, within a limited speed range (around 60 mph. in the case of the test car) the car body vibrations resulting from unbalance commonly found in wheels were more important than vibrations resulting from any other type of disturbance (rail joints, truck nosing, etc.) It is a controllable factor because it can be eliminated by a relatively simple process, while other types of disturbance can not.

(2) Car body vibrations are caused by many sources of disturbance, and several important vibrations are usually present simultaneously at all speeds. As the speed changes the relative importance of each vibration changes, so that at different speeds the overall riding quality is determined by different types of disturbances.

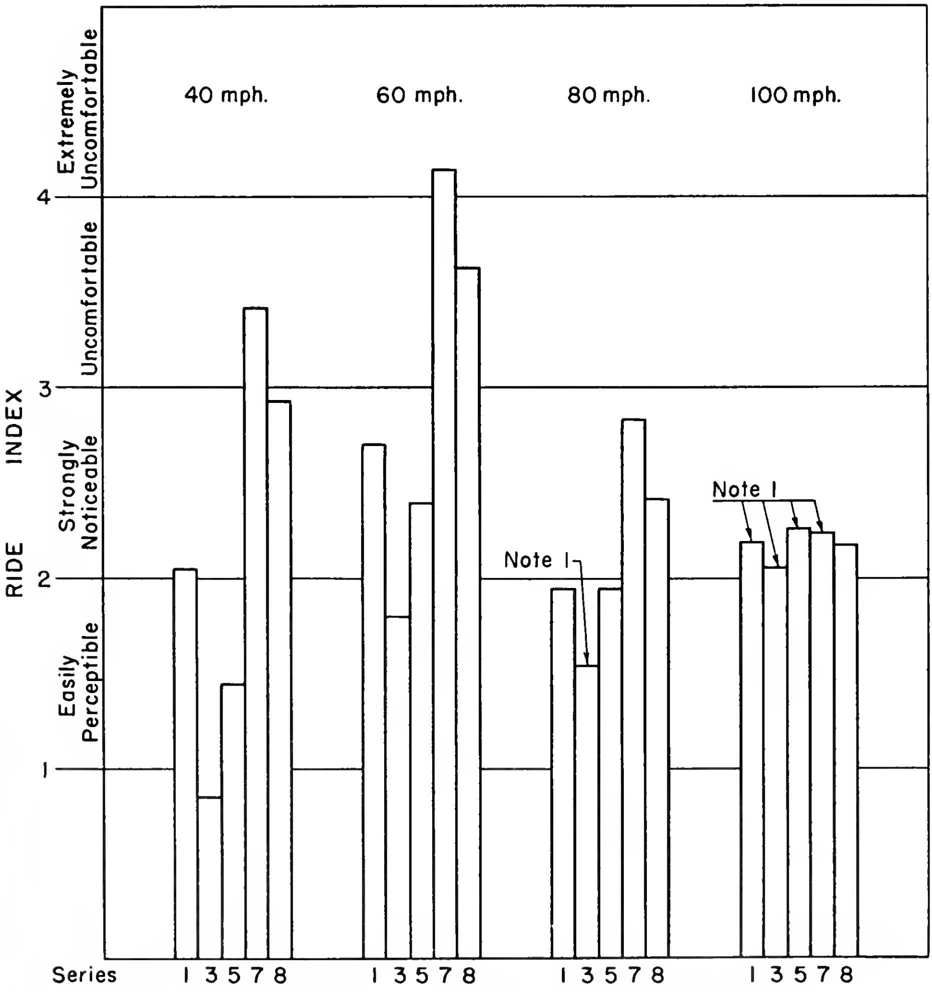
(3) Only those car body vibrations having a frequency equal to the frequency of rotation of the wheels were found to be influenced by wheel unbalance. All other car body vibrations (originating with rail joint disturbances, truck nosing, etc.) were not found to be influenced by wheel unbalance.

(4) Unbalanced weight in wheels when mounted on axles causes static and/or dynamic unbalance in the wheel-axle assemblies. These types of unbalance produce different effects, as follows:

Fig. 25 - EFFECT OF UNBALANCE
ON
RIDING QUALITY

FORE-AND-AFT vibration at wheel frequency (except where noted)

Series 1 – "A" Wheels, as received
Series 3 – "A" Wheels, treads ground, balanced
Series 5 – "A" Wheels, treads ground, 10 lb. unbal. at 180° phase
Series 8 – "A" Wheels, treads ground, 5 lb. unbal. at 0° phase
Series 7 – "A" Wheels, treads ground, 10 lb. unbal. at 0° phase

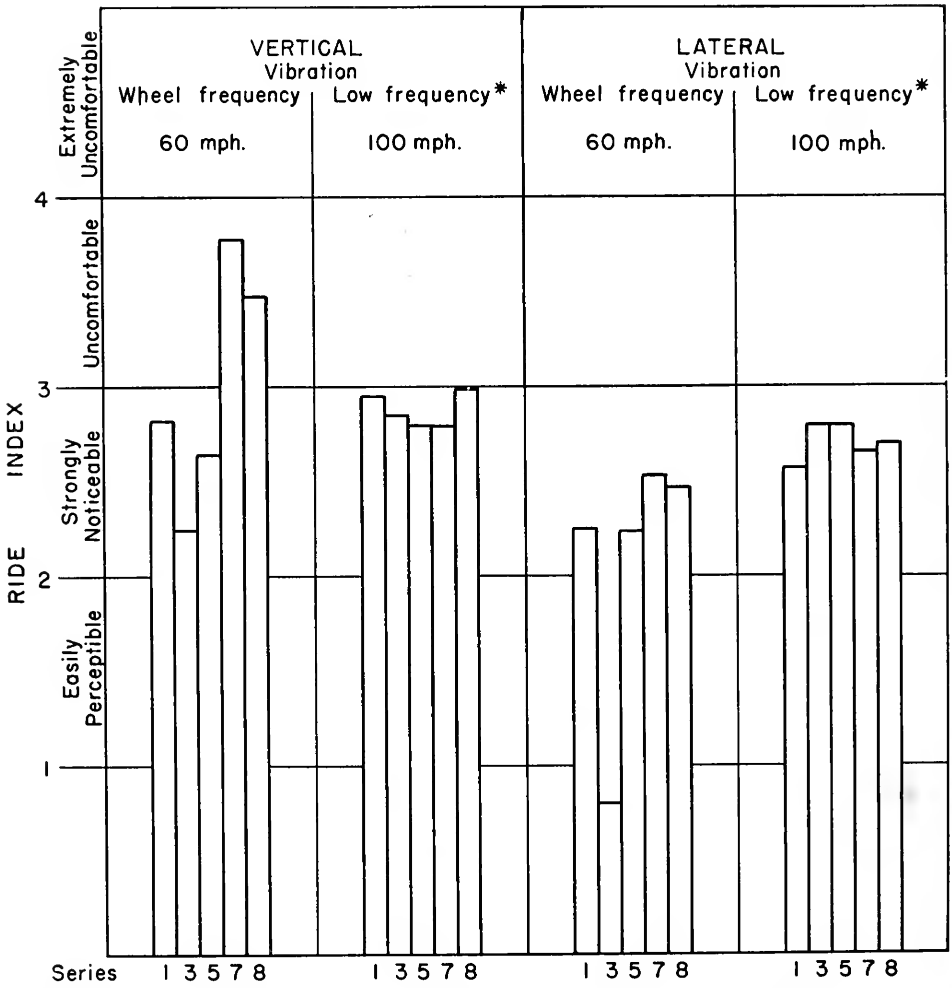


Note 1 - These vibrations are low frequency, caused by rail joint disturbances

Fig. 26 - EFFECT OF UNBALANCE ON RIDING QUALITY

VERTICAL and LATERAL vibration

Series 1 – "A" Wheels, as received
Series 3 – "A" Wheels, treads ground, balanced
Series 5 – "A" Wheels, treads ground, 10 lb. unbal. at 180° phase
Series 8 – "A" Wheels, treads ground, 5 lb. unbal. at 0° phase
Series 7 – "A" Wheels, treads ground, 10 lb. unbal. at 0° phase

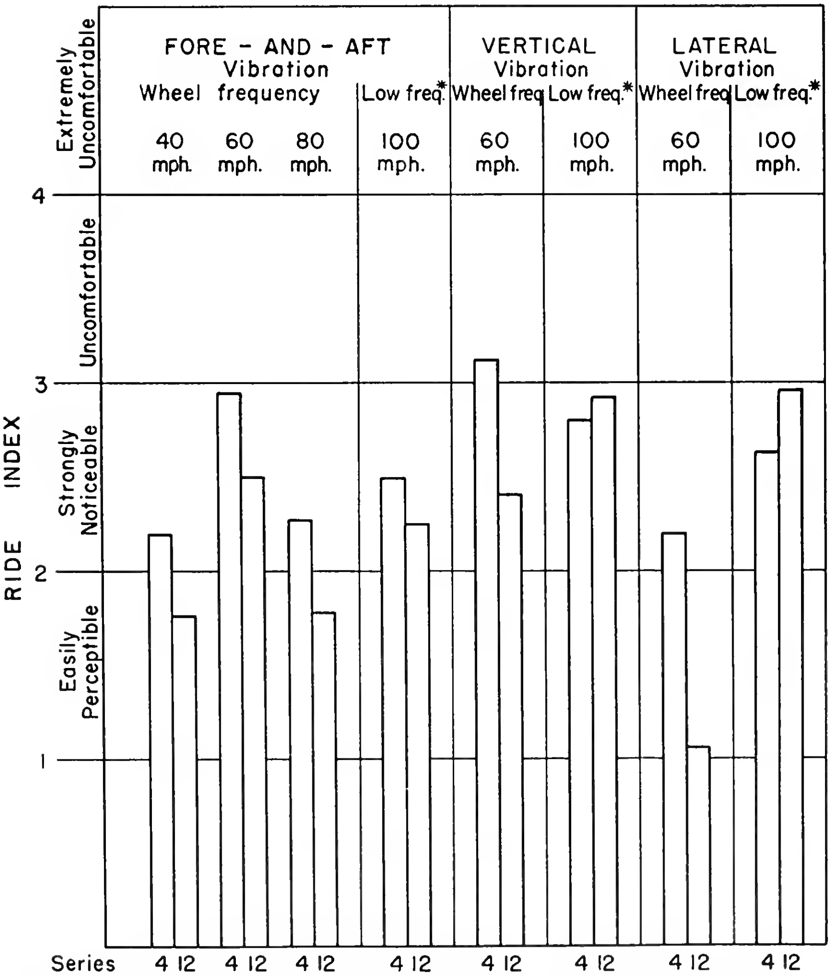


*Low frequency vibration is from rail joints and car body - spring movements

Fig. 30 – EFFECT OF MACHINING WHEELS ON RIDING QUALITY

FORE-AND-AFT, VERTICAL and LATERAL vibration

Series 4 – "B" Wheels, as received
Series 12 – "B" Wheels, treads ground, rims and hubs machined



*Low frequency vibration is from rail joints and car body-spring movements

A

(a) Static unbalance of even very small magnitude causes car body vibrations detrimental to riding quality, due to fore-and-aft oscillation of the wheel-axle assemblies. The maximum effect of static unbalance was usually produced at 60 mph. (the speed at which wheel frequency vibrations were resonant with car body flexural vibrations), and when the unbalance in the two wheel-axle assemblies in the test truck were in phase. When all four wheel-axle assemblies have progressed to certain phase relationships, the maximum effect of static unbalance should be produced at the critical speed.

(b) Dynamic unbalance does not materially influence riding quality, but if sufficiently large to overcome friction between the wheel and rail, it will cause oscillation of the wheel-axle assembly about a vertical axis. Slippage and oscillation will begin under conditions determined by the amount of dynamic unbalance, wheel load, train speed, condition of rail surface, and braking forces.

(5) The recommended maximum limit of total wheel unbalance is 2 lb. per wheel. This limiting condition was established by a calculation based on test results, which indicated that wheels with unbalance not exceeding this limit should not produce unsatisfactory riding quality resulting from wheel unbalance.

(6) This recommended 2-lb. limit of unbalance per wheel was exceeded by 30 percent of the group of 108 wheels surveyed. It is assumed that the group surveyed is typical of wheels as normally manufactured under AAR Specification M–107. Therefore, some treatment is indicated which would improve the balance of wheels as normally manufactured under this specification.

(7) Some degree of benefit should be derived from any improvement of wheel balance. In the range of 2 lb. total unbalance per wheel or greater, the riding quality is directly affected and truck oscillation will occur. Further improvement of balance to an amount below 2 lb. per wheel would reduce vibrations which could be amplified by resonance with the seat suspension, and which could cause noises by resonance with natural vibration frequencies of insecure or flexible objects (partitions, silverware, etc.). Such further improvement would also reduce any tendency of a wheel-axle assembly to oscillate about a vertical axis under extreme conditions of slippery rail and braking. Therefore, the level to which the wheels should be balanced should be determined by cost analyses of various degrees of balance improvement.

[Note: The discussion of the methods of improvement of wheel balance is not included in this synopsis due to space limitation.]

Effect of Machining Wheels on Riding Quality

Since machining wheels is a common method of improving the wheel balance, one car set of wheels (Car Set B) was used in four series of tests (Series 4, 9, 12 and 14), in which the wheels were progressively machined. These machining operations provided wheels which were typical of machined wheels found in service.

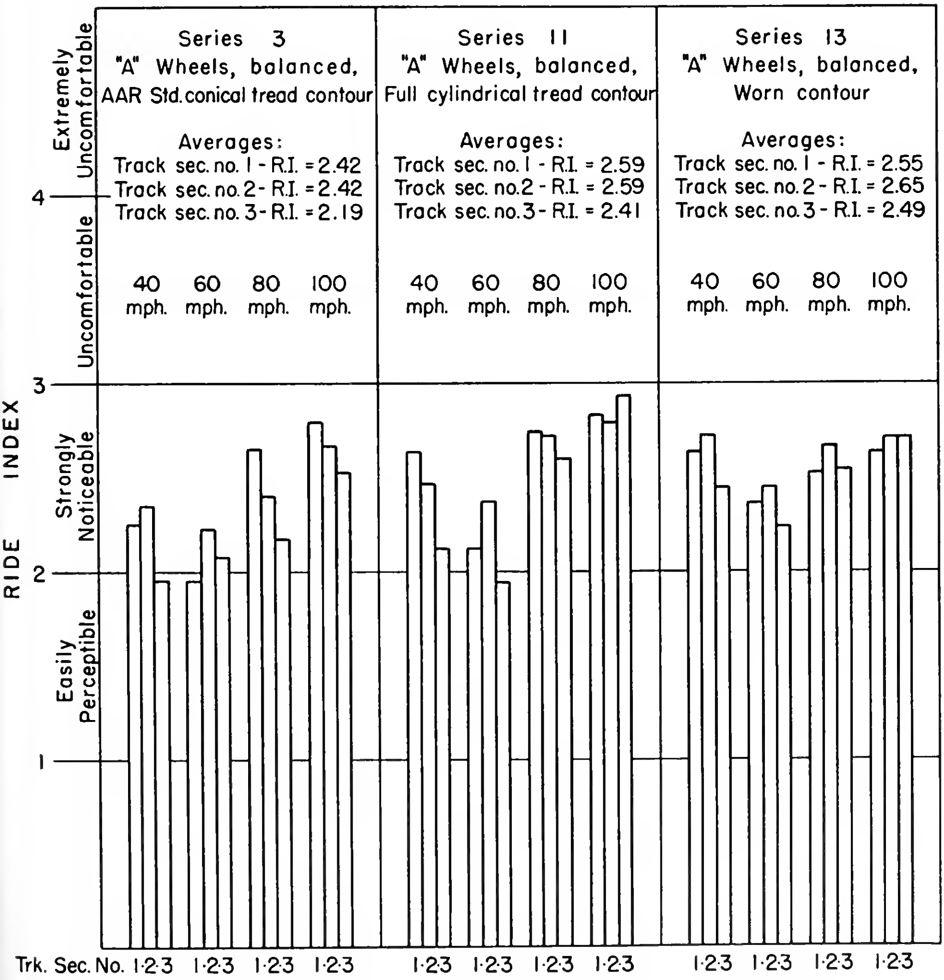
Wheel frequency vibrations at the car floor on the forward center plate are shown in Fig. 30 to be definitely improved as a result of machining the rims and hubs and grinding the treads. Ride Indices of 3 on the diagram ("uncomfortable" threshold) were caused by "as received" wheels, but were reduced to the "strongly noticeable" region by machining. Low-frequency vibrations in the vertical and lateral directions appear to be greater in the case of the machined wheels. However, it has been shown that these low-frequency vibrations are not particularly influenced by variations in wheel balance.

The results shown in Fig. 30 are based on tests of a car having wheels which had the character typical of machined wheels actually found in service. However, the relative improvement due to machining the average car set of wheels would be less than the amount shown because the original eccentricities of rims and hubs of the tested "B" wheels were appreciably greater than those found in the tread eccentricity survey.

Fig. 38 — EFFECT OF TRACK GAGE ON RIDING QUALITY

LATERAL vibration at low frequency*

Track Section No. 1 : 4'-8½" gage
Track Section No. 2 : 4'-8⅜" gage
Track Section No. 3 : 4'-8¼" gage



*Low frequency vibration is from rail joints and car body - spring movements

The following conclusions relate to the effect of machining wheels on riding quality:

(1) The effect of machining wheels on riding quality was shown to be an improvement proportional to the improvement in wheel balance.

(2) Machining wheels caused an average improvement in wheel balance, in the case of the "B" set of wheels, of the following amounts:

Grinding the treads = 0.10 lb. per wheel
Machining the rims and rim fillets = 0.40 lb. per wheel
Machining the hubs and hub fillets = 0.71 lb. per wheel
Machining the plates = 0.01 lb. per wheel

(3) Machining rims and hubs should cause an improvement in wheel balance in wheels chosen at random from the wheel survey, of approximately the following amounts:

Machining the rims and rim fillets = 0.28 lb. per wheel
Machining the hubs and hub fillets = 0.29 lb. per wheel

(4) Machining the rims and rim fillets, and the hubs and hub fillets of all wheels which have unbalance exceeding 2 lb., to within 0.010 in. concentricity with the treads, should reduce total wheel unbalance to approximately the desired 2-lb. limit as established earlier.

Effect of Wheel Tread Eccentricity on Riding Quality

The eccentricity of a wheel tread, as defined in this report, is the total radial deviation of the tread surface at the taping line as the wheel is rotated in the axle bearing.

The tread eccentricity of 72 wheels "as received" in the survey is summarized as follows:

Range of Tread Eccentricity—In.	*Percent of Wheels*
0.000 through 0.009	11.1
0.010 through 0.019	52.8
0.020 through 0.029	26.4
0.030 through 0.041	9.7
0.018 in. eccentricity, average	

Evaluation of the effect of tread eccentricity on the riding quality of a passenger car is based on two test series—Series 3 with 0.004 in. average wheel eccentricity, and Series 15 with 0.035 in. average eccentricity. In both series all wheels were balanced and had the AAR standard conical tread contour.

The extreme amount of tread eccentricity of Series 15 as tested is to cause somewhat higher Ride Indices at wheel frequency, but not to produce a definite effect on the low-frequency vibrations. The effect on riding quality of 0.035 in. average tread eccentricity per wheel was comparable to the effect of approximately 1 lb. total unbalance per wheel with random mounting. Evidence for this fact is offered as follows:

	Ecc. Tread In.	*Fore-and-Aft*		*Vertical*		*Lateral*	
		R.I.	*Lb. Avg. Unbalance*	*R.I.*	*Lb. Avg. Unbalance*	*R.I.*	*Lb. Avg. Unbalance*
Series 3	0.004	1.80	0	2.24	0	0.80	0
Series 15	0.035	2.10	0.7*	2.50	0.9*	2.04	1.8*
Series 1	0.013	2.71	2.1	2.82	2.1	2.25	2.1

---

* Equivalent to 1.1 lb. wheel unbalance based on relative values of Ride Indices.

Wheel frequency vibrations for both series are shown not to approach the "uncomfortable" region (R.I. = 3 to 4) in any direction of vibration, even at the critical speed (60 mph.). The greatest increase of Ride Index due to eccentricity was found to be that based on vertical wheel frequency vibration at 60 mph. This increase was from 2.24 (concentric wheels) to 2.50 (eccentric wheels). A definite increase in Ride Index is shown for lateral vibration at wheel frequency at 60 mph.. but this increase is within a range which is not very important to riding quality.

The following conclusions have to do with the effect of wheel tread eccentricity on riding quality.

(1) The effect on riding quality of 0.035 in. average tread eccentricity was comparable to the effect of 1 lb. total unbalance per wheel, all other wheel conditions being the same.

(2) The extreme value of average tread eccentricity as tested represents a condition found in about five percent of individual wheels in the survey, and probably found in less than one percent of car sets of wheels as received from the manufacturer. Therefore, considering the relatively minor effect of the extreme amount of eccentricity as tested, it is considered that wheel tread eccentricity in wheels as normally manufactured is not an important factor in riding quality.

Effect of Tread Contour on Riding Quality

Evaluation of the effect of tread contour on riding quality is based on the following series of tests with the "A" set of wheels.

Series 3: AAR standard conical tread contour.
Series 11: Full cylindrical tread contour.
Series 13: "Worn" contour of AAR standard conical tread.

In these three series of tests, the wheels were balanced to eliminate the variable of unbalance from the test results. Since variations in the tread contour should affect the lateral vibrations at frequencies below wheel frequency, only low-frequency lateral vibrations are compared. In all cases, Ride Indices are minimum at 60 mph. and maximum at 100 mph. These Ride Indices lie within the "strongly noticeable" region at all speeds.

The full cylindrical tread contour produced Ride Indices which were slightly, but consistently, higher than those produced by the AAR standard conical tread contour. The small margin of improvement of the AAR standard tread over the cylindrical is considered to be relatively important because:

(1) It was effective in some degree at all speeds, and at all phase relations between the wheel-axle assemblies, whereas vibrations due to unbalanced wheels are important only at a narrow speed range and when the wheel-axle assemblies attain certain phase relationships; and

(2) Lateral low-frequency vibrations affect the passenger walking or reclining, and cause spillage of beverages.

The "worn" tread contour produced Ride Indices which were appreciably higher than those produced by the AAR standard conical tread contour at 40 and 60 mph., but the Ride Indices were approximately the same for the two contours at higher speeds.

The following conclusions relate to the effect of tread contour on riding quality:

(1) The full cylindrical tread contour consistently produced somewhat poorer riding quality than did the AAR standard conical tread contour.

(2) The "worn" tread contour was found to produce slightly poorer riding quality than did the AAR standard conical tread contour.

Effect of Track Gage on Riding Quality

Evaluation of the effect of track gage on riding quality is based on the following tests with the "A" set of wheels:

Series 3: AAR standard conical tread contour.
Series 11: Full cylindrical tread contour.
Series 13: "Worn" contour of AAR standard conical tread.

In these three series of tests, the wheels were balanced to eliminate the variable of unbalance from the test results. Since variation in track gage should affect the lateral vibration at frequencies below wheel frequency, only low-frequency lateral vibrations are compared.

Fig. 38 shows the effect of track gage on riding quality. In practically all cases, Ride Indices are minimum at 60 mph. and maximum at 100 mph. These Ride Indices lie within the "strongly noticeable" region at all speeds.

The following conclusions pertain to the effect of track gage on riding quality:

(1) No difference in riding quality was found between the 4-ft. 8½-in. standard track gage section and the 4-ft. 8⅜-in. track gage section.

(2) The track section with the ¼ in. tight gage (4 ft. 8¼ in.) produced a slight improvement in the riding quality.

Acknowledgment

The project was under the general direction of G. M. Magee, research engineer, and J. R. Jackson, mechanical engineer, Association of American Railroads. Randon Ferguson, electrical engineer of the research staff, AAR, was in charge of the testing, and G. U. Moran, former assistant mechanical engineer of the staff supervised the preparation and checking of the wheels and shop work on the car during the tests. The report was prepared by Mr. Ferguson, assisted by W. E. Baillie, mechanical assistant.

The Budd Company, the Pennsylvania Railroad, and the Bear Manufacturing Company cooperated very effectively in providing equipment and personnel for the tests.

R. N. Janeway, head of the dynamics research department, Chrysler Corporation, cooperated by contributing advice and extensive general technical data which was used in the development of methods and analysis used in this report.

S. G. Guins and J. A. Kell, of the office of research consultant, Chesapeake & Ohio Railway Company, cooperated by providing advice in various phases of the preparation of the report.

Steel and Timber Pile Tests

West Atchafalaya Floodway—New Orleans, Texas & Mexico Railway

Advance Report of Committee 8—Masonry

1. Digest

This report embraces a description and analysis of tests made on hollow steel and timber bearing piles in the swamps of southern Louisiana on the New Orleans, Texas and Mexico Railway. The tests were made during the driving of the piles, and under static loading of the piles, to shear failure in some cases, and in others to the practical limit of the loading. The tests were made at the request and expense of the Corps of Engineers, U. S. Army, in accordance with an agreement between the N.O.T.&M. and the United States of America.

Single hollow steel piles, as well as a group of nine hollow steel piles, were tested to failure or near failure by placing large concrete blocks on especialy built loading platforms on top of the piles.

The stresses were determined in the steel piles at 5-ft. intervals of length by placing SR–4 wire gages on the inside of the piles, and recording the strains during driving by oscillograph recordings on sensitized photographic paper. The strains were recorded during the static loading of the piles by a portable strain indicator.

Single timber piles, as well as two groups of nine timber piles each, were tested to shear failure in the same manner as that employed in testing the steel piles, but no effort was made to record the dynamic strains or the strains along the length of the pile. However, strain gages were used to determine the distribution of load to the various piles of the group.

The results of these tests are of particular interest to the engineering profession for they indicate how the load, both dynamic and static, was transferred from the pile to the penetrated material, as well as how the load was distributed to the individual piles of the various groups.

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

1. The measured dynamic stresses in the top of the pile became greater as resistance to driving increased. The total stress was about the same at all sections of the pile above the ground line, but decreased below the ground line. Only a relatively small percentage of the dynamic stress was observed at the point of the pile in penetrating the ground, even in piles driven to refusal (see Figs. 4 to 7, incl.).

2. The static weight of the pile driving hammer ram was 5000 lb., but this weight with a 3-ft. stroke developed a measured dynamic force during driving of over 20 times that amount in the 65-ft. friction pile (see Fig. 4), and over 30 times that amount in the 110-ft. end bearing pile (see Fig. 6).

3. The static load carried by the steel friction piles driven into clay depended almost entirely upon the shear between the pile and the penetrated material for transfer to the surrounding material. At the termination of the test period the center of bearing resistance for these piles was determined as at about half the penetration of the pile (see typical Fig. 16).

4. The long steel pile driven into a layer of sand to refusal, after penetrating very deep clay having a high moisture content, continued to act principally as a friction pile under the short-time loading, which was, however, considerably longer than any duration of a moving live load, with only about 16 percent of the total load carried by end bearing. Unfortunately the test could not be continued to show the effects of change due to long duration of loads.

5. The shearing forces between the surfaces of the steel piles and the penetrated material became quite large for single piles, attaining a value of 1980 lb. per sq. ft. for the 65-ft. friction pile (Fig. 23), and 3050 lb. per sq. ft. for the 110-ft. fluted pile (Fig. 25). These high shear values occurred for only a relatively short length of the pile and were a maximum just below the ground line.

6. The magnitude of the shearing forces for the individual piles of the group was considerably below that occurring for the single 65-ft. pile, attaining maximum values varying from 810 lb. per sq. ft. to 1050 lb. per sq. ft. (see Figs. 17, 19 and 21). The high shearing forces occurred over a much greater length of the pile than that for the single pile and attained a maximum at a much greater depth.

7. The single straight 65-ft. steel pipe pile failed under a total static load of 140,000 lb. which produced an average shear between the pile surface and the penetrated material of 740 lb. per sq. ft. The single tapered steel pile of the same length did not fail until a total load of 196,000 lb. was attained, resulting in an average shear value of 1095 lb. per sq. ft. (see Table 11).

8. There was considerable variation in the magnitude of the load required to produce shear failure in single timber piles driven in the same locality. The load required to produce failure in four 65-ft. timber piles varied from 90,000 lb. to 170,000 lb. (see Table 13). It appears that the number of blows required to drive a single timber friction pile the last foot of penetration is a poor criteria of its ultimate carrying capacity.

9. The distribution of the static load to the various piles of the group, both steel and timber, was fairly uniform, with the center pile carrying its approximate share of the load (see Figs. 26, 30 and 31). This uniform distribution was especially true within the usual design loads placed on the piles.

2. Foreword

As a part of the Mississippi River Flood Control, a high-level crossing is being constructed by the New Orleans, Texas and Mexico Railway over the West Atchafalaya Floodway in accordance with an agreement between the railway and the United States of America, under the jurisdiction of the Mississippi River Commission and the Corps of Engineers, U. S. Army. The construction of the high-level crossing necessitated a relocation and raise in grade of about 7 miles of the main-line track extending from a point near Cortableau to Krotz Springs, La. (see Fig. 1). The change in line required the construction of three bridges of 1000 ft., 2500 ft. and 4000 ft., respectively, a total of 7500 ft. of bridges, consisting of reinforced concrete T beam spans 31 ft. 3 in. long supported by reinforced concrete bents (except at bridge ends and over borrow pits or streams) with an "H" shaped base on 24 timber piles. This particular part of the country is swamp lands (see Fig. 2), consisting of about 90 ft. of clay and silty clay over a deep bed of sand, and all bridge superstructures must be supported on piles to avoid excessive settlement.

The contract between the railway and the United States of America called for a series of pile tests to determine the proper design bearing values for the foundation

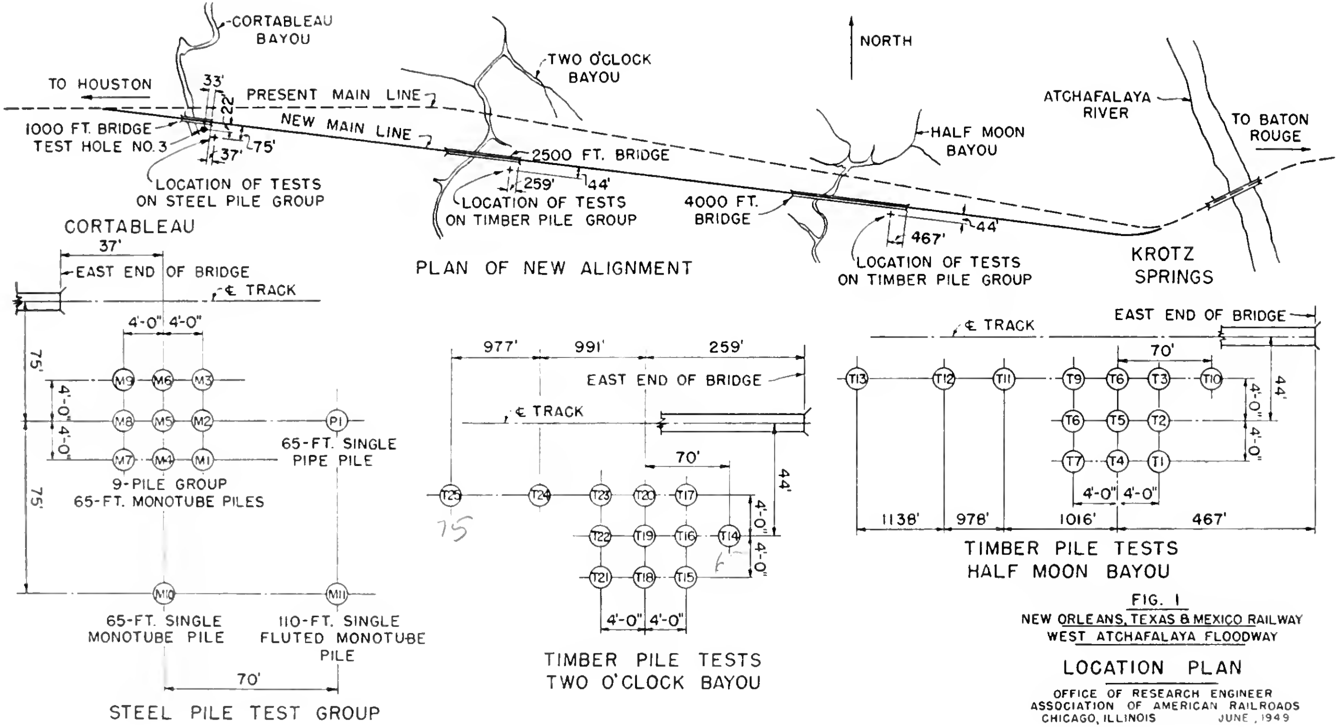


FIG. 1
NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
LOCATION PLAN
OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS JUNE, 1949

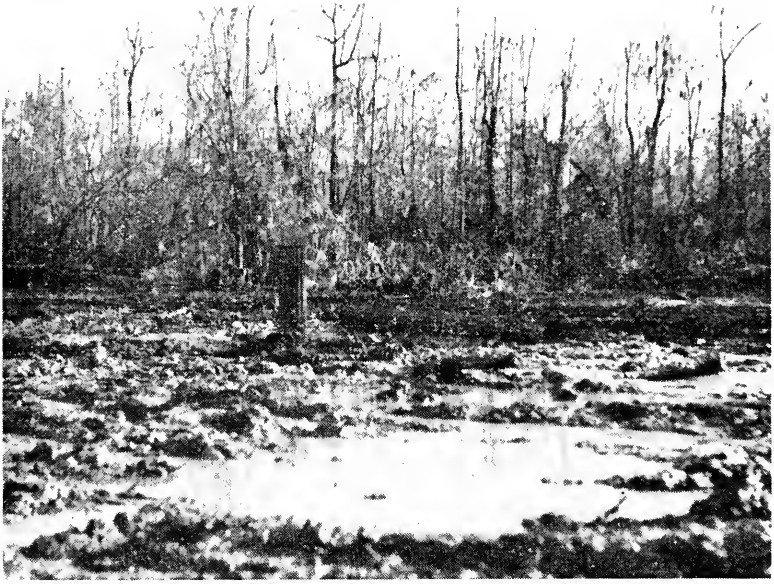


Fig. 2. Location of test piles in swamp land.

piles. The pile tests included static loading on two 9-timber pile groups with a penetration of 60 ft., one 9-hollow tapered steel pile group with 60-ft. penetration, one single hollow pipe pile with 60-ft. penetration, one single hollow tapered steel pile with 60-ft. penetration, one single fluted hollow tapered pile with about 91-ft. penetration, driven to refusal in a bed of medium coarse sand, and seven single timber piles with 60-ft. penetration.

The development of the program for the loading tests indicated that it would be desirable to determine how the load on a pile is distributed to the penetrated material at various depths below the ground line, and how the total load is distributed to the individual piles in a group. Consequently, it was decided to place strain gages on the inside of the steel piles to determine the longitudinal strains in the piles at 5-ft. intervals under both dynamic and static loads.

The construction of the high-level crossing, including all the bridges and the conduct of the pile tests, was handled by the N.O.T.&M. Ry., under the general direction of C. S. Kirkpatrick, chief engineer of the Missouri Pacific Lines, with Roscoe Owen, construction engineer, in direct charge. Arrangements were made with the research staff of the Association of American Railroads, under the general direction of G. M. Magee, research engineer, to conduct all strain gage readings. The instrumentation, analysis of data and preparation of the report were in charge of E. J. Ruble, structural engineer, research staff, AAR.

3. Instrumentation

The instruments used in these tests for the determination of both the dynamic and static strains in the piles were of the electrical type and consisted of the following:

a) Portable Strain Indicator (Static Strains)

The portable strain indicator is a self-contained, battery-powered instrument, containing two legs of an electrical bridge circuit, oscillator, amplifier, null balance meter, and a dial for indicating strains in micro-inches resulting from static loads.

The self-contained oscillator in this instrument provides a 1000 cycle per second current of about 4 volts. The unbalanced voltage in the bridge circuit is fed to an amplifier through a step-up transformer, so that the power output is sufficient to drive the indicating meter. The amplifier is a resistance-capacity, coupled vacuum tube type. No gain control is provided.

The output circuit from the amplifier contains a phase discriminator, which enables the operator of the instrument to distinguish tensile from compressive stresses, since one deflects the needle of the meter in one direction, whereas the other produces a deflection in the opposite direction.

The dial on the indicator is graduated in micro-inches so that by assuming a modulus of elasticity of 30,000,000 psi. for the steel, a dial division indicates a unit stress of 30 psi. A periodic check on the accuracy of this stress factor is made by comparing the readings secured on a standard bar under variable known loads.

b) Wire Resistance Gages (Both Static and Dynamic Strains)

The wire resistance or SR-4 gages used in these tests for both the static and dynamic readings consist essentially of a grid of fine resistance wire about 0.001-in. diameter cemented to a piece of special paper. The wires are usually made of an alloy, such as Advance, Copel or Constantan, consisting of about 45 percent nickel and 55 percent copper. The gage is fastened to the steel by lacquer cement which is absorbed by the special paper, so that the wire and paper are thoroughly bonded to the surface of the steel. The gage is then coated with Petrosene wax to keep out all moisture.

The gage cemented to the steel in which the strain is to be measured, called the indicating gage, is placed in one arm of an electrical bridge circuit, while a similar gage, or balancing gage, is placed in the other arms of the circuit. A strain in the steel produces the same strain in the wires of the indicating gage, resulting in a resistance change in this gage. In measuring dynamic strains, a carrier of 2 volt, 5000 cycles per second current is applied to the bridge circuit. A strain in the steel of 0.0005 in. over a 1-in. gage length, which is equivalent to a stress of 15,000 psi., produces a change of about 0.001 volt in the bridge circuit.

c) Power Unit (Dynamic Strains)

The 2-volt high-frequency carrier current of 5000 cycles per second for the bridge circuit, and a regulated direct current plate supply for the amplifiers, are supplied by an electronic power unit operating directly from 110-volt 60-cycle current. The power unit regulates the output current over reasonable changes in the input voltage and load changes.

The 110-volt, 60-cycle input circuit for these tests was provided by a 2500-watt Homelight 2-cycle gasoline engine generator unit.

d) Amplifier Unit (Dynamic Strains)

The output from the wire resistance indicating gages is insufficient to swing the 7-ohm magnetic galvanometers in the oscillograph, therefore, it is necessary to amplify this output a considerable amount. The amplifier unit has 12 separate amplifiers in one cabinet, with a panel for their control and calibration.

The amplifiers are the carrier-wave type, and the high frequency current of 5000 cycles per sec. is applied to each bridge circuit. The bridge circuits are then balanced for capacity and resistance by the amplifiers' control panel. The change in inductance is neglible. The amplifier alternating current output from the bridge circuit is rectified by a discriminator circuit which makes the output phase sensitive, so that a tension in the steel will deflect the galvanometer in one direction and compression in the opposite direction.

A current output of 50 milliamperes is available from each amplifier, and the sensitivity is high enough so that a stress in the steel as low as 1000 psi. will deflect the light from the galvanometer mirror about 1 in. This means that the strain gage equipment is capable of magnifying the actual strains in the steel about 30,000 times.

The amplifiers have a flat frequency response up to 1500 cycles per sec., which is above the frequency response of the galvanometers in the oscillograph, and well above any frequency encountered in railroad structures.

e) Oscillograph (Static or Dynamic Strains)

The oscillograph is a light-proof case with a row of 12 magnetic galvanometers at one end, a light source and focusing prisms in the center, and a moving film or sensitized paper, 10 in. in width, at the other end.

The magnetic galvanometer consists of a small mirror, oil damped, suspended on two wires in a permanent magnetic field in such manner that the mirror rotates in proportion to the amount of current flowing through the galvanometer. In general, a current of 4 milliamperes is required to deflect the light from the mirror 1 in. on the film. The galvanometers have a flat response for frequencies up to 800 cycles per sec., with a 10-percent loss in response at 1000 cycles per sec. In other words, the mirror in the galvanometer will rotate essentially the same amount under a current change applied 800 cycles per sec., as it does under the current change applied statically.

The oscillographs are so designed that either film or sensitized paper can be used for the recording of the galvanometer deflections. The film is very sensitive to light and thus can be run at high speeds to record rapid changes in stresses. The disadvantages of the film are that it is expensive, hard to handle, and comes in shorter lengths; thus it is soon used up at high film speeds. The sensitized paper comes in rolls 200 ft. long, but it is not sensitive enough to record excessively rapid changes in stress.

f) Switching Box (Static Strains)

The switching box contains a series of 10-point silver-coated selector switches, and this arrangement enables the operator to complete a circuit from the strain indicator to each gage by just turning a knob to the correct switch point.

g) Installation of Gages

The installation and wiring of the strain gages on the steel piles were done principally in the shops of the pile fabricator. The basic arrangement of the gage locations is shown in Fig. 3, which is typical for all the single steel piles, M10, M11 and P1, and three piles of the 9-pile group, M1, M4 and M5. The remaining six piles of the 9-pile group, M2, M3, M6, M7, M8 and M9 only, had four gages on the outside of each pile at the top. The gages on the outside of the six piles were mounted in the field after the piles had been driven.

In general, the piles with the interior gages had four gages at Sections A–A and B–B at the tip end of the pile, and four at Section M–M at the butt end. Two gages were then placed at each of the remaining sections, but alternate sections were rotated 90 deg. as shown. The principal reason for using the four gages at the sections shown was to determine any high bending stresses resulting from the eccentricity of the load.

Since the diameter of the piles was too small to permit a man to mount the gages from the inside, it was necessary to drill a 4-in. diameter arm hole in the pile at a point 6-in. above each section and at 45 deg. from the gage position. After completing the work on the gages, the 4-in. diameter plate was welded back in the hole and the surface ground smooth. The arm holes were staggered at 180 deg. to eliminate any

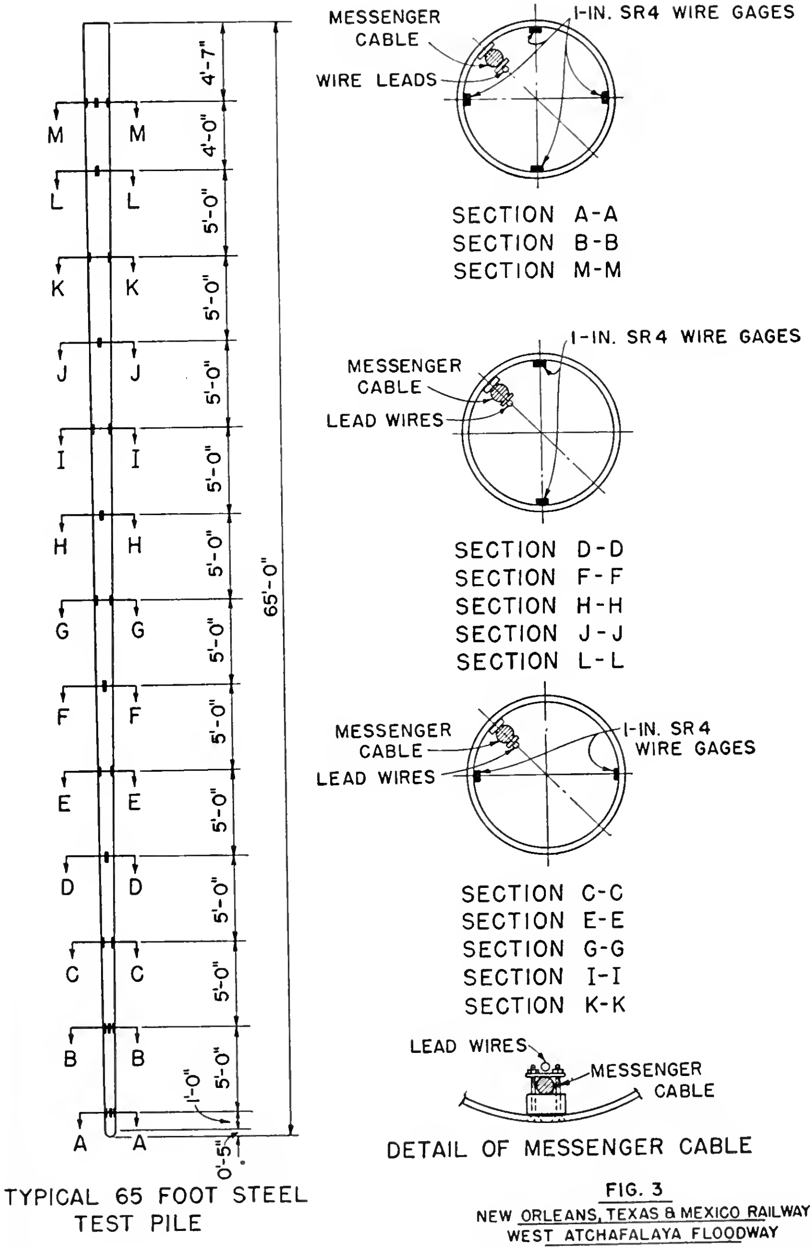


FIG. 3

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

TYPICAL LOCATION OF GAGES

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CHICAGO, ILLINOIS JUNE, 1949

warping of the pile due to welding. The surface of the steel at the gage locations was kept cool by ice water, so that the intense heat resulting from the welding of the arm holes would not harm the gage installations.

In an effort to secure stable zeros over a long period of time, the following procedure was followed in mounting the gages:

1. The steel surface was ground smooth by a portable grinder and then finished with emery cloth.
2. The steel surface was kept at a temperature of about 200 deg. F. to free it from all moisture for about 24 hours by installing a series of light bulbs inside the piles.
3. The steel surface was cleaned thoroughly with acetone.
4. The steel was allowed to cool to about 120 deg. F., or just below a point where the acetone solvent in the cement forms bubbles.
5. The gages were cemented to the steel surface with "Duco" cement.
6. The cement was allowed to harden for a short period before the heat lamps were again turned on. However, the surface was never allowed to reach room temperature.
7. The heat was kept on the gages until the resistance to ground, as indicated by an insulation meter, was about 1000 megohms. This usually required keeping the lights on about 12 hours.
8. The leads were soldered to the gages and then both the gages and soldered connections were completely covered with melted petrosene wax. The entire installation was then allowed to cool to room temperature.
9. Each circuit consisting of lead wires and gage was then checked by the insulation meter for resistance to ground. The average resistance was about 100 megohms, which was considered satisfactory.

h) Wiring

It was realized that the driving of the piles would produce considerable vibration of the lead wires, resulting in possible breakage if they were not firmly anchored in place. To eliminate the possibility of breakage, all the wires leading to the gages were placed in a group and then securely taped to the ⅜-in. messenger cable, as shown in Fig. 3. The ⅜-in. stranded wire messenger cable was held in tension by cross-frames at the tip and butt ends of the pile and was fastened to the pile at 5-ft. intervals by the clamping device shown in Fig. 3.

The complete installation of wires and gages was made with single-conductor No 18, stranded copper wire with waterproof plastic (Gencaseal) insulation. A separate common wire was used for each group of four gages.

The general plan of assembling and installing the wires was to lay the proper length wires on a long work table. For example, the five wires—four gage and one common wire—for the gages at Section A–A, Fig. 3, were first laid out, and were of sufficient length to extend about 5 ft. past the butt end of the pile. The wires for the gages at Section B–B were then laid out, and this procedure was followed until all the wires were laid out. The wires were then bound securely together with linen tape, except for the 2-ft. pig-tails for each gage connection. The linen tape was then impregnated with an insulating material.

The entire group of wires was then fastened by friction tape at short intervals to the messenger cable which had previously been placed in tension. When this assembly was completed, the wires and messenger cable were drawn through the pile and the cable was fastened to the cross-frames at the tip and butt ends of the pile. The cable was

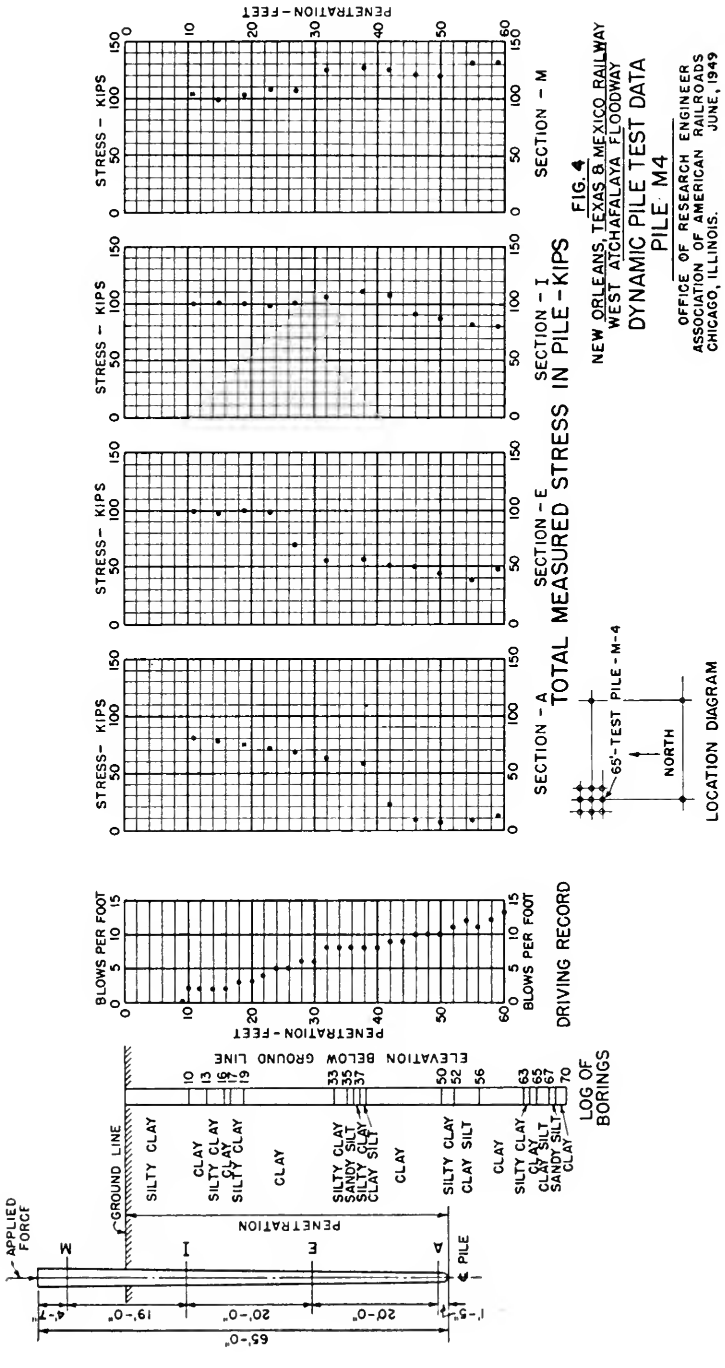

FIG. 4

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
DYNAMIC PILE TEST DATA
PILE M4

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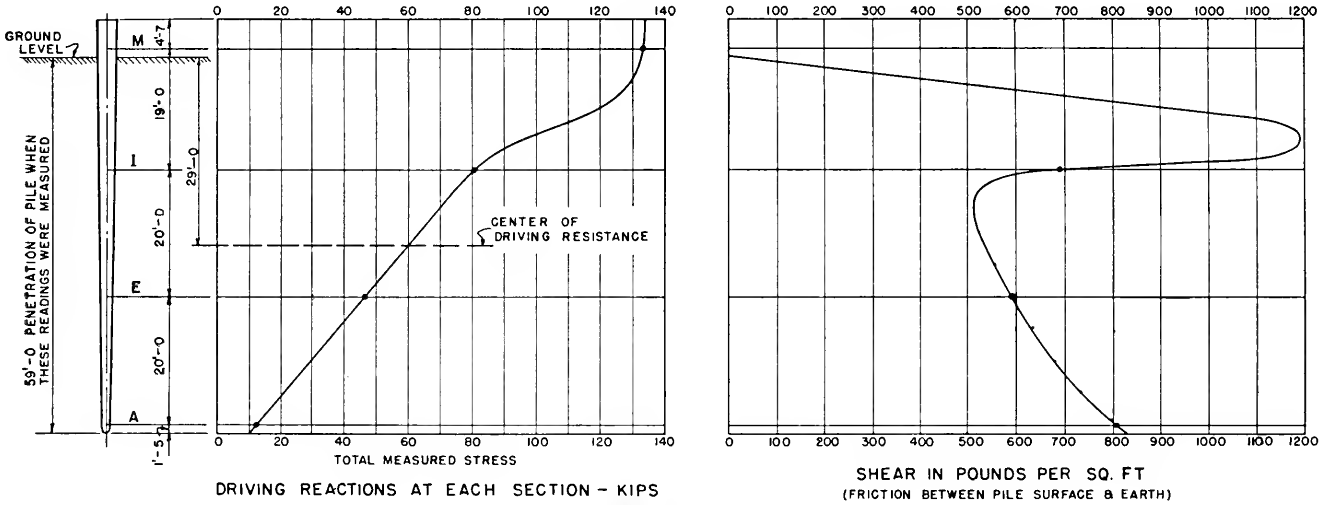

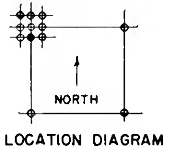

FIG. 5

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
DYNAMIC PILE TEST DATA
PILE M4
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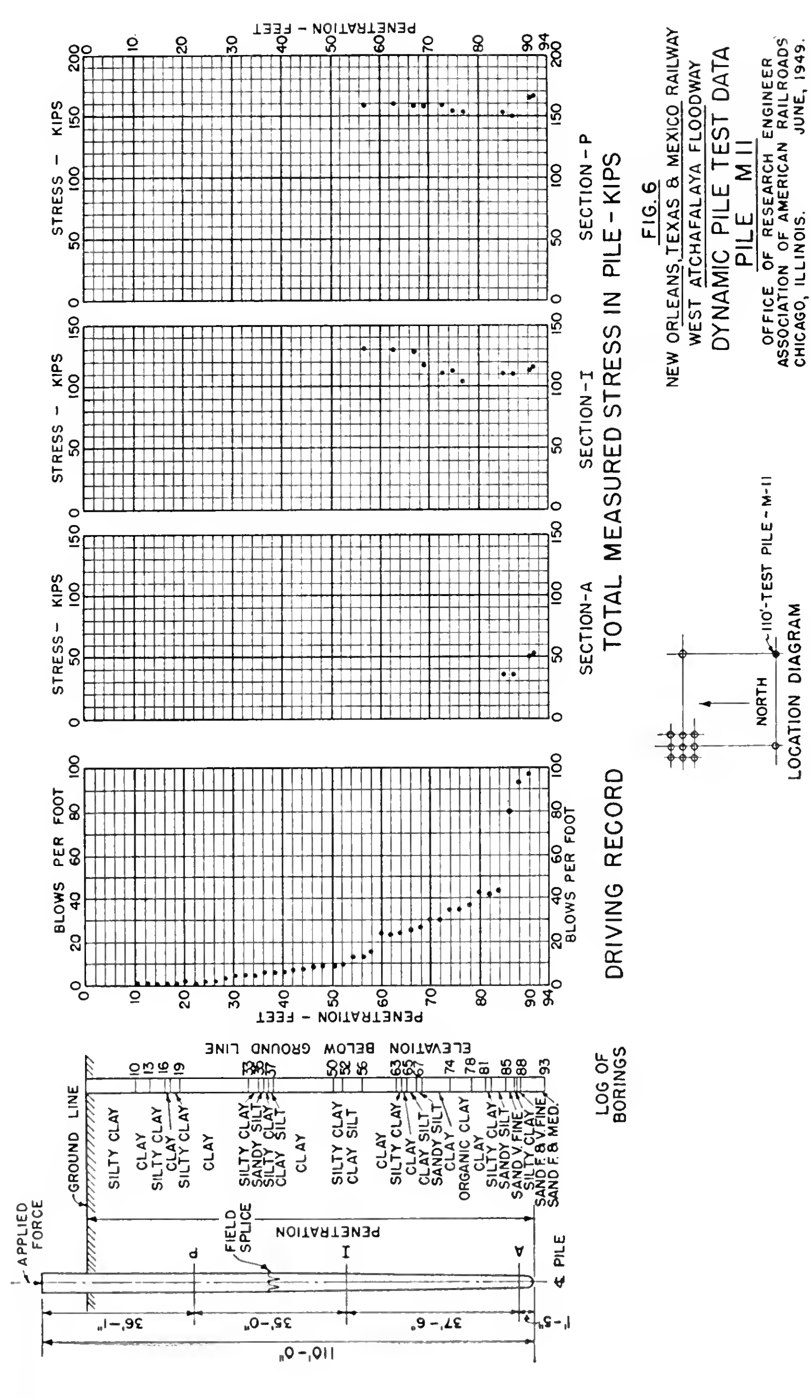

FIG. 6

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
DYNAMIC PILE TEST DATA
PILE M11

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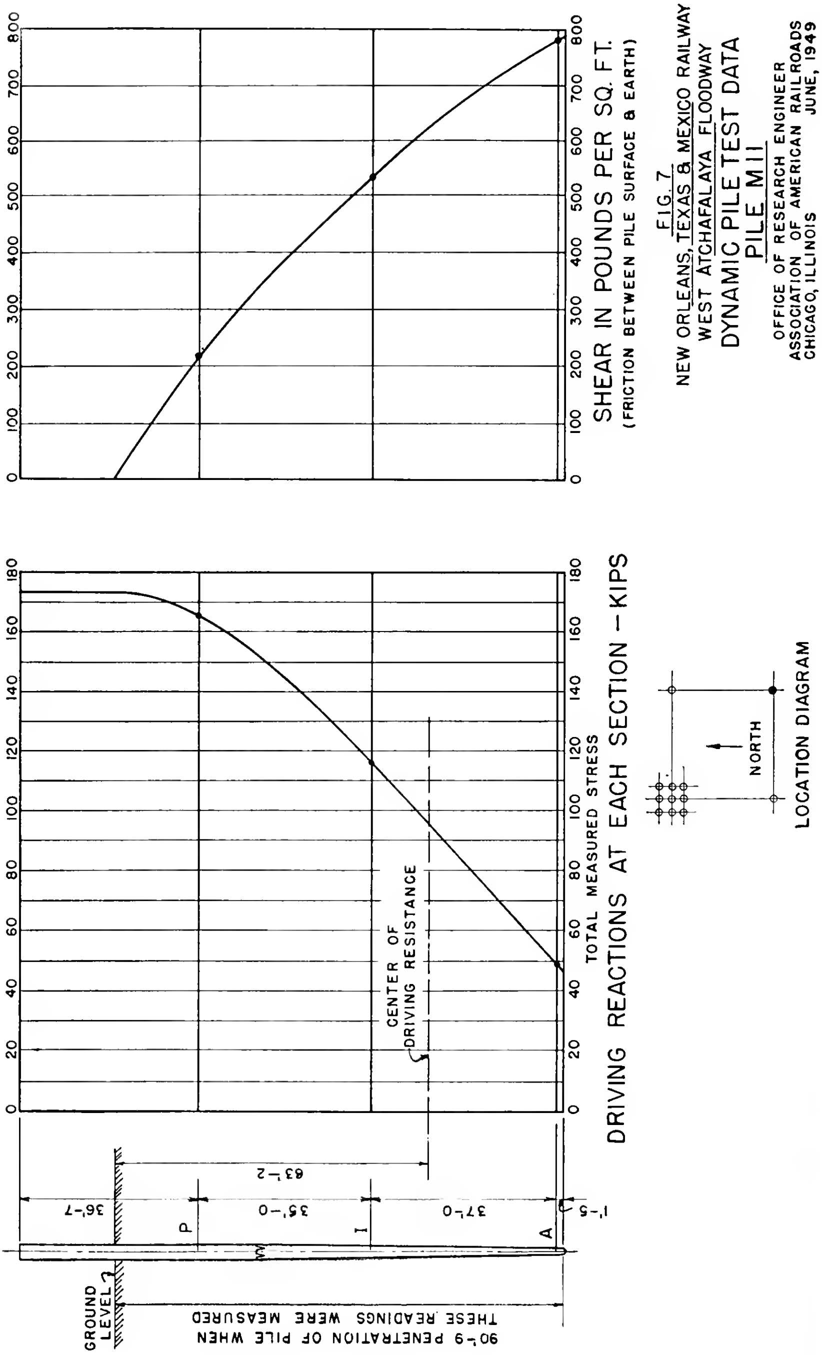

FIG. 7

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
DYNAMIC PILE TEST DATA
PILE M11

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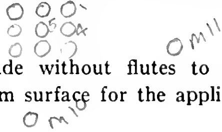
then placed in tension and securely fastened to the pile at 5-ft. intervals by the clamping device shown in Fig. 3. The 2 ft. of lead wire extending from the group was then cut to the proper length and soldered to the gages. The gage, soldered connection, and short lead wire were then waxed with petrosene, as previously explained.

Upon completion of the wiring and installation of the gages, the 5 ft. of wires extending past the butt end of the pile were coiled inside the pile and a cover placed over the butt end. The piles were then shipped by freight to the test site.

4. Test Piles

The steel piles tested were located close to the Cortableau Bayou (see Fig. 1) and consisted of the following vertical piles:

1. Single 65-ft. Monotube pile—Type E, No. 7 gage, tapered but not fluted, with a tip diameter of 8 in. and a butt diameter of 16½ in. Instr. M10
2. Single 110-ft. Monotube pile—Type FN, No. 3 gage, tapered and fluted, with a tip diameter of 8 in. and a butt diameter of 15⅞ in. This pile was shipped in two sections, each 55 ft. long. Instr. M11
3. Single 65-ft. pipe pile, ⅜ in. in thickness, neither tapered nor fluted, with a tip and butt diameter of 12¾ in. F1
4. Nine 65-ft. Monotube piles in a group at 4-ft. centers—Type E, No. 7 gage, tapered but not fluted, with tip diameters of 8 in. and butt diameters of 16½ in. M1, M4, M5 Instr. M1 - M9



The 65-ft. Monotube piles were especially made without flutes to simulate the shape of the timber piles and afford a smooth uniform surface for the application of the gages.

The piles were driven with a Vulcan No. 1 single-acting steam hammer with about 120 to 130 lb. steam pressure at approximately 53 blows per minute. The piles penetrated from 7 to 12 ft. under their own weight and the weight of the hammer. The driving record for the 110-ft. pile M11 is shown in Fig. 6, while the driving record for pile M4, shown in Fig. 4, is typical for the 65-ft. piles. In general, the 65-ft. piles were driven in about 10 min. The 9 steel piles of the group were driven in the following order: M7, M8, M9, M6, M3, M5, M2, M4 and M1.

The 110-ft. pile M11 encountered heavy driving at about 85-ft. penetration, and the number of blows per foot increased from 45 blows at this depth to 435 blows from 90 ft. to 91 ft. The driving was stopped at a penetration of 91 ft. 2½ in. as 100 blows were required to drive the pile the final ½ in. It should be pointed out that in usual construction the piles would not be subjected to this heavy driving, but for this particular test pile every effort was made to drive the pile to refusal.

Since the 110-ft. pile M11 could not be driven its full depth, it was necessary to cut it off about 5 ft. above the ground to erect the loading platform preparatory to loading. The removal of the top 15 ft. of the pile eliminated the top section having the four gages.

Upon completion of the driving of the steel piles, the 9-pile group was capped with a 12-ft. by 12-ft. by 3-ft. reinforced concrete cap or loading platform, with the piles extending 7½ in. into the cap in preparation for the concrete loading blocks (see Fig. 8). The single piles were equipped with a ring plate around the pile about 8 ft. below the top, supported by vertical flat stirrups fastened to a loading plate on top of the pile (see Figs. 9 and 10). The purpose of the ring plate and stirrups was to take the vertical and horizontal components of the load resulting from the deflection of the long concrete loading blocks or any eccentricity of the load.

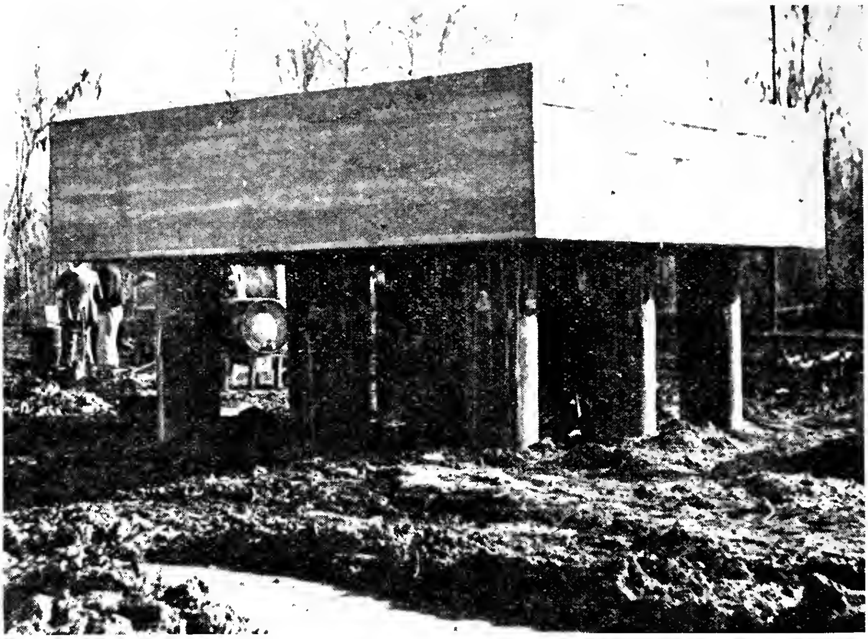


Fig. 8. Reinforced concrete cap on 9-pile group.

The steel pipe and tapered steel piles were all driven with shoes welded to the tip end, and all tests were conducted without any concrete on the inside of the piles. The piles were all waterproof and remained dry on the inside for the duration of the tests.

One group of timber piles tested was located at Half Moon Bayou (see Figs. 1 and 11), and consisted of nine 65-ft. untreated yellow pine piles having an average diameter of 6¼ in. and at the tip and 16¾ in. at the butt. The piles were all driven vertically and were spaced at 4-ft. centers. The piles were driven with either a Vulcan No. 1 or No. 2 hammer, and the average driving time per pile was 12 min. The average penetration was 60.2 ft. through clay and sandy silt, with the number of blows per last foot varying from 19 for pile T8, using a No. 1 hammer, to 157 for pile T1, using a No. 2 hammer.

Four single timber piles, having about the same physical and driving characteristics as the piles of the group, were also tested at this location, as shown in Fig. 1.

The second group of timber piles tested are located at Two O'clock Bayou (see Figs. 1 and 12), and consisted of nine 65-ft. untreated yellow pine piles having an average diameter of 6 in. at the tip and 15¾ in. at the butt. The center pile of this group, T19, was driven vertically, but the remaining 8 piles were battered ¾ in. in 1 ft., with the corner piles battered in two directions. The piles were spaced at 4-ft. centers at the top. The piles were driven with the Vulcan No. 1 hammer, and the average driving time per pile was 6.8 min. The average penetration was 59.6 ft. through clay and silty clay, with the number of blows per last foot varying from 11 for pile T20 to 22 for pile T15. The average number of blows for the last foot was 16.4.

Three single timber piles, having about the same physical and driving characteristics as the piles of the group, were also tested at this location, as shown in Fig. 1.

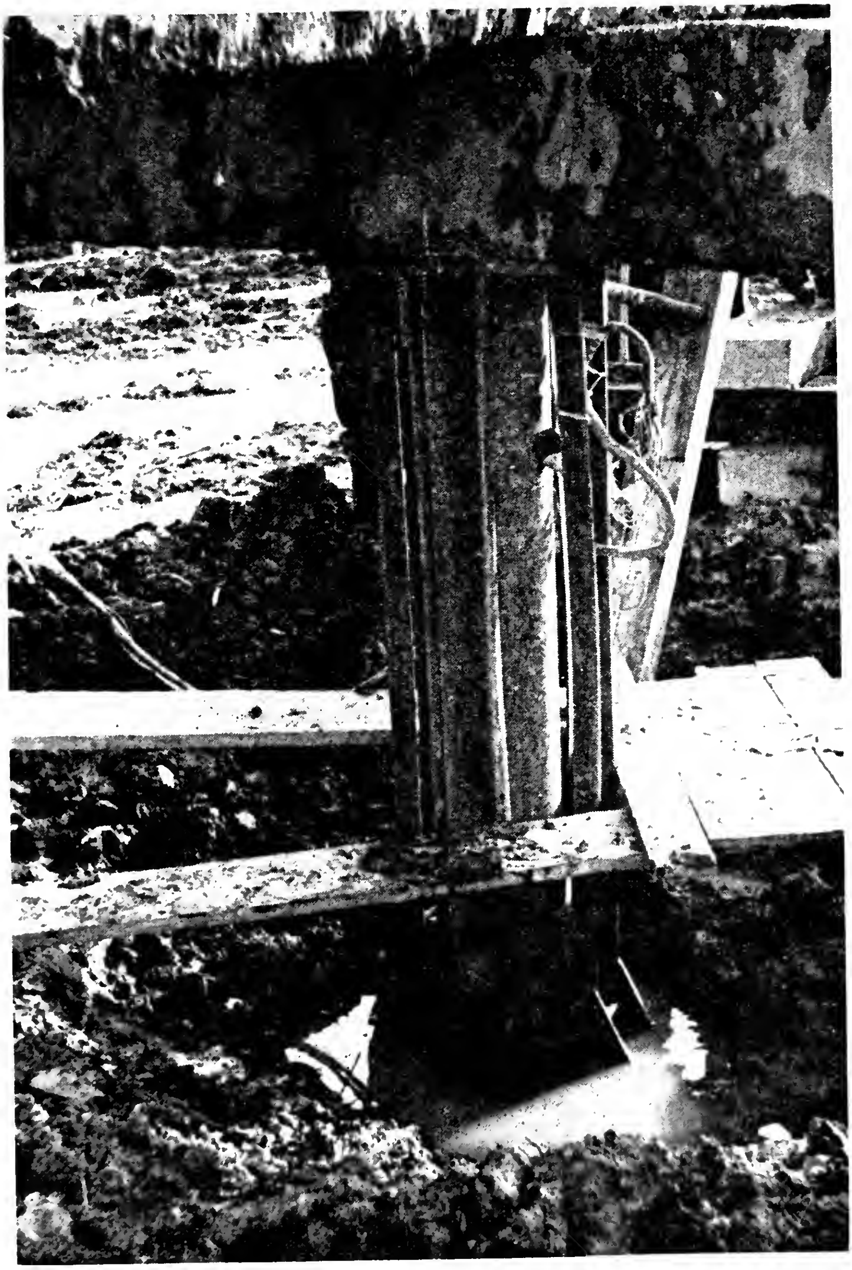


Fig. 9. Method of carrying load on single piles.

Fig. 10. Method of carrying load on single piles.

Upon completion of the driving of the timber piles, each pile of the group was cut to the same elevation as the others and the butt trimmed to a diameter of 14 in. to receive a special loading cap. The loading cap, consisting of an 8-in. diameter pipe, 5 in. long and ¼ in. in thickness, and welded between two 14-in. by 14-in. by 1½-in. bearing plates, was provided for attaching strain gages for the tests to determine the distribution of the load to the piles. A 12-ft. by 12-ft. by 3-ft. reinforced concrete loading platform was then cast on top of the steel loading caps, encasing only the top steel bearing plates. Four wire gages were mounted on the outside of the 8-in. diameter pipe of each loading cap. By measuring the strains in this pipe of known cross-sectional area, the proportion of the total load carried by each pile could be determined.

5. General Test Procedure

a) Dynamic Tests

The steel piles arrived at the test site, as previously mentioned, with all the gages in place and with the 5-ft. extra length of lead wires in each case in a coil at the butt end of the pile. The extra length of lead wires was then extended out of a small hole close to the butt end of the pile (see Fig. 13). The wires and reference gages leading to the amplifiers and oscillograph were then soldered to the gage wires before the pile was placed in position for driving.

No effort was made to measure the dynamic strains at all the gage positions as equipment was available for only eight simultaneous readings. Two gages were selected at the tip of the pile, two at the butt end, and the remaining gages at intermediate points.

Dynamic strains were measured on the six steel piles having gages on the inside, but reliable data were secured on only two of the piles, M4 and M11. It had previously been decided to use the sensitized paper to record the galvanometer deflections on account of its available length. The sensitivity of this paper was considered great enough to record any expected changes in stress, but after the pile driving was completed and the

Fig. 11. Timber pile group at Half Moon Bayou.

Fig. 12. Timber pile group at Two O'Clock Bayou.

Fig. 13. Butt end of pile, showing leads from recording instruments being connected to leads from wire gages.

paper was developed, it was found that only the oscillograms recorded during the driving of these two piles were sufficiently clear to be reliable. The clarity of these two oscillograms was undoubtedly the result of more oscillograph light being used for these two records.

During the driving of the pile, a short interval of record was taken about every 2 ft. of penetration for the 65-ft. piles, and each interval of record consisted of three or four blows of the hammer. The first section of the long pile was driven without any oscillogram being taken, but as soon as the driving was started on the full-length pile, records were taken about every 2 ft., except during the final driving where several records were taken.

No effort was made to secure strain gage readings during the driving of the timber piles.

The driving of the steel piles was started on December 18, 1948, and was completed December 20, 1948.

b) Static Tests

The construction of the loading platforms on the piles required considerable time, but as soon as this work was completed the lead wires from the switch boxes were soldered to the wires extending from the piles, and all the gages were again checked for resistance to ground. It is interesting to note that only 25 gages of a total of 186 were lost during shipment and driving.

It was realized when the tests were planned that there would be some drifting of the gages, or a change in the dial reading without any change in the load on the pile. To determine the amount of this "drift" during the loading tests so that the necessary corections could be made, a series of indicating gages were mounted on a steel bar, called the "drift bar," and this assembly was then lowered into the pile. Since the strain in the drift bar remained constant, any change in the gage readings was the result of drift. In addition to the drift bar, a gage was mounted on another bar, called the reference or temperature bar, to correct automatically for any temperature changes between readings. The lead wire connecting the switch boxes to the gages on the drift bar and the reference bar were in the same group of wires as those connecting the main gages, so it was expected that any temperature or humidity changes would have the same effect on all the gages. It was interesting to note that the temperature inside the piles remained fairly constant from day to day.

The static tests on the piles, which were started on January 6, 1949, were conducted by first taking a "NO LOAD" reading on all the gages on a single pile or the group of piles being tested. Several large concrete blocks of calculated weight were then placed on the loading platform by means of a crane, and then another set of readings was taken on all the gages. The difference in these two sets of readings, after correcting for any drift of the gages, was the stress in the pile at that section. No additional load was placed on the pile until about four hours after the pile had stopped all movement, as measured by a level. A typical static pile test log for the single piles is shown in Table 1. It can be seen that it took only 20 to 30 minutes to load the single pile M10 with an increment of load, but that three to four hours were required to load the group of 9 piles with an increment of 90,000 lb., as shown in Table 2.

The static tests on the pipe pile P1 were conducted first, and it was soon noticed that the drift of the gages on the pile and on the drift bar was considerably more than expected and did not appear to be uniform among the gages. In addition to the large drift of the gages, it was noticed that the equipment was very slow to respond to resistance changes, taking about 30 sec. before the gages could be balanced. The loading tests of the pipe pile continued, with the instrument operators working on a solution of the difficulties. However, before the trouble could be located and corrected, the pile failed to shear.

It can be seen from Fig. 2 that the tests were conducted under unfavorable conditions, wtih either rain or high humidity every day. It was realized that the high humidity in itself was not detrimental to the conduct of the tests, but any changes in the humidity from one reading to the next changed the impedance of the strain gage circuits, especially since the lead wires from the switching boxes to the wire gages were quite long. The principal step in correcting the trouble was to introduce capacity balance into the circuits, by placing condensors or decade capacitors across either the indicating gage leg of the bridge circuit or the reference gage leg; the correct amount required to balance was determined by a Cathode-Ray Oscilloscope.

To equalize the temperature effects on the indicating and reference gage leads, and to reduce the rapid changes in capacitance in the exposed lengths of the leads outside the piles, the lead wires were securely bundled together and placed in a trench filled with water, so that the exposed portion of the lead wires remained completely wet during the remaining tests. Another precaution taken was to dry out completely the strain indicator and switching boxes by electric heaters before taking any readings. After taking these corrective measures, the difficulty in operating the instruments largely disappeared and reproducibility became much better. The drift that did take place was of about equal magnitude in all the indicating gages on the piles and drift bar.

TABLE I
TYPICAL STATIC PILE TEST LOG
PILE M10

LOAD INCREMENT			TOTAL LOAD ON PILE	TIME OF STRAIN GAGE READING	LOAD INCREMENT			TOTAL LOAD ON PILE	TIME OF STRAIN GAGE READING
KIPS	TIME STARTED	TIME COMPLETED	KIPS		KIPS	TIME STARTED	TIME COMPLETED	KIPS	
30	1-27-49 @ 1:30 PM	1-27-49 @ 2:17 PM	0 30	1-27-49 @ 1:28 PM 1-27-49 @ 2:19 PM	$13\frac{1}{3}$	2-16-49 @ 1:27 PM	2-16-49 @ 1:55 PM	130 $143\frac{1}{3}$	2-16-49 @ 1:25 PM 2-16-49 @ 1:57 PM
20	2-14-49 @ 8:50 AM	2-14-49 @ 9:38 AM	30 50	2-14-49 @ 8:48 AM 2-14-49 @ 9:40 AM	$13\frac{1}{3}$	2-17-49 @ 8:55 AM	2-17-49 @ 9:00 AM	$143\frac{1}{3}$ $156\frac{2}{3}$	2-17-49 @ 8:53 AM 2-17-49 @ 9:02 AM
20	2-14-49 @ 1:40 PM	2-14-49 @ 2:00 PM	50 70	2-14-49 @ 1:38 PM 2-14-49 @ 2:02 PM	$13\frac{1}{3}$	2-17-49 @ 1:09 PM	2-17-49 @ 1:29 PM	$156\frac{2}{3}$ 170	2-17-49 @ 1:07 PM 2-17-49 @ 1:31 PM
20	2-15-49 @ 8:32 AM	2-15-49 @ 9:00 AM	70 90	2-15-49 @ 8:30 AM 2-15-49 @ 9:02 AM	$13\frac{1}{3}$	2-19-49 @ 8:28 AM	2-19-49 @ 9:35 AM	170 $183\frac{1}{3}$	2-19-49 @ 8:26 AM 2-19-49 @ 9:37 AM
20	2-15-49 @ 2:39 PM	2-15-49 @ 3:00 PM	90 110	2-15-49 @ 2:37 PM 2-15-49 @ 3:02 PM	$13\frac{1}{3}$	2-19-49 @ 1:22 PM	2-19-49 @ 1:41 PM	$183\frac{1}{3}$ $196\frac{2}{3}$	2-19-49 @ 1:20 PM 2-19-49 @ 1:43 PM
20	2-16-49 @ 8:22 AM	2-16-49 @ 9:47 AM	110 130	2-16-49 @ 8:20 AM 2-16-49 @ 9:49 AM	$13\frac{1}{3}$	2-21-49 @ 10:02 AM	2-21-49 @ 10:25 AM	$196\frac{2}{3}$ 210(1)	2-21-49 @ 10:00 AM 2-21-49 @ 10:27 AM

(1) PILE FAILED DURING LOADING @ 10:25 AM.

TABLE 2
TYPICAL STATIC PILE TEST LOG
9 PILE GROUP

LOAD INCREMENT			TOTAL LOAD ON PILE	TIME OF STRAIN GAGE READING	LOAD INCREMENT			TOTAL LOAD ON PILE	TIME OF STRAIN GAGE READING
KIPS	TIME STARTED	TIME COMPLETED	KIPS		KIPS	TIME STARTED	TIME COMPLETED	KIPS	
102.6	1-28-49 @8:30AM	1-28-49 @10:28AM	77.4 180	1-28-49 @8:25 PM 1-28-49 @10:33AM	45	2-3-49 @8:10AM	2-3-49 @10:25AM	810 855	2-3-49 @8:05AM 2-3-49 @10:30AM
180	1-28-49 @1:30PM	1-28-49 @4:05 PM	180 360	1-28-49 @1:25 PM 1-28-49 @4:10PM	45	2-3-49 @10:40AM	2-3-49 @12:02 PM	855 900	2-3-49 @10:35AM 2-3-49 @12:07PM
90	1-29-49 @8:05AM	1-29-49 @10:10AM	360 450	1-29-49 @8:00AM 1-29-49 @10:15 AM	86.4	2-5-49 @7:52 AM	2-5-49 @12:05 PM	900 986.4	2-5-49 @7:47AM 2-5-49 @12:10PM
90	1-29-49 @10:25AM	1-29-49 @12:17 PM	450 540	1-29-49 @10:20AM 1-29-49 @12:22 PM	80.1	2-7-49 @7:58 AM	2-7-49 @12:10 PM	986.4 1066.5	2-7-49 @7:53AM 2-7-49 @12:15 PM
90	2-1-49 @8:15AM	2-1-49 @12:10 PM	540 630	2-1-49 @8:10AM 2-1-49 @12:15 PM	93.6	2-8-49 @8:05AM	2-8-49 @12:08 PM	1066.5 1160.1	2-8-49 @8:00AM 2-8-49 @12:13 PM
90	2-1-49 @1:48PM	2-1-49 @3:30PM	630 720	2-1-49 @1:43PM 2-1-49 @3:35 PM	99.9	2-10-49 @8:00AM	2-10-49 @12:01 PM	1160.1 1260.0	2-10-49 @7:55AM 2-10-49 @12:06 PM
90	2-2-49 @8:08AM	2-2-49 @10:54AM	720 810	2-2-49 @8:03AM 2-2-49 @10:59 AM					

Fig. 14. Loading the steel pile group with 1,183,000 lb. of concrete blocks.

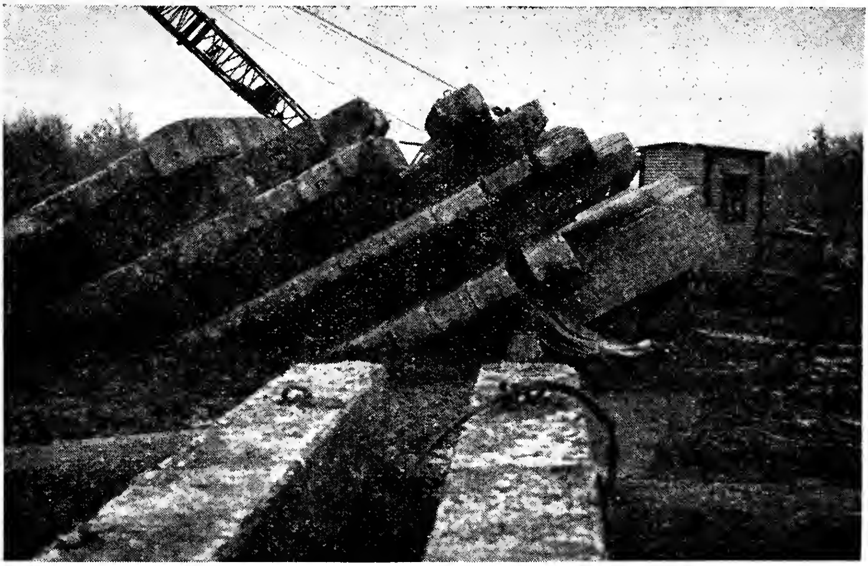


Fig. 15. Failure of timber piles at Two O'Clock Bayou.

As soon as the equipment was working properly, the tests on the 9-pile group were started. The group was loaded by increments of about 90,000 lb., or 10,000 lb. per pile. A total of 1,182,600 lb. was placed on this group, or 113,400-lb. average per pile (see Fig. 14), without any failure in the piles. It was considered too dangerous because of overturning of the loading blocks to place any more load on this group, so the load was removed by three 400,000-lb. (approximately) decrements.

The single 110-ft. pile was loaded by increments to 300,000 lb. without failure. The tests were discontinued at this load because of danger of overturning of the blocks, and the load was removed by two 150,000-lb. decrements.

The single 65-ft. steel Monotube pile was loaded by increments to failure at 196,600 lb. The load was removed from the pile, which completed the tests on the steel piles.

The concrete loading blocks and other equipment were moved to the timber test group at Two O'clock Bayou. The entire group of piles was loaded by increments to failure at 990,000 lb., or 110,000 lb. per pile. There was complete failure of the piles at this location, with the load turning over, as shown in Fig. 15. Two single timber test piles close to the 9-pile group, and having about the same dimensions and driving characteristics as the piles in the group, failed at loads of 150,000 lb. and 110,000 lb., respectively.

The group of piles at Half Moon Bayou failed at a total of 1,170,000 lb., or 130,000 lb. per pile, and failure was complete with the load overturning. Four single timber test piles close to the 9-pile group, and having about the same dimensions and driving characteristics as the piles in the group, failed at loads ranging from 90,000 lb. to 170,000 lb., with an average of 130,000 lb.

c) Soil Test

Soil test data were obtained by the Corps of Engineers from samples taken from three test holes with a 5 in. dia. thin wall piston type sampler. Test hole 2 was located adjacent to the bridge at Two O'Clock Bayou, test hole 3 adjacent to the bridge at the Floodway Levee borrow pit, and test hole 4 adjacent to the bridge at Half Moon Bayou. The test data were obtained during October and November 1948, about two months prior to the driving of the piles. The 5 in. dia. test samples were then removed to the laboratory for testing and analysis.

6. Analysis of Data

A. Dynamic Tests

The magnitude of the galvanometer deflections, as recorded by the oscillograph during the driving of the piles, was scaled from the oscillograms for each increment of driving, and then multiplied by the gage stress factor to arrive at the unit stress in the pile at each gage location. The exact frequency of the hammer blow was determined from the oscillograms by means of the 0.01-sec. timing lines. The frequency of hammer blow, recorded stresses, and the maximum stresses were then correlated with the depth of pile penetration and tabulated, as shown in Tables 3 and 4 for piles M4 and M11, respectively.

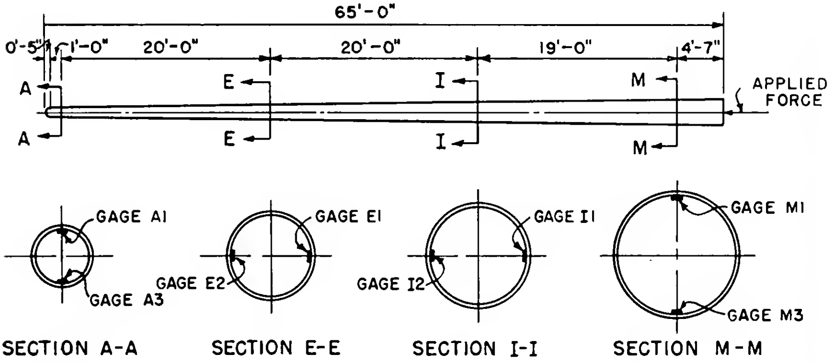
The cross-sectional area of the 65-ft. piles at section M–M, as shown in Table 3, is 8.91 sq. in., so the average calculated stress in the steel at this section under the static weight of the 5000-lb. hammer is 560 psi. However, during the driving of the pile the hammer applies an energy load, and the magnitude of the resulting stress in the pile depends upon many variables, such as: the height of hammer drop, type of pile cap, mass of pile, and the friction between the soil and the pile.

TABLE 3

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

TABLE OF RECORDED DYNAMIC STRESSES
PILE M4

OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS. JUNE, 1949.



PENETRATION FEET	FREQUENCY HAMMER BLOWS PER SECOND	MAXIMUM STRESSES															
		SECTION A-A AREA 4.47□"				SECTION E-E AREA 6.05□"				SECTION I-I AREA 7.43□"				SECTION M-M AREA 8.91□"			
		RECORDED STRESSES			TOTAL STRESS KIPS	RECORDED STRESSES			TOTAL STRESS KIPS	RECORDED STRESSES			TOTAL STRESS KIPS	RECORDED STRESSES			TOTAL STRESS KIPS
		GA.A1	GA.A3	AV.		GA.E1	GA.E2	AV.		GA.I1	GA.I2	AV.		GA.M1	GA.M3	AV.	
11	0.77	-19.8	-16.2	-18.0	81	-16.4	-16.6	-16.5	100	-13.7	-13.3	-13.5	100	-15.0	-8.2	-11.6	104
15	0.77	-19.5	-15.9	-17.7	79	-14.7	-17.7	-16.2	98	-12.0	-15.2	-13.6	101	-15.0	-7.2	-11.1	99
19	0.81	-18.6	-15.6	-17.1	76	-14.6	-18.6	-16.6	100	-12.6	-14.6	-13.6	101	-16.2	-7.2	-11.7	104
23	0.82	-16.8	-15.6	-16.2	72	-14.6	-18.0	-16.3	99	-12.0	-14.6	-13.3	99	-15.8	-8.6	-12.2	109
27	0.85	-14.7	-16.3	-15.5	69	-11.7	-11.1	-11.4	70	-12.6	-14.6	-13.6	101	-13.8	-10.2	-12.0	107
32	0.85	-15.3	-12.7	-14.0	63	-8.3	-9.1	-9.2	56	-14.4	-14.4	-14.4	107	-19.3	-8.7	-14.1	126
38	0.88	-11.7	-14.1	-12.9	58	-10.2	-8.4	-9.3	57	-16.6	-13.2	-14.9	111	-16.4	-12.0	-14.2	127
42	0.89	-5.4	-4.8	-5.1	23	-8.7	-8.1	-8.4	51	-15.4	-13.8	-14.6	108	-15.6	-12.6	-14.1	126
46	0.89	-1.8	-2.4	-2.1	9	-8.1	-8.3	-8.2	50	-12.3	-12.1	-12.2	91	-14.4	-13.0	-13.6	121
50	0.90	-1.5	-1.5	-1.5	7	-6.9	-7.9	-7.4	45	-12.0	-11.4	-11.7	87	-14.7	-12.3	-13.5	120
55	0.88	-1.5	-1.9	-1.7	8	-5.7	-6.7	-6.2	38	-10.5	-11.5	-11.0	82	-15.4	-14.4	-14.9	133
*59	0.88	-2.4	-3.2	-2.8	12	-7.8	-7.8	-7.8	47	-11.1	-10.3	-10.7	80	-15.0	-14.8	-14.9	133

*PILE VIBRATED VERTICALLY AT 12.5 OSCILLATIONS PER SECOND AT THIS DEPTH OF PENETRATION

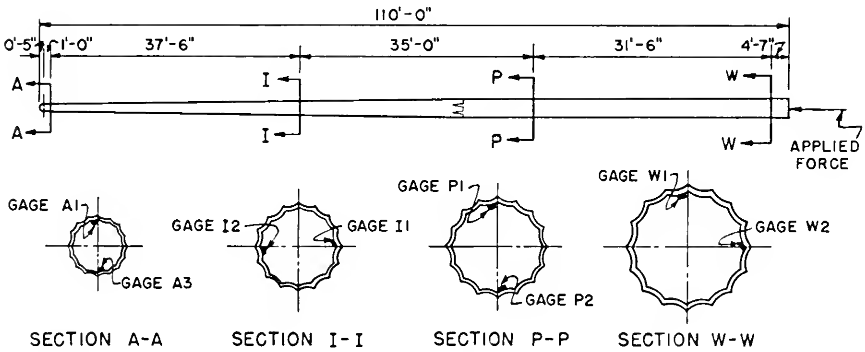
TABLE 4

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

TABLE OF RECORDED DYNAMIC STRESSES

PILE M11

OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS. JUNE, 1949.



PENETRATION FEET	FREQUENCY HAMMER BLOWS PER SECOND	MAXIMUM STRESSES															
		SECTION A-A AREA 5.93 □"				SECTION I-I AREA 9.44 □"				SECTION P-P AREA 11.45 □"				SECTION W-W AREA 11.72 □"			
		RECORDED STRESSES			TOTAL STPESS KIPS	RECORDED STRESSES			TOTAL STRESS KIPS	RECORDED STRESSES			TOTAL STRESS KIPS	RECORDED STRESSES			TOTAL STRESS KIPS
		GA. A1	GA. A3	AV.		GA. I1	GA. I2	AV.		GA. P1	GA. P2	AV.		GA. W1	GA. W2	AV.	
57	0.97					-14.0	-13.8	-13.9	131	-13.8	-13.8	-13.8	158				
63	0.98					-13.8	-13.8	-13.8	130	-13.8	-14.0	-13.9	159				
67	0.97					-13.2	-13.8	-13.5	128	-13.8	-13.8	-13.8	158				
69	0.99					-12.3	-12.7	-12.5	118	-13.8	-13.8	-13.8	158				
73	0.99					-11.7	-11.7	-11.7	111	-13.8	-13.8	-13.8	158				
75	0.97					-12.6	-11.4	-12.0	113	-12.3	-14.7	-13.5	154				
77	1.00					-11.1	-11.1	-11.1	105	-12.3	-14.3	-13.3	153				
85	1.00		-6.0	-6.0	36	-11.1	-12.3	-11.7	111	-12.3	-14.3	-13.3	153				
87	1.01		-6.0	-6.0	36	-11.4	-12.2	-11.8	111	-12.3	-13.9	-13.1	150				
90.5	1.00		-8.4	-8.4	50	-12.3	-11.7	-12.0	113	-13.8	-15.0	-14.4	165				
90.75	0.97		-8.4	-8.4	50	-12.0	-12.6	-12.3	116	-13.8	-15.0	-14.4	165				

A maximum stress of 11,600 psi. was recorded in Pile M4 at Section M–M during the first few blows of the hammer, and this stress times the area amounts to 104,000 lb., or 20.8 times the static weight of the hammer. The total stress at the four sections for various depths of pile penetration was determined, and these values are shown in the diagrams of Fig. 4. For example, the total measured stress for Sections M–M, I–I and E–E at a penetration of 11 ft. was about 100,000 lb., but was only about 80,000 lb. at Section A–A. The 20,000-lb. difference in total stress between Sections A–A and E–E was undoubtedly carried by friction between the pile and the 9 ft. 6 in. of silty clay above the gages at Section A–A. It can be seen from these diagrams that the recorded total stress at Section M–M increased with an increase in pile penetration until it reached a maximum of 133,000-lb., or 26.6 times the static weight of the hammer ram. In like manner, the load at Section A–A decreased with an increase in pile penetration and became negligible at a penetration of about 46 ft.

The oscillograms were further studied for vibration characteristics, and it was found that the stress at Section M–M for a penetration of 11 ft. increased from zero at instant of hammer contact to a maximum in about 0.005 sec. The pile continued to vibrate vertically at these high frequencies for about 0.1-sec., but with decreasing amplitudes. There was a considerable amount of horizontal vibration in the part of the pile above the ground line at a frequency of about 14.7 vibrations per sec., but these vibrations completely died out in about 0.7-sec.

At a penetration of 59 ft. the vibration characteristics of the pile were very similar to those recorded at a penetration of 11 ft., except that there were no horizontal vibrations of the pile.

The total stress determined at each of the four sections at a penetration of 59 ft. for pile M4 is plotted on the diagram of Fig. 5, and a smooth curve drawn through the points. The center of driving resistance or the center of gravity of the total shear resistance from the soil below the ground line was calculated as 29 ft., or 0.49 of the penetration depth, as shown on this diagram.

The total stress and the center of driving resistance determined from the oscillograms recorded during the driving of the long pile M11 are shown on the diagrams of Figs. 6 and 7. It can be seen from these diagrams that only about a third of the hammer blow load is effective in penetrating the sand at the bottom of the pile. The center of driving resistance, as determined from the diagram in Fig. 7, was found to be 63 ft. 2 in., or 0.70 of the penetration depth.

A study of the stresses recorded in pile M4, Table 3, indicates there was considerable bending produced by the hammer at the top of the pile. It can be seen that the stress on one side of the pile for 11 ft. of penetration was 15,000 psi., while on the opposite side it was only 8200 psi., with an average value of 11,600 psi. However, at a penetration of 59 ft. the stresses were practically equalized. There was very little bending in the pile at the other sections. It should be pointed out that the bending in the pile at the top might have been larger about another axis since only two gages at 180 deg. were used at this section.

B. Static Tests

The difference in the strain indicator readings, in micro-inches, for each gage position resulting from an increment of load being placed on the pile was tabulated, and the two or four gage values at each section were then averaged. The average difference for the gages at each section of the pile was then corrected by the amount of variation that had occurred in the gage readings on the drift bar. For example, the average of the four gages at the top of the group pile M4 for the first load increment of 102,600 lb. on the

TABLE 5 – PART 1

TABLE OF RECORDED STATIC STRESSES

PILE M1

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT APPLIED = 20K LOAD ON PILE = 20 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT APPLIED = 20K LOAD ON PILE = 40 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 3 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 6 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1												
		2												
		3												
		4												
		AV												
B	4.86	1	[illegible]		[illegible]				[illegible]		+.308			
		2	+.277		-.286				-.256		-.329			
		3	-.275		[illegible]				-.236		-.234			
		4	+.269		-.293				-.296		-.275			
		AV	-.275	+3.7	-.294	-4.9	[illegible]	[illegible]	-.283	-3	-.326	-2.7	-3.4	[illegible]
C	5.26	1	+.236		-.291				[illegible]		-.333			
		2	[illegible]		-.290				-.15		-.339			
		AV	+.273	+4	-.290	-4.7	-2.6	-0.6	-.15	-4.3	-.339	-1	-6.3	6.4
D	5.65	1	-.236		-.292				-.266		-.332			
		2	+.242		+.244				[illegible]		-.345			
		AV	+.68	+9.5	[illegible]	[illegible]	[illegible]	-2.2	[illegible]	[illegible]	-.233	.9	-.5	-5.3
E	6.05	1	+.279		-.298				[illegible]		-.334			
		2	+.268		-.294				.28		[illegible]			
		AV	-.74	+2.5	-.94	-.5	.3	-.3	-.28	4.9	-.254	-3.3	-8.3	[illegible]
F	6.44	1	-.21		-.08				[illegible]		+.22			
		2	+.256		-.20				-.296		-.254			
		AV	+.238	-2.5	-.25	+.68	-4.3	-4.3	[illegible]	[illegible]	-.230	-.9	-.96	-3.9
G	6.54	1												
		2	+.25		-.4				[illegible]		-.269			
		AV	+.25	+3.5	-.4	-.96	-.6	-.6	[illegible]	-.76	-.169	-.27	-.73	-8.4
H	7.04	1	+.22		-.56				-.26		+.154			
		2	+.25		-.4				-.4		-.082			
		AV	+.22	+.5	-.50	-2.5	-9.0	-9.0	-.35	-.95	-.165	-4.3	-4.4	-23.4
I	7.43	1	-.22		-.28				-.20		+.25			
		2	+.294		-.159				-.26		-.274			
		AV	+.232	+2.2	-.090	-.67	-4.5	-4.5	-.65	-12.5	-.175	-.56	-.79	-22.4
J	7.81	1	-.265		-.239				-.26		-.234			
		2	+.061		-.35				[illegible]		-.27			
		AV	-.226	+7.5	-.287	+.68	-7.3	-7.3	-.95	-.55	-.93	-14.3	-19.5	-36.2
K	8.20	1	+.25		-.079				-.20		-.339			
		2	+.25		-.28				-.20		-.233			
		AV	+.25	+2	-.293	-.78	-6.4	-6.4	[illegible]	-16.5	-.339	-3.2	-.97	-.26
L	8.50	1	-.093		[illegible]				-.20		-.339			
		2	-.024		[illegible]				-.56		-.324			
		AV	-.02	[illegible]	-.4	-.35	-.28	-.28	-.94	+.68	-.015	-1.2	-.18	-28.3
M	8.91	1	+.22		-.45				-.26		-0.74			
		2	+.257		+.19				-.56		-0.69			
		3	-.236		+.65				-.56		-0.39			
		4	+.287		+.29				-.4		-0.99			
		AV	+.251	+4.5	-.59	-14.2	-9.7	-9.7	-.83	-16.3	-0.42	-3.7	-20.0	-29.7
CALCULATED							-4	-4					-20.0	-31.4

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT APPLIED = 10K LOAD ON PILE = 50 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT APPLIED = 10K LOAD ON PILE = 60 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 68 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1												
		2												
		3												
		4												
		AV												
B	4.86	1							-0.57		+1.05			
		2							-0.42		+1.05			
		3							-0.42		+0.95			
		4							-0.42		+2.20			
		AV							-0.45	-2.2	+1.32	+6.4	+4.2	-0.3
C	5.26	1							-0.57		+0.75			
		2							-0.42		+0.75			
		AV							-0.48	-2.5	+0.75	+3.9	+1.4	-5.5
D	5.65	1							-1.02		+0.90			
		2							-0.57		+0.60			
		AV							-0.81	-4.6	+0.75	+4.2	-0.4	-5.7
E	6.05	1							-1.17		+0.15			
		2							-1.02		+0.45			
		AV							-1.08	-6.5	+0.30	+1.8	-4.7	-14.2
F	6.44	1							-1.17		+3.30			
		2							-1.32		+0.45			
		AV							-1.26	-8.1	+1.89	+12.2	+4.1	-9.8
G	6.54	1												
		2							-1.62		-0.15			
		AV							-1.62	-11.1	-0.15	-1.0	-12.1	30.5
H	7.04	1							-1.77		+0.45			
		2							-1.47		0			
		AV							-1.62	-11.4	+0.21	+1.5	-9.9	33.3
I	7.43	1							-1.92		-0.30			
		2							-1.92		-0.60			
		AV							-1.92	14.3	-0.45	-3.3	-17.6	-40.0
J	7.81	1							-1.92		-0.45			
		2							-2.22		+0.90			
		AV							-2.07	-16.1	+0.21	+1.6	-14.5	-51.3
K	8.20	1							-2.22		-0.30			
		2							-2.37		-0.30			
		AV							-2.28	-18.7	-0.30	-2.5	-21.2	-47.3
L	8.50	1							-2.67		-0.30			
		2							-2.37		-0.15			
		AV							-2.52	-21.6	-0.21	-1.8	-23.4	-57.3
M	8.91	1	-1.68						-1.17		+0.15			
		2	-.38						-1.62		-0.30			
		3	-1.08						-1.67		0			
		4	-1.08						-1.32		-0.15			
		AV	-1.25	-11.5			-11.6	-41.2	-1.44	-12.8	0.09	-0.8	-13.6	-54.8
CALCULATED							-10.0	-41.4					-10.0	-51.4

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT APPLIED = 10K LOAD ON PILE = 70 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT APPLIED = 10K LOAD ON PILE = 80 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 2 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 16 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1												
		2												
		3												
		4												
		AV												
B	4.86	1							-0.78		+0.60			
		2							0.63		+0.15			
		3							-0.33		+0.30			
		4							-0.48		+0.30			
		AV							-0.54	-2.6	+0.27	+1.0	-1.6	-1.9
C	5.26	1							-0.63		+0.75			
		2							-0.93		+0.30			
		AV							-0.78	-4.1	+0.51	+2.7	-1.4	-6.9
D	5.65	1							1.23		+0.45			
		2							-1.23		+0.30			
		AV							-1.23	-7.0	+0.39	+2.2	-5.8	-11.5
E	6.05	1							-1.23		+0.15			
		2							-1.38		+0.15			
		AV							-1.32	-8.0	+0.15	+0.9	-7.1	-21.3
F	6.44	1							-0.78		+0.45			
		2							-1.38		+0.15			
		AV							-1.08	-7.0	+0.30	+1.9	-5.1	-14.9
G	6.54	1												
		2							-1.53		0			
		AV							-1.53	-10.0	0	0	-10.0	-40.5
H	7.04	1							-1.98		+0.15			
		2							-1.83		+0.15			
		AV							-1.92	-13.5	+0.15	+1.1	-12.4	-45.7
I	7.43	1							-1.23		-0.30			
		2							-1.38		-0.15			
		AV							-1.32	-9.8	-0.21	-1.6	-11.4	-51.4
J	7.81	1							-1.38		-0.30			
		2							-3.03		-0.30			
		AV							-2.22	-16.5	-0.30	-2.3	-18.8	-70.1
K	8.20	1							-1.98		0			
		2							-2.13		-0.15			
		AV							-2.04	-16.7	+0.09	+0.7	-16.0	-63.3
L	8.50	1							-2.13		0			
		2							-2.13		+0.45			
		AV							-2.13	-18.3	+0.21	+1.8	-16.5	-68.8
M	8.91	1	-0.69		-0.12				-1.32		+0.15			
		2	-0.84		+0.18				-1.02		-0.45			
		3	-0.99		+0.18				-1.32		+0.45			
		4	-0.84		+0.18				-1.47		+0.45			
		AV	0.84	-7.5	[illegible]	+1.1	-6.4	-61.2	-1.29	-11.8	+0.15	+1.3	-10.5	-71.7
CALCULATED							-10.0	-61.4					-10.0	-71.4

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 10K LOAD ON PILE = 90 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = 5.0K LOAD ON PILE = 95 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 21 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1												
		2												
		3												
		4												
		AV												
B	4.86	1	-0.09		+0.18				-0.36					
		2	-0.09		+0.24				-0.24					
		3	+0.06		+0.18				-0.21					
		4	-0.09		+0.18				-0.21					
		AV	-0.06	0.3	+0.18	+0.9	+0.6	-1.3	-0.27	-1.3			-1.3	-2.6
C	5.26	1	-0.69		+0.03				-0.21					
		2	-0.09		+0.03				-0.27					
		AV	-0.39	-2.0	+0.03	+0.2	-1.8	-8.7	-0.24	-1.3			-1.3	-10.0
D	5.65	1	-0.39		+0.03				-0.36					
		2	-0.24		+0.03				-0.36					
		AV	-0.33	5	+0.03	+0.2	-1.7	-13.2	-0.36	-2.0			2.0	-15.2
E	6.05	1	-0.54		-0.12				-0.45					
		2	-0.39		-0.12				-0.51					
		AV	-0.45	-2.7	-0.12	-0.7	-3.4	-24.7	-0.48	-2.9			-2.9	-27.6
F	6.44	1	-0.24		+0.63				-0.42					
		2	-0.54		0				-0.48					
		AV	-0.39	-2.5	+0.30	+1.9	-0.6	-15.5	-0.45	-2.9			-2.9	-18.4
G	6.54	1												
		2	-0.54		+0.03				-0.51					
		AV	-0.54	-3.7	+0.03	+0.2	-3.5	-44.0	-0.51	-3.5			-3.5	-47.5
H	7.04	1	-0.69		-0.12				-0.66					
		2	-0.69		-0.12				-0.60					
		AV	-0.69	-4.9	-0.12	-0.8	-5.7	-51.4	-0.63	-4.4			-4.4	-95.8
I	7.43	1	-0.24		+0.12				-0.24					
		2	-0.39		+0.33				-0.12					
		AV	-0.33	-2.5	+0.24	+1.8	-0.7	-52.1	-0.18	-1.3			-1.3	-53.4
J	7.81	1	-0.39		+0.18				-0.24					
		2	-0.39		+0.33				-0.36					
		AV	-0.39	-3.0	+0.24	+1.9	-1.1	-71.2	-0.30	-2.3			-2.3	-73.5
K	8.20	1	-0.99		-0.06				-0.72					
		2	-1.14		-0.06				-0.72					
		AV	-1.05	-8.6	-0.06	-0.5	-9.1	-72.4	-0.72	-5.9			-5.9	-78.3
L	8.50	1	-1.14		+0.03				-1.05					
		2	-0.99		-0.21				-0.69					
		AV	-1.05	-9.0	-0.09	-0.8	-9.8	-78.6	-0.87	-7.5			-7.6	-86.1
M	8.91	1	-0.54		-0.51				-0.87					
		2	-0.84		+0.33				-0.66					
		3	-0.99		-0.36				-0.63					
		4	-0.69		-0.57				-0.51					
		AV	-0.75	-6.7	-0.27	-2.4	-9.1	-80.8	-0.66	-5.9			-5.9	-86.7
CALCULATED							-10.0	-81.4					-5.0	-86.4

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 5.0K LOAD ON PILE = 100 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 20 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1						
		2						
		3						
		4						
		AV						
B	4.86	1	0		-0.51			
		2	-0.06		-0.45			
		3	-0.03		-0.99			
		4	0		-0.54			
		AV	-0.03	-0.1	-0.63	-3.1	-3.2	-5.8
C	5.26	1	0		-0.27			
		2	-0.06		-0.57			
		AV	-0.03	-0.2	-0.42	-2.2	-2.4	-12.4
D	5.65	1	-0.15		-0.21			
		2	-0.06		-0.08			
		AV	-0.12	-0.7	-0.12	-0.7	-1.4	-16.6
E	6.05	1	-0.21		-0.54			
		2	-0.09		-0.33			
		AV	-0.15	-0.9	-0.42	-2.5	-3.4	-31.0
F	6.44	1	-0.09		+0.48			
		2	-0.15		-0.12			
		AV	-0.12	-0.8	+0.18	+1.2	+0.4	-18.0
G	6.54	1						
		2	-0.15		-0.12			
		AV	-0.15	-1.0	-0.12	-0.8	-1.8	-49.3
H	7.04	1	-0.15		-0.36			
		2	-0.30		-0.03			
		AV	-0.24	-1.7	-0.18	-1.3	-3.0	-58.8
I	7.43	1	0		-0.24			
		2	+0.06		-0.12			
		AV	+0.03	+0.2	-0.18	-1.3	-1.1	-54.5
J	7.81	1	+0.03		-0.39			
		2	0		-0.18			
		AV	0	0	-0.30	-2.3	-2.3	-75.8
K	8.20	1	-0.36		+0.09			
		2	-0.30		+0.03			
		AV	-0.33	-2.7	+0.06	+0.5	-2.2	-80.5
L	8.50	1	-0.15		0			
		2	-0.39		+0.24			
		AV	-0.27	-2.3	+0.12	+1.0	-1.3	-87.4
M	8.91	1	0		+0.15			
		2	0		+0.18			
		3	-0.30		0			
		4	-0.30		-0.09			
		AV	-0.15	-1.3	+0.09	+0.5	-0.8	-87.5
CALCULATED							-5.0	-91.4

TABLE 5 - PART 2

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

TABLE OF RECORDED STATIC STRESSES

PILE MI

OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS
JUNE, 1949

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED) = [illegible] LOAD ON PILE = [illegible] KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = [illegible] LOAD ON PILE = [illegible] KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = 96K LOAD ON PILE = 109.6 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF [illegible] HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 8 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 44 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1																		
		2																		
		3																		
		4																		
		AV																		
B	4.86	1			-0.36						+0.78				-0.46		+1.02			
		2			-0.45						[illegible]				-0.54		+0.81			
		3			-0.2						+0.78				-0.30					
		4			-0.34						+0.79				-0.39		+0.66			
		AV			-0.36	-1.7	[illegible]	-7.5			+0.84	+4.1	+4.1	-3.4	-0.41	-2.0	+0.84	+4.1	+2.1	-1.3
C	5.26	1			+0.39						-0.57				-0.63		+0.90			
		2			+0.36						+0.78				-0.42		+0.84			
		AV			+0.62	+3.2	[illegible]	[illegible]			-0.06	-0.3	-0.3	-9.5	-0.5	-2.7	+0.87	+4.6	+1.9	-7.6
D	5.65	1			-0.42						+0.78				-0.69		+0.81			
		2			-0.2						+0.78				-0.72		+0.84			
		AV			-0.32	[illegible]	[illegible]	[illegible]			+0.78	+4.4	+4.4	-13.9	-0.72	-4.1	+0.81	+4.6	+0.5	-13.4
E	6.05	1			-0.74						-0.78				-0.78		+0.45			
		2			+0.56						+0.78				-0.87		+0.34			
		AV			[illegible]	-8	[illegible]	-32.3			+0.72	+4.7	+4.7	-28	-0.81	-4.9	+0.31	+3.1	-1.8	-29.9
F	6.44	1			-0.26						+0.98				-0.78		+1.35			
		2			-0.36						+0.63				-0.93		+0.57			
		AV			[illegible]	-4	-4	-9.4			+0.92	+6.6	+6.8	-12.8	-0.84	-5.4	+1.26	+8.1	+2.7	-10.1
G	6.84	1																		
		2			-0.36						+0.83				-1.05		+0.27			
		AV			-0.36	-2.5	-2.5	-5.8			+0.61	+4.3	+4.3	-47.5	-1.05	-7.2	+0.27	+1.8	-5.4	-52.9
H	7.04	1			-0.27						+1.63				-1.17		+0.54			
		2			-0.36						+0.63				-1.23		+0.45			
		AV			-0.33	-2.3	-2.3	-6			+0.63	+4.4	+4.4	-56.7	-1.20	-8.5	+0.51	+2.9	-5.6	-62.3
I	7.43	1			-0.45						+0.32				-1.20		+0.27			
		2			+0.36						+0.13				-1.05		+0.42			
		AV			+0.39	-2.9	-2.9	-57.4			+0.24	+1.8	+1.8	-55.6	-1.11	-8.3	+0.33	+2.5	-5.8	-61.4
J	7.81	1			-0.24						+0.18				-1.20		+0.27			
		2			-0.32						+0.33				-1.26		+0.33			
		AV			-0.27	-2	-2.1	-77.9			+0.24	+1.9	+1.9	-76.0	-1.23	-9.6	+0.30	+2.3	-7.3	-83.3
K	8.20	1			-0.36						+0.78				-1.35		+0.27			
		2			-0.2						+0.63				-1.35		+0.42			
		AV			-0.27	-2.2	-2.2	[illegible]			+0.72	+5.9	+5.9	-76.2	-1.35	-11.1	+0.33	+2.7	-8.4	-85.2
L	8.50	1			-0.29						+0.78				-1.53		+0.45			
		2			-0.2						+0.63				-1.35		+0.42			
		AV			-0.15	-3	-1.3	-82.7			+0.72	+6.2	+6.2	-82.5	-1.44	-12.4	+0.42	+3.6	-8.8	-91.3
M	8.91	1			-0.18						+0.63				-1.44		+0.8			
		2			-0.06						+0.48				-1.65		+0.57			
		3			-0.12						+0.42				-1.35		+0.97			
		4			-0.09						+0.48				-1.70		+0.42			
		AV			-0.12	-1.1	-1.1	-88.6			+0.51	+4.5	+4.5	-84.1	-1.41	-12.6	+0.60	+5.3	-7.3	-91.4
CALCULATED							0	-91.4					0	-91.4					-9.6	-101.0

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 89K LOAD ON PILE = 118.5 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = 104K LOAD ON PILE = 128.9 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = 111K LOAD ON PILE = 140 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 21 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 44 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 44 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1																		
		2																		
		3																		
		4																		
		AV																		
B	4.86	1	-0.42		+0.57				-0.57		+0.15				-0.90		+0.99			
		2	-0.12		+0.57				-0.45		+0.48				-0.45		+0.84			
		3	-		-				-		-				-		-			
		4	-0.2		+0.57				-0.30		+0.18				-0.30		+0.69			
		AV	-0.21	-1.0	+0.57	+2.8	+1.8	+0.5	-0.42	-2.0	+0.27	+1.3	-0.7	-0.2	-0.54	-2.6	+0.84	+4.1	-1.5	-1.7
C	5.26	1	-0.27		+0.57				-0.51		+0.84				-0.18		+0.27			
		2	-0.27		+0.57				-0.45		+0.03				-0.21		+0.75			
		AV	-0.27	-1.4	+0.57	+3.0	+1.6	0	-0.48	-2.5	+0.42	+2.2	-0.3	-6.3	-0.18	-0.9	+0.51	+2.5	+1.6	-4.7
D	5.65	1	-0.42		+0.57				-0.51		-				-		+0.51			
		2	-0.42		+0.57				-0.69		+0.42				-0.39		+0.78			
		AV	-0.42	-2.4	+0.57	+3.2	+0.8	-12.6	-0.60	-3.4	+0.42	+2.4	-1.0	-13.6	-0.39	-2.2	+0.66	+3.7	+1.5	-12.1
E	6.05	1	-0.57		+0.42				-0.90		+0.03				-0.30		+0.39			
		2	-0.57		+0.42				-0.87		+0.30				-0.45		+0.24			
		AV	-0.57	-3.5	+0.42	+2.5	-1.0	-30.9	-0.90	-5.4	+0.18	+1.1	-4.3	-35.2	-0.36	-2.2	+0.33	+2.0	-0.2	-35.4
F	6.44	1	-0.57		+0.87				-0.48		-				-					
		2	-0.72		-0.18				-0.75		+0.33				-0.36		-0.15			
		AV	-0.66	-4.3	+0.36	+2.3	-2.0	-12.1	-0.60	-3.9	+0.33	+2.1	-1.8	-13.9	-0.36	-2.3	-0.15	-1.0	-3.3	-17.2
G	6.84	1																		
		2	-1.67		+1.17				-0.90		+0.18				-0.60		-0.21			
		AV	-1.62	-11.1	+1.17	+8.0	-3.1	-56.0	-0.90	-6.2	+0.18	+1.2	-5.0	-61.0	-0.60	-4.1	-0.21	-1.4	-5.5	-66.5
H	7.04	1	-1.02		+0.12				-1.05		+0.33				-0.87		0.09			
		2	-1.02		+0.27				-1.23		+0.21				-0.75		+0.09			
		AV	-1.02	-7.2	+0.18	+1.3	-5.9	-68.2	-1.14	-8.0	+0.27	+1.9	-6.1	-74.3	-0.84	-5.9	0	0	-5.9	-80.2
I	7.43	1	-0.57		-0.03				0		-0.27				0.78		-0.93			
		2	-0.42		-0.03				-0.30		+0.18				-0.30		-0.96			
		AV	-0.48	-3.6	-0.03	-0.2	-3.8	-65.2	-0.15	-1.1	-0.03	-0.2	-1.3	-66.3	-0.54	-4.0	-0.96	-7.1	-11.1	-77.4
J	7.81	1	-0.57		-0.03				-0.15		+0.33				-0.60		-0.96			
		2	-0.72		+0.17				-0.51		-0.06				-0.45		-0.81			
		AV	-0.68	-5.2	+0.06	+0.5	-4.7	-88.0	-0.33	-2.6	+0.12	+0.9	-1.7	-89.7	-0.54	-4.2	-0.87	-6.8	-11.0	-100.7
K	8.20	1	-1.32		+0.12				-1.20		-0.27				-0.60		-0.21			
		2	-1.32		+0.12				-1.35		+0.03				-0.60		-0.81			
		AV	-1.32	-10.8	+0.12	+1.0	-9.8	-95.0	-1.26	-10.3	-0.12	-1.0	-11.3	-106.3	-0.60	-4.9	-0.15	-1.2	-6.1	-112.4
L	8.50	1	-1.47		+0.12				-1.29		-0.18				0		+0.09			
		2	-1.32		+0.27				-1.20		+0.18				-0.96		-0.90			
		AV	-1.38	-11.9	+0.18	+1.5	-10.4	-101.7	-1.26	-10.8	0	0	-10.8	-112.5	-0.48	-4.1	-0.42	-3.6	-7.7	-120.2
M	8.91	1	-1.32		+0.12				-1.20		+0.33				+0.45		-0.81			
		2	-1.62		+0.57				-1.20		+0.03				0		-0.36			
		3	-1.17		+0.12				-1.14		+0.51				-1.05		-0.96			
		4	-0.87		-0.18				-1.20		+0.33				-0.75		-1.26			
		AV	-1.32	-11.2	+0.15	+1.3	-9.9	-101.3	-1.20	-10.7	+0.30	+2.7	-8.0	-109.9	-0.33	-2.9	-0.84	-7.5	-10.4	-120.3
CALCULATED							-8.9	-109.9					-10.4	-120.3					-11.1	-131.4

SECTION	AREA SQ IN	GAGE	LOAD DECREMENT (REMOVED) = 46.6K LOAD ON PILE = 93.4 KIPS					TOTAL LOAD ON SECTION	LOAD DECREMENT (REMOVED) = 43.3K LOAD ON PILE = 50.1 KIPS					TOTAL LOAD ON SECTION	LOAD DECREMENT (REMOVED) = 43.1K LOAD ON PILE = 7 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF DECREMENT		EFFECT OF HOURS		FINAL INCREMENT		EFFECT OF DECREMENT		EFFECT OF 16 HOURS		FINAL INCREMENT		EFFECT OF DECREMENT		EFFECT OF 18 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1																		
		2																		
		3																		
		4																		
		AV																		
B	4.86	1	+0.45						+1.17		+0.18				+0.87		-0.36			
		2	-0.15						+1.38		-0.18				+1.29		-0.48			
		3									+0.27				+0.99		+0.57			
		4	-0.30						+1.05		+0.30				+0.78		+0.63			
		AV	0	0			0	0	+1.20	+5.4	+0.15	+0.7	+6.1	+6.1	+0.99	+4.8	+0.09	+0.4	+5.2	+11.3
C	5.26	1	+0.30						+1.59		+0.06				+1.44		+0.66			
		2	+0.60						+1.89		+0.27				+1.41		+0.69			
		AV	+0.45	+2.4			+2.4	+2.4	+1.71	+9.0	+0.15	+0.8	+9.8	+12.2	+1.44	+7.6	+0.69	+3.6	+11.2	+23.4
D	5.65	1	+0.90						+2.37		+0.18				+2.07		+0.93			
		2	+1.05						+2.43		+0.57				+1.83		+0.99			
		AV	+0.96	+5.4			+5.4	+5.4	+2.40	+13.6	+0.39	+2.2	+15.8	+21.2	+1.95	+11.0	+0.96	+5.4	+16.4	+37.6
E	6.05	1	+1.35						+2.88		+0.12				+2.64		+0.81			
		2	+1.35						+3.03		+0.42				+2.58		+0.93			
		AV	+1.35	+8.2			+8.2	+8.2	+2.94	+17.8	+0.27	+1.6	+19.4	+27.6	+2.61	+15.8	+0.87	+5.3	+21.1	+48.7
F	6.44	1																		
		2	+1.80						+3.48		+0.42				+3.03		+1.17			
		AV	+1.80	+11.6			+11.6	+11.6	+3.48	+22.4	+0.42	+2.7	+25.1	+36.7	+3.03	+19.5	+1.17	+7.5	+27.0	+63.7
G	6.84	1																		
		2	+2.10						+3.78		+0.57				+3.63		+1.08			
		AV	+2.10	+14.4			+14.4	+14.4	+3.78	+25.9	+0.57	+3.9	+29.8	+44.2	+3.63	+24.8	+1.08	+7.4	+32.2	+76.4
H	7.04	1	+2.25						+4.08		+0.72				+3.78		+0.93			
		2	+2.10						+4.23		+0.42				+4.32		+0.99			
		AV	+2.16	+15.2			+15.2	+15.2	+4.14	+29.2	+0.57	+4.0	+33.2	+48.4	+4.05	+28.5	+0.96	+6.8	+35.3	+83.7
I	7.43	1	+3.30						+4.38		+0.27				+2.58		+0.57			
		2	+3.75						+4.65		+0.30				+3.48		+0.78			
		AV	+3.54	+26.3			+26.3	+26.3	+4.53	+33.6	+0.27	+2.0	+35.6	+61.9	+3.03	+22.5	+0.69	+5.1	+27.6	+89.5
J	7.81	1	+3.75						+4.41		+0.24				+3.93		+0.42			
		2	+3.75						+4.59		+0.36				+4.08		+0.48			
		AV	+3.75	+29.3			+29.3	+29.3	+4.50	+35.1	+0.30	+2.3	+37.4	+66.7	+4.02	+31.4	+0.45	+3.5	+34.9	+101.6
K	8.20	1	+2.55						+4.23		+0.57				+4.92		+0.63			
		2	+3.45						+4.68		+0.27				+5.64		+0.93			
		AV	+3.00	+24.6			+24.6	+24.6	+4.44	+36.4	+0.42	+3.4	+39.8	+64.4	+5.28	+43.3	+0.78	+6.4	+49.7	+114.1
L	8.50	1	+3.30						+4.53		+0.27				+6.39		+0.63			
		2	+3.15						+4.83		+0.12				+5.52		+0.60			
		AV	+3.24	+27.9			+27.9	+27.9	+4.68	+40.3	+0.21	+1.8	+42.1	+70.0	+5.94	+51.1	+0.63	+5.4	+56.5	+126.5
M	8.91	1	+4.05						+4.68		+0.27				+6.57		+0.69			
		2	+4.05						+4.38		+0.42				+6.33		+0.69			
		3	+3.45						+6.03		+0.57				+5.28		+0.27			
		4	+3.60						+5.01		+0.39				+5.22		+0.75			
		AV	+3.78	+33.7			+33.7	+33.7	+5.01	+44.6	+0.39	+3.7	+48.3	+82.0	+5.85	+52.1	+0.60	+5.3	+57.4	+139.4
CALCULATED							+46.6	+46.6					+43.4	+90.0					+43.1	+133.1

TABLE 6 - PART I
TABLE OF RECORDED STATIC STRESSES
PILE M4

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT APPLIED = +4[illegible], LOAD ON PILE = [illegible] — EFFECT OF INCREMENT: STRESS IN KSI	LOAD IN KIPS	EFFECT OF 3 HOURS: STRESS IN KSI	LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION	LOAD INCREMENT [illegible], LOAD ON PILE = [illegible] — EFFECT OF INCREMENT: STRESS IN KSI	LOAD IN KIPS	EFFECT OF 16 HOURS: STRESS IN KSI	LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
A	[illegible]	1												
		2												
		3	[illegible]		[illegible]				-0.96		[illegible]			
		4												
		AV	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.96	-4.3	[illegible]		-5.4	-3.4
B	4.56	1												
		2	[illegible]		[illegible]				[illegible]		-2.54			
		3	[illegible]		-2.45				[illegible]		[illegible]			
		4	[illegible]		-2.69				-1.96		-2.54			
		AV	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-1.96	-4.7	+2.08	+2.3	-4.4	+5.3
C	[illegible]	1												
		2	[illegible]		[illegible]									
		AV	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-5.9	[illegible]	[illegible]	-4.9	-6.9
D	[illegible]	1												
		2	[illegible]		[illegible]				[illegible]					
		AV	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-8.5	[illegible]
E	[illegible]	1	[illegible]		[illegible]						[illegible]			
		2	[illegible]		[illegible]				[illegible]		[illegible]			
		AV	[illegible]		[illegible]	[illegible]	-4.7	-4.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-9.5
F	[illegible]	1	[illegible]		[illegible]						[illegible]			
		2	[illegible]		[illegible]						[illegible]			
		AV	[illegible]	[illegible]	[illegible]	-5.4	-4.3	-4.3		-7	[illegible]	[illegible]	[illegible]	[illegible]
G	[illegible]	1	[illegible]		[illegible]				[illegible]		-0.54			
		2	[illegible]		[illegible]				[illegible]		-0.24			
		AV	[illegible]	[illegible]	[illegible]	[illegible]	-5.8	-5.8	[illegible]	[illegible]	-0.39	[illegible]	[illegible]	-16.9
H	[illegible]	1	[illegible]		[illegible]				[illegible]		[illegible]			
		2	[illegible]		[illegible]				-1.41		-0.39			
		AV	[illegible]	[illegible]	[illegible]	-3.2	-5	-5	[illegible]	[illegible]	[illegible]	-3.4	-14.4	-9.5
I	[illegible]	1	[illegible]		[illegible]				-1.56		-0.39			
		2	[illegible]		[illegible]				-1.56		[illegible]			
		AV	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-8.0	-1.56	-11.6	-0.39	-2.9	-14.5	-22.5
J	[illegible]	1	[illegible]		[illegible]				-2.46		[illegible]			
		2	[illegible]		[illegible]				[illegible]		-0.39			
		AV	[illegible]	-2.4	[illegible]	-5.9	-8.3	-8.3	-2.32	-9.7	-0.39	-3.0	[illegible]	-31.0
K	[illegible]	1	[illegible]		[illegible]				[illegible]		-0.39			
		2	[illegible]		[illegible]				[illegible]		-0.39			
		AV	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.39	[illegible]	-18.5	-25.6
L	[illegible]	1	[illegible]		[illegible]				-2.31		-0.39			
		2	-2.84		[illegible]				-2.31		[illegible]			
		AV	[illegible]	[illegible]	[illegible]	-2.8	-9.8	-9.8	[illegible]	-9.9	[illegible]	-0.8	[illegible]	-30.5
M	[illegible]	1	[illegible]		[illegible]				[illegible]		[illegible]			
		2	[illegible]		+2.5				-2.31		-0.54			
		3	[illegible]		+0.15				-2.16		-0.69			
		4	-0.48		+0.09				-2.01		-0.54			
		AV	[illegible]	-5.4	[illegible]	[illegible]	[illegible]	[illegible]	-2.13	-19.0	-0.54	-4.8	-23.8	-31.1
CALCULATED							-4	-4					-20.0	-31.4

SECTION	GAGE	LOAD INCREMENT (APPLIED) = +5K, LOAD ON PILE = 50 KIPS — EFFECT OF INCREMENT: STRESS IN KSI	LOAD IN KIPS	EFFECT OF HOURS: STRESS IN KSI	LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = +10K, LOAD ON PILE = 60 KIPS — EFFECT OF INCREMENT: STRESS IN KSI	LOAD IN KIPS	EFFECT OF 68 HOURS: STRESS IN KSI	LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
A	3							+0.18					
	AV							+0.18	+0.8			+0.8	-2.6
B	2							-0.12					
	3							+0.18					
	4							-0.12					
	AV							-0.03	-0.1			-0.1	-5.4
C	2							-0.42					
	AV							-0.42	-2.2			-2.2	-9.1
D	2							-1.02		+1.05			
	AV							-1.02	-5.8	+1.05	+5.9	+0.1	-11.6
E	1							-1.17		+1.20			
	2							-1.32		+0.45			
	AV							-1.23	-7.5	+0.81	+4.9	-2.6	-12.4
F	1							-1.47		+0.45			
	2							-1.32		+0.15			
	AV							-1.38	-8.9	+0.30	+1.9	-7.0	-20.1
G	1							-1.62		-0.15			
	2							-1.77		-0.30			
	AV							-1.68	-11.5	-0.21	+1.4	-12.9	-29.8
H	1							-1.92		+0.15			
	2							-1.62		-0.15			
	AV							-1.77	-12.5	0	0	-12.5	-32.0
I	1							-1.92		-0.30			
	2							-1.92		-0.45			
	AV							-1.92	-14.3	-0.36	-2.6	-16.9	-39.4
J	1							-2.07		-0.30			
	2							-2.22		-0.15			
	AV							-2.13	-16.7	-0.21	-1.6	-18.3	-49.3
K	1							-2.37		-0.15			
	2							-1.92		-0.45			
	AV							-2.13	-17.5	-0.30	-2.5	-20.0	-45.6
L	1							-2.07		0			
	2							-2.67		+0.15			
	AV							-2.37	-20.4	+0.09	+0.9	-19.5	-50.0
M	1	-1.23						-1.17		0			
	2	-1.23						-1.17		-0.45			
	3	-1.08						-1.47		-0.45			
	4	-0.78						-1.62		0			
	AV	-1.08	-9.7			-9.7	-40.8	-1.35	-12.0	-0.21	-1.9	-13.9	-54.7
CALCULATED						[illegible]	[illegible]					-10.0	-51.4

SECTION	GAGE	LOAD INCREMENT (APPLIED) = +10K, LOAD ON PILE = 70 KIPS — EFFECT OF INCREMENT: STRESS IN KSI	LOAD IN KIPS	EFFECT OF 2 HOURS: STRESS IN KSI	LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = +10K, LOAD ON PILE = 80 KIPS — EFFECT OF INCREMENT: STRESS IN KSI	LOAD IN KIPS	EFFECT OF 16 HOURS: STRESS IN KSI	LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
A	3							-0.18		0			
	AV							-0.18	-0.8	0	0	-0.8	-3.4
B	2							-0.18		+0.60			
	3							-0.03		+1.20			
	4							-0.18		+0.45			
	AV							-0.12	-0.6	+0.75	+3.7	+3.1	-2.3
C	2							-0.18		+0.90			
	AV							-0.18	-1.0	+0.90	+4.7	+3.7	-5.4
D	2							-0.78		+0.30			
	AV							-0.78	-4.4	+0.30	+1.7	-2.7	-14.3
E	1							-1.08		+0.30			
	2							-1.23		+0.45			
	AV							-1.14	-6.9	+0.39	+2.4	-4.5	-16.9
F	1							-1.38		+0.30			
	2							-1.08		+0.15			
	AV							-1.26	-8.1	+0.21	+1.3	-6.8	-26.9
G	1							-0.63		+0.30			
	2							-1.38		+0.30			
	AV							-1.02	-7.0	+0.30	+2.0	-5.0	-34.8
H	1							-1.68		+0.15			
	2							-1.53		+0.15			
	AV							-1.62	-11.4	+0.15	+1.0	-10.4	-42.4
I	1							-1.83		+0.30			
	2							-1.83		+0.15			
	AV							-1.83	-13.6	+0.21	+1.5	-12.1	-51.5
J	1							-1.83		+0.30			
	2							-1.68		+0.15			
	AV							-1.74	-13.6	+0.21	+1.6	-12.0	-61.3
K	1							-1.98		+0.15			
	2							-1.68		+0.45			
	AV							-1.83	-15.0	+0.30	+2.5	-12.5	-58.1
L	1							-1.98		+0.30			
	2							-1.83		+0.15			
	AV							-1.92	-16.5	+0.21	+1.8	-14.7	-64.7
M	1	-0.69		+0.03				-1.32		+0.45			
	2									+0.15			
	3	-0.39		-0.12				-1.32		+0.60			
	4	-0.54		+0.03				-1.32		+0.45			
	AV	-0.54	-4.8	-0.03	-0.3	-5.1	-59.8	-1.32	-11.8	+0.42	+3.7	-8.1	-67.9
CALCULATED						-10.0	-61.4					-10.0	-71.4

SECTION	GAGE	LOAD INCREMENT (APPLIED) = +10K, LOAD ON PILE = 90 KIPS — EFFECT OF INCREMENT: STRESS IN KSI	LOAD IN KIPS	EFFECT OF 21 HOURS: STRESS IN KSI	LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = +5K, LOAD ON PILE = 95 KIPS — EFFECT OF INCREMENT: STRESS IN KSI	LOAD IN KIPS	EFFECT OF HOURS: STRESS IN KSI	LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
A	3	+0.06		+0.33				+0.09					
	AV	+0.06	+0.3	+0.33	+1.5	+1.8	-1.6	+0.09	+0.4			+0.4	-1.2
B	2	+0.21		+0.66				+0.21					
	3	+0.21		+1.23				+0.15					
	4	+0.21		+0.23				+0.12					
	AV	+0.21	+1.0	+0.75	+3.6	+4.6	+2.3	+0.15	+0.7			+0.7	+3.0
C	2	+0.06		+1.08				+0.09					
	AV	+0.06	+0.3	+1.08	+5.7	+6.0	+0.6	+0.09	+0.5			+0.5	+1.1
D	2	-0.24		+0.18				-0.12					
	AV	-0.24	-1.4	+0.18	+1.0	-0.4	-14.7	-0.12	-0.7			-0.7	-15.4
E	1	-0.39		+0.09				-0.12					
	2	-0.54		+0.09				-0.27					
	AV	-0.45	-2.7	+0.09	+0.5	-2.2	-19.1	-0.18	-1.1			-1.1	-20.2
F	1	-0.54		-0.12				-0.36					
	2	-0.39		-0.09				-0.24					
	AV	-0.45	-2.9	-0.12	-0.8	-3.7	-30.6	-0.30	-1.9			-1.9	-32.5
G	1	-0.69		-0.12				-0.39					
	2	-0.69		+0.03				-0.36					
	AV	-0.69	-4.7	-0.06	-0.4	-5.1	-39.9	-0.36	-2.5			-2.5	-42.4
H	1	-0.69		-0.12				-0.51					
	2	-0.69		-0.03				-0.36					
	AV	-0.69	-4.9	-0.06	-0.4	-5.3	-47.7	-0.42	-3.0			-3.0	-50.7
I	1	-0.84		-0.12				-0.06					
	2	-0.84		-0.06				-0.42					
	AV	-0.84	-6.2	-0.09	-0.7	-6.9	-57.4	-0.24	-1.8			-1.8	-39.2
J	1	-0.84		-0.12				-0.51					
	2	-0.99		-0.06				-0.57					
	AV	-0.93	-7.3	-0.09	-0.7	-8.0	-69.3	-0.54	-4.2			-4.2	-73.3
K	1	-0.99		+0.03				-0.51					
	2	-0.84		-0.12				-0.36					
	AV	-0.93	-7.6	-0.06	-0.5	-8.1	-66.1	-0.42	-3.4			-3.4	-69.5
L	1	-0.99		-0.06				-0.51					
	2	-1.14		+0.03				-0.60					
	AV	-1.05	-9.0	0	0	-9.0	-73.7	-0.54	-4.6			-4.6	-78.3
M	1	-1.14		-0.24				-0.39					
	2	-0.54		-0.12				-0.45					
	3	-1.44		+0.30				-0.33					
	4	-0.84		+0.03				-0.21					
	AV	-0.99	-8.8	0	0	-8.8	-76.7	-0.36	-3.2			-3.2	-79.9
CALCULATED						-10.0	-81.4					-9.0	-86.4

SECTION	GAGE	LOAD INCREMENT (APPLIED) = +5K, LOAD ON PILE = 100 KIPS — EFFECT OF INCREMENT: STRESS IN KSI	LOAD IN KIPS	EFFECT OF 20 HOURS: STRESS IN KSI	LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION	AREA SQ IN
A	1							4.47
	2							
	3	-0.03		-0.12				
	4							
	AV	-0.03	-0.1	-0.12	-0.5	-0.6	-1.8	
B	1							4.86
	2	-0.09		+0.27				
	3	+0.12		+0.66				
	4	+0.03		+0.33				
	AV	+0.03	+0.2	+0.42	+2.0	+2.2	+5.2	
C	1							5.26
	2	0		+0.45				
	AV	0	0	+0.45	+2.4	+2.4	+3.5	
D	1							5.65
	2	-0.27		-0.12				
	AV	-0.27	-1.5	-0.12	-0.7	-2.2	-17.6	
E	1	-0.27		+0.03				6.05
	2	-0.27		-0.09				
	AV	-0.27	-1.6	-0.03	-0.2	-1.8	-22.0	
F	1	-0.33		-0.36				6.44
	2	-0.33		-0.24				
	AV	-0.33	-2.1	-0.30	-1.9	-4.0	-36.5	
G	1	-0.30		-0.12				6.84
	2	-0.39		-0.06				
	AV	-0.36	-2.4	-0.09	-0.6	-3.0	-45.4	
H	1	-0.27		-0.33				7.04
	2	-0.42		0				
	AV	-0.36	-2.5	-0.18	-1.3	-3.8	-54.5	
I	1	-0.90		-0.12				7.43
	2	-0.35		+0.09				
	AV	-0.63	-4.7	0	0	-4.7	-63.9	
J	1	-0.83		+0.03				7.81
	2	-0.48		+0.15				
	AV	-0.57	-4.5	+0.09	+0.7	-3.8	-77.3	
K	1	-0.48		+0.18				8.20
	2	-0.54		+0.09				
	AV	-0.51	-4.2	+0.12	+1.0	-3.2	-72.7	
L	1	-0.66		+0.21				8.60
	2	-0.39		+0.03				
	AV	-0.54	-4.7	+0.12	+1.0	-3.7	-82.0	
M	1	-0.57		+0.12				8.91
	2	-0.39		+0.24				
	3	-0.48		-0.03				
	4	-0.48		+0.18				
	AV	-0.48	-4.3	+0.12	+1.1	-3.2	-83.1	
CALCULATED						-5.0	-91.4	

TABLE 6 – PART 2

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

TABLE OF RECORDED STATIC STRESSES

PILE M4

OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS
JUNE, 1949

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT APPLIED = NONE LOAD ON PILE = [illegible]					TOTAL LOAD ON SECTION	LOAD INCREMENT APPLIED = NONE LOAD ON PILE = 20.4 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = +39K LOAD ON PILE = 59.4 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF [illegible] HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 8 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 44 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1																		
		2																		
		3			[illegible]						+0.78				-0.02		+0.78			
		4																		
		AV			[illegible]	-1.9	-1.9	-2.7			+0.78	+3.5	+3.5	+0.8	-0.02	-0.9	+0.78	+3.5	+2.6	+3.4
B	4.86	1																		
		2			[illegible]						+0.93				-0.15		+1.62			
		3			[illegible]						[illegible]				-0.15		+1.62			
		4			[illegible]						+0.69				0		+0.72			
		AV			[illegible]	-1.4	-1.4	[illegible]			+0.84	+4	+4	+9.9	-0.12	-0.6	+1.32	+6.5	+5.9	+15.8
C	5.26	1																		
		2			[illegible]						+0.93				0		+1.32			
		AV			[illegible]	[illegible]	[illegible]	[illegible]			+0.93	+4.9	+4.9	+9.7	0	0	+1.32	+7.0	+7.0	+16.7
D	5.65	1																		
		2			[illegible]						+0.63				-0.30		+0.42			
		AV			[illegible]	[illegible]	[illegible]	[illegible]			+0.63	+3.6	+3.6	-14.3	-0.30	-1.7	+0.42	+2.4	+0.7	-13.6
E	6.05	1			-0.03						+0.75				-0.60		+0.42			
		2			[illegible]						+0.63				-0.60		+0.42			
		AV			[illegible]	[illegible]	-2.4	-22.4			+0.72	+4.4	+4.4	-18.0	-0.60	-3.6	+0.42	+2.5	-1.1	-19.1
F	6.44	1			[illegible]						+0.45				-0.63		+0.15			
		2			[illegible]						+0.48				-0.69		+0.36			
		AV			[illegible]	[illegible]	[illegible]	-36.7			+0.48	+3.1	+3.1	-33.6	-0.66	-4.2	+0.27	+1.7	-2.5	-36.1
G	6.84	1			[illegible]						+0.45				-0.84		+0.36			
		2			[illegible]						+0.63				-0.87		+0.48			
		AV			[illegible]	[illegible]	[illegible]	[illegible]			+0.54	+3.7	+3.7	-43	-0.87	-6.0	+0.45	+3.1	-2.9	-46.0
H	7.04	1			[illegible]						+0.45				-1.02		+0.45			
		2			[illegible]						[illegible]				-0.78		+0.30			
		AV			[illegible]	[illegible]		-54.9			+0.48	+3.4	+3.4	-51.5	-0.90	-6.3	+0.42	+2.9	-3.4	-54.9
I	7.43	1			[illegible]						+0.48				-0.93		+0.30			
		2			[illegible]						[illegible]				-1.05		+0.42			
		AV			0	0	0	-63.9			+0.48	+3.6	+3.6	-60.3	-0.99	-7.3	+0.36	+2.7	-4.6	-64.9
J	7.81	1			-0.06						+0.63				-1.05		+0.27			
		2			-0.18						+0.45				-1.05		+0.42			
		AV			-0.12	-0.9	-0.9	-78.2			+0.54	+4.2	+4.2	-74.0	-1.05	-8.2	+0.33	+2.6	-5.6	-79.6
K	8.20	1			[illegible]						+0.48				-1.14		+0.36			
		2			[illegible]						+0.45				-0.87		+0.24			
		AV			-0.06	-0.5	-0.5	-73.2			+0.45	+3.9	+3.9	-69.3	-0.99	-8.1	+0.30	+2.4	-5.7	-75.0
L	8.60	1			[illegible]						+0.78				-1.05		+0.42			
		2			+0.09						+0.48				-1.17		+0.54			
		AV			[illegible]	+0.5	+0.5	-81.5			+0.63	+5.4	+5.4	-76.1	-1.11	-9.6	+0.48	+4.1	-5.5	-81.6
M	8.91	1			[illegible]						+0.48				-1.05		+0.42			
		2			+0.03						+0.33				-0.99		+0.51			
		3			[illegible]						+0.48				-1.08		+0.60			
		4			[illegible]						+0.63				-0.96					
		AV			+0.09	+0.8	+0.8	-82.5			+0.48	+4.3	+4.3	-78.0	-1.02	-9.1	+0.51	+4.5	-4.6	-82.6
CALCULATED							[illegible]	[illegible]					[illegible]	-91.4					-9.6	-101.0

SECTION	GAGE	LOAD INCREMENT (APPLIED) = 59.1K LOAD ON PILE = 118.5 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = +60.4K LOAD ON PILE = 178.9 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = +61.1K LOAD ON PILE = 240 KIPS					TOTAL LOAD ON SECTION
		EFFECT OF INCREMENT		EFFECT OF 20 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 44 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 44 HOURS		FINAL INCREMENT	
		STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	1																		
	2																		
	3	+0.03		+0.42				+0.75		+0.33				+0.09		+0.30			
	4																		
	AV	+0.03	+0.1	+0.42	+1.9	+2.0	+5.4	+0.75	+3.3	+0.33	+1.5	+4.8	+10.2	+0.09	+0.4	+0.30	+1.3	+1.7	+11.9
B	1																		
	2	+0.18		+1.02				+0.81		+1.47				+0.33		+1.26			
	3	+0.18		+0.57				+0.90		+1.53				+0.45		+1.59			
	4	+0.03		+0.57				+0.72		+0.81				-0.33		+0.09			
	AV	+0.12	+0.6	+0.51	+3.9	+4.5	+22.3	+0.81	+3.9	+1.26	+6.1	+10.0	+30.3	-0.15	-0.7	+0.96	+4.7	+4.0	+34.3
C	1																		
	2	+0.18		+0.72				+0.75		+0.93				-0.15		+0.54			
	AV	+0.18	+0.9	+0.72	+3.8	+4.7	+21.4	+0.75	+3.9	+0.93	+4.9	+8.8	+30.2	-0.15	-0.8	+0.54	+2.8	+2.0	+32.2
D	1																		
	2	-0.12		+0.57				+0.51		+0.42				-0.09		+0.93			
	AV	-0.12	-0.7	+0.57	+3.2	+2.5	-11.1	+0.51	+2.9	+0.42	+2.4	+5.3	-5.8	-0.09	-0.5	+0.93	+5.2	+4.7	-1.1
E	1	-0.42		+0.57				-0.27		+0.45				0		+0.24			
	2	-0.42		+0.57				-0.24		+0.12				0		+0.09			
	AV	-0.42	-2.5	+0.57	+3.5	+1.0	-18.1	-0.24	-1.5	+0.27	+1.8	+0.1	-18.0	0	0	+0.15	+0.9	+0.9	-17.1
F	1	-0.42		+0.27				-0.54		-0.03				-0.03		-0.18			
	2	-0.27		+0.27				-0.42		+0.30				-0.15		-0.06			
	AV	0.36	-2.3	+0.27	+1.7	-0.6	-36.7	-0.48	-3.1	+0.12	+0.8	-2.3	-39.0	-0.09	-0.6	-0.12	-0.8	-1.4	-40.4
G	1	-0.57		+0.27				-0.51		+0.24				-0.45		-0.21			
	2	-0.72		+0.42				-0.60		+0.33				-0.45		-0.36			
	AV	-0.66	-4.5	+0.36	+2.4	-2.1	-48.1	-0.54	-3.7	+0.27	+1.8	-1.9	-50.0	-0.45	-3.1	-0.27	-1.8	-4.9	-54.9
H	1	-0.87		+0.42				-0.84		+0.42				-0.66		-0.60			
	2	-0.72		+0.42				-0.75		+0.33				-0.69		-0.27			
	AV	-0.78	-5.5	+0.42	+2.9	-2.6	-57.5	-0.78	-5.5	+0.39	+2.7	-2.8	-60.3	0.66	-4.6	-0.45	-3.2	-7.8	-68.1
I	1	-0.87		+0.42				-0.93		+0.39				-0.66		-0.45			
	2	-0.87		+0.27				-0.75		+0.18				-0.69		-0.57			
	AV	-0.87	-6.5	+0.33	+2.5	-4.0	-68.9	-0.84	-6.2	+0.27	+2.0	-4.2	-73.1	-0.66	-4.9	-0.51	-3.8	-8.7	-81.8
J	1	-0.87		+0.27				-0.30		+0.63				1.26		-0.42			
	2	0.87		+0.12				-0.12		+0.45				-0.90		-0.81			
	AV	-0.87	-6.8	+0.18	+1.4	-5.4	-85.0	-0.21	-1.6	+0.54	+4.2	+2.6	-82.4	-1.08	-8.5	-0.60	-4.7	-13.2	-95.4
K	1	-0.87		+0.12				-0.90		+0.33				-0.90		-0.21			
	2	-0.72		+0.27				-0.75		+0.18				-0.90		-0.81			
	AV	-0.78	-6.4	+0.18	+1.5	-4.9	-79.9	-0.84	-6.9	+0.27	+2.2	-4.7	-84.6	-0.90	-7.4	-0.51	-4.2	-11.6	-96.2
L	1	-0.87		+0.27				0		+0.33				-0.75					
	2	-1.32		+0.57				-1.41		+0.39				-1.20		-0.36			
	AV	-1.08	-9.3	+0.42	+3.6	-5.7	-87.3	0.72	-6.1	+0.36	+3.1	-3.0	-90.3	-0.96	-8.3	-0.36	-3.1	-11.4	-101.7
M	1	-0.72		+0.27						+1.08				-1.28		-0.93			
	2	-0.72		+0.27				-1.20		+0.78						-0.21			
	3	-1.02		+0.57				-1.35		+1.23				-1.50					
	4	-0.72		+0.42				-1.05		+1.68				-1.50		-0.21			
	AV	-0.78	-7.0	+0.39	+3.5	-3.5	-86.1	-1.20	-10.7	+1.20	+10.7	0	-86.1	-1.47	-13.1	-0.45	-4.0	-17.1	-103.2
CALCULATED						-8.5	-109.9					-10.4	-120.3					-11.1	-131.4

SECTION	GAGE	LOAD DECREMENT (REMOVED) = 146.7K LOAD ON PILE = 93.3 KIPS					TOTAL LOAD ON SECTION	LOAD DECREMENT (REMOVED) = 43.3K LOAD ON PILE = 50 KIPS					TOTAL LOAD ON SECTION	LOAD DECREMENT (REMOVED) = 43.1K LOAD ON PILE = 6.9 KIPS					TOTAL LOAD ON SECTION	AREA SQ IN
		EFFECT OF DECREMENT		EFFECT OF HOURS		FINAL INCREMENT		EFFECT OF DECREMENT		EFFECT OF 16 HOURS		FINAL INCREMENT		EFFECT OF DECREMENT		EFFECT OF 18 HOURS		FINAL INCREMENT		
		STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			
A	1																			4.47
	2																			
	3	-0.15						+1.05		+0.36				-0.78		-0.51				
	4																			
	AV	0.15	-0.7			-0.7	-0.7	+1.05	+4.7	+0.36	+1.6	+6.3	+5.6	-0.78	-3.5	-0.51	-2.3	-5.8	-0.2	
B	1																			4.86
	2	+0.75						+2.49		+0.72				+0.27		-0.12				
	3	+1.05						+2.61		+0.39				+0.39		+0.03				
	4	+0.90						+1.89		+0.54				+0.30		+0.39				
	AV	+0.90	+4.4			+4.4	+4.4	+2.34	+11.4	+0.54	+2.6	+14.0	+18.4	+0.33	+1.6	+0.09	+0.4	+2.0	+20.4	
C	1																			5.26
	2	+1.20						+2.10		+0.36				+2.16		+0.33				
	AV	+1.20	+6.3			+6.3	+6.3	+2.10	+11.0	+0.36	+1.9	+12.9	+19.2	+2.16	+11.4	+0.33	+1.7	+13.1	+32.3	
D	1																			5.65
	2	+1.05						+2.28		+0.27				+1.53		+0.18				
	AV	+1.05	+5.9			+5.9	+5.9	+2.28	+12.9	+0.27	+1.5	+14.4	+20.3	+1.53	+8.6	+0.18	+1.0	+9.6	+29.9	
E	1	+2.25						+3.48		+0.54				+1.80		+0.18				6.05
	2	+2.25						+3.33		+0.45				+1.80		+0.54				
	AV	+2.25	+13.6			+13.6	+13.6	+3.42	+20.7	+0.51	+3.1	+23.8	+37.4	+1.80	+10.9	+0.36	+2.2	+13.1	+50.5	
F	1	+2.70						+3.75		0				+2.34		+0.57				6.44
	2	+2.70						+3.63		+0.51				+2.40		+0.36				
	AV	+2.70	+17.4			+17.4	+17.4	+3.69	+23.8	+0.27	+1.7	+25.5	+42.9	+2.37	+15.2	+0.48	+3.1	+18.3	+61.2	
G	1	+2.85						+4.17		+0.39				+2.82		+0.39				6.84
	2	+3.15						+4.17		+0.33				+2.73		+0.48				
	AV	+3.00	+20.5			+20.5	+20.5	+4.17	+28.5	+0.36	+2.5	+31.0	+51.5	+2.76	+18.9	+0.45	+3.1	+22.0	+73.5	
H	1	+3.75						+4.53		+0.45				+3.15		+0.24				7.04
	2	+3.15						+4.29		+0.12				+2.91		+0.45				
	AV	+3.45	+24.3			+24.3	+24.3	+4.41	+31.1	+0.27	+1.9	+33.0	+57.3	+3.03	+21.3	+0.33	+2.3	+23.6	+80.9	
I	1	+3.75						+4.89		-0.03				+3.42		+0.27				7.43
	2	+3.60						+4.98		+0.27				+3.42		+0.27				
	AV	+3.66	+27.2			+27.2	+27.2	+4.92	+36.6	+0.12	+0.9	+37.5	+64.7	+3.42	+25.4	+0.27	+2.0	+27.4	+92.1	
J	1	+3.75						+4.68		-0.03				+3.84		+0.57				7.81
	2	+3.75						+4.59		+0.21				+3.48		+0.33				
	AV	+3.75	+29.3			+29.3	+29.3	+4.62	+36.1	+0.09	+0.7	+36.8	+66.1	+3.66	+28.6	+0.45	+3.5	+32.1	+98.2	
K	1	+3.90						+5.28		+0.03				+4.32		+0.03				8.20
	2	+3.90						+5.28		+0.36				+3.33		+0.09				
	AV	+3.90	+32.0			+32.0	+32.0	+5.28	+43.3	+0.21	+1.7	+45.0	+77.0	+3.84	+31.4	+0.06	+0.5	+31.9	+108.9	
L	1									-0.18				+4.38		+0.03				8.60
	2	+4.65						+5.94		+0.51				+4.44		+0.12				
	AV	+4.65	+40.0			+40.0	+40.0	+5.94	+51.1	+0.15	+1.3	+52.4	+92.4	+4.41	+37.9	+0.09	+0.8	+38.7	+131.1	
M	1	+4.50						+4.98		+0.03				+4.20		+0.27				8.91
	2	+4.50						+5.49		-0.03				+4.23		+0.12				
	3	+4.50						+6.72		+0.27				+4.14		-0.27				
	4	+4.65						+7.95		+0.75				+4.08		+0.03				
	AV	+4.53	+40.4			+40.4	+40.4	+6.26	+55.8	+0.27	+2.4	+58.2	+98.6	+4.17	+36.3	+0.03	+0.3	+36.6	+135.2	
CALCULATED							+46.6					+43.4	+90.0					+43.1	+133.1	

TABLE 7 – PART I

TABLE OF RECORDED STATIC STRESSES

PILE M5

SECTION	AREA - SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 20K LOAD ON PILE = 20 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = 20K LOAD ON PILE = 40 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 3 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 10 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	+ 22		[illegible]				-0.2		+2.06			
		2	+2.45		+0.36				-0.51		+0.36			
		3	+2.45		- 52				-0.36		+0.96			
		4	-2.29		-1.20				+0.21		+0.06			
		AV	+2.33	+2	-0.57	+2.5	-2.4	-2.4	-0.33	-1.5	+0.36	+1.6	+0.1	-2.3
B	4.86	1	+2.26		-1.20				-0.66		-1.74			
		2	-2.36		- 22				-0.36		+0.51			
		3	+2.39		-1.44				+0.51		-1.44			
		4	+2.32		1.44				-0.36		-1.74			
		AV	+2.27	- 3	- 32	+6.4	-5	-5	-0.69	-3.3	[illegible]	-5.4	-8.7	-13.8
C	5.26	1	-3.60		-0.24				- 26		+0.06			
		2	-3.51		-3.09				-1.26		+0.21			
		AV	-2.54	-2.8	-0.59	-0.5	-3.3	-3.3	- 26	-6.6	+0.15	+0.8	-5.8	-9.1
D	5.65	1	-2.69		+3.36				- 41		+0.06			
		2	+ 4		+ 74				[illegible]		-0.24			
		AV	-2.24	+ 4	+2.52	-4.7	-3.3	-3.3	- 26	-7.1	+0.09	+0.5	-6.6	-9.9
E	6.05	1	+2.92		-2.29				- 4		+0.21			
		2	-2.54		- 4				- 4		-0.39			
		AV	-2.8	[illegible]	-0.69	-4.2	-5.3	-5.3	- 4	-8.5	-0.09	-0.5	-9.0	-14.3
F	6.44	1	[illegible]		-2.5				-1.4		-0.99			
		2	[illegible]		0				- 41		-0.54			
		AV	[illegible]	-7.5	+0.09	-0.6	-6.9	-6.9	-1.41	-9	-0.75	-4.8	-13.9	-22.5
G	6.84	1	-1.4		-0.2				-1.41		-0.09			
		2	- 35		-2.26				-1.56		+0.06			
		AV	- 26	-5.6	-2.5	- 0	-9.6	-9.6	-1.47	-11.7	+0.03	+0.2	-11.9	-21.5
H	7.04	1	- 22		-2.40				- 71		+0.21			
		2	- 23		-2.2				-1.71		+0.06			
		AV	- 22	-8.4	-2.33	-2.3	-10.7	-10.7	-1.71	-12.0	+0.15	+1.1	-10.9	-21.6
I	7.43	1	+2.27		-2.5				- 86		+0.21			
		2	- 14		-2.8				-1.71		-0.09			
		AV	-2.42	-3	+0.15	[illegible]	-4.2	-4.2	-1.77	-13.2	-0.06	+0.4	-12.8	-17.0
J	7.81	1	- 20		-0.30				- 86		+0.21			
		2	-1.32		+0.99				-1.86		+0.06			
		AV	-1.26	-9.3	+2.33	+2.6	-7.2	-7.2	-1.36	-14.5	+0.15	+1.2	-13.3	-20.5
K	8.20	1	-0.90		+0.39				-1.7		-0.37			
		2	- 4		-0.23				-1.71		-0.37			
		AV	- 02	-8.4	-0.24	+2.0	-10.4	-10.4	-1.71	-14.0	-0.37	-3.0	-17.0	-27.4
L	8.60	1												
		2	-2.8		-0.8				-2.01		-0.81			
		AV	-2.8	-7.0	-0.18	-1.5	-8.5	-8.5	-2.01	-17.3	-0.81	-7.0	-24.3	-32.8
M	8.91	1	-0.5		+2.33				-1.41		-0.84			
		2	[illegible]		-2.33				-1.86		-0.99			
		3	-1.53		-2.63				-2.01		-0.84			
		4	-0.99		-2.66				- 71		-0.84			
		AV	-1.02	-9.1	-2.63	-5.6	-4.7	-14.7	- 74	-15.5	-0.87	-7.7	-23.2	-37.8
CALCULATED							-11.4						-20.0	-31.4

SECTION	AREA - SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 10K LOAD ON PILE = 50 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = 10K LOAD ON PILE = 60 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 68 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1							-0.2		+0.45			
		2							-0.12					
		3							+0.03					
		4							+0.03		+0.45			
		AV							-0.06	-0.3	+0.45	+2.0	+1.7	-0.6
B	4.86	1							-0.27		+0.45			
		2							+0.03					
		3							-0.16		+0.30			
		4							-0.12		0			
		AV							-0.12	-0.6	+0.24	+1.2	+0.6	-13.2
C	5.26	1							-0.87		+0.60			
		2							-1.02		+0.60			
		AV							-0.96	-5.1	+0.60	+3.2	-1.9	+11.0
D	5.65	1							-1.17		+0.30			
		2							-0.72		-0.15			
		AV							-0.96	-5.4	+0.09	+0.5	-4.9	-14.8
E	6.05	1							-1.47		0			
		2							-1.02		-0.15			
		AV							-1.26	-7.6	-0.09	-0.5	-8.1	-22.4
F	6.44	1							-1.32		0			
		2							-1.62		0			
		AV							-1.47	-9.5	0	0	-9.5	-30.3
G	6.84	1							-1.62		0			
		2							-1.77		0			
		AV							-1.68	-11.5	0	0	-11.5	-32.0
H	7.04	1							-1.92		+0.15			
		2							-1.77		-0.15			
		AV							-1.86	-13.1	0	0	-13.1	-34.7
I	7.43	1							-1.77		-0.15			
		2							-1.62		-0.15			
		AV							-1.68	-12.5	-0.15	-1.1	-13.6	-30.6
J	7.81	1							-1.92		-0.15			
		2							-1.92		-0.15			
		AV							-1.92	-15.0	-0.15	-1.2	-16.2	-36.7
K	8.20	1							-1.77		-0.30			
		2							-1.92		-0.45			
		AV							-1.86	-15.2	-0.39	-3.2	-18.4	-45.8
L	8.60	1												
		2							-1.77		-0.45			
		AV							-1.77	-15.2	-0.45	-3.9	-19.1	-51.9
M	8.91	1	-0.78						-1.17		+0.15			
		2	-0.99						-1.17		-0.30			
		3	-1.23						-0.87		-0.15			
		4	-0.93						-1.17		-0.30			
		AV	-0.99	-8.8			-5.8	-46.7	-1.08	-9.6	-0.15	-1.3	-10.9	-57.6
CALCULATED							-10.0	-41.4					-10.0	-51.4

SECTION	AREA - SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 10K LOAD ON PILE = 70 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = 10K LOAD ON PILE = 80 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 2 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF 16 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1							+0.27		+0.30			
		2							+0.57		+0.75			
		3							-0.48		+0.45			
		4							-0.03		+0.30			
		AV							+0.09	+0.4	+0.45	+2.0	+2.4	+1.8
B	4.86	1							-0.03		0			
		2							+0.57		+0.75			
		3							+0.27		0			
		4							+0.27		0			
		AV							+0.27	+1.3	+0.18	+0.9	+2.2	-11.0
C	5.26	1							-0.48		+0.30			
		2							-0.48		+0.30			
		AV							-0.48	-2.5	+0.30	+1.6	-0.9	-11.9
D	5.65	1							-0.78		+0.15			
		2							-0.78		+0.15			
		AV							-0.78	-4.4	+0.15	+0.8	-3.6	-18.4
E	6.05	1							-1.08		+0.15			
		2							-1.23		+0.30			
		AV							-1.14	-6.9	+0.21	+1.3	-5.6	-28.0
F	6.44	1							-1.23		0			
		2							-1.29		0			
		AV							-1.23	-7.9	0	0	-7.9	-38.2
G	6.84	1							-1.38		+0.15			
		2							-1.38		+0.15			
		AV							-1.38	-9.4	+0.15	+1.0	-8.4	-40.4
H	7.04	1							-1.68		+0.15			
		2							-1.53		0			
		AV							-1.62	-11.4	+0.09	+0.6	-10.8	-45.5
I	7.43	1							-1.68		0			
		2							-1.68		+0.15			
		AV							-1.68	-12.5	+0.09	+0.7	-11.8	-42.4
J	7.81	1							-1.83		+0.15			
		2							-1.83		+0.30			
		AV							-1.83	-14.3	+0.21	+1.6	-12.7	-49.4
K	8.20	1							-1.68		-0.15			
		2							-1.38		-0.15			
		AV							-1.53	-12.5	-0.15	-1.2	-13.7	-59.5
L	8.60	1												
		2							-1.53		-0.15			
		AV							-1.53	-13.2	-0.45	-3.9	-17.1	-69.0
M	8.91	1	-0.69		-0.12				-0.87		+0.60			
		2	-0.69		-0.12				-1.17		+0.45			
		3	-0.84		-0.12				-1.02		+0.30			
		4	-0.54		-0.12				-1.02		0			
		AV	-0.69	-6.1	-0.12	-1.1	-7.2	-64.8	-1.02	-9.1	+0.33	+2.9	-6.2	-71.0
CALCULATED							-10.0	-61.4					-10.0	-71.4

SECTION	AREA - SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 10K LOAD ON PILE = 90 KIPS					TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = 5K LOAD ON PILE = 95 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 21 HOURS		FINAL INCREMENT		EFFECT OF INCREMENT		EFFECT OF HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	+0.06		+0.03				+0.15					
		2	-0.09		+0.75				+0.09					
		3	-0.24		+0.33				+0.09					
		4	-0.09		+0.18				+0.09					
		AV	0.15	0.7	+0.33	+1.5	+0.8	+2.6	+0.09	+0.4			+0.4	+3.0
B	4.86	1	+0.36		+0.33				+0.39					
		2	+0.51		+1.08				+0.54					
		3	+0.51		+0.18				+0.48					
		4	+0.51		+0.18				+0.48					
		AV	+0.48	+2.3	+0.45	+2.2	+4.5	-6.5	+0.48	+2.3			+2.3	-4.2
C	5.26	1	-0.24		+0.03				-0.06					
		2	-0.24		+0.03				-0.15					
		AV	-0.24	-1.3	+0.03	+0.2	-1.1	-13.0	-0.12	-0.6			-0.6	-13.6
D	5.65	1	-0.24		-0.21				-0.21					
		2	-0.39		-0.12				-0.36					
		AV	-0.33	-1.9	-0.18	-1.0	-2.9	-21.3	-0.30	-1.7			-1.7	-23.0
E	6.05	1	-0.54		-0.27				+0.36					
		2	-0.69		+0.03				+0.36					
		AV	-0.63	-3.8	-0.12	-0.7	-4.5	-32.5	-0.36	-2.2			-2.2	-34.7
F	6.44	1	-0.54		+0.09				-0.27					
		2	-0.54		+0.33				-0.36					
		AV	-0.54	-3.5	+0.21	+1.4	-2.1	-40.3	-0.30	-1.9			-1.9	-42.2
G	6.84	1	-0.84		+0.03				-0.45					
		2	-0.84		-0.12				-0.36					
		AV	-0.84	-5.7	-0.06	-0.4	-6.1	-46.5	-0.42	-2.9			-2.9	-49.4
H	7.04	1	-0.99		-0.03				-0.45					
		2	-0.84		-0.12				-0.51					
		AV	-0.93	-6.5	-0.12	-0.8	-7.3	-52.8	-0.48	-3.4			-3.4	-56.2
I	7.43	1	-0.84		-0.27				-0.45					
		2	-0.99		-0.12				-0.42					
		AV	-0.93	-6.9	-0.18	-1.3	-8.2	-50.6	-0.42	-3.1			-3.1	-53.7
J	7.81	1	-0.99		-0.06				-0.48					
		2	-1.14		+0.18				-0.51					
		AV	-1.05	-8.2	+0.06	+0.5	-7.7	-57.1	-0.48	-3.8			-3.8	-60.9
K	8.20	1	-0.24		+0.48				+0.24					
		2	-0.24		+0.48				+0.12					
		AV	-0.24	-2.0	+0.48	+3.9	+1.9	-57.6	+0.18	+1.5			+1.5	-56.1
L	8.60	1												
		2	-0.09		+0.48				-0.21					
		AV	-0.09	-0.8	+0.48	+4.1	+3.3	-65.7	-0.21	-1.8			-1.8	-67.5
M	8.91	1	-0.99		+0.57				-0.15					
		2	-0.99		+0.48				-0.06					
		3			+0.39				-0.36					
		4	-0.54		+0.39				-0.18					
		AV	-1.14	-10.2	+0.45	+4.0	-6.2	-77.2	-0.18	-1.6			-1.6	-78.8
CALCULATED							-10.0	-81.4					-5.0	-86.4

SECTION	AREA - SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 5K LOAD ON PILE = 100 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 20 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	+1.98		-1.41			
		2	+1.69		-1.02			
		3	+1.56		-3.81			
		4	+1.95		-1.04			
		AV	+1.86	+8.3	-1.86	-8.3	0	+3.0
B	4.86	1	+0.15		-0.87			
		2	+0.21		-0.41			
		3	+0.24		-1.35			
		4	+0.30		-0.90			
		AV	+0.24	+1.2	-0.90	-4.4	-3.2	-7.4
C	5.26	1	-0.15		-0.36			
		2	-0.06		-0.57			
		AV	-0.12	-0.6	-0.48	-2.5	-3.1	-16.7
D	5.65	1	-0.15		-0.27			
		2	-0.15		-0.27			
		AV	-0.20	-1.1	-0.27	-1.5	-2.6	-25.6
E	6.05	1	-0.36		-0.21			
		2	-0.42		+0.15			
		AV	-0.39	-2.4	-0.03	-0.2	-2.6	-37.3
F	6.44	1	-0.30		+0.18			
		2	-0.30		+0.27			
		AV	-0.30	-1.9	+0.24	+1.5	-0.4	-42.6
G	6.84	1	-0.36		-0.12			
		2	-0.45		-0.15			
		AV	-0.42	-2.9	-0.12	-0.8	-3.7	-53.1
H	7.04	1	-0.54		-0.27			
		2	-0.30		-0.09			
		AV	-0.42	-3.0	-0.18	-1.3	-4.3	-60.5
I	7.43	1	-0.36		-0.15			
		2	-0.39		-0.30			
		AV	-0.36	-2.7	-0.24	-1.8	-4.5	-58.2
J	7.81	1	-0.60		+0.27			
		2	-0.60		+0.21			
		AV	-0.60	-4.7	+0.24	+1.9	-2.8	-63.7
K	8.20	1	-2.43		+2.61			
		2	-2.28		+2.43			
		AV	-2.34	-19.2	+2.52	+20.7	+1.5	-54.6
L	8.60	1						
		2	-2.07		+2.55			
		AV	-2.07	-17.8	+2.55	+21.9	+4.1	-63.4
M	8.91	1	-0.12		+0.75			
		2	-0.30		+0.69			
		3	-0.15		+0.84			
		4	-0.30		+0.78			
		AV	-0.21	-1.9	+0.78	+6.9	+5.0	-73.8
CALCULATED							-5.0	-91.4

TABLE 7 – PART 2

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

TABLE OF RECORDED STATIC STRESSES
PILE M5

OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED) = [illegible] LOAD ON PILE = [illegible] KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 6 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1			-0.27			
		2			0			
		3			-0.15			
		4			+0.09			
		AV			-0.03	-2.4	-2.4	+2.6
B	4.86	1			-0.22			
		2			+0.03			
		3			-0.26			
		4			+0.03			
		AV			0	0	0	-7.4
C	5.26	1			-0.2			
		2			-0.26			
		AV			-0.09	-2.5	-0.5	-17.2
D	5.65	1			+0.13			
		2			+0.09			
		AV			+0.06	+0.3	+0.3	-25.3
E	6.05	1			+0.29			
		2			-0.06			
		AV			+0.03	+0.2	+0.2	-37.1
F	6.44	1			-0.06			
		2			0			
		AV			-0.03	-0.2	-0.2	-47.8
G	6.84	1			+0.09			
		2			+0.21			
		AV			+0.15	+1.2	+1.0	-52.1
H	7.04	1			+0.09			
		2			+0.21			
		AV			+0.15	+	+1.1	-59.4
I	7.43	1			+0.21			
		2			+0.06			
		AV			+0.15	+	+1.1	-57.1
J	7.81	1			+0.2			
		2			+0.21			
		AV			+0.21	+1.6	+1.6	-62
K	8.20	1			-0.21			
		2			-0.26			
		AV			-0.15	-1.2	-1.2	-55.8
L	8.60	1						
		2			-0.21			
		AV			-0.2	-.8	-.8	-65.2
M	8.91	1			+0.09			
		2			-0.12			
		3			+0.03			
		4			0			
		AV			0	0	0	-73.8
CALCULATED							0	-91.4

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED) = [illegible] LOAD ON PILE = [illegible] KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 3 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1			+1.83			
		2			+2.63			
		3			+1.08			
		4			+0.63			
		AV			+1.75	+3.3	+3.3	+5.9
B	4.86	1			-0.2			
		2			+1.48			
		3			+0.03			
		4			-0.2			
		AV			+0.06	+0.3	+0.3	-7.1
C	5.26	1			+0.33			
		2			+0.33			
		AV			+0.33	+1.7	+1.7	-15.5
D	5.65	1			+0.18			
		2			+0.13			
		AV			+0.16	+1.0	+1.0	-24.3
E	6.05	1			+0.18			
		2			+0.18			
		AV			+0.18	+1.1	+1.1	-36.0
F	6.44	1			+0.03			
		2			+0.18			
		AV			+0.12	+0.8	+0.8	-47.0
G	6.84	1			+0.18			
		2			+0.03			
		AV			+0.12	+0.8	+0.8	-51.3
H	7.04	1			+0.12			
		2			+0.09			
		AV			+0.12	+0.8	+0.8	-58.6
I	7.43	1			+0.03			
		2			+0.18			
		AV			+0.12	+0.9	+0.9	-56.2
J	7.81	1			+0.12			
		2			+0.18			
		AV			+0.18	+1.4	+1.4	-60.7
K	8.20	1			-0.27			
		2			-0.42			
		AV			-0.36	-3.0	-3.0	-58.8
L	8.60	1						
		2			-0.27			
		AV			-0.27	-2.3	-2.3	-67.5
M	8.91	1			-0.12			
		2			-0.27			
		3			-0.27			
		4			-0.27			
		AV			-0.24	-2.1	-2.1	-75.9
CALCULATED							0	-91.4

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 9.6K LOAD ON PILE = 109.6 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 44 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	0					
		2	+0.06					
		3	0					
		4	-0.18					
		AV	-0.03	-0.1			-0.1	+5.8
B	4.86	1	+0.15		+0.12			
		2	+0.15		+1.17			
		3	+0.15		+0.12			
		4	+0.15		+0.12			
		AV	+0.15	+0.7	+0.39	+1.9	+2.6	-4.5
C	5.26	1	+0.06		+0.06			
		2	+0.06		+0.06			
		AV	+0.06	-0.3	+0.06	+0.3	+0.6	-14.9
D	5.65	1	-0.18		+0.15			
		2	-0.18		0			
		AV	-0.18	-1.0	+0.09	+0.5	-0.5	-24.8
E	6.05	1	-0.30		-0.03			
		2	-0.36		+0.03			
		AV	-0.33	-2.0	0	0	-2.0	-38.0
F	6.44	1	-0.63		0			
		2	-0.72		+0.09			
		AV	-0.66	-4.3	+0.03	+0.2	-4.1	-46.1
G	6.84	1	-0.51		+0.18			
		2	-0.60		-0.03			
		AV	-0.57	-3.9	+0.09	+0.6	-3.3	-54.6
H	7.04	1	-0.63		0			
		2	-0.72		+0.24			
		AV	-0.66	-4.6	+0.12	+0.8	-3.8	-62.4
I	7.43	1	-0.63		0			
		2	-0.75		+0.12			
		AV	-0.69	-5.1	+0.06	+0.4	-4.7	-60.9
J	7.81	1	-0.87		+0.09			
		2	-0.63		0			
		AV	-0.75	-5.9	+0.03	+0.2	-5.7	-66.4
K	8.20	1	-0.66		+0.03			
		2	-0.60		+0.12			
		AV	-0.63	-5.2	+0.09	+0.7	-4.5	-63.3
L	8.60	1						
		2	-0.60		+0.12			
		AV	-0.60	-5.2	+0.12	+1.0	-4.2	-71.7
M	8.91	1	-0.72		+0.69			
		2	-0.72		+0.24			
		3	-0.90		+0.27			
		4	-0.90		+0.27			
		AV	-0.81	-7.2	+0.36	+3.2	-4.0	-79.9
CALCULATED							-9.6	-101.0

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 8.9K LOAD ON PILE = 118.5 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 20 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	-0.[illegible]		+0.57			
		2	+0.03		+0.57			
		3	-0.12		+0.42			
		4	-0.03		+0.42			
		AV	-0.06	-0.3	+0.51	+2.3	+2.0	+7.8
B	4.86	1	+0.33		+0.27			
		2	+0.48		+0.57			
		3	+0.48		+0.27			
		4	+0.48		+0.27			
		AV	+0.45	+2.2	+0.36	+1.7	+3.9	-0.6
C	5.26	1	+0.03		+0.27			
		2	-0.12		-0.03			
		AV	-0.06	-0.3	+0.12	+0.6	+0.3	-14.6
D	5.65	1	-0.27		+0.27			
		2	-0.27		+0.27			
		AV	-0.27	-1.5	+0.27	+1.5	0	-24.8
E	6.05	1	-0.42		+0.12			
		2	-0.42		+0.27			
		AV	-0.42	-2.5	+0.18	+1.1	-1.4	-39.4
F	6.44	1	-0.42		+0.27			
		2	-0.27		+0.27			
		AV	-0.36	-2.3	+0.27	+1.7	-0.6	-46.7
G	6.84	1	-0.72		+0.12			
		2	-0.72		+0.27			
		AV	-0.72	-4.9	+0.18	+1.2	-3.7	-58.3
H	7.04	1	-0.87		+0.27			
		2	-0.87		+0.12			
		AV	-0.87	-6.1	+0.18	+1.3	-4.8	-67.2
I	7.43	1	-0.72		+0.12			
		2	-0.87		+0.12			
		AV	-0.78	-5.8	+0.12	+0.9	-4.9	-65.8
J	7.81	1	-0.87		+0.27			
		2	-0.72		+0.12			
		AV	-0.79	-6.1	+0.18	+1.4	-4.7	-71.1
K	8.20	1	+0.03		+0.12			
		2	-0.12		-0.03			
		AV	-0.06	-0.5	+0.06	+0.5	0	-63.3
L	8.60	1						
		2	-0.12		-0.03			
		AV	-0.12	-1.0	-0.03	-0.3	-1.3	-73.0
M	8.91	1	-0.42		+0.27			
		2	-0.42		+0.12			
		3	-0.72		+0.12			
		4	-0.57		+0.12			
		AV	-0.54	-4.8	+0.15	+1.3	-3.5	-83.4
CALCULATED							-8.9	-109.9

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 10.4K LOAD ON PILE = 128.9 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 44 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	+0.60					
		2	+0.62					
		3	+1.74					
		4	+1.92					
		AV	+1.[illegible]	+5.5			+5.5	+13.3
B	4.86	1	+1.20		-0.12			
		2	+1.05		+0.63			
		3	+1.20		-0.27			
		4	+1.20		+0.03			
		AV	+1.17	+5.7	+0.09	+0.4	+6.1	+5.5
C	5.26	1	0.15		+0.48			
		2	+0.06		-0.42			
		AV	-0.06	-0.3	+0.45	+2.4	+2.1	-12.5
D	5.65	1	-0.30		-0.63			
		2	+0.96		+0.42			
		AV	+0.33	+1.9	+0.51	+2.9	+4.8	-20.0
E	6.05	1	-0.60		+0.63			
		2	+0.75		+0.33			
		AV	+0.06	+0.4	+0.48	+2.9	+3.3	-36.1
F	6.44	1	-0.66		+0.84			
		2	-0.54		+1.02			
		AV	-0.77	-4.8	+0.93	+6.0	+1.2	-45.5
G	6.84	1	-0.60		+0.63			
		2	-0.75		+0.63			
		AV	-0.66	-4.5	+0.63	+4.3	-0.2	-58.5
H	7.04	1	-0.90		+0.63			
		2	-0.81		+0.69			
		AV	-0.84	-5.9	+0.66	+4.6	-1.3	-68.5
I	7.43	1	-0.90		+0.63			
		2	-0.84		+0.72			
		AV	-0.87	-6.5	+0.69	+5.1	-1.4	-67.2
J	7.81	1	-0.99		+0.57			
		2	-0.87		+0.75			
		AV	-0.93	-7.3	+0.66	+5.2	-2.1	-73.2
K	8.20	1	-1.71		+0.99			
		2	-1.44		+1.02			
		AV	-1.56	-12.8	+0.99	+8.1	-4.7	-68.0
L	8.60	1						
		2	-1.65		+0.93			
		AV	-1.65	-14.2	+0.93	+8.0	-6.2	-79.2
M	8.91	1	-1.44		+1.53			
		2	-1.59		+0.75			
		3	-1.62		+0.78			
		4	-1.62		+0.63			
		AV	-1.57	-14.0	+0.93	+8.3	-5.7	-89.1
CALCULATED							-10.4	-120.3

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED) = 11.1K LOAD ON PILE = 140.0 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 44 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	+0.15					
		2	+0.21					
		3	+0.63					
		4	+0.60					
		AV	+0.39	+1.7			+1.7	+15.0
B	4.86	1	+0.36		1.17			
		2	+0.60		-0.21			
		3	+0.45		-1.11			
		4	+0.30		-1.11			
		AV	+0.42	+2.0	-0.90	-4.4	-2.4	+3.1
C	5.26	1	+0.03		+0.06			
		2	+0.09		-0.15			
		AV	+0.06	+0.3	-0.03	-0.2	+0.1	-12.4
D	5.65	1	0		+0.09			
		2	-0.21		-0.75			
		AV	-0.12	-0.7	-0.33	-1.9	-2.6	-22.6
E	6.05	1	-0.54		-0.42			
		2	0.48		-0.18			
		AV	-0.51	-3.1	-0.30	-1.8	-4.9	-41.0
F	6.44	1	-0.51		-1.05			
		2	-0.51		-0.75			
		AV	-0.51	-3.3	-0.90	-5.8	-9.1	-54.6
G	6.84	1	-0.69		-0.57			
		2	-0.81		-0.60			
		AV	-0.75	-5.1	-0.57	-3.9	-9.0	-67.5
H	7.04	1	-0.84		-0.51			
		2	-0.90		-0.51			
		AV	-0.87	-6.1	-0.54	-3.8	-9.9	-78.4
I	7.43	1	-0.93		-0.63			
		2	-0.81		-0.90			
		AV	-0.87	-6.5	-0.75	-5.6	-12.1	-79.3
J	7.81	1	-0.84		-0.87			
		2	-0.87		-0.39			
		AV	-0.87	-6.8	-0.63	-4.9	-11.7	-84.9
K	8.20	1	-0.97		-2.79			
		2	-0.51		-2.40			
		AV	-0.54	-4.4	-2.61	-21.4	-25.8	-93.8
L	8.60	1						
		2	-0.15		-2.31			
		AV	-0.15	-1.3	-2.31	-19.9	-21.2	-100.4
M	8.91	1	-1.44		-0.12			
		2	-1.35		-0.96			
		3	-1.05		-0.21			
		4	-0.84		-0.12			
		AV	-1.17	-10.4	-0.36	-3.2	-13.6	-102.7
CALCULATED							-11.1	-131.4

SECTION	AREA SQ IN	GAGE	LOAD DECREMENT (REMOVED) = 46.7K LOAD ON PILE = 93.3 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF DECREMENT		EFFECT OF HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	+1.10					
		2	+1.26					
		3	+3.00					
		4	+3.30					
		AV	+10.17	+45.4				+45.4
B	4.86	1	+1.95					
		2	+2.10					
		3	+2.10					
		4	+1.95					
		AV	+2.04	+9.9				+9.9
C	5.26	1	+1.50					
		2	+1.50					
		AV	+1.50	+7.9				+7.9
D	5.65	1	+1.95					
		2	+1.80					
		AV	+1.86	+10.5				+10.5
E	6.05	1	+2.55					
		2	+1.95					
		AV	+2.25	+13.6				+13.6
F	6.44	1	+3.30					
		2	+3.00					
		AV	+3.15	+20.3				+20.3
G	6.84	1	+3.00					
		2	+3.15					
		AV	+3.06	+20.9				+20.9
H	7.04	1	+3.45					
		2	+3.30					
		AV	+3.36	+23.7				+23.7
I	7.43	1	+3.60					
		2	+3.90					
		AV	+3.75	+27.9				+27.9
J	7.81	1	+3.90					
		2	+3.75					
		AV	+3.84	+30.0				+30.0
K	8.20	1	+5.85					
		2	+5.40					
		AV	+5.64	+46.2				+46.2
L	8.60	1						
		2	+5.40					
		AV	+5.40	+46.4				+46.4
M	8.91	1	+4.90					
		2	+5.10					
		3	+4.20					
		4	+4.20					
		AV	+4.62	+41.2				+41.2
CALCULATED								+46.7

SECTION	AREA SQ IN	GAGE	LOAD DECREMENT (REMOVED) = 43.3K LOAD ON PILE = 50.0 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF DECREMENT		EFFECT OF 16 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	-1.11		-6.15			
		2	-0.09		-5.97			
		3	-1.98		-6.42			
		4	-1.02		-6.03			
		AV	-1.05	-4.7	-6.15	-27.5	-32.2	+13.2
B	4.86	1	+1.59		-0.15			
		2	+2.19		+0.36			
		3	+1.44		+0.30			
		4	+1.47		-0.12			
		AV	+1.65	+8.0	-0.06	-0.3	+7.7	+17.6
C	5.26	1	+2.49		0			
		2	+2.43		+0.12			
		AV	+2.46	+12.9	+0.06	+0.3	+13.2	+21.1
D	5.65	1	+2.88		-0.03			
		2	+2.58		+0.12			
		AV	+2.73	+15.4	+0.03	+0.2	+15.6	+26.1
E	6.05	1	+3.42		+0.03			
		2	+3.18		+0.12			
		AV	+3.30	+20.0	+0.09	+0.5	+20.5	+34.1
F	6.44	1	+4.26		+0.24			
		2	+4.14		+0.21			
		AV	+4.20		+0.21	+1.4	+28.4	+48.7
G	6.84	1	+4.02		+0.18			
		2	+4.05		+0.15			
		AV	+4.02	+27.5	+0.15	+1.0	+28.5	+49.4
H	7.04	1	+4.59		-0.09			
		2	+4.38		-0.27			
		AV	+4.50	+31.7	+0.09	+0.6	+32.3	+56.0
I	7.43	1	+4.44		+0.51			
		2	+4.53		+0.33			
		AV	+4.50	+33.4	+0.39	+2.9	+36.3	+64.2
J	7.81	1	+4.74		-0.09			
		2	+4.38		+0.12			
		AV	+4.56	+35.6	-0.27	-2.1	+33.5	+63.5
K	8.20	1	+4.80		-0.09			
		2	+4.53		-0.18			
		AV	+4.68	+38.4	-0.15	-1.2	+37.2	+83.4
L	8.60	1						
		2	+4.23		-0.18			
		AV	+4.23	+36.4	-0.18	-1.5	+34.9	+81.3
M	8.91	1	+5.58		+0.93			
		2	+5.34		+0.21			
		3	+4.83		+0.27			
		4	+4.83		+0.33			
		AV	+5.16	+46.0	+0.42	+3.7	+49.7	+90.9
CALCULATED							+43.3	+90.0

SECTION	AREA SQ IN	GAGE	LOAD DECREMENT (REMOVED) = 43.1K LOAD ON PILE = 6.9 KIPS					TOTAL LOAD ON SECTION
			EFFECT OF DECREMENT		EFFECT OF 18 HOURS		FINAL INCREMENT	
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	+3.09		+0.45			
		2	+3.24		+0.63			
		3	+2.67		-0.21			
		4	+2.97		+0.18			
		AV	+3.00	+13.4	+0.27	+1.2	+14.6	+27.8
B	4.86	1	+0.54		-0.21			
		2	+1.20		+0.21			
		3	+0.54		+0.39			
		4	+0.54		-0.24			
		AV	+0.69	+3.4	-0.15	-0.7	+2.7	+20.3
C	5.26	1	+1.59		+0.18			
		2	+1.68		+0.03			
		AV	+1.67	+8.5	+0.09	+0.5	+9.0	+30.1
D	5.65	1	+2.13		+0.12			
		2	+2.13		+0.33			
		AV	+2.13	+12.0	+0.21	+1.2	+13.2	+39.3
E	6.05	1	+2.88		+0.15			
		2	+2.79		+0.21			
		AV	+2.82	+17.1	+0.15	+1.1	+18.2	+52.3
F	6.44	1	+3.03		+0.18			
		2	+2.88		+0.03			
		AV	+2.94	+18.9	+0.09	+0.6	+19.5	+68.2
G	6.84	1	+3.18		+0.18			
		2	+3.48		+0.27			
		AV	+3.33	+22.8	+0.21	+1.4	+24.2	+73.6
H	7.04	1	+4.02		+0.09			
		2	+3.78		+0.03			
		AV	+3.90	+27.5	+0.06	+0.4	+27.9	+83.9
I	7.43	1	+3.48		+0.03			
		2	+3.57		+0.03			
		AV	+3.66	+27.2	+0.03	+0.2	+27.4	+91.6
J	7.81	1	+4.08		+0.09			
		2	+3.84		-0.03			
		AV	+3.96	+30.9	+0.03	+0.2	+31.1	+94.6
K	8.20	1	+4.68		-0.24			
		2	+4.53		-0.27			
		AV	+4.62	+37.9	-0.27	-2.2	+35.7	+119.1
L	8.60	1						
		2	+4.98		-0.33			
		AV	+4.98	+42.8	-0.33	-2.8	+40.0	+121.3
M	8.91	1	+2.76		-0.21			
		2	+2.88		-0.36			
		3	+4.47		-0.06			
		4	+3.78		-0.18			
		AV	+3.48	+31.0	-0.21	-1.9	+29.1	+120.0
CALCULATED							+43.1	+133.1

TABLE 8 - PART I

TABLE OF RECORDED STATIC STRESSES

LOAD INCREMENT (APPLIED)= [illegible] LOAD ON PILE = 20.0 KIPS

SECTION	AREA-SQ IN	GAGE	EFFECT OF INCREMENT STRESS IN KSI	EFFECT OF INCREMENT LOAD IN KIPS	EFFECT OF 3 HOURS STRESS IN KSI	EFFECT OF 3 HOURS LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
PILE M2								
M	8.91	1	-0.55		-0.75			
		2	-0.5		-0.2			
		3	-0.78		-0.30			
		4	-0.5		-0.84			
		AV	-0.54	-4.8	-0.72	-6.4	-11.4	-11.4
PILE M3								
M	8.91	1	-0.75		-0.72			
		2	-0.57		-0.9			
		3	-1.4		-1.44			
		4	-1.02		-0.21			
		AV	-1.02	-9	-0.9	-7.2	-16.3	-16.3
PILE M6								
M	8.91	1	-0.69		-0.5			
		2	-0.63		-1.05			
		3	-0.78		-1.02			
		4	+0.8		-1.05			
		AV	-0.33	-2.9	-0.81	-7.2	-10.1	-10.1
PILE M7								
M	8.91	1	-0.63		-0.66			
		2	-0.93		-0.60			
		3	-1.17		-0.57			
		4	-0.54		-0.39			
		AV	-0.92	-5.0	-0.57	-5	-13.1	-13.1
PILE M8								
M	8.91	1	-0.72		-0.60			
		2	-0.90		-0.63			
		3	-0.90		-0.30			
		4	-0.57		-0.60			
		AV	-0.84	-7.5	-0.54	-4.8	-12.3	-12.3
PILE M9								
M	8.91	1	-1.32		-0.5			
		2	-1.77		-0.33			
		3	-0.60		-0.72			
		4	-0.57		-0.57			
		AV	-1.05	-9.4	-0.45	-4.0	-13.4	-13.4
CALCULATED							-11.4	-11.4

LOAD INCREMENT (APPLIED)= +20.0K LOAD ON PILE = 40.0 KIPS

SECTION	AREA-SQ IN	GAGE	EFFECT OF INCREMENT STRESS IN KSI	EFFECT OF INCREMENT LOAD IN KIPS	EFFECT OF 16 HOURS STRESS IN KSI	EFFECT OF 16 HOURS LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
PILE M2								
M	8.91	1	-2.46		-0.54			
		2	-2.3		-0.69			
		3	-2.2		-0.84			
		4	-2.46		+1			
		AV	-2.3	-20.6	-0.24	-2	-20.7	[illegible]
PILE M3								
M	8.91	1	-2.91		-0.84			
		2	-2.56		-1.59			
		3	-2.56		-1.74			
		4	-3.36		-0.54			
		AV	-2.58	-25.7	[illegible]	-0.4	-36.1	[illegible]
PILE M6								
M	8.91	1	-2.61		-0.99			
		2	-2.76		-0.54			
		3	-2.6		-0.69			
		4	-2.3		-0.39			
		AV	-2.35	-23.0	-0.66	-5.9	-28.9	-39.0
PILE M7								
M	8.91	1	-1.86		-1.29			
		2	-2.6		-0.69			
		3	-2.6		-0.69			
		4	-2.01		-0.99			
		AV	-2.38		-0.93	-8.3	-28.6	-41.7
PILE M8								
M	8.91	1	-1.86		-0.54			
		2	-2.61		-0.54			
		3	-2.61		-0.24			
		4	-1.88		-0.84			
		AV	-2.25	-20.1	-0.63	-5.6	-25.7	-38.0
PILE M9								
M	8.91	1	-2.61		-1.29			
		2	-3.21		-1.29			
		3	-2.61		-0.39			
		4	-3.08		-0.69			
		AV	-2.88	-25.6	-0.93	-8.3	-33.9	-47.3
CALCULATED							-20.0	-31.4

LOAD INCREMENT (APPLIED)=+10.0K LOAD ON PILE = 50.0 KIPS

SECTION	AREA-SQ IN	GAGE	EFFECT OF INCREMENT STRESS IN KSI	EFFECT OF INCREMENT LOAD IN KIPS	EFFECT OF HOURS STRESS IN KSI	EFFECT OF HOURS LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
PILE M2								
M	8.91	1	[illegible]					
		2	-1.53					
		3	-1.23					
		4	-2.73					
		AV	-1.65	-15.0			-15.0	-48.9
PILE M3								
M	8.91	1	-1.38					
		2	-1.08					
		3	-1.53					
		4	-1.83					
		AV	-1.47	-13.1			-13.1	-65.5
PILE M6								
M	8.91	1	-0.63					
		2	-0.78					
		3	-0.93					
		4	-1.08					
		AV	-0.87	-7.7			-7.7	-46.7
PILE M7								
M	8.91	1	-0.63					
		2	-1.08					
		3	-1.23					
		4	-0.63					
		AV	-0.90	-8.0			-8.0	-49.7
PILE M8								
M	8.91	1	-0.33					
		2	-0.78					
		3	-1.23					
		4	-0.78					
		AV	-0.78	-6.9			-6.9	-44.9
PILE M9								
M	8.91	1	-0.33					
		2	-0.63					
		3	-0.33					
		4	-0.93					
		AV	-0.57	-5.1			-5.1	-52.4
CALCULATED							-10.0	-41.4

LOAD INCREMENT (APPLIED)=10.0K LOAD ON PILE = 60.0 KIPS

SECTION	AREA-SQ IN	GAGE	EFFECT OF INCREMENT STRESS IN KSI	EFFECT OF INCREMENT LOAD IN KIPS	EFFECT OF 68 HOURS STRESS IN KSI	EFFECT OF 68 HOURS LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
PILE M2								
M	8.91	1	-1.32		+0.15			
		2	-1.02		+0.30			
		3	-0.42		+0.75			
		4	-0.12		0			
		AV	-0.72	-6.4	+0.30	+2.7	-3.7	-52.6
PILE M3								
M	8.91	1	-1.02		+0.30			
		2	-0.72		+1.05			
		3	-0.57		+0.90			
		4	-1.02		+0.30			
		AV	-0.84	-7.5	+0.63	+5.6	-1.9	-67.4
PILE M6								
M	8.91	1	-1.02		-0.15			
		2	-0.87		+0.30			
		3	-1.02		-0.15			
		4	-1.02		-0.30			
		AV	-1.05	-9.4	-0.09	-0.8	-10.2	-56.9
PILE M7								
M	8.91	1	-1.32		0			
		2	-1.77		-0.30			
		3	-1.62		-0.45			
		4	-1.62		+0.15			
		AV	-1.59	-14.2	-0.15	-1.3	-15.5	-65.2
PILE M8								
M	8.91	1	-1.02		0			
		2	-1.32		-0.15			
		3	-1.62		-0.60			
		4	-1.32		-0.15			
		AV	-1.32	-11.7	-0.21	-1.9	-13.6	-56.5
PILE M9								
M	8.91	1	-1.17		0			
		2	-1.47		0			
		3	-1.47		-0.45			
		4	-1.32		-0.30			
		AV	-1.35	-12.0	-0.18	-1.6	-13.6	-66.0
CALCULATED							-10.0	-51.4

LOAD INCREMENT (APPLIED)=+10.0K LOAD ON PILE = 70.0 KIPS

SECTION	AREA-SQ IN	GAGE	EFFECT OF INCREMENT STRESS IN KSI	EFFECT OF INCREMENT LOAD IN KIPS	EFFECT OF 2 HOURS STRESS IN KSI	EFFECT OF 2 HOURS LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
PILE M2								
M	8.91	1	-0.93		[illegible]			
		2	-0.99		[illegible]			
		3	-0.69		-0.27			
		4	-0.69		-0.42			
		AV	-0.84	-7.5	-0.36	-3.2	-10.7	-63.3
PILE M3								
M	8.91	1	-1.29		-0.27			
		2	-1.44		-0.27			
		3	-1.44		-0.27			
		4	-1.14		-0.42			
		AV	-1.26	-11.2	-0.36	-3.2	-14.4	-81.8
PILE M6								
M	8.91	1	+0.51		-1.32			
		2	-1.29		-0.27			
		3	-1.29		-0.12			
		4	-0.84		-0.42			
		AV	-0.72	-6.4	-0.54	-4.8	-11.2	-68.1
PILE M7								
M	8.91	1	-0.39		-0.12			
		2	-0.84		-0.12			
		3	-0.69		-0.12			
		4	-0.24		-0.42			
		AV	-0.54	-4.8	-0.18	-1.6	-6.4	-71.6
PILE M8								
M	8.91	1	-0.54		-0.12			
		2	-0.99		-0.12			
		3	-1.14		-0.12			
		4	-0.54		-0.12			
		AV	-0.81	-7.2	-0.12	-1.1	-8.3	-66.8
PILE M9								
M	8.91	1	-0.99		+0.03			
		2	-1.29		-0.12			
		3	-1.14		-0.42			
		4	-0.99		-0.27			
		AV	-1.11	-9.9	-0.18	-1.6	-11.5	-77.5
CALCULATED							-10.0	-61.4

LOAD INCREMENT (APPLIED)=+10.0K LOAD ON PILE = 80.0 KIPS

SECTION	AREA-SQ IN	GAGE	EFFECT OF INCREMENT STRESS IN KSI	EFFECT OF INCREMENT LOAD IN KIPS	EFFECT OF 16 HOURS STRESS IN KSI	EFFECT OF 16 HOURS LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
PILE M2								
M	8.91	1	-1.02		+0.60			
		2	-1.02		+0.75			
		3	-0.87		-0.30			
		4	-0.87		-0.45			
		AV	-0.93	-8.3	+0.15	+1.3	-7.0	-70.3
PILE M3								
M	8.91	1	-1.17		+0.60			
		2	-1.02		+0.60			
		3	-0.87		-1.05			
		4	-0.87		+0.15			
		AV	-0.99	-8.8	+0.09	+0.8	-8.0	-89.8
PILE M6								
M	8.91	1	-1.17		0			
		2	-0.87		0			
		3	-1.02		-0.30			
		4	-1.02		0			
		AV	-1.02	-9.1	-0.15	-1.3	-10.4	-78.5
PILE M7								
M	8.91	1	-1.17		-0.45			
		2	-1.77		0			
		3	-1.77		-0.45			
		4	-1.02		-0.60			
		AV	-1.44	-12.8	-0.39	-3.5	-16.3	-87.9
PILE M8								
M	8.91	1	-0.87		-0.60			
		2	-1.32		-0.30			
		3	-1.47		0			
		4	-1.17		-0.15			
		AV	-1.20	-10.7	-0.27	-2.4	-13.1	-79.9
PILE M9								
M	8.91	1	-1.32		-0.75			
		2	-1.47		-0.45			
		3	-0.72		-0.15			
		4	-1.17		-0.15			
		AV	-1.17	-10.4	-0.39	-3.5	-13.9	-91.4
CALCULATED							-10.0	71.4

LOAD INCREMENT (APPLIED)=+10.0K LOAD ON PILE = +90.0 KIPS

SECTION	AREA-SQ IN	GAGE	EFFECT OF INCREMENT STRESS IN KSI	EFFECT OF INCREMENT LOAD IN KIPS	EFFECT OF 21 HOURS STRESS IN KSI	EFFECT OF 21 HOURS LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
PILE M2								
M	8.91	1	-1.44		+0.03			
		2	-1.53		+0.03			
		3	-0.54		-0.12			
		4	-0.54		+0.36			
		AV	-1.02	-9.1	+0.06	+0.5	-8.6	-78.9
PILE M3								
M	8.91	1	-1.44		-0.12			
		2	-1.89		+0.12			
		3	-0.39		-0.21			
		4	-1.44		-0.12			
		AV	-1.29	11.5	-0.09	-0.8	-12.3	-102.1
PILE M6								
M	8.91	1	-1.14		+0.18			
		2	-1.14		+0.24			
		3	-0.39		-0.12			
		4	-1.14		-0.09			
		AV	-0.96	-8.6	+0.06	+0.5	-8.1	-86.6
PILE M7								
M	8.91	1	-0.54		-0.12			
		2	-1.29		+0.03			
		3	-0.84		-0.27			
		4	-0.24		+0.03			
		AV	-0.72	-6.4	-0.09	-0.8	-7.2	-95.1
PILE M8								
M	8.91	1	-0.33		+0.03			
		2	-0.99		+0.03			
		3	-1.29		-0.42			
		4	-0.84		-0.16			
		AV	-0.87	-7.8	-0.12	-1.1	-8.9	-88.8
PILE M9								
M	8.91	1	-0.69		+0.33			
		2	-0.99		+0.21			
		3	-0.84		-0.42			
		4	-1.14		+0.03			
		AV	-0.93	-8.3	+0.03	+0.3	-8.0	-99.4
CALCULATED							-10.0	-81.4

LOAD INCREMENT (APPLIED)=+5.0K LOAD ON PILE = 95.0 KIPS

SECTION	AREA-SQ IN	GAGE	EFFECT OF INCREMENT STRESS IN KSI	EFFECT OF INCREMENT LOAD IN KIPS	EFFECT OF HOURS STRESS IN KSI	EFFECT OF HOURS LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
PILE M2								
M	8.91	1	-0.81					
		2	-0.96					
		3	-0.51					
		4	-0.24					
		AV	-0.63	-5.6			-5.6	-84.5
PILE M3								
M	8.91	1	-0.81					
		2	-0.78					
		3	-0.69					
		4	-0.99					
		AV	-0.81	-7.2			-7.2	-109.3
PILE M6								
M	8.91	1	-0.36					
		2	-0.42					
		3	-0.51					
		4	-0.45					
		AV	-0.42	-3.7			-3.7	-90.3
PILE M7								
M	8.91	1	+0.09					
		2	-0.33					
		3	-0.36					
		4	+0.03					
		AV	-0.15	-1.3			-1.3	-96.4
PILE M8								
M	8.91	1	+0.09					
		2	-0.15					
		3	-0.45					
		4	-0.21					
		AV	-0.18	-1.6			-1.6	-90.4
PILE M9								
M	8.91	1	+0.09					
		2	-0.06					
		3	-0.33					
		4	-0.93					
		AV	-0.15	-1.3			-1.3	-100.7
CALCULATED							-5.0	-86.4

LOAD INCREMENT (APPLIED)=+5.0K LOAD ON PILE = 100.0 KIPS

SECTION	AREA-SQ IN	GAGE	EFFECT OF INCREMENT STRESS IN KSI	EFFECT OF INCREMENT LOAD IN KIPS	EFFECT OF 20 HOURS STRESS IN KSI	EFFECT OF 20 HOURS LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION
PILE M2								
M	8.91	1	-0.30		+0.21			
		2	-0.15		+0.03			
		3	0		+0.33			
		4	-0.27		+0.15			
		AV	-0.18	-0.5	+0.18	+0.5	0	-84.5
PILE M3								
M	8.91	1	-0.30		+0.03			
		2	-0.12		-0.27			
		3	+0.12		-0.27			
		4	-0.39		+0.06			
		AV	-0.18	-1.6	-0.12	-1.1	-2.7	-112.0
PILE M6								
M	8.91	1	-0.30		+0.93			
		2	-0.30		+0.21			
		3	-0.24		+0.54			
		4	-0.39		+0.27			
		AV	-0.30	-2.7	+0.48	+4.3	+1.6	-88.7
PILE M7								
M	8.91	1	-0.45		-0.42			
		2	-0.87		-0.09			
		3	-0.66		+0.09			
		4	-0.69		+0.93			
		AV	-0.66	-5.9	+0.12	+1.1	-4.8	-101.2
PILE M8								
M	8.91	1	-0.45		-0.18			
		2	-0.54		+0.12			
		3	-0.81		+0.03			
		4	-0.63		-0.09			
		AV	-0.69	-6.1	-0.03	-0.3	-6.4	-96.8
PILE M9								
M	8.91	1	-0.67		+0.21			
		2	-0.78		+0.09			
		3	-0.45		+0.15			
		4	-0.93		+0.93			
		AV	-0.75	-6.7	+0.36	+3.2	-3.5	-104.2
CALCULATED							-5.0	-91.4

TABLE 8 – PART 2

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

TABLE OF RECORDED STATIC STRESSES
PILES: M2, M3, M6, M7, M8, & M9

OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS

STATION	AREA SQ IN	GAGE	LOAD INCREMENT APPLIED = [illegible] LOAD ON PILE = 42.7 KIPS				FINAL INCREMENT	TOTAL LOAD ON SECTION	LOAD INCREMENT APPLIED = [illegible] LOAD ON PILE = 100.0 KIPS				FINAL INCREMENT	TOTAL LOAD ON SECTION	LOAD INCREMENT APPLIED = +9.6K LOAD ON PILE = +109.6 KIPS				FINAL INCREMENT	TOTAL LOAD ON SECTION
			EFFECT OF INCREMENT		EFFECT OF 6 HOURS				EFFECT OF INCREMENT		EFFECT OF 6 HOURS				EFFECT OF INCREMENT		EFFECT OF 44 HOURS			
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
PILE M2																				
		1			-0.09						-0.42				-0.72		-0.51			
		2			-0.06						-0.27				-0.84		-0.24			
[illegible]		3			[illegible]						-0.12				-0.54		-0.24			
		4			-0.06										-0.84		-0.24			
		AV			-0.09	-0.8	-0.8	-35.3			-0.66	-5.9	-5.9	-91.2	-0.75	-6.7	-0.30	-2.7	-9.4	-100.6
PILE M3																				
		1			-0.06						-0.12				-0.72		-0.21			
		2			+0.06						-0.42				-0.75		-0.48			
[illegible]		3			-0.26						[illegible]				-1.02		+0.54			
		4			[illegible]						[illegible]				-1.02		-0.36			
		AV			-0.09	-0.8	-0.8	-12.3			-0.18	-1.6	-1.6	-114.4	-0.87	-7.8	-0.12	-1.1	-8.9	-123.3
PILE M6																				
		1			+0.54						+0.78				-0.90					
		2			+0.06						-0.12				-0.81		-0.03			
[illegible]		3			-0.18						-0.42				-1.05		-0.33			
		4			0						-0.72				-0.45		-0.48			
		AV			+0.09	+0.8	+0.8	-37.9			-0.42	-3.7	-3.7	-91.6	-0.81	-7.2	-0.27	-2.4	-9.6	-101.2
PILE M7																				
		1			-0.06						-0.42				-1.11		-0.42			
		2			0						-0.96				-1.05		-0.63			
[illegible]		3			-0.06						-0.22				-0.99		+0.06			
		4			+0.54										-0.54					
		AV			+0.09	+0.8	+0.8	-100.4			-0.36	-3.2	-3.2	-103.6	-0.91	-8.1	-0.33	-2.9	-11.0	-114.6
PILE M8																				
		1			-0.15						-0.12				-0.75		-0.33			
		2			+0.03						-0.27				-0.96		-0.42			
[illegible]		3			-0.21						-0.27				-1.05		-0.63			
		4			+0.06						-0.27				-0.90		-0.33			
		AV			+0.09	-0.8	-0.8	-97.6			-0.24	-2.1	-2.1	-99.7	-0.93	-8.3	-0.42	-3.7	-12.0	-111.7
PILE M9																				
		1			-0.12						-0.42				-0.87		-0.21			
		2			-0.12						-0.42				-1.20		-0.48			
[illegible]		3			+0.09						-0.72				-0.75		-0.48			
		4			-0.06						-0.42				-1.20		-0.03			
		AV			-0.06	-0.5	-0.9	-104.7			-0.48	-4.3	-4.3	-109.0	-0.99	-8.8	-0.30	-2.7	-11.5	-120.5
CALCULATED							0	-91.4					0	-91.4					-9.6	-101.0

GAGE	LOAD INCREMENT (APPLIED) = +8.8K LOAD ON PILE = +118.4 KIPS				FINAL INCREMENT	TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = +10.4K LOAD ON PILE = +128.8 KIPS				FINAL INCREMENT	TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED) = +11.2K LOAD ON PILE = +140.0 KIPS				FINAL INCREMENT	TOTAL LOAD ON SECTION
	EFFECT OF INCREMENT		EFFECT OF 20 HOURS				EFFECT OF INCREMENT		EFFECT OF 44 HOURS				EFFECT OF INCREMENT		EFFECT OF 44 HOURS			
	STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
PILE M2																		
1	-0.87		0.33				-1.08		2.09				1.29		-1.32			
2	-1.02		0.18				-0.90		+0.19				-0.84		0.57			
3	-0.87		-0.16				-0.60		1.47				+1.50		-0.91			
4	-0.42		1.08				+2.79		+1.89									
AV	0.78	-6.9	0.33	-2.9	-9.8	-110.4	+0.06	+0.5	+0.12	+1.1	+ [illegible]	-108.8	-0.21	-1.9	-0.90	-8.0	-9.9	-115.7
PILE M3																		
1	-0.87		-0.03				-1.11		+0.39				-1.17		-0.69			
2	-1.02		-0.18				-0.75		0.27				-1.20		-0.51			
3	-0.87		+0.12				-0.31		+0.39				+1.44		-1.20			
4	-0.87		-0.18				-1.35		0.12				-0.15		-0.51			
AV	-0.90	-8.0	-0.06	-0.5	-8.5	-131.8	-1.02	-9.1	+0.06	+0.5	-8.6	-140.4	-0.27	-2.4	-0.81	-7.2	-9.6	-150.0
PILE M6																		
1	-0.57		+0.72				+0.15						-1.71		-1.05			
2	-0.72		+0.27				-1.65		+0.18				-1.05		-0.51			
3	-0.87		-0.33				-1.65		-1.32				-0.24		-1.17			
4	-0.72		-0.33				-1.65		-0.87				-0.96		[illegible]			
AV	-0.72	-6.4	+0.06	+0.5	-5.9	-107.1	-1.20	-10.7	-0.66	-5.9	-16.6	-123.7	-0.99	-8.8	-0.93	-8.3	-17.1	-140.3
PILE M7																		
1	-0.12		-0.48				-1.20		-1.32				-1.29		-1.17			
2	-0.12		-0.33				-1.65		-0.27				-1.83		-0.63			
3	-0.42		-0.03				-1.62		+1.50				-1.20		-0.21			
4	-0.12		+1.32				-0.99											
AV	-0.18	-1.6	+0.12	+1.1	-0.5	-115.1	-1.38	-12.3	-0.03	-0.3	-12.6	-127.7	-1.44	-12.8	-0.66	-5.9	-18.7	-146.4
PILE M8																		
1	-0.42		-0.03				-1.20		-1.47				-1.66		-1.71			
2	-0.57		-0.18				-1.80		-1.47				-1.47		+0.06			
3	-0.57		+0.12				-1.80		-1.17				-1.80		-1.71			
4	-0.42		-0.33				-1.35		-1.17				-1.35		-1.56			
AV	-0.57	-5.1	-0.12	-1.1	-6.2	-117.9	-1.53	-13.6	-1.23	-11.0	-24.6	-142.5	-1.56	-13.9	-1.23	-11.0	-24.9	-167.4
PILE M9																		
1	-0.57		+0.12				-1.80		-1.32				-1.35		-0.81			
2	-0.87		+0.12				-1.77		-1.05				-1.95		-1.11			
3	-0.87		-0.33				-1.74		-0.78				-1.11		-0.75			
4	-0.57		+0.12				-1.86		-0.36				-1.65		-0.06			
AV	-0.81	-7.2	0	0	-7.2	-127.7	-1.80	-16.0	-0.87	-7.7	-23.7	-151.4	-1.50	-13.4	-0.69	-6.1	-19.5	-170.9
CALCULATED					-8.9	-109.9					-10.4	-120.3					-11.1	-131.4

LOAD DECREMENT (REMOVED) = 46.6K LOAD ON PILE = 93.4 KIPS				FINAL INCREMENT	TOTAL LOAD ON SECTION	LOAD DECREMENT (REMOVED) = 43.4K LOAD ON PILE = +50.0 KIPS				FINAL INCREMENT	TOTAL LOAD ON SECTION	LOAD DECREMENT (REMOVED) = 43.2K LOAD ON PILE = 6.8 KIPS				FINAL INCREMENT	TOTAL LOAD ON SECTION	GAGE	AREA SQ IN	SECTION
EFFECT OF DECREMENT		EFFECT OF HOURS				EFFECT OF DECREMENT		EFFECT OF 16 HOURS				EFFECT OF DECREMENT		EFFECT OF 16 HOURS						
STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS					
PILE M2																				
+4.20						+5.01		+0.24				+4.53		+0.18				1		
+3.60						+4.83		+0.27				+7.38		+0.03				2		
+3.00						+4.14		-1.17				+5.01		-0.18				3	8.91	M
						+4.23		-0.48				+4.68		-0.03				4		
+3.60	+32.1			+32.1	+32.1	+4.56	+40.6	-0.30	-2.7	+37.9	+70.0	+5.40	+48.1	0	0	+48.1	+118.1	AV		
PILE M3																				
+4.95						+6.09		+0.27				+5.37		+0.27				1		
+4.05						+4.74		-0.09				+5.97		-0.36				2		
+4.50						+5.88		-0.54				+7.74		-0.12				3	8.91	M
+5.10						+6.33		+0.12				+7.38		+0.33				4		
+4.65	+41.4			+41.4	+41.4	+5.76	+51.3	-0.06	-0.5	+50.8	+92.2	+6.60	+58.8	+0.03	+0.3	+59.1	+151.3	AV		
PILE M6																				
+3.45						+7.52		+0.18				+4.98		-0.03				1		
+4.95						+6.48		+0.18				+6.12		-0.12				2		
+4.65						+5.43		-0.18				+6.93		-0.42				3	8.91	M
+4.95						+5.13		+0.03				+6.12		-0.12				4		
+4.50	+40.1			+40.1	+40.1	+6.03	+54.2	+0.06	+0.5	+54.7	+94.8	+6.03	+53.7	-0.18	-1.6	+52.1	+146.9	AV		
PILE M7																				
+5.25						+6.06		-0.42				+3.69		-0.72				1		
+4.65						+6.96		+0.33				+6.09		+0.12				2		
+7.20														+0.18				3	8.91	M
+5.70						+7.83		+0.42				+4.83		+0.09				4		
+6.45	+53.5			+53.5	+93.9	+6.96	+62.0	+0.12	+1.1	+63.1	+118.6	+4.86	+43.2	-0.09	-0.8	+42.4	159.0	AV		
PILE M8																				
+3.90						+6.72		-0.42				+4.38		-0.48				1		
+6.45						+5.97		-0.03				+4.98		-0.15				2		
+6.60						+5.58		+0.21				+6.09		+0.03				3	8.91	M
+5.10						+5.34		-0.15				+4.44		-0.51				4		
+5.52	+49.2			+49.2	+49.2	+5.91	+52.6	-0.09	-0.8	+51.8	+101.0	+4.98	+44.4	-0.27	-2.4	+42.0	+143.0	AV		
PILE M9																				
+5.25						+6.96		-0.63				+4.50		-0.48				1		
+7.35						+6.63		-1.89				+8.55		-0.48				2		
+6.75						+5.73		+0.03				+3.96		+0.09				3	8.91	M
+6.30						+8.49		+0.51				+7.29		+0.06				4		
+6.32	+56.4			+56.4	+56.4	+6.81	+60.7	-0.51	-4.5	+56.2	+112.6	+6.09	+54.2	-0.21	-1.9	+52.3	+164.9	AV		
				+46.6	+46.6					+43.4	+90.0					+43.1	+133.1	CALCULATED		

TABLE 9 – PART I

TABLE OF RECORDED STATIC STRESSES

PILE M10

LOAD INCREMENT (APPLIED)=20K LOAD ON PILE=130 KIPS EFFECT OF INCREMENT STRESS IN KSI	 LOAD IN KIPS	 EFFECT OF 3 HOURS STRESS IN KSI	 LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD IN SECTION	LOAD INCREMENT (APPLIED)=13.3K LOAD ON PILE = 143.3 KIPS EFFECT OF INCREMENT STRESS IN KSI	 LOAD IN KIPS	 EFFECT OF 19 HOURS STRESS IN KSI	 LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION	LOAD INCREMENT (APPLIED)=13.3K LOAD ON PILE = 156.6 KIPS EFFECT OF INCREMENT STRESS IN KSI	 LOAD IN KIPS	 EFFECT OF 4 HOURS STRESS IN KSI	 LOAD IN KIPS	FINAL INCREMENT	TOTAL LOAD ON SECTION	GAGE	AREA-SQ IN	SECTION
-0.42		+0.2				+0.42		+0.33				+0.09		+0.06				1	4.47	A
-0.42		+0.45				+0.36		+0.33				+0.09		+0.15				2		
-0.36		+0.93				-0.18		+0.66				+0.15		+0.36				3		
0.36		+0.39				+0.27		+0.42				+0.08		+0.30				4		
0.39	-7	+0.51	+2.3	+0.6	+6.6	+0.21	+0.9	+0.42	+1.9	+2.8	+9.4	+0.09	+0.4	+0.24	+1.1	+1.5	+10.9	AV		
-0.12		-0.24				+0.15		-0.18				-0.09		+0.24				1	4.86	B
-0.33		0				-0.09		-0.09				-0.06		+0.27				2		
-0.18		-0.39				+0.36		-0.66				-0.09		-0.33				3		
-0.33		-0.24				+0.20		-0.66				-0.12		+0.21				4		
-0.24	-1.2	-0.2	-1.0	-2.2	-7.9	+0.18	+0.9	-0.54	-2.6	-1.7	-9.6	-0.09	-0.4	+0.27	+1.3	+0.9	-8.7	AV		
-0.45		+0.06				+0.24		-0.15				-0.24		+0.15				1	5.26	C
-0.42		+0.33				-0.33		-0.27				-0.12		+0.12				2		
-0.42	-2.2	+0.21	+1.1	-1.1	-6.8	+0.12	+0.6	-0.21	-1	-0.5	-7.3	-0.18	-0.9	+0.12	+0.6	-0.3	-7.6	AV		
-0.48		-0.30				-0.27		-0.57				-0.45		+0.03				1	5.65	D
-0.45		-0.06				+0.12		-0.60				-0.39		+0.06				2		
-0.48	-2.7	-0.18	-1.0	-3.7	-23.0	+0.18	+0	-0.60	-3.4	-2.4	-25.4	-0.42	-2.4	+0.06	+0.3	-2.1	-27.5	AV		
-0.63		+0.15				-0.16		-0.66				-0.39		+0.06				1	5.05	E
-0.63		-0.27				+0.03		-0.72				-0.42		0				2		
-0.63	3.8	-0.06	-0.4	-4.2	-30.0	-0.06	-0.4	-0.83	-4.2	-4.6	-34.6	-0.48	-2.5	+0.03	-0.2	-2.3	-36.9	AV		
-0.72		-0.30				-0.15		-0.72				-0.48		+0.03				1	6.44	F
-0.72		-0.09				-0.24		-0.69				-0.51		+0.09				2		
-0.72	-4.5	-0.21	-1.4	-5.9	-42.5	-0.18	-1.2	-0.69	-4.5	-5.7	-48.2	-0.48	-3.1	+0.06	-0.4	-2.7	-50.9	AV		
-0.93		+0.06				-0.45		-0.33				-0.57		-0.12				1	6.84	G
0.87		-0.24				-0.33		-0.30				-0.66		-0.12				2		
0.90	-6.2	-0.09	-0.6	-6.8	-5.5	-0.39	-2.7	-0.33	-2.3	-5.0	-56.8	-0.60	-4.1	-0.12	-0.8	-4.9	-61.7	AV		
-1.08		-0.15				-0.48		-0.12				-0.90		+0.06				1	7.04	H
-1.23		+0.15				-0.78		-0.24				-0.87		-0.03				2		
-1.14	-8.0	0	0	-8.0	-64.2	-0.63	-4.4	-0.18	-1.3	-5.7	-69.9	-0.90	-6.3	0	0	-6.3	-76.2	AV		
-1.41		0				-0.69		-0.18				-1.02		-0.03				1	7.43	I
-1.32		-0.24				-0.60		+0.03				-1.02		+0.12				2		
-1.38	-10.3	-0.12	-0.9	-11.2	-80.7	-0.65	-4.8	-0.09	-0.7	-5.6	-86.3	-1.02	-7.6	+0.06	+0.4	-7.2	-93.5	AV		
-1.53		-0.09				-0.93		-0.39				-1.20		0				1	7.81	J
-1.56		+0.09				-0.72		+0.39				-1.26		+0.33				2		
-1.56	-12.2	0	0	-12.2	-93.5	-0.81	-6.6	0	0	-6.6	-101.1	-1.23	-9.6	+0.18	+1.4	-8.2	-109.1	AV		
-0.93		-0.60				-0.59		-0.57				-1.02		+0.57				1	8.20	K
-2.16		-0.51				-1.68		-0.96				-1.89		-0.24				2		
-1.56	-12.4	-0.57	-4.7	-17.5	-117.0	-1.11	-9.1	-0.21	-1.7	-10.8	-127.8	-1.44	-11.8	+0.18	+1.5	-10.3	-138.1	AV		
-5.28		-1.05				-4.95		-1.53				-8.43		-1.71				1	8.60	L
+1.38		+0.15				+2.16		+1.41				+3.09		+1.32				2		
-1.95	-16.8	-0.45	-3.9	-20.7	-130.4	-1.38	-11.9	-0.06	-0.5	-12.4	-142.8	-2.67	-22.9	-0.18	-1.5	-24.4	-167.2	AV		
-4.41		-0.66				-2.28		-0.75				-1.90		-0.42				1	8.91	M
-2.04		+0.15				-0.94		+0.03				-0.98		+0.12				2		
-0.60		+0.54				-0.16		+0.90				-0.10		+0.51				3		
-4.17		-0.45				-2.32		-0.69				-2.80		-0.72				4		
-2.79	-24.8	-0.12	-1.1	-25.9	-144.9	-1.42	-12.7	-0.12	-1.1	-13.8	-158.7	-1.45	-13.0	-0.12	[illegible]	[illegible]	[illegible]	AV		
				-20.0	-130.0					-13.3	-143.3					-13.3	-156.6	CALCULATED		

TABLE 9 - PART 2

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

TABLE OF RECORDED STATIC STRESSES

PILE M10

OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED)=13.3K LOAD ON PILE 170 KIPS						LOAD INCREMENT (APPLIED)=13.3K LOAD ON PILE=183.3					
			EFFECT OF INCREMENT		EFFECT OF 43 HOURS		FINAL INCREMENT	TOTAL LOAD ON SECTION	EFFECT OF INCREMENT		EFFECT OF 3 HOURS		FINAL INCREMENT	TOTAL LOAD ON SECTION
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	+0.39		[illegible]				-0.06		-0.16			
		2	+0.24		[illegible]				-0.15		[illegible]			
		3	+0.24		+0.98				+0.15		-0.27			
		4	+0.24		+1.62				+0.03		-0.27			
		AV	+0.27	+2	+0.77	+7.9	+9	+20.0	0.09	-0.4	-0.30	-1.3	-.7	+18.3
B	4.86	1	+0.18		+0.52				-0.09		-0.27			
		2	+0.18		+0.41				+0.03		-0.15			
		3	-0.18		+0.14				+0.15		+0.09			
		4	+0.18		+1.26				+0.2		0			
		AV	-0.18	+8.9	+0.14	+6.9	+7.8	-8.9	+0.06	+0.3	-0.09	-0.4	-8	-16
C	5.28	1	+0.13		+1.21				-0.03		-0.24			
		2	+0.12		+1.55				-0.33		-0.30			
		AV	+0.12	+2.6	+1.50	+7.9	+8.5	+0.9	-0.18	-1.5	-0.27	-1.4	-2.3	-1.4
D	5.65	1	-0.63		+1.17				-0.18		-0.27			
		2	-0.36		+1.05				-0.03		-0.24			
		AV	-0.36	-2.3	-1.11	+6.3	+4.0	-21.5	-0.09	-0.5	-0.27	-1.5	-2.0	-23.5
E	6.05	1	-0.18		+1.02				-0.18		-0.24			
		2	-0.12		[illegible]				-0.12		-0.30			
		AV	-0.18	-1.1	+1.28	+6.5	+4.4	-32.5	-0.15	-0.9	-0.27	-1.6	-2.5	-35.0
F	6.44	1	-0.33		+0.78				-0.21		-0.27			
		2	-0.39		+0.8				-0.15		-0.42			
		AV	-0.36	-2.3	+0.78	+5.0	+2.7	-48.2	-0.18	-1.2	-0.33	-2.1	-3.3	-51.5
G	6.54	1	-0.42		+1.72				-0.27		-0.36			
		2	-0.48		+0.96				-0.5		-0.27			
		AV	-0.45	-3	+0.84	+5.7	+2.6	-59.1	-0.33	-2.7	-0.33	-2.3	-5.0	-64.1
H	7.04	1	-0.69		+0.99				-0.54		-0.24			
		2	-0.69		+0.8				-0.18		-0.30			
		AV	-0.69	-4.9	+0.60	+4.2	-0.7	-78.0	-0.36	-2.5	-0.27	-1.9	-4.4	-82.4
I	7.43	1	-0.93		+0.36				-0.27		-0.39			
		2	-0.78		+1.12				-0.81		-0.36			
		AV	-0.84	-6.2	+0.69	+5.1	-1.1	-94.6	-0.54	-4.0	-0.39	-2.9	-6.9	-101.5
J	7.81	1	-1.92		-0.24				-0.75		-0.21			
		2	-1.99		+2.22				-0.78		-0.30			
		AV	-1.92	-8.0	+0.99	+7.7	-0.3	-109.6	-0.75	-5.9	-0.27	-2.1	-6.0	-117.6
K	8.20	1	-0.42		+2.07				-2.37		-0.21			
		2	-2.10		-1.50				+0.93		+0.15			
		AV	-1.26	-10.3	+0.30	+2.5	-7.8	-145.9	-0.72	-5.9	-0.03	-0.2	-6.1	-152.0
L	8.60	1	-4.40		-4.38				+9.18		+0.27			
		2	+1.40		+4.26				-11.52		-0.33			
		AV	-1.50	-12.9	-0.06	-0.5	-13.4	-180.6	-1.17	-10.0	-0.03	-0.3	-10.3	-190.9
M	8.91	1	-1.51		-0.04				-1.50		-0.03			
		2	-0.65		-0.02				-0.65		0			
		3	-2.45		-0.04				-0.45		-0.09			
		4	-3.24		-0.02				-3.21		-0.12			
		AV	-1.45	-13.0	-0.05	-0.3	-13.3	-186.1	-1.45	-12.8	-0.06	-0.5	-13.3	-199.4
CALCULATED							-13.3	-170.3					-13.3	-183.3

SECTION	AREA SQ IN	GAGE	LOAD INCREMENT (APPLIED)=13.3K LOAD ON PILE 196.6 KIPS						LOAD INCREMENT (APPLIED)=13.3K LOAD ON PILE = 210 KIPS					
			EFFECT OF INCREMENT		EFFECT OF 44 HOURS		FINAL INCREMENT	TOTAL LOAD ON SECTION	EFFECT OF INCREMENT		EFFECT OF HOURS		FINAL INCREMENT	TOTAL LOAD ON SECTION
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS		
A	4.47	1	+0.24		-0.66				-0.33					
		2	+0.03		-0.39				-0.18					
		3	+0.03		+0.66				+0.27					
		4	0		-0.27				+0.33					
		AV	+0.06	+0.3	-0.15	-0.7	-0.4	+7.9	-0.15	-0.7			-0.7	+17.2
B	4.86	1	-0.03		0				+0.93					
		2	-0.06		+0.24				-0.30					
		3	-0.06		+0.30				+1.35					
		4	-0.06		+0.30				+1.17					
		AV	-0.06	-0.3	+0.21	+1.0	+0.7	-0.9	+0.78	+3.8			+3.8	+2.9
C	5.28	1	-0.21		+0.72				+2.34					
		2	-0.15		+0.63				-1.41					
		AV	-0.18	-0.9	+0.66	+3.5	+2.6	+1.2	+1.89	+9.9			+9.9	+11.1
D	5.65	1	-0.36		+0.96				-0.36					
		2	-0.33		+0.84				+3.90					
		AV	-0.36	-2.0	+0.90	+5.1	+3.1	-20.4	+1.77	+10.0			+10.0	-10.4
E	6.05	1	-0.60		+0.54				+1.17					
		2	-0.45		+0.33				+5.40					
		AV	-0.54	-3.3	+0.42	+2.5	-0.8	-35.8	+3.27	+19.8			+19.8	-16.0
F	6.44	1	-0.60		-0.06				+2.85					
		2	-0.57		+0.30				+3.33					
		AV	-0.60	-3.9	+0.12	+0.8	-3.1	-54.6	+3.09	+19.9			+19.9	-34.7
G	6.54	1	-0.75		-0.03				+5.34					
		2	-0.75		+0.12				+5.64					
		AV	-0.75	-5.1	+0.06	+0.4	-4.7	-68.8	+5.49	+37.5			+37.5	-31.3
H	7.04	1	-0.93		-0.06				+9.12					
		2	-0.90		+0.03				+5.58					
		AV	-0.90	-6.3	0	0	-6.3	-88.7	+7.35	+51.7			+51.7	-37.0
I	7.43	1	-1.02		-0.27				+7.83					
		2	-1.11		-0.30				+6.93					
		AV	-1.08	-8.0	-0.30	-2.2	-10.2	-111.7	+7.38	+54.8			+54.8	-56.9
J	7.81	1	-1.26		-0.33				+5.28					
		2	-1.20		-0.57				+6.45					
		AV	-1.23	-9.6	-0.45	-3.5	-13.1	-130.7	+5.85	+45.7			+45.7	-85.0
K	8.20	1	-1.56		-0.87				+3.81					
		2	-1.05		-0.08				+10.53					
		AV	-1.32	-10.8	-0.48	-3.9	-14.7	-166.7	+7.17	+58.8			+58.8	-107.9
L	8.60	1	+1.71		+0.84				-0.33					
		2	-4.83		-1.65				+14.37					
		AV	-1.56	-13.4	-0.42	-3.6	-17.0	-207.9	+7.02	+60.4			+60.4	-147.5
M	8.91	1	-0.66		+0.60				+4.62					
		2	-0.75		0				+4.17					
		3	-2.25		-0.87				+5.19					
		4	-0.39		+0.12				+6.78					
		AV	-1.01	[illegible]	[illegible]	[illegible]	-9.4	-208.8	+5.19	[illegible]			+46.3	-162.9
CALCULATED							-13.3	-196.6					-13.3	-210.0

SECTION	AREA SQ IN	GAGE	LOAD DECREMENT (REMOVED)=100K LOAD ON PILE = 110 KIPS						LOAD DECREMENT (REMOVED)=110K LOAD ON PILE = 0 KIPS						GAGE	AREA-SQ IN	SECTION
			EFFECT OF DECREMENT		EFFECT OF HOURS		FINAL INCREMENT	TOTAL LOAD ON SECTION	EFFECT OF DECREMENT		EFFECT OF HOURS		FINAL INCREMENT	TOTAL LOAD ON SECTION			
			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS			STRESS IN KSI	LOAD IN KIPS	STRESS IN KSI	LOAD IN KIPS					
A	4.47	1	+0.72						-0.24						1	4.47	A
		2	+0.48						+0.18						2		
		3	+0.78						+0.12						3		
		4	+0.54						+0.30						4		
		AV	+0.63	+2.8			+2.9	+2.8	+0.09	+0.4			+0.4	+3.2	AV		
B	4.86	1	+1.47						+1.23						1	4.86	B
		2	+1.56						+1.20						2		
		3	+0.51						+1.20						3		
		4	+0.99						+1.26						4		
		AV	+1.14	+5.5			+5.5	+5.5	+1.23	+6.0			+6.0	+11.5	AV		
C	5.28	1	+1.17						+1.74						1	5.28	C
		2	+0.87						+1.71						2		
		AV	+1.02	+5.4			+5.4	+5.4	+1.74	+9.2			+9.2	+14.6	AV		
D	5.65	1	+2.73						+2.79						1	5.65	D
		2	+1.95						+2.64						2		
		AV	+2.34	+13.2			+13.2	+13.2	+2.70	+15.3			+15.3	+18.5	AV		
E	6.05	1	+3.33						+3.42						1	5.05	E
		2	+2.40						+3.12						2		
		AV	+2.85	+17.2			+17.2	+17.2	+3.27	+19.8			+9.8	+37.0	AV		
F	6.44	1	+3.42						+4.23						1	6.44	F
		2	+3.66						+4.23						2		
		AV	+3.54	+22.8			+22.8	+22.8	+4.23	+27.3			+27.3	+50.1	AV		
G	6.54	1	+3.42						+4.77						1	6.34	G
		2	+3.66						+4.83						2		
		AV	+3.54	+34.8			+24.2	+24.2	+4.80	+32.8			+32.8	+57.0	AV		
H	7.04	1	+3.81						+5.04						1	7.04	H
		2	+4.53						+5.52						2		
		AV	+4.17	+29.3			+29.3	+29.3	+5.28	+37.2			+37.2	+66.5	AV		
I	7.43	1	+4.43						-6.06						1	7.43	I
		2	+4.65						+5.94						2		
		AV	+4.53	+33.6			+33.6	+33.6	+6.00	+44.6			+44.6	+78.2	AV		
J	7.81	1	+5.34						+6.81						1	7.81	J
		2	+6.57						+6.60						2		
		AV	+5.97	+46.6			+46.6	+46.6	+6.72	+52.5			+52.5	+99.1	AV		
K	8.20	1	+6.33						—						1	8.20	K
		2	+6.72						—						2		
		AV	+6.51	+53.4			+53.4	+53.4	—	—			—	—	AV		
L	8.60	1	+9.09						—	—					1	8.60	L
		2	+5.88						—	—					2		
		AV	+7.47	+64.2			+64.2	+64.2	—	—			—	—	AV		
M	8.91	1	+9.09						+19.35						1	8.91	M
		2	+7.50						+12.60						2		
		3	+8.30						-4.02						3		
		4	+9.36						+13.26						4		
		AV	+8.61	+76.7			+76.7	+76.7	+10.29	+91.6			+91.6	+168.3	AV		
CALCULATED															CALCULATED		

TABLE 10

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

TABLE OF RECORDED STATIC STRESSES
PILE M11

OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS JUNE, 1949

SECTION	AREA-SQ IN	GAGE	LOAD INCREM'T (APPLIED) = +50^{K} LOAD ON PILE = 50 KIPS			LOAD INCREM'T (APPLIED) = +30^{K} LOAD ON PILE = 80 KIPS			LOAD INCREM'T (APPLIED) = +30^{K} LOAD ON PILE = 110 KIPS			LOAD INCREM'T (APPLIED) = +30^{K} LOAD ON PILE = 140 KIPS			LOAD INCREM'T (APPLIED) = +30^{K} LOAD ON PILE = 170 KIPS			LOAD INCREM'T (APPLIED) = +30^{K} LOAD ON PILE = 200 KIPS			LOAD INCREM'T (APPLIED) = +30^{K} LOAD ON PILE = 230 KIPS			LOAD INCREM'T (APPLIED) = +30^{K} LOAD ON PILE = 260 KIPS			LOAD INCREM'T (APPLIED) = +40^{K} LOAD ON PILE = 300 KIPS			LOAD DECREM'T (REMOVED) = 150^{K} LOAD ON PILE = 150 KIPS			LOAD DECREM'T (REMOVED) = 150^{K} LOAD ON PILE = 0 KIPS			GAGE	AREA-SQ IN	SECTION
			EFFECT OF INCREMENT		TOTAL LOAD ON SECTION	EFFECT OF INCREMENT		TOTAL LOAD ON SECTION	EFFECT OF INCREMENT		TOTAL LOAD ON SECTION	EFFECT OF INCREMENT		TOTAL LOAD ON SECTION	EFFECT OF INCREMENT		TOTAL LOAD ON SECTION	EFFECT OF INCREMENT		TOTAL LOAD ON SECTION	EFFECT OF INCREMENT		TOTAL LOAD ON SECTION	EFFECT OF INCREMENT		TOTAL LOAD ON SECTION	EFFECT OF INCREMENT		TOTAL LOAD ON SECTION	EFFECT OF DECREMENT		TOTAL LOAD ON SECTION	EFFECT OF DECREMENT		TOTAL LOAD ON SECTION			
			STRESS IN KSI	LOAD IN KIPS		STRESS IN KSI	LOAD IN KIPS		STRESS IN KSI	LOAD IN KIPS		STRESS IN KSI	LOAD IN KIPS		STRESS IN KSI	LOAD IN KIPS		STRESS IN KSI	LOAD IN KIPS		STRESS IN KSI	LOAD IN KIPS		STRESS IN KSI	LOAD IN KIPS		STRESS IN KSI	LOAD IN KIPS		STRESS IN KSI	LOAD IN KIPS		STRESS IN KSI	LOAD IN KIPS				
A	5.93	1																																		1	5.93	A
		2																																		2		
		3	-1.65			-0.48			-1.26			-1.32			-0.03			-1.17			-0.66			-0.78			-1.77			-0.81						3		
		4	-1.02			-0.27			-0.33			-1.17			+0.45			-1.29			-0.18			-0.33			-2.07			-0.51			-0.60			4		
		AV	-1.35	-8.0	-8.0	-0.36	-2.5	-10.5	-0.78	-4.6	-15.1	-1.23	-7.3	-22.4	+0.21	+1.2	-21.2	-1.23	-7.3	-28.5	-0.42	-2.5	-31.0	-0.54	-3.2	-34.2	-1.92	-11.4	-45.6	-0.66	-3.9	-3.9	-0.60	-3.6	-7.5	AV		
B	6.36	1																																		1	6.36	B
		2																						-0.20						-0.36			+0.15			2		
		3																																		3		
		4																																		4		
		AV																						-0.20						-0.36	-2.3	-2.3	+0.15	+1.0	-1.3	AV.		
C	6.77	1	-1.23			-1.23			-0.57			-0.87			-0.15			-0.51			-0.33									+0.84			+0.75			1	6.77	C
		2																																		2		
		3																																		3		
		4																																		4		
		AV	-1.23	-8.4	-8.4	-1.23	-8.4	-16.8	-0.57	-3.9	-20.7	-0.87	-5.9	-26.6	-0.15	-1.0	-27.8	-0.51	-3.5	-31.1	-0.33	-2.3	-33.4	-0.63	-4.3	-37.7		-11.4	-49.1	+0.84	+5.7	+5.7	+0.75	+5.1	+10.8	AV		
D	7.19	1																																		1	7.19	D
		2																																		2		
		3	-0.72			+0.12			-3.18																					+0.84			+0.96			3		
		4	-0.87			-0.42			-0.09																											4		
		AV	-0.81	-5.8	-5.8	-0.15	-1.1	-6.9	-1.65	-11.9	-18.8																			+0.84	+6.0	+6.0	+0.96	+6.9	+12.9	AV		
J	9.95	1	-0.45			-0.72			-0.06			-0.57			-0.03			-0.69			-0.45			-1.38			-1.32			+3.09			+4.32			1	9.95	J
		2	-0.33			-0.24			-0.39			-0.30			-0.24			-0.84			-0.09			-1.17			-1.62									2		
		AV	-0.39	-3.9	-3.9	-0.48	-4.8	-8.7	-0.24	-2.4	-11.1	-0.45	-4.5	-15.6	-0.15	-1.5	-17.1	-0.78	-7.8	-23.4	-0.27	-2.7	-26.1	-1.26	-12.5	-38.6	-1.47	-14.6	-53.2	+3.09	+31	+31	+4.32	+43	+74	AV		
K	10.48	1																																		1	10.48	K
		2	-0.72			-0.54			-0.72			-0.12			-0.39			-1.29			-0.09			-1.95			-1.80			+3.66			+5.16			2		
		AV	-0.72	-7.6	-7.6	-0.54	-5.7	-13.3	-0.72	-7.6	-20.9	-0.12	-1.3	-22.2	-0.39	-4.1	-26.3	-1.29	-13.5	-39.8	-0.09	-1.0	-40.8	-1.95	-20.5	-61.3	-1.80	-18.9	-80.2	+3.66	+38	+38	+5.16	+54	+92	AV.		
N	11.22	1	-1.32			-1.08			-0.78			-0.78			-0.66			-1.77			-0.72			-2.16			-2.46			+6.15			+8.28			1	11.22	N
		2	-1.26			-1.02			-0.57			-0.57			-0.36			-1.62			-0.15			-2.22			-1.69			+6.27			+8.28			2		
		AV	-1.29	-14.5	-14.5	-1.05	-11.8	-26.3	-0.69	-7.8	-34.1	-0.69	-7.8	-41.9	-0.51	-5.7	-47.6	-1.71	-19.2	-66.8	-0.45	-5.1	-71.9	-2.19	-24.6	-96.5	-2.16	-24.2	-120.7	+6.21	+70	+70	+8.28	+93	+163	AV		
O	11.32	1	-2.19			-1.59			-1.32			-1.26			-0.75			-2.28			-0.36			-1.14						+7.14			+9.51			1	11.32	O
		2																																		2		
		AV	-2.19	-24.8	-24.8	-1.59	-18.0	-42.8	-1.32	-15.0	-57.8	-1.26	-14.3	-72.1	-0.75	-8.5	-80.6	-2.28	-25.8	-106.4	-0.36	-4.1	-110.5	-1.14	-12.9	-123.4		-28.0	-151.4	+7.14	+81	+81	+9.51	+108	+189	AV		
P	11.45	1	-2.70			-1.77			-1.89			-1.56			-1.38			-2.13			-1.41			-2.58			-2.91			+9.09			+11.01			1	11.45	P
		2	-2.52			-1.56			-1.92			-1.47			-1.29			-2.13			-0.75			-2.25			-2.73			+9.06			+10.05			2		
		AV	-2.61	-29.9	-29.9	-1.68	-19.2	-49.1	-1.92	-22.0	-71.1	-1.53	-17.5	-88.6	-1.35	-15.5	-104.1	-2.13	-24.4	-128.5	-1.08	-12.4	-140.9	-2.40	-27.5	-168.4	-2.82	-32.3	-200.7	+9.06	+104	+104	+10.53	+132	+236	AV		
Q	11.55	1	-3.15			-2.04			-2.46			-2.01			-1.86			-2.88			-0.84			-2.43			-3.15			+9.48			+12.51			1	11.55	Q
		2	-2.85			-1.68			-1.92			-1.38			-0.84			-2.13						-2.13			-3.57			+9.99						2		
		AV	-3.00	-34.7	-34.7	-1.86	-21.5	-56.2	-2.19	-25.3	-81.5	-1.71	-19.8	-101.3	-1.35	-15.6	-116.9	-2.49	-28.8	-145.7	-0.84	-9.7	-155.4	-2.28	-26.3	-181.7	-3.36	-38.8	-220.5	+9.72	+112	+112	+12.51	+145	+257	AV		
R	11.67	1	-3.24			-2.04			-1.92			-1.17			-0.15			-3.63			+2.31			-1.68			-5.82			+11.10			+6.78			1	11.67	R
		2	-4.35			-3.00			-3.66			-3.99			-4.80			-3.12			-4.77			-5.40			-1.71			+10.14			+21.63			2		
		AV	-3.81	-44.4	-44.4	-2.52	-29.4	-73.8	-2.76	-32.2	-106.0	-2.58	-30.1	-136.1	-2.49	-29.0	-165.1	-3.36	-39.1	-204.2	-1.23	-14.3	-218.5	-3.54	-41.4	-259.8	-3.75	-43.7	-303.5	+10.62	+124	+124	+14.22	+166	+290	AV.		
S	11.38	1	-1.95						+0.48									-1.71						-1.71			-5.37			+13.95						1	11.38	S
		2	-4.26			-3.66			-4.38									-4.77						-3.00			-2.61			+9.48						2		
		AV	-3.12	-35.6	-35.6	-3.66	-41.5	-77.1	-1.95	-22.2	-99.3		-30.3	-140.0		-35.0	-175.0	-3.24	-37.0	-212.0		-27.0	-239.0	-2.34	-26.6	-265.6	-3.99	-45.4	-311.0	+11.70	+133	+133		+167	+300	AV.		
T	11.48	1	-3.51						-0.81			-0.72			-1.41			-2.73			+0.36			-1.62						+11.94			+6.87			1	11.48	T
		2	-4.11			-3.30			-4.44			-4.62			-5.43			-2.58			-5.16			-3.09						+10.20			+22.50			2		
		AV	-3.81	-43.6	-43.8	-3.30	-38.0	-81.8	-2.61	-30.0	-111.8	-2.67	-30.6	-142.4	-3.42	-39.2	-181.6	-2.67	-30.6	-212.2	-2.40	-27.6	-239.8	-2.34	-26.8	-266.6		-45.0	-311.6	+11.07	+128	+128	+14.67	+169	+297	AV.		
CALCULATED				-50.0	-50.0		-30.0	-80.0		-30.0	-110.0		-30.0	-140.0		-30.0	-170.0		-30.0	-200.0		-30.0	-230.0		-30.0	-260.0		-40.0	-300.0		+150	+150		+150	0	CALCULATED		

group, or 11,400 lb. average load per pile, indicated there was a compressive strain of 28 micro-inches in the steel at this section, but the gages on the drift bar indicated a compressive strain of 8 micro-inches due to drift. The average difference of 28 micro-inches in the gage readings on the pile was reduced to 20 micro-inches, and this value then multiplied by the stress factor of 30 psi., to determine the average stress in the pile at this particular section. The stresses recorded in the various test piles, after correcting for drift, are shown in Tables 5 to 10, incl.

Considering pile M4 as an example, it can be seen from Table 6 that the average unit stress of 600 psi., at Section M–M, when multiplied by the steel area of 8.91 sq. in., indicated a total stress or load of 5400 lb. in the pile. No additional load was placed on the pile for 3 hours, but the gages indicated, after again correcting for drift, that there was some redistribution of the load among the piles of the group, as well as along the height of the individual pile, during this period, as shown in Table 6. It appears that the total stress or load in the pile at Section M–M was increased by 1900 lb. during this 3-hour period; also, from study of Table 6, the skin friction between the silty clay and the pile at the top released the load somewhat, allowing it to be carried further down the pile.

The effect of all the load increments, and the various time periods on the unit stresses and total stresses of loads at every 5-ft. interval of the piles are shown in these tables, and the total load carried at any section is a summation of all the preceding increments. A summation of all the load increments as recorded at the top of the pile is the total load carried by each pile. Again using pile M4 as an example, a total calculated average load of 131,400 lb. per pile was placed on the group. However, the strain gages at Section M–M of pile M4, as shown in Table 6, indicated that the pile was only carrying 103,200 lb. Upon completion of the loading tests, the load was removed by large decrements and strain gage readings again taken for all the piles, except M10, which had failed during loading.

The pile reactions obtained at the lower sections of pile M4, Fig. 18, are of particular interest because they indicate a downward pull at these locations. It can be seen from a study of the table of recorded stresses for this pile, Table 6, that the indicated downward pull results from the duration of the load and not from the application of the load. The magnitude of the maximum downward reaction is about the same as the difference between the reaction at the top and the average reaction of all the piles of the group. It is quite possible that this downward reaction is a result of the group action, but it could also be due to local distortion of the pile or to excessive drift of these particular gages.

A check on the accuracy of the readings on the drift bar was maintained by comparing these readings with the average secured on all the gages at the top of the nine piles of the group without any load applied on the group. The drift bar readings usually checked the average readings on the nine piles within three or four micro-inches, indicating that the drift was generally about the same for all the gages.

The loading and unloading pile reactions, as measured in the field and tabulated in the previously mentioned tables, are shown in Figs. 16, 18, 20, 22 and 24 for the steel piles tested. For example, the plotted total stress values shown by the open circles on the Loading Reaction diagram of Fig. 24 were secured in the long pile M11 under a concrete block load of 50,000 lb. The smooth curve drawn through the plotted values indicates that the load decreases rapidly below the ground level. The plotted total stress values shown by the solid circles were secured under a load of 300,000 lb. and the smooth curve drawn through the plotted values indicates a measured load of about 312,000 lb.

(text continued on page 185)

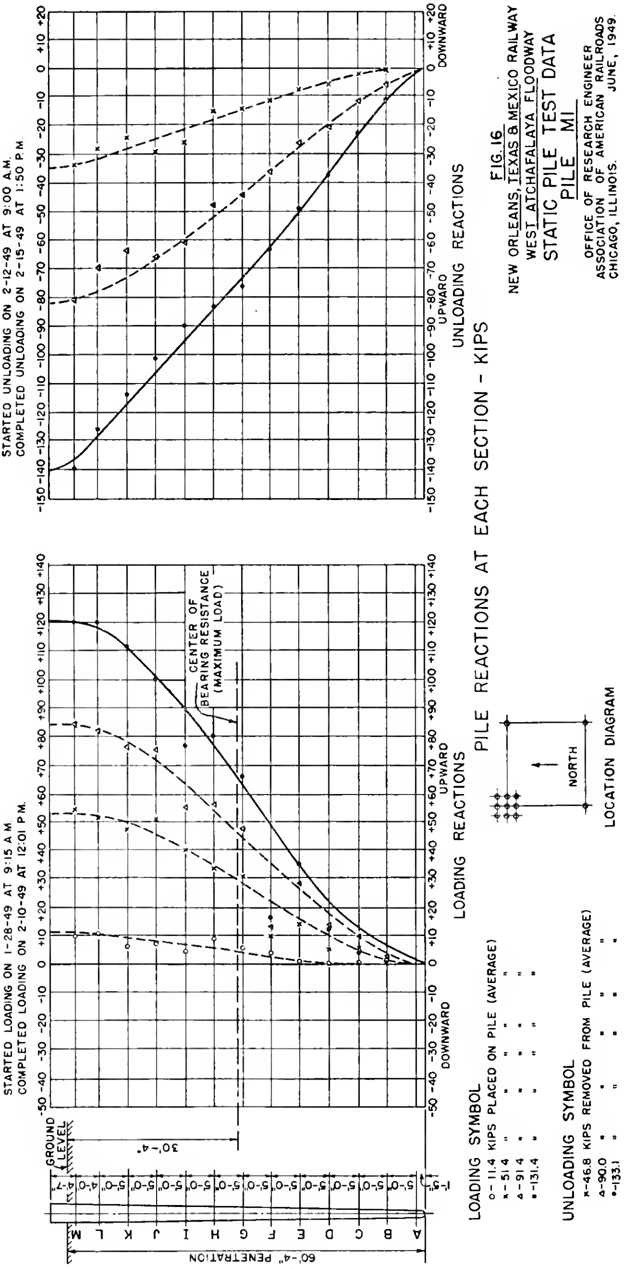


FIG. 16
NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STATIC PILE TEST DATA
PILE M1

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ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS. JUNE, 1949.

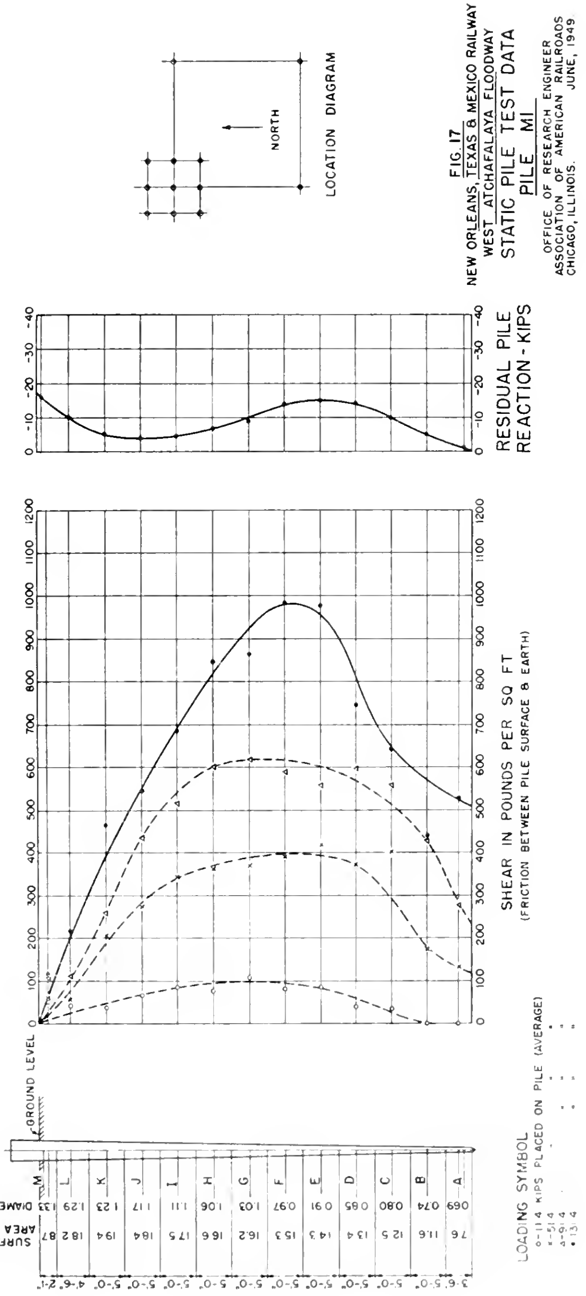

FIG. 17

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STATIC PILE TEST DATA
PILE M1

OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS. JUNE, 1949

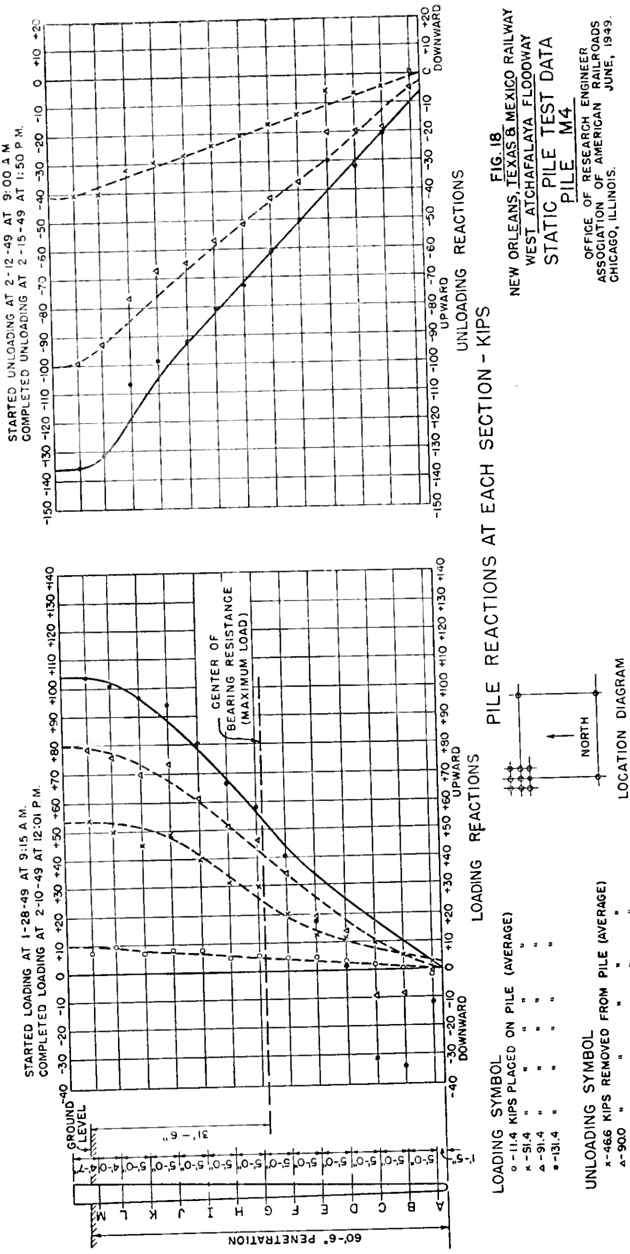

FIG. 18
NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STATIC PILE TEST DATA
PILE M4

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ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS. JUNE, 1949.

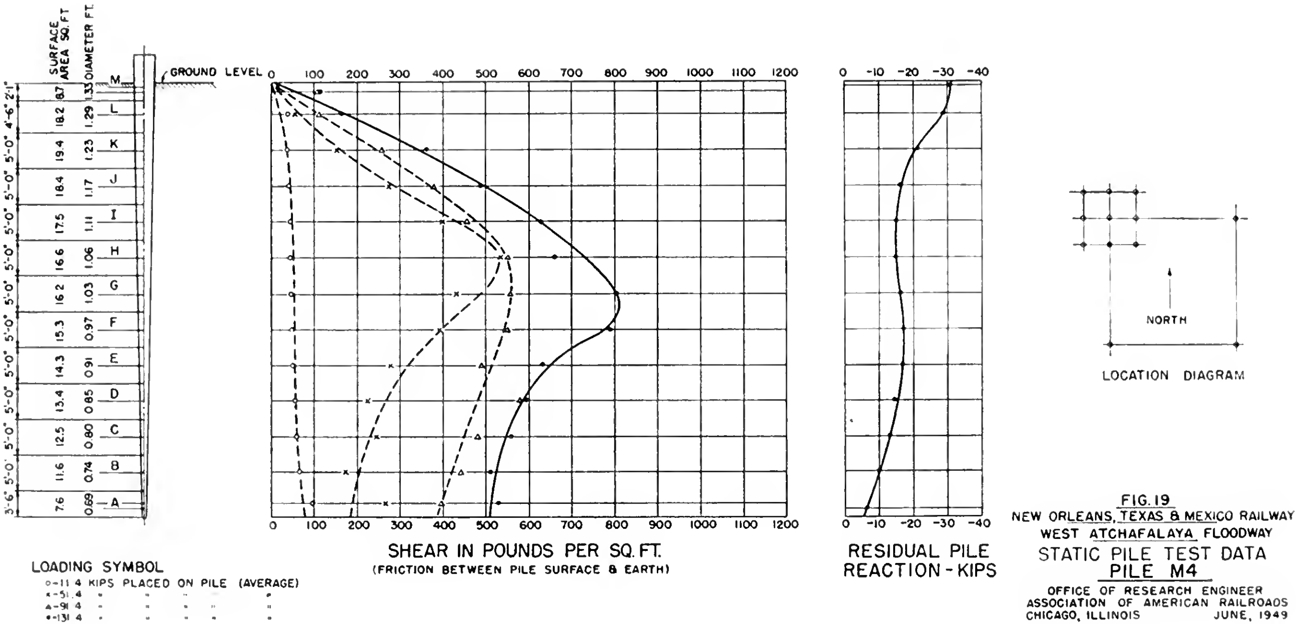

FIG. 19

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STATIC PILE TEST DATA
PILE M4

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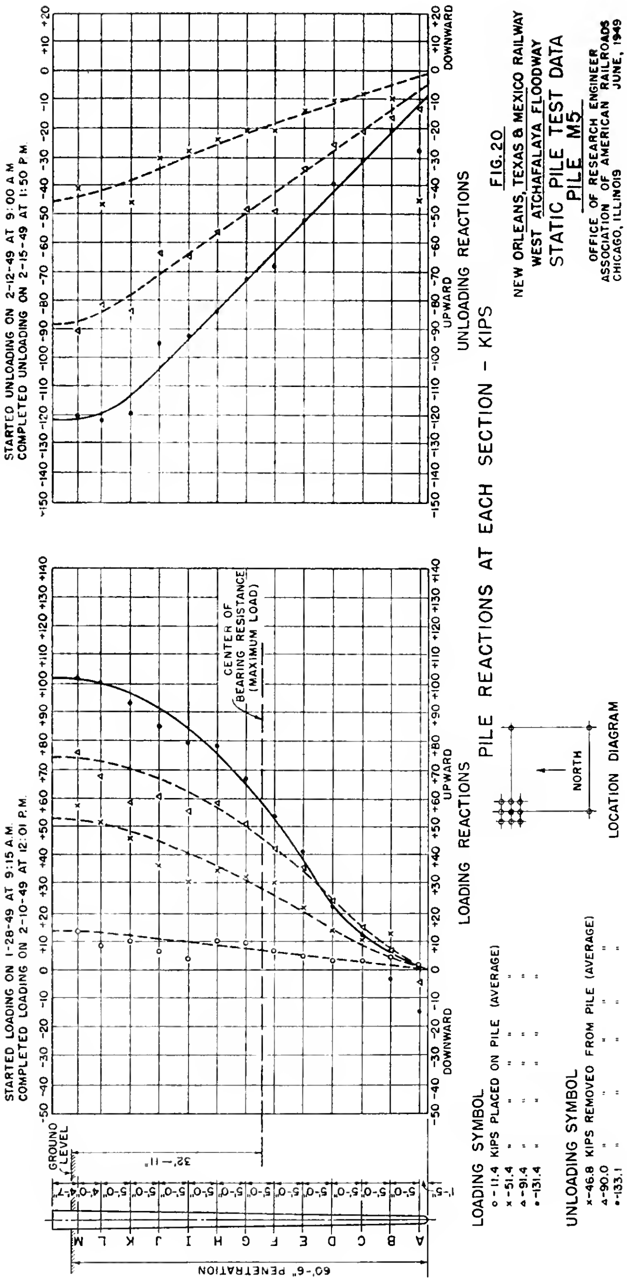

FIG. 20

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STATIC PILE TEST DATA
PILE M5

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CHICAGO, ILLINOIS JUNE, 1949

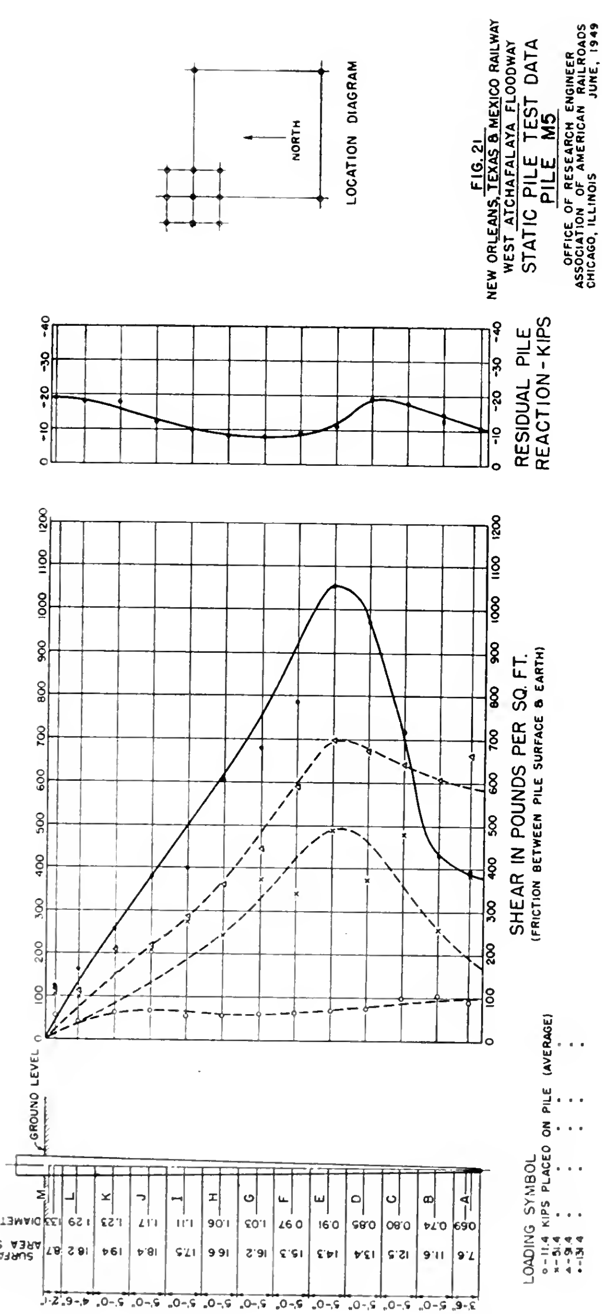

FIG. 21
NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STATIC PILE TEST DATA
PILE M5
OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS JUNE, 1949

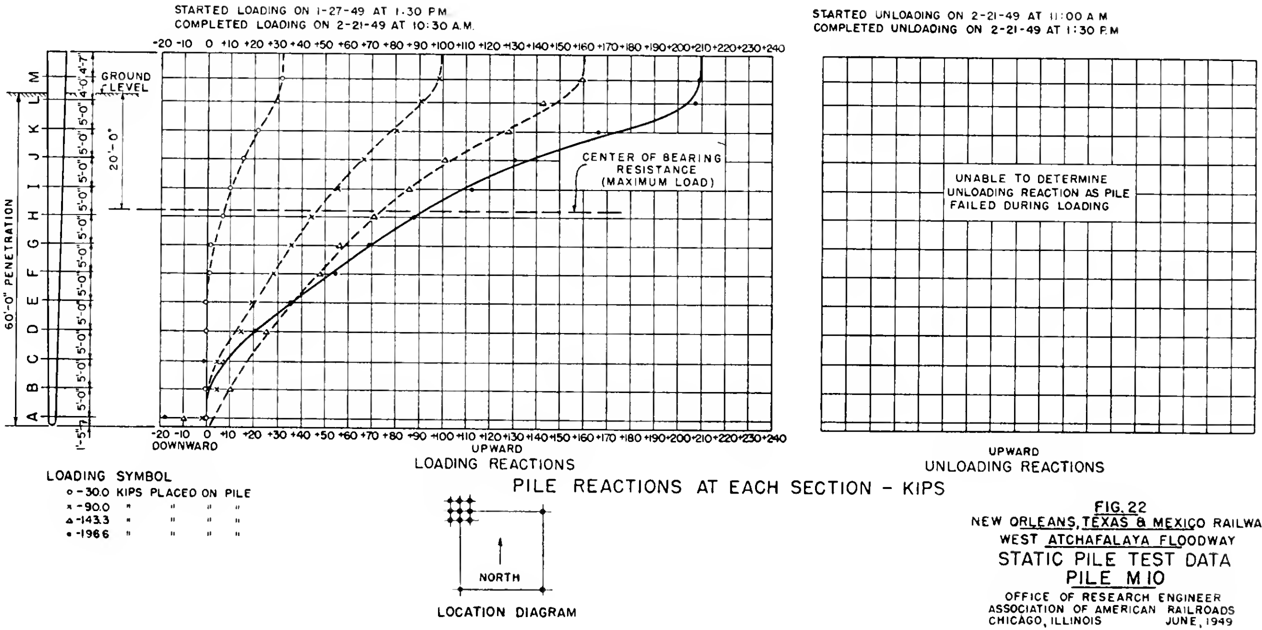

FIG. 22
NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STATIC PILE TEST DATA
PILE M 10
OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS JUNE, 1949

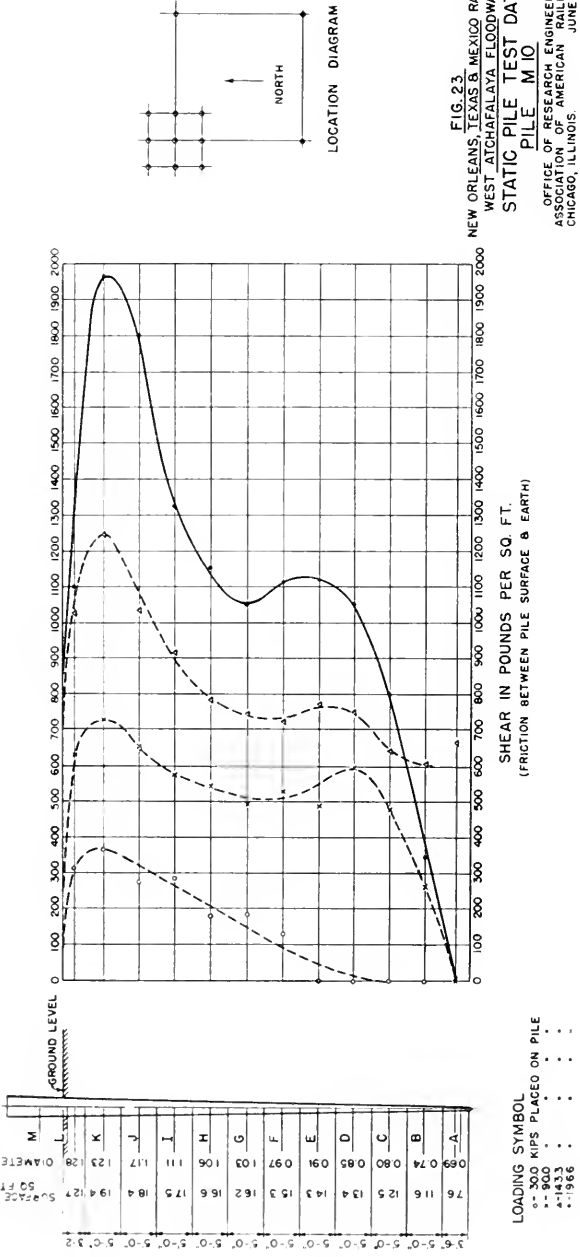

FIG. 23
NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STATIC PILE TEST DATA
PILE M 10

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ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS. JUNE, 1949

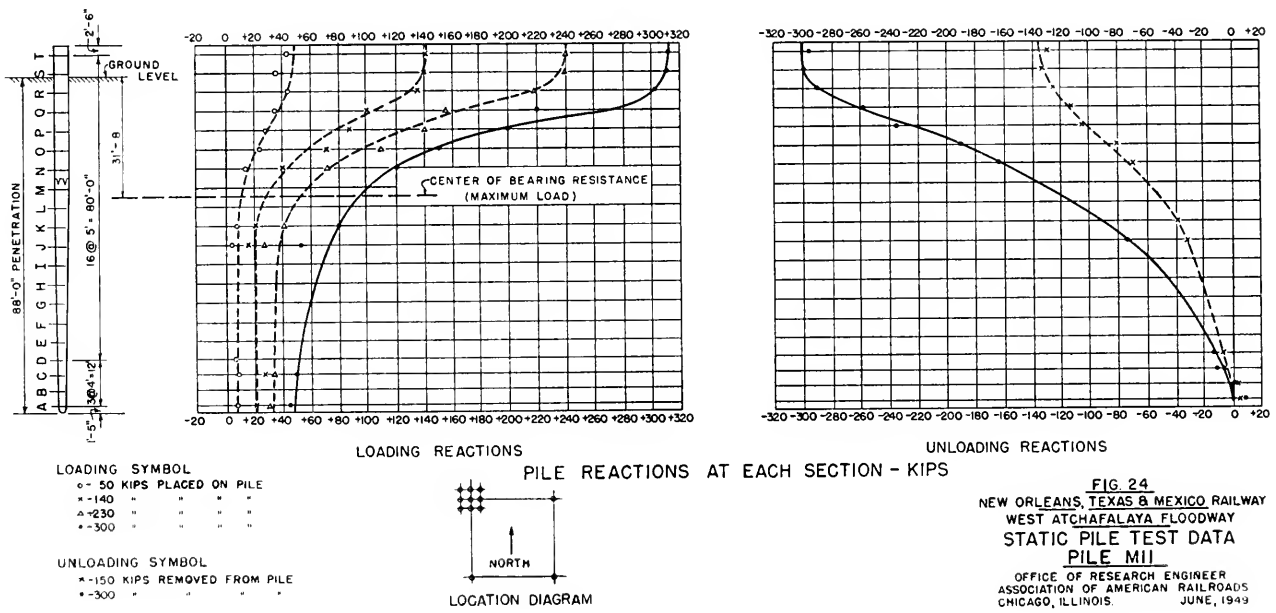

FIG. 24
NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STATIC PILE TEST DATA
PILE M11
OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS. JUNE, 1949

(text continued from page 175)

The load carried by the pile decreased very rapidly below the ground level and only about 47,000 lb., or 15.7 percent, of the load at the top was carried by end bearing at the bottom.

The plotted total stress values shown on the right diagram of Fig. 24 were obtained during the unloading of pile M11. It can be seen that, in general, the loading and unloading curves are about the same both as to shape and magnitude. It should be mentioned that the total load on this pile was removed in two decrements with a very short time period between decrements.

The center of bearing resistance, or the center of gravity of the total shears transmitted to the surrounding earth, was calculated for each pile under maximum load and is shown on the loading reaction diagrams, Figs. 16, 18, 20, 22 and 24. For example, the total shear transmitted to the earth between sections K and J of pile M1, Fig. 16. was 111 — 101 = 10 kips, and the center of gravity of the total shears between all sections for this pile was calculated as 30 ft. 4 in., or 50 percent of the penetration depth, as shown on this figure.

The shear diagrams for the steel piles tested are shown by the left diagrams in Figs. 17, 19, 21, 23 and 25. The values of the shear or friction between the pile surface and the earth for each 5-ft. length of pile were determined directly from the loading reactions for each pile. For example, the shear value of 1890 lb. per sq. ft. at Section 0–0 of the long pile M11, under a load of 300,000 lb., as shown by the curve in Fig. 25, was obtained by taking the difference in pile reactions at sections 2 ft. 6 in. above and below Section 0–0. The pile reaction at a section 2 ft. 6 in. above Section 0–0 is 168,000 lb., while the reaction 2 ft. 6 in. below is 130,000 lb. (see Fig. 24). The reduction of 38,000 lb. in the pile reaction between these two sections must be carried in shear between the pile and the earth. The average surface area of the pile between the two sections is 20.1 sq. ft., resulting in an average shear value of 1890 lb. per sq. ft., as shown in Fig. 25.

It can be seen from the shear diagrams that exceedingly high shear values were recorded for all the piles. However, these maximum values occur for only a relatively short length of the pile, except for the pile M10. Before failure of the pile could occur, it would be necessary for these high shear values to occur over a much greater depth of the pile. The single pile M10 failed at a load of 196,000 lb., and it can be seen from Fig. 23 that the maximum shear values were more uniform for almost the entire depth of the pile.

It is interesting to note that, while the shear curves for piles M1, M4 and M5 of the 9-pile group are very similar to those of the single piles M10 and M11, the distance from the ground level to the point of maximum shear is very much greater in the piles of the group. The results of the tests on the single piles indicated a high resistance capacity of the soil near the surface of the ground under short-time loading; however, the tests on the 9-pile group indicated that the maximum shear resistance was considerably lower in the ground.

The residual pile reaction curves shown on the right diagrams of Figs. 17, 19, 21 and 25 for the steel piles that did not fail were obtained directly from the loading and unloading pile reaction curves. For example, the loading reaction curve for the long pile M11, Fig. 24, indicates that the pile reaction at Section G–G under a load of 300,000 lb was 60,000 lb. However, when the 300,000-lb. load was removed from the pile, only 36,000 lb. were removed at Section G–G, indicating that the friction between the pile surface and the earth retained a load of 24,000 lb. in the pile at this section (see Fig. 25).

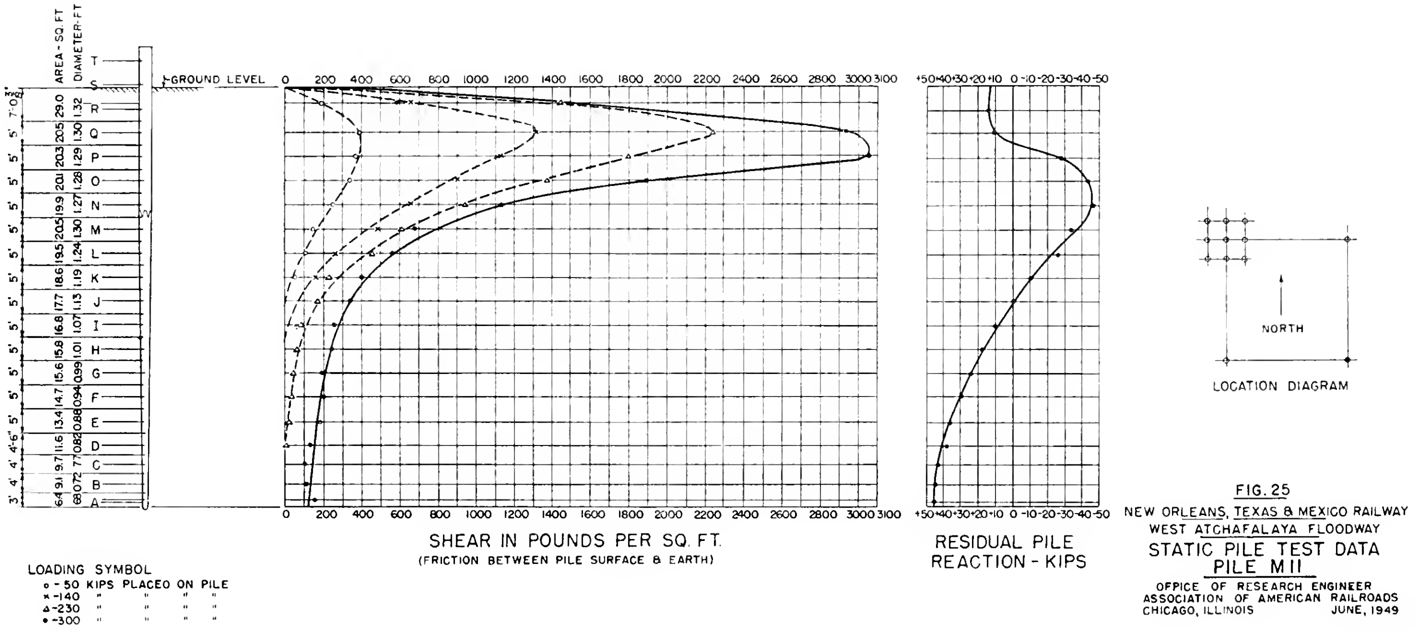

FIG. 25

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STATIC PILE TEST DATA
PILE M11

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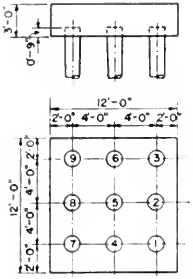
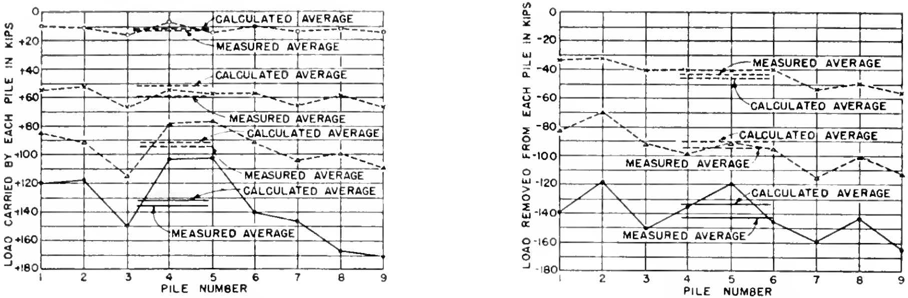
CHICAGO, ILLINOIS JUNE, 1949



PLAN AND ELEVATION
OF PILE GROUP



INCREASING LOAD

SYMBOL:
○ -11.4 KIPS PLACED ON PILE (CALCULATED AVERAGE)
× -51.4 " " " " " "
△ -91.4 " " " " " "
● -131.4 " " " " " "

DECREASING LOAD

SYMBOL:
× - 46.6 KIPS REMOVED FROM PILE (CALCULATED AVERAGE)
△ - 90.0 " " " " " "
● - 133.1 " " " " " "

DISTRIBUTION OF LOAD TO INDIVIDUAL PILES OF GROUP

TABLE OF LOAD DISTRIBUTION TO INDIVIDUAL PILES

CALCULATED LOAD ON GROUP	CALCULATED AVERAGE LOAD PER PILE	MEASURED LOAD ON GROUP	MEASURED AVERAGE LOAD PER PILE	PILE NUMBERS																	
				1		2		3		4		5		6		7		8		9	
				LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD
103	11 4	108.1	12 0	97	9.0	112	10 3	16.3	15.1	73	6.8	147	13 6	10.1	9.3	131	12.1	12.3	11.4	13.4	12.4
463	51.4	533.7	59.3	54.8	10.2	526	9 9	674	12 6	54 7	10 2	576	10.8	56 9	10.7	652	12 2	58.5	11.0	66.0	12 4
823	91 4	847 5	94 2	84 1	9 9	91 2	10.8	114 4	13 5	78.0	9 2	75.9	8.9	91.6	10.8	1036	12.2	99 7	11.8	109.0	12.9
1283	131.4	1220.4	135.6	120.3	9.9	118.7	9.7	150.0	'2.3	103.2	8.5	102.7	8 4	140.8	11.5	1464	12.0	167.4	13.7	170.9	14 0
• 420	46 6	388.0	43 1	33 7	8.7	32.1	8 3	41 4	10 7	40 4	10 4	41 2	10.6	40.1	10.3	53.5	13 8	49.2	12 7	56.4	14 5
• 810	90.0	858 7	95 4	82 0	9 5	70 0	8 2	92 2	10 7	98 6	11 5	90.9	10.6	94.8	11.0	116 6	13 6	101.0	11.8	112.6	13.1
• 1198	133.1	1277 8	142 0	139.4	10.9	118.1	9 2	151.3	11 9	135 2	10 6	120.0	9.4	146 9	11.5	159.0	12.4	143.0	11.2	164.9	12 9

• LOAD REMOVED FROM THE PILE GROUP ALL PILE LOADS IN KIPS

FIG. 26

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

STATIC PILE TEST DATA
STEEL PILE GROUP

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CHICAGO, ILLINOIS JUNE, 1949

At first glance the diagrams of residual pile reactions look peçuliar, but a detailed study of the data indicates that the reactions as shown are possible. The reactions shown by the curve for pile M11, Fig. 25, are fairly well balanced against upward and downward values. It appears that piles M1, M4 and M5 of the 9-pile group should rebound out of the ground (see Figs. 17, 19 and 21). However, a study of the soil exploration data shows stratification of the material, and where permanent displacement or compression has taken place, the residual reactions shown are possible.

In general, it can be seen from the loading and unloading diagrams that the 65-ft. piles were entirely friction piles with no end bearing, and from a study of the soil boring samples there is no reason to expect any end bearing. The soil data indicated a majority of clays having a high moisture content. Apparently these clays varied considerably in plasticity, as indicated by the liquid limits, but the moisture content of the soils in the field generally increases with the liquid limits so it can be assumed, to a certain extent, that the materials through the depth of the piles were of approximately the same strength.

As previously mentioned, the stresses at the tops of all the 9 piles of the group were determined from field measurements, and the reactions of the individual piles at various load increments are shown in tabular form in Fig. 26. For example, for a calculated total load of 1,183,000 lb. on the 9 piles, or an average of 131,400 lb. per pile as determined from the estimated weight of the concrete blocks, the strain gage readings indicated that pile M1 was carrying 120,300 lb., or 9.9 percent of the total measured load, pile 2 was carrying 118,700 lb., or 9.7 percent of the total, etc. A summation of the loads carried by each pile, as indicated by the strain gage readings, is 1,220,400 lb., or an average of 135,600 lb. per pile. It should be noted that pile M2 carried the smallest load while pile M9 carried the greatest. However, the load carried by pile M2 was only 12.5 percent below the average load, while the load carried by pile M9 was 26 percent above the average.

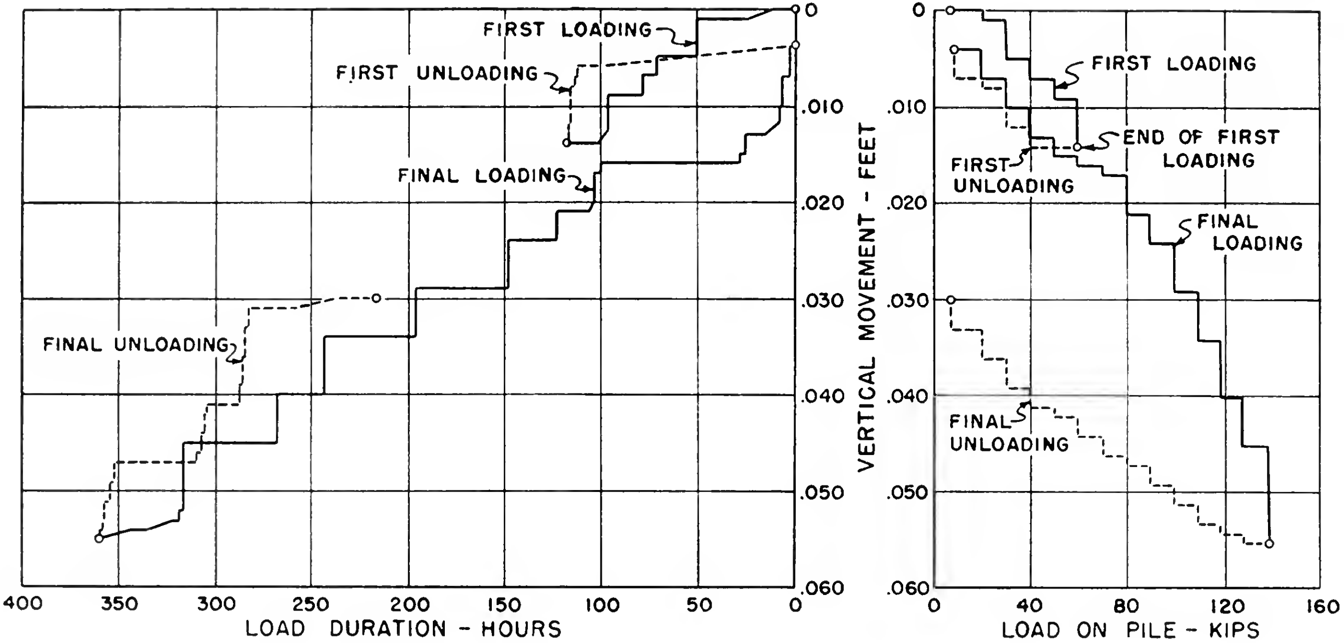
The data, as presented in the table on Fig. 26, are also presented by the two diagrams in the same figure. It should be mentioned that the pile reactions shown in this report do not include the weight of the concrete loading platform. When the loading tests were started on the 9-pile group, concrete blocks weighing 15,000 lb. were already in place on the loading platform, so they are not included in the loading reactions, but they are included in the unloading reactions as all the load was removed, which accounts for the variation between the loading and unloading values.

In addition to the strain gage readings, the vertical movement of the butt end of each pile was measured by means of a level during the loading and unloading of all the single piles, as well as each pile of the 9-pile group. The vertical movements of the butt end of the pile, with respect to the load and duration of the load, are shown in the diagrams of Figs. 27, 28 and 29, for typical piles M4, M10 and M11. The loading diagram of pile M10, Fig. 28, is of particular interest for it shows that this pile was failing under a load of 196,600 lb., although it carried 210,000 lb. for a very short interval of time.

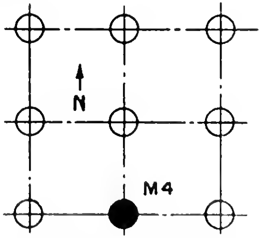
A brief resumé of all the pertinent data pertaining to the tests on the steel piles is shown in Table 11.

The strain gage readings on the timber pile group at Two O'clock Bayou and Half Moon Bayou consisted essentially of taking readings on the 8-in. diameter pipe of the loading cap. as previously explained. The strain gage readings secured during the loading of the piles were analyzed and tabulated in the same manner as that employed on the steel piles.

(text continued on page 200)



NOTE: PILE DRIVEN DEC. 20, 1948
FIRST PILE LOADING
STARTED: JAN. 8, 1949
FIRST PILE LOADING
COMPLETED: JAN 14, 1949
FINAL PILE LOADING
STARTED: JAN. 28, 1949
FINAL PILE LOADING
COMPLETED: FEB. 10, 1949



LOCATION DIAGRAM

FIG. 27
NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STEEL PILE TEST DATA
PILE M4

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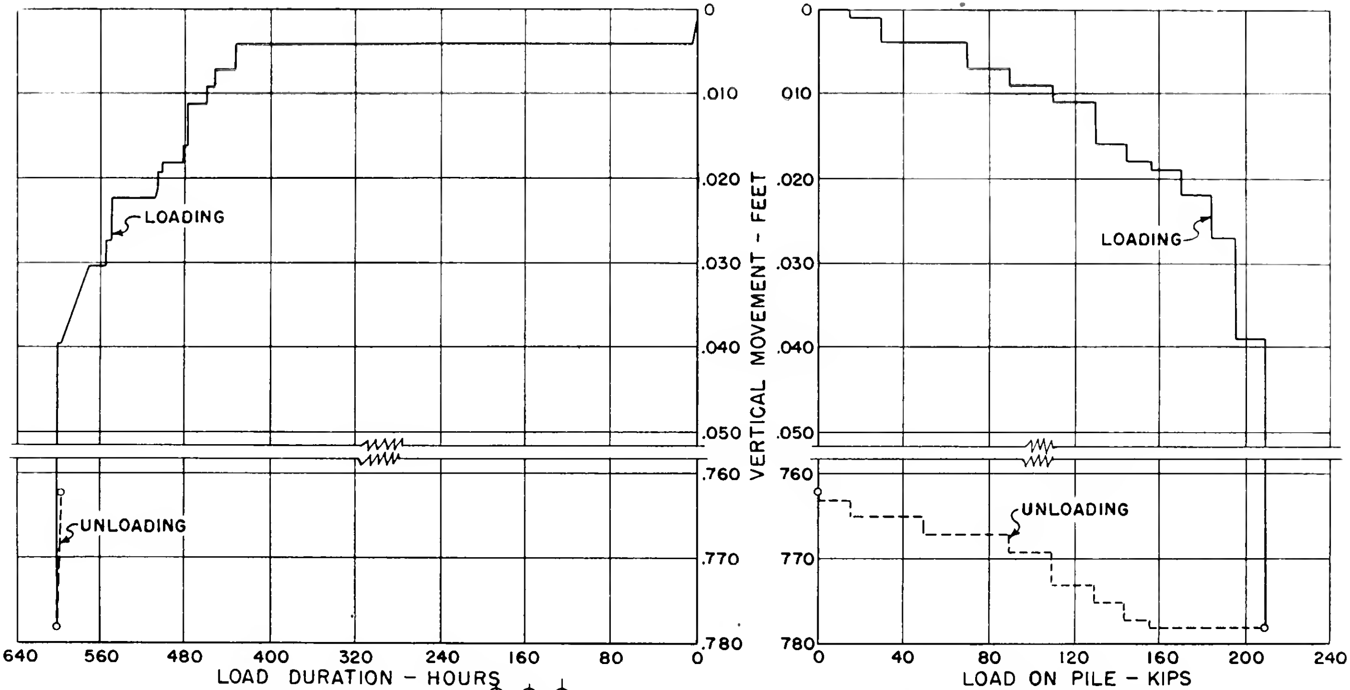

NOTE: PILE DRIVEN DEC. 19, 1948
PILE LOADING STARTED
JAN. 27, 1949
PILE LOADING COMPLETED
FEB. 21, 1949

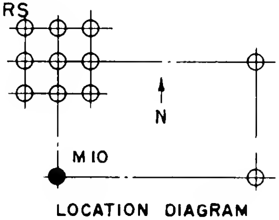

FIG. 28

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

STEEL PILE TEST DATA
PILE M10

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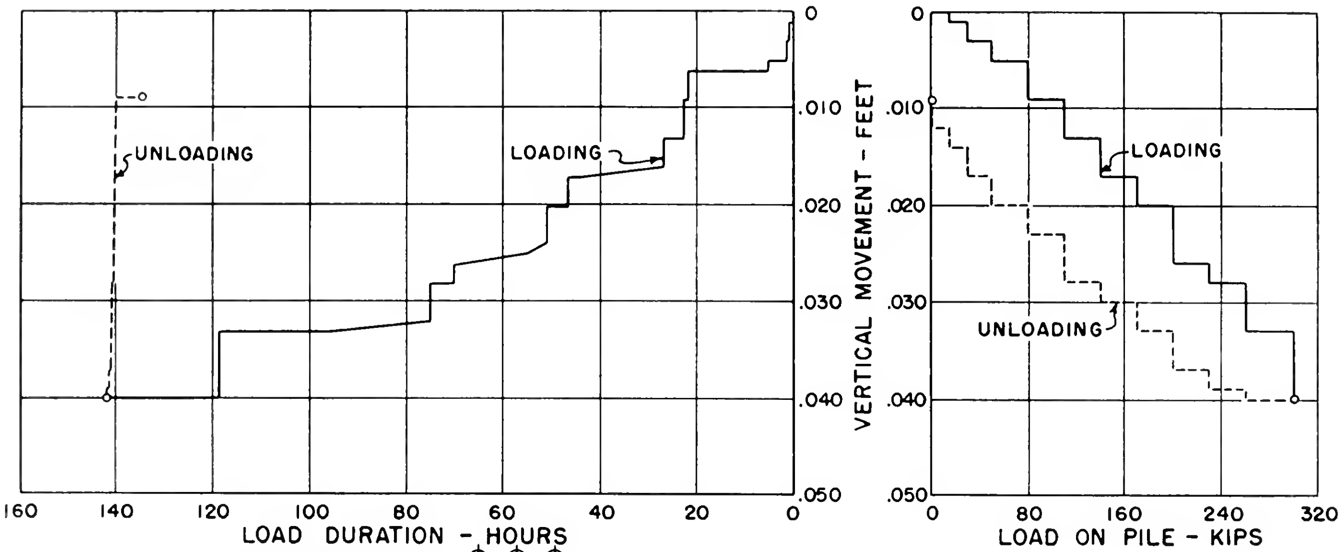
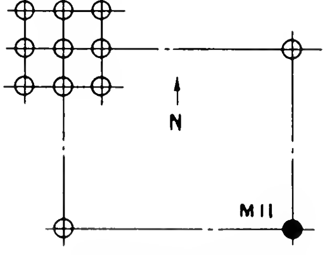


NOTE: PILE DRIVEN DEC. 18, 1948
PILE LOADING STARTED
FEB. 23, 1949
PILE LOADING COMPLETED
FEB. 28, 1949



LOCATION DIAGRAM

FIG. 29

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

STEEL PILE TEST DATA
PILE M11

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CHICAGO, ILLINOIS. JUNE, 1949

TABLE 11

SUMMARY OF STEEL PILE TEST DATA

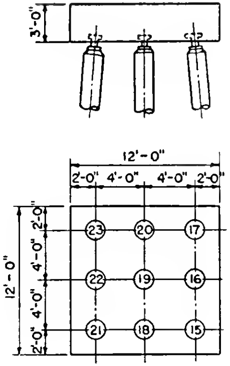
PILE NUMBER	SINGLE			GROUP									
	P1(3)	M10(3)	M11	M1	M2	M3	M4	M5	M6	M7	M8	M9	AVERAGE
BUTT END - INCHES	$12\frac{3}{4}$	$16\frac{1}{2}$	$15\frac{7}{8}$	$16\frac{1}{4}$	$16\frac{5}{8}$	$16\frac{1}{2}$	$16\frac{5}{8}$	$16\frac{1}{2}$	$16\frac{1}{2}$	$16\frac{5}{8}$	$16\frac{1}{2}$	$16\frac{1}{2}$	$16\frac{3}{8}$
TIP END - INCHES	$12\frac{3}{4}$	8	8	8	8	8	8	8	8	8	8	8	8
LENGTH OF PILE - FEET	65	65	110	65	65	65	65	65	65	65	65	65	65
WEIGHT OF PILE - KIPS	2.88	1.50	3.94	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
TOTAL PENETRATION - FEET	60.5	60.0	91.2	60.3	61.2	60.7	60.5	60.5	60.5	60.5	60.7	59.5	60.5
PENETRATION IN SAND - FEET	0	0	6.1	0	0	0	0	0	0	0	0	0	0
TOTAL DRIVING - BLOWS	331	255	2470	337	346	316	365	363	349	306	324	394	344
BLOWS - LAST FOOT	11	9	(1)	12	13	13	13	14	12	11	11	14	12.6
DRIVING TIME - MINUTES	10	14	351	8	$6\frac{1}{2}$	6	11	12	$7\frac{1}{2}$	$5\frac{1}{2}$	$6\frac{1}{2}$	18	9
PENETRATION CONTACT AREA - SQ.FT.	189.4	179.8	299.1	196.3	197.5	196.8	196.6	196.6	196.6	196.6	196.8	195.2	2180 (4)
MAXIMUM TEST LOAD - KIPS	140	210	300	133.1	133.1	133.1	133.1	133.1	133.1	133.1	133.1	133.1	1198 (4)
DURATION MAX. TEST LOAD HOURS & MINUTES	0-02	0-15	22-50	44-05	44-05	44-05	44-05	44-05	44-05	44-05	44-05	44-05	44-05
GROSS SETTLEMENT - FEET	0.889	0.778	0.040	0.054	0.055	0.056	0.055	0.057	0.060	0.059	0.061	0.062	0.0576
NET (PERMANENT) SETTLEMENT - FEET	0.876	0.762	0.009	0.029	0.029	0.029	0.030	0.030	0.031	0.031	0.032	0.032	0.0304
MAXIMUM AVERAGE SKIN FRIGTION - LB. PER SQ.FT.	740	1095	1000(2)	680	670	680	680	680	680	680	680	680	580 (4)
MAXIMUM MEASURED SKIN FRICTION - LB. PER SQ. FT.		1960	3050	980			810	1050					
PERCENT OF TOTAL LOAD CARRIED BY EACH PILE				10.9	9.2	11.9	10.6	9.4	11.5	12.4	11.2	12.9	11.1

(1) 100 BLOWS FOR LAST 0.5 INCH.
(2) COMBINATION OF SKIN FRICTION AND END BEARING.
(3) FAILURE OCCURED IN THESE TWO PILES.
(4) SKIN FRICTION BASED ON OUTSIDE PERIMETER OF GROUP.

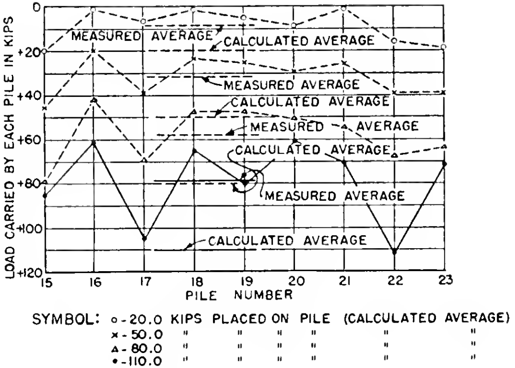
TABLE 12
SUMMARY OF TIMBER TEST PILE DATA
TWO - O'CLOCK BAYOU

PILE NUMBER	SINGLE			GROUP									
	T14	T24	T25	T15	T16	T17	T18	T19	T20	T21	T22	T23	AVERAGE
BUTT END - INCHES	$15\frac{1}{4}$	$16\frac{1}{2}$	16	16	16	16	$15\frac{1}{4}$	$15\frac{1}{2}$	15	$15\frac{5}{8}$	16	$16\frac{1}{2}$	$15\frac{3}{4}$
TIP END - INCHES	$6\frac{1}{4}$	6	$6\frac{1}{2}$	$7\frac{1}{2}$	$4\frac{3}{4}$	$6\frac{1}{2}$	$5\frac{1}{4}$	$6\frac{7}{8}$	$6\frac{1}{2}$	$5\frac{5}{8}$	$5\frac{1}{2}$	6	6
LENGTH OF PILE - FEET	65	65	65	65	65	65	65	65	65	65	65	65	65
WEIGHT OF PILE - KIPS	2.02	2.32	2.34	2.80	1.92	2.50	2.06	2.26	2.08	2.18	2.42	2.40	2.30
TOTAL PENETRATION - FEET	61.0	60.0	55.5	58.0	60.0	59.5	60.0	60.0	60.0	59.0	60.0	59.5	59.6
TOTAL DRIVING BLOWS	255	462	656	466	364	425	354	237	230	320	363	283	338
BLOWS - LAST FOOT	16	15	68	22	16	20	15	15	11	15	21	13	16.4
DRIVING TIME - MINUTES	5	9	12	9	7	8	6	4	5	8	7	7	6.8
PENETRATION CONTACT AREA - SQ.FT.	157.7	159.7	155.4	187.4	156.1	178.7	164.1	170.6	164.3	165.4	175.1	173.3	2150 (2)
MAXIMUM TEST LOAD - KIPS	130	150	150	110	110	110	110	110	110	110	110	110	990 (2)
DURATION MAX. TEST LOAD - HOURS & MINUTES	3-00	1-05	0-25	1-25	1-25	1-25	1-25	1-25	1-25	1-25	1-25	1-25	1-25
GROSS SETTLEMENT - FEET	0.575	0.658	0.903										(1)
NET (PERMANENT) SETTLEMENT - FEET	0.550	0.633	0.711										(1)
MAXIMUM AVERAGE SKIN FRICTION - LB. PER SQ. FT.	825	940	710	585	705	615	670	645	670	665	630	635	460 (2)
PERCENT OF TOTAL LOAD CARRIED BY EACH PILE				11.8	8.6	15.3	9.1	11.2	8.5	9.9	15.6	10.0	11.1

(1) COMPLETE FAILURE AND OVERTURNING OF PILE GROUP.
(2) SKIN FRICTION BASED ON OUTSIDE PERIMETER OF GROUP.



PLAN AND ELEVATION OF PILE GROUP



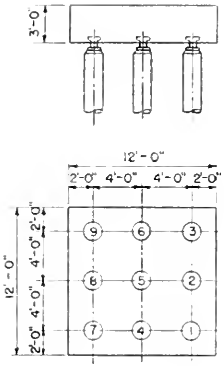
DISTRIBUTION OF LOAD TO INDIVIDUAL PILES OF GROUP

TABLE OF LOAD DISTRIBUTION TO INDIVIDUAL PILES

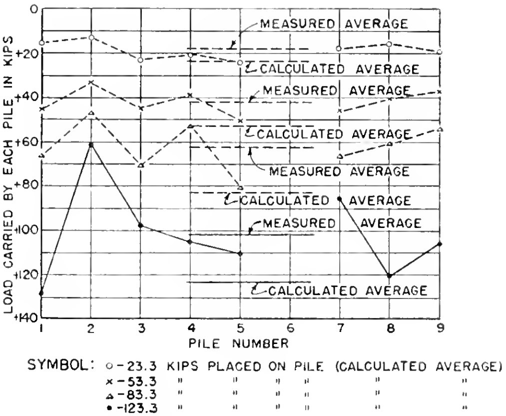
CALCULATED LOAD ON GROUP	CALCULATED AVERAGE LOAC PER PILE	MEASURED LOAD ON GROUP	MEASURED AVERAGE LOAD PER PILE	PILE NUMBERS																	
				15		16		17		18		19		20		21		22		23	
				LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD
180	20	78.3	8.7	20.0	25.5	1.8	2.3	6.8	8.7	1.3	1.7	4.2	5.3	8.3	10.6	1.7	2.2	15.5	19.8	18.7	23.9
450	50	283.1	31.5	44.8	15.8	19.9	7.0	38.5	13.6	22.6	8.0	24.6	8.7	28.7	10.1	25.7	9.1	389	13.8	394	13.9
720	80	519.9	57.8	79.4	15.3	41.8	8.1	69.7	13.4	47.0	9.0	47.0	9.0	50.5	9.7	54.1	10.4	678	130	62.6	12.1
990	110	715.4	79.5	84.7	11.8	61.4	8.6	109.2	15.3	647	9.1	804	11.2	61.0	8.5	705	9.9	111.9	15.6	71.6	10.0

FIG. 30

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY
STATIC PILE TEST DATA
TIMBER PILE GROUP
TWO O'CLOCK BAYOU
OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS. JUNE, 1949.



PLAN AND ELEVATION
OF PILE GROUP



DISTRIBUTION OF LOAD TO INDIVIDUAL PILES OF GROUP

TABLE OF LOAD DISTRIBUTION TO INDIVIDUAL PILES

CALCULATED LOAD ON GROUP	CALCULATED AVERAGE LOAD PER PILE	*MEASURED LOAD ON GROUP	MEASURED AVERAGE LOAD PER PILE	PILE NUMBERS																	
				1		2		3		4		5		6		7		8		9	
				LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD	LOAD IN KIPS	PERCENT OF TOTAL LOAD
210	23.3	167.4	18.6	15.7	9.4	12.9	7.7	23.0	13.7	21.0	12.5	23.9	14.3			17.7	10.6	16.1	9.6	18.5	11.0
480	53.3	377.9	42.0	45.1	11.9	33.0	8.7	45.5	12.0	38.5	10.2	50.5	13.4			45.6	12.1	40.6	10.7	37.1	9.8
750	83.3	560.0	62.2	64.8	11.6	47.2	8.4	70.8	12.6	53.1	9.5	80.2	14.3			66.8	11.9	60.5	10.8	54.4	9.7
1110	123.3	916.5	101.8	127.6	13.9	61.1	6.7	97.6	10.6	104.8	11.4	110.6	12.1			85.7	9.4	120.8	13.2	106.5	11.6

ALL PILE LOADS IN KIPS

*GAGES ON PILE 6 DID NOT RECORD PROPERLY SO MEASURED LOAD ON GROUP IS BASED UPON PILE 6 CARRYING THE AVERAGE LOAD IN THE OTHER EIGHT PILES.

FIG. 31

NEW ORLEANS, TEXAS & MEXICO RAILWAY
WEST ATCHAFALAYA FLOODWAY

STATIC PILE TEST DATA
TIMBER PILE GROUP
HALF MOON BAYOU

OFFICE OF RESEARCH ENGINEER
ASSOCIATION OF AMERICAN RAILROADS
CHICAGO, ILLINOIS JUNE, 1949

2 Oclock

HOLE NO 2
Sta 2060+88; Right of test pile group
Boring made – 20 October 1948
5" Dia Undisturbed Boring

NOTE
All triaxial and direct shear tests are quick undrained.
Samples were taken with 5" dia thin wall piston type sampler

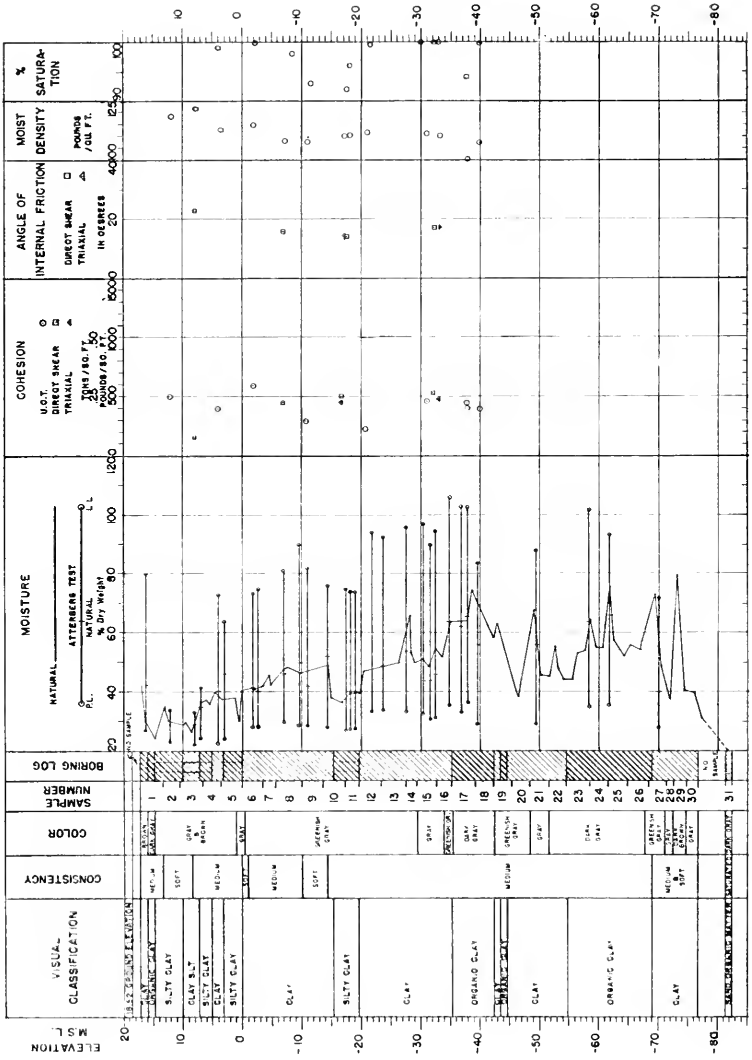


Fig. 32. Soil borings at pile test sites--Hole No. 2.

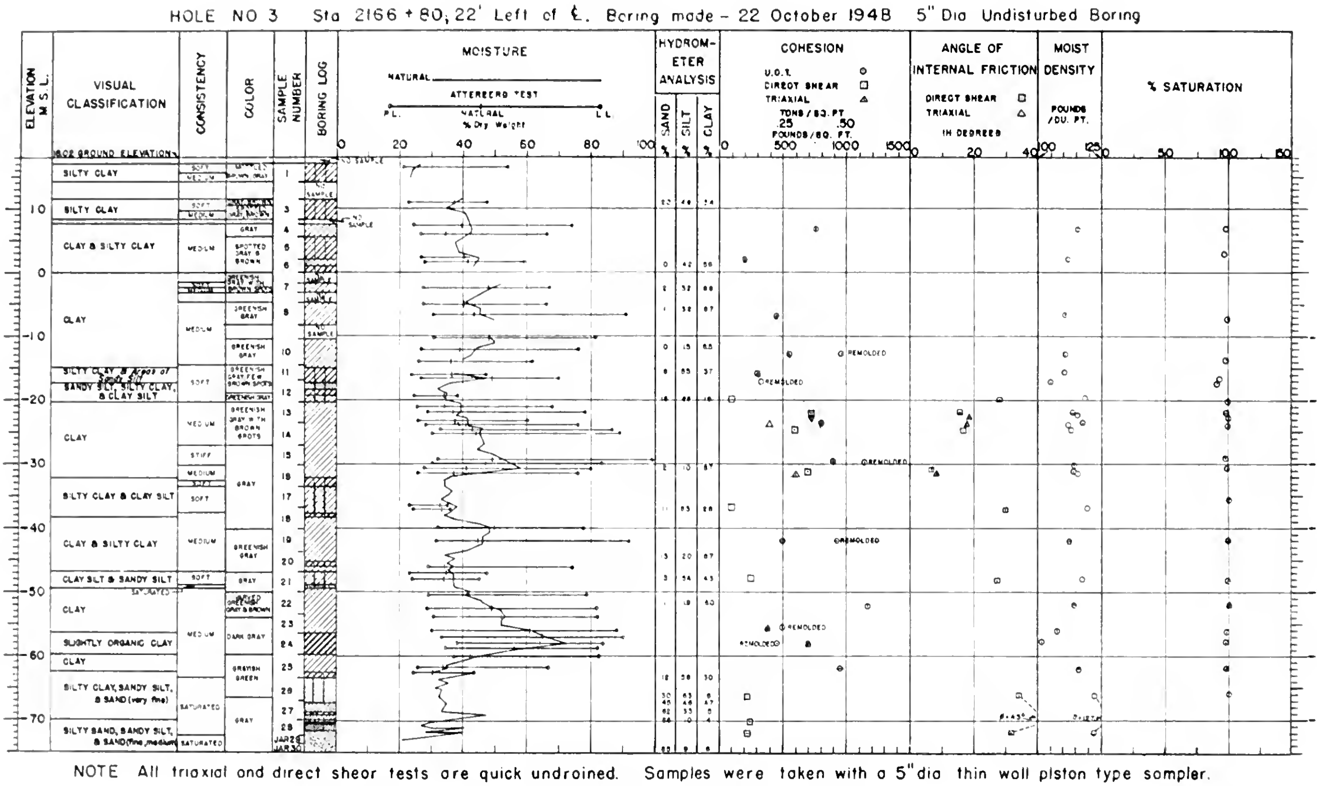
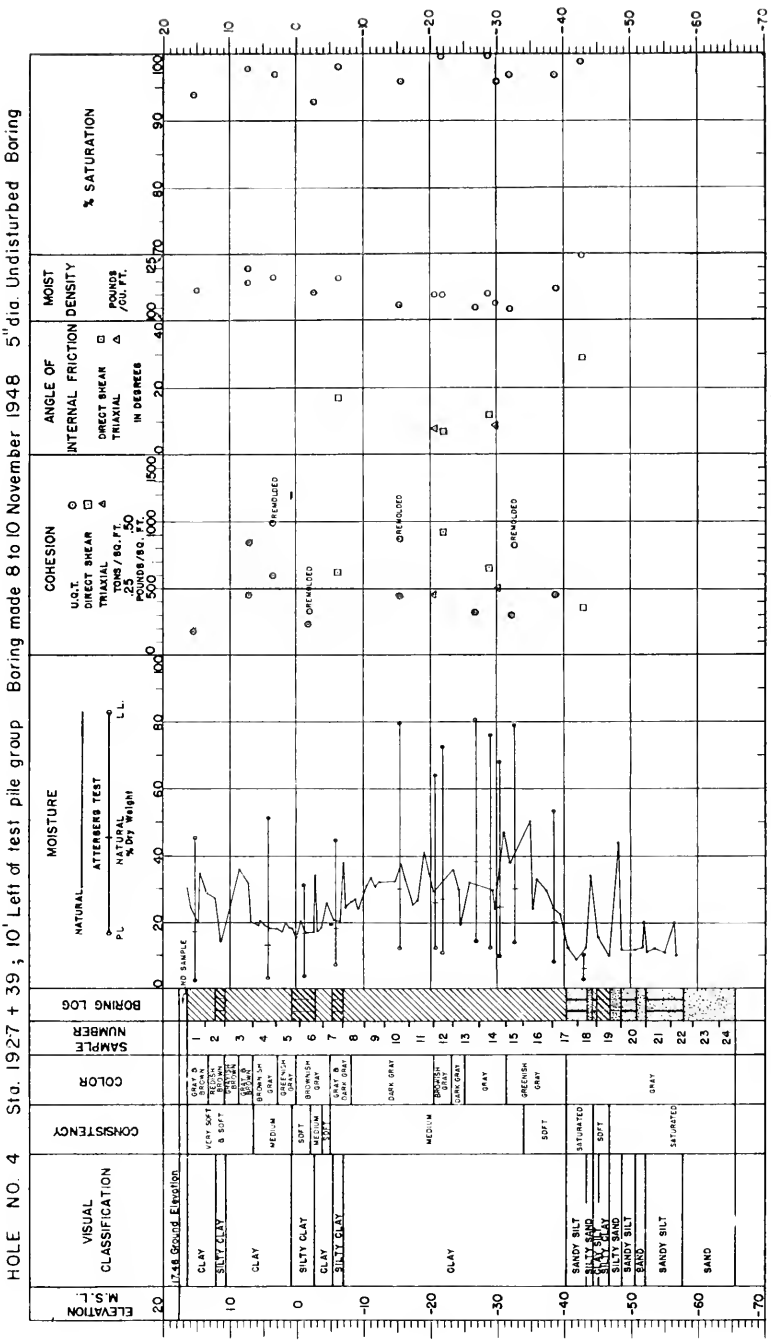


Fig. 33. Soil borings at pile test sites—Hole No. 3.



NOTE: All triaxial and direct shear tests are quick undrained. Samples were taken with a 5"dia. thin wall piston type sampler.

Fig. 34. Soil borings at pile test sites—Hole No. 4.

Errata: Moisture scale should read 20, 40, 60 instead of 0, 20, 40.

1/2 Moon

TABLE 13
SUMMARY OF TIMBER TEST PILE DATA
HALF-MOON BAYOU

PILE NUMBER	SINGLE				GROUP									
	T10	T11	T12	T13	T1	T2	T3	T4	T5	T6	T7	T8	T9	AVERAGE
BUTT END - INCHES	$16\frac{1}{2}$	17	$18\frac{1}{4}$	$16\frac{1}{4}$	$16\frac{1}{2}$	16	$16\frac{3}{4}$	15	$17\frac{1}{4}$	$19\frac{1}{4}$	$16\frac{1}{2}$	$16\frac{1}{2}$	$16\frac{1}{2}$	$16\frac{3}{4}$
TIP END - INCHES	$6\frac{1}{2}$	$5\frac{3}{4}$	7	$6\frac{1}{4}$	$6\frac{1}{2}$	5	$6\frac{1}{4}$	$5\frac{1}{2}$	$6\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$	6	$5\frac{1}{2}$	$6\frac{1}{4}$
LENGTH OF PILE - FEET	65	65	65	65	65	65	65	65	65	65	65	65	65	65
WEIGHT OF PILE - KIPS	2.78	2.16	3.14	2.36	2.50	2.38	2.58	2.08	2.72	3.54	2.84	2.38	2.42	2.60
TOTAL PENETRATION-FEET	58.0	58.0	60.0	60.5	61.0	59.0	60.5	60.0	60.0	61.0	60.0	60.5	60.0	60.2
TOTAL DRIVING BLOWS	515	348	374	387	3116	2597	1453	444	438	583	593	388	366	1109
BLOWS - LAST FOOT	24	15	13	17	157	39	55	17	22	24	22	19	21	41.8
DRIVING TIME - MINUTES	10	8	8	8	52	129	27	22	10	10	12	8	10	33
PENETRATION CONTACT AREA - SQ. FT.	175.9	151.8	188.6	166.0	180.5	172.8	184.3	164.4	187.0	215.6	193.7	176.2	174.4	2170 (2)
MAXIMUM TEST LOAD - KIPS	150	110	170	90	130	130	130	130	130	130	130	130	130	1170 (2)
DURATION MAX. TEST LOAD HOURS & MINUTES	0-27	9-30	0-18	24-19	9-45	9-45	9-45	9-45	9-45	9-45	9-45	9-45	9-45	9-45
GROSS SETTLEMENT - FEET	0.661	0.635	0.804	1.379										(1)
NET (PERMANENT) SETTLEMENT - FEET	0.646	0.624	0.791	1.351										(1)
MAXIMUM AVERAGE SKIN FRICTION - LB. PER SQ. FT.	740	725	900	540	720	750	705	790	695	605	670	740	745	540 (2)
PERCENT OF TOTAL LOAD CARRIED BY EACH PILE					13.9	6.7	10.6	11.4	12.1		9.4	13.2	11.6	11.1

(1) COMPLETE FAILURE AND OVERTURNING OF PILE GROUP.
(2) SKIN FRICTION BASED ON OUTSIDE PERIMETER OF GROUP.

(text continued from page 188)

The derived pile reactions for the two timber pile groups are shown in tabular form in Figs. 30 and 31. The load carried by each pile, as shown in these tables, is also shown by the diagrams on the same figures.

It should be pointed out that there is considerable variation between the calculated load on the timber pile group and the load as determined by strain gage readings. For example, the total calculated load on the pile group at Two O'Clock Bayou was 990,000 lb., as shown by the table in Fig. 30, while the measured load as determined by strain gage readings was 715,400 lb. The loading caps used on these piles, consisting of the 8-in. diameter pipe between the two 1½-in. bearing plates, were never calibrated in a testing machine, so it is quite possible that the actual loading factors were different from those used.

It is interesting to note from the tables in Figs. 30 and 31 that the center pile, contrary to some theories, was carrying about the same load as the average on the group. For example, the center pile 19 of the group at Two O'Clock Bayou, Fig. 30, was carrying 80,400 lb., while the average load on all the piles was 79,500 lb. It should be noted that pile 16 carried the smallest load of 61,400 lb., or 22.8 percent below the average load, while pile 22 carried the greatest load of 111,900 lb., or 40.7 percent above the average.

A brief summary of all the pertinent data pertaining to the tests on all the timber piles is shown in Tables 12 and 13. It is interesting to note that the two single piles at Two O'Clock Bayou carried 150,000 lb. before failure, while the 9-pile group failed at 110,000 lb. However, the 9-pile group at Half Moon Bayou required an average load per pile of 130,000 lb. to produce failure.

There was considerable variation in the load carrying capacity of the individual timber piles at Half Moon Bayou (see Table 13), the load varying from 90,000 lb. for pile T13 to 170,000 lb. for pile T12, with an average of 130,000 lb. Pile T13, which failed at 90,000 lb., required 17 blows of the pile driver for the last foot of penetration, while pile T12, which failed at 170,000 lb., required only 13 blows for the last foot of penetration.

C. Soil Tests

A study of the soil test data, as presented on Figs. 32, 33 and 34, indicates that the following comments should be considered in a detailed study of the complete report:

1. The soils are typical of the sedimentary deposits of the locality and consist principally of clays and silty clays of high plasticity and on the basis of the unconfined compressive strength, would be generally classed as medium and soft clays. A number of strata appear to contain organic material. By the Casagrande classification, practically all the soils are "CH" clays of high plasticity. The natural soil moistures and liquid limits indicate a slight general increase with depth. The plastic limit values for the soils from test holes 2 and 3, Figs. 32 and 33, are fairly constant throughout the depth tested, ranging generally from 22 to 30 percent.

2. In general, most of the soils approach 100 percent saturation below 10 ft. from the surface so the increase in natural moisture content with increase in depth appears to be the result of decreased in-place density or higher clay content or both. The moist density determinations shown indicate a decrease relative to depth. The strength data, as determined by unconfined compressive tests and the direct and tri-axial shear tests, however, do not conform to the trend indicated by the moisture and limit tests. There

is no general or definite trend toward a decrease in strength with a decrease in density, increase in natural moisture or increase in liquid limit.

3. The unconfined compressive strengths of the soils obtained from test holes 2 and 4, Figs. 32 and 34, are generally smaller than those secured by the direct and tri-axial shear tests with the minimum values obtained by the direct shear tests on the specimens from test hole 3. For all the results, where a direct comparison is possible, the direct and tri-axial shear values are in good agreement.

4. The remolded samples from test holes 3 and 4 generally indicated greater test strengths in unconfined compression than those not molded which is contrary to the common or expected result. However, these results are consistent with other sensitivity data from other projects within the Atchafalaya Basin, and are believed to be due to the fact that the undisturbed fat clay soils are brittle and slickensided. It should be noted, that in some cases the skin friction between the pile and the soil was considerably greater than the laboratory test values for cohesion.

5. The skin friction between the pile and the soil obtained during the driving of pile M 11, see Fig. 7, is in general agreement with the trend of values obtained from the unconfined compression tests on the soil samples removed from test hole 3. However, this correlation is not apparent for pile M 4, Fig. 5, where the skin friction is much greater than that obtained by the unconfined compression tests on samples removed at depths varying from 10 ft. to 20 ft. below the surface. Values for direct and tri-axial shear strengths show no correlation with the skin friction obtained during the driving of either pile.

6. There is a general trend towards agreement between the skin friction developed by the group piles M 1, M 4 and M 5, Figs. 17, 19 and 21 during the static loading tests and the strength data obtained on the soil samples removed from test hole 3 although the actual skin friction is considerably larger than the cohesion obtained by the laboratory tests. There is no apparent correlation between the skin friction developed during the static loading of the single piles M 10 and M 11, Figs. 23 and 25, and the actual skin friction is several times greater than the laboratory values even though pile M 11 was not loaded to failure. It is quite possible that for remote single piles, considerable earth pressure can be developed normal to the pile thus producing high skin friction. However, for the piles in a group, the driving of the other piles undoubtedly produces additional disturbance as indicated by the limited data. In general, it appears that the high skin friction developed by these piles is possible without exceeding the passive resistance of the adjacent soil.

7. The average skin friction or shearing strength developed by the soil around the perimeter of the timber pile group at Two O'Clock Bayou was calculated at 460 psf., see Table 12 when the group was loaded to failure. The laboratory test data on the specimens removed from test hole 2, adjacent to this group indicates strength value consistent with this average value. The corresponding average shearing strength of 540 psf. developed by the pile group at Half Moon Bayou, see Table 13, is consistent with the laboratory test strength on the specimens removed from test hole 4 adjacent to the group.

7. Conclusions

These tests afforded an opportunity to measure and compare the simultaneous stresses at five-foot intervals of pile length resulting from the impact of the pile driving hammer as well as those under static loads. The tests also afforded an opportunity to compare the stresses at five-foot intervals of the pile on single piles and of certain individual piles of a group. It is felt that the results of these tests provide information not heretofore available.

Many interesting and valuable data were obtained, but it must be remembered that these tests were conducted with only one particular type of soil condition for a limited loading time, and it is quite likely that other soils would act entirely different.

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

1. The measured driving stresses in the top of the steel piles increased with an increase in pile penetration, and attained a maximum value equal to 20 to 34 times the static weight of the hammer ram with a 3-ft. stroke.

2. Only about 7 percent of the driving stress measured in the top of the single friction steel pile was observed at the point of the pile.

3. Only about a third of the total driving stress measured in the top of the 110-ft. steel pile driven through 90 ft. of clay, silt, and silty clay into sand was observed at the pile point.

4. The tapered steel piles driven into clays having a high moisture content acted as friction piles, the center of bearing resistance being at a point about half of the length of their penetration into the ground.

5. The 110-ft. fluted steel pile driven into a layer of sand to refusal, after penetrating very deep clay having a high moisture content, continued to act principally as a friction pile under the imposed short-time loading, with only about 16 percent of the total load being carried by end bearing.

6. The greatest part of the load on the single steel piles, both friction and end-bearing types, was carried by friction between the pile and the clay relatively close to the ground line. Exceedingly high shear values existed for a very short length of pile.

7. The load on the individual steel piles of the group was carried by friction, but was transferred to the soil at a greater depth than in the case of the single pile. In addition, the load was distributed over a greater length of the pile at lower maximum shear values.

8. The single tapered steel pile carried more load than the single straight pile.

9. The distribution of the load to the various steel piles of the group was fairly uniform, especially for usual design loads, with the center pile carrying its share of the load.

10. The number of blows required to drive the single timber friction piles the last foot was a very poor criterion to determine their load-carrying capacities.

11. The distribution of the usual design load to the various timber piles of a group was fairly uniform, with the center pile carrying its share of the load.

12. The outside battered timber piles of a group carried their proportion of the load.

13. The actual skin friction developed between the pile surface and the soil is greater than the cohesive strength indicated gy laboratory tests on soil specimens.

14. There is closer correlation between the as run laboratory test strengths and the skin friction developed by the piles in a group than that developed by remote single piles.

8. Acknowledgments

The Committee on Masonry and the American Railway Engineering Association are deeply indebted to Col. Chas. G. Holle, district engineer, Corp of Engineers, U. S. Army, New Orleans, La., and to Brig. General Peter A. Feringa, president, Mississippi River Commission, Vicksburg, Miss., for making the data covering these tests available for publication.

Report of Committee 16—Economics of Railway Location and Operation

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Committee

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* Died May 9, 1950

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions .... page 205

2. Methods for increasing the use of existing railway facilities, collaborating with Signal Section, AAR.

   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.

   Progress report submitted as information .... page 206

5. Comparison of running time with total time between points of receipt and delivery of freight cars, and methods of reducing total time, collaborating with Car Service Division, AAR, and American Association of Railroad Superintendents.

   No report.

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

AREA Bulletin 490, November 1950.

Bernard J. Schwendt

Ben Schwendt, assistant signal engineer of the Big Four District, New York Central System, with headquarters at Cincinnati, Ohio, died on May 9. 1950, at his home in Fort Thomas, Ky. He was born July 25, 1884, at Green Springs, Ohio, and received his engineering education at Ohio State University, being awarded the degree of M.E. in 1907 and E.E. in 1936.

Prior to attending the university, he entered railroad service on the Great Northern in 1902 and served until 1903 in various capacities. During the summer months while in college, he was employed by the Bullock Electric Company (now Allis–Chalmers Company) of Cincinnati.

Upon graduation he joined the Union Switch & Signal Company, and was employed from 1907 to 1909 in the installation of interlockings and automatic block signals on the Pennsylvania Lines West, Baltimore & Ohio, and the Erie. In 1909 he became supervisor of signals for the Hocking Valley (now part of the C. & O.), Toledo & Ohio Central, Kanawha & Michigan, Kanawha & West Virginia, Zanesville & Western, and Gauley & Eastern (now all N.Y.C.). In 1912 he was appointed signal engineer and electrical engineer of the Ohio Central Lines (part of the N.Y.C.).

From 1915 to 1925, Mr. Schwendt served as superintendent telegraph and signals and electrical engineer with the same lines. From 1925 to 1937, he was assistant signal engineer of the New York Central Lines West, Ohio Central Lines, Indiana Harbor Belt, Chicago Junction and Chicago River and Indiana. In 1937 he was promoted to assistant signal engineer Big Four District, New York Central System, at Cincinnati.

Mr. Schwendt was a member of the Telegraph and Telephone Section, AAR, the Association of Railroad Superintendents, Cleveland Engineering Society, and Cincinnati Traffic Club. He was a member of the Signal Section, AAR, being chairman in 1937. He was the senior member of Committee I, Economics of Railway Signaling, having been appointed in 1922, and chairman from 1932 to 1935.

Mr. Schwendt joined the American Railway Engineering Association in 1925, and since 1927 had been one of the most valued and active members of Committee 16—Economics of Railway Location and Operation.

He was a student of all phases of railway signaling, engineering, and operation, and one of the early believers in signal indication operation without train orders on single track lines. He was sponsor for, and he actively progressed the first installation of centralized traffic control on the Ohio Central Lines, between Berwick and Stanley, Ohio, 44 track miles, in 1927. He contributed many articles to the technical press from 1918 to 1939.

A gentleman, always; honest with everyone including himself; never selfish; affable and considerate; he was distinguished for his bright and cheerful disposition, and unfailing good humor and sociability.

In the death of Mr. Schwendt, the American Railway Engineering Association, other societies of which he was a member, and a host of friends, have suffered a great loss.

Report on Assignment 1

Revision of Manual

E. G. Allen (chairman, subcommittee), H. A. Aalberg, B. T. Anderson, Herbert Ashton, J. W. Barriger, F. C. Berghaus, C. H. Blackman, I. C. Brewer, H. B. Christianson, Jr., P. J. Claffey, Miss Olive W. Dennis, J. T. Fitzgerald, J. M. Fox, H. C. Hutson, W. B. Irwin, W. M. Jaekle, D. B. Jenks, E. E. Kimball, H. A. Lind, J. M. MacBride, F. H. McGuigan, Jr., R. L. Milner, F. N. Nye, F. B. Peter, W. E. Quinn, J. P. Ray, W. T. Rice, C. P. Richmond, A. L. Sams, J. A. Schoch, K. W. Schoeneberg, H. M. Shepard, L. K. Sillcox, R. F. Spars, A. E. Street, J. F. Swenson, J. E. Teal, D. K. van Ingen, H. D. Walker, F. G. Walter, H. P. Weidman, H. L. Woldridge, J. A. Wood, W. H. Wood, J. S. Worley.

Your committee makes the following recommendations for revision of the Manual:

Page 16–6

Under (4) Train Resistance, delete entire text under (a′) and insert the following:

(4) TRAIN RESISTANCE

(aa) Train resistance may be determined by dynamometer car tests which also provide graphical records of a wide variety of other data pertaining to the general problem, among which should be shown:

(1) Record of draw bar pull.
(2) Distance.
(3) Time.
(4) Speed.
(5) Mile post locations.
(6) Curves right or left.
(7) Other events coded.
(8) Fuel consumption, with train heat boiler fuel separate if used.
(9) Position of reverse lever or of series or parallel motor connections.
(10) Boiler pressure or volts and amperes of each main generator.
(11) Throttle position.
(12) Condition of track surface and gage.

Delete subparagraph letters (b′), (c′) and (d′), and insert therefor (bb), (cc) and (dd).

Delete text following (9″) under Track, and insert:

(13) Office profile and alinement showing mile posts.

Delete subsection numbers (10″) to (21″) incl., and substitute therefor (14) to (25) incl.

Page 16–7

Delete the fifteenth and sixteenth lines and substitute therefor:

On the basis of the above resistance formulas the tonnage rating of any locomotive can be calculated by equating the drawbar pull of the locomotive to the total resistance of the train on the ruling grade (compensated for curvature). In order that the tonnage rating will be independent of the number of cars in the train, an adjustment, commonly called "car factor," must be added to the actual weight of each car. This adjustment and the percentage of adjusted *A* rating to be used for *B*, *C* and *D* temperature ranges are shown in the following table:

Delete first and second column headings of table, "Percent Grade," and "Adjustment," and insert:

Ruling Grade Percent and Adjustment Tons per Car.

Delete the eight lines in the table beginning with 0.15, 0.25, 0.35, 0.45, 0.55, 0.65, 0.75 and 0.85 so that the remainder of table will be based on increments of 0.1 percent change in grade.

Page 16–8

Delete subparagraph letters (e′), (f′), (g′), (h′) and (i′), and subsection numbers (1″), (2″), (3″) and (4″) and insert:

(ee), (ff), (gg), (hh), (ii), (1), (2), (3) and (4).

Delete the word "roadway" opposite subparagraph letter (f′), and in the second line of subparagraph (i′), and insert the word "track."

Delete subsection number (1′) in subparagraph (g), and substitute therefor (1).

In the fifth and sixth lines from the bottom of the page,

Delete the words "The last may be by far the most important single item, constituting in certain cases approximately ½ of total delays."

Page 16–9

Delete subsection numbers (2′), (3′) and (4′), and insert therefor (2), (3) and (4).

Page 16–45, lines numbered 1 and 2 under Development of Present Costs.

Delete entire wording and insert:

1. Gross ton-miles of freight traffic, including or excluding locomotives, in each direction.

2. Gross ton-miles of passenger traffic, including or excluding locomotives, in each direction.

Page 16–47, in last three lines at bottom of page.

Delete the final sentence beginning with the word "Similarly"

Insert: Where fuels other than coal are used, apply the fuel conversion factors used by individual railroads. Similarly, fuel saved in curve reduction can be estimated by converting curve resistance to equivalent grade resistance on the basis of a 0.04 percent grade as the equivalent to one degree of curvature.

Report on Assignment 4

Effect of Higher Speed on Railway Revenues, Operating Expenses and Charges to Capital Account

J. A. Schoch (chairman, subcommittee), H. A. Aalberg, B. T. Anderson, J. W. Barriger, I. C. Brewer, D. E. Brunn, J. T. Fitzgerald, D. B. Jenks, E. E. Kimball, H. A. Lind, J. M. MacBride, F. N. Nye, W. E. Quinn, J. P. Ray, C. P. Richmond, M. D. Robb. A. L. Sams, L. K. Sillcox, R. F. Spars, D. K. van Ingen, W. H. Wood.

This is a progress report, submitted as information.

Part 2—Merchandise Freight Service

There can be no question that railroad transportation is the most economical means for the mass transportation of goods. This is fundamental, because long trains of cars with flanged wheels rolling on steel rails of a right-of-way having limited grades, result in the lowest cost per ton mile for fuel, labor and repairs. Generally, other transportation agencies can give competitive or lower rates only because part of their costs of operation are absorbed by subsidies. Comparable taxation, regulation, and political treatment are needed to correct these artificial inequalities.

The time in transit is becoming equally as important as the cost of transportation. This may be dictated by deterioration or spoilage, as in the case of fresh produce; lower servicing costs for live stock; reduction in time to convert commodities into cash; reduced inventories; and similar factors which contribute to lower costs in carrying on general commerce. The railroads can expect to hold traffic only when their service is equal to that offered by competing agencies.

As compared to the railroads, an appreciable saving in time of transit is now being offered by airplanes and, in many cases, by trucks. The inherently higher cruising speed of airplanes makes it impossible to match their performance. This is not true of trucks; however, due to their unit loads, which eliminate the necessity for stops and transfers, they provide an expedited service from shipper's platform to consignee's door. The popularity and demand for this fast, dependable and convenient service is evidenced by the continuing sharp increase in the percentage of the nation's total inter-city ton mileage which is being handled by the motor carriers. For 1949, the gross business of inter-city for-hire carriers was 11 percent below the 1948 level, while railroad freight traffic declined 17 percent.

Considerable inroads have been made on heavy tonnage commodities, but this competition is especially severe in the field of l.c.l. and carload merchandise. This study is, therefore, limited to symbol trains which handle this type of traffic.

High Schedule Speeds

The overall average speed of freight trains on Class I railroads is about 16 mph. While this average includes all types of trains, it may be safely assumed that practically none operate at a maximum speed under 30 mph., and many operate at speeds of 50 mph. or more. It is obvious then, that maximum train speed has less bearing on overall average speed, than loss in time for intermediate stops and delays in yards and terminals. Reduction in this loss of time must be brought about if truck delivery time is to be met.

From the practical standpoint, this merchandise service need not be superior to "head-end" passenger service. Shipments by the latter means are assessed higher rates, and this differential in speed between terminals is thus recognized. Practically all streamliners and limited passenger trains maintain schedule speeds of 50 mph. or higher. The objective for merchandising service should then be an overall schedule speed of the order of 35 mph. Obviously, some services will require a higher schedule speed, and, in some cases, it may even be lower. However, this should be the objective for the average service. This speed would also match competitive performance by truck for hauls of 300 miles or more.

For a balancing speed of 45 mph. on straight and level track, a locomotive capacity of 1160 hp. is required per thousand tons of trailing load. This locomotive capacity becomes 3750 hp. for a maximum speed of 80 mph. Over the normal profile, due to grades and speed restrictions, the average speed maintained over the line without stops will be about 35 mph. with 45 mph. top speed. Under similar conditions, and 80 mph. top speed, the average will be about 55 mph. Thus with an increase of 225 percent in locomotive capacity the average speed has been increased only 57 percent. In the interest of lowest capitalization and operating expenses, it is desirable to keep the maximum speed as low as consistent with matching competitive delivery by truck.

It is generally recognized that time lost due to intermediate stops, and time spent in terminals and yards and delays enroute, produce a greater effect on the schedule speed between terminals than maximum train speed. Of these, terminal and yard delays are the major obstructions, and efficient operation is imperative to reduce them to a minimum. These delays are brought about by industrial switching movements at origin and destination, makeup and breakup of trains at terminals, and classification at intermediate yards. Expedited switching movements, mechanized freight stations, and elimination of car handling in local freight stations and yards contribute toward faster deliveries. Other problems are involved. These problems not only can be solved but are being solved.

As pointed out previously, an average speed of 35 mph. can be maintained with a maximum speed of 45 mph. without intermediate stops. If one stop of 40 min. duration is made every 100 miles, then the schedule speed is 27.7 mph. With two stops in this same distance, the schedule speed falls to 23 mph. With 80 mph. maximum speed, the respective schedule speeds drop from 55 mph. to 38.6 and 27.2 mph. With one stop per one hundred miles, the 78 percent higher maximum speed results in only 40 percent higher average speed, and if the number of stops is doubled, the gain in average speed is only 18 percent. These figures emphasize the necessity of minimizing stop time.

It is realized that the number of stops will be influenced by the area served. In the industrial East, more than one stop per one hundred miles may be necessary. In the South and West they may be even less frequent. In any case, intermediate stops must be limited to the principal cities, and the rail service supplemented by truck for pickup and distribution to the smaller communities.

The desired objective of 35 mph. schedule speed can be attained with a maximum speed of 65 mph., and making one intermediate stop of 40 min. duration every 100 miles. Essentially, the same overall results can be obtained by making one stop of 30 min. duration every 75 miles, or a stop of 20 min. duration every 50 miles. It is evident that the maximum speed need not exceed 60 mph. If the stop time can be further reduced. then schedule speeds in excess of 35 mph. can be maintained, or the 35 mph. schedule can be maintained with a lower maximum speed. For a top speed of 65 mph., locomotive capacity of 2450 hp. is required per thousand tons of trailing load. This compares to 1160 hp. for 45 mph. and 3750 hp. for 80 mph. maximum speeds.

Prerequisites of Speedy Reliable Service

The diversion of merchandise traffic from the railroads to the highways has been progressively increasing as new and improved trucks and highways have been built, and has now reached a new high. One of the major reasons for this diversion is that the American economy requires rapid movement of goods to carry on trade at minimum expense. Unless the railroads can provide a fast, reliable service, they will be replaced for the same reason that they replaced their slower predecessors.

This subject assignment refers only to higher train speeds, but fast, reliable merchandise service depends on many factors other than high speed trains. Insofar as the high speed trains themselves are concerned, suitable motive power and rolling stock are now available. Modern diesel motive power with electric drive has ideal characteristics in high tractive effort for smooth starts and rapid accelerations, high availability for maximum utilization and good tracking qualites for speeds in excess of the top speed requirement of 65 mph. Experience has dictated that an improved design of cars is necessary for safe and efficient shipment of goods at higher speeds. Good riding trucks, adequate draft gear and brakes, and specially-equipped bodies are justified to protect lading and to provide more economic handling. Car designs of varying degree of advanced construction are available.

The track and track layout must be suitable for the train speeds considered. Furthermore, obstacles imposing speed restrictions should be reduced to a minimum.

The schedules of merchandise freight trains must be as rigid as passenger train schedules. Trains must be dispatched on schedule regardless of the tonnage available for movement, and printed schedules should be made available to the shipping public.

Another important function is to provide prompt tracing of shipments, give information on arrival time, and report on shipments enroute.

Extensive mechanization of freight stations will speed shipments through terminals and save loss and damage. Attention must be given to obtaining maximum movement of through tonnage from origin to destination. Obviously, direct shipments cannot be made from origin to all destinations, thereby eliminating yard movements for classification and transfer, but modernization and improvements, together with technological aids, can achieve speed and flexibility in movements through these yards.

To give shippers a complete modern expedited service, presupposes a coordinated rail-truck operation. Pickup and delivery service must be provided. To relieve long heavy trains of local stops and burdensome switching, rail-coordinated trucks should be substituted for distribution to the small villages and towns. The assistance of shippers and the public can be enlisted to support legislation to remove all obstacles against coordinated highway and rail service that can be shown to be in the public interest.

Another important consideration is the establishment of competitive l.c.l. rates for the complete door-to-door service. These rates should possibly provide incentives for larger shipments, that is, quantity rates, where economies in handling can be achieved.

The preceding discussion outlines the plant required to provide service to meet fully the shippers needs. To maintain this service with complete efficiency and dependability, the plant must be staffed by an organization well trained and carefully instructed. Supervision must be of a high order, and must keep the personnel constantly alerted in all operations from origin to destination.

Loss and Damage

Further improvement in the safe handling of freight must be effected. In 1948, loss and damage claims totalled about $135,000,000. In 1949, the total exceeded $110,000,000. About one-third of these claims are in connection with merchandise shipments, although this traffic represents only a small percentage of the total tonnage. This emphasizes the need for suitable equipment and adequate training of personnel.

Whether a shipment involves only one railroad or several, the overall performance is no better than that of the worst constituent. Too frequently, the majority of these damage claims are brought about by improper handling in one small yard or terminal, or on a single short line connecting railroad. It is obvious, therefore, that thorough training and instructing of all personnel is imperative, and constant vigilance must be pursued in all operations. Substantial reduction in this loss is the joint responsibility of the shippers and the carriers. Single or occasional corrective actions are insufficient. Constant policing is necessary.

Charges to Capital Account

As train speeds are raised, the locomotive capacity required to haul a given tonnage increases as the square of the speed. The relation between locomotive capacity and maximum train speed is tabulated below:

Max. Train Speed mph.	*Locomotive Capacity Percent*
45	100
55	151
65	211
75	280

Since diesel electric motive power has approximately a fixed price per unit of capacity, the tabulation is representative of the increase in first cost. The need for cars of advanced design for safe and efficient shipment of goods has been previously pointed out. This need is becoming more generally recognized, but there is little agreement as to the standard of design for their construction. The cost of such cars may vary from a moderate addition to as much as 65 percent more than a standard car. The most elaborate cars are equipped to hold packages and pieces in place, and also for double decking. Theoretically, loads can be increased so that fewer cars will be required. Unfortunately, stowing and unloading costs per ton may also increase when cars are equipped with interior loading devices.

By reason of higher schedule train speeds, both locomotives and cars are capable of reduced time per round trip and are thus available for more trips in a given period. This, together with fast turn-around time, permits high utilizaiton of equipment. Better utilization means that fewer cars and locomotives are required.

Many factors influence the cost of preparing the track for higher train speed. These factors have been discussed in detail in AREA Proceedings, Vol. 48, 1947, Part 1, pages 145–167, dealing with passenger service. The freight movement considered is largely among the principal cities which are also served by passenger trains. If the track is suitable for the higher speed passenger trains, then merchandise trains can be operated at the speed herein considered without additional capital expenditures.

The capital expenditures previously outlined are the result of moving commodities over the road at a higher speed, and do not include consideration of the expenditures for terminal facilities, or those incident to collection and delivery service where such service is provided by the railroad. Such expenditures are independent of train speed, and represent investment for speeding up the handling of goods at terminals and providing complete service to the shippers. The investment necessary to make such improvements will vary widely, and will depend largely on local conditions and the competitive situation. While these costs may be of considerable magnitude, they frequently bring about savings which provide an attractive return on investment.

Freight handling at transfer points not only entails delay but represents an appreciable item of labor costs. Where volume is great, mechanization is justified because of the more efficient method of handling. Time is saved in loading and unloading, with a corresponding saving in man-power. Furthermore, unnecessary handling of merchandise is eliminated and receiving and shipping are expedited. In many cases the capacity of freight stations may be materially increased without making extensive alterations or additions. Capital expenditures for mechanized handling may vary from a few thousand to several hundred thousand dollars.

Expenditures for modernization and improvement of yards will also vary widely. Such changes may include one or more of the following items; 1) addition to or rearrangement of tracks; 2) installation of car retarders; 3) improved lighting; and 4) improved communications. The cost of these changes may vary from several hundreds of thousands to several millions of dollars.

Coordinated rail-highway freight service is now being rendered by a number of railroads. Such coordination may be attributed to the necessity for the railroads to maintain a complete carrier service. These services are generally carried on by one or more of four arrangements:

1) Wholly-owned subsidiary of the railroads.
2) Railway Express Agency contract.
3) Use of existing railroad organization.
4) Other contractors under rail supervision.

Equipment for highway transport may be owned by the railroad; its subsidiary; an affiliate; or an independent motor carrier. The choice is dependent on a number of factors, and the most economical arrangement must be worked out for each location.

Effect on Operating Expenses

The relation between the various items of operating expense and train speed has been determined for maximum train speeds of 45, 55, 65 and 75 mph. This relation is based on the following conditions:

1) Assumed profile.
2) Average distance between stops—100 miles.
3) Average duration of stop—40 min.
4) Average weight of loaded car—40 tons.
5) Average train consist—65 cars.

Only those items of operating expense which increase with train speed are considered.

Engine Crew Expense

Since trains operated at higher speeds require greater capacity motive power, engine crew expense increases with the increased weight on drivers. Wages will vary somewhat for different railroads, but the following tabulation is representative of the increase of this item of expense with speed:

Max. Train Speed mph.	*Ratio*
45	100
55	105
65	112
75	119

Cost of Fuel

The horsepower hours and hours of engine idling for the various train speeds were calculated from speed time curves. Based on these figures, the relative cost of fuel and lubricating oils is tabulated below:

Max. Train Speed mph.	*Ratio*
45	100
55	118
65	138
75	160

Motive Power Maintenance

The cost of maintaining motive power increased with train speed because of the increased capacity required. It is also affected by the number of hours operated annually. The following tabulation gives the relation of cost of maintenance per locomotive mile for different speeds and utilization:

Max. Train Speed mph.	*Hours Operated*		
	3000	*4000*	*5000*
45	100	91	86
55	140	128	117
65	190	176	168
75	238	224	215

Car Maintenance

The cost of maintaining cars will vary with utilization. The relation of cost per car mile with different maximum train speeds and hours operated is shown below:

Max. Train	*Hours Operated*		
Speed mph.	*3000*	*4000*	*5000*
45	100	93	89
55	96.5	90	86.5
65	94.5	88.5	85
75	92	86.5	84

Track Maintenance

Although higher train speeds contribute to higher track maintenance, merchandise freight constitutes only a small percentage of the total traffic. Furthermore, in most cases it will be necessary to maintain a track standard for passenger trains operating at higher speeds than the merchandise trains. In view of these conditions, it is doubtful if there is any appreciable increase in the cost of this item.

Fixed Charges

The increased investment in motive power and cars results in a corresponding increase in fixed charges. A substantial part of this increase should be offset by reduction in damage costs, with improved terminal handling and advanced design of cars.

Other Costs

Terminal handling, yard operations and other incidental costs are independent of train speed and represent constants to be added to the cost of the run. Investments made to speed up these operations also bring about reductions in yard and terminal costs, wages and per diem charges. Usually these reductions in cost will liquidate the necessary investment.

Effect on Operating Revenues

The increased costs which accompany higher train speeds have been discussed previously. Because of the diversity of commodities handled at different rates, it is difficult to establish the number of revenue tons required to balance the additional expense. For the proposed train speed of 65 mph., it is estimated that on the average, 5 percent or less additional revenue tons per train will offset the extra expense as compared to a maximum train speed of 45 mph.

Today, the railroad's economic problem must be approached in terms of greater volume to reduce operating expense. It has been demonstrated that high speed, dependable service cannot only hold business in the face of expanding competition but can actually attract new high-grade traffic. Volume is essential for an efficient operation.

Conclusions

There are now at least 124 trains which offer shippers afternoon closings, with first morning delivery of shipments between points 300 miles or more apart. In addition, there are a number of fast freights which provide first morning service between points separated less than 300 miles. More spectacular are the long-distance "red-ball' freights which are providing expedited services throughout the country.

Many factors enter into the accomplishment of better service. Most railroads now operating such services are confident that they are profitable. This is particularly true where potential traffic volume is high and hauls are 300 miles or more. Users of modern railroad transportation demand that the general level of freight service be raised to that of the best which now exists.

Report of Committee 9—Highways

W. H. Huffman,
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D. A. Steel
B. M. Stephens
F. A. Stone
C. V. Talley
R. R. Thurston
V. R. Walling
R. E. Warden
J. W. Wheeler
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Design and specifications for full-depth plank crossings.

   Progress report, presented as information .... page 214

3. Merits of various types of highway–railway grade crossing protection, collaborating with Signal Section, AAR, and Highway Research Board.

   No report.

4. Location of highways parallel with railways.

   Progress report, submitted as information .... page 216

5. Method of classifying highway–railway crossings with respect to public safety.

   No report.

6. Principles for determining allocation of cost of public improvement projects involving highway–railway crossings.

   Final report, presented as information .... page 218

7. Economics of highway–railway grade separations.

   No report.

8. Design and specifications for pavements in railway tracks, collaborating with Committee 5.

   No report.

The Committee on Highways,
W. H. Huffman, *Chairman.*

AREA Bulletin 490, November 1950

Report on Assignment 2

Design and Specifications for Full-Depth Plank Crossings

R. E. Nottingham (chairman, subcommittee), O. C. Benson, H. D. Blake, D. A. Bryan, L. W. Green, C. I. Hartsell, W. J. Hedley, J. T. Hoelzer, W. H. Huffman, V. R. Walling.

This report is submitted as information.

The committee will consider any comments or criticisms on the specifications presented in the report which are received during the coming year, and proposes to submit the specifications a year hence for adoption and inclusion in the Manual.

The report is in the form of a proposed revision of the Specifications for the Construction of Wood Plank Crossing—1948 now included in the Manual.

The present specifications are expanded to cover both full-depth type and shimmed plank-type construction of wood plank crossings. An alternate arrangement of the planks adjacent to the rail is included, namely, either dapped to fit the rail or set back about 2½ in. on each side to facilitate removal of the rail without disturbing the adjacent planks. The anchorage and installation procedure is outlined in detail.

SPECIFICATIONS FOR THE CONSTRUCTION OF PLANK CROSSING

1. Scope

These specifications cover the use of wood plank in the construction of crossings.

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 the track structure.

2. Ties

New treated sawed ties shall be used throughout the crossing area and shall be properly spaced to permit preboring of the crossing plank.

3. Materials

Creosoted planking should be of a fine-grained hardwood timber, preferably gum, maple or birch. Shims should be of the same type material.

Untreated planking is not recommended, except for temporary installations or where suitable secondhand material is available.

4. Size of Plank

(a) Length.—Commercial lengths of planking of the most economical lengths for the individual crossing shall be used to the extent practical. Lengths of planks which will allow staggering of joints, with no two adjacent planks having their intermediate ends on the same tie, are preferable to avoid double spiking in the same tie.

(b) Width and Thickness.—All plank should be of 8 in. or 10 in. width. In no case shall planks be less than 4 in. thick, and planks shall be sized to insure uniform thickness and width.

5. Types of Wood Plank Crossing

Type A crossing shall be full depth. The thickness of the planks shall be such that the top surface of the crossing will lie ¼ in. below the plane of the tops of the rails, with the bottoms of the planks 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 A flangeway guard planks and planks adjacent to the outside of the rail, shall be fabricated from full-depth planks by shaping the underside of one edge of each plank used in Type A crossings, to allow for the necessary clearance over tie plates and spike heads on each side of the rail. The width of flangeway on the gage side shall be in accordance with the general specifications. The planks adjacent to the rail may either be shaped to set against the rail, with proper flangeway dapped out on the gage side, or, as an alternate, may be set back 2½ in. from each side of the ball of the rail to facilitate renewal of the rails in the crossing without the necessity of first removing the adjacent planks on each side; in which case this space, as well as the flangeway space, shall be filled with some mastic material in order to close up these openings. This mastic material should be such that it will seal out water from getting down through the flangeway to the ties, and yet be readily removable with a pick if it should be necessary to renew the rail. The top surface of each plank will lie ¼ in. below the plane of the top of the rail.

Type B crossings are made with shims or a furring strip between the bottoms of the planks and the tops of the ties. The combined depth of the plank and shims shall be such that the top surface of the crossing will lie ¼ in. below the plane of the tops of the rails. Proper allowance should be made for the depth of the tie plate and for the nominal depth of adzing of the ties. Shims should not be less than 8 in. in width, with a minimum thickness of 1⅝ in., and shall be securely nailed to each tie.

Type B flangeway guard planks are made by using plank at least 4 in. thick, and shims of the proper thickness to make the combined depth of plank and shim such that the top surface of the plank will lie ¼ in. below the plane of the tops of the rails. The planks adjacent to the rail may either be set against the ball of the rail, with proper flangeway dapped out on the gage side, or the planks may be set back 2½ in. from the ball of the rail, similar to alternate specifications under Type A flangeway guard planks.

6. Beveled End on Plank

The outer end of each plank shall be beveled not more than 45 deg. with the horizontal, with a minimum end thickness of 1 in., or in lieu thereof, a beveled end timber shall be fastened to the ties. The outside ends of the planks shall not project beyond the shims on which they rest.

7. Anchorage

Each plank shall be securely spiked down at its ends and to at least every other tie. Each plank shall be bored for drive-spikes and dowels to prevent splitting. For crossings where the rail is between 5 in. and 6 in. in height, drive-spikes ½ in. by 10 in. shall be used. Where the rail is more than 6 in. in height, lag screws or twist dowels at least ¾ in. by 11 in. should be used, and only one lag screw or twist dowel in every other tie for each plank shall be required. Planks shall be bored for lag screws with holes 1/16 in. larger diameter than that of the lag screw, and shall be countersunk for the washers and lag screw heads. Where twist dowels are used, the plank shall be bored with the diameter of the bit ⅛ in. less than the size of the dowel.

8. Installation

The top of the plank crossing shall be even with the highway pavement. The edges of outside planks shall extend to, and may project not more than 1 in. beyond the ends of the ties. If the pavement beyond the track is of concrete, a space of 1 in. shall be provided between the edge of the planking and the pavement. Planks shall be laid with edges close together to seal out water. Edges and top cracks shall be mopped with hot tar as planks are laid. Apply creosote to all wood exposed by adzing, boring or sawing. All planking should be prebored where possible to reduce the labor time required for installing the plank at the crossing. Any prebored holes not used should be plugged and sealed off.

Report on Assignment 4

Location of Highways Parallel with Railways

W. C. Pinschmidt (chairman, subcommittee), H. D. Blake, P. W. Elmore, J. S. Findley, L. W. Green, W. J. Hedley, W. H. Huffman, G. P. Palmer, Walker Paul, R. J. Pierce, P. T. Simons, C. V. Talley, J. W. Wheeler.

This report is submitted as information.

The subject is one of increasing importance and should be given the utmost consideration in long range planning.

Many instances have occurred in the past where new highways have been built parallel and close to existing lines of railroad, followed later by the construction of spur or connecting tracks crossing the highways at grade, in order to serve industrial plants subsequently established beyond the highways. In other instances, in residential sections, after streets or highways have been built parallel and close to existing railroad tracks, it has been considered necessary to cut streets through an area and across the main running tracks at grade, in order to serve the area more adequately. Many such cases have not only increased the number of grade crossings, but have increased the accident hazard potential to an extent undreamed of by the original planners.

A study of some of these cases has brought forth ideas and principles, the adherence to which should have the effect of holding to an absolute minimum the construction of highways parallel and close to railroad tracks.

The principles set forth in this report are offered for the guidance of railroads, industries, public authorities and developers of property, in cooperative planning for the future.

Industrial or Manufacturing Areas in or Near Cities

It is desirable that public highways paralleling railroad main tracks in industrial or light manufacturing areas be located not less than 500 ft., and preferably 800 ft., from the normal right-of-way line of the railroad. Such location will enable industries served by the railroad to utilize a full 500 to 800 ft. depth of property adjacent to the railroad, will permit the installation of ample track connections and facilities to serve the industrial plants, and will eliminate the necessity for highway–railway grade crossings that would otherwise be required on the industrial tracks or their connections.

In a heavy industrial development where large areas of land are required for the location of manufacturing plants, a minimum distance of 2000 ft. between railroad tracks and parallel highways is desirable.

The number of public highways crossing railroad main tracks, either over, under, or at grade within a given industrial area should be kept to a minimum. To minimize the interference with track connections serving industrial plants, it is generally desirable that any such crossings of highways and main tracks be located not closer than one-half mile apart, measured along the tracks.

Where parallel highways intersect highways that cross the tracks, there should be sufficient distance to permit appropriate roadway connections to enable highway traffic in all directions to move expeditiously with safety.

Where through highways, limited access freeways, and full freeways or parkways are planned to be constructed parallel to railroad main tracks in other than urban residential areas, it is desirable that they be located at least 1000 ft. from the railroad main tracks.

Urban Residential or Retail Commercial Areas

It is desirable that streets paralleling railroad main tracks in urban residential or retail commercial areas be located at least 200 ft. from the normal right-of-way of the railroad.

It is desirable that highway crossings, whether over, under or at grade of main tracks, be located not closer than one-half mile apart, measured along the tracks.

Where a community has been built up close to a railroad, and there are numerous street crossings of main tracks, together with parallel streets existing close to the tracks, these parallel streets can be effectively used in some instances to serve as outlets for the intersecting streets, thus enabling the abandonment of some of the intermediate crossings.

At locations where parallel streets intersect cross streets near grade crossings of main tracks, suitable highway traffic control protection should be provided to protect the traffic moving from the parallel streets, intending to cross the main tracks, in the event of a train movement. Likewise, adequate protection should be provided to take care of traffic crossing the main tracks to enter the parallel streets. If automatic gates and flashing-light signals are used at these crossings, they should be so interconnected with the highway traffic control devices as to prevent the trapping of highway vehicles on the tracks.

Rural Areas

Even though there appears to be no immediate prospects in sight for the establishment of either light or heavy manufacturing plants along a given line of railroad in a rural area, before planning to construct a new highway parallel to the railroad, consideration should be given to the factors that would influence the selection of a site or sites for location of such manufacturing or industrial plants. As a matter of precaution, unless the geographical features appear to preclude the possibility of locating industrial plants along the railroad, sufficient space should ordinarily be reserved to permit such location of plants adjacent to the railroad without interference from a new highway. Therefore, in rural areas it is generally desirable to build new highways parallel to existing railroads not closer than 1000 ft. to the railroad.

General

In planning for the location of streets, through highways, limited access freeways, and full freeways or parkways, either in new areas or in areas where property is approaching a transition stage—such as from retail commercial to either light or heavy industrial—care should be taken to avoid locating any of these types of highways immediately adjacent to railroad right-of-way or station grounds.

Report on Assignment 6

Principles for Determining Allocation of Cost of Public Improvement Projects Involving Highway–Railway Crossings

J. A. Droege, Jr. (chairman, subcommittee), R. F. Bishop, H. D. Blake, W. J. Hedley, G. A. Heft, W. H. Huffman, J. W. Jones, J. A. Jorlett, A. E. Korsell, R. W. Mauer, Walker Paul, R. J. Pierce, B. M. Stephens, V. R. Walling, R. E. Warden.

Last year your committee presented a progress report as information (AREA Proceedings, Vol. 50, 1949, pages 206–210, inclusive), and requested comments and criticisms thereon. No adverse comments have been received; therefore, it is felt that the assignment is complete, at least for the time being.

Such a schedule of suggested participation by the railroads in grade crossing projects should remain firm unless, or until, economic conditions, public opinion or legislation have changed to the point where the schedule set forth in the report requires alteration. If and when this occurs, it would be in order to re-assign a subcommittee to review the previously published report. Until then it is our belief that the assignment is completed.

Report of Committee 13—Water Service and Sanitation

H. E. Silcox, *Chairman,*
R. A. Bardwell
R. C. Bardwell
I. C. Brown
R. W. Chorley
George Clark
R. E. Coughlan
M. W. Cox
B. W. DeGeer
C. E. Fisher
A. K. Frost
R. S. Glynn
H. E. Graham
F. E. Gunning
S. H. Hailey
M. A. Hanson
T. W. Hislop, Jr.
H. M. Hoffmeister
A. W. Johnson
C. O. Johnson
H. F. King
J. J. Laudig
P. H. McGee
W. A. McGee
H. L. McMullin
G. F. Metzdorf
L. R. Morgan
Theodore Morris
J. Y. Neal
A. R. Nichols
A. B. Pierce
E. R. Schlaf
G. E. Martin,
Vice-Chairman,
H. M. Schudlich
R. W. Seniff
J. M. Short
H. M. Smith
R. M. Stimmel
D. C. Teal
T. A. Tennyson, Jr.
J. E. Tiedt
A. G. Tompkins
J. W. Ussher
H. W. Van Hovenberg
R. E. Wachter
J. E. Wiggins, Jr.
E. L. E. Zahm
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, embracing recommended revision of Specifications for Welded Steel Tanks for Railway Water Service and addition of Schwarzenbach hardness test to Standard Methods of Water Analysis and Interpretation of Results .... page 221
2. Intercrystalline and other types of corrosion of steam boilers.
   Final report on the intercrystalline corrosion phase, submitted as information .... page 223
3. Federal and state regulations pertaining to railway sanitation, collaborating with Joint Committee on Railway Sanitation, AAR.
   Progress report, presented as information .... page 224
4. Mechanics of foaming and carry-over in locomotive boilers.
   No report.
5. Methods and materials for protection of underground pipe lines.
   Final report, submitted as information .... page 225
6. New developments in water conditioning for diesel locomotive cooling systems.
   No report.
7. Railway waste disposal.
   Progress report, submitted as information .... page 229
8. Sanitation practices for location, construction and maintenance of drinking water wells and pumping equipment.
   Final report, submitted as information .... page 230
9. Design and maintenance of septic tanks for railway purposes.
   Progress report, submitted as information .... page 241
10. Specifications for design and installation of diesel fuel oil facilities, collaborating with Committee 6.
    No report.

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11. Specifications for design and installation of diesel lubricating oil facilities, collaborating with Committee 6.
    Final report, submitted as information .... page 253
    Special report—Water resources.
    Submitted to the President's Water Resources Policy Commission through AAR .... page 255

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

James Harry Davidson

James Harry Davidson, a former member of the committee, died on August 23, 1950. He was born at Burlington, Kans., on January 7, 1882.

He was graduated from Kansas University engineering school in 1908, and his picture has been included in a gallery of Who's Who in Engineering at Marvin Hall at Kansas University, Lawrence.

Upon graduation he was employed in the test department of the Santa Fe, and in 1915 he entered the service of the Kansas City Southern as chemist at Pittsburg, Kans. In 1917 he was employed as water engineer by the Missouri–Kansas–Texas Lines and served in this capacity until his retirement on January 31, 1947.

He was elected to membership in the AREA in 1920, and was a valued member of Committee 13—Water Service and Sanitation for 27 years, contributing much to the development of water treatment. His death is regretted by his friends in the Association.

Mr. Davidson married Myrtle Sager of South Bend, Ind., in 1911. Mrs. Davidson and their daughter, Mrs. Joseph Brewer, survive Mr. Davidson.

John Patrick Hanley

John Patrick Hanley died on July 26, 1950. He was born at Ramsey, Ill., on February 3, 1879, the son of Bernard and Ellen Cunningham Hanley. In August 1934, he married Lucille Lyons, who survives him. His education was obtained in local grade and high schools at Ramsey. Throughout his life he studied and read many books and this, combined with a keen and active mind, gave him a broad education.

He entered the service of the Illinois Central as a pumper at Ramsey in 1895; he was promoted to division foreman at Clinton in 1904, and was transferred to Chicago in the same capacity in 1905. In 1917 he was promoted to system water inspector, and in 1946 was made assistant superintendent water service, which position he held until his retirement July 31, 1948. On that date he concluded 50 years of service on the Illinois Central. He was quite interested in water treatment for locomotives, and in the early days of water treatment on the Illinois Central made valuable contributions to the establishment of treatment and boiler blowdown schedules.

Mr. Hanley became a member of the American Railway Engineering Association in 1924, and was particularly active in Committee 13, giving serious and sincere consideration to his committee work. He was chairman of a number of subcommittees and always developed reports beneficial to the Association. He was also a member of the American Railway Bridge & Building Association and active in that Association.

He was a member of the Calumet Country Club for many years and a very enthusiastic golfer. After retirement, Mr. and Mrs. Hanley made their home in Miami, Fla.

Mr. Hanley was a member of the Roman Catholic Church and the Knights of Columbus.

Report on Assignment 1

Revision of Manual

G. E. Martin (chairman, subcommittee), R. A. Bardwell, R. C. Bardwell, George Clark, B. W. DeGeer, T. W. Hislop, Jr., A. W. Johnson, H. F. King, H. L. McMullin, G. F. Metzdorf, J. Y. Neal, D. C. Teal, T. A. Tennyson, Jr., J. W. Ussher, H. W. Van Hovenberg, R. E. Wachter, J. E. Wiggins, Jr.

Your committee recommends for adoption the following revisions in Chapter 13 of the Manual:

Page 13–38.1

[1]SPECIFICATIONS FOR WELDED STEEL TANKS FOR RAILWAY WATER SERVICE

1951

Reword as follows:

101. Scope of Specifications

These specifications apply to the construction of shielded metal-arc welded steel water storage tanks.

102. Weather

Welding shall not be done when the surfaces of the parts to be welded are wet from rain, snow or ice; when rain or snow is falling on such surfaces, nor during periods of high winds unless the welder and work are properly shielded.

Welding shall not be done when the base metal temperature is less than 0 deg. F. When the base metal temperature is within the range of 0 to 32 deg. F. incl., the base metal within 3 in. of the place where welding is to be started shall be heated to a temperature warm to the hand.

Page 13–38.2

Reword as follows:

201. Quality of Metal

All steels shall be made by the open-hearth or electric furnace process and shall conform to any of the current ASTM Specifications A 7, A 283 (Grade A, B, C, or D), or A 113 Grade C. Copper-bearing steel with about 0.20 percent copper shall be used when specified.

Page 13–38.3.

Reword as follows:

401. Definitions and Symbols

Welding terms shall be as given in the latest edition of "Standard Welding Terms and Their Definitions" issued by the American Welding Society.

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

Page 13–59

[1]STANDARD METHODS OF WATER ANALYSIS AND INTERPRETATION OF RESULTS

1951

Page 13–61

Add the following to the reagants shown on page 13–61:

Schwarzenbach Hardness Buffer Solution.—Solution 1—Dissolve 40 g. of cp. sodium tetraborate ($Na_2P_4O_7.10H_2O$) in approximately 800 ml. of distilled water. Solution 2—Dissolve 10 g. of cp. NaOH in 100 ml. of distilled water. When cool, mix the two solutions and make up to 1 liter with distilled water.

Schwarzenbach Hardness Titrating Solution.—Dissolve 4.0 g. of disodium ethelenediaminetetraacetate in approximately 800 ml. of distilled water. Add 0.86 g. of cp. NaOH. Adjust with distilled water against standard calcium chloride solution so that 1 ml. equals 1 mg. as $CaCO_3$.

Schwarzenbach Hardness Indicator Solution.—To 30 ml. of distilled water add 1.0 ml. of 1.0 N sodium carbonate solution. Add 1.0 g. of Eriochrome black T and mix. Make up to 100 ml. with alcohol.

Sodium Hydroxide.—2.0 N Solution.

Schwarzenbach Calcium Indicator.—Mix well 0.20 g. ammonium purpurate with 100 g. cp. NaCl. Grind mixture to 40–50 mesh.

Page 13–62

Substitute the following for (b) and (c) on page 13–62 and change present (b) and (c) to (d) and (e), respectively.

(b) *Alternate Schwarzenbach Test for Total Hardness.*—Measure 58.3 ml. of the water under investigation into a white porcelain casserole. Add 0.5 ml. of the hardness buffer solution and stir. Add 4 to 6 drops of the hardness indicator solution and stir. If hardness is present the sample will turn red.

Add hardness titrating solution slowly from burette with continued stirring. The endpoint is reached when color changes from red to blue. (Color change at endpoint from red to blue is sharp and rapid and should be approached carefully).

The number of milliliters of hardness titrating solution used gives total hardness direct as grains per gallon in terms of calcium carbonate.

(c) *Alternate Schwarzenbach Test for Calcium.*—Measure 58.3 ml. of water under investigation into a white porcelain casserole. Add 1 ml. of 2.0 N NaOH solution and stir. Add 0.20 g. of calcium indicator from calibrated dipper, and stir. If calcium is present the sample will turn salmon-pink.

Add hardness titrating solution slowly with continued stirring. The endpoint is a final change to orchid-purple.

The number of milliliters of hardness titrating solution used gives calcium direct as grains per gallon in terms of calcium carbonate.

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, T. W. Hislop, Jr., H. M. Hoffmeister, R. W. Seniff, R. M. Stimmel, J. E. Tiedt.

This is a final report on the intercrystalline corrosion phase of Assignment 2, and is offered as information.

The history of intercrystalline corrosion, or, as it was formerly called, caustic embrittlement, of locomotive boiler material, dates back to an epidemic of cracking of boiler plates in the seams, and of broken rivets, which occurred in 1912 on the Chicago and North Western Railway. Subsequent to 1912, other railroads reported similar difficulties in more or less acute stages.

In 1927, five of the nationally known organizations interested in steam boiler operation selected a Joint Research Committee on Boiler Feed Water Studies, on which committee AREA Committee 13—Water Service and Sanitation has always been represented by a minimum of three members.

In 1928 the University of Illinois issued a bulletin compiled by Professor Parr and Professor Straub on the study made at the University of Illinois in regard to embrittlement of boiler plates.

The recommendations in this bulletin were that in order to insure safe operating conditions in a boiler in which sodium hydroxide was present, a definite sodium sulfate-hydroxide ratio should at all times be maintained in the boiler. It was claimed this would prevent intercrystalline corrosion or embrittlement.

The findings listed in the University of Illinois bulletin were not in accord with the experiences of the various railroads.

On the railroads it was found that embrittlement was occurring in boilers where high sulfate-hydroxide ratios were maintained, and no embrittlement was being experienced with feed water containing no sulfate and a very high sodium carbonate content. The sodium carbonate hydrolized into sodium hydroxide in excessive amounts at boiler temperatures.

Some 20 years ago, the experimental work done at the Bureau of Mines under the direction of the Joint Research Committee on Boiler Feed Water Studies, confirmed the fact that the phenomenon of intercrystalline corrosion, commonly called embrittlement, was the result of three different factors, all of which must be present simultaneously in a steam boiler before intercrystalline corrosion would occur. These factors were:

1. Water containing sodium carbonate or sodium hydroxide free from inhibitors.
2. Interior or exterior stressed boiler material in contact with these alkaline solutions.
3. Minute slow leakage, which allowed loss of steam and concentration of the alkaline salts in the water to a high degree in the stressed area of the boiler.

At the same time, the work of the Bureau of Mines conclusively proved the findings of several of the railroads that tannin, lignins, and waste sulfate liquor had an inhibiting effect in highly alkaline waters when such organic material was used under proper supervision and control.

In the meantime, the American Society of Mechanical Engineers had issued their Suggested Rules on Care of Power Boilers, in which the railroad findings, as well as the results of the research studies at the Bureau of Mines, as published in Bulletin No. 443, were completely ignored, and the results of the tests at the University of Illinois, as outlined in its Bulletin, Volume 25—No. 40, issued June 5, 1928, suggesting the use of sodium sulfate-hydroxide ratio under various boiler pressures, were made a boiler code standard.

Further developments in the studies at the Bureau of Mines resulted in the device known as an embrittlement detector. In this device a small polished section of steel of the same chemical composition as that from which the boiler was manufactured was placed under stressed conditions, and when the device was attached directly to a locomotive boiler, concentrated boiler water was kept in constant contact with the stressed test pieces by means of a very small orifice. This device proved an excellent means of determining the embrittlement characteristics of boiler water under actual service conditions and of indicating whether or not the inhibitors in use were effective.

Representative members of your committee have attended all of the meetings of the Joint Research Committee on Boiler Feed Water Studies, as well as the annual and semiannual meetings of the ASME for the past 25 years, especially since the time this Joint Research Committee was formed. A satisfactory agreement has never been reached between the railroad representation and the Mechanical Section of the ASME regarding the use of sodium sulfate-hydroxide ratios as an embrittlement inhibitor. Due to the fact that the sulfate-hydroxide ratio maintained in steam boilers was found worthless as an inhibitor in railroad service, it is the opinion of your committee that the results secured at the Bureau of Mines, as well as in the various railroad laboratories, supplemented by experience in actual railroad operation, have furnished sufficient information to prevent embrittlement of steam boilers in railroad service to formulate the following recommendations:

1. It is the opinion of your committee that the railroad should disregard the sodium sulfate–hydroxide ratio recommendations, as outlined in the American Society of Mechanical Engineers' Boiler Code of 1949, which ratios are of questionable value and increase operating difficulties in railroad steam boilers.
2. Complete investigation of boiler feed waters, with special reference to alkaline content and the presence of natural inhibitors.
3. Installation of the embrittlement detectors on boilers operating in suspected water districts on the various railroads.
4. Properly supervised and controlled use of sodium nitrate or lignin in water known to have embrittling tendencies, as outlined in previous reports of your committee.
5. Proper workmanship, resulting in tight boiler seams in all boiler construction.

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, B. W. DeGeer, R. S. Glynn, S. H. Hailey, H. F. King, G. E. Martin, G. F. Metzdorf, A. B. Pierce, J. M. Short, D. C. Teal, R. E. Wachter.

This is a report of progress, presented as information.

Your representatives on the Joint Committee on Railway Sanitation, AAR, have participated during the past year in the revision of the Interstate Quarantine Regulations as proposed by the U. S. Public Health Service, and as affecting railway interstate carriers. The modification of the regulations, as has been proposed for further federal legislative action, is in the railways' interest and clarifies the regulations considerably. It is now possible to complete the drafting of a handbook on Servicing Area Facilities and Operation, in which your representatives also participated, so that its text will be in conformity with the revised Interstate Quarantine Regulations. This handbook, or guide to the interpretation of the regulations, will be used by the regulatory state and federal authorities in cooperation with the railroads in an effort to effect an improvement in general sanitation in terminals, coach yards and passenger coach watering points.

The AAR Sanitation Research Project that has had as its object the subject of toilet waste disposal from railway passenger cars has completed its more than four years of excellent research and study. The research laboratory at Baltimore has been abolished and certain of the personnel moved to new quarters in the AAR Research Center in Chicago, where they are now participating in the final proofing of certain of the technical reports, prior to the assignment of such other duties as may be prescribed by the Joint Committee.

The membership of the Joint Committee has reviewed the final personal completion report prepared by the consultnat director of the research project, and the railway members of the committee are now preparing their report covering the history of the research project, and their comments as affecting the recommendations and conclusions of the consultant director, before submission to the AAR. 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

Methods and Materials for Protection of Underground Pipe Lines

H. E. Graham (chairman, subcommittee), R. C. Bardwell, R. W. Chorley, George Clark, R. E. Coughlan, M. W. Cox, C. E. Fisher, A. K. Frost, F. E. Gunning, A. W. Johnson, J. J. Laudig, G. F. Metzdorf, L. R. Morgan, J. Y. Neal, A. R. Nichols, A. B. Pierce, R. W. Seniff, H. M. Smith, A. G. Tompkins.

Your committee submits the following final report as information.

The damage done each year to underground pipes by corrosion is considerable, and the cost to the railroads each year amounts to a very large sum. Costly replacements of pipe are due mostly to the effects of corrosion. Losses of the fluid through leaks caused by corrosion may amount to another sizeable sum. Increased maintenance costs and greater out-of-service time are other effects of damage caused by corrosion. This is especially true of pipe lines under several feet of cover or in inaccessible places. While not all of these losses can be prevented, they can be reduced considerably by one or more of the main techniques used for controlling the rate of corrosion, namely; selection of materials, protective coatings, change of environment, cathodic protection, or treatment of the fluid.

This report deals primarily with the protection of the exterior surfaces of underground metal pipe lines from corrosion and will only be indirectly concerned with the corrosion of the interior surfaces.

Corrosion of the interior surfaces of pipes in return systems has been previously reported upon.* The corrosion taking place on the interior surfaces of a pipe may be

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* AREA Proceedings, Vol. 51, 1950, page 150.

more severe than the corrosion caused by the soil on the exterior surfaces; therefore, the internal surfaces must be given consideration when installing underground pipe lines. It may be desirable to reduce this corrosive action on the interior surfaces by protective linings or chemical treatment of the fluid conveyed.

Cast iron, wrought iron and steel are the metals most generally used for underground piping systems and which are subject to the major portion of the corrosion that takes place. Certain types of installations can be protected from corrosion by various coating materials, supplemented where necessary by cathodic protection. The corrosion of small diameter pipe systems is usually controlled more economically by metals and alloys that are inherently resistant to corrosion, such as copper, brass and lead.

Corrosion of pipes is simply a chemical or electrochemical reaction by nature in an attempt to revert the metal back to its original form as an ore. By fully understanding the basic principles of corrosion and by making use of the most effective methods of reducing the rate of corrosion, large sums of money can be saved by the railroads annually.

Factors Entering Into Soil Corrosion

There are many factors entering into soil corrosion, for which reason any previous experience of the corrosive conditions of the soil is most valuable. The physical and chemical properties of soils vary considerably at different locations, causing a wide variation in the rate of corrosion. Cinder fills contribute much to accelerate corrosion.

The corrosive character of a soil depends primarily upon the amount of ground water present and its dissolved materials, mainly calcium and magnesium sulfate, sodium and magnesium chloride, sulphuric and organic acids. The dissolved gases which accelerate the rate of corrosion will consist of oxygen, carbon dioxide, hydrogen sulfide and sulfur dioxide in varying amounts. As the amount of ground water bears a direct relation to the corrosion rate, anything that can be done to improve drainage will reduce the action on the pipe. Drainage may be improved by bedding and backfilling with sand, gravel, or crushed limestone. Limestone has the additional advantage of raising the pH value of the ground water in contact with the pipe. Clay also affords protection, but cannot be relied on in a highly corrosive soil where the drainage is poor.

When soil water is in contact with dissimilar metals of a buried pipe system, severe local bi-metallic corrosion often results, and the pipe may fail with unexpected rapidity. Bi-metallic corrosion can be reduced to a minimum by using the same metal throughout the entire piping system. The depth to which bi-metallic corrosion penetrates is directly proportional to the ratio of the areas of the less noble metal to that of the anodic metal exposed to the electrolyte. In the case of brass valves with iron and steel pipe or brass-trimmed iron and steel valves, the effect of a small area of brass is distributed over a relatively large area of ferrous metal, and under most conditions does not cause serious corrosion.

Variations in the kinds of soil in contact with the pipe may cause marked local corrosion. It is important, therefore, that various soils should not be mixed while trenches are being back-filled. Acid soils contribute much to the rate of pitting, usually in proportion to their acidity.

Stray electric direct current often causes severe local corrosion in underground pipe systems. Usually this stray current is the result of defective grounds or bonding in a near-by direct current circuit, which should be corrected. Protective coatings cannot be depended on for the prevention of stray current electrolysis. Any failure in the coating on a pipe that is anodic will concentrate the flow of current to a small area on the pipe, which increases the rate of penetration at this point. Alternating currents have a relatively small effect on the corrosion rate.

Metallic Pipe Material

The U. S. Bureau of Standards has been making a study of underground corrosion since 1922. The object of the investigation has been to determine the extent of the corrosive action of the various soils, and the differences in the rate of corrosion of various commercial metals exposed in these soils. In its report on the ferrous metals and alloys, presented as Research Paper RP2057 and published January 1950, the Bureau has summarized, in part, as follows:

> "This report contains the results of measurements of corrosion made on a variety of wrought and cast ferrous materials after exposure to different soil conditions for periods up to 14 years. Steels containing small amounts of nickel and chromium showed increased resistance to soil corrosion, but the resulting improvement was small. However, certain wholly austenitic steels containing high percentages of chromium and nickel were completely resistant to corrosion. High sustained rates of corrosion occurred generally in poorly aerated soils high in soluble salts or in acidity. In well aerated soils low in soluable salts, corrosion virtually ceased after a relatively short period because of the formation of layers of corrosion products close to the metal surface."

Sand cast pipe has a natural protective iron silicate surface coat fused on to the metal when the iron is cast. The rapid chilling given centrifugally-cast pipe also tends to give the cast metal greater surface resistance. When the corrosion of cast iron is severe, it undergoes a process known as graphitization. The corrosion follows the graphite flakes and the iron retains its original form but it is soft and has little strength, while in wrought iron and steel the corrosion occurs only on the surface.

Copper and copper-base alloys are normally highly resistant to corrosion and are used in many applications where ordinary ferrous materials are not suited. When copper or brass pipe is exposed in cinder fills or soils that are high in sulfides, chlorides, or carbon dioxide, corrosion proceeds at an accelerated rate. Very soft water containing large amounts of carbon dioxide is also corrosive to copper and brass.

Zinc, while not used normally as a pipe material, is the most common metallic coating applied to pipe for underground protection. Hot-dip galvanizing applied to iron and steel pipes will provide protection in slightly corrosive soils. It must be remembered, however, that under severe corrosive conditions, such as cinder fills, zinc, being anodic to iron, will corrode at a faster rate than iron, and too long a life should not be expected; also, the threaded joints of the pipe must receive special attention.

Lead pipe has a high degree of resistance to soil corrosion, but must be used with caution for the conveyance of soft water for drinking purposes. Lead salts in solution in excess of 0.1 ppm may produce toxic effects.

Non-Metallic Coatings

The extreme variation in the corrosive conditions encountered around railroad terminals and shops results in a wide range in the life of iron and steel pipe. These pipe lines, which are usually comparatively short, require materials and methods of protection particularly suitable for this type of work. Your committee feels that elaborate equipment for applying special protective coatings cannot normally be justified. However, the non-metallic protective coatings that are applied should provide waterproofing, shielding from soil stress, and electrical insulation.

All coatings should be applied only to a clean surface, as their life bears a direct relation to the condition of the surface of the pipe at the time they are applied.

The linseed oil paints are not generally used underground as they cannot be relied upon for permanent protection. Paints with a coal-tar base and certain rubber-derivative base paints have proved more resistant and can be used to a limited extent in mildly corrosive soils.

Asphaltic or bituminous coatings applied hot are used widely for coating pipes to be used underground. No additional coating is normally applied to cast iron pipe, while steel pipe, if the soil conditions warrant, may have the additional protection of a spirally wrapped fabric saturated with a bituminous material. The fabric helps to prevent injury to the protective coating caused by soil stress or abrasion. In applying asphaltic or bituminous coatings, it is not only important that the steel or cast iron pipe be thoroughly clean, but also thoroughly dry. These coatings may be applied at the mill before shipping, or in the field with special equipment.

The petroleum-base coatings to which has been added a chromate rust inhibitor have proved very effective in preventing soil corrosion. This type of coating is usually protected with a spirally applied reinforced fabric wrapper in direct contact with the undercoating. A service coat, consisting of a combined petroleum and resin-base material, is applied over the wrapper for the purpose of sealing the seams against moisture penetration. All of this material may be applied on the same day in the field, without special equipment. It is applied cold with hand tools.

Probably the most permanent coating for underground protection is portland cement mortar, which forms a film of alkaline solution in contact with the iron pipe to inhibit corrosion. The cement mortar coating may be applied by placing forms around the pipe and filling with a mixture of sand and portland cement, or with the cement gun with wire reinforcement. Concrete coatings are very durable and may be applied on a wet surface.

Cathodic Protection

Cathodic protection of underground pipe systems is used to reduce corrosion of existing uncoated pipe systems, and to insure continued protection with the coatings now available as most all coatings will deteriorate or become damaged in time. Any break in the protective coating will tend to concentrate the corrosion activity at that point, thus causing rapid failure.

To apply cathodic protection, auxiliary anodes are buried at suitable distances from the pipe line, through which a direct current is introduced into the soil. This current must be of sufficient magnitude to counteract any corrosion currents. The protective current may be obtained from a direct current generator, a rectifier, or by the use of galvanic anodes of magnesium, aluminum or zinc. All types of the above anodes will be corroded in the process of protecting the pipe line and must be renewed at regular intervals. Where cathodic protection is applied to a new pipe line, it should be used in combination with a protective coating in order to reduce the current density requirements. On existing pipe systems, which were not coated when installed, safe cathodic protection can be provided, when indicated, with higher values of current density.

Conclusions

Finally, it must be remembered that not all losses due to corrosion can be economically prevented. The choice of the method of corrosion control used, then, is dependent upon the required service life of the pipe, the life of unprotected pipe as compared with the increased life due to the protection, the cost of protection, and the cost of renewing the pipe line. No one type of protection is suitable for all conditions; therefore, the factors controlling the corrosion must be studied carefully.

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Report on Assignment 7

Railway Waste Disposal

T. A. Tennyson, Jr. (chairman, subcommittee), A. K. Frost, F. E. Gunning, J. J. Laudig, W. A. McGee, L. R. Morgan, Theodore Morris, A. R. Nichols, E. R. Schlaf, J. M. Short, H. M. Smith, J. W. Ussher, J. E. Wiggins, Jr.

This is a progress report, submitted as information.

For the past two years your committee has studied and reported on federal and state regulations pertaining to waste disposal as they involve the railroads, and on the problems which appeared to be of major importance. With the rapid expansion of stream pollution control and the progress in development of methods of waste treatment, your committee could continue this study indefinitely. However, it is felt that the interests of the railroads in the problem of waste disposal can be better and more effectively served from now on through a joint or collaborating committee within the American Railway Engineering Association or within the Association of American Railroads, to keep abreast of the trend in waste disposal regulations and the developments in methods of compliance. Since most all railroad departments are involved more or less in waste disposal problems, such a committee is needed as a source of advice for the railroad industry to avoid duplicated effort and to serve the interests of the railroads in controversies which will arise with the controlling agencies in stream pollution and related problems.

Therefore, it is the recommendation of your committee that the Association endeavor to bring about such joint collaboration, in which Subcommittee 7 would have representation, to serve the ends outlined above.

Report on Assignment 8

Sanitation Practices for Location, Construction and Maintenance of Drinking Water Wells and Pumping Equipment

H. M. Schudlich (chairman, subcommittee), George Clark, C. E. Fisher, R. S. Glynn, H. E. Graham, T. W. Hislop, Jr., H. M. Hoffmeister, A. W. Johnson, H. F. King, P. H. McGee, W. A. McGee, Theodore Morris, J. Y. Neal, J. M. Short, D. C. Teal, J. E. Tiedt, A. G. Tompkins, J. W. Ussher, H. W. Van Hovenberg, E. L. E. Zahm.

This report is submitted as information.

Since the beginning of civilization man has obtained water for domestic purposes from the ground. The ancient wells were merely holes from the surface of the ground that penetrated to the water-bearing stratum, and the only problem involved was the providing of an opening large enough to accommodate the crude equipment necessary to remove the required water for drinking, cooking and other domestic use. No thought was given to sanitation or to the quality of the water obtained, and not until it was realized that the advancement of civilization depended entirely upon the degree of sanitation, were there regulations considered that would promote the construction of sanitary ground-water supplies. During the Middle Ages there was no improvement or development in the drilling of wells, and the domestic water supplies obtained from shallow holes and springs contributed to severe outbreaks of pestilential diseases.

Geological conditions vary greatly, and in order to provide a general specification for the construction of a sanitary water well, the worst condition that can be encountered must be used as a guide for proper construction. It is also necessary to provide for the protection of the water stratum itself, since a private supply tapping a stratum might contribute to the pollution of a source for a municipal or public supply. It is the intention of this report to cover briefly the construction of the important types of drinking water wells. Practically all the states have enacted minimum construction requirements that cover location and design, and some states require the submission of detailed construction plans. For convenience, and to avoid delay, illustrations showing the aprpoved designs are included.

Types

There are essentially five basic types of wells, which are classified according to the method used in their construction. The primary consideration in selecting the type to be constructed is the ease in protecting the water against pollution and, secondly, the earth formations above the aquifer, as well as the depth and kind of water strata. The present types of well construction are, in the order of preference, drilled, driven, dug, bored and jetted. The last four are only used where ground conditions are favorable and the aquifer is relatively shallow or the upper soil is such as to avoid construction difficulties. Jetted wells are used very little, and the difficulties and expense of construction, as well as the special equipment required, do not warrant their consideration. They are also the most difficult to construct in order to provide a sanitary water.

Location

The location of a well is important in the avoidance of future difficulties and the assurance of a sanitary supply. To insure this, it is sometimes necessary to sacrifice convenience, since the site should always be at a higher elevation than the surrounding ground in order to avoid surface drainage from stock yards or other contaminated areas and stagnant surface pollution. If the proposed site is fairly level, the area adjacent to the well should be filled with about 2 ft. of compacted earth to avoid any surface drainage pooling in the immediate vicinity. The site should be remote from privy pits, absorption fields, cesspools, septic tanks and sewers. Fifty to 100 ft. will in most cases provide a sufficient horizontal distance, except where subsurface fissured rock and heavy gravel may alter the above figures and require greater distances.

Sewers and drainage lines discharging into sewers should be no closer than 50 ft., and when at this minimum distance, should be constructed of heavy cast iron pipe with leaded joints and should be tested with water pressure after construction to assure a seepage-free line. Wells terminating in creviced limestone, basalt, granite, disintegrated rock, talus, shallow coarse sand and gravel, or in the bed of a dry creek, should be regarded as probable producers of insanitary water. Wells should not be located at the edge of the property or within any area where the ground is not completely controlled for a horizontal distance of at least 50 ft. Adjacent tenants may pollute the surface with undesirable drainage, or construct septic tanks, disposal fields, or poorly jointed tile sewers which could contribute to the pollution of the ground water supplying the well.

Construction

All types of well construction require a platform or cover of impervious material, preferably of water-tight reinforced concrete not less than 4 ft. square and from 4 to 6 in. thick. The slab should be placed on compacted earth, with the exception of a large diameter dug well, and be trowled smooth and sloped well away from the pump to the edges. The well casing should extend about 4 in. above the slab, which will allow the face of the pump stand, which is fastened to the casing and about 2 in. below the end, to be covered with 2 in. of concrete. The soft concrete should be well puddled around the well casing and the stand to assure a water-tight joint. A properly constructed slab with stand and pump are shown in Figure 1–B. Another very desirable design in which the pump stand is attached to the casing, which extends at least six inches above the slab, is shown in Figure 1–C. Many state boards desire this type of construction. A sanitary well should not be drilled in a pit or closer than 10 ft. from an existing pit or unfilled space, and it is undesirable to install a drinking water well in a basement on account of the possibility of sanitary sewers backing up and discharging sewage into the well, and thus contaminating the water-bearing stratum.

Drilled Wells

Drilling with percussion or rotary equipment is the most satisfactory method of constructing a sanitary drinking water well as this design is the least likely to become contaminated. It has the advantage of a single string of steel pipe, with either welded or screwed water-tight joints, sealed in concrete or puddled clay to prevent the entrance of any surface water. Harmful bacteria are seldom found lower than 10 to 15 ft., being filtered out by the upper soil and sand or dying from the unfavorable environment at this depth. It is desirable that the well have a tight seal between the casing and the ground at the surface and to a depth of 10 to 15 ft. Such a seal can be provided by several methods:

1. Drill the hole 6 in. larger than the well casing and pressure grout the annular space between the casing and the soil with cement slurry. This method is used where the open hole will stand up, and is shown in Fig. 2.
2. Drill and set larger casing 15 to 25 ft. deep, depending on local geology, then finish well and grout annular space between the casings with cement slurry. This method is used where the upper formations are unstable, and is shown in Fig. 3.

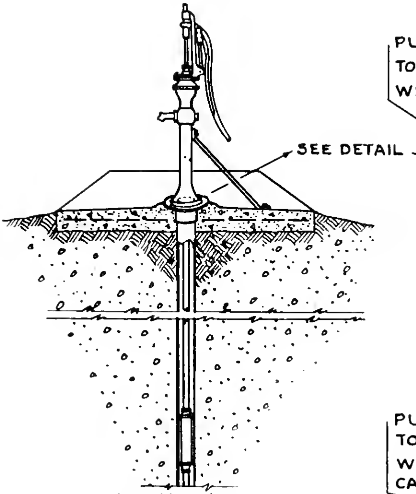


FIGURE 1-A

PROPERLY CONSTRUCTED DRILLED WELL.

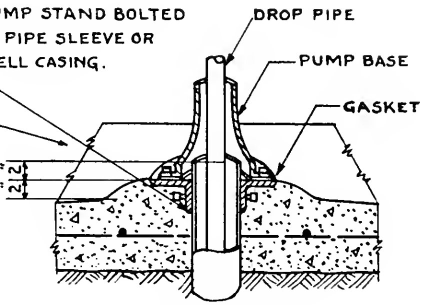


FIGURE 1-B

SANITARY PUMP SETTING.

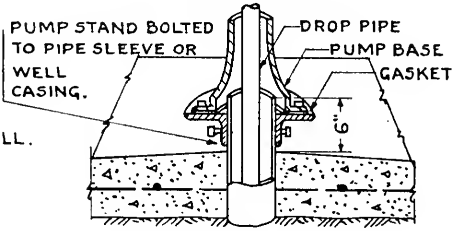


FIGURE 1-C

SANITARY PUMP SETTING.

CONCRETE PLATFORM SLOPED 1" IN 4', NOT LESS THAN 4' SQUARE AND 4" TO 6" THICK, WITH 3/8" BARS ABOUT 12" ON CENTERS.

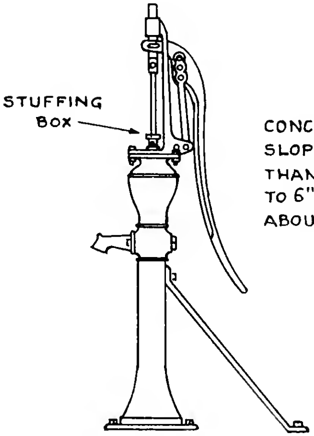


FIGURE 1-D

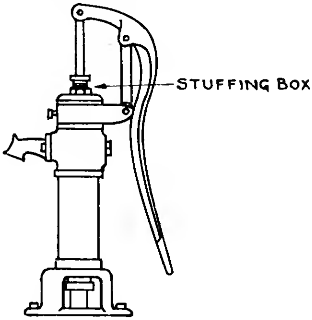


FIGURE 1-E

PROPER TYPE OF PUMP HEADS.

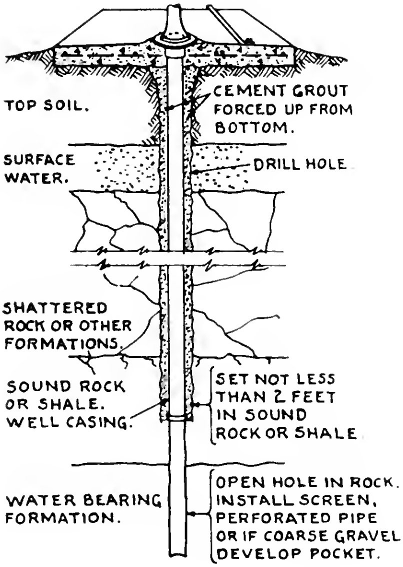


FIGURE 2

PROPERLY DRILLED WELL WITH GROUTED CASING.

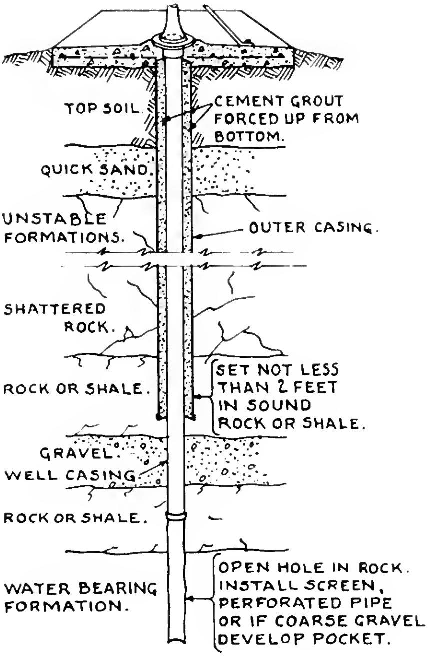


FIGURE 3

PROPERLY DRILLED WELL WITH DOUBLE CASING AND ANNULAR GROUTING.

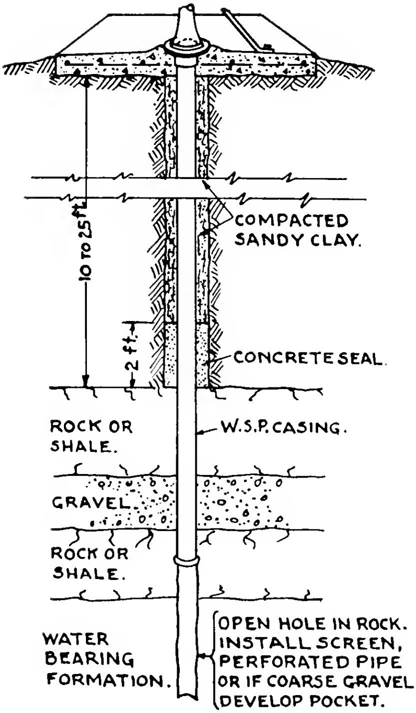


FIGURE 4
PROPERLY DRILLED WELL WITH CONCRETE SEAL OR COMPACTED EARTH SEAL.

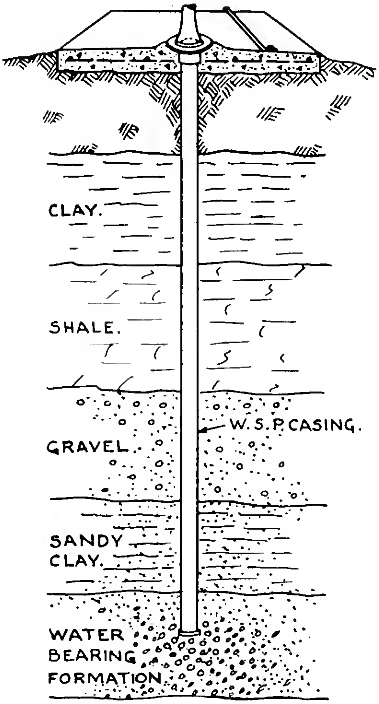


FIGURE 5
PROPERLY DRILLED WELL WITH NATURAL EARTH FORMING CASING SEAL.

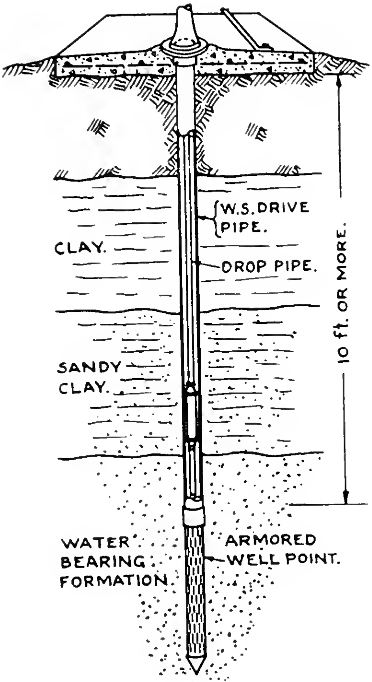


FIGURE 6-A
PROPERLY CONSTRUCTED DRIVEN WELL.

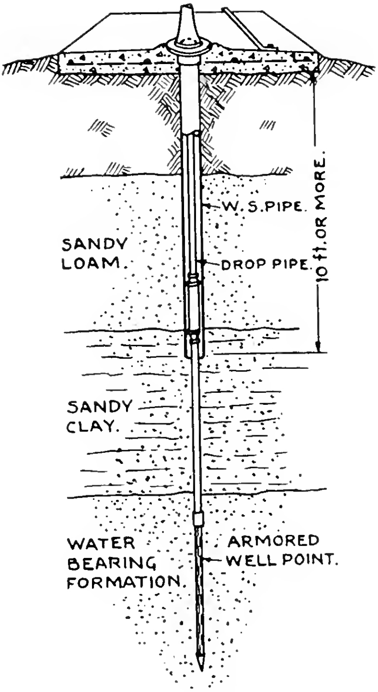


FIGURE 6-B
PROPERLY CONSTRUCTED DRIVEN WELL.

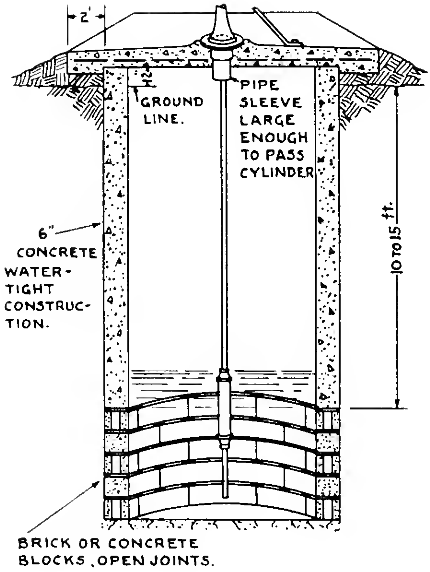


FIGURE 7-A
PROPERLY CONSTRUCTED DUG WELL.

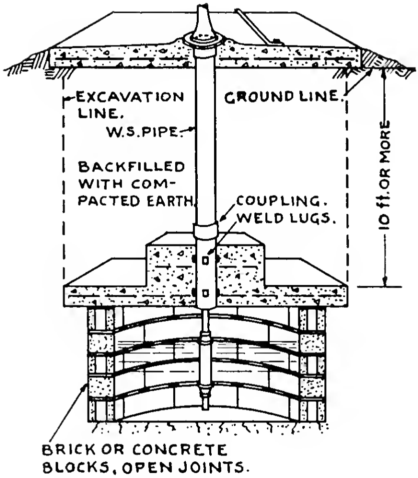


FIGURE 7-B
PROPERLY CONSTRUCTED DUG WELL.

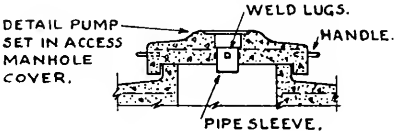


FIGURE 7-C
PUMP STAND SET IN CONCRETE COVER FOR DUG WELL.

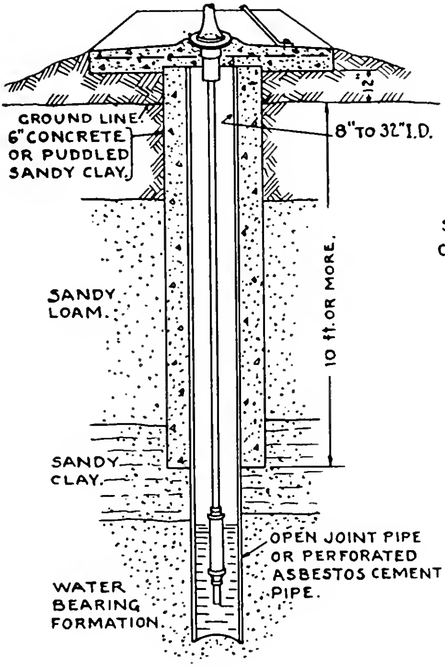
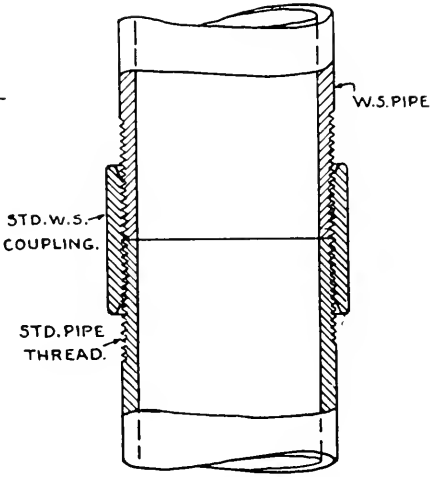


FIGURE 8

PROPERLY CONSTRUCTED BORED WELL.



ENDS OF PIPE TO BE MACHINED AND THREADED SO THAT WHEN SCREWED TOGETHER, PIPES WILL BUTT, ALSO FORM A TIGHT FIT IN COUPLING.

FIGURE 9

THREADED WELL CASING COUPLING.

3. Drill hole 8 in. larger than casing for 10 to 25 ft. and puddle clay in the annular space. The addition of bentonite to the well at the start assists in forming a water-tight seal, or a 2-ft. cement grout seal is very effective in preventing surface water from following down the casing. This is shown in Fig. 4.
4. Many soft clays and unconsolidated formations will compact themselves around the casing and it is only necessary to set the drive shoe firmly into shale, solid rock, or into the water-bearing formation; thus the grouting or puddling of clay is unnecessary. This type of construction is shown in Fig. 5.

Driven Wells

A driven well is constructed by driving a screen with an armored point from the surface to the water-bearing formation, which should consist of sand and gravel with relatively high porosity. The casing consists of small diameter steel pipe, and successive sections are added as the pipe is driven into the earth. After the point has been driven well into the water-bearing stratum, a small surge block, swab, or compressed air is used to remove the fine sand and create a gravel pocket around the point. This type of well should only be considered where the soil above the water formation is unconsolidated, free from boulders, and of such texture as to allow the pipe to drive freely. In certain localities these conditions are found and wells can be driven up to a depth of 150 ft. The proper method of constructing a driven well is shown in Figs. 6–A and 6–B.

Dug Wells

Dug wells are to be considered when the ground water is relatively close to the surface, or for the purpose of collecting water from the upper earth formations, and should always be more than 15 ft. deep. This type of well serves as a storage reservoir to accumulate seepage supplies in formations of low water content, and is only used where other designs are impracticable. Two types of construction which will provide a sanitary water are shown in Figs. 7–A, 7–B and 7–C. It is necessary to provide a waterproof concrete liner that is poured in one continuous operation to avoid construction cracks which may allow infiltration of contaminated surface water. The inside form for the concrete may be tile or corrugated pipe. Concrete blocks or brick, laid with open joints in the water formation, are used for support of the wall and liner.

Bored Wells

Bored wells are constructed with either hand or power-driven augers and range in diameter up to 32 in. They are used only where small amounts of water are required and where the water is found in relatively shallow formations. The limitations of this type of well are the same as those of the driven well, and such wells are constructed in areas where the soil formation is relatively soft and free from boulders. The proper design for the construction of such a well is shown in Fig. 8. The concrete lining should likewise be poured in one continuous operation. Corrugated galvanized pipe, asbestos cement pipe, and vitrified tile can be used as the interior lining, but the exterior concrete seal, to a depth of at least 15 ft., should be installed to prevent surface water from entering.

Well Casing

Every well should have a water-tight casing not less than 10 ft. below the ground surface. The casing should never be used as the suction pipe or the working barrel for the pump plunger. The casing should be of adequate strength and durability to retain its shape in all formations when driven, and of sufficient thickness to resist the action of aggressive waters. The recommended wall thickness of single-pipe wells is ¼ in., and in no case should the pipe or casing be lighter in weight than standard weight pipe. Large size wells and wells driven in corrosive soil should be constructed of extra strong or heavier pipe. The casing should be threaded so that the walls butt against each other, as shown in Fig. 9. The following table shows the weight and wall thickness of various sizes of steel pipe used in the construction of wells.

TABLE OF WELL CASINGS—PLAIN ENDS—IRON AND STEEL

Size in in.	Standard		Extra Strong		Double Extra Strong	
	Wt. Lb. per ft.	Wall Thickness in.	Wt. Lb. per ft.	Wall Thickness In.	Wt. Lb. per ft.	Wall Thickness in.
1 I.D.	1.67	0.133	2.17	0.179	3.65	0.358
1¼ "	2.27	0.140	2.99	0.191	5.21	0.382
1½ "	2.71	0.145	3.63	0.200	6.40	0.400
2 "	3.65	0.154	5.02	0.218	9.02	0.436
2½ "	5.79	0.203	7.66	0.276	13.69	0.552
3 "	7.57	0.216	10.25	0.300	18.58	0.600
3½ "	9.10	0.226	12.50	0.318	22.85	0.636
4 "	10.79	0.237	14.98	0.337	27.45	0.674
4½ "	12.53	0.247	17.61	0.355	32.53	0.710
5 "	14.61	0.258	20.77	0.375	38.55	0.750
6 "	18.97	0.280	28.57	0.432	53.16	0.864
8 "	28.55	0.322	43.38	0.500	72.42	0.875
10 "	40.48	0.365	54.73	0.500	92.28	0.875
12 "	49.56	0.375	65.41	0.500	110.97	0.875
14 O.D.	54.56	0.375	80.72	0.562	122.65	0.875
15 "	58.57	0.375	86.73	0.562	132.00	0.875
16 "	62.57	0.375	102.62	0.625	141.34	0.875
18 "	70.58	0.375	115.96	0.625	160.03	0.875
20 "	78.59	0.375	129.33	0.625	178.72	0.875
22 "	86.60	0.375	142.68	0.625	170.21	0.75
24 "	94.61	0.375	156.03	0.625	186.23	0.75
26 "	119.44	0.437	----------	----------	----------	----------
28 "	146.85	0.500	----------	----------	----------	----------
30 "	157.53	0.500	----------	----------	----------	----------

Disinfection

After a well has been completely constructed, or after repairs have been made to an old installation, it should be thoroughly disinfected with a concentrated chlorine solution. Ordinary chloride of lime, or the high percentage chloride of lime (calcium hypochlorite), as well as any of the common household laundry bleaches (sodium hypochlorite), are generally used for the purpose. One of the laundry bleaches that are readily available at every grocery store is the most convenient. To sterilize a well, use one quart of bleach to 200 gal. of water contained in the well, or a minimum of one quart. Dilute to 3 gal., and pour the solution into the well so that it flows down the pump drop pipe and casing.

When using chloride of lime mix, use ½ lb. of the material with sufficient water to form a thin paste. This is then added to 3 gal. of water, is mixed thoroughly and allowed to settle, and the clear solution added to the well in the manner mentioned above.

After the addition of the disinfecting agent the water in the well should be agitated with air if convenient, otherwise, the pump can be raised, and by pumping, circulate the water by returning the effluent to the well by means of a hose attached to the pump outlet. The disinfecting solution may be conducted to the bottom of a relatively shallow well by means of a hose or several lengths of pipe, and by gradually withdrawing the conductor when adding the disinfecting material the entire water body will be chlorinated. Allow the chlorine solution to remain in the well for 12 to 24 hours, then pump until the water is completely free from chlorine. Samples are then taken for bacterial analyses.

Maintenance

Proper maintenance of a sanitary water supply not only includes repairs to the pump and equipment to keep it in proper order, but should also include the elimination of all possible sources of contamination, since improper maintenance can result in condemnation of a water source due to bacterial pollution. Unused wells should not be merely abandoned, but thoroughly disinfected; the water-bearing formation sealed with a concrete plug, and the hole filled with sandy clay. This practice protects the quality of the water in the adjacent wells. Pumps of improper design and construction, and which are poorly maintained, contribute to the failure of a sanitary water. Following which are several suggestions for proper maintenance:

1. Pumps that are of insanitary construction or which have broken castings should be replaced by pumps with bell-shaped bases to receive the extended well casing; they should be of the deep-well force type with a stuffing box to prevent the entrance of aerial borne bacteria and to prevent the introduction of insanitary priming water. No pump should be allowed to remain in service that needs priming or which can be primed in any manner.
2. Split base or adjustable base pumps may admit leakage and contamination from dogs and other animals; therefore, it is necessary that no loose fastenings be permitted.
3. The pump stand should be firmly embedded in the concrete base and the gasket between the base and the pump should be accurately cut so that it fits properly. Lubrication should not be used since oil and greases are very frequently contaminated, and the excess material will squeeze out and drop into the well upon tightening the fastenings, and thus contribute to possible contamination.
4. All pooling of drainage water in the well vicinity should be avoided by filling the ground with material that will pack other than cinders, sand and gravel. If there is a considerable amount of waste water from the well this should be piped 15 ft. or more away to avoid washouts around the slab. Any settling of the earth around or below the slab should be promptly taken care of to avoid cracked concrete. Minor slab cracks should be repaired with asphalt that remains mastic at low temperatures, so as to prevent the small cracks from developing due to action by frost.
5. Corrosion of casing is largely eliminated when the entire well is grouted. If this has been omitted and the casing fails, it can be repaired by the installation of a smaller diameter interior casing or liner, pressure grouted into place.
6. Leaky and defective stuffing boxes require immediate attention, avoiding the use of oil and grease which may cause contamination. The packing should be clean and handled carefully. Likewise, pump leathers should be sterilized with chlorine solution and handled carefully before replacement.
7. Power pumps should not be installed without a sanitary seal, even though the casing terminates above the floor. Turbine pumps should be set so that the casing extends above the base. Some pumps have too large a column supporting flange in which instance the casing should be rebuilt by the addition of a swaged nipple of greater diameter, welded to the casing before pouring the pump supporting pier.

8. Earth movements, new construction, casing corrosion and other factors may contribute to the pollution of a sanitary well and it may, therefore, be desirable to make annual or periodical sanitary analyses of the water.

Summary

The recommendations are general and will cover the minimum standards as required in most states. Since local ground conditions vary, the Local Board of Health should be consulted before the work on a new well is begun. Very detailed information pertaining to the construction and location of wells is found in Sections IV and V, "Water Supply Sanitation and Construction of Wells", which may be obtained from the Minnesota Department of Health, Minneapolis, Minn., and in supplement No. 124 to the Public Health Report, "Ground Water Supplies," obtainable from the Surgeon General, U. S. P. H. S., Washington, D. C.

Report on Assignment 9

Design and Maintenance of Septic Tanks for Railway Purposes

D. C. Teal (chairman, subcommittee), C. E. Fisher, H. E. Graham, P. H. McGee, Theodore Morris, J. Y. Neal, E. R. Schlaf, H. M. Schudlich, J. M. Short, J. E. Tiedt, A. G. Tompkins, J. W. Ussher, H. W. Van Hovenberg, R. E. Wachter, E. L. E. Zahm.

This is a progress report on a new assignment and is submitted as information.

Much authoritative information on septic tank sewage disposal systems has already been developed by U. S. and State Public Health Agencies. Rather than attempt original research of its own, your committee conceives it as its duty to review of all the information already published, to condense and adjust such information to railway conditions, and to present it in a manner than can best be utilized by the railway engineer.

Scope.—This year's report covers the basic principles involved in the design and operation of small septic tank disposal systems of 200 to 1000 gal. sewage flow per day capacity and consisting of 1) Building Sewer, 2) Single Compartment Septic Tank, 3) Distribution Box, and 4) Subsurface Absorption Field. Fig. 1 illustrates a typical small septic tank system.

General Information on Septic Tank Sewage Disposal

The septic tank is an underground settling tank intended to separate sewage solids from liquid by gravity, retaining the solids in the tank and allowing the more or less clear water effluent to pass into a subsurface absorption field. The retained solids are decomposed into sludge and scum by bacteriacidal action in the tank. A septic tank should therefore function as a settling, digestion and sludge-storage tank, and should be designed accordingly.

Degree of Purification.—Possibly ½ of the bacteria normally present in sewage is retained in the septic tank with the sludge. The neutralization of the remaining bacteria in the effluent has to occur in the drainage field.

Life Expectancy.—A septic tank sewage system with absorption field disposal should have a useful life of 20 or more years.

Seeding.—The addition of yeast does not stimulate bacteriacidal action in the tank. Seeding with sludge from another tank or from the digestion chamber of a city sewage treating plant, however, will start up and accelerate digestion in new tanks. About 10 gal. of digested sludge per 100 gal. daily sewage flow should be added. When tanks

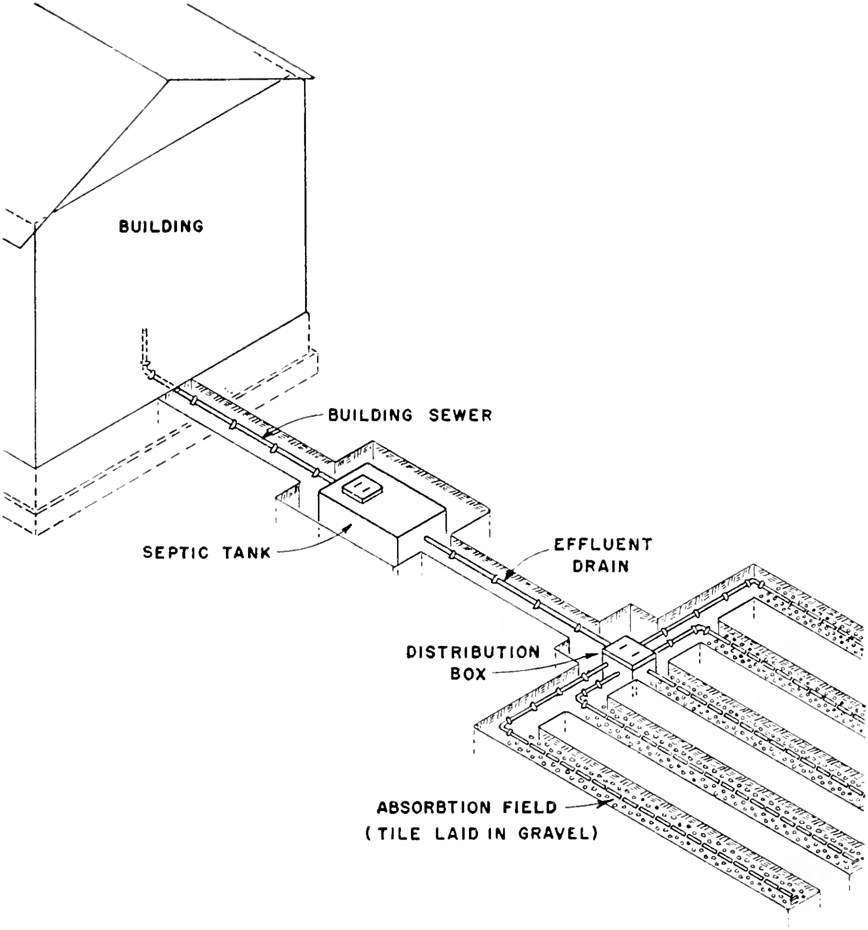


Fig. 1. Typical septic tank disposal system.

are cleaned some of the old sludge should be left. It is particularly necessary to seed tanks in northern climates.

Effects of Grease.—Research to date indicates that the presence of small amounts of grease, up to 200 ppm, have no apparent effect on the digestive processes within the tank. However, it is generally conceded that excessive amounts of grease, such as from a restaurant kitchen, may eventually clog up the tank and sewer lines. Grease traps should, therefore, be installed on large-volume kitchen waste lines.

Effects of Chemicals.—The addition of disinfectants or other chemicals in appreciable amounts will retard and sometimes completely destroy bacteriacidal action in the tank. However, small amounts of chlorine, up to five ppm when added ahead of the tank for odor control, will not affect operation. The use of small quantities of acid or lye for cleaning pipe fixtures is not objectionable.

Effects of Zeolite Softener Salts.—Salt ($NaCl$, $CaCl_2$ and $MgCl_2$) concentrations up to 0.4 percent in a septic tank have no adverse effect and, indeed, seem to stimulate digestion. In higher concentrations, digestion is inhibited proportional to the concentration.

Garbage Grinders.—The addition of ground garbage to the sewage will not interfere with operation, providing it is finely ground, and the tank sludge storage space is adequate.

Newspapers, Rags and Waste.—Such material should not be flushed into a septic tank as it will not digest readily.

Inspection.—Proper maintenance requires that septic tanks be inspected and cleaned periodically; otherwise they will become overloaded and solids will be carried over and cause trouble in the absorption field. They should be inspected at least every other year and cleaned when the combined volume of sludge at the bottom and the scum at top occupies ¼ to 1/3 the total liquid capacity.

Cleaning.—Septic tanks are designed to operate from three to five years between cleaning. When possible, they should be cleaned in the spring or the summer since bacterial digestion starts more readily in warm weather. In most cases it is best to have the cleaning done by an outside contractor. When necessary to handle the sludge with company forces, empty it into a city sewer if possible; otherwise bury it 300 ft. or more from any residence, office or drinking water well. In connection with inspection and cleaning, it is recommended that the responsible supervisory officer should have a location plan of each septic tank under his jurisdiction; also, brief written instructions as to procedures to follow.

Preliminary Considerations and Investigations For Design

A septic tank sewage disposal system should be adequate in size with regard to present and future amounts and types of wastes to be handled. The design must take into consideration location with respect to drinking water supplies, topography, type of soil, ground water table, and space available. Final disposal of effluent by percolation into the soil is the regular method of disposal, but should not be used unless conditions are favorable. Extreme care must be taken to prevent contamination of drinking water supplies and to prevent public health nuisances that might result from saturated and overflowing absorption fields. The ideal is to provide facilities which, with due allowance for future increases, will meet the needs under conditions encountered. Facilities in excess of those needed are a waste of money.

Permits.—Most states require that permits be obtained from the state or local boards of health for the installation of septic tank systems. These ordinances should be consulted before undertaking design, and their provisions complied with in all respects.

Omission of Absorption Fields.—Some states permit discharge of septic tank effluent directly into their larger rivers. When applicable, this should be investigated.

Estimates of Sewage Flows.—Sewage normally consists of toilet and bath or washroom wastes, kitchen wastes and laundry wastes. A septic tank should not be expected to handle surface water or roof drainage. Sometimes the sewage discharge can be approximated from existing water meter readings. When water consumption measurements are not available, the sewage flow has to be estimated. The following table may be used for this purpose:

Table 1—Average Daily Sewage Flows

Type of Establishment	*Gal. Per Person*
Single family dwellings	50
Multiple family residences	40
Rooming houses	40
Combined rooming and boarding houses (YMCA's)	50
Restaurants (toilet and kitchen wastes per patron)	9
Restaurants (kitchen wastes per meal served)	3
Labor camps	50
Day office workers	15
Shops (gal. per person per shift)	20
Hotels with private baths	100

It is desirable, but not always possible, to separate bath and laundry from toilet wastes and to dispose of them in another manner. Where such is possible the values shown above should be adjusted.

Accumulation of Sludge and Scum.—During the first 2 years of operation sludge and scum accumulate at an average rate of 45 gal. per year 100 gal. daily sewage flow. After about the fourth year, due perhaps to better digestion and compaction, the rate of accumulation slows down to around 20 gal. per year per 100 gal. daily sewage flow.

Scum.—Approximately 27 percent of the total scum thickness lies above the water line.

Location.—Both the tank and the absorption field should be located where surface drainage will be away from buildings and away from sources of water supplies. Elevation should permit sufficient fall in the building sewer line and proper grading of the seepage lines in the absorption field without excessive cover. Tanks should be at least 5 ft. from any basement or from property lines, and 50 ft. from any drinking water well. The nearest point of a seepage absorption field should be at least 100 ft. from any water supply, 25 ft. from any dwelling, and 10 ft. from any property line. The absorption field should lie in an open, unshaded area, exposed to the sun, away from tree roots, and should never be installed in low, swampy areas or where the natural ground water level is less than 10 ft. below finished grade.

Permeability of Soil.—Satisfactory disposal of septic tank effluent by filtration depends mostly on the permeability of the soil; for proper design work, it is essential that a reliable method be used for determining the rate of absorption that can be expected. The test described below will supply this information.

Soil Percolation Test

Make two or more percolation tests at different locations in the proposed absorption field as follows:

1) Excavate holes 1 ft. sq. to a depth proposed for the drain line system. A square wood box with open ends may be used to prevent cave in.

2) Fill the hole with water and continue adding until the bottom and sides of the hole are thoroughly saturated. Judgment must be used regarding unusual (wet or dry) seasonal conditions.

3) With 6 in. of water in the hole, observe the time required for the water to completely seep away. This time in min. divided by 6 will give the average time for seepage of 1 in. of water and is referred to as the porcolation time "t" of the soil in question.

Extensive research by Public Health Service engineers had established a relationship between the percolation time "t" and the number of sq. ft. of bottom trench area required for 1 gal. of sewage effluent. This is called the PERCOLATION COEFFICIENT and is empirically expressed by the formula $PC = \frac{t + 6.24}{29}$, in which $PC =$ sq. ft. of absorption area required for each gal. of effluent per day. The general range of percolation coefficients for various types of soils is shown in Table 2 below. This, however, should never be used as a substitute for actual field tests.

TABLE 2—PERCOLATION COEFFICIENTS—$PC = \frac{t + 6.24}{29}$

Type of Soil	*Range of "t" in min.*	*Range of PC*	*Relative Absorption*
Coarse sand—fine gravel	1 to 2	0.1 to 0.3	Rapid
Fine sand—light loam	2 to 11	0.3 to 0.6	Medium
Sandy clay—loam	11 to 31	0.6 to 1.3	Slow
*Medium clay	31 to 51	1.3 to 2.0	Semi-impervious
*Tight clay—rock	Over 51	Above 2.0	Impervious

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* Should never be used for absorption fields unless sand filters and collecting tile drains are also provided

As an example, with a sewage flow of 500 gal. per day and for soil with a *PC* of 0.5, the absorption field should be designed with $0.5 \times 500 = 250$ sq. ft. of bottom of trench.

Design of Building Sewer

Materials—Pipe used for the construction of the building sewer should be of durable material and have long life water-tight joints. Use cast iron soil pipe with B&S lead joints under the following conditions:

1) Within 50 ft. of wells or suction lines from wells.
2) Within 10 ft. of any drinking water line under pressure.
3) Under tracks, driveways or where subject to heavy loads.
4) Near trees.

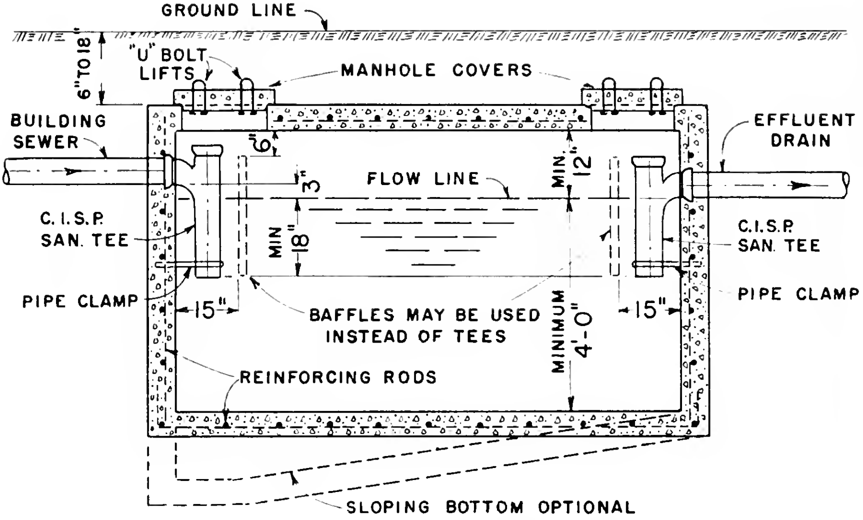
Otherwise, use vitrified clay or concrete sewer pipe with B&S cement joints.

Sizes.—See Table 3.

Grades.—The slope of a house sewer should be not less than 1 percent or ⅛ in. per ft. A fall of ¼ in. is preferable and should be provided when possible. The grade for the last 10 ft. just before entering the septic tank should not exceed ¼ in. per ft.

Cleanouts.—Should be installed at 80 to 90-ft. intervals on straight lins, at every change in line of 45 deg. or more, and at every change in grade in excess of 22½ deg. A cleanout should be provided convenient to the septic tank.

Short Radius 90-deg. Bends.—Should be avoided.



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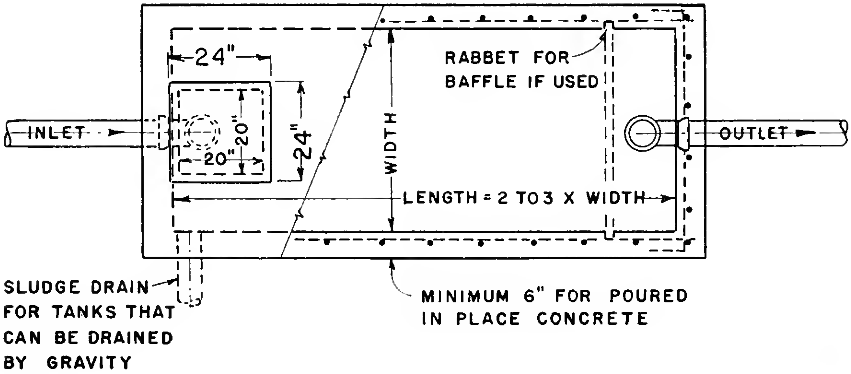

PLAN VIEW

Fig. 2. Small single chamber septic tank.

TABLE 3—MINIMUM SIZE OF BUILDING SEWER AS RELATED TO GRADE AND KIND OF PIPE

*Water closets or equivalent**	*Grade ⅛ in. per ft.*		*Grade ¼ in. per ft.*	
	For CISP	*For VC or Conc.*	*For CISP*	*For VC or Conc.*
2	4 in.	6 in.	4 in.	6 in.
3–4	4	6	4	6
5–12	6	6	5	6
13–50	8	8	6	6
51–120	8	8	8	8
121–180	10	10	10	10

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* Equivalents of one water closet are: One laundry tub, one shower bath, three bath tubs, six lavatories.

Design of Septic Tank

Recommended design and construction features of small septic tanks as discussed below are illustrated in Fig. 2.

Materials.—Poured-in-place or precast concrete tanks under normal conditions will last 20 years or more. Monolithic construction is preferred because it is more water tight. Steel tanks average 7 years useful life and are not recommended.

Shapes.—Although research indicates there is but little difference in efficiency between rectangular, oval, or circular shaped tanks of approximately the same capacity and depth the long rectangular tank is usually easier to construct and is recommended for this reason. The inside length of single-compartment septic tanks should be 2 to 3 times the width; the minimum depth of the liquid, 4 ft. and there should be at least 12 in. of air space between the surface of the liquid and the underside of the top.

Wall Thickness and Reinforcing.—Should be in accordance with regular concrete design practices for underground structures. Small precast tanks should have a minimum wall thickness of 2 in. and be adequately reinforced. The bottoms of such tanks should have a minimum thickness of 4 in., tops 3 in. Removable top slabs should not weigh more than 200 lb.

Capacities.—The minimum liquid capacity of any septic tank should be 500 gal. Experience indicates that such tanks handling up to 2000 gal. sewage flow daily need a retention period of approximately 24 hours, and that larger tanks can digest as efficiently with less retention time; also, in either case, room must be provided for the accumulation and storage of sludge. The following formulas are recommended for determining capacities:

(1) For sewage flows of 400 to 2000 gal. per day, $C = 1.9\ Q$

(2) For sewage flows between 2000 and 6000 gal. per day,
$C = 1500 + 1.15\ Q$ in which $C =$ the liquid capacity of tank and $Q =$ the daily sewage flow.

Table 4, showing recommended dimensions of tanks for given sewage flows up to 1000 gal. per day, is based on the above criteria. For greater flows, limitations of the absorption field usually necessitates construction of a dosing chamber and one or two automatic siphons in the tank, not covered in this report.

When domestic garbage grinders are in use or contemplated, the total required capacity of tank should be increased 50 percent.

Bury.—In temperate climates, and with topography and sewer line grades permitting, the tank need not be buried more than 12 to 18 in. Tanks with precast removable top slabs should never have more than 18 in. cover.

Manholes.—Are required for inspection and cleaning purposes. Only one manhole need be installed on tanks handling up to 500 gal. daily sewage flow and this should be

Table 4—Recommended Dimensions of Septic Tanks for Given Sewage Flows

			Recommended Inside Dimensions			
Estimated Daily Sewage Flow–gal.	*2 Yrs. Sludge Accumulation*	*Recom. Liquid Capacity–gal.*	*Width ft.–in.*	*Length ft.–in.*	*Depth ft.–in.*	*Air Space in.*
100 to 300	90 to 270	500	3–0	6–0	5–0	12
400	360	760	3–3	8–0	5–0	12
500	450	950	3–6	9–0	5–0	12
600	540	1140	4–0	9–0	5–6	15
700	630	1330	4–3	10–0	5–6	15
800	720	1520	4–6	10–0	5–9	15
900	810	1710	4–8	11–0	5–9	15
1000	900	1900	4–8	11–6	6–0	15

located over the inlet. Larger tanks should have two manholes with one at each end. Circular manholes should be at least 24 in. in diameter and the square ones 20 in. each side. When tanks are to be buried more than 18 in., the manholes should be extended to within 6 in. of the finished ground surface. The removable top slabs of the precast tanks serve as manholes.

Tee Inlets and Outlets Versus Baffle Wiers.—There is no significant difference in performance between tee fitting inlets–outlets and baffle wiers. The tee fittings are usually easier to install.

Vents.—Are not desirable at septic tanks. Adequate venting of the tank should be obtained through the building plumbing.

Design of the Distribution Box

The distribution box is the means by which the absorption field drainage layout may be adapted to suit topographic conditions. It also regulates the amount of effluent fed into each drain line and provides an inspection point for observing the quality of the effluent. Fig. 3 shows typical distribution box designs.

Construction.—The box should be of concrete with 3 or 4-in. walls and need be no larger than necessary to contain the inlet and outlet piping. Its shape can be varied to suit the layout of the drain lines. Its top should be brought up to within 12 in. of the finished ground level and should have a movable cover. The sewer line from tank to box should have a ⅛ to ¼ in. per ft. of slope, and its invert should enter about 3 in. above the bottom. The inverts of drain lines leaving the box should be level with or just above the bottom. Flow diversion devices should be installed in boxes serving large absorption fields.

Design of Absorption Field

The regular absorption field consists of a subsurface pipe line system of open jointed farm tile laid in gravel or equal. The liquid sewage effluent drains into the gravel and is then absorbed into the soil. Recommended design and construction methods as discussed below are illustrated in Figs. 4 and 5.

Layout and Spacing of Drain Lines.—The shape of an absorption field will be governed largely by the available space, slope of ground and total amount of drain tile required. Parallel laterals should be 6 ft. apart when space permits, and never less than 5 ft.

Sizes and Kind of Pipe.—Use 4 or 5-in. diameter farm tile, length 12 in. spaced ¼ in. apart for drain lines. Perforated pipe tends to clog up and is not recommended.

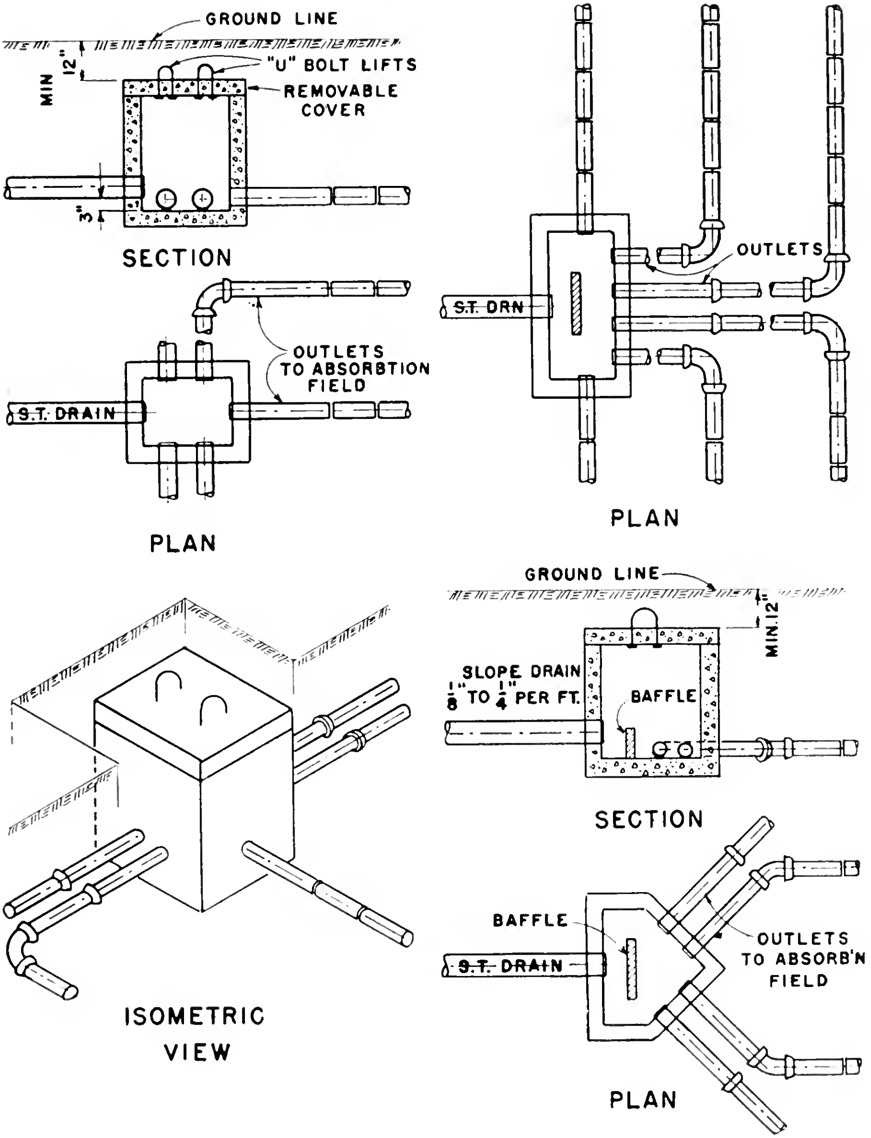
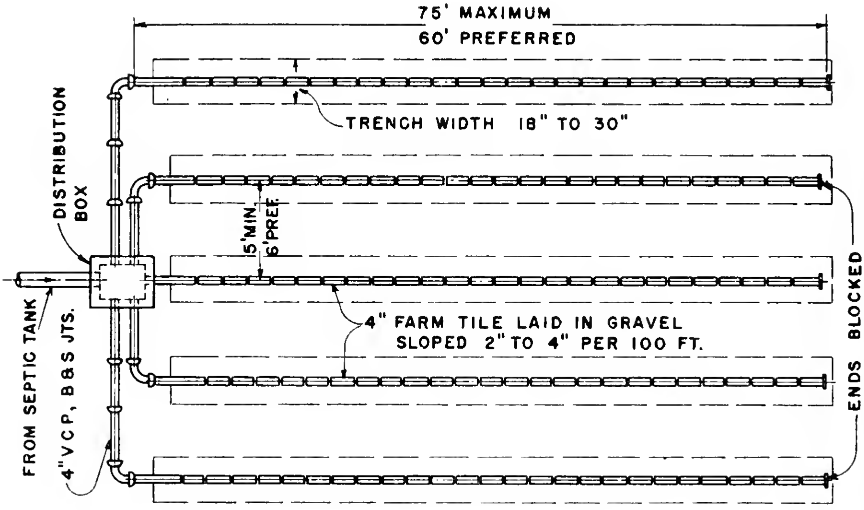
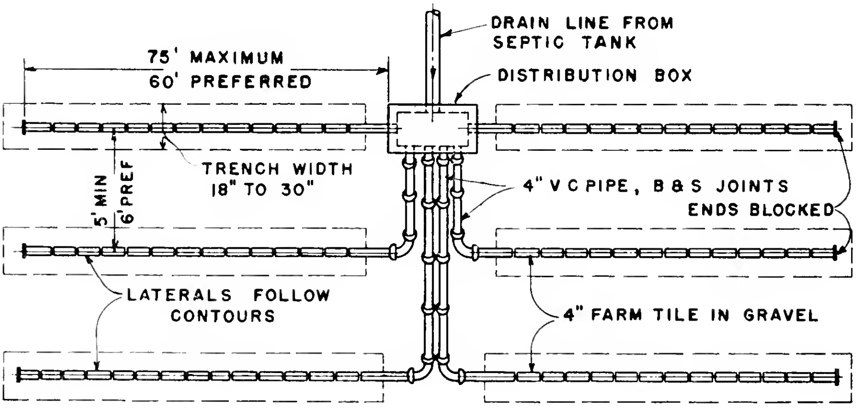


Fig. 3. Types of distribution boxes.



ABSORBTION FIELD SYSTEM FOR LEVEL GROUND



ABSORBTION FIELD SYSTEM FOR SLOPING GROUND

Fig. 4. Typical layouts of absorbtion fields.

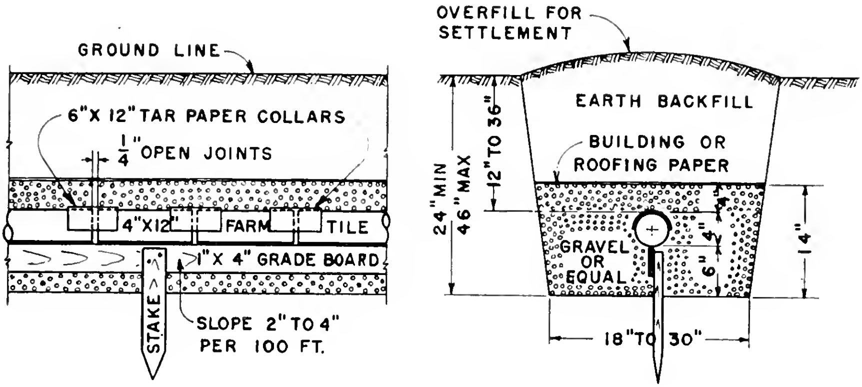


Fig. 5. Installation of drains in absorbtion field.

Length of Drain Tile.—May be calculated by multiplying average daily sewage flow in gallons by the percolation coefficient of the soil and dividing by the width of drain trench in feet. A formula for this would be: Length = Gal. *X PC/W*. For regular absorption fields, the length of individual drain lines should be limited to 75 ft., with 60 ft. preferred. When more than 600 ft. of drain tile are required, a dosing chamber with an automatic siphon should be installed in the septic tank (not covered in this report), and the length of individual drain lines may be increased to 100 ft., with 80 to 90 ft. preferred.

Grades and Cover.—Drain tile should be sloped 2 to 4 in. per 100 ft., and never more than 6 ft. A cover of 12 to 18 in. is preferred but not always possible because of adverse topography. A drainage field should never be located where conditions would require more than 36-in. bury.

Grade Boards.—The use of a method for insuring accurate lining up of the tile drain and their use is recommended.

Trenches.—The bottom of the trench in which drain lines are installed represents the absorption or leaching area over which sewage effluent is spread. The following widths are suggested, according to the percolation coefficient of the soil.

1) When the *PC* is less than 0.4, use an 18-in. wide trench.
2) When the *PC* is between 0.4 and 1.0, use a 24-in. wide trench.
3) When the *PC* is between 1.0 and 2.3, use a 30-in. wide trench.

Construction Details.—Lay tile in trench with ¼-in. open joints and surround with clean gravel, crushed rock, clinker cinders or similar aggregate ranging in size from ½ to 2½ in. This porous material should extend at least 6 in. below the flow line of the drain tile and 4 in. above the top of the tile. The top of the aggregate should then be covered with building or roofing paper or a 2-in. layer of hay, straw, pine needles or similar material to prevent sifting in of the earth backfill. The ¼-in. opening between the tile should also be covered at the top for the same reason. Metal covers for these spaces are excellent for the purpose but are expensive. Collars made of 6 by 12-in. pieces of tar paper make an acceptable substitute.

End of Drain Lines.—Should be blocked off or plugged. Riser pipes with vents are sometimes used in connection with automatic siphon-dosing chamber tanks, but are not needed for the regular slow fed absorption fields.

Summary

The design, construction and maintenance of a septic tank sewage disposal system should consist of the following steps:

1. A field investigation to include:
   a) Survey of physical features, topography, locations, levels, etc.
   b) Data for estimating the daily sewage flow.
   c) Percolation tests of ground proposed for the absorption field.
2. Investigate as to whether state or local health ordinances will have to be considered.
3. Office work to include:
   a) Preparation of general location map showing physical features.
   b) Calculation of size of septic tank and length of drain line.
   c) Lay out proposed facilities on map for size and shape.
   d) Prepare detail construction plans.
4. Field engineering work to include:
   a) Layout and supervision of construction work.
   b) Water tests on completed facilities.
5. Maintenance to include:
   a) Inspection every two years.
   b) Cleaning when needed.

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Report on Assignment 11

Specifications for Design and Installation of Diesel Lubricating Oil Facilities,

Collaborating With Committee 6

G. F. Metzdorf (chairman, subcommittee), R. A. Bardwell, M. W. Cox, A. K. Frost, F. E. Gunning, S. H. Hailey, M. A. Hanson, A. W. Johnson, C. O. Johnson, J. J. Laudig, W. A. McGee, L. R. Morgan, R. M. Stimmel, J. E. Wiggins, Jr.

Your committee submits the following report as information.

Diesel lubricating oil facilities consist of one or more clean oil supply systems of distribution, and dirty or waste oil return systems.

In general, the clean lubricating oil distributing systems include storage tanks, strainers, pumps, air releases, meters, valves, piping, storage supply loading stations and diesel locomotive filling stations. When various brands of oil are intended to be kept in separate storage, each brand of oil should have an entirely separate system.

The dirty or waste oil return systems generally consist of diesel locomotive drain stations, pumps, storage tanks, valves, piping and storage tank unloading stations for shipment to reclamation plants. Some railroads install their own reclamation plants; others pump the waste oil into boiler fuel oil storage tanks and use it as fuel, together with the regular fuel oil, for stationary heating boilers.

The size or capacity of storage tanks for diesel lubricating oil is governed by operation requirements and whether the oil is to be purchased in barrel lots or in bulk carload quantities.

Lubricating oil must be kept warm enough to pump properly in cold weather. When practical, storage tanks should be placed inside of heated buildings. Outdoor tanks exposed to cold weather must be provided with heating coils and temperature controls. In addition, the oil piping which leads to and from the tanks must be provided with steam tracers, traps, etc., all of which involves additional maintenance. The exposed above-ground tanks and pipe lines also require a protection of insulating material with a waterproof jacket.

Crankcase oil generally used for diesel locomotives is S.A.E. 40. The economical pumping temperature is usually 60 deg. F. to 100 deg. F., depending upon the length of pipe run from the supply to the filling stations. Steam heating coils placed inside of storage tanks must be controlled automatically to limit the temperature rise of the lubricating oil. High oil temperatures would create a hazard to workmen operating these facilities.

Each tank should be provided with a manhole, vent with flame arrestor, fill and discharge pipe connections, liquid level gage and base drain valve. The base drain valve, when not protected against freezing, should be of a frostproof type. Swing joints should be installed near the pipe entrance to the tank, where the tank foundation is subjected to frost action or when it is necessary to relieve strain in piping.

Where oil flows by gravity from a storage tank, a shut-off valve should be placed in the line at the tank.

The filling of storage tanks is accomplished either by gravity flow from barrels placed on racks or fill boxes above the tanks, or by pumping from bulk carload. When pumping from bulk carload, the oil should be metered before it is discharged into storage tanks. The pumping arrangement from a tank car is through an unloaidng station, strainer, pump, check valve, air release and meter, and in that order to the storage tanks.

In cold weather when unloading is done out of doors, a steam connection to the tank car heating coils is required.

The general sequence of pumping arrangement from the storage tank to the diesel locomotive is as follows:

a) From a float or pipe suction in the tank through a strainer to the suction side of pump.
b) From the discharge side of the pump through a check valve and an air release, to a meter.
c) From the meter to a lubricating station, with a hose connection, with a shut-off nozzle at the delivery end.

The air release is necessary to insure a true recording of oil flow through the meter.

At small installations where filling is intermittent, only one pump is required. Where pumping is required for filling storage tanks, the same pump is generally used.

For large installations where filling is frequent and simultaneous, a meter is placed at each station to facilitate recording the quantities of oil supplied to each diesel locomotive. Two pumps are generally required for such installations, with piping and valves so arranged that pumping operation can be switched from one pump to the other in the event of failure of either pump. The two-pump installation also permits the use of one pump for filling storage tanks from unloading stations while the other is pumping to diesel filling stations.

Crankcase capacities range from about 85 gal. for switchers to about 250 gal. for diesel road locomotives. The flow required through the nozzle of the filling station is normally about 25 to 35 gal. per min. At large installations, throttling valves should be placed in each filling station standpipe for equalizing the rate of flow and to shut off the line when maintenance work on the filling hose or nozzle is required.

Pumps generally used for pumping lubricating oil are of the rotary, positive displacement type, with a built-in by-pass relief valve, and are driven by an explosion-proof electric motor. The pump capacity required and the by-pass valve setting is governed by the anticipated number of filling stations to be operated simultaneously, the length and size of piping, and the temperature and viscosity of the oil.

The control of pumping the oil supply to lubricating stations is either by remote push-button stations or by an automatic pressure system. In the pressure system, the pump motor is automatically controlled by a pressure switch mounted on a pressure tank which holds a moderate supply of oil under pressure, ready for use. Unless the push-button station is provided with a timing device, the pressure system has an advantage over the push-button station in that it eliminates a man failure to shut off the pump.

The pressure tank is placed in the line of piping between the check valve on the discharge side of the pump and the air release. The capacity of the pressure tank is usually from 400 to 600 gal. A cut-in and cut-out setting on the pressure switch controls the operation of the pump motor. The range between the low, or cut-in, setting and the high, or cut-out, setting is generally not over 10 lb. Based on the assumption that the rate of flow to each filling station is balanced by throttling valves, the high-pressure setting is governed by a maximum desired flow and the low-pressure setting by a minimum desired flow, through the station having the greatest flow pressure loss through the piping, with the throttling valve in a full open position at that station.

In addition to the pressure switch, the pressure tank should be provided with a pressure-type access cover, pressure gage, pop safety valve, liquid level gage and tapping for inlet and outlet oil piping and a compressed air connection; compressed air being used for make-up air for initial charging of pressure tank. The initial charging is accomplished by first filling the pressure tank about 2/3 full with lubricating oil and then charging the tank with air to a pressure equal to that of the pump cut-out pressure setting.

By-pass piping with a shut-off valve arrangement should be installed around the air release, meter and pressure tank to facilitate repairs to or the replacement of this equipment. Where the meter is placed at the diesel filling station, only the throttling or shut-off valve is required, which should be placed in the line just ahead of the meter. A shut-off valve should also be placed in all branch lines adjacent to the main run.

The general sequence of a waste pumping arrangement from diesel locomotive drain stations to a storage tank is as follows:

a) Through a hose connection at the drain stations, by gravity flow, to a sump receiving tank provided with float switch for pump motor control.
b) Then through suction pipe, check valve, and strainer to pump.
c) From pump discharge to storage tank.

Where required to pump from a storage tank to a tank car or other loading stations, the same pump may be used by having the piping and valves so arranged as to shut off the sump suction and to draw oil from the waste oil storage tanks at the suction side of the pump, and the oil then discharged through a branch line to loading stations.

Special Subcommittee on Water Resources

G. E. Martin (chairman, subcommittee), B. W. DeGeer, H. L. McMullin.

Your committee has given consideration to water consumption requirements and problems of American railroads as these may affect or influence federal legislation and policies in the water resources field—particularly the development of additional supplies, as well as the conservation and use of the nation's water resources.

The nation's railways have been and will continue to be large users of water for many years to come. The use of the diesel locomotive has substantially reduced water consumption for generating steam on the railroads using that type of locomotive; however, the more liberal use of water for cleaning equipment and property has resulted in some increase in water used for that purpose.

The railroads developed many water supplies along their lines as the roads were contructed, many of which were improved from time to time in order that the water requirement of the railroads could be supplied at the points needed. At first very little attention was given to quality, but about 1900 considerable attention was given to the quality of water furnished for locomotive use, and since that time many changes and developments in supplies have been made to improve the quantity and quality. In the early days of the railroads, they were forced to develop their own supplies and to produce their requirements because water was not available from cities and towns along their lines. Even in some of the larger cities, water for railroad purposes was generally supplied from railroad company-owned pumping stations. As the cities and towns developed water facilities for domestic use, they sought to sell the surplus in their plants to the railroads at rates that made water from such sources economically justified. The water offered was of somewhat better quality than was generally found in untreated railroad water supplies. Consequently, the railroads now generally purchase water from the cities through which they operate when it can be secured from that source at a reasonable rate. From 1930 on, the Reconstruction Finance Corporation assisted many small communities in financing their water plants and solicited railroad accounts to assist in the retirement of the indebtedness of these communities. During that period the railroads abandoned many of their plants in favor of purchase from city supplies. This change in the trend of securing water by railroads brings out the point that their consumption has considerable bearing on the supplies for communities.

The locating of new industries along railroads is a matter given considerable attention by railroad managements in order that such industries may stimulate the railroad business. The proper selection of locations for new industries, particularly those requiring large amounts of water, will have considerable influence on the nation's water resources. Adequate information on available water for use by new industries should be provided those considering the locating of these industries to insure against water shortages developing because of the requirements of such industries in a community.

A survey of the requirements and difficulties of the railroads indicates that while some difficulties are encountered due to a lack of adequate water supplies, the overall picture is considerably improved over the last 20-year period. Some difficulties are encountered in fast-growing cities because of lack of proper distribution facilities, and there are a few isolated cases of shortage of supply where growth in a particular area has been great and the available water somewhat limited. Certain areas have a limited water supply and such has been the case for many years. There generally has been an improvement in this respect as reservoirs and other facilities have been provided.

The pollution of streams and lakes with waste from industrial and municipal operations is resulting in the water from the sources affected being unsuited for domestic or industrial water supplies. This is growing increasingly important from year to year and is a matter that can develop into a very troublesome situation from a water supply standpoint.

Conclusion

The water requirements of the railroads are relatively large and will not increase; instead they will possibly decrease with the increased use of diesel locomotives. Adequate information on the available water supplies in all communities in connection with new industries; qualified engineers and funds to develop and install supplies in localities having difficulties because of shortages, with adequate control of sources of pollution, might prove beneficial in conserving our water resources. Any legislation making these means available should, in our opinion, provide a plan that would result in liquidating any funds advanced by or costs to the federal government.

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.
   No report.

2. Classification yards, collaborating with Committee 16.
   Progress report, presented as information .... page 258

3. Scales used in railway service.
   No report.

4. Bibliography on subjects pertaining to yards and terminals.
   Final report presented as information with recommendation that subject be discontinued .... page 259

5. Locomotive terminal facilities.
   Final report, submitted for adoption and printing in Manual .... page 261

6. Design and location of facilities for icing refrigerator cars.
   No report.

7. Design and typical layouts of air lines in freight yards.
   Final report offered as information .... page 273

8. Design of the track layout and gradients in connection with scales located on the hump of a classification yard.
   Final report presented as information .... page 277

9. Factors to be considered in determining the location of a track scale in a yard.
   Final report presented as information .... page 281

The Committee on Yards and Terminals,
W. H. Giles, *Chairman.*

AREA Bulletin 490, November 1950.

Report on Assignment 2

Classification Yards, Collaborating with Committee 16

A. S. Krefting (chairman, subcommittee), C. J. Astrue, A. E. Biermann, W. O. Boessneck, E. G. Brisbin, N. C. L. Brown, R. J. Coffee, Oscar Fischer, W. H. Giles, H. J. Gordon, E. E. Hammond, L. C. Harman, F. M. Hawthorne, W. W. Hay, B. Laubenfels, J. L. Loida, R. H. Peak, Jr., R. B. Rhode, H. T. Roebuck, M. S. Rose, W. B. Rudd, C. F. Worden.

Your committee presents as information the following report pertaining to classification yards:

Effect of Assisting Gradients on Drill Tracks, Ladder Tracks and Body Tracks of a Flat Yard

Switching at a yard which has its drill tracks, ladder tracks and body tracks on either a level or adverse gradient is apt to be quite slow and, therefore, expensive. The switching crew must exercise a great deal of care and judgment to give each cut of cars the proper velocity to carry it to its destination in the yard without damage to the cars or their contents, and yet not delay the succeeding switching movement. Since it is not always possible to predict the manner in which a cut of cars will run, and since many switching crews are not always careful, cars and their contents are often damaged because of rough handling or through being "cornered" by the following cut of cars.

The rate of the assisting gradient which should be given to drill tracks, ladder tracks and body tracks to obtain the most efficient operation will depend upon many factors, such as kind of cars handled, climate, prevailing winds, alinement, size of turnouts, and the extent to which proper surface is maintained. The gradient for body tracks will also depend on whether the yard is to be switched from one or both ends. It is, therefore, impractical to set up any fixed set of gradients which will be applicable to all yards with varying operating conditions and topographic limitations. At locations where the climate is not too severe, where the cars handled are ordinary cars, part loads and part empties, and where good alinement and surface for the tracks and turnouts will be maintained, the following gradients may be considered satisfactory:

Drill Track

A 0.2-percent gradient for the 300-ft. section of track which precedes the first switch, and the remainder of the track level or with a light assisting gradient.

Ladder Track

Usually a gradient between 0.2 percent and 0.3 percent. In some yards gradients as low as 0.1 percent, and in others as high as 0.5 percent, are being used. The length of a ladder track should be taken into account if an accelerating gradient is being considered.

Body Tracks

The gradient immediately following the turnout to be 0.2 percent or 0.25 percent for a distance of about 300 ft., and gradually decreasing, with a level gradient about 400 ft. long at the end of the section of track to be switched from the ladder in question.

By providing assisting gradients for drill tracks, ladder tracks and body tracks which will best suit the operating conditions which prevail at a yard, it is possible to keep switching time to a minimum, thereby reducing operating expenses and speeding up the handling of cars through that yard. Damage to cars and their contents through rough handling should be reduced. and it is also probable that fewer personal injuries will occur.

Report on Assignment 4

Bibliography on Subjects Pertaining to Yards and Terminals in Recent Publications

W. C. Sadler (chairman, subcommittee), J. C. Bussey, W. H. Giles, W. H. Goold, M. J. J. Harrison, W. W. Hay, C. H. Mottier.

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Report on Assignment 5

Locomotive Terminal Facilities

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In 1947 your committee revised the Manual section having to do with Steam Locomotive Terminals (AREA Manual, pages 14–32 to 14–32.84, incl.). In 1948 a report was submitted as information covering Diesel Locomotive Terminal Facilities (Proceedings, Vol. 49, 1948, pages 110 to 113, incl.). In 1949 a report was submitted as information covering Electric Locomotive Terminal Facilities (Proceedings, Vol. 50, 1949, pages 200 to 203, incl.).

This year a final report on Locomotive Terminals is submitted, with the recommendation that it be adopted and published in the Manual in place of the section now appearing on pages 14–32 to 14–32.84, incl. This report covers facilities for handling all three types of motive power.

[1]LOCOMOTIVE TERMINALS

1951

1. Functional Considerations

(a) In the establishment or modification of any large railway terminal, it is necessary to determine whether separate locomotive terminals should be provided for freight and passenger equipment, or whether the power for both types of service should be handled in a single facility. Convenience, expedition, low unit operating costs and carrying charges involved in both alternatives must be given proper consideration. In the case of a modification where only one company is involved, which has a locomotive terminal of adequate capacity, or one that can be readily enlarged to meet all requirements, economy will favor the retention of such terminal in service, unless it is prohibitively remote from either the passenger station or the center of freight activities.

(b) In situations where the railway terminal is joint, with two or more railways, for either passenger or freight service, or both, there are additional factors to be considered in making a decision. (1) In case only the passenger terminal is joint, it is more likely to be advisable to have it include a joint locomotive terminal handling passenger equipment exclusively, together with shops equipped to make all required running repairs, but there is no arbitrary rule to be applied. All costs involved must have exhaustive analysis and be weighed against the manifestly superior expedition, simplicity of operation, and avoidance of conflicting movements of power to and from the station to be derived under the delegated unity of control and responsibility of the terminal management. (2) In the case of a joint freight terminal, if a substantially new layout is to be

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[1] References, Vol. 33, 1932, pp. 467, 709; Vol. 37, 1936, pp. 332, 962; Vol. 48, 1947, pp. 225 879; Vol. 49, 1948, pp. 110 to 113, incl.; Vol. 50, 1949, pp. 200 to 203, incl.

substituted for several individual layouts, it may be advisable, as in the case of a joint passenger terminal, to provide a new joint freight locomotive terminal, but where existing separate facilities are merely coordinated and delegated to joint management, it will generally be advisable to rely upon the existing facilities.

(c) Disel terminal shops can be incorporated with steam locomotive facilities by remodeling or reconstructing existing structures. It may be found advantageous to utilize existing facilities and forces to the fullest extent, as economies may result from incorporating diesel and steam locomotive facilities in the same terminal. Where existing steam locomotive shop facilities are to be remodeled or reconstructed to provide facilities for the diesel locomotives also, the two areas should be separated by a fire wall.

(d) The ordinary steam locomotive facilities are not, as a rule, adequate to accommodate 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.

2. Location and Arrangement

(a) General Requirements

(1) A new locomotive terminal should be so located that provision can be made for the movement of locomotives to and from their trains with the minimum use of tracks on which there are other thoroughfare movements, the minimum of reverse or conflicting movements, and the minimum of light engine mileage.

(2) In designing a locomotive terminal layout, a thorough study of the traffic and operating requirements of the terminal should be made jointly by the engineering, operating and mechanical departments. This study should include consideration of the following data:

Type and size of locomotives to be handled.
Number of locomotives handled in each direction daily, by classes.
Schedule of arrival and departure of locomotives, by classes.
Number of locomotives arriving during peak period.
Time within which locomotives arriving must be hosteled, by classes.
Maximum number of locomotives in terminal at one time.
Number of locomotives repaired daily, by classes of work.
Number of locomotives under repair at one time, by classes of work.
Amount of fuel (coal, diesel or fuel oil) issued daily.
Amount of water consumed daily.
Amount of sand consumed daily.
Number of men required to operate the terminal.

(3) A locomotive terminal should be designed not only for present requirements but also with provision for future expansion.

(4) The locomotive terminal must be coordinated with all other facilities so that the movement of each locomotive may be made orderly and expeditiously from the time it is detached from its train in the yard or at the station, serviced, and again attached to a train.

(5) The required servicing facilities should be provided and arranged in the sequence in which it is desired that incoming and outgoing locomotives be served by them.

(6) Separate facilities may be required for the various types of locomotives.

(b) Site

The selection of a proper site requires a study of all factors affecting costs of construction and operation, including:

(1) Land value.
(2) Cost of preparing site.
(3) Foundation conditions, drainage, sewage disposal, water supply, electricity.
(4) Relation to existing or proposed yards and to passenger and freight stations.
(5) Labor supply, including housing facilities and transportation.
(6) Availability of public fire-fighting apparatus and stations.

(c) Track Layout

(1) The layout should be arranged for all locomotives to enter the locomotive terminal from the same end, but a separate exit should be provided for additional flexibility in movement and to insure that the terminal will not be tied up in case of derailment or other trouble at the main entrance.

(2) Entrance tracks should be so located and of such capacity as to permit the prompt receipt of locomotives immediately on arrival, with space between those which may have to wait their turn for servicing. Steam locomotives requiring different types of fuel may be routed over different tracks between the entrance and the turntable. Where climatic conditions permit outside storage, sufficient tracks should be provided near the exit for holding locomotives already prepared for service.

(3) The layout should provide for the orderly movement of locomotives without reverse movement, with at least one runaround track to provide flexibility.

(4) Crossovers should be so arranged that yard locomotives, or others, which do not require turning, may be serviced without crossing the turntable.

(5) All approach and departure tracks to and from the turntable should line across the table with enginehouse tracks to permit convenient movement of dead locomotives or carloads of supplies into or out of the enginehouse.

(6) Sufficient tangent should be provided on all turntable approach tracks to permit all engine trucks to be on straight track before passing onto turntable.

3. Enginehouse

(a) General Considerations

The preferred form of enginehouse will depend largely upon the type or types of locomotives to be housed. The circular form is preferable, under ordinary conditions, for steam locomotives. Diesel and electric power can be handled best in a rectangular house. Other special conditions may make a rectangular house desirable, such as restricted location, small number of locomotives handled, greater ease of providing a "Y" than a turntable. At shops where a transfer table is used, a rectangular enginehouse served by the transfer table may be desirable.

(b) Steam Locomotives

The length of stall along center line of track for steam locomotives should be at least 20 ft. greater than the overall length of the locomotive and tender, so as to provide a trucking space 10 ft. wide in front of the pilot, and space in which to detach the tender and provide a walkway between it and the engine without opening the door. The stall angle of a circular enginehouse should be such that when extended beyond a half circle the pit tracks will line up across the turntable. Radial stub end tracks on the side of turntable opposite the enginehouse, and in line with the pit tracks, are sometimes desirable.

(c) Shop Building for Diesel–Electric and Electric Locomotives

(1) 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.

(2) The construction employed should be fire resistant.

(3) The number and length of tracks should be sufficient to accommodate all of 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.

(4) 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.

(5) 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.

(6) Fire protection facilities should be provided and so arranged as to permit complete protection coverage of the shop and terminal structures.

(7) All 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.

(8) 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.

(9) The pits should be of adequate length to accommodate the longest assembly of locomotive units.

(10) It is desirable that the elevation of the shop floor between the pit tracks be 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.

(11) Where required, facilities should be provided in pits for the melting of snow and ice on the running gear of 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.

(12) In shops where screw or hydraulic locomotive jacks will be used to raise the body of the 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.

(13) A drop table which will permit the replacing of a complete truck or a single pair of wheels should be provided, and should be so arranged as to permit moving the trucks or wheels to and from the machine shop or truck storage track.

(14) To permit repair work along side the tracks in the shop, elevated platforms are provided, with the surface of the platforms at the approximate elevation of the floor of the

locomotive body. 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 the top of pit rail of 4 ft. 10 in., will provide good working space. Some diesel locomotives have removable hatches for access to motor heads. Repair work at this level is facilitated by providing a second tier of high platforms at locomotive roof level.

(15) The elevated platforms should be constructed of fire-resisting material. Each of the running repair tracks in the shop should be provided with an elevated platform. The platforms should be of such length as to accommodate the longest of the diesel locomotives. The desirable minimum width of a platform serving two tracks is 12 ft. As a safety measure, the platforms should be equipped with removable railings.

(16) To permit the handling of engines, generators and heavy parts, overhead traveling cranes are provided to carry parts to and from the areas set aside for repair purposes. Clearance below the crane bridge should be sufficient to handle the parts to the desired location. A 25-ton to 30-ton crane with a 50-ton auxiliary hoist is desirable. Smaller cranes of 2 to 5 tons capacity have been found ample for running repair shops.

(17) The machine shop, in which is placed the necessary tools and machines for making the required repairs to the diesel engine units, should be located adjacent to the repair shop. Hoists, ranging from ½ ton to 1½ tons capacity, will facilitate operations in the shop.

(18) Wheel supply and storage facilities adjacent to the repair shop should be provided to assure a convenient supply of wheels for repair purposes. Facilities should be provided to store pairs of wheels with their traction motors attached.

(19) A room equipped with benches, tools, rack and trays for necessary reconditioning of the various parts should be provided convenient to the machine shop and adjacent to a room equipped with tanks, rinsing trays, drying trays, and racks for the cleaning of parts.

(20) The tanks for new lubricating oil should be of sufficient size to handle oil in carload lots. Tanks will be required for new oil (usually two), worn and dirty oil, and reclaimed oil.

(21) Pumps of the desired size and capacity, equipped with bypasses and explosion-proof motors with remote or pressure-operated switches, should be provided for handling the oil.

(22) The lubricating oil facilities may be housed in the repair shop proper or in a separate structure. Fire-resistant construction should be employed. Meters should be provided to measure accurately the lubricating oil delivered to the units. Facilities may be provided for reclaiming worn and dirty lubricating oil.

(23) A lubricating oil piping system should be installed so that outlets are available at the engine room door locations, either above or below the elevated platform level in the running repair shop. A drain line should also be installed from these locations to the dirty oil tanks for convenient draining of the locomotive crank cases.

(24) Locker, wash and toilet room facilities for employees should be installed adjacent to the repair shop area.

(25) At electric locomotive terminals the electric trolley and high-tension conductors should be terminated outside the shop building.

4. Turning Facilities

(a) Unless the locomotives to be handled are exclusively of the diesel or electric type with operating controls at both ends, some form of turning facility, such as a turntable, a balloon or loop track, or a wye track, must be provided.

(b) Turntable

(1) The use of a three-point turntable is preferable. If a balanced-type table is used, it should be long enough so the locomotive can be balanced when the tender is empty. In some cases the life of the old balanced-type turntables may be extended and economy effected by converting them to the three-point bearing type.

(2) A deck turntable is usually more economical, but in the balanced type a through table may be desirable where the use of a deck structure would greatly increase the cost or make satisfactory drainage difficult.

(3) Mechanical power for operating turntables should be provided. Where current is available, electricity is the most reliable means of operating. The power wires may be led to the table either overhead or underground, care being taken to minimize the danger of interruption of supply in case of fire, storm, inadequate drainage or other emergency. Where electric power is not available, a compressed air motor may be used.

(4) The deck of the turntable should be wide enough to provide a walk on each side, and should be protected with hand rails.

(5) The turntable pit should be paved and adequately drained.

(6) The circle wall preferably should be of concrete masonry, with proper supports and fastenings for rails on the coping. A timber or steel coping is preferable to a rigid concrete masonry coping.

(7) The circle rail preferably should be supported on a concrete base, with the load properly distributed by ties, plates, or castings.

(8) Easy access to the parts of a turntable, for the oiling of bearings, painting, and inspection, should be provided in the design of the pit, unless ample provision is made in the turntable itself.

(9) Thorough lubrication, systematic cleaning of both table and pit, and careful inspection at regular intervals, are essential to satisfactory operation of a turntable. The table should be raised and the center thoroughly inspected at least once a year.

(10) Radial tracks should be kept in good line and surface. Radial track and turntable rails should be maintained with proper spacing between their ends, and at proper relative elevation.

(11) Some mechanical means of locking the turntable in line with a radial track should be provided.

5. Servicing Facilities

(a) Coaling Stations

(1) Coaling stations should be located to serve as many locomotives as possible on their regular routes. There are two general locations for coaling stations: those at enginehouse leads at terminals, and those adjacent to main tracks between terminals. At terminals, coaling stations should be located to serve both inbound and outbound tracks as recommended for the engine terminal layout.

(2) Coaling stations can be arranged readily to deliver coal on one or more tracks. Each location should be studied separately and the most suitable track arrangement for that particular installation selected.

(3) Complete information on the design of coaling stations may be found in Chapter 6—Buildings.

(b) Fuel Oil Stations

(1) General

Fuel oil stations should be located to serve as many locomotives as possible on their regular routes, either in the locomotive terminal or on the main tracks.

Where oil is used as fuel for steam locomotives, the facilities required include those for unloading it from cars, for holding it in storage, and for delivering it to locomotive tenders. Fuel oil for diesel locomotives requires similar facilities. To keep an accurate inventory of the oil received, disbursed and on hand, meters should be provided for all the operations. Strainers in the line from the tank car delivery point to the storage tanks, and filters in the delivery line to the locomotive, are necessary to prevent foreign matter entering the locomotive fuel tanks.

The details of design necessarily vary with the composition and gravity of the oil to be used and the climatic conditions to be encountered, as these affect the temperature which must be maintained in the oil for convenient handling.

Fire protection for the entire fuel oil station is desirable and an automatic chemical or water fog system may be installed.

(2) Unloading Facilities for Steam Locomotives

Fuel oil for steam locomotives should be unloaded from tank cars by discharging directly into a trough or boxes of steel or concrete between the rails of the track on which cars stand for unloading. Where boxes are used they should be spaced at car-length intervals for convenience in spotting cars for unloading. The trough or boxes should be equipped with metal covers, and kept closed when not in use. The unloading facilities should be located on a track assigned for this purpose, preferably at some distance from buildings or other tracks, so that it will be unnecessary for locomotives to pass over them. While tank cars are being unloaded a sign warning against disturbing them should be posted between the first car and the switch.

The unloading trough or boxes should deliver oil by gravity through a pipe line to a depressed sump, from which it may be pumped to a storage or delivery tank. Such pipe line should be of sufficient size and be laid with sufficient grade so that the oil will flow by gravity to the sump as fast as it will be discharged from the total number of cars which will be opened at any time. This should not be in excess of the capacity of the pumps.

Sumps may be of steel or reinforced concrete and should be covered. They should have a capacity of not less than one carload. If of steel, the pits in which they are located should be drained or the sump should be anchored to prevent displacement by ground water when empty. The sump should be vented to draw off gases generated by heating oil in the sump tank, and, in some circumstances, it may be desirable to install an oil trap or barrier in the pipe line leading from the sump to the track trough or box to prevent the flow of gases from the sump to the track trough or box.

(3) Unloading Facilities for Diesel and Electric Locomotives

Fuel oil for diesel and electric locomotives can be unloaded from tank cars by gravity, pumping, or air pressure, subject to restrictions. It is desirable to unload tank cars from the top. Discharge lines should be of ample size to unload the tank cars in a reasonable time. Where a pump is used it is important to install a strainer in the suction line.

(4) Pump House

Pumping facilities should be installed in an independent pump house, together with the metering and filtering equipment. This pump house should be of fire-resistant construction and provided with heating facilities when necessary. All electrical equipment, controls and wiring should be of the explosion-proof type.

(5) Storage

The storage capacity which should be provided depends largely upon the reliability and source of supply, and probable variations in the market price of oil. In general, there should be at each station sufficient storage to protect against any interruption which may occur in the delivery from the regular source of supply. Additional storage for the purpose of taking advantage of variations in market conditions may either be located at various terminals where oil is used, or concentrated at one convenient point.

Cylindrical steel tanks of large capacity, erected on leveled earth foundations, provide convenient and economical storage, and can commonly be obtained promptly and at less cost because they are standard construction with tank manufacturers. Roofs should be provided of steel, or of wood frame and sheathing, covered with asbestos, composition, tar and gravel, or sheet metal. In permanent installations, or where oil having large gasoline content is to be handled, gas-tight steel roofs equipped with breather pipes having outlets outside the dike, and floating roofs, have the advantage of reducing evaporation of gases and danger of fire. Each tank should be surrounded with a dike, enclosing below the elevation of the top of the dike a volume equal to 1½ times the capacity of the tank. Where a specified type of construction is used, designed to minimize splashing and wave action, the capacity within the dike may be reduced. In localities where ground areas are limited, underground tanks of steel or concrete may be used.

Adequate means should be provided for the escape of gases evaporating from the surface of the oil. The character and extent of such provisions required will depend on the tightness of the roof and the character of the oil. They should be designed to reduce the circulation of air over the surface of oil to the minimum consistent with means of precluding the generation of pressure due to the accumulation of gases.

Provision should be made for draining off water and refuse which may settle in the bottoms of storage tanks.

(6) Delivery

Oil may be delivered to locomotives or tenders by gravity from elevated steel tanks, or under direct pump pressure. If the gravity system is used, particular attention should be given to the introduction and proper location of cutoff valves in the delivery lines so that the flow of oil from the tanks can be immediately controlled.

The size of delivery tanks required varies with local conditions as to the receipt and handling of oil, but the capacity should, in general, be not less than the average amount of oil to be delivered in 24 hours.

Valves should be provided for draining off water and refuse which may accumulate in the bottoms of delivery tanks.

Meters should be provided in delivery pipe lines for accurately measuring deliveries of oil.

Some wastage of oil around an engine terminal is inevitable, and provision which will reduce such wastage to the minimum is an important item in the design of the facilities for handling oil. If all unnecessary waste and leakage are eliminated, the cost of recovery of waste oil is generally in excess of the value of the oil. Where such waste is excessive or becomes a nuisance, and causes damage to neighboring property, it becomes necessary to provide traps in drainage channels or sewers, equipped with baffles, to catch the waste oil, separate it from water, and permit its recovery.

For steam locomotives, delivery columns should be so constructed that the spout can be swung to position and the valve opened from the locomotive or tender to be served. Spouts should have maximum freedom of movement in both horizontal and vertical directions, consistent with the prevention of leakage. They should be provided with a drip bucket, reversible end elbow, or other means to prevent drip.

For diesel locomotives, a section of hose to which is attached a pressure-type fuel nozzle having a quick-acting coupling fitting for connecting to the locomotive fuel tank is desirable. This hose should be connected to the fuel oil line either on a fueling crane or in a box. Fueling cranes consisting of a fixed vertical structural support, to which is attached the fuel oil delivery pipe, may be located so as to serve multiple-unit locomotives without moving the locomotive. The vertical fuel oil delivery pipe should be of suitable height and should have the fueling hose connected by a swing-type fitting. Where underground boxes are used they should be large enough to accommodate the fueling hose when not in use.

(7) Heating

Where heavy oil is used, or where low temperatures are experienced, it is necessary to provide means for heating oil in cars, tanks and pipe lines, in order that it will flow freely. Such heat is best provided by steam pipes.

Pipe coils in tank cars, which can be readily connected by flexible hose or pipe to steam pipe lines from the pump house, provide satisfactory means for heating before unloading. The discharge of live steam directly into the oil in the car may be resorted to in case heating coils are out of order or the car is not equipped with coils.

Similar steam pipe coils provide satisfactory heat for storage and delivery tanks. In the larger tanks they are more effective if enclosed with the end of the discharge line leading from the tank in a wood box so that the heat will be applied directly to the oil as it leaves the tank, and not disseminated through the whole tank full of oil. The heating of oil in pipe lines will often prove advantageous and may be accomplished by the introduction of small steam pipe lines inside the oil lines, or by enclosing the steam line inside an insulating box, along side the oil line. The latter method simplifies construction and maintenance, but requires a more extensive first installation and greater consumption of steam in proportion to the results obtained.

Where steam lines are installed in oil lines, it is necessary to take precaution against excessive heating. On this account, the steam line should not be larger than necessary for heating the pipe line. Steam for tank coils and other purposes may better be carried outside the oil lines.

(8) Small Fuel Oil Stations

While the foregoing recommendations apply primarily to the larger stations, the general principles involved apply to the small stations, except that their application requires special adaption to the problem. In some cases the oil is used direct from the cars, in other cases storage from one or more cars is combined with delivery tanks, delivery being made by gravity, pumps or air pressure.

(9) Fuel Oil Stations for Electric Locomotives

Electric locomotives require a supply of fuel oil for the boilers used to generate steam for train heating. The stations and methods of delivery for this type of motive power will conform in general to those for diesel locomotives, but will vary in size according to the individual requirements.

(10) Mobile or Fixed Auxiliary Facilities

At yards and terminals and along the line of road where diesel power is used, it is often necessary to install a fixed auxiliary fueling station or to utilize mobile servicing facilities. In some of the larger terminals, outlying auxiliary servicing points substantially increase the productive time of yard engines. The stations and methods of delivery should conform in principle to the requirements outlined in the foregoing recommendations.

(c) Sanding Facilities

From an operating standpoint it is desirable to supply locomotives with fuel and sand at the same time, but for diesel locomotives separate facilities are advisable to prevent mixing sand with the fuel oil. The specifications should provide for the requirement of unloading, storing and drying of green sand and for the elevating, storing and delivery of dry sand to locomotives. Complete information on the design of various types of sanding facilities may be found in Chapter 6—Buildings.

(d) Water Facilities

Sufficient watering facilities should be provided to serve all locomotives entering and leaving the terminal.

(e) Cinder-Handling Facilities

Methods of disposal of locomotive cinders may be conveniently grouped in the following types:

(1) Cinders discharged directly on the track and removed by shoveling. This method is used at points where a few fires are partially cleaned between terminals.

(2) Shallow shovel pits, with rails supported on noncombustible walls, metal ties or pedestals, with or without adjoining depressed track for standing cars into which cinders are to be loaded.

(3) Water pits, where cinders are discharged into pits nearly full of water, from which they are removed and loaded into cars by clamshell bucket operated by locomotive crane or overhead crane.

> Water pits are of two classes:
>
> Shallow pits, which extend longitudinally between the rails of one track, the cinders being loaded by an overhead traveling or gantry crane into cars on an adjoining track.
>
> Deep pits, which extend between and serve adjoining tracks, or along side a single track. They may be long enough to serve two or more locomotives in line, or more nearly square or circular in shape, serving only one locomotive on each track.

(4) Mechanical plant where cinders are discharged into hoppers and thence into buckets or continuous conveyors. The buckets or conveyors are power operated and empty directly into cinder cars. This type has the advantage of comparatively low cost of installation and operation in proportion to its capacity and efficiency. A single bucket or conveyor may serve several tracks. These are suitable for either large or small terminals.

(f) Track Arrangement for Cinder-Handling Facilities

The following featuress hould be provided wherever possible:

(1) Sufficient track standing capacity to accommodate all engines which cannot be immediately serviced.

(2) Crossovers or other track connections to open yard or running tracks so that preferred attention may be given to any engine regardless of its time of arrival, and so that cinder cars may be switched with minimum interference with the movement of engines over the pit.

(3) Except at minor terminals, two or more tracks over the pit.

(4) Sufficient track space beyond the pit to enable the pit to be cleared of engines regardless of all other terminal work, particularly operations at the turntable.

(5) Track connections between the pit and the turntable to allow engines to proceed outbound without using the turntable.

(g) Inspection Pits

(1) Inspection pits are usually located on the inbound track near the entrance to the terminal. The pit should be of suitable depth for inspection of the locomotives to be

handled and of a length not less than the longest locomotive to be inspected, and provided with ample drainage.

(2) Convenient access should be provided by a stairway. In some instances, direct access has been provided from the inspector's office by a tunnel.

(3) Fixtures should be provided for general lighting, and service outlets for extension-cord attachments for detail inspection.

(4) A telephone should be provided for communication with the enginehouse, and may be supplemented by the installation of a pneumatic tube system for sending reports to the enginehouse.

(h) Locomotive Washing Facilities

(1) The washing platform should be located between the cinder pit and the turntable, since the locomotive should not be washed until after the fires have been cleaned.

(2) At important terminals where locomotives are washed, platforms between and outside the rails should be provided for drainage purposes and for the use of workmen. The platform should be of permanent construction with a top surface that can be readily cleaned. The surface of the platform should be approximately level with the top of rail.

(3) The platform should be of sufficient size to provide drainage and to accommodate the men cleaning the locomotive. The platform should extend a minimum of 7½ ft. from the center of track. Where the washing is done on adjoining tracks, the platform should be continuous between the tracks. The platform should be approximately 10 ft. longer than the longest locomotive and its tender.

(4) The platform should be adequately sloped and should have a sufficient number of openings leading to a drain in order to remove waste water from the platforms as rapidly as possible. A catch basin or basins should be provided to keep dirt out of the drainage system. In case oil is used in the cleaning process, it is desirable to provide some means of preventing the oil from entering the drainage system, and possibly to provide an arrangement for reclaiming it.

(5) At terminals where the washing of locomotives is done at night, the platforms should be adequately lighted.

(6) If a stationary machine is used in the washing process it should be housed. At terminals where a portable machine is used it may be housed in the enginehouse or some other convenient building.

(7) Where oil is used in the cleaning process and where the amount of cleaning warrants, a storage tank should be provided and the oil piped directly to the machine. Otherwise, the oil may be kept in barrels or drums and delivered by hand to the machine.

(8) An engine laundry drainage system can be designed with a depression between the rails so it can also be used as a blowoff pit when the number of engines serviced and method of servicing will permit.

(9) For diesel and electric locomotives, 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.

(i) Blowoff Facilities

(1) At some engine terminals the number of engines serviced and the manner of servicing is such that separate blowoff pits are required. These may be located between the engine laundry and the turntable, or on the outbound engine lead.

(2) The blowoff pit should be of a permanent type of construction and be provided with sufficient drainage. The size of the pit should be such that water, condensed steam and sludge will not overflow.

(j) Facilities for Locomotives in Turn-Around Service

At the ends of 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, sanding, and for filling tanks with oil and water where locomotives have heating boilers. Inspection pits also are sometimes provided.

6. Miscellaneous Facilities

(a) Office

Adequate office facilities should be provided for the officer in charge of the terminal and his staff.

(b) Service Buildings

One or more structures should be provided at a convenient location to house the following:

Locker, toilet and washrooms for employees
Flagging equipment and supplies
Buildings used for storing oil and lanterns should be of fire-resistant construction.

(c) Communication Facilities

Adequate telephone or other communication facilities should be provided.

(d) Lighting

Lights should be so located as to facilitate the servicing and turning of locomotives, without throwing a glaring light into the eyes of the enginemen.

(e) Fire Protection

(1) Fire hydrants with hose houses and equipment should be located at various points within the terminal, so as to permit the use of at least two streams of water on any structure.

(2) Water mains and hydrants should be located with due regard to future expansion of the terminal.

(3) Water mains should be built in loops, if practicable.

(4) The terminal should be equipped with chemical extinguishers conveniently placed to afford protection, especially against oil and electric fires.

(5) A fire road should be provided to furnish access to fire-fighting facilities and to all buildings.

7. Repair Shops

(a) Repair shops should be located at terminals where bad order equipment can be moved to them over the shortest convenient routes from various parts of the system.

(b) Information on the design of shop buildings and appurtenances will be found in Chapter 6—Buildings.

Report on Assignment 7

Design and Typical Layouts of Air Lines in Freight Yards

F. A. Hess (chairman, subcommittee), M. H. Aldrich, F. E. Austerman, W. O. Boessneck, W. S. Broome, K. L. Clark, R. J. Coffee, Oscar Fischer, W. H. Giles, J. E. Griffith, E. E. Hammond, L. C. Harman, B. Laubenfels, J. L. Loida, C. F. Parvin, J. L. Perrier, R. B. Rhode, M. S. Rose, R. A. Sharood.

This is a final report, submitted as information.

This report outlines the reasons for having air lines for charging trains in freight yards; operating procedure; requisites of an air line; factors governing design; and describes typical air line layouts in freight yards.

Rules governing the dispatching of freight trains from terminal yards require that the air brakes on cars, except in special cases, be in effective operating condition. The procedure for charging, inspecting and testing air brakes is covered by Association of American Railroads, Operation and Maintenance Department, Mechanical Division regulations pertaining to the maintenance of Brake and Train Air Signal Equipment, adopted as standard in 1925, and subsequently revised, and the rules of the individual roads. The AAR rules were formulated jointly by the Bureau of Safety of the ICC and the Safety Appliance Committee of the Mechanical Division, AAR.

After a freight train is assembled the air brake system must be charged to the required pressure, followed by a car to car inspection of the system. For freight trains the train line pressure on the various roads ranges from 70 lb. to 90 lb. Passenger trains require a minimum pressure of 110 lb., and a freight yard air line would not be suitable.

The train may be charged and tested from a yard air supply or by air furnished from a locomotive. If charged by the road locomotive. the train lines are brought to the required pressure, an inspection is made of the brake system along with performing any necessary repairs or adjustments, followed by brake application and release tests. These operations require a considerable amount of time, probably an hour or more, depending on the length of the train being handled. If defects are discovered which require repair, or possibly setting out of a car, the time involved may increase appreciably. This results in lost time in locomotive service. The use of yard air lines permits the later calling of crews and dispatchment of locomotives.

When a train is charged from a yard plant, an engine brake valve or similar device is used in performing the brake tests. If the latter is used it must provide for the increase and reduction of brake pipe pressure at the same or a slower rate than can be accomplished by an acceptable engine brake valve. It is preferable, but not mandatory, that the charging connection and the brake testing device be applied at the same point in the train at which the locomotive is to be attached. When practicable, a train charged and tested from a yard plant should be kept charged until the road locomotive air supply is connected.

When a train has been charged and tested from a yard plant and kept charged until the road engine is coupled on, the outgoing engineman must, on signal, apply the brakes and judge by the length and force of brake pipe discharge whether there is open communication through the train air line; also note that the leakage does not exceed the requirement for the specified period of time, with brake valve in lap position. The car inspector, or a train crew member, must note that the brakes on the rear car of the train apply, and then signal for release, observing that the rear brakes release properly.

When a train has been charged and tested from a yard plant and is not kept charged until the road locomotive is coupled on, the train, after coupling of the locomotive, must be charged to the required pressure and the brakes applied as outlined above. An examination must then be made of the brakes on each car to determine whether proper application is made. When this examination is completed, a release signal is given and each brake examined to see that it releases properly.

Requisite of a Properly Designed Air Line for a Freight Train Yard

The requisite of a properly designed air line is to provide stabilized air in sufficient volume at a specified pressure at all outlets. This requires:

(a) A compressor of suitable capacity.
(b) Efficient after-cooler.
(c) Adequate primary air receiver.
(d) Efficient condensate trap.
(e) Proper reducing valve.
(f) Adequate secondary air receiver.
(g) Well designed pipe line.
    (1) Balanced location.
    (2) Adequate size.
    (3) Securely fastened.
    (4) Necessary expansion joints.
(h) Adequate number and size of yard volume air receivers and reservoirs.
(i) Proper type and location of service outlets.

The air compressor, of suitable capacity should, preferably, be electrically driven. When a separate compressor is provided for a yard system it is preferable to discharge through a receiver at about 100 lb. pressure and to regulate the pressure in the yard line by means of reducing valves.

The after-cooler reduces the temperature of the air discharged from the compressor and provides a very effective means of removing moisture from the compressed air. It should be of ample cooling capacity for the volume of air delivered by the compressor.

The air receiver should be of suitable size and equipped with safety and drain valves. This receiver serves as storage for air discharged from after-coolers and absorbs discharge pulsations. It is often desirable to insert a reservoir in a long supply line or at the end of a supply line. In addition to collecting moisture, these tanks also afford some reserve air supply. The air lines connecting the compressor, after-cooler and main receiver should be of ample size.

If a compressor furnishes air for tools and equipment, the air is generally supplied at higher pressures than allowable in the train lines. The train should not be charged to a higher pressure than the established pressure provided by the locomotive reduction valve. Overcharging will not permit release of the brakes following a test application, and requires manual bleeding of the brake cylinders, with considerable loss of time.

When pressure greater than the established train charging pressure is generated by the compressor, pressure in the yard line should be regulated by pressure reducing valves. As most types of pressure reducing valves also restrict the volume of air flow, it is usually necessary to use a valve of larger size than the main supply line, or to place several valves in parallel following the receiver tank at the compressor.

While the conventional angle cocks are preferable at the outlet stubs along the tracks, the usual type of air gate valve is desirable in the supply lines. These valves should be inserted at suitable points along the supply system for the purpose of shutting off sections of the line or certain of the units in the system.

It is desirable to provide a moisture separator and automatic drain trap near the compressor and manual blow-downs along the supply line, the number required being dependent on the volume of air consumed and local condition of the atmosphere. It is also desirable to provide a small box or pit for these devices in order that they can be inspected readily and the accumulated condensate discharged. The supply lines are usually laid to conform with the elevations of the tracks. If there are any low sections in the supply pipe, moisture separators should be located at these points.

There are two general schemes for the location of air lines in freight yards of the usual track layout, with ladders at both ends of the tracks. The preferable location is a system of piping providing air connections a short distance behind the clearance points of the tracks at the departure end of the yard. In cases of yards dispatching trains in both directions, the air connections should be located toward the end from which the majority of trains depart. Rear end charging and testing is acceptable and nearly as efficient in operation as the front end procedure.

The second choice of location is a straight supply line across the yard at approximately the center, between ladders. This provides a simple pipe line system which can be constructed at minimum expense. In a long yard with a preponderance of movements in one direction, the center charging and testing of trains involves some lost time for the inspectors, with resulting delay in reaching and preparing other trains.

The transverse pipe lines are generally laid with the top of the pipe at or below ground level. The longitudinal pipe lines may be carried below ground or on top of the ties adjacent to the outside of the rail. Pipe at or near the yard surface is exposed to the action of the elements, brine, cinders and accidental damage. On the other hand, the piping is open to visual and audible inspection, which are probably the most satisfactory means of detecting leaks and defects in the air lines. When the air lines are buried, a satisfactory depth for air pipes is slightly below the bottom of tie. Pipe can be laid at this depth without excessive added expense. Generally, lines can be laid at right angle to the tracks where they cross, and between the ties, rather than directly under the ties. With a minimum of care during relaying, renewing and spacing of ties, this relative position of ties and pipe line can be maintained. The excavation adds to the cost of the pipe installation, but this is offset by the protection afforded from mechanical damage. In cinder ballast the pipe can be protected by providing sand, crushed stone or similar backfill, and treating the pipe with commercial coatings and wrapping materials.

Pipe lines in railroad freight yards, either at the surface or underground, may be exposed to electrolysis, and to corrosive material such as cinder ballast or brine from cars, along with ordinary oxidation from ground moisture. For long service with minimum attention, the use of double-strength wrought iron pipe is most economical. If the pipe is to be treated, consideration should be given to the use of black pipe.

The size of the main supply line depends on the length and number of trains to be charged at any one time. The connecting stubs ordinarily should be of 1¼-in. pipe to match the conventional train line angle cock. The outlets should be located between the rail and the ends of the ties where they are easily accessible. A single outlet between each pair of tracks may be sufficient; however, double connections may be required, as illustrated in Fig. 1. A section of air hose fitted with quick connectors at each end is furnished at each outlet. The car men usually employ a short length of regular air hose, fitted with a quick connector on one end and a standard air coupling at the other, for making the connection to the train line, along with other essential apparatus for testing the brakes.

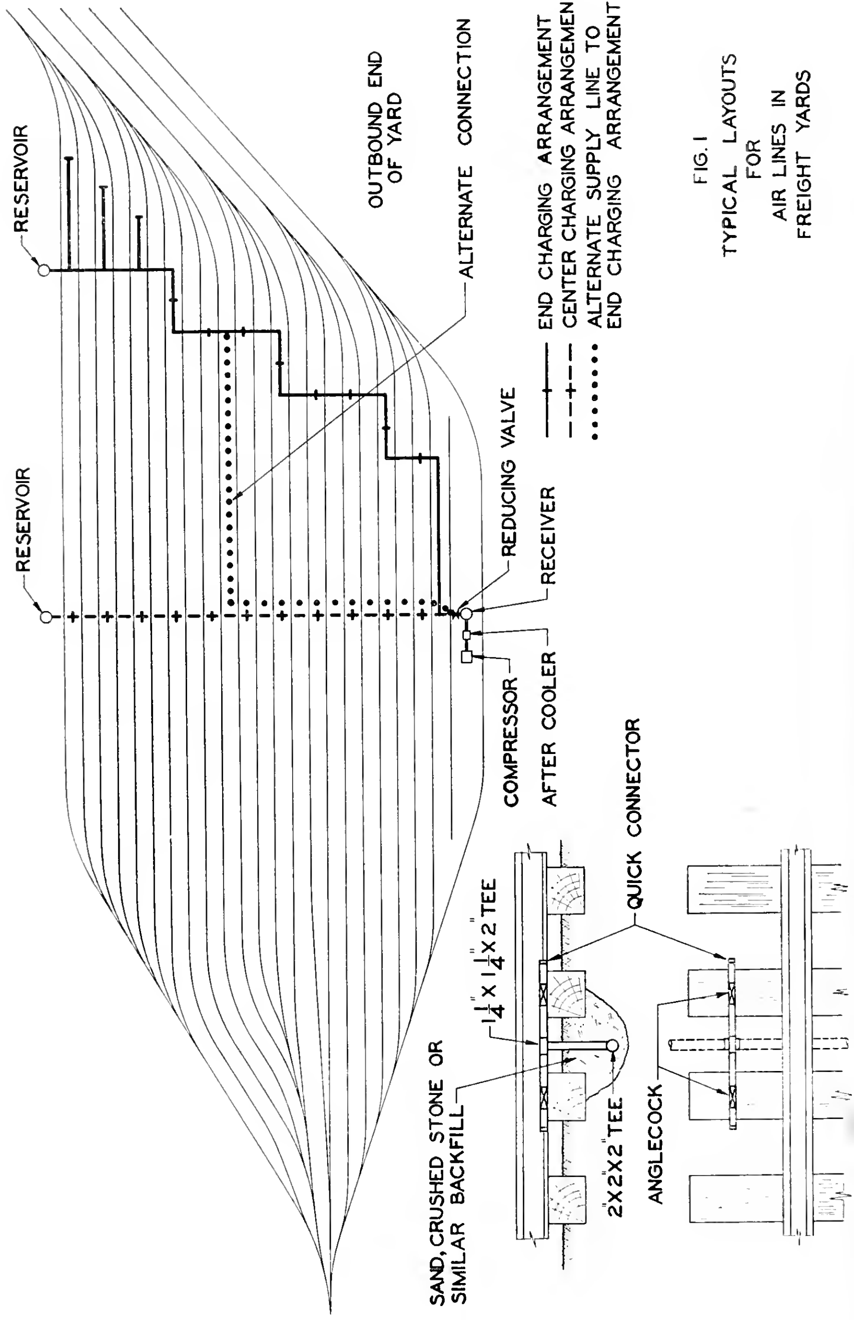

FIG. I
TYPICAL LAYOUTS
FOR
AIR LINES IN
FREIGHT YARDS

In establishing the size of the main supply line several factors should be considered. including length of pipe, required charging pressure, number of cars that can be assembled on the yard tracks in making up a train, and the number of trains that will be charged simultaneously; also, the time in which it is desired to charge the trains completely.

All cars are, or soon will be, equipped with the "AB" type brake control and air cylinder, which, together with the train line, will have a total volume of approximately 4 cu. ft. per car. On short trains and under favorable conditions about 7 min. are required to bring the train line pressure up to 80 lb. On long trains and under certain conditions the period required to charge the train line may increase to one hour or more. On long trains the 1¼-in. train line, together with air hoses, fittings and angle cocks, offers considerable resistance to the flow and distribution of air to the brake valves and cylinders along the line.

Where the compressor can be located reasonably close to the yard track outlets, a 2-in. to 3-in. main pipe line is usually ample; the size depending on the length of line and the number of trains to be charged at one time.

In many cases a compressor is required to serve other facilities along with the yard air system, and it then becomes necessary to determine the requirements of the other tools and equipment, which are often operated intermittently. It may be desirable to provide a compressor for the sole purpose of supplying air for charging trains.

The same factors considered in determining the size of the yard supply line should be used in arriving at the required capacity of the compressor. A compressor with rated capacity of 200 to 300 cu. ft. of free air per min. at a pressure of 100 psi. or greater, is generally adequate. The installation can be arranged to operate automatically with minimum attention. The air-cooled machine available in the smaller capacity compressors avoids the need of cooling water.

Typical layouts are illustrated in Fig. 1.

Report on Assignment 8

Design of the Track Layout and Gradients in Connection with Scales Located on the Hump of a Classification Yard

This is a final report, submitted as information.

W. H. Goold (chairman, subcommittee), C. J. Astrue, A. E. Biermann, N. C. L. Brown, W. H. Giles, E. D. Gordon, H. J. Gordon, M. J. J. Harrison, D. C. Hastings, F. M. Hawthorne, F. A. Hess, L. L. Lyford, C. E. Merriman, C. H. Mottier, B. G. Packard, C. M. Ratliff, W. B. Rudd, J. N. Todd.

The report on this assignment in the Proceedings, Vol. 51, 1950, page 190, refers to the assignment in its entirety. The primary purpose of this present report is to develop further information pertaining to gradients, and any restatement of what has been previously reported is limited to what falls within that scope.

Where motion weighing on a hump is justified, the problem is related to one of three categories:

1. The car rider yard (see Fig. 1).
2. Retarder yard without retarder above the scale (see Fig. 2).
3. Retarder yard with retarder above the scale (see Fig. 3).

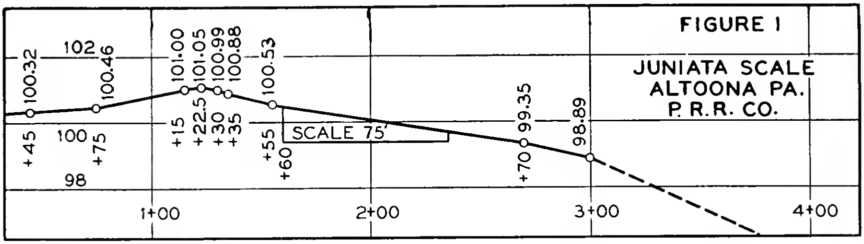

FIGURE 1

JUNIATA SCALE
ALTOONA PA.
P. R.R. CO.

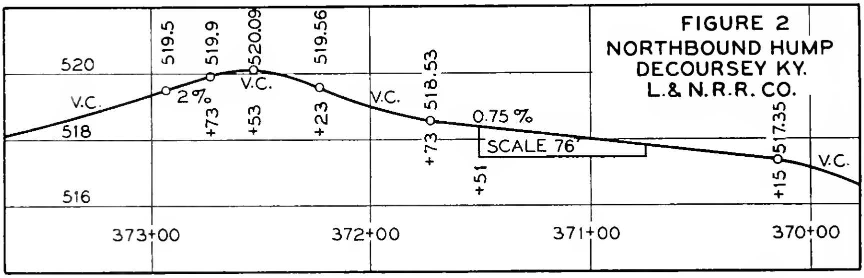

FIGURE 2
NORTHBOUND HUMP
DECOURSEY KY.
L.& N.R.R. CO.

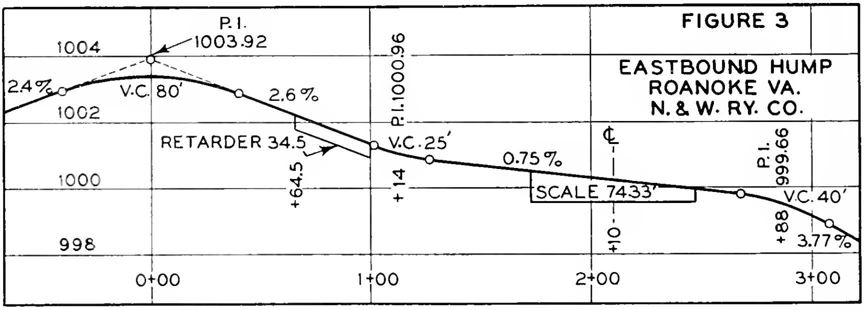

FIGURE 3

EASTBOUND HUMP
ROANOKE VA.
N.& W. RY. CO.

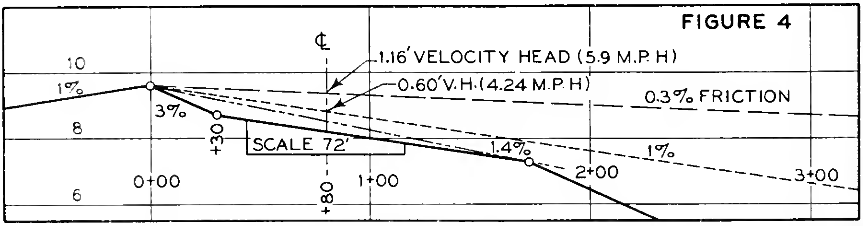

FIGURE 4

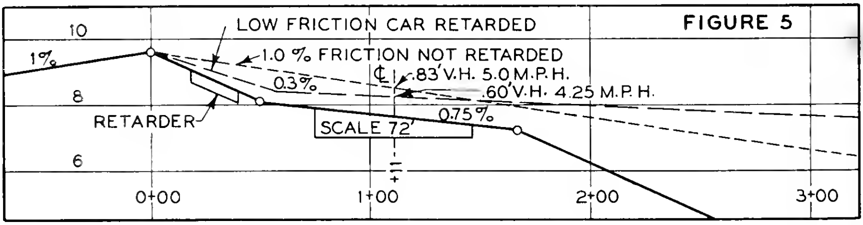

FIGURE 5

In all three cases the weigh rails proper, and preferably one car length in each direction, should be on tangent. Dead rails are normally provided, and when used, the distance from end of scale to point of switch should be as short as possible. To accomplish this, a distance of 12 in. center to center for the two tracks should be considered.

Design of gradients for motion weighing, either with or without retarders, normally involves too many variables to permit a direct solution. Instead, a tentative profile should be laid out and investigated with respect to various operating criteria. Modifications are then made to adjust the operating characteristics to the requirements.

In designing gradients for motion weighing on a hump it is necessary to give consideration to the following:

1. The requirement of a 4-sec. minimum weighing time per car.
2. The car must be uncoupled and alone on the scale during the weighing operation.
3. The gradient of weigh rails.
4. Approach gradient to weigh rails.
5. Maximum and minimum wheelbase of cars.
6. Prevailing winds.
7. Climatic conditions.
8. Physical conditions limiting elevation or location of apex of hump.
9. Distribution of loads and empties in train.
10. Maximum humping speed.

Due regard having been given to what is set forth in the foregoing, the design in question can be effected by the following procedures:

The prime purpose of any hump gradient is to provide energy to carry cars to clearance, and approach gradients to scale must provide for rolling hard-running cars across the relatively flat gradient permitted on a scale.

Wherever empties or mixed traffic are handled over the hump, the gradient from apex to the point of leaving the weigh rail should average 1.4 percent or higher. Where loads are handled exclusively, the average gradient may be reduced. Where extreme temperatures or strong head winds are expected, a higher average gradient should be used.

These gradients and the distance within which they are developed should be so related to the length of the scale and the weigh rail gradient that a minimum weighing time of 4 sec. per car will be secured for free-running cars. The weigh rail gradient should not exceed 1 percent and should be extended for at least 10 ft. in each direction from the scale (see Manual, page 14–34).

The use of a velocity head profile is helpful in investigating gradients for motion weighing. Fig. 4 illustrates, and what follows discusses, how gradients for weighing without deceleration can be investigated by the velocity head method. From the apex of the hump, a line is drawn to the lower end of the 1 percent scale gradient. This provides an average gradient of 1.4 percent for hard-rolling cars. To investigate the approximate length of car that can be weighed, when minimum friction conditions apply, a 0.3 percent friction line (6 lb. per ton,—see Proceedings, Vol. 32, 1931, page 212) is drawn from the apex and projected over the scale profile. The velocity head available at the center line of the scale is measured between the 0.3 percent friction line and the scale grade, in this example 1.16 ft. This is converted to velocity in feet-per-second by the formula $S^2 = 64.4$ h, where S equals velocity in feet-per-second and h equals the head in feet. This formula becomes $h = 0.0334V^2$ if V is given in miles per hour, and if no allowance is made for the rotative energy of the wheels. Thus, $S^2 = 64.4 \times 1.16$, and $S = 8.64$ ft. per sec., or $V = 5.89$ mph.

The above result may be used as the average velocity during the time all wheels are on the weigh rails. Then the wheel base of the longest car that can be weighed within the 4-sec. time may be determined by the formula $W = L - 4S$, where W is the distance between the outer axles of the car, L is the length of weigh rails, and S is the average velocity in feet per second. Thus, $W = 72 - 4 \times 8.64$, or 37.44 ft.

If operations require the motion weighing of cars longer than W as determined, the weigh rails must be longer to use this profile. Note that, in modifying the design, the approach must be heightened to maintain the average gradient as the scale is lengthened.

A profile that will provide both energy and weighing time should be checked to see that cars will be separated sufficiently to weigh. To provide proper weighing conditions, the leading wheels of one car must leave the weigh rail before the leading wheels of the following car bear on the weigh rail. For a given profile, humping speed will be limited by the time required to separate cars of short-coupled length and high rolling resistance. In most installations it is expected that motion weighing will be accomplished at normal humping speed of approximately 2 mph. In a preliminary study, the limiting humping speed can be estimated by the following formula:

$H = \frac{C}{L} V$, where H = humping speed in miles per hour

C = coupled length of shortest car in feet

L = length of weigh rails in feet

V = average velocity in miles per hour at scale.

This will restrict humping capacity if the humping speed for weighing is too low, and should be estimated at values of V corresponding to hard-running conditions when separation is most difficult; a 1 percent friction condition is illustrated in Fig. 4, for which the estimated maximum humping speed would be

$$H = \frac{33}{72} \times 4.24 = 1.94 \text{ mph.}$$

This provides for about 4 cars per minute.

When this approximation indicates a potentially satisfactory profile, more exact operating characteristics should be developed by a time-distance study. This should include a study of low-friction cars following high-friction cars, and the effects of cars of mixed length.

If a profile similar to Fig. 4 will meet operating requirements, it may be applied to either a ride or retarder-operated hump.

At locations where mixed traffic is to be weighed, both car lengths and resistances vary widely. Installation of a car retarder ahead of the scale will assist in holding low-resistance cars to lower speeds, keeping the scale length suitable for separation when short cars of high resistance are encountered. Fig. 5 is typical of a hump lead with a retarder preceding the scale. Velocity head curves show low-friction cars retarded and high-friction cars unretarded.

The Fig. 5-type of profile may be used also in a rider-operated yard if the riders brake the low-friction cars to give weighing time on the scale. It is not desirable to apply the brakes to cars while on the weigh rails.

In attempting to arrive at layouts satisfactory for wide variations in friction and car length, studies indicate that weigh rails should have the maximum gradient (1 percent), and that long scales permitting higher car speeds give the best operating characteristics, because at higher velocities frictional variations between cars have less significance.

Figs. 1, 2 and 3 illustrate profiles of some existing scale humps. Fig. 1 is a scale profile used in a car rider yard on the Pennsylvania Railroad at Juniata, Pa.

Fig. 2 indicates a profile used at the northbound hump of the Louisville & Nashville Railroad at DeCoursey, Ky. This is a retarder-operated yard with no retarder above the scale.

Fig. 3 represents the scale profile at the eastbound hump of the Norfolk & Western Railway at Roanoke, Va., where a retarder is used above the scale.

All of these installations are used principally for coal traffic.

Report on Assignment 9

Factors To Be Considered in Determining the Location of a Track Scale in a Yard

H. T. Roebuck (chairman, subcommittee), W. O. Boessneck, J. C. Bussey, K. L. Clark, Oscar Fischer, H. C. Forman, W. H. Giles, W. H. Goold, E. E. Hammond, H. H. Harsh, D. C. Hastings, W. H. Hobbs, J. E. Hoving, A. S. Krefting, B. Laubenfels, J. L. Loida, C. E. Merriman, C. H. Mottier, R. H. Peak, Jr., J. L. Perrier, W. C. Sadler, D. J. Strauch, J. N. Todd.

This is a final report, presented as information.

The installation of a scale in a much used track should be avoided, except in special cases where such location can be justified. The presence of a scale in such a track results in increased cost of maintaining the scale and makes inspection and testing difficult.

The scale track in the vicinity of the scale should be set above the elevation of the adjacent tracks so that it will not be lower than the other tracks if they are raised during ordinary maintenance operations.

Factors which should be given consideration in determining the location of track scales are:

(a) Number of weigh cars handled.
(b) Percentage of cars handled to be weighed.
(c) Time available for weighing.
(d) Time available to classify cars to be weighed.
(e) Time available for engine to handle weigh cars while classifying.
(f) Reclassification of weigh cars.
(g) Proximity of weighmaster's office.
(h) Cost of installation and maintenance.
(i) Availability of suitable existing track.
(j) Weighing of cars at outlying industrial areas.
(k) Weighing of rebuilt and new cars and check-weighing of cars at repair plants and car assembly plants.
(l) Future expansion of terminal.
(m) Weighing of cars for trans-shipment.

Consideration may be given to the installation of a track scale at the following locations:

(1) In a body track of a classification yard or track adjacent thereto.
(2) In a track adjacent to and parallel with the drill track of a classification yard.
(3) In drill track of classification yard.
(4) In a track adjacent to and parallel with ladder track of a classification yard.
(5) In a location convenient to an auxiliary yard in an outlying district.
(6) In a location convenient to car repair facilities and car assembly plants.
(7) Near the crest of the hump.
(8) In a track by-passing the hump track.
(9) In an industrial lead centrally located for shippers.
(10) In tracks serving points of trans-shipment.
(11) In a track connecting two classification yards.

Report of Committee 20—Contract Forms

L. A. OLSON, *Chairman,*
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G. H. BEASLEY
H. F. BROCKETT
A. B. COSTIC
G. K. DAVIS
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E. E. PHIPPS
BRUCE SHAFFNER
B. M. STEPHENS
W. R. SWATOSH
J. L. WAY
CLARENCE YOUNG
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions .... page 283

2. Form of agreement for division of work, maintenance and operation of flood protection projects .... page 284

   Final report, submitted for adoption and printing in the Manual.

3. Form of agreement covering subsurface rights to mine under railway carrier property.

   No report.

4. Form of agreement covering subsurface rights to mine under railway noncarrier property.

   No report.

5. Form of agreement for elimination of railway-highway grade crossing.

   No report.

THE COMMITTEE ON CONTRACT FORMS,
L. A. OLSON, *Chairman.*

AREA Bulletin 490, November 1950

Report on Assignment 1

Revision of Manual

W R. Swatosh (chairman, subcommittee), E. H. Barnhart, C. J. Henry, J. S. Lillie, A. A. Miller, O. K. Morgan, C. B. Niehaus, W. G. Nusz, L. A. Olson, G. W Patterson, J. L. Way.

The committee recommends removing the word "gold" from the first paragraph of clause (b), Article 202 in Form of Agreement for the Organization and Operation of Joint Passenger Terminal Project (Manual page 20–26).

The committee recommends reapproval of the Form of Agreement for Joint Use of Passenger Station Facilities (Manual pages 20–47 to 20–51) with the addition of "Whereas" and "Therefore" clauses, in order that this agreement may be in harmony with Manual agreements containing similar clauses, and the replacement of the word "whole" contained in fifth line of clause (b) Article 10, with the word "whose."

The present "WITNESSETH" clause to be deleted in its entirety and replaced by the following:

WITNESSETH:

WHEREAS, Corporation "A" is agreeable to joint use with Corporation "B" of passenger station facilities hereinafter described, and

WHEREAS, Corporation "B" is agreeable to joint use thereof subject to conditions herein set forth,

NOW, THEREFORE, in consideration of the mutual covenants and agreements herein stipulated to be kept by the parties hereto, it is mutually agreed as follows:

The committee recommends that the Form of Agreement for the Use of Railway Property by High Pressure Pipe Lines with Special Reference to Pipe Lines Carrying Inflammable Oils and Gas (Manual pages 20–105 to 20–107) be reapproved without change.

The committee recommends that the Form of Agreement for Operation of Commissary and Boarding Outfits (Manual pages 20–122.1 to 20–122.4) be reapproved with minor editorial changes.

The paragraph under existing Article 3, "Camp Equipment," to be eliminated and the following substituted: "To furnish at its own expense all cooking utensils, dishes, tableware, mattresses, springs, and all necessary bedding, and keep all equipment clean and in good sanitary condition."

The word "lamps" appearing in the third line of Article 15 should be changed to read "lighting."

The word "employees" in the fourth line of Article 18 should be changed to read in the singular, and the word "respectively" immediately following should be deleted.

In the fifth line place a comma after the word "period."

The committee recommends that Form of Agreement for Pickup and Store-Door Delivery (Manual pages 20–124.1 to 20–124.7) be deleted from the Manual.

Report on Assignment 2

Form of Agreement for Division of Work, Maintenance and Operation of Flood Protection Projects

W. D. Kirkpatrick (chairman, subcommittee), E. H. Barnhart, G. H. Beasley, H. F. Brockett, A. D. Duffie, C. J. Henry, A. A. Miller, W. L. Mogle, S. R. Nestingen, G. W. Patterson, Bruce Shaffner, B. M. Stephens, J. L. Way, Clarence Young.

Last year your committee presented as information a tentative draft for Form of Agreement for Division of Work, Maintenance and Operation of Flood Protection Projects (Proceedings, Vol. 51, 1950, pages 169–173) and requested comments and criticism thereon. This form of agreement, with only minor revisions, is now submitted for adoption and publication in the Manual.

Report of Committee 6—Buildings

A. G. Dorland,
Chairman,
F. H. Alcott
C. M. Angel
W. F. Armstrong
G. A. Belden
C. E. Booth
H. M. Booth
R. R. Cahal
T. S. Carter, Jr.
E. Christiansen
H. M. Church
C. E. Close
G. V. Coffey
L. H. Corning
C. O. Coverley
L. B. Curtiss
W. T. Dorrance
V. E. Elshoff
T. J. Engle
A. H. Exon

D. W. Converse,
Secretary,
M. C. Fleming
R. L. Fletcher
J. P. Gallagher
C. S. Graves
W. G. Harding
J. W. Hayes
R. V. Hazer
J. F. Hendrickson
V. V. Holmberg
K. E. Hornung
C. D. Horton
B. J. Johnston, Jr.
L. P. Kimball
Earl Kimmel
S. E. Kvenberg
L. H. Laffoley
C. E. Lex, Jr.
E. M. Loebs
H. C. Lorenz

J. B. Schaub,
Vice-Chairman,
I. A. Moore
G. A. Morrison
R. H. Morrison, Jr.
B. M. Murdoch
W. C. Oest
J. S. Parsons
C. L. Robinson
J. J. Schnebelen
J. T. Schoener
E. W. Scripture, Jr.
E. R. Shultz
J. E. South
O. W. Stephens
R. C. Turnbell
W. L. Turner*
S. G. Urban
W. E. Webb
J. W. Westwood
O. G. Wilbur
Committee

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* Died September 1, 1950.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions .... page 286
2. Specifications for railway buildings.
   No report.
3. Shop facilities for diesel locomotives.
   No report.
4. Servicing facilities for diesel locomotives.
   No report.
5. Lumber specifications for railway buildings, collaborating with Committee 7.
   Final report, including specifications submitted for adoption .... page 290
6. Docks and wharves.
   Progress report, submitted as information .... page 290
7. Pile foundations for railway buildings, collaborating with Committees 7 and 8.
   No report.
8. Modernization of station buildings.
   Progress report, submitted as information .... page 293
9. Modernization of freight houses.
   No report.
10. New materials for buildings.
    No report.

The Committee on Buildings,
A. G. Dorland, *Chairman.*

AREA Bulletin 491, December 1950.

Walter L. Turner

Walter L. Turner, eastern engineering editor of Railway Age, and eastern editor of Railway Engineering and Maintenance, New York, and an AREA member since 1947, died on September 1. Mr. Turner was born at Bluefield, W. Va., on January 27, 1913, and was graduated from Virginia Polytechnic Institute with the degree of Bachelor of Science in Civil Engineering. He entered railroad service in 1936 as a rodman with the Pennsylvania, and in 1938 joined the Pennsylvania Turnpike Commission, returning to railroad service with the Pennsylvania in 1939. In 1941 he entered military service, and in 1946, after having returned to the Pennsylvania for a few months as assistant track supervisor, became associated with Railway Age and Railway Engineering and Maintenance, at Chicago, being transferred to New York in 1948. Mr. Turner became a member of Committee 6—Buildings in January 1950, and his loss is deeply regretted by the entire committee.

Report on Assignment 1

Revision of Manual

J. B. Schaub (chairman, subcommittee), G. A. Belden, H. M. Church, C. E. Close, D. W. Converse, C. O. Coverley, W. T. Dorrance, C. S. Graves, J. W. Hayes, L. H. Laffoley, H. C. Lorenz, O. W. Stephens, O. G. Wilbur.

Your committee recommends the following revisions for adoption and publication in the Manual:

Pages 6–7 to 6–10, incl.

Delete the entire specification on Sewers and Drainage dated 1949, and substitute the following:

SEWERS AND DRAINAGE

1951

1. General

The work covered consists of all necessary excavation, backfill, and the construction of sewers, manholes, catchbasins, sewer connections to existing manholes, etc., as called for on the drawings.

2. Excavation and Backfilling

All excavation and backfilling shall be done in accordance with AREA Committee 6 specification covering Excavation, Filling and Backfilling. In general, the excavation shall be to line and grade as furnished by the engineer and shall be made by open cut from the surface, and the clear width at the bottom of the trench shall be at least one foot greater than the diameter of the pipe. The sides shall be cut vertically or with only slight slope. When the material encountered permits, the bottom of the trench shall be rounded and a hole dug under each joint to give the pipe an even bearing and permit the making of the joint. Where the trench is excavated below the grade of the sewer, except at joints, it shall be refilled to grade with easily compacted material and thoroughly tamped.

No portion of a trench or excavation shall be backfilled until the sewer contained in it has been examined and approved.

No rock or frozen earth shall be put in the trench until the refilling has reached at least 2 ft. above the top of the pipe. Fine earth shall be carefully thrown into the trench and around the pipe in layers not more than 6 in. thick, each layer being thoroughly tamped. The remainder of the filling shall be thoroughly compacted so there will be no settlement. Any surplus shall be disposed of at a place designated by the engineer. Whenever the engineer deems the excavated material unsuitable, he may require the contractor to furnish suitable material to be paid for at the unit price bid per cubic yard for extra fill. Rock in pieces weighing over 50 lb. shall not be put in the trench. Any rock used as backfilling shall be placed with alternate layers of earth so that all spaces between the pieces of rock shall be filled with earth.

In all cases, trenches for subdrains shall be backfilled with a pervious filter material of bank run gravel or sand of such gradation as will prevent the entry of the soil fines into the trench. Perforated pipe shall be laid on a solid foundation with the perforations in the lower half of the pipe. Joints in perforated corrugated metal drains shall be made with coupling bands. Joints in perforated vitrified drain tile shall be cemented as described in Section 5. When open jointed vitrified drain tile is used, the tile shall be laid in and completely surrounded with a bed of gravel, graded to prevent the entrance of filter material into the pipe.

3. Pumping and Bailing

The contractor shall pump, bail or otherwise remove all water that may be found in or that may assemble in the trenches while the sewer is being laid. No manholes, catchbasins or sewers shall be constructed or laid in water, nor shall water be allowed to run through the sewer until the mortar has satisfactorily hardened. All necessary precautions shall be taken to prevent the entrance of sand, mud or other obstructing material into the sewer. Any such material remaining in the sewer when completed shall be removed by the contractor.

4. Sheeting

The contractor shall furnish, place and maintain such sheeting and bracing as may be required to support the sides of the excavation and insure the protection of the work. The sheeting and bracing shall be removed as the work progresses, in such a manner as to prevent the caving in of the sides of the excavation or injury to the sewer.

5. Grade, Joints, etc.

Each pipe shall be laid on a firm bed and in conformity with line and grades as given by the engineer.

The end of each pipe shall be pressed firmly into the bell of the other in such manner that there will be no shoulder or want of uniformity of surface on the interior of the sewer. The joints are to be as uniform as possible in thickness and thoroughly filled with cement mortar. Each joint is to be wiped clean on the inside as the work progresses. After the joint is made, the pipe shall be firmly fixed in place by means of earth carefully placed around it before the following pipe is laid.

6. Vitrified Sewer Pipe

The pipes and specials shall be of standard length and of the best quality of salt-glazed vitrified sewer pipe of the "bell and spigot pattern." The pipe shall be smooth, dense and sound, thoroughly burned, impervious to moisture, free from laminations, cracks, flaws, blisters or other imperfections. The interior surface shall be smooth and well glazed. Straight pipe shall form a true cylinder and the interior diameter shall be the full specified dimension. The inner and outer surfaces shall be concentric. No pipe less than 6 in. shall be used except for downspout connections.

The pipe shall comply with current specifications of the ASTM Designation C 200 when "extra strength" pipe is called for on plans or specified, and ASTM Designation C 13 when "standard strength" pipe is called for on plans or specified, and shall be subject to inspection and approval or rejection by the engineer.

7. Mortar

All mortar for cementing pipe joints and for brickwork shall be prepared from portland cement, thoroughly mixed with clean, sharp sand in the proportion of one part by volume of loose cement to three parts of sand.

The cement shall meet the requirements of the ASTM Specifications for Portland Cement, Serial Designation C 150. Unless otherwise specified, Type I cement shall be used.

The sand shall conform to current ASTM Specification C 144 and shall be composed of clean, uncoated grains of strong material. Fine aggregate subjected to the colorimetric test for organic impurities (ASTM Designation C 40) and producing a color darker than the standard shall be rejected unless, when tested in accordance with the standard method of test for measuring mortar-making properties of fine aggregates (ASTM Designation C 87), the mortar develops a compressive strength at 7 and 28 days of not less than 95 percent of that developed by the mortar specified in that method as a basis for comparison. Deleterious materials such as coal and lignite, clay lumps. shale, coated grains, soft or flakey particles, and other deleterious substances, including material finer than No. 200 mesh sieve, as determined by the method of ASTM Designation C 117, shall not exceed 3 percent by weight of the sand. The sand shall be free from salts and alkalis.

8. Cast Iron Pipe

Cast iron pipes shall be used for all sewers and drains under building floors. Cast iron pipes and special fittings shall be used where shown on drawings.

All joints between sections of cast iron pipe and between cast iron pipe and special fittings shall be made by being yarned with oakum, the joint filled with molten pure virgin lead, and then thoroughly caulked.

9. Concrete Pipe

Concrete pipe shall be used when and where called for on the drawings or as directed by the engineer. Non-reinforced concrete sewer pipe shall conform to current specifications of the ASTM Designation C 14. Reinforced concrete sewer pipe shall conform to current specifications of the ASTM Designation C 75.

10. Corrugated Pipe

Corrugated pipe shall conform to AREA Committee 1—Roadway, Specifications for Corrugated Metal Culverts, and for Corrugated Metal Pipes for Subdrainage, and shall be of thickness or gage metal recommended by the pipe manufacturer for the particular size of pipe and depth of bury, unless otherwise called for on drawings.

11. Underground Drainage

When underground drainage is required, it shall be provided by using either vitrified tile, perforated vitrified tile, or perforated, corrugated, coated iron pipe. The pipe shall be of size and kind as called for on drawings.

12. Manholes and Catchbasins

Manholes and catchbasins shall be built at the places shown on the plans or where otherwise directed by the engineer, and shall be of the form and dimension shown on the detailed drawings. Unless otherwise specified, manholes shall be 6 ft. deep and manhole catchbasins 8 ft. deep. The aforesaid depths shall be measured from the top of the cover down to the top of the concrete base.

The brick used shall be of the best quality and comply with current specifications of the ASTM Designation C 62, and samples must be approved by the engineer.

All manholes for both sanitary and storm sewers shall have closed-top covers. All catchbasins or manhole catchbasins for storm sewers, when located in platforms or walks, or where used as grease basins, shall have closed-top covers. Elsewhere manhole catchbasins shall have open-top covers, and catchbasins shall have open-top covers without side inlet, except when adjacent to curbs where they shall have closed-top covers with side inlet. All covers in platforms or walks shall have checkered tops but without projecting knobs. All covers in driveways or where subject to vehicular traffic shall be of heavy traffic design; elsewhere, and on passenger or freight platforms, of light traffic design.

13. Cast Iron Covers

All covers shall be made of gray iron, free from defects, shall be clean and have a workmanlike finish. They shall conform to the detail drawings.

The iron shall comply with the current specifications of the ASTM Designation A 48.

14. Special Fittings

In case vitrified clay pipe is used for the sewer and is to be paid for on a unit price per foot basis, all fittings, including Y's, T's, L's, etc., shall be considered as two lengths of straight pipe.

The same basis of payment shall apply in the event concrete pipe is used.

Cast iron pipe fittings shall be paid for on a per pound basis.

15. Acceptance of Work

In general, all materials entering into the work shall be subject to the approval of the engineer, and no part of the work will be considered finally accepted until all of the work is completed.

16. Guaranty

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 improvements, 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 of the railroad company for a period of two years as above set forth. The guarantee shall include all repairs to be made, or, if necessary, the entire reconstruction of the work as the engineer of the railroad company may elect, without additional charge or cost to the railroad company.

17. Protection

The contractor shall erect and maintain suitable barriers to protect the work. Any damage, prior to its official acceptance, shall be repaired or replaced by the contractor at his expense, in a manner satisfactory to the engineer.

18. Final

The general conditions as given in Section 1 shall be read by this contractor as all conditions therein set forth are a part of this contract and binding on this contractor. Pages 6–223 and 6–224.

The text matter dated 1936, appearing under Rest Houses, is submitted for reapproval dated 1951, without change.

Report on Assignment 5

Lumber Specifications for Railway Buildings

H. M. Church (chairman, subcommittee), F. H. Alcott, R. R. Cahal, E. Christiansen, C. E. Close, D. W. Converse, V. E. Elshoff, T. J. Engle, M. C. Flemming, R. L. Fletcher, Earl Kimmel, C. E. Lex, Jr., H. C. Lorenz, J. B. Schaub, O. W. Stephens, W. E. Webb, O. G. Wilbur.

Your subcommittee recommends for adoption and publication in the Manual, the Yard Lumber Specifications for Railway Buildings which were submitted last year as information with a request for comments and criticisms thereon. These specifications, including inserts of Tables 1 and 2 (two parts), were published in AREA Proceedings, Vol. 51, 1950, pages 240–241, and have since been edited for typographical errors, as well as for minor references in the tables to bring them up to date.

Report on Assignment 6

Docks and Wharves

J. P. Gallagher (chairman subcommittee), R. R. Cahal, L. H. Corning, W. T. Dorrance, R. L. Fletcher, V. V. Holmberg, L. P. Kimball, Earl Kimmel, S. E. Kvenberg, L. H. Laffoley, C. L. Robinson, J. E. South, O. W. Stephens.

This is a progress report submitted as information.

General

This subject deals with the important interchange facilities established between land and water transportation—piers, docks and wharves. Such facilities represent one of the most important transfer and interchange mediums between these two major means of transportation for the handling of both freight and passengers.

Great strides have been made in the past 20 years to improve the design, construction and functional use of piers and pier enclosures to guard against loss, particularly by fire, of the structure, of passengers and of freight. Passenger traffic has been a major consideration in such improvements, along wtih economic considerations in the handling of freight and merchandise, but another major consideration has been to guard against the loss of a pier or pier shed, which would disrupt the processes of both industry and transportation.

Pier and wharf developments, including enclosures, in recent years, have been improved considerably through betterments in design, construction and fire protection facilities, and through the cooperation of industry and the railroads in seeking a method to overcome economic waste due to the old theory of superflexibility and elasticity in design. Modern design has introduced rigid construction, and has permitted fire-resistive and semi-fire-resistive construction not only in the substructure, but also in the superstructure assembly.

It should be remembered that docks and wharves are used primarily for the handling of passengers and the transfer and storage of valuable merchandise between land and water, and might, in some instances, be classified as passenger terminals or as warehouses and storehouses for valuable cargo. It is important, therefore, to consider not only the value of the structure, but also that of the contents, when designing such facilities, not forgetting the possible loss of life.

Areas

The size of piers and wharves, and of piers under roof, varies, depending upon use, location, community service, and type of vessels and water or rail transportation facilities the piers or wharves are intended to serve. In any event, due consideration should be given to the various limitations noted above, and every effort should be made in planning to subdivide the total areas and to regulate heights to accommodate the traffic for which the structure is intended. Efficient operation and the economical movement of both passenger and freight traffic should be the guide of the designer.

Substructures

The solid-fill type, wherein the enclosing walls are constructed with sheet piling, concrete or masonry, and filled with earth or incombustible material, is ideal where site conditions are favorable. It overcomes the possibility of underdeck exposure to decay, corrosion and fire, and lends itself to the construction of pits and other subdeck facilities which are generally essential for enclosed piers or wharves serving railroads.

Reinforced concrete piles supporting a reinforced concrete deck is a type which has been introduced into several recently constructed piers. In some cases, wood piles have been used to a height approximating mean low water, in tidal areas, supporting reinforced concrete piers and sills, or cross walls, to carry the reinforced concrete deck. Other similar non-combustible substructures, including decks, have been used, but generally in the past, designers resort to the wood pile supporting a wood deck covered with non-combustible construction.

The design of a pier foundation generally is dependent upon the conditions existing in the particular area where the pier is to be located, which may require a wood pile design due to soft or yielding conditions of the river bed. This condition may also require wood construction of the deck and its supporting members. The preferred construction is a deck of heavy double planking laid diagonally or at right angles to each layer, with the under deck protected from fire spread by fire stops of heavy planking laid diagonally to below the water level, or in case of tidal areas, below mean low water. Past experience has shown that where adequate fire extinguishing and alarm equipment in installed, fire damage to structures and contents is negligible.

Recently, several designs for the substructures of piers and wharves have been introduced, using nests or assemblies of steel sections, filled with concrete. It is claimed that this type of design, while rigid in construction, lends itself somewhat to the flexibility and elasticity of the wood pile design. Later designs may be improved by the introduction of electrical influences, similar to methods used in electro-plating, which will promote deposits of salts on the exposed steel surfaces and retard or overcome oxidation of these surfaces.

In pier or wharf construction over water, fire stops of suitable material under the deck are an essential requisite in good design. Therefore, this particular feature should always be kept in mind.

Superstructures

The superstructure design is dependent upon many conditions. Use and occupancy must be considered. Inland waters and tidal coastal areas influence the superstructure assembly as well as substructure design. Sheds, warehouses, or whatever term may be used for structures over water, must necessarily be influenced by their location in relation to the Great Lakes and other fresh water areas, and those located at various places along the Pacific and the Atlantic seaboard where tidal conditions are prevalent.

A fire-resistive construction is preferred where such structures warrant the expenditure. This applies not only to the one-story shed design but also to two-story pier enclosures, including bulkheads, as well. Irrespective of this type of construction, due study should be given to the use and occupancy of the structure, which may influence the introduction of fire walls or division walls to guard against the loss of the entire facility and contents, say, in the case of fire. The use of baffles under the roof as draft stops should be considered where large individual areas exist.

Due to conditions peculiar to the locale in which the improvement is located, it may be necessary to resort to unprotected steel framing, siding and roof construction, covered by non-combustible materials. In most building codes, the floor area permitted with this type of construction is equal to that for fire-resistant construction, except that the floor area is reduced for use and occupancy.

The use of heavy timber construction should be considered because the use of mill construction or its equivalent is warranted in most localities. Its use is particularly applicable where soft and yielding foundations are encountered and fire resistance is a factor.

Many municipalities have included in their building codes rules, regulations and recommended practices regarding the design and construction of the facilities covered by this assignment. Other agencies having jurisdiction over of waterfront properties have also made valuable contributions insofar as construction and design of bulkhead and pier shed properties are concerned. As an example, the National Board of Fire Underwriters, some time ago, issued a pamphlet covering the subject not only insofar as construction is concerned, but also protection from fire. While it should be brought up to date, it is recommended for your reading. The use of sprinkler systems and other protective devices is of prime consideration in protecting contents and structures of any type from loss and damage by fire.

Recommendations, which may in any way be considered conclusive, cannot be submitted at this time. It is suggested therefore, that this committee be continued so that a final report can be submitted at the next convention—not as a recommended practice of the Association, but as the latest information available.

Report on Assignment 8

Modernization of Station Buildings

J. J. Schnebelen (chairman, subcommittee), W. F. Armstrong, H. M. Booth, E. Christiansen, C. O. Coverley, A. H. Exon, J. W. Hayes, R. V. Hazer, J. F. Hendrickson, V. V. Holmberg, C. D. Horton, C. E. Lex, Jr., H. C. Lorenz, B. M. Murdoch, W. C. Oest, J. S. Parsons, J. T. Schoener, E. R. Shultz, S. G. Urban.

This progress report on the modernization of station buildings is submitted as information, and is a revised edition of a previous report by the committee on the subject, appearing in the AREA Proceedings, 1943, Vol. 44, pages 223–229.

1. General

In the present streamlined era of mass transportation, with its intensive competition and accelerated tempo of modern life, the traveling public must be served at all times. To meet this competition, change and demand, the modernization of station buildings forms a vital and necessary step and is in line with the direction taken so widely and successfully by the railroads in the United States and Canada in the progressive modernization of locomotives and trains. The "streamliner," beautifully designed both inside and out in appropriate modern style, with its added comforts and conveniences, coupled with a faster schedule, provides the patron with an attractive environment for the duration of his journey. Only too often these rolling "good-will-ambassadors" stop at stations with crude, outmoded and obsolete facilities representative of a by gone era of railroading, and provide the alighting patron with a terrific let-down due to the contrast. Railroad stations have often been neglected in essential maintenance; this neglect accentuates their unprepossessing appearance and places them entirely out of keeping with the convenience, comfort and atmosphere of the new trains. Many of the "on-the-line" stations are closed part of the day, and during that period provide no protection from the elements to the alighting patron. It is obvious that they should provide an equally pleasing appearance and equivalent accommodations; however, changes in train equipment to date have far surpassed improvements in passenger stations, both in number and achievement.

The railroad station, which at one time was the center of the activities of a community, should be restored to its rightful place—a building to encourage the civic pride of the town. The value of this community pride and the advertising value to be derived from a station of both beauty and convenience should be realized. This strong psychological appeal, coupled with the speed, comfort and safety of modern trains, will help railroads to maintain a dominant position in the field of mass transportation in competition with air and bus lines.

The better and more modern accommodations provided for the traveler by competitive air and bus lines are another reason in favor of modernization of railroad station buildings. Air and bus line terminals are equipped with modern comforts and conveniences. Some have been built in extreme modernistic styles, in an effort to derive the full advertising value which such treatment affords. Such extreme contemporary style is not recommended as an advertising medium for railroad stations, since the life and scope of such an attraction is too limited.

Most stations were modern when built, and accurately reflect the spirit of their day; modern architecture will so record the spirit of the present streamlined era of mass transportation. The architecture should be governed by, and conform to local geographical and topographical conditions, the materials available, and the potential requirements of the individual station. In most cases the architectural style of a station and of the buildings in the vicinity, reflect both the spirit of the same era and a similar degree of decay, deterioration and obsolescence, and should not be considered in determining the style of architecture to be used.

This report deals with the modernization of existing station buildings. Nevertheless, the majority of the factors covered herein should be given full consideration in designing new facilities, either directly or indirectly, to eliminate all obsolete features of the past from the design. This consideration is particularly important where standard plans for buildings have been used indiscriminately.

The problem of modernizing existing buildings should be analyzed thoroughly as to the scope and cost of the work to be undertaken. The flexibility of the existing plan and design, and its adaptability to obtain the desired result, will affect the amount and nature of the work to be done and the total cost of the improvement. Where the work is extensive, the estimated cost of the improvement should be compared to the cost of a new building. Some old buildings will not lend themselves favorably to all that might be considered desirable in the way of improved appearance and convenience, because of structural or architectural design, condition or size. In such cases, consideration should be given to a new structure instead of an expensive modernization, which, on completion, would not be as effective as new construction involving approximately the same cost.

The scope of the work can sometimes be confined to a few essentials when the permissible expenditure is limited and a satisfactory measure of modernization can still be achieved. No sacrifice should be made to eliminate the structural defects of building in all modernization projects. Structural soundness, particularly of the foundations, should be determined by a thorough and careful inspection at an early stage. This inspection should disclose, in the case of timber frame construction, whether termite activity is present, and if so, proper means should be taken to stop it and correct any weakness that has been caused thereby.

Whenever practicable, a modernization project should be complete and include any necessary changes in floor plan, interior and exterior treatment and design, lighting, heating, furnishings, and landscaping. Consideration should be given to "off-street" parking for automobiles, so as to conform to modern zoning regulations. The work will vary with each building and, as a general rule, will be limited by the funds granted by the authority for expenditure. The need of each building for modernization, the character of its surroundings, its future usefulness, the potential growth of the community, and the amount of revenue derived from the community, should determine the extent and scope of the work to be done. In some buildings a change in decoration alone, particularly a change from the drab standardized colors of paint to modern bright combinations, will accomplish all the modernization warranted. More comprehensive programs should consider the subjects that follow.

2. Plan of Building

Readjustment of the existing floor plan will often be necessary to provide adequate areas to handle the character and volume of passenger traffic to the best advantage. Where there are now separate waiting rooms for men and women, it is suggested that they be consolidated. Separate waiting rooms for colored persons need not be maintained in some areas. In locations where the station is used jointly with air lines, or bus lines, or both, the size of the waiting room and other services should be adequate to carry the average peak traffic load for the combined service. The tempo of modern life calls for a station in which all the facilities can be quickly found and reached. It is most important that the traffic route from the street entrance to the ticket office, baggage checking facilities and train gates be as direct as possible, and that the waiting, rest, lounge, toilet and powder rooms should be located off to one side of the principal lane of traffic.

The ticket office may need modernization. It need not be a separate enclosed room. Opening the office into the waiting room, with only counters and railings to set off the enclosure, creates a more spacious effect, and also places the station personnel in closer contact with the public. It means that the station personnel will, of necessity, maintain their office in a presentable condition. Counters should be ample in size and should be equipped with drawers, compartments, racks, shelving, etc., to take care of tickets, cash, tariffs, records, stationery, time tables, and a supply of advertising literature. Every article should be close at hand, but generally out of view of the public. Counter tops can often be completely open or, if desired, modern bank-type glass or grill rails may be installed on top of the counters with designated openings at which to meet and serve the public. Where operating conditions demand the closing of the office while the waiting room remains open, drop sash or grills should be provided to separate the ticket office from the waiting room.

Toilet rooms should conform to modern sanitary requirements. A first consideration is their location within the building, convenient access from the waiting room. Placing the rooms for men and women adjacent is often economical with respect to plumbing lines, but when this is done it is desirable to keep the entrances to the two rooms widely separated and properly screened.

Existing toilet rooms should be investigated as to capacity requirements. In many stations, remodeling the toilet facilities will improve them immeasurably and do away with the most serious objection to the station as it exists. Old style toilet fixtures should be replaced with modern units. Individual urinal fixtures should replace the old insanitary urinals. Modern flush valves, if water under sufficient pressure to operate them properly is available, are preferable to gravity or pneumatic tank supplies for closet or urinal flushing. Lavatories should always be provided in sufficient number.

It is of utmost importance that soil and water lines be inspected for size and condition. In many cases it will be desirable, and perhaps necessary, to renew all plumbing lines. In conjunction with the plumbing layout, it is desirable that a sink be provided in a service or janitor's closet, which is a necessary component of a modern station plan.

Existing smoking rooms for men can be eliminated from the modern plan. Smoking rooms for women may be retained, but their size can often be reduced, or they can be converted into a retiring room or powder room in the new arrangement. Space for the care of infants and small children should be considered where the volume of traffic warrants. News-stands, too, should be planned so that the opportunity to examine their offerings is all a part of a pleasant experience of waiting for a train.

Where freight, baggage and express rooms are provided in combination with passenger stations, they should be adequate in size. In many cases these rooms will be found to be unnecessarily large for present fast freight, pick-up and delivery rail shipment requirements. The most direct access to these rooms from the ticket office or waiting room is highly desirable.

This is also true of the heater room, particularly where the heater is hand-fired. The heater room in some stations will comprise an addition to the plan due to the installation of a central heating plant in place of stoves. A separate enclosed room is most desirable, with ample space for fuel storage for the type and volume of fuel to be consumed.

3. Interior Remodeling

Stations often reflect the period in which they were built. Where the present interior treatment is basically along pleasing lines the addition of an attractive color scheme will accentuate this. Painting the walls and ceilings with modern colors and adding a new colorful floor of modern materials will often produce a satisfactory appearance without structural change.

It will often be found desirable to create a new pattern for the interior treatment. Bulky cornices and moldings, wide decorative trim around openings and high base moulds, once the rule, are frequently of poor design and are dust collectors. They should be replaced with plaster or other new materials now available, and their application should be consistent with good architectural design. Well designed moldings, narrow trim, low sanitary bases, architecturally correct doors and windows, all in modern decorative colors, will bring an old interior up to pleasing present-day standards. Treatment of the walls, using decorative wallboard in attractive color combinations, with metal or plastic molding laid out in an architectural design of horizontal or vertical motifs, is recommended, particularly on walls where the finish is of wood, matched and beaded, or "V"-joint material. This has a common finish, and in smaller stations provides a good base for nailing the applique material. Cementing decorative wallboard to the wall is also practicable. With this material, beveled panels of the same or similar materials can be used on the ceilings where plaster is not desired. Both decorative wallboard and beveled panel boards are obtainable in pleasing colors.

Floors in old stations are often drab, uninteresting, badly worn and insanitary. The modern trend is toward colors in the floor, and materials such as asphalt tile, rubber tile, linoleum, and other similar materials may be used. These materials are easily installed over existing floors, but careful attention should be given to their cleaning and maintenance. They do not have the longevity of terrazzo or quarry tile, which are recommended above all others. Where feasible, wood floor framing should be removed and replaced with concrete slabs. The finish can be marked-off colored cement or any of the previously mentioned materials.

Rest rooms with floors of terrazzo or ceramic tile, coved, flush, glazed tile base, glazed tile wainscot 6½ to 7 ft. high to discourage the poets and scribes from practicing their art, and plaster walls and ceilings, are recommended. Sanitary metal, marble or structural glass toilet stalls should be used. The toilets should be well ventilated and lighted; the use of glass blocks in outside walls will provide the maximum of daylight. For toilets of small stations that might not fit the budget, a hard cement plaster should be applied to the walls. A coved cement base, and a marked-off cement-finished floor with integral waterproofing and coloring are also acceptable.

Fluorescent fixtures attached to or suspended from the ceiling are recommended for lighting the interior. The effect, using white-light tubes, is pleasing and their use is gaining in popularity. They provide a far superior quality and intensity of light without additional cost. While not entirely satisfactory from a maintenance standpoint, the public nevertheless looks for this type of lighting in a modern project. It is expected that continued development in fluorescent lighting will correct any shortcomings from the maintenance standpoint.

Indirect, concealed lighting is highly desirable, but costs considerably more for installation, operation and maintenance. Electric fixtures in all projects, of whatever type, should be selected to complement the design of the interior.

Acoustical treatment of both ceilings and sidewalls can play an important part in creating an air of unhurried quiet, even in a large station, and is also an important factor in providing proper acoustics for the public address systems that are replacing the old station callers. The two problems should be closely coordinated for good results.

4. Heating

Unfortunately all stations are not equipped with modern heating plants, and therefore, station heating is an important factor to be considered in most plans for the modernization of station buildings. The old-fashioned stove located in each room of the station is not satisfactory, nor is it in keeping with this streamlined age. Its removal and the installation of a central heating system is of the utmost importance. The system selected can be steam with radiators or unit heaters, hot water, or forced warm air, and should be temperature-controlled. Exposed pipes are to be avoided in rooms open to the public. Pipes or ducts can often be carried through the attic space or the space provided when ceilings are suspended; some consideration might also be given to radiant heating, with the pipes placed in the floors, walls, and ceilings.

Where radiators are used they should be of a modern type, although it is acceptable to use old radiators when they are covered with modern metal shields. Recessed radiators are efficient and very practical where space is an important factor. Where warm air ducts under pressure are used, registers can be located in the ceiling, either combined with electric light fixtures or separated. A diffusing fin-type register should be used.

The insulation of walls and ceilings is an important factor in order to conserve fuel, to increase heating efficiency in winter, and to afford better control of summer temperatures within the building, particularly if air-conditioned.

If the fuel used is coal, it is advisable to install an automatic stoker firing furnace. In a few years the amount of fuel saved will equal the cost of installing the automatic-fired central heating system.

Where low gas heating rates are available, an automatic gas-fired heating plant can be used, or in the smaller stations vented gas steam radiators are acceptable.

Where local conditions warrant, an automatic oil-fired heating plant may be used.

Air conditioning may be considered in certain areas of larger stations, such as restaurants or other concessions where the volume of business will justify the expense of installation and operation.

5. Furnishings

Furniture for a remodeled station should be consistent with the adopted style and color scheme of the interior. Chrome and upholstered lounges add color to the waiting room and can be arranged in pleasing groups that create an atmosphere of friendliness and cheerfulness, thus making a station an inviting place to meet friends; lounges obstruct the floor area less than settees, and are desirable where stations are amply policed. They are more expensive to maintain and do not have the durability of wood settees, which are recommended, in part at least, for larger stations. Wood settees, however, should be modern in design, preferably with flush panels that are both comfortable and easily maintained.

Furniture for the ticket offices should likewise harmonize with the interior design. New desks of wood or metal, with flat tops in natural wood, green or gray finish, should be installed in remodeled ticket offices.

Ticket counters should be carefully designed, using materials that harmonize with the walls. Glass blocks and wood veneers can be used attractively. Desk top linoleum, available in colors, makes a very satisfactory type of counter top. As mentioned previously, the ticket counter should be designed to accommodate most of the office working material, which should always be available but out of view of the public.

Telephone booths and baggage lockers for public use are necessary accessories in any station. Where feasible, they should be located in recesses, in furred-out wall space in the waiting room, or in alcoves of the waiting room, and should harmonize with the interior treatment. New and pleasing locker cabinets and telephone booths are available for this type of installation.

Neon directional signs for regulating the traffic flow are recommended; signs, bulletin board, train schedule boards, etc., should be neat and compact in glass enclosed cases, and placed with discrimination. Advertisements to encourage railroad travel can take the form of artistic murals or photographs placed on walls that otherwise lack interest.

Where news-stands and soda fountains, or the like, are provided, they, too, should harmonize with the interior treatment.

Drinking fountains should be of the electric cooler type, now available in beautiful cabinets suitable for the modernized station. The fountain should be located in a convenient location in the waiting room.

6. Exterior Remodeling

Necessary changes in the exterior appearance of stations will vary with each building. Cost will frequently determine the amount of work that can be done, even though additional remodeling might be desirable. Some station buildings are pleasing and attractive, although not conforming to contemporary ideas of styles in architecture. Under such circumstances salient parts and basic lines should be retained with minor alterations, supplemented by a program of redecorating. For masonry building, chemically washing the outer wall, or painting the doors, windows, cornices, etc., will in many cases aid greatly in improving the appearance and add a cheerful and inviting atmosphere.

It will sometimes be necessary or desirable to renew or add doors or windows and their frames. These should be designed to conform to the style of modernization adopted. Where additional ventilation is not required, glass blocks in large panels can be used to advantage in admitting light to create a cheerful atmosphere both inside and out.

Of foremost importance in a remodeling program is a study of the roof, not only of its condition, but also of its appearance. The roof, naturally should be made watertight before any interior work is undertaken. The shingles on hip or gable roofs should be more colorful than those used in the past. Harmonious blends of several different colors of shingles will make roofs more attractive and enhance the appearance of the entire building. Fire-resistant shingles are available in a wide color range and are recommended. Clay tile and slate are highly acceptable where conditions permit their use.

Stations constructed of wood covered with narrow wood shingles, or boards and battens and wide trim boards can be improved by applying a brick or stone veneer. Where the cost of this method is considered excessive for the particular project, fire-resistant shingles or clapboards may be applied to the walls. Wood shingles with a wide exposure, and alternating overlapping of shingles at building corners and hip roof ridges, give a pleasing appearance. The use of flat, wide trim should be avoided where a building of character is desired. Instead, the trim should consist of narrow molds adequate to cover the door and window frames. On other buildings, clapboards or drop siding may be used to harmonize with the design or architecture. Colonial-type wood shingles, as well as other parts of the building, such as doors, windows, cornices, etc., should be painted in light appropriate colors.

Repainting existing wood siding frequently will fail to produce the desired effect because of an accumulation of paint from many previous paintings. Even after burning off old paint, which is an expensive process, the siding might not be as pleasing as desired. In this case, asbestos–cement shingles and flat sheets can be used successfully.

Glazed surface shingles should be used, however, because they can be washed satisfactorily after an accumulation of dirt.

Most modern zoning laws require "off-street" parking to ease traffic congestion; where sufficient land is available or can be acquired to meet these requirements, off-street parking facilities should be provided if the business of the railroad at any location where a modernization program is carried out warrants an investment for that purpose. Parking areas should be provided with hard-surface paving or finish, and with proper and adequate drainage.

The remodeling of outside illumination is important for improved lighting conditions at night. The building should be easily recognizable after dark. Lantern fixtures located at the entrances add a decorative effect to the exterior both day and night. Electric advertising signs should be placed with discrimination so as not to detract too much from the architectural design.

Generally, any study for a remodeling project should include an investigation of platforms their condition and whether of adequate length for accommodating longer trains. Extensions should be made where necessary, and repairs and resurfacing should be carried out if required. Platform illumination should also be checked.

Landscaping should be provided wherever possible. Shrubs planted around the building should be carefully selected species that will give the desired effect. Grass plots are desirable and should be laid out without detracting unduly from necessary parking areas and platforms.

Report of Committee 30—Impact and Bridge Stresses

J. P. Walton, *Chairman,*
D. B. Barge
D. S. Bechly
E. E. Burch
A. B. Chapman
Abram Clark
F. H. Cramer
J. A. Erskine
E. F. Gifford
S. F. Grear
R. R. Gunderson
A. R. Harris

R. H. Heinlen
Meyer Hirschthal
C. S. Johnson
Frank Kerekes
M. B. Lagaard
A. N. Laird
C. T. G. Looney
J. F. Marsh
J. P. Michalos
C. H. Newlin
N. M. Newmark
M. J. Plumb

E. S. Birkenwald, *Vice-Chairman,*
E. W. Prentiss
C. H. Sandberg
J. H. Shieber
C. E. Sloan
C. B. Smith
R. L. Stevens
W. M. Wilson
E. Wollett, Jr.
L. T. Wyly

Committee

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 301

2. Steel girder spans with open decks and with ballasted decks.
   Progress report, presented as information .... page 301

3. Dynamic shear in girder and truss spans.
   Progress report, presented as information .... page 301

4. Impact and bending stresses in columns and hangers of truss spans.
   No report.

5. Concrete structures, collaborating with Committee 8.
   Progress report, presented as information .... page 301

6. Determination of braking and traction forces in bridge structures, collaborating with Committees 7, 8 and 15.
   No report.

7. Stresses and impacts in timber stringer bridges, collaborating with Committee 7.
   Progress report, presented as information .... page 302

8. Steel truss spans with open decks and with ballasted decks.
   Progress report, presented as information .... page 302

9. Distribution of live load in bridge floors:
   (a) floors consisting of transverse beams;
   (b) floors consisting of longitudinal beams.
   Progress report, presented as information .... page 302

10. Stresses in lateral bracing of bridges.
    Progress report, presented as information .... page 302

The Committee on Impact and Bridge Stresses,
J. P. Walton, *Chairman.*

AREA Bulletin 491, December 1950.

Report on Assignment 1

Viaduct Columns, Collaborating with Committee 15

A report of the investigation of impacts and stresses in the viaduct columns supporting the 70-ft. ¼-in. deck girder spans on the Chicago and North Western Railway was presented in AREA Bulletin 488, June–July 1950.

Your committee will continue to assemble data on this assignment.

Report on Assignment 2

Steel Girder Spans with Open Decks and with Ballasted Decks

A report of the investigation of impacts and stresses in the flanges of three girder spans on the Chicago and North Western Railway was presented in AREA Bulletin 488, June–July 1950.

During the past season tests were made on three more girder spans as part of this assignment. The AAR research staff now has complete data on 27 girder spans. Data will be secured on two more spans next year and then a final report will be presented on this subject.

Report on Assignment 3

Dynamic Shear in Girder and Truss Spans

A report of the investigation of impacts and stresses in the web members of three girder spans on the Chicago and North Western Railway was presented in AREA Bulletin 488, June–July 1950.

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.

Report on Assignment 5

Concrete Structures, Collaborating with Committee 8

Tests were made during 1950 on a reinforced concrete slab having the reinforcing bars exposed on the tension side of the slab due to a spalling of the concrete. Static strains were measured in both the concrete and reinforcing steel on the tension side and in the concrete on the compression side.

During 1950 tests were conducted on two reinforced concrete trestles of the Missouri Pacific Railroad wherein the static and dynamic stresses were measured in both the concrete and reinforcing steel of the slabs and piles.

The research staff of the AAR collaborated with the Portland Cement Association in testing a prestressed concrete slab designed for railroad loading.

Progress is being made in the analysis of the accumulated data, and a report of these tests will be presented as soon as possible.

Report on Assignment 7

Stresses and Impacts in Timber Stringer Bridges,

Collaborating with Committee 7

Tests were made during 1950 on the stringers of a ballasted floor timber trestle on the Chicago, Milwaukee, St. Paul & Pacific Railroad.

Laboratory tests are now in progress at the Forest Products Laboratory and Purdue University to determine the fatigue strength in flexure of full size bridge stringers.

It is planned to conduct further tests in the field on timber stringers and correlate this data with the results of the laboratory tests.

Report on Assignment 8

Steel Truss Spans with Open Decks and with Ballasted Decks

The stresses were measured in the chord and web members of three 156-ft. pin-connected deck truss spans on the Illinois Central Railroad bridge across the Illinois river at La Salle, Ill., at the request and expense of the railroad. A summary of these results will be published.

The stresses were measured in the counterweight truss members of a double-track bascule bridge on the Baltimore and Ohio Railroad in South Chicago, Ill., and in the corresponding members of a triple-track bascule bridge on the Chicago and North Western Railway in Chicago, to determine the primary and secondary effects of the concrete counterweight during the opening of the bridge. These tests were conducted at the request and expense of the individual railroad and a summary of the results will be published.

Report on Assignment 9

Distribution of Live Load in Bridge Floors

(a) Floors consisting of transverse beams
(b) Floors consisting of longitudinal beams

Tests were made during 1950 on six girder spans having transverse beams and two girder spans having longitudinal beams to determine the distribution of the axle loads to these beams under both static and high-speed locomotives.

Progress is being made in the analysis of the accumulated data, and a report on these tests will be presented as soon as possible.

Report on Assignment 10

Stresses in Lateral Bracing of Bridges

A report of the investigation of stresses in the lateral bracing of three girder spans on the Chicago and North Western Railway was presented in AREA Bulletin 488, June–July 1950.

The stresses in the lateral bracing have been measured in most of the girder spans tested 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 on Assignment 2 are completed.

Report of Committee 29—Waterproofing

R. L. Mays, *Chairman,*
Lyle Bristow
R. A. M. Deal
L. J. Deno
L. P. Drew
E. T. Franzen
Nelson Handsaker
W. G. Harding
W. H. Hoar

E. A. Johnson
M. L. Johnson
J. A. Lahmer
J. F. Marsh
J. D. McGarry
B. J. Ornburn
H. A. Pasman
J. F. Piper
F. J. Pitcher

T. M. von Sprecken,
Vice-Chairman,
W. E. Robey
G. E. Robinson
Henry Seitz
A. L. Sparks
V. G. Tellis
J. P. Walton
C. A. Whipple

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, collaborating with Committees 8 and 15.
   No report.
3. Waterproofing protection to prevent concrete deterioration, collaborating with Committee 8.
   Progress report, presented as information below.

The Committee on Waterproofing,
R. L. Mays, *Chairman.*

Report on Assignment 3

Waterproofing Protection to Prevent Concrete Deterioration,

Collaborating with Committee 8

Last year your committee presented as information the progress of making tests on commercial waterproofing paints and coatings for surface treatments. This investigation was recommended by your committee and is in progress at Purdue University under contract with the Association of American Railroads.

These tests were made to determine the waterproofing ability and durability of 72 different commercial waterproofing coatings, and they were conducted on an accelerated laboratory basis. Concrete test specimens 1 in. by 3 in. by 8 in. coated with the waterproofing paints were subjected to a 72-hour immersion test in water, and the gain in weight because of moisture absorbed was compared to an unpainted specimen subjected to the same test to determine the waterproofing ability of the paints.

Further tests were made, subjecting the specimens to a weatherometer test of 150 hours, and the absorbed moisture in the coated specimens was determined as compared with the uncoated specimens after 72 hours immersion in water. This test was followed by another of 50 cycles of freezing and thawing, determining the moisture absorbed in the same manner as previously. Finally, all specimens were placed outside for an out-of-doors weathering test of 90 days, and were then subjected to the 72 hours of immersion in water to determine the effects of weathering on their waterproofing effectiveness and durability.

AREA Bulletin 491, December 1950.

The results of the studies indicate that the commercial waterproofing paints tested are not capable of preventing the passage of water through them in an immersion test. There was, however, a wide range in performance between the most waterproof and the least waterproof, both as to waterproofing ability and to durability in weathering test. Some of the painted specimens absorbed as much water during the immersion tests as the unpainted control specimens, but four paints were fairly waterproof throughout the testing period.

The range of durability in the weathering tests was just as great as that for waterproofing ability when all the paints were considered. It was not the intention to completely destroy the paint films in the weathering test, and only three complete failures occurred.

A description of the tests and the results thereof appear in the first progress report which has been sent to chief engineers of member roads, but it has not as yet been published.

Additional tests are in progress using 16 paints, and will be described in the next progress report. These tests are intended to be destructive to the various paint coatings so that a relative index of impermeability and durability can be determined. The paints chosen for the new series of tests were those which showed good to fair waterproofing ability before the weathering tests, regardless of the effects of the subsequent weathering tests on the paint coatings. The tests, utilizing different specimens in each, are as follows:

1. Coated specimens exposed to the carbon-arc light of the weatherometer until failure occurs.
2. Coated specimens subjected to freeze-thaw cycles until the coatings have failed.
3. Coated specimens half-buried in the ground, in an upright position, for field exposure durability tests.
4. Coated specimens, containing a coarse aggregate with known poor laboratory and field performance records in concrete, subjected to freezing and thawing cycles to determine the additional life the specimens will have as compared to unpainted specimens, because of the ability of the paint coating to prevent water from being absorbed by the specimens.
5. Field exposure tests, on a vertical concrete surface with southerly exposure, in which 3-ft. by 3-ft. concrete panels are coated with each of the paints to obtain information on durability.

These tests will be reported at a later date. When all tests are completed, your committee expects to draft a set of specifications for performance requirements and acceptability tests for surface waterproofing paints.

Report of Committee 3—Ties

B. D. Howe, *Chairman,*
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C. S. Burt
W. J. Burton
R. F. Bush
R. E. Butler
G. B. Campbell
C. M. Coates
E. L. Collette
L. C. Collister
W. P. Conklin
B. S. Converse
R. L. Cook
R. W. Cook
T. Crawford
B. E. Crumpler
W. T. Donoho
L. P. Drew
H. R. Duncan
W. F. Dunn, Sr.
T. H. Friedlin
W. E. Fuhr
L. E. Gingerich
M. J. Hubbard
W. J. Kernan
L. W. Kistler
C. R. Lapeza
J. R. Latimer
C. M. Long
Roy Lumpkin
F. L. McLean
W. O. Nelson
R. A. Pidgeon
L. H. Powell
P. D. Brentlinger,
Vice-Chairman,
M. H. Priddy
W. C. Reichow
H. S. Ross
E. F. Salisbury
T. D. Saunders
H. W. Seeley, Jr.
F. S. Shinn
Stuart Shumate
E. F. Snyder
J. G. Sutherland
P. V. Thelander
S. Thorvaldson
R. H. Timmins
C. D. Turley
B. J. Worley

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Extent of adherence to specifications.
   Progress report, presented as information .... page 306

3. Substitutes for wood ties.
   No report.

4. Tie renewals and costs per mile of maintained track.
   Progress report, presented as information .... page 306

5. Methods of retarding the splitting and the mechanical wear of ties, including stabilization of wood, collaborating with Committee 5 and NLMA.
   Progress report, presented as information .... page 307

6. Bituminous coating of ties for protection from the elements.
   Progress report, presented as information .... page 308

7. Causes leading to the removal of ties.
   Progress report, presented as information .... page 309

8. Prebored ties: Benefits and factors affecting economy.
   Final report, presented as information .... page 310

The Committee on Ties,
B. D. Howe, *Chairman.*

AREA Bulletin 491, December 1950.

Report on Assignment 2

Extent of Adherence to Specifications

P. D. Brentlinger (chairman, subcommittee), R. E. Butler, G. B. Campbell, E. L. Collette, T. Crawford, W. F. Dunn, Sr., T. H. Friedlin, W. J. Kernan, L. W. Kistler, C. R. Lapeza, F. L. McLean, M. H. Priddy, H. S. Ross, E. F. Salisbury, F. S. Shinn, P. V. Thelander.

The observations made on three field trips by Committee 3 comprise the following report.

During the latter part of 1949 and subsequently to date the committee continued field inspection trips to inspect stocks of cross ties stored by the railroads at various treating plants throughout the country. Eight treating plants, located in six states were visited. Ten railroads had approximately 1,000,000 ties stacked at the plants visited. Oak, Southern pine, Western pine, Douglas fir, and gum ties produced in 14 states were inspected by committee members.

Generally speaking, the treating plant storage yards were well maintained and free of injurious high weeds, decayed sills, and standing pools of water. The adoption of mechanical methods for stacking ties has improved the appearance of tie storage yards. Various types of mechanical stackers were observed in use; lift trucks being the most common, but including cranes and straddle buggies adapted to moving entire stacks of ties. The expenditure of large sums of money for lift trucks, crane or carrier yards, and the investment in this machinery to store ties by the treating companies are highly commendable, and the railroads appreciate these improved methods of storing ties, which will result in better seasoning.

The ties in storage represented the property of 10 railroads, and, in general, the quality of the ties and their sizing were good. Non-conformance to the specification regarding the marking of ties to indicate size, ownership and identity of the inspector was the most repeated comment from members. Railroads which do not require the marking of ties for checking the quality of the inspector's work should weigh carefully the merits of branding ties. Inspectors not held responsible for their work are likely to be more lax than inspectors whose work can be identified. Visual inspection at its best is not perfect because of the element of human failure involved.

The committee recommends that that part of the Specification for Cross-Ties, entitled Marking Ties To Indicate Size Acceptance, be adopted if not in use.

Report on Assignment 4

Tie Renewals and Costs Per Mile of Maintained Track

B. D. Howe (chairman, subcommittee), R. F. Bush, W. P. Conklin, B. E. Crumpler, J. R. Latimer, F. L. McLean, R. A. Pidgeon, H. W. Seeley, Jr., E. F. Snyder, J. G. Sutherland, B. J. Worley.

This is a progress report, presented as information.

The statistics compiled annually to provide information regarding the number and cost of cross ties laid in replacement are supplied for 1949 in Tables A and B. These are compiled by the Bureau of Railway Economics, AAR. The number of ties applied in 1949 in the United States was slightly over 30,000,000, the smallest number for many years. The average cost per tie in 1949 was $0.16 above the 1948 average.

In order to make this information available as promptly as possible, these tables were published in Bulletin 488, June–July 1950.

Report on Assignment 5

Methods of Retarding the Splitting and the Mechanical Wear of Ties, Including Stabilization of Wood, Collaborating with Committee 5 and NLMA

T. H. Friedlin (chairman, subcommittee), R. S. Belcher, C. S. Burt, G. B. Campbell, R. L. Cook, H. R. Duncan, W. F. Dunn, Sr., W. O. Nelson, L. H. Powell, W. C. Reichow, T. D. Saunders, C. D. Turley.

This is a progress report, presented as information.

The cross-tie research program which has been carried on in the Timber Engineering Company laboratory in Washington, D. C., since the spring of 1948 has shown promising progress toward the ultimate objective of increasing the service life of ties. This work has been made possible through the joint auspices of the Association of American Railroads and the National Lumber Manufacturers Association.

One of the important initial phases of the investigation was centered on the detailed microscopic analysis of the material beneath the tie plate areas of nearly 50 representative plate-cut cross ties removed from service. Three main types of failure were found in this portion of the ties. Crushing of the relatively thin-walled springwood cells, lateral shifting of the general cellular structure, and pronounced buckling of the wood ray elements were found singly or in various combinations in the several species studied. Failures visible in the microscope were confined largely to the first ½ in. below the tie plate. It is significant that these same types of failure could be duplicated in laboratory tests on new tie sections. Loads required to produce such failures exceeded 2000 psi. for red oak and 1200 psi. for Douglas fir.

Chemical analyses of wood in the same plate areas indicate the presence of complex ferrous compounds. The evidence of change in the ratio of normal celluloses and lignin indicates a form of chemical deterioration and change. Thus, it is possible that the presence of iron in the form of spikes and plates has some influence on the ultimate reduction of wood strength.

Extensive studies are being made of means for controlling the checking and splitting of ties, both during the seasoning period and during service. Experiments to date on control methods during seasoning have resulted in the accumulation of important data, but have given no significant answer to the problem. An evaluation of over 20 coatings and end treatments under exterior exposure conditions shows that effective control can be insured during the first two or three months of air drying, but that over longer periods their effect becomes insignificant.

Control of check and split progression during service, however, is more promising. The use of special surface coatings on ties, either freshly laid or with some service, is producing interesting results. A few such coatings on a tie test section at the laboratory have given fine performance toward that objective after nearly a year of exposure.

A definitely new approach toward improving the treatability of wood used for cross ties, as well as for other products, is being investigated in conjunction with the other phases of the overall tie research program. Extensive experimentation is being done on the use of supersonic vibrations as a possible means for increasing preservative penetration on normally treatable species, and for improving the treatability of heartwood and certain refractory woods. This program is particularly fundamental, and a large amount of basic data has already been accumulated. The results to date offer some promise, but definite conclusions cannot be reported at this time.

Work is also underway on the development of a laminated wood tie. The design of such a composite and engineered tie is dependent both upon economic limitations and upon the necessary strength properties required of ties in service. Inasmuch as these properties have not been evolved satisfactorily through past studies and investigations, Teco research men have developed special techniques for the use of electrical resistance strain gages as a medium for the determination of the stresses to which ties are subjected. It is possible that the proposed field studies will result in more complete knowledge of tie strength requirements.

A number of tie inserts have been designed and made up in scale models. Such inserts have been based on four main considerations, namely:

1) Possible reduction in tie splitting.
2) Increase in resistance to plate cutting.
3) Dampening vibration caused by impact loading.
4) Anti-splitting feature for the inserts themselves.

Although these factors are important and would distinctly improve the wear resistance of ties in service, it is readily appreciated that the ultimate value of any type of insert will be dependent upon adequate and lasting attachment to the tie. For several reasons, little work has been done toward that end in the Timber Engineering Company program. In due time, it is believed that special testing facilities will be available for more complete analysis of this problem.

From this brief summary, it can be appreciated that a great deal of progress has been made toward the main objectives. In the year ahead, it is hoped that many of the proposed innovations can be service tested and then made available for rather general use.

Report on Assignment 6

Bituminous Coating of Ties for Protection from the Elements

R. W. Cook (chairman, subcommittee), C. S. Burt, R. E. Butler, W. E. Fuhr, L. E. Gingerich, M. J. Hubbard, Roy Lumpkin, R. A. Pidgeon, W. C. Reichow, F. S. Shinn, J. G. Sutherland, S. Thorvaldson.

This is a progress report, presented as information.

This subject is becoming more important every day for the consideration of track supervisors. It is very important in the matter of conservation of our natural resources, as the available supply of good timber is becoming depleted at an alarming rate.

A large number of ties are removed from track because of mechanical failure. It is believed that the natural weathering, checking and splitting of ties is one of the main causes for mechanical failure. Tests are being run by several roads to determine if the application of bituminous coatings will prevent or retard the natural weathering and checking of ties. By eliminating open splits and checks extending under the rail bearing, this area will be kept drier, thereby reducing plate cutting. It is also believed that the coating will prevent checks extending into untreated heartwood, particularly in the *Tc* group, thus eliminating center rot.

There are several different types of bituminous coatings being offered for this purpose, and several different methods of application. So far it is believed that the spray method is more satisfactory and most economical, although it is too early yet to recommend the best type of compound as the various tests have not been under way long enough to draw any conclusions.

A very interesting article appeared in Railway Engineering and Maintenance, October 1949, by H. D. Currie, master carpenter, Baltimore and Ohio Railroad, on the Prolonging Life of Ties on Bridges and Trestles. There was also a long article in Modern Railroads, December 1949, entitled Tie Weathering Checked and Retarded by Sealing Compound on the Erie Railroad.

A questionnaire was sent to Members of Committee 3—Ties, AREA, and of 39 replies received, 4 roads are making tests of bituminous compounds to prevent tie checking and weathering, 5 roads expect to start tests at an early date, and 30 roads have no plans for the use or tests of this material.

Report on Assignment 7

Causes Leading to the Removal of Ties

B. S. Converse (chairman, subcommittee), C. M. Coates, E. L. Collette, R. L. Cook, W. F. Dunn, Sr., W. J. Kernan, C. M. Long, W. O. Nelson, M. H. Priddy, E. F. Salisbury, P. V. Thelander.

Your committee presents as information the following progress report of a study to determine the causes leading to the removal of cross ties from track.

One previous report on this assignment has been made (Proceedings, Vol. 47, 1946, pages 133 and 134), in which a statement form was described which would standardize the tabulation of tie failure causes to permit comparative studies of records from a wide variety of sources. It was intended originally that a large source of data would be field inspections made biannually by the committee, but it became apparent that the committee was unable to inspect a sufficient number of cross ties which had been removed from track to compile a record from which definite conclusions could be drawn. Therefore, it became necessary to interest as many railroads as possible in collecting and transmitting to the committee tie failure data on the statement form. Solicitation of all Class 1 railroads was made for records of tie failures in established tie test sections or from records from test sections which could be established in the interest of this study. Also, in that it appeared that another excellent source of data was the inspection of ties removed from track in connection with seasonal programs, some roads were solicited for information from such inspections.

The results of this solicitation have been most encouraging. Five roads, which are now keeping tie failure statistics on a form similar to that published, have furnished complete records to the committee. Two additional roads caused inspections to be made of substantial numbers of ties removed during the season's program, tabulating the results on the recommended form. Five other railroads agreed to adopt the recommended statement form in connection with established tie test sections, and ten other roads agreed to collect tie failure data for the use of the committee. To date, records of failure for cause have been received on 302,621 ties.

In order to obtain the proper percentage of total ties failed for each cause, it was necessary to classify them into groups of similar performance characteristics, as there would be little value in overall figures. Therefore, the ties of record have been classified into four timber groups, designated as oaks, gums, needleleaved, and other, and further classified into two treatment groups—creosote and other—with untreated ties eliminated from the study.

A summation of the failure records received to date has been made for each of the groups, and the percent of ties failed for cause determined. However, there is not yet sufficient diversification of territories or inspecting personnel represented by these records for the committee to come to a definite conclusion. Nevertheless, it would seem proper to indicate progress being made on the subject, so the following comments on the analysis of the failure records studied to the present time are being published as a matter of information:

Oaks

Based on the record of 50,992 ties in this group, it would appear that a very large majority of the treated oak ties removed from track have failed from splitting. The only exception to this general statement is ties removed from track in the middle south, where the principal cause of failure is decay.

Needleleaved Group

There is a marked lack of consistency in the failure records of the 230,267 ties in this group, so that no conclusive statement can be made. However, we take note of the fact that a large number of these ties are removed because of plate cutting, and that splitting appears to be another substantial cause for removal.

Gums

Inspection reports on only 20,248 ties in this group have been received. From analysis of this small number it would appear that the major portion of ties removed have failed because of either splitting or decay.

Your committee will continue to progress its study of this subject until such time as a sufficient amount of diversified statistical material has been accumulated to permit the drawing of definite conclusions.

Report on Assignment 8

Prebored Ties: Benefits and Factors Affecting Economy

W. J. Burton (chairman, subcommittee), R. F. Bush, W. P. Conklin, T. Crawford, W. T. Donoho, C. R. Lapeza, J. R. Latimer, H. W. Seeley, Jr., E. F. Snyder, S. Thorvaldson.

This report is offered as information and is a summary of material contained in previous reports to the Association.

The preboring of ties is done for the following reasons:

1. Cut spikes driven into prebored holes of the proper size damage the wood less than those driven without holes.
2. Cut spikes driven into prebored holes of the proper size have greater holding power than those driven without holes.
3. Spikes driven into prebored holes have greater resistance to side thrust.

4. With holes in correct position, and using spikes adapted to following the holes, exact line and gage of track is more easily attained. There is less difficulty in centering ties in the track, as centering is done by the adzing and boring machine.
5. At least with certain woods, the spike holes assist in obtaining better penetration of the creosote, or other preservative, in the vicinity of the spikes and the rail seat, where the preservative is most needed.
6. For good track, tie plates must have full bearing, and the two plates must lie in the same plane, parallel to the length of the tie. Adzing should be done prior to treatment to avoid the likelihood of exposing untreated wood, such as heartwood. Machine adzing at the tie plant, after the ties have seasoned (some of which have warped during seasoning) is not only superior in workmanship to hand adzing or machine adzing in the field, but is less costly. As adzing is so necessary, and as the additional cost of boring holes with the same adzing and boring machine at the same time is small, the boring may be considered to cost very little. Such additional cost is much less than the benefits derived.
7. In most cases, some ties will be supplied to locations where the boring does not fit the rail and plates. Careful planning and programming of work can minimize the number of these misfits. Where these do occur, creosoted plugs, driven into the prebored holes, will permit driving spikes into the tie plate holes with little or no difficulty.

Proceedings of the AREA contain reports supporting these statements.

Report of Committee 17—Wood Preservation

G. B. CAMPBELL,
Chairman,
W. P. ARNOLD
W. W. BARGER
J. A. BARNES
A. S. BARR
R. S. BELCHER
P. D. BRENTLINGER
WALTER BUEHLER
C. M. BURPEE
C. S. BURT
G. L. CAIN
H. B. CARPENTER
W. F. CLAPP
G. H. DAYETT, JR.
J. W. DIFFENDERFER
R. F. DREITZLER
H. R. DUNCAN
W. F. DUNN
T. H. FRIEDLIN
F. J. FUDGE
W. H. FULWEILER
H. F. GILZOW
W. R. GOODWIN
F. W. GOTTSCHALK
B. D. HOWE
M. S. HUDSON
R. P. HUGHES
M. F. JAEGER
A. L. KAMMERER
L. W. KISTLER,
Vice-Chairman,
A. J. LOOM
G. L. P. PLOW
R. R. POUX
M. H. PRIDDY
J. W. REED
W. C. REICHOW
HENRY SCHMITZ
L. B. SHIPLEY
W. B. STOMBOCK
J. E. TIEDT
H. C. TODD, JR.
HERMANN VON SCHRENK
C. H. WAKEFIELD
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.
2. Service test records of treated wood.
   Progress report, presented as information .... page 314
3. Destruction by marine organisms; methods of prevention.
   No report.
4. Creosote-petroleum solutions.
   No report.
5. Destruction by wood destroying insects; methods of prevention, collaborating with Committees 6 and 7.
   Progress report, presented as information .... page 317
6. New impregnants and procedures for increasing the life and serviceability of forest products.
   No report.
7. Incising forest products.
   Progress report, presented as information .... page 317
8. Review the specifications for creosote, particularly with respect to limitation of residue above 355 deg. C., and other revisions resulting from changes in processes of manufacture.
   Progress report, presented as information .... page 318
9. Treatment of wood to make it fire resistant.
   Progress report, presented as information .... page 319
10. Artificial seasoning of forest products prior to treatment.
    No report.

THE COMMITTEE ON WOOD PRESERVATION,
G. B. CAMPBELL, *Chairman.*

AREA Bulletin 491, December 1950.

Report on Assignment 2

Service Test Records of Treated Wood

A. J. Loom (chairman, subcommittee), G. H. Dayett, Jr., T. H. Friedlin, W. R. Goodwin, R. P. Hughes, G. L. P. Plow, J. W. Reed, W. C. Reichow.

The following report of test records is submitted as information:

The Baltimore & Ohio Railroad reports on 1949 inspection of experimental ties in test tracks at Germantown—Barnesville, Md., Backus, Pa., and Hills–Loveland, Ohio.

The Northern Pacific Railway reports on the 1950 inspection of experimental ties in new test tracks near Cle Elum, Wash., Scoria and Joppa, N. Dak. Annual inspections are being made and future reports will show cause for removal of each tie replaced in each of these tracks.

TIE TEST—BACKUS, PA.

Length of Test—39 Years; Report for 1949 Renewals; Installed—November 1910

Kind of Wood	*Straight Creosote 10 lb. per cu. ft.*				*Avg. Life to date*
	Ties Placed	*In Test*	*Removed to date*		
			Number	*Percent*	
Red oak	72	8	64	89	31.2
Black oak	260	17	243	93	32.3
Pin oak	316	17	299	95	32.5
Maple	543	143	400	74	33.3
Beech	824	100	724	88	31.1
Birch	19	4	15	79	30.5
Cherry	9	1	8	89	29.6
Gum	12	1	11	92	31.4
Chestnut	170	0	170	100	21.2
Hickory	146	9	137	94	29.8
Total	2371	300	2071	87	31.1

Note—Entire test on 3-deg. curve.

TIE TEST—HILLS–LOVELAND, OHIO

Length of Test—20 Years; Report for 1949 Renewals; Installed—January 1930

Kind of Wood	*Straight Creosote*					*Avg. Life to date*
	Absorption	*Ties Placed*	*In Test*	*Removed to date*		
				Number	*Percent*	
Red oak	4.78 lb.	600	600	56	9	19.5
Red oak	6.25 lb.	600	600	73	12	19.3
Red oak	8.17 lb.	600	600	136	23	19.2
	60 Percent Creosote—40 Percent Petroleum					
Chestnut	8.97 lb.	400	400	400	100	13.8
Gum	8.97 lb.	400	400	3	1	20.0
Hickory	8.48 lb.	400	400	15	4	19.9
Sap beech	8.97 lb.	200	200	1	0	20.0
Heart beech	10.47 lb.	200	200	0	0	20.0
White oak	5.47 lb.	600	600	1	0	20.0
Red oak	8.15 lb.	1200	743	29	4	20.0
R. O. (Damaged)	8.15 lb.	457	457	119	26	18.8

TIE TESTS AT GERMANTOWN—BARNESVILLE, MD.

Length of Test—21 Years

Report for 1949 Renewals Installed Summer—1928

Treatment		*Ties Placed*	*In Test*	*Removed to date*		*Avg. Life to Date*	*Condition*
				No.	*Per-cent*		
Red Oak							
8 lb. Creo-petroleum	50–50	300	68	232	77	18.6	good, splits and decay
9 lb. Creo-petroleum	50–50	900	452	448	50	19.6	bad splits, decay
9 lb. Creo-coal tar	50–50	900	410	490	55	19.9	fair, some decay
10 lb. Creo-coal tar	60–40	900	358	542	60	19.8	much decay
8 lb. Water gas tar	100%	900	138	762	85	17.2	much decay
9 lb. Creo-pet-w.g. tar	30–30–40	900	151	749	83	18.1	splits
8 lb. Creosote	100%	900	89	811	90	19.8	splits and decay
8 lb. Creo-water gas tar	50–50	900	142	758	84	20.0	bad splits and decay
9 lb. Creo-water gas tar	40–60	900	21	879	98	19.9	bad splits and decay
10 lb. Creo-water gas tar	30–70	900	799	101	11	20.9	jt. ties decayed
8 lb. Creo-pet- w. g. tar	30–50–20	900	458	442	49	19.3	fair condition
10 lb. Creo-pet-w. g. tar	40–30–30	900	866	34	4	20.9	poor, decay
6 lb. Creosote	100%	900	430	470	52	20.4	splits, decay
0.47 lb. Zinc-3.75 lb. petroleum	----------	600	61	539	90	15.6	worthless
0.32 lb. Zinc-4.70 lb. petroleum	----------	600	145	455	76	16.1	worthless
10 lb. Creo-coal tar	80–20	900	887	13	1	21.0	good
9 lb. Creo-coal tar	70–30	900	889	11	1	20.9	splits, rail cut
9 lb. Creo-petroleum	40–60	900	899	1	0	21.0	bad splits, decay
Total	----------	15000	7263	7737	52	19.6	
White Oak							
5 lb. Creosote-coal tar	50–50	300	147	153	51	20.0	much decay
7 lb. Creosote-coal tar	60–40	300	99	201	67	19.6	some splits, decay
7 lb. Water gas tar	100%	300	250	50	17	19.9	splits
7 lb. Creo-pet-w. g. tar	30–30–40	300	134	166	55	18.9	splits, spike killed
6 lb. Creosote	100%	300	34	266	89	19.2	some checked
8 lb. Creosote	100%	300	64	236	79	20.1	some decay, splits
8 lb. Creo-water gas tar	50–50	300	65	235	78	20.2	good
7 lb. Creo-water gas tar	40–60	300	173	127	42	20.5	some decay
8 lb. Creo-water gas tar	30–70	300	280	20	7	20.9	some rail cut
5 lb. Creo-pet-w. g. tar	30–50–20	300	146	154	51	18.7	good
7 lb. Creo-pet-w. g. tar	40–30–30	300	300	0	0	21.0	very good
0.41 lb. Zinc-2.82 lb. petroleum	----------	300	176	124	40	19.0	much decay
7 lb. Creo-coal tar	80–20	300	300	0	0	21.0	good, decay
8 lb. Creo-coal tar	70–30	300	300	0	0	21.0	good, rail cut
7 lb. Creo-petroleum	50–50	300	300	0	0	21.0	fair, rail and decay
7 lb. Creo-petroleum	40–60	300	300	0	0	21.0	very good
Total	----------	4800	3068	1732	36	20.1	
Mixed Woods							
9 lb. Creo-coal tar	50–50	300	241	59	20	20.6	good
8 lb. Creo-coal tar	60–40	300	235	65	22	20.6	good, splits
9 lb. Water gas tar	100%	300	264	36	12	20.2	some decay
10 lb. Creo-pet-w. g. tar	30–30–40	300	186	114	38	19.5	some splits, decay
8 lb. Creosote	100%	300	88	212	71	19.1	good
8 lb. Creosote	100%	300	146	154	51	20.5	very good
8 lb. Creo-water gas tar	50–50	294	70	224	75	20.2	some decayed
10 lb. Creo-water gas tar	40–60	300	296	4	1	20.9	more decayed
10 lb. Creo-water gas tar	30–70	300	300	0	0	21.0	rail cut
9 lb. Creo-pet-w. g. tar	30–50–20	300	272	28	9	20.6	good, a few splits
10 lb. Creo-pet-w. g. tar	40–30–30	300	300	0	0	21.0	very good
9 lb. Creo-coal tar	80–20	300	300	0	0	21.0	very good
8 lb. Creo-coal tar	70–30	300	300	0	0	21.0	some splits
8 lb. Creo-petroleum	50–50	300	300	0	0	21.0	very good
9 lb. Creo-petroleum	40–60	300	300	0	0	21.0	very good
Total	----------	4494	3598	896	20	20.5	
Grand Totals	----------	24294	13929	10365	43	19.9	

Northern Pacific Railway Company

Tie Record Test Track No. 9

Roslyn Branch, Tacoma Division, near Cle Elum, Wash. Line to N. W. I. Co. No. 9 Mine.

1000 No. 4 Coast hemlock ties treated at Seattle, Wash., and placed in track in 1930.

No renewals have been made to date.

Most of these ties are covered by dirt, coal dust and weeds. Some joint spikes are loose but ties are in good condition.

Northern Pacific Railway Company

Tie Record Test Track No. 6

Bristol Line Change, Tacoma Division M. P. 16 + 00 to M. P. 16 + 1700. About 7 miles east of Cle Elum, Wash.

1000 No. 5 Coast Douglas fir ties treated at Seattle, Wash., with 50–50 creosote-petroleum solution and placed in track in 1944.

No renewals have been made to date.

Ties are in good condition.

Northern Pacific Railway Company

Tie Record Test Track No. 3

Scoria Line Change, Yellowstone Division between M. P. 146 and 147, about 35 miles west of Dickinson, N. Dak.

644 No. 5 hardwood ties treated at Brainerd, Minn., with 50–50 creosote–petroleum solution and placed in track in 1946.

No renewals have been made to date. Some ties are split and checked but only two to the extent that they will need to be renewed within the near future. The balance are in very good condition.

Northern Pacific Railway Company

Tie Record Test Track No. 4

Joppa Line Change, Yellowstone Division between M. P. 106 and 107. About 18 miles east of Forsyth, Mont.

1000 No. 5 Coast Douglas fir and hemlock ties treated at Hillyard, Wash., with 50–50 creosote–petroleum solution and placed in track in 1945. Tie plates lagged to ties.

No renewals have been made to date and all ties are in good condition.

Report on Assignment 5

Destruction by Wood Destroying Insects; Methods of Prevention, Collaborating with Committees 6 and 7

W. F. Dunn, Sr. (chairman, subcommittee), Walter Buehler, W. F. Clapp, W. H. Fulweiler, H. F. Gilzow, F. W. Gottschalk, B. D. Howe, M. F. Jaeger, A. L. Kammerer, H. C. Todd, Jr., Hermann von Schrenk.

The following report is submitted as information.

During the year all subcommittee matters were handled by correspondence.

Dr. A. L. Kammerer will, when conditions are propitious, make a progress, or perhaps final, report on the 1939 test at Florissant, Mo., the last progress report on which appears in the Proceedings, Vol. 50, 1949, pages 379–381.

Dr. W. H. Fulweiler is assembling data from railroads in the South and Southwest on destruction by insects other than termites. The list of such destructive insects brought to the committee's attention so far includes:

Termites	*Species*
Subterranean termites	*Reticulitermes*
Drywood termites	*Kalotermes*
Dampwood termites	*Zootermopsis*
Bees and Ants	
Carpenter ants	*Campomotus*
Carpenter bees	*Xylocopa*
Wood-Boring Beetles	
Powder-post beetles	*Lyctus*
Death-watch beetles	*Xestobium*
Bostrichid beetles	*Scobicia*
Ambrosia beetles	*Trypodendron*
Flatheaded borers	*Buprestidae* family
Roundheaded borers	*Cerambycidae* family

The investigation now in progress may indicate additional species that may also attack timber.

Report on Assignment 7

Incising Forest Products

W. P. Arnold (chairman, subcommittee), Walter Buehler, F. W. Gottschalk, B. D. Howe, R. P. Hughes, A. J. Loom, C. H. Wakefield.

This is a progress report, presented as information.

Effect of incising on checks and splits in hardwood ties.

Erie Railroad

The Erie has started a test of incising and end ironing *Tc* ties before seasoning. Approximately 1400 cross ties, including hickory, beech, gum, elm, cherry, maple and walnut, were arranged into four groups, handled as follows when delivered at the treating plant yard for seasoning.

A

1. Incised and end ironed
2. Incised only
3. End ironed only
4. Controls—no incising or ironing

The ties have been placed in conventional 1 by 8 stacks for air seasoning. Their condition will be observed when taken down for treatment, and later on after they have been placed in track.

Wheeling and Lake Erie Division of Nickel Plate Road

The test of incised ties reported in the 1950 Proceedings is still in progress, and will be reported on further when new information is available.

Boston and Maine

The Boston and Maine Railroad has made the incising of mixed hardwood ties a standard practice. Results to date indicate a definite reduction in large seasoning checks and some improvement in penetration.

Great Northern and Soo Railways

Tests, described in the 1950 Proceedings, under the Great Northern Railway and the Minneapolis, St. Paul & Sault Ste. Marie Railway are still in progress and will be reported as new information develops.

Report on Assignment 8

Review the Specifications for Creosote, Particularly with Respect To Limitation of Residue Above 355 deg. C., and Other Revisions Resulting from Changes in Processes of Manufacture

L. B. Shipley (chairman, subcommittee), W. W. Barger, R. S. Belcher, Walter Buehler, C. M. Burpee, W. H. Fulweiler, W. R. Goodwin, A. L. Kammerer, Henry Schmitz, J. E. Tiedt.

This is a progress report, presented as information.

Subcommittee 8 has continued with its investigations on this assignment. It has not as yet reached conclusions regarding revisions of the present AREA specifications for creosote.

In this connection it is of interest to note that at the annual convention of the American Wood-Preservers' Association during April 1950, at Houston, Tex., the Preservatives Committee P-2 of the AWPA recommended a revision of the present AWPA specifications for creosote, and that steps were initiated to have this revised specification adopted as a tentative standard by the AWPA.

Subcommittee 8 has given careful consideration to the proposed tentative AWPA specifications for creosote and is of the opinion that they represent quiet a departure from the present standard specifications for creosote of the AWPA and of the AREA. The proposed revisions would place both maximum and minimum limitations of residue above 355 deg. C. They would also place minimum limitations on the specific gravities of the fractions, which in footnote No. 1 of the present specifications is but one of three optional purity tests, thereby eliminating the other two optional purity tests of footnote

No. 1. Subcommittee 8 is of the opinion that these features of the revisions as proposed by Preservatives Committee P–2 of the AWPA warrant further study and that all available data should be carefully reviewed before satisfactory and reliable conclusions can be recommended regarding the revision of present AREA specifications for creosote.

Report on Assignment 9

Treatment of Wood to Make It Fire Resistant

W. H. Fulweiler (chairman, subcommittee), W. P. Arnold, W. W. Barger, R. S. Belcher, P. D. Brentlinger, T. H Friedlin, F. W. Gottschalk, M. S. Hudson, R. R. Poux, Henry Schmitz, H. C. Todd, Jr., Hermann von Schrenk, C. H. Wakefield.

The subcommittee feels, at the present time, that it is only in a position to make a progress report.

The reason therefor is the lack of general agreement as to the standards by which fire resistance may be defined or evaluated.

There are three points that must receive consideration:

1. A definition of fire-resistant or fire-retardant wood.

2. The acceptance of some standard to define the degree of fire resistance.

There appears to be a feeling that in view of all the circumstances surrounding the development of the flame-spread test as exemplified by the Underwriters' Laboratory work, this should be accepted as a standard. The committees of the ASTM and AWPA are apparently thinking in this direction.

3. The Underwriters' test is not suitable as a plant acceptance test. It would be necessary to adopt some test that could be used as an acceptance test.

The Underwriters' test determines essentially flame spread, while the two existing laboratory tests appear to determine combustibility, and there is not sufficient data to indicate the degree of correlation between these two characteristics.

Your committee is following the work of other committees in the field and hopes that it will be prepared to present something more definite for consideration in the near future.

Report of Committee 22—Economics of Railway Labor

H. E. Kirby, *Chairman,*
Lem Adams
A. D. Alderson
M. B. Allen
H. C. Archibald
B. L. Beier
E. J. Brown
J. A. Bunjer
F. G. Campbell
R. H. Carpenter
G. E. Chambers
J. B. Clark
M. W. Clark
P. A. Cosgrove
A. A. Cross
J. P. Ensign
J. L. Fergus
H. W. Flemming
R. J. Gammie
L. C. Gilbert
E. A. Gill
W. W. Greiner
C. G. Grove
C. T. Gunsallus
K. H. Hanger
K. E. Henderson
T. B. Hutcheson
J. E. Inman
G. A. Kellow
N. M. Kelly
W. I. King
Roy Lumpkin
J. S. McBride
E. H. McIlheran
W. H. Miesse
H. L. Miller
H. C. Minteer
H. K. Modery
G. L. Sitton,
Vice-Chairman,
G. M. O'Rourke
W. G. Pfohl
W. G. Powrie
L. F. Racine
A. G. Reese
C. W. Reeve
H. F. Reilly
C. R. Riley
D. E. Rudisill
W. H. Vance
E. C. Vandenburgh
G. E. Warfel
J. S. Wearn
H. J. Weccheider
J. G. West, Jr.
Edward Wise, Jr.
C. R. Wright
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 322
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 322
3. Organization of forces for track maintenance operations.
   Progress report presented as information .... page 329
4. Labor economies of various methods of tamping track.
   No report.
5. Organized training of supervisors.
   No report.
6. Labor economies of various types of foundation under railroad crossings.
   No report.
7. Labor economics which may be effected through grading right-of-way.
   Final report, presented as information .... page 332
8. Meeting conditions imposed by shorter work week.
   No report.
9. Economies which may be effected by mechanical cribbing and/or cleaning of ballast.
   No report.
10. Economics of continuous welded rail, collaborating with Committee 4.
    No report.

The Committee on Economics of Railway Labor,
H. E. Kirby, *Chairman.*

AREA Bulletin 491, December 1950.

Report on Assignment 1

Revision of Manual

C. G. Grove (chairman, subcommittee), Lem Adams, E. J. Brown, J. B. Clark, R. J. Gammie, E. A. Gill, G. A. Kellow, Roy Lumpkin, J. S. McBride, G. M. O'Rourke, W. G. Powrie, A. G. Reese, G. L. Sitton, W. H. Vance, Edward Wise, Jr., C. R. Wright.

During 1949 your committee revised the material on pages 22–10, 11 and 12 in the Manual relating to the Housing of Maintenance of Way Employees, and same was approved at the 1950 convention and entered in the Manual as pages 22–10 and 22–11.

This year the committee has reviewed the drawings on pages 22–13 and 22–14 and, as a result, makes the following recommendations for revision of the Manual.

1. It is recommended that the following two types of cars be added to the list on page 22–11:

Kitchen—cook car
Wash—shower—toilet car.

2. It is recommended that the last paragraph on page 22–11 be deleted and the following substituted:

"The following drawings, Figs. 1 and 2, show typical plans for the construction and arrangement of:

Sleeping car
Kitchen—dining car
Recreation car
Kitchen—dining—sleeping car
Foreman car
Dining car
Kitchen car
Kitchen—cook car
Laundry car
Wash—shower—toilet car

for use in maintenance of way work, using freight equipment. The general arrangement of facilities may be similar for passenger equipment. The plans are suggestive only and may be changed to meet local conditions."

3. It is recommended that Figs. 2201 and 2202 on pages 22–13 and 22–14 be deleted and the plans shown as Figs. 1 and 2 on the following pages be substituted therefore.

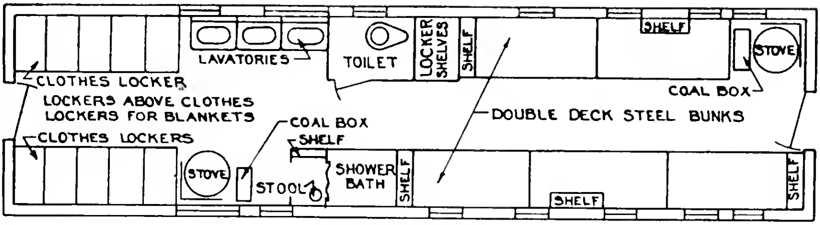
Report on Assignment 2

Analysis of Operations of Railways That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work

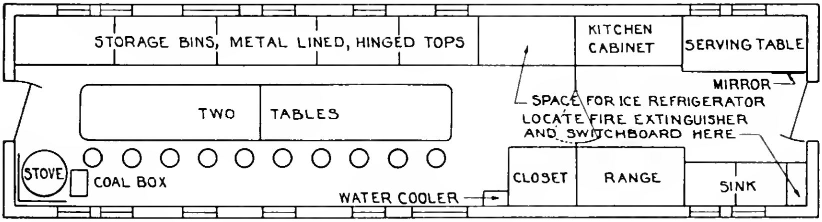
C. W. Reeve (chairman, subcommittee), Lem Adams, H. C. Archibald, E. J. Brown, F. G. Campbell, R. J. Gammie, W. W. Greiner, K. H. Hanger, T. B. Hutcheson, E. H. McIlheran, H. C. Minteer, G. M. O'Rourke, D. E. Rudisill, G. L. Sitton, E. C. Vandenburgh, J. S. Wearn, Edward Wise, Jr.

This report is presented as information.

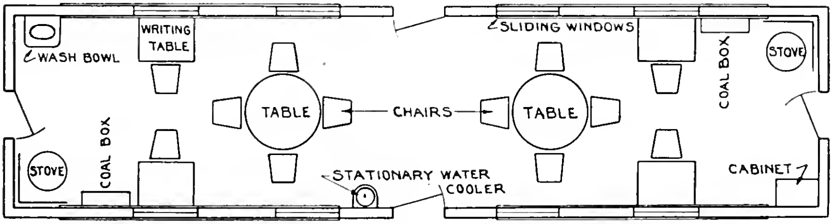
On September 20, 1950, Committee 22 was given an opportunity to make a study of the economies that have been realized by the Elgin, Joliet & Eastern Railway through the use of mechanized yard cleaning methods. Following are the findings of the committee:



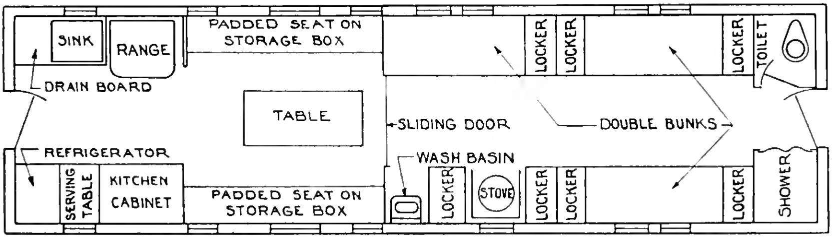
SLEEPING CAR



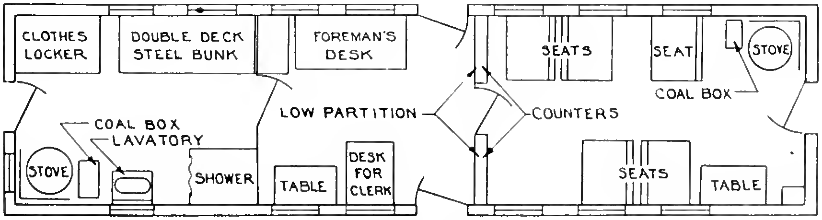
KITCHEN-DINING CAR



RECREATION CAR



KITCHEN-DINING-SLEEPING CAR

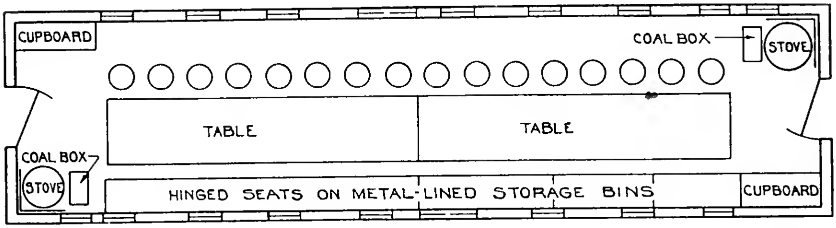


FOREMAN CAR

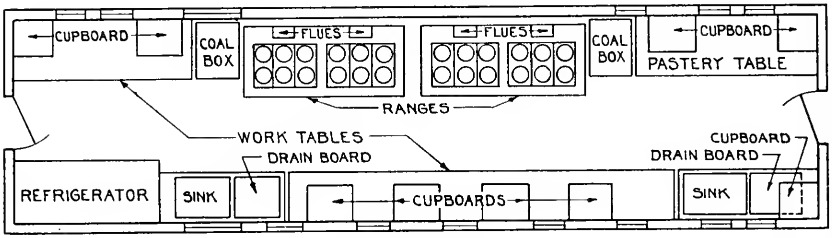
SCALE IN FEET

1 0 1 2 3 4 5 6 7

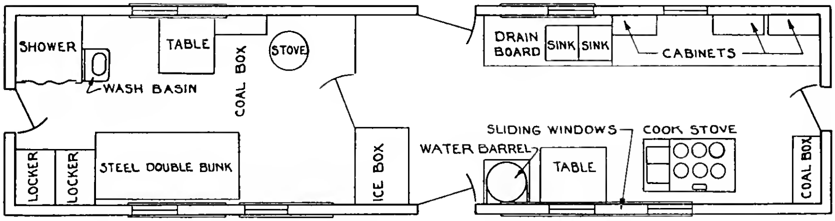
FIG. 1



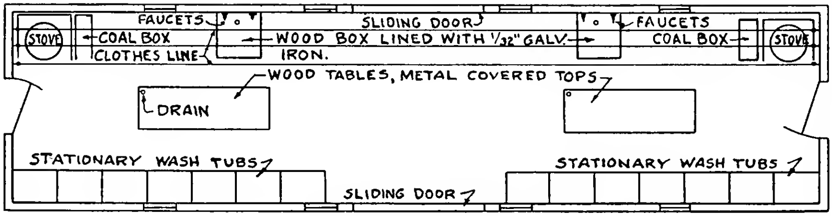
DINING CAR



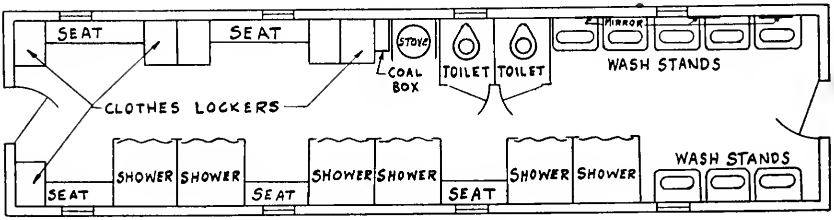
KITCHEN CAR



KITCHEN-COOK CAR



LAUNDRY CAR



WASH-SHOWER-TOILET CAR

SCALE IN FEET
1 0 1 2 3 4 5 6 7

FIG. 2

The cleaning of tracks on this property has for many years been of considerable importance. It was not until 1939, however, that regular gangs were organized in the four largest industrial yards and terminals of the E. J. & E. solely for the purpose of yard cleaning. Total recorded costs of yard cleaning in these principal yards from 1940 to 1949, inclusive, are shown in Table 1.

TABLE 1.—TOTAL COSTS OF YARD CLEANING 1940 TO 1949, INCLUSIVE

	South Chicago Mill yard	*Kirk yard*	*Gary Mill yard*	*East Joliet*	*Total*
1940	$ 20,688	$ 9,358	$ 30,808	$ 8,828	$ 69,682
1941	19,825	6,600	31,239	14,472	72,136
1942	37,750	16,451	50,999	14,791	119,991
1943	46,216	21,669	88,849	21,157	177,891
1944	74,083	20,869	135,437	31,828	262,217
1945	50,974	17,337	90,412	33,721	192,444
1946	44,903	17,314	74,266	28,047	164,530
1947	49,616	38,026	101,071	29,538	218,251
1948	46,304	53,728	107,068	36,397	243,497
1949	48,561	32,497	108,819	28,074	217,951
Total	$438,920	$233,849	$818,968	$246,853	$1,738,590

The marked increase in costs over the ten-year period covered by the above tabulation was brought about both by increased labor costs and through more thorough and intensive yard cleaning. The rapid increase in labor costs over this period is indicated in Table 2.

TABLE 2.—BASIC RATES PAID TRACK LABOR, JANUARY 1, 1940 TO JUNE 30, 1950

January 1, 1940, to November 30, 1941	$0.45	per hour
December 1, 1941, to January 31, 1943	0.55	" "
February 1, 1943, to December 26, 1943	0.64	" "
December 27, 1943, to December 31, 1945	0.65	" "
January 1, 1946, to May 21, 1946	0.81	" "
May 22, 1946, to August 31, 1947	0.835	" "
September 1, 1947, to September 30, 1948	0.99	" "
October 1, 1948, to August 31, 1949	1.06	" "
*September 1, 1949, to June 30, 1950	1.258	" "

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* 40-hour week.

The E. J. & E. reports that during the first three years of the period 1940 to 1949, inclusive, thorough cleaning of tracks was confined, for the most parts, to switching leads, and that cleaning in the body of yards, to a large extent, was left until it was necessary in connection with tie and rail renewals. Demands upon the maintenance of way forces for more thorough yard cleaning have, however, been constantly increasing, and, beginning with about 1943, a serious effort was made to keep the entire trackage in these large yards free of debris, until at the present time all tracks are cleaned at least once each year and some are cleaned two or more times every year.

Beginning in 1939, yard cleaning was done almost entirely by hand labor, except for the final loading of debris from piles in standard cars with cranes handled by work train. In some cases debris was trucked a considerable distance on push cars, where it was unloaded into temporary piles to be picked up later by crane. In other cases standard cars were pinched along the tracks and the debris was loaded directly into these cars by hand labor.

Fig. 1. Beginning in 1943 motor-car-hauled hydraulic dump-box trains were used to dispose of the yard debris.

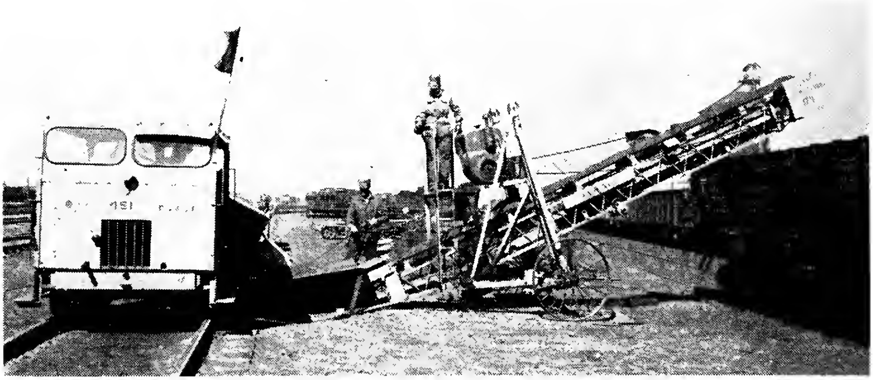

Fig. 2. One of the portable elevating loaders used to dispose of the yard refuse in cars.

In 1943 a plan was begun to equip push cars with hydraulic dump boxes similar to those shown in Fig. 1. These dump boxes were loaded by hand and were hauled by motor car to convenient low spots where they were dumped. Such accessible low spots were soon filled and it was necessary to acquire portable elevating loaders to elevate the debris from the hydraulic dump boxes into standard cars (see Fig. 2). One of these elevating loaders is now being used in each of the four large yards.

Even this limited amount of mechanization, together with improved efficiency, considerably reduced yard cleaning costs. This is illustrated in Table 1 and Table 2, from which it may be noted that the increase in yard cleaning costs since 1943 has been much less than the comparative increase in the rates paid track labor, regardless of the fact that since 1943 the yard tracks have been constantly and more thoroughly cleaned, and that each year a greater amount of debris has been removed.

Early in 1949 there was placed in service in Kirk yard a track cleaning machine which consists essentially of a powered impeller, which throws the debris from between

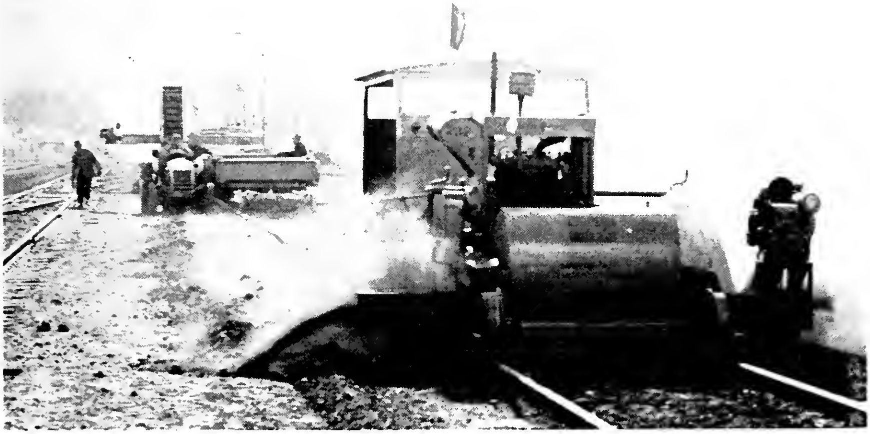

Fig. 3. The track cleaning machine in action. Note windrows of debris plowed outward from the rails.

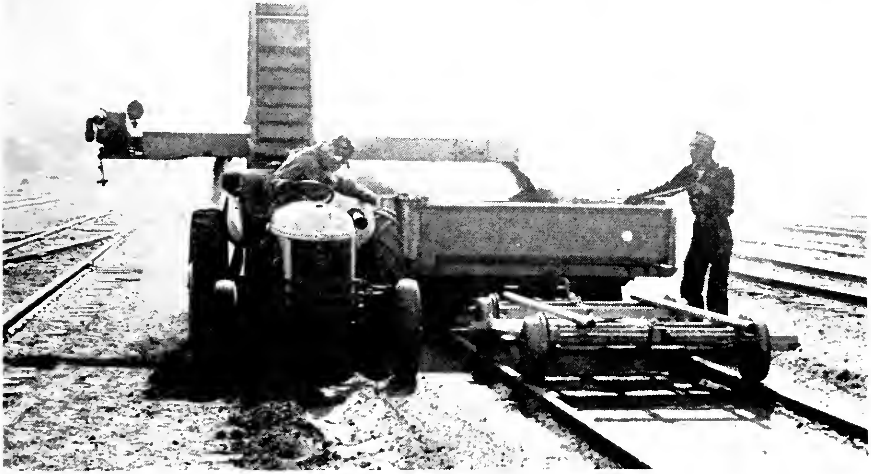

Fig. 4. The tractor-mounted loader, picking up the windrowed debris and loading it into hydraulic dump boxes.

the rails onto a horizontal conveyor, which in turn conveys the debris to a windrow alongside the track. Plows are mounted on the track cleaning machine, which plow the debris from outside the rail into the same window (Fig. 3). During the first year this machine was in use, debris from the windrow was loaded into hydraulic dump boxes by hand and disposed of as described previously. It will be noted from Table 1 that through the use of this machine the yard cleaning costs in Kirk yard in 1949 were reduced by more than $21,000 from the 1948 costs. The actual saving was considerably more than this since, as will be shown later, the yard debris removed from Kirk yard in 1949 was almost double that removed in 1948.

It was not until the close of 1949 that a successful power loader could be developed which would mechanically load the debris from the windrows into the hydraulic dump boxes. Such a machine was placed in service early in 1950. This loader consists essentially of a vertical bucket conveyor and a horizontal belt conveyor, each independently powered, mounted on an ordinary rubber-tired tractor (Fig. 4). This loader is being used with the track cleaner. These two machines, with a foreman, six laborers, and two machine operators, can do approximately the same amount of yard cleaning as could previously be done with 1 foreman and 25 laborers, using the same equipment for transporting and loading into standard cars.

To illustrate better the savings which can be effected in yard cleaning work through mechanization, reference is made to the accompanying Tables 3 to 8, inclusive, which present various statistics relative to yard cleaning operations on the Gary division of the E. J. & E. during the years 1948 to 1949, and during the first six months of 1950.

TABLE 3.—TOTAL CUBIC YARDS OF DEBRIS REMOVED JANUARY 1, 1948, TO JUNE 30, 1950

	1948	*1949*	*1st 6 Mo. 1950*
South Chicago Mill yard, Ill.	5,100	5,200	1,660
Kirk yard, Ind.	4,350	8,325	2,793
Gary Mill yard, Ind.	9,700	11,950	4,700
Total	19,150	25,475	9,153

TABLE 4.—TOTAL COSTS OF YARD CLEANING JANUARY 1, 1948 TO JANUARY 30, 1950

	1948	*1949*	*1st 6 Mo. 1950*
South Chicago Mill yard, Ill.	$ 46,304	$ 48,561	$19,773
Kirk yard, Ind.	53,728	32,497	12,197
Gary Mill yard, Ind.	107,068	108,819	35,231
Total	$207,100	$189,877	$67,201

TABLE 5.—COST PER CUBIC YARD

	1948	*1949*	*1st 6 Mo. 1950*
South Chicago Mill yard, Ill.	$ 9.08	$ 9.35	$ 11.90
Kirk yard, Ind.	12.33	3.90	4.37
Gary Mill yard, Ind.	11.04	9.10	7.50

Note. Cost figures do not include any percentage of the original cost of the mechanical yard cleaning machinery.

TABLE 6.—TOTAL MAN-HOURS USED IN YARD CLEANING JANUARY 1, 1948 TO JUNE 30, 1950

	1948	*1949*	*1st 6 Mo. 1950*
South Chicago Mill yard, Ill.	33,295	33,667	13,037
Kirk yard, Ind.	47,296	25,696	8,217
Gary Mill yard, Ind.	76,716	76,763	23,209
Total	157,307	136,126	44,463

TABLE 7.—MAN-HOURS PER CUBIC YARD

	1948	*1949*	*1st 6 Mo. 1950*
South Chicago Mill yard, Ill.	6.53	6.48	7.84
Kirk yard, Ind.	10.86	3.09	2.94
Gary Mill yard, Ind.	7.91	6.42	4.93

TABLE 8.—COST PER MILE OF TRACK

	Miles of Track	*1948*	*1949*
South Chicago Mill yard, Ill.	102	$454.00	$476.00
Kirk yard, Ind.	79	680.00	411.00
Gary Mill yard, Ind.	204	525.00	533.00

Tables 3 and 4 show the total cubic yards of debris removed and the total cost of cleaning, respectively, for these periods. Table 5 shows the resultant costs per cubic yard. Since these costs have been considerably affected by changes in rates paid labor, there is shown in Table 6 the total man-hours of track labor required to remove the debris shown in Table 3.

In Table 7 are shown the corresponding man-hours per cubic yard of debris removed. It is believed that Table 7 is more valuable for comparative purposes than Table 5. It is true that Table 5 reflects certain work-train costs that Table 6 does not, but during these particular years work-train costs were relatively minor and are not considered important.

Referring again to Table 7, it will be noted that in 1948 the yard cleaning costs per cubic yard were a great deal higher in Kirk yard than in the other two yards. This was caused largely by the fact that in Kirk yard refuse was being shovelled by hand directly into standard cars, while at South Chicago and Gary hydraulic dump boxes and elevating loaders were used. On the other hand, in 1949 the man-hours required per cubic yard in Kirk yard were less than half those required in the other two yards. This was due entirely to the track cleaning machine which was used in Kirk yard. At the South Chicago and Gary mill yards, the methods used in 1949 were exactly the same as those used in 1948. As previously stated, during the first six months of 1950 a mechanized loader was used in Kirk yard.

Conclusion

This investigation shows that the E. J. & E. has effected marked economies by the adaption of mechanized yard cleaning methods.

Report on Assignment 3

Organization of Forces for Track Maintenance Operations

H. C. Archibald (chairman, subcommittee), A. D. Alderson, J. A. Bunjer, R. H. Carpenter, A. A. Cross, J. P. Ensign, J. L. Fergus, N. M. Kelly, W. I. King, L. F. Racine, A. G. Reese, H. F. Reilly, W. H. Vance, J. S. Wearn, H. J. Weccheider, J. G. West, Jr.

The subject assigned for study by Subcommittee 3 under the above general heading is the use of a special machine for a particular operation in track maintenance—namely, a multiple electric tamper. Last year the subcommittee considered the practices and organization of crews for the use of the power ballaster, a machine likewise used for the mechanical tamping of track.

A canvass made of the practices in effect and the results secured by 25 railroads using multiple electric tampers forms the basis of the comments and recommendations given below. However, conditions vary over such a wide range (different types of ballast are in use, volume of traffic is never comparable, and the individual ideas of maintenance officers bring forth differences in methods of use) that it is impossible to say that certain methods will bring forth certain results.

The conclusions reached by the committee are general in scope and are offered as an aid in setting up an organization and procedure to secure good results from the use of a mechanized tool. The adaptation of this particular tool to fit local conditions of labor, rail, ballast, and traffic is properly under the sole control of the officers in the field.

Description

The multiple electric tamper is a self-propelled, on-track machine. A cross-head, to which are attached 12 vibratory tamping units, is lowered by gravity and raised hydraulically by a machine operator, who also moves the machine along the track, spotting it over each tie. When the cross-head is lowered, the tie is tamped on both sides and both ends simultaneously by the insertion of vibrating blades.

Eight blades, or "spuds", tamp the ends of the ties outside the rails, and four blades tamp the portions adjacent to the rails on the gage side. The cross-head is raised and lowered several times at each tie, simulating the practice of tamping with individual hand units. The tamping blades are mounted opposite each other and are inclined towards the center of the tie, thus compacting the ballast under the tie.

The machine is capable of travelling along the track at a speed of 20 mph., and may be removed from the track at a prepared set-off when it is necessary to work under traffic and a sidetrack is not available. However, if it is possible to secure possession of a reasonable length of track for the work of this machine, much better progress will be made and a more uniform job will be done.

As the cross-head is mounted on a cantilever arm projecting from the front end of a four-wheel carriage, the carriage itself, at all times, stands on tamped track, and there is no jarring of the roadbed when the tamping blades are inserted.

Preparatory Work—Distribution

In order that this machine may do its work economically, the proper amount of ballast must be distributed in advance to conform to the raise to be made. At no other operation is more intensive supervision and education of foremen required than at the unloading train. Ballast is valuable, work-train expense is large, and there is serious loss in unloading either too much or too little ballast, as the cost of picking up surplus ballast is prohibitive, the distribution of additional ballast increases the work-train expense, and lack of ballast may call for excessive hand forking to feed ballast to the tamper.

It is possible to secure proper distribution of ballast by the use of suitable equipment. For a heavy lift, the plowing off with a timber of ballast dumped from cars may be satisfactory, but for a surfacing lift of a few inches this method is hardly suitable. Special ballast cars are used by some roads to good advantage. Other roads use ballast pans, which are hung below the hoppers of hopper-bottom coal cars. The pans have openings (with sliding doors) which may be regulated to permit the ballast to flow through in small or large quantities as desired.

Whatever the method used, an intelligent foreman is needed, and with experience and close supervision he will find ways to place just the correct amount of new ballast in the track for the tamper operation.

Raising Track

A large majority of the railroads replying to the questionnaire reports the use of a considerable number of hand jacks to raise track ahead of the tamper. As many as 40 jacks are used by some roads in this operation, with the average of about 24. The track is raised and held to a true surface and cross level, and the jacks are not removed until the tamper is close to the nearest pair, after which they are carried ahead. With this method a refinement in surface is obtained that is suitable for high-speed operation.

A small number of roads use a power jack for raising track, or a combination of power jack and a number of hand jacks.

Tamping

When the multiple tamper was first put into use it was the practice to make a definite number of insertions of the tamping blades—say three or four to each tie. With experience it has developed that some ties need more tamping than others, as they may lie over a new bed of ballast, or may require a greater lift due to surfacing out a small sag, or for other reasons. Therefore, the number of insertions of the tamping blades should be varied to fit the conditions. It has been found that a good operator can tell by the "feel" of the machine, and by observation of the manner in which the spuds enter the ballast, just when to stop tamping.

It has become general practice to leave the number of insertions to the judgment of a good operator, subject of course, to the foreman's opinion and direction.

In this operation the quality of work is of greater importance than the quantity, and to secure the greatest benefits from modern machinery, sufficient time should be taken to secure long-lasting results.

Some roads have found it desirable to fill under the centers of the ties after the machine has passed. With certain types of ballast, vibration of the roadbed under traffic tends to cause ballast to roll down into the cavity at the center from the tamped portions near the rails. For a lasting job it would appear beneficial to fill this cavity.

Some roads do an extensive follow-up job of spot tamping to correct small irregularities promptly. It has been the experience of others, however, that if a careful job is done by the machine, with possibly additional insertions of the tamping blades, extensive spot-tamping behind will not be needed.

Organization

In the following table, any forces for installing ties are omitted, as the size of such forces will obviously depend on the extent of tie renewals, which, of course, vary greatly. The forces for unloading ballast are also omitted.

For a crew capable of producing 1500 ft. to 2000 ft. of tamped track per day, using one multiple tamper, the following organization is suggested:

1. Foreman—in charge
1 Trackman—water carrier
2 Trackmen—digging jack holes
1 Asst. foreman—raising track
4 Trackmen—jacking
1 Trackman—cross-leveling track, handling spot board and level board
8 Trackmen—filling cribs

2 Trackmen—removing jacks
1 Asst. foreman—ballast feeding and tamping
2 Trackmen—feeding ballast to tamper
2 Trackmen—holding up tie ends
1 Tamper operator (some roads use relief operators)
2 Trackmen—carrying jacks
2 Trackmen—filling in centers
1 Asst. foreman—lining track
12 Trackmen—lining track

Supervision		Personnel	
Foreman	1	Machine operator	1
Asst. foreman	3	Trackmen	38
		Total	39

In addition to the trackmen listed, operations may require the use of flagmen and watchmen, depending upon local conditions.

Some railroads have found it desirable to use a multiple tamper along with the installation of ties, in addition to the machine which makes the final surface.

The practice in such case has been to:

(a) Raise the track about 2½ in. on what ballast is in the cribs.
(b) Make tie renewals and respace ties as required.
(c) Rough tamp all ties with the multiple tamper, but not to refusal. Feeding ballast to tamper is not necessary.
(d) Unload ballast for final lift.
(e) Raise track to exact surface and level on jacks.
(f) Tamp all ties thoroughly with multiple tamper.

Note: It is desirable to have a good distance, say several days' work, between items (c) and (e). This allows for settlement under traffic.

Grade and Alinement Stakes

Some roads set both grade and line stakes, but the majority do not set grade stakes except on jobs involving improvement in grade line, or the elimination of sags. Where there is a uniform grade line, a uniform lift may be made without stakes.

Line stakes are used on curves where the character of traffic justifies the refinement. Tangents require staking in high-speed territory, or the use of a lining instrument.

Report on Assignment 7

Labor Economies Which May be Effected Through Grading of Right-of-Way

E. J. Brown (chairman, subcommittee), A. D. Alderson, J. A. Bunjer, F. G. Campbell, M. W. Clark, P. A. Cosgrove, A. A. Cross, J. L. Fergus, E. A. Gill, K. E. Henderson, J. S. McBride, H. K. Modery, H. F. Reilly, C. R. Riley, D. E. Rudisill, W. H. Vance, J. S. Wearn.

This is a final report, presented as information.

The primary requisite for good roadbed to support the track structure is to provide adequate drainage. In the early days of roadbed construction, this rule was followed as far as finances would permit, but because the grading equipment used in those days was limited in capacity and mobility, cuts and fills were narrow. As speeds and wheel loads were increased, the track structure necessarily had to be proportionately maintained at a high level—and with it, an improved roadbed section.

Rapid development of mobile earth-moving equipment capable of moving larger yardage solved the problem in this regard as it afforded the opportunity of widening cut and flattening slope to the desired standard. Moreover, the mobility and larger capacity of this equipment also made possible the correcting of a condition brought about by the use of on-track equipment which could perform only a restricted job of cleaning out cuts and depositing the material on fills. This practice eventually resulted in an overloading of the fills to the point where slides occurred and water pockets developed.

Present modern earth-moving equipment made possible a more complete job of grading the right-of-way. Some of the highlights are:

1. Widening and cleaning cuts.
2. Restoring embankments.
3. Constructing special drainage and interception ditches.
4. Leveling right-of-way to allow the transportation of employees by trucks.
5. Smoothing right-of-way to permit the use of mowing machines.
6. Eliminating small cuts where snow conditions made necessary the use of equipment to keep them clear.

The widening of cuts will permit better drainage. This is made possible by moving the cut ditch out from the roadbed section and deepening it, thus lowering the water table and thereby effecting drainage relief and reducing the labor necessary to maintain smooth track. Further, in wet cuts particularly, shimming during freezing and thawing weather is reduced, and in some cases entirely eliminated.

With the modern grading equipment, slopes can be flattened so that the time between periodic cleaning of the cut ditch is extended—and in some instances the need for further cleaning is eliminated.

The restoration of embankments, depositing the material thereon with the proper slope equalized to eliminate the possibility of slides, can be effected through the use of off-track equipment. On high fill, additional berms can be made for stabilization purposes.

The construction of special and intercepting ditches with modern grading equipment has made possible the removal of ditches from the toe of the embankment slope to a point beyond where the water will strike it, eliminating a condition which often causes slides. Surface ditches, always important, can be constructed where they will do the most good, and the outlet can be such as to reduce erosion. By straightening the channels of meandering streams coming to the right-of-way, the water may be confined to fewer crossings of the roadbed section.

Transporting employees by trucks on right-of-way which has been graded to accommodate them effects a material saving, without delays due to train interruptions. The trucks can move the men, their tools, and sometimes their material from assembling point to work point without delay or interruption of train service. The distribution of material in this manner also yields attractive savings in labor through the elimination of work trains and motor cars. The larger the gang, the more attractive the savings.

Smoothing the right-of-way to permit the use of mowing machines effects other savings, the extent of which, of course, will depend on the policy of the individual railway. With the ever increasing demand by certain groups and communities for mowing of the right-of-way, the savings to be realized, where such operation is necessary, compared with the old method of hand mowing, should be readily appreciated.

In territories where snow is a problem, grading of the right-of-way has reduced the need for maintaining snow fences. Several railways have reported that they have also been able to reduce the need for snow plows. Prior to grading, plows were used several times a year.

Conclusion

The definite trend of the railroad industry toward the use of mobile earth-moving equipment for grading of the right-of-way was accelerated during the recent war due to labor shortages, and received further impetus more recently when increased wage rates and the shorter work week went into effect.

Contour leveling, grading and draining of the right-of-way lessen the shock of extreme weather elements, allowing the forces of nature to dissipate themselves in a less harmful manner. Moreover, they permit greater flexibility in the handling of labor forces at much less cost.

Report of Committee 27—Maintenance of Way Work Equipment

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Committee

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. Improvements and additions to existing work equipment.
   Final report, presented as information .... page 336

4. New developments in work equipment.
   Progress report, presented as information .... page 340

5. New types of work equipment needed.
   Final report, presented as information .... page 357

6. Equipment for fence building.
   Final report, presented as information .... page 364

7. Special cars for handling work equipment.
   Final report, presented as information .... page 367

8. Special attachments for tractors.
   Final report, presented as information .... page 372

9. Depreciation of work equipment, collaborating Committee 11.
   No report.

AREA Bulletin 491, December 1950.

10. Portable lighting outfits.
 Final report, presented as information .... page 378

THE COMMITTEE ON MAINTENANCE OF WAY WORK EQUIPMENT,
R. K. JOHNSON, *Chairman.*

Report on Assignment 3

Improvements and Additions to Existing Work Equipment

N. W. Hutchison (chairman, subcommittee), C. L. Fero, A. J. Flanagan, Herbert Huffman, H. H. Main, P. G. Petri, J. R. Rushmer, C. E. Stoecker, M. C. Taylor.

This report is submitted as information

Since World War II, a considerable number of new types of work equipment have been manufactured and marketed, many of which had been in an experimental stage. During the postwar period, some of these machines have been redesigned to increase their efficiency or utility, or to permit them to perform work other than that for which they were originally designed.

To determine what improvements and additions have been made to work equipment during the period from 1945 to 1950, inclusive, inquiries were directed to 135 work equipment manufacturers. Thirty-one of these manufacturers listed a total of 280 specific improvements to one or more machines of their manufacture. Certain of the manufacturers stated that their machines had been improved but that the improvements were of a minor nature; others advised that their machines were completely redesigned and that to list each improvement was impractical.

While many of the advertised improvements are of a minor nature, the great number of improvements made is indicative of the desire on the part of the manufacturers to better their products. Since it would be impractical to burden this report with a complete list of the improvements made, your committee has carefully screened the improvements specified and has tabulated below those which, in its opinion, are of sufficient importance to justify inclusion. The improvements are grouped by types of machines and, for obvious reasons, manufacturers' names are omitted.

Adzers

Improved belt guard.

Ballast Car

New door operating mechanism designed to permit ballast to be dropped under control to each side of each rail, with doors individually operated.

Ballast Maintenance Car

Addition of ballast equalizing boxes and center plow.
Spring-mounted frame with hydraulic shock absorbers.
Enclosed cab.
Four-wheel drive with hydraulic engine—transmission coupling.
Eight speeds.
Air-hydraulic brakes.
Hydraulic controls.

Ballast Cleaners (Center Ditch and Shoulder)

Application of motor drive to rear swing conveyor.
Arrangement for excavating ballast and dirt from center ditch and shoulder.

Ballast Cleaners (Crib)

Dirt chutes replaced by belt conveyors on digging head.
Single shaker screen in center replaced by screen on each side.
Screw conveyor at rear, replaced by belt conveyor at middle of machine.
Use of more rugged motors for hydraulic system.

Ballast Cribber

Width of double-flange track roller increased.
Steel guard for digging wheel.
Steel guards for final V-belt drive.
Two-wheel carriage replaced by four-wheel.

Ballast Plow and Distributor

Redesigned into a self-contained unit.
Special turntable for removing machine from track.
Plow unit equipped with riders to glide over high ties.
Reversing blade for regulating and distributing ballast in center of track.

Ballast Regulator and Scarifier

Special four-wheel drive.
Universal mounting arrangement for wing flexibility.
Separate hydraulic controls to raise and lower wings.
Scarifier teeth installed on regulator wings.
Reversing blade for plowing ballast from tie ends.
Extension blades for pulling ballast in to toe line.
Special turntable for removing unit from track.

Bolt Tightener (Gasoline Operated)

Lifting bail added to facilitate handling of machine.
Rain guard to protect driving frictions from moisture.
Improved lifting handles.
Increased speed and power of high and low-speed chucks.
Improved operating controls, with high and low speeds available on each chuck.
Sealing device for torque setting to prevent unauthorized adjustment.
Larger and stronger gears.

Cars, Air Dump

Shortened and streamlined, with no decrease in capacity.
Lower overall height and center of gravity.
Rubber shock absorbing cushion pads under draft sill under frame.

Compressors, Air

Electric starter with generator voltage regulator.
Live hose reels on ends of air receiver.
Automotive-type front wheels.

Cranes, Crawler

Machine made completely demountable for shipping.
Crane unit detachable from propelling unit.
Torque converter.

Cranes, Locomotive

Dual control to permit better vision.
Metered air controls, providing precise pressure variation.
Boom redesigned for greater strength and better visibility.
Cab tapered at rear, for more clearance.

Derricks, Utility

Capacity increased from 2000 to 2500 lb.
Boom redesigned so it may be set up on either rail.
Made completely demountable.

Derrick Cars

Boom length increased from 7 ft. to 8 ft.
Full 360 deg. swing.
Larger usable deck area.

Drills, Rail

Eccentric stabilizer bar to permit leveling drill.
Improved ratchet for drill feed.

Extinguisher Cars

300 gal. more water capacity.
Air-cooled engine.
Flexible pump lines.

Gager, Track

Quadrant gear replaced by simple bolt and nut control.
Change in distance between gage stops.

Graders, Power

Four-wheel drive and four-wheel steering.
High-lift blade.
Extreme blade reach.
Elevating grader.

Grinders, Rail, Frog and Switch—Gasoline

Machine lightened in weight.
Positive throttle control for rapid adjustment of spindle speed.
Improved frame, spindle, and driving frictions.
Flexible arm extension.
Larger guard to permit use of larger wheel.
Redesign of stabilizer bar to act as a skid.
Replaced steel wheel with pneumatic tire.
Simpler feed and drive arrangement.
Redesign to permit grinding throat-way of frogs.

Grouting Outfits

Change in sand screen to give better screening.
Openings added to mixing tank to make paddles more accessible.

Hammers, Electric

Rectifiers now built into handle instead of special unit.
Rotating device which changes hammers to drills.

Hammers, Gasoline

Increase in power.
New design in cable attachment, circuit breaker, and carburetor.
Reduction in weight from 95 lb. to 85 lb.
Increase in power through use of heavier piston.

Impactors

Insulated flexible gas line.
All bolts and screws anchored.
Hotter, quicker heating blade.
New shock absorber.

Jacks, Power

Redesign of lifting handles.
Solid bar for clamp-operating shaft instead of hollow tube.

Material Loaders

Converted to on-track cleaner.
Converted to off-track ballast cleaner.

Motor Cars

Wheel silencer for demountable-hub steel wheels.
All-steel construction, except in the top seat.
Automotive type selective gear transmission.
Redistribution of weight for easier handling.
Equipped with rubber cushion or spring axle housings.
Equipped with enclosed power plant and tool compartment.

Mowing Machines

Cutter bar assembly available with widths in multiples of 4 in.
Cutter bar assembly may be offset 10 in. to the right.
Sprayer attachment available.

Oil Sprayers

Pump capacity increased from 5 to 10 gal. per hour.
May be converted to weed sprayer.

Payloader

Special notched railroad bucket.

Rail Layers

Self-propelling device with crawler treads on one side.
Improved rail grip.
Improved set-off and transfer.

Shovels

Special cab for tunnel clearance.
Special adaptor on dipper to permit digging between tracks.
Wider overall width to straddle ditches.

Spiking Hammers, Gasoline

Addition of lifting bail.
Carriage for transporting machines along the track.

Spike Pullers, Gasoline

Interchangeable spike tong jaws instead of right and left.
Addition of lifting bail.
Improved wider spike tong hook.

Spreaders

Redesign to handle high walls of snow more efficiently.
Full-length, double-track high snow plow attachment.

Tampers, Multiple

Improved hydraulic pump of greater capacity.
Improved, positive, quickly adjustable tamper suspension.
Demountable cab.
Greater speed of operation.

Tampers, Tie—Gasoline

Elimination of battery box and connecting cable.
New type carburetor to decrease fuel consumption.

Tie Cutters

Undercarriage to permit cutting both ends of tie without turning machine.

Weed Burners

Electric ignition on each burner head for lighting it.
May be converted to weed sprayers.
More powerful tow car and blower engine.
Engine controls in cab.

Welders, Arc—Gasoline

Reduction in weight.
Air-cooled engine, replacing liquid-cooled.

Report on Assignment 4

New Developments in Work Equipment

E. L. Anderson (chairman, subcommittee), R. E. Buss, W. M. Dunn, F. L. Etchison, J. R. Rushmer, P. S. Settle, G. M. Strachan, M. C. Taylor.

This is a final report, presented as information

The Assignment 4 is intended to cover new machines manufactured or developed since the last report on this subject, which was presented to the Association in 1949 and which can be found in the Proceedings, Vol. 50, 1949, pages 350 to 353, incl. This previous report covered all known developments up to about September 1, 1948.

It is not the intention of this present report to include improvements in or additions to existing machines that were covered in previous reports; neither does it cover developments relative to fence building equipment, special attachmnts for tractors, or portable lighting outfits, which are covered by other assignments. The brief description of machines, with illustrations where possible to secure same, are general, and are intended only to bring up to date the subject of new equipment as covered by previous reports.

Ultrasonic Detector Car

The ultrasonic detector car consists of a generator mounted on a small inspection motor car, with a searching unit which transmits intermittent ultrasonic vibrations into the rail. The results are indicated visually on a screen showing the location, type and size of defect in the rail, particularly within the joint area. It is adapted to detecting cracks around the bolt holes, head and web separations, and minute defects in some types of welded joints. It can be used successfully without removing the joint bars. See Fig. 1.

Audigage Flaw Detector

The Audigage Flaw Detector is an instrument for locating cracks across the webs of rails within the joint bar area. It is powered by a portable, self-contained radio-type battery in a pack which is intended to be strapped to the operator's back. Ultra-high frequency sound waves are transmitted into the top of the rail from a small crystal vibrator in the hand of the operator. Signal indications by headphones permit the operator to determine whether a flaw is present or absent. This unit has proved very efficient in service, and due to its portability, permits the detection of small flaws without obstructing track. See Fig. 2.

Yard and Track Cleaner

Three machines represent new developments in this class of equipment. One such machine is particularly adapted to cleaning excess waste material from between the rails and between tracks in yards. This machine is of the off-track type, is either gasoline or diesel powered, and is mounted on 13.00 by 24 tires, making it easily maneuverable over yard tracks and uneven terrain. A winged scraper blade extending from rail to rail can be adjusted to various heights of rail, and permits cleaning down to the tops of the ties. "Dragger-back" scraper blades pass the material picked up to an intermediate conveyor, which elevates it to a swivel conveyor that rotates through 180 deg.

Operation for cleaning a yard track usually consists of three movements; one outside each rail, discharging the material picked up into the center of the track to be cleaned; and a last movement down the center of the track. By means of the swivel conveyor the material can be discharged into a car on an adjacent track, or into a car pulled behind the cleaner; or it can be loaded into trucks.

The machine is said to be rated at 5 to 8 cu. yd. per min. in handling loose material; however, in yard track work that rating is reduced 50 percent. See Fig. 3.

A second machine, track mounted, non-self-propelling, uses a rotating impeller, which kicks material forward and upward. The material is discharged through a curved, steel, hood-like baffle downward onto a horizontal transverse flat-belt conveyor, which carries it to the side of the track. A plow on each side of the machine cleans the area outside of rail for a distance of 3 ft. The machine is pulled or propelled by a heavy-duty motor car, and will clean to a depth of 4 in. at one pass.

To load the debris after it is windrowed by the machine, an ordinary farm tractor, equipped with ingathering wings, vertical bucket conveyor and horizontal belt conveyor as a front attachment, is used. This unit loads the debris directly into car or truck. See Fig. 4.

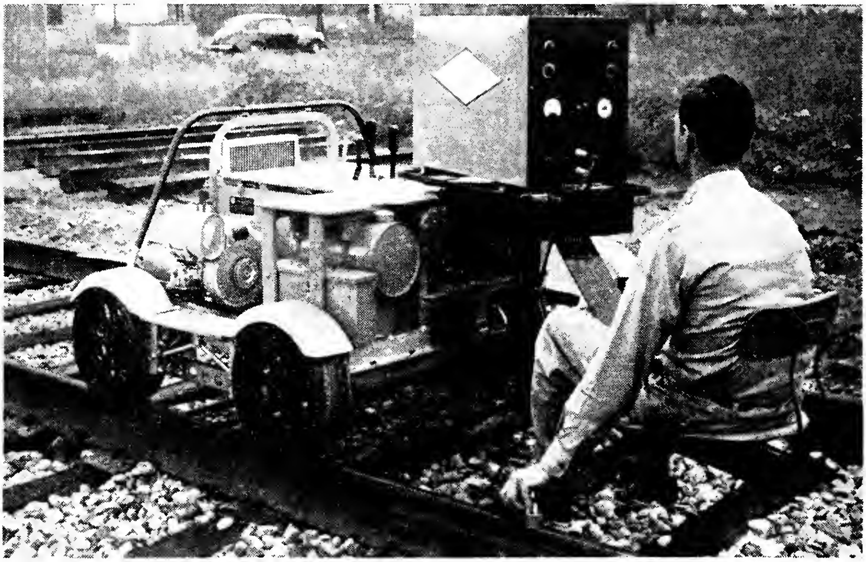


Fig. 1. Ultrasonic detector car.

Fig. 2. Audigage flaw detector.

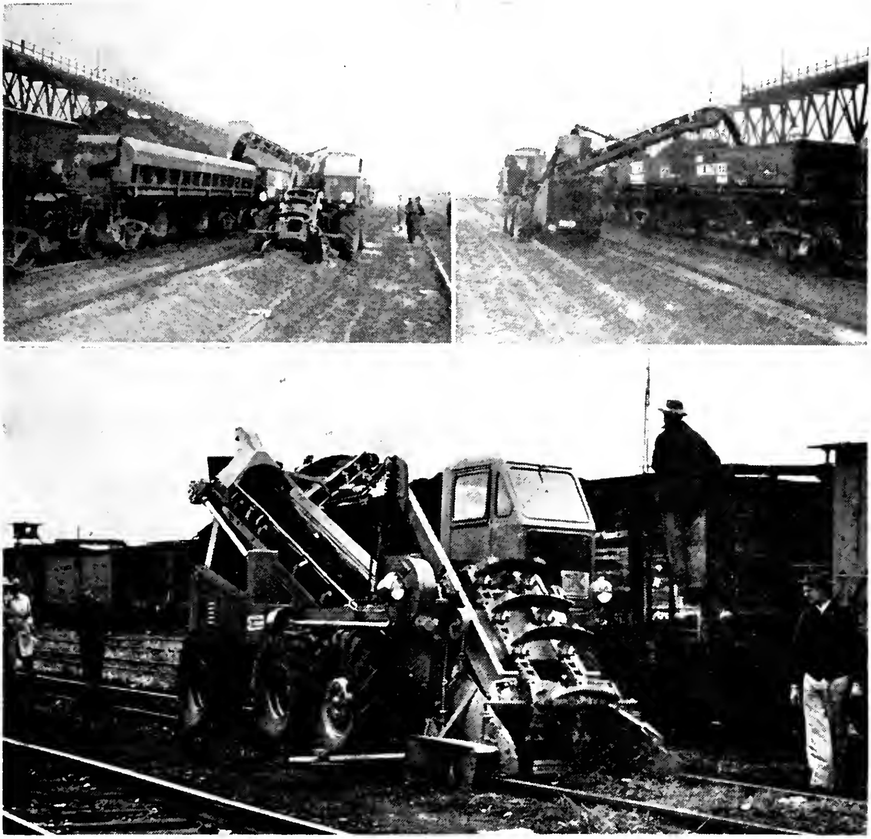


Fig. 3. Off-track, diesel-powered yard and track cleaner.

A third machine, which is used for several off-track purposes, such as loading snow in the winter, can be converted to a track-mounted unit and used for cleaning tracks when desired.

Full information on this machine is not available, and the development of a device for loading into cars the material picked up, is not complete. See Fig. 5.

Ballast Cleaners

Four machines of this type have been developed. One such machine is diesel-electric powered and track mounted. The towing and digging unit precedes the cleaning portion of the machine, and by means of a drum and cable anchored along the tracks pulls the equipment forward at the speed desired, and at the option of the operator. It is said that this machine can dig to a maximum of 36 in. if desired, and can move from 200 to 300 ft. per hour when removing ballast to a depth of 6 in. below the ties. The material removed is passed from the digging unit, by means of inclined conveyors, to a screening device, where separation is made between the good ballast and the fouling material. The cleaned ballast is passed back by conveyor and distributed on the track, while the residue is discharged by conveyor to waste on the embankment or otherwise See Fig. 6.

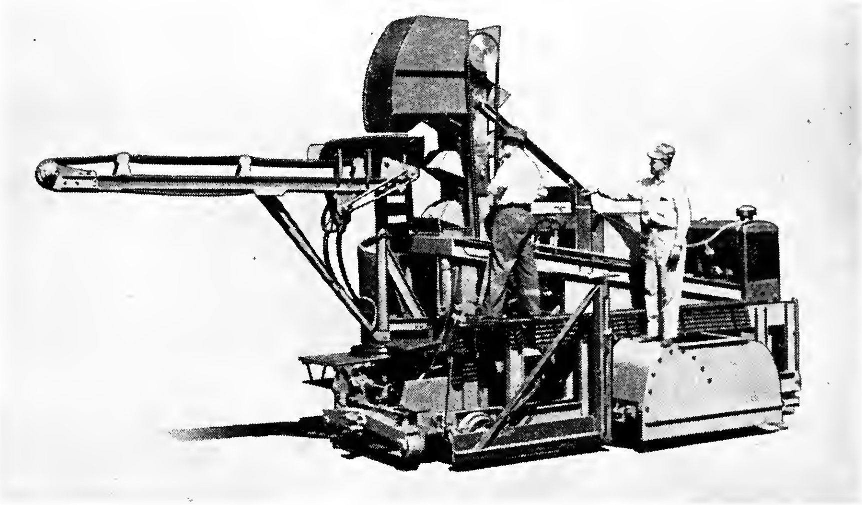


Fig. 4. Track-mounted, non-self-propelling yard and track cleaner.

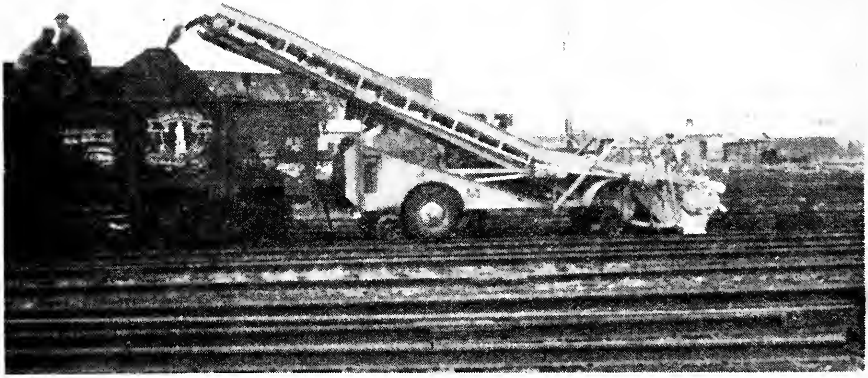


Fig. 5. Convertible snow loader and yard and track cleaner.

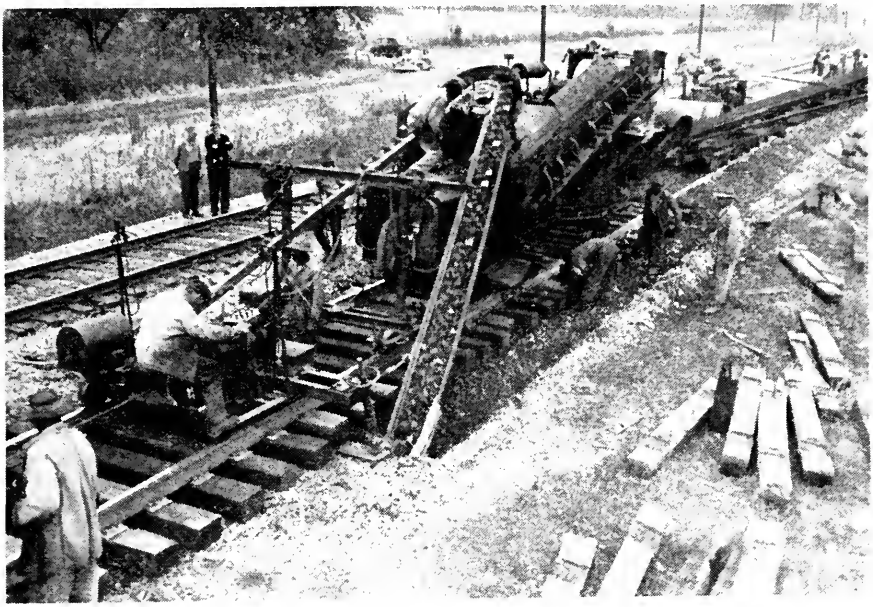


Fig. 6. This machine excavates and cleans the entire ballast section.

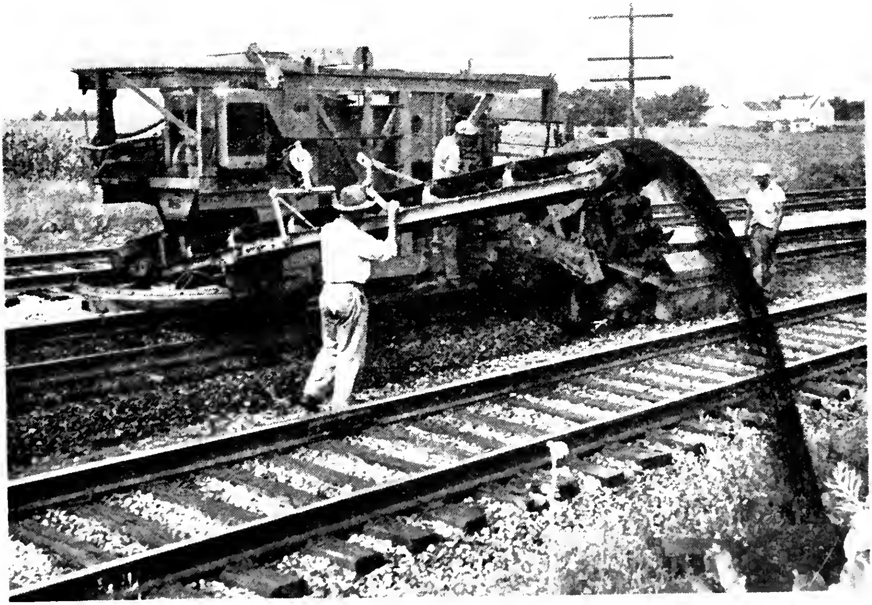


Fig. 7. On-track, self-propelled ballast cleaner.

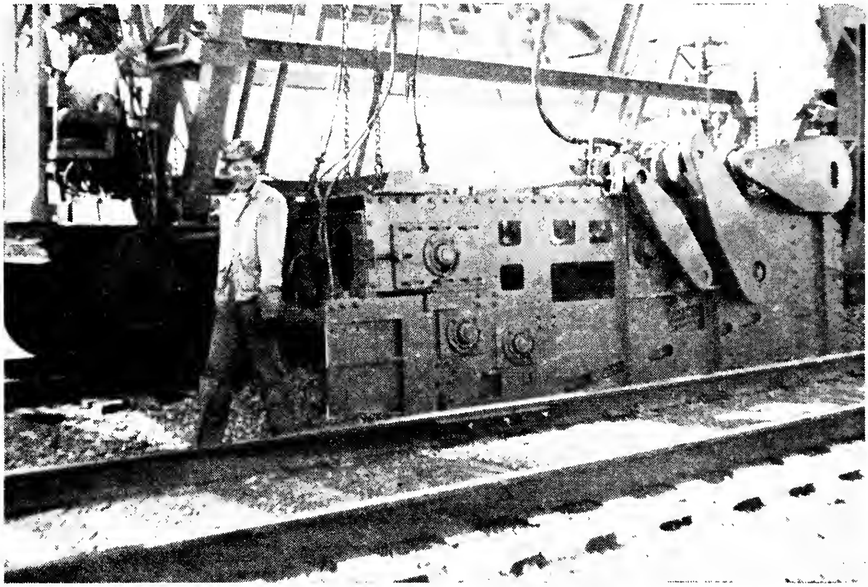


Fig. 8. Heavy-duty, track-mounted ballast cleaner.

Fig. 9. Crawler mounted, off-track ballast cleaner.

A second machine, on-track and self-propelled, consists of two units—a digging unit pulling a cleaning unit—powered by a gasoline engine, which operates a winch and wire rope.

The digging unit can be used separately to pick up the ballast from the ends of the ties out, or from between multiple tracks. The forward progress of the machine, it is said, varies from 800 to 1600 ft. an hour, depending upon the depth of the trenching and the quantity of ballast handled, working one side of the track at a time. The machine can be readily turned by means of an hydraulic turntable to work the opposite side of the track. The conveyor on the machine can throw material a maximum of 11 ft. from the center of the track, or can load into cars by means of auxiliary conveyor equipment. Likewise, the conveyor system can be changed to pass the material back to the cleaning unit.

The cleaning unit screens and separates the material passed to it by the digging unit, discharging the waste by means of a 20-ft. conveyor swinging through 270 deg., and the cleaned ballast to the intertrack or shoulder. See Fig. 7.

A third machine, of the heavy-duty, track-mounted type, cleans a path of ballast 4 ft. wide on both sides of the track simultaneously—under favorable conditions, it is said, at a speed of 1 mph. The machine is powered by steam turbines, steam being provided by a locomotive which propells the machine.

The machine has a cleaning box on each side, with gathering-in wings on the front of the box, which pick up all ballast from the ends of the ties out—the tie side wing being continuously regulated by the operator of the machine to follow variations in the lengths of ties. The ballast picked up in the box goes over a vibratory screen, and when the separation is made the clean ballast is passed back to the roadbed along the ends of the ties and the debris is carried out to the side of the roadbed by means of a belt conveyor. See Fig. 8.

A fourth machine is crawler mounted for off-track operation. This machine cleans the shoulder on one side only at a time. It has a capacity, it is said, of 250 cu. yd. an hour. A bulldozer, with a special blade, is used ahead of the machine to windrow the ballast away from the tie ends. The cleaner picks up the ballast, cleans and returns the clean ballast to the track, and deposits the residue 20 ft. from the ends of the ties, over the shoulder. See Fig. 9.

Tamper

A tamping machine has been introduced which both vibrates and tamps the ballast to proper compaction. The machine is track mounted, self propelled, has 16 tamping bars, and, it is said, will tamp an average of a tie every 10 sec. The tamping bars are dropped down into the ballast under the weight of the tamper assembly of approximately 2000 lb., and when the desired depth of the bars is reached, the operator starts the compaction phase, which compresses and pushes the ballast compactly under the ties. See Fig. 10.

Sprayers

A new machine has been introduced recently for spraying joints. This machine has a 30-gal. oil storage tank (the oil being heated by an exhaust heater), and a small gas engine driving a gear-type pump. It is track mounted, with two wheels running on one rail, which carry the major portion of the weight of the machine, and a third wheel running on the opposite rail. It can be readily cleared to the side of the track. The operator pushes the machine along the track as desired. It has two nozzles, with hose connections, so that both sides of the joint can be sprayed at the same time. See Fig. 11.

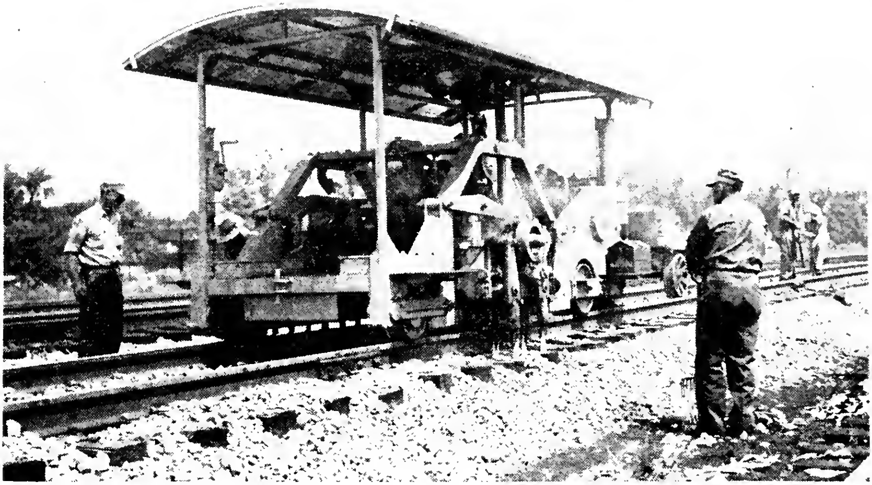


Fig. 10. Automatic power tamper.

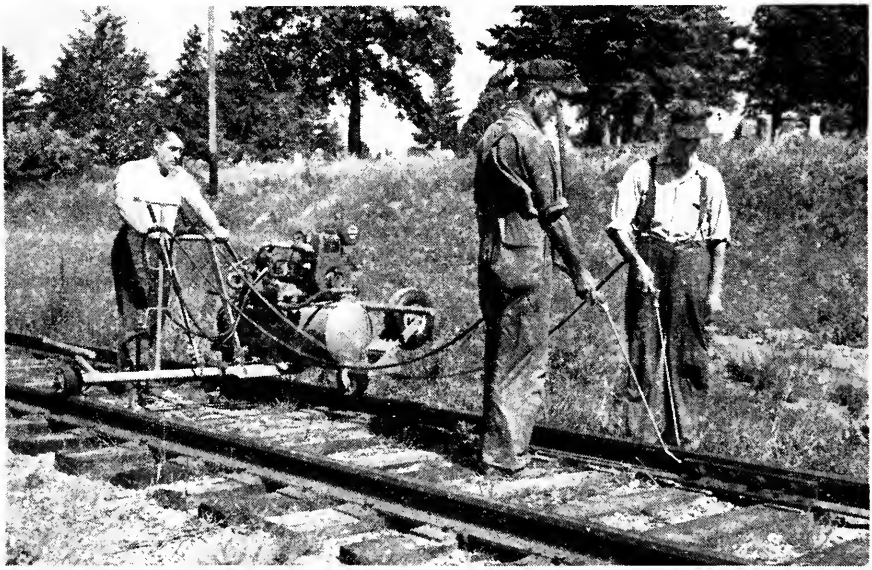


Fig. 11. Track-mounted rail joint sprayer.

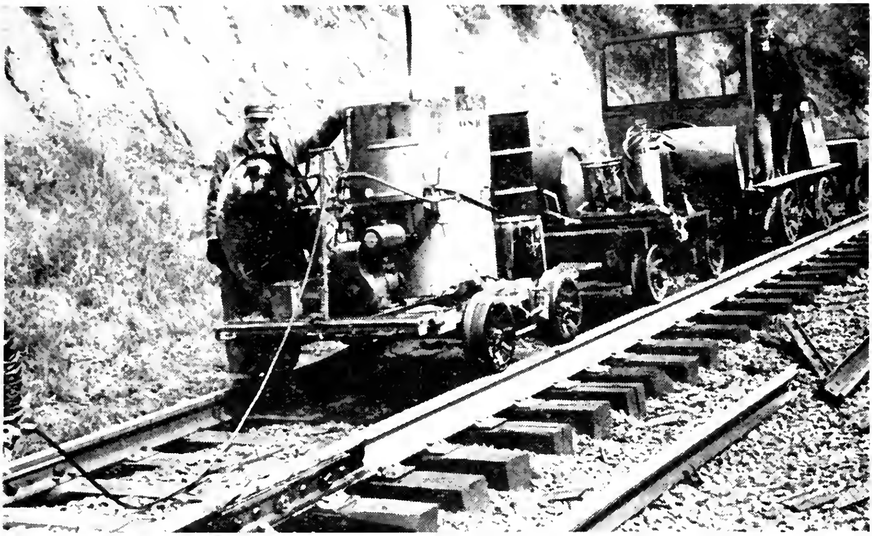


Fig. 12. Motor-car-pulled rail joint sprayer.

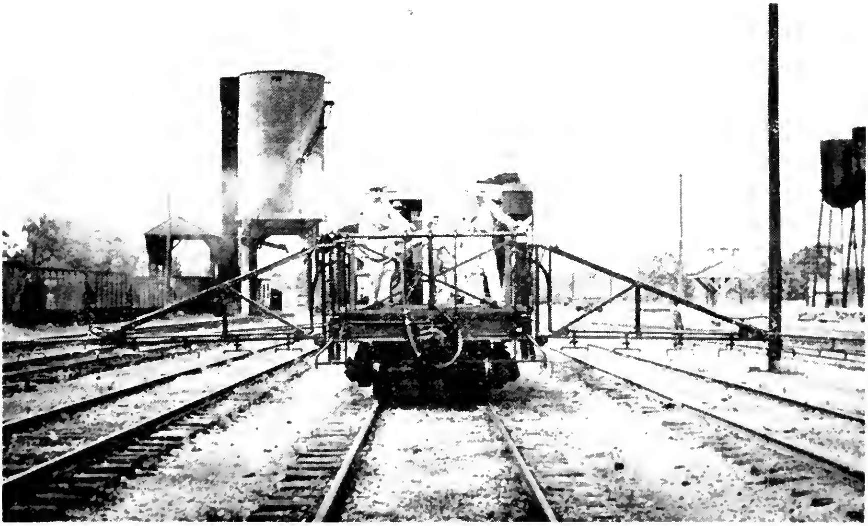


Fig. 13. Track-mounted weed spray car.

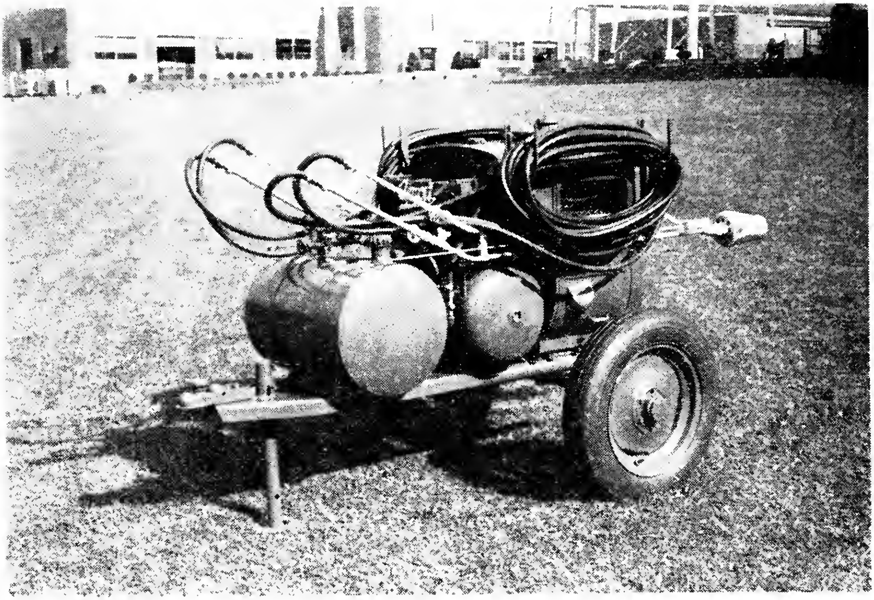


Fig 14. Off-track, trailer-mounted weed sprayer.

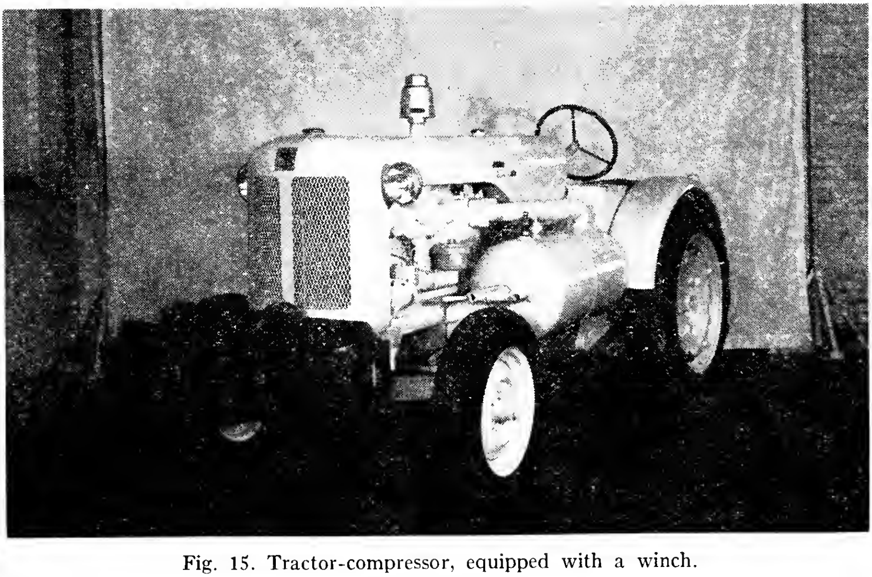


Fig. 15. Tractor-compressor, equipped with a winch.

An oil sprayer has been developed that can be converted to spray grease for joint work. This is accomplished by placing a barrel of grease inside a tank surrounded by water—the tank being a preheating insulated unit, with the heating being done by a kerosene heater. This machine is used with rail gangs for spraying rail ends and angle bars and, it is reported, can spray 50 joints an hour. It is propelled or pulled by motor car, and supplies are carried on a push car. See Fig. 12.

A track-mounted weed spray car has been developed which is handled by work train, and which can pump from as many as six tank cars. It is said that it will cover from 100 to 120 miles of line a day, spraying an over-all maximum width of 50 ft. See Fig. 13.

A number of small off-track weed sprayers have been developed. One such is trailer-mounted on two wheels, and can be readily pulled behind a truck. The sprayer has a tank capacity of 17 gal. and a small gasoline-engine-powered compressor. It will spray to a width of 6 ft. It also has a hand boom attachment with 4 spray heads, with 25 ft. of hose. See Fig. 14.

Tractor–Compressor

Two off-track, power-mounted combination compressor-tractor units are now being produced. One such machine has a capacity of 105 ft. of air and is powered by a 35-hp. gasoline engine. The tractor unit has five traveling speeds. In addition to furnishing compressed air, the machine can be used for many other purposes. See Fig. 15.

Another machine is produced in two different models—one delivering 60 ft. of air and the other 105 ft.—powered by gasoline engines, 18 and 36 hp., respectively, which likewise can be utilized for purposes other than supplying compressed air. See Fig. 16.

Weed Burner

A number of small off-track weed burners have been developed. One such, of the trailer type, can be pulled behind a truck or, at option, can be skid-mounted so it can be set on the bed of a truck. This unit has a 20-gal. kerosene tank for the burning oil supply, and a small gasoline-engine-powered compressor. Two burners are provided, each on the end of a 50-ft. section of hose. Flames can be thrown from each burner, it is stated, a distance of 6 to 8 ft. See Fig. 17.

Pile Hammer

A self-contained pile hammer operating on diesel fuel has been developed, which consists of a cylinder, piston or ram, fuel tank, fuel pump and compressors, mechanical lubricator, and lubricant tank. This hammer fits in standard 20½-in. leads and requires one line for lifting the hammer and another line for both lifting the pile and starting the hammer by lifting the piston. The force of each blow is controlled remotely by the operator on the ground through an hydraulic fuel pump control system. It is said that the power per blow can be regulated from zero up to a maximum of 16,000 ft.-lb. Thus far, this hammer has not been developed for railroad use, but it appears to have great possibilities for such usage. See Fig. 18.

A new single-acting pile hammer has been developed in four sizes, developing, it is said, from 9,000 to 37,500 ft.-lb. per blow.

This hammer is either steam or compressed-air powered, requiring from 100 to 125 lb. pressure. Weights run from 9030 lb. to 31,700 lb., and the number of blows ranges from 55 to 65 per min. This hammer can drive under water. See Fig. 19.

Fig. 16. Different model tractor-compressor.

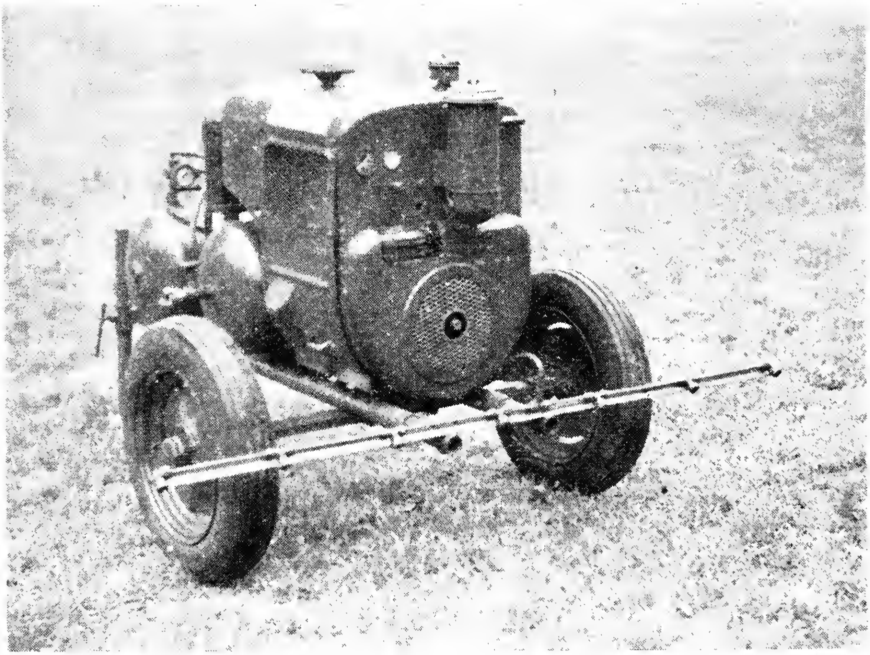


Fig. 17. Weed burner.

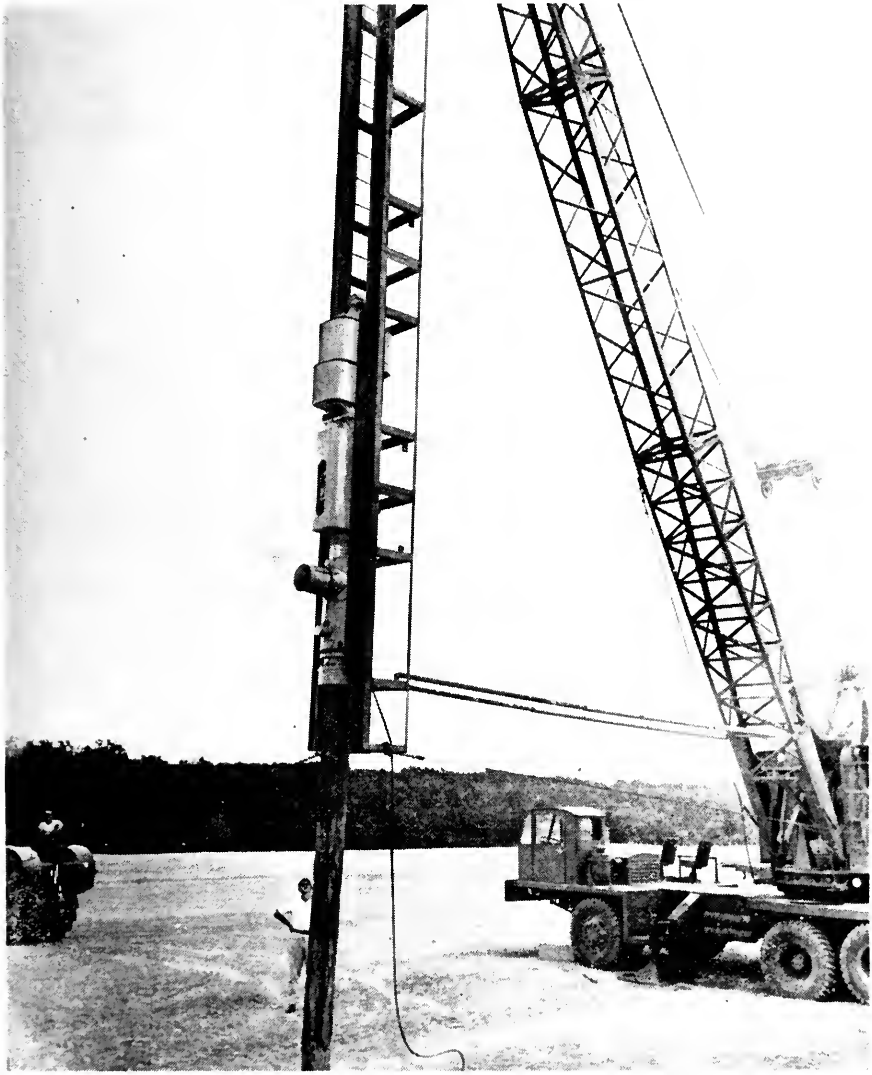


Fig. 18. Self-contained pile hammer.

Drum and Cylinder Carrier

A drum and cylinder carrier has been developed in three models ranging in capacity from 2 to 6 standard 55-gal. drums. This carrier can be applied to any standard fork-lift truck, and has a misalinement compensator and specially engineered angles for automatically placing the drums into gripping position. Specially designed gripping shoes, with non-slip linings, insure positive grip through gravity wedging action. The load release requires that the gripping shoes be retracted through hydraulic pressure, the power control unit of which is within easy reach of the operator. See Fig. 20.

Fig. 19. Single-acting pile hammer.

Fig. 20. Drum and cylinder carrier.

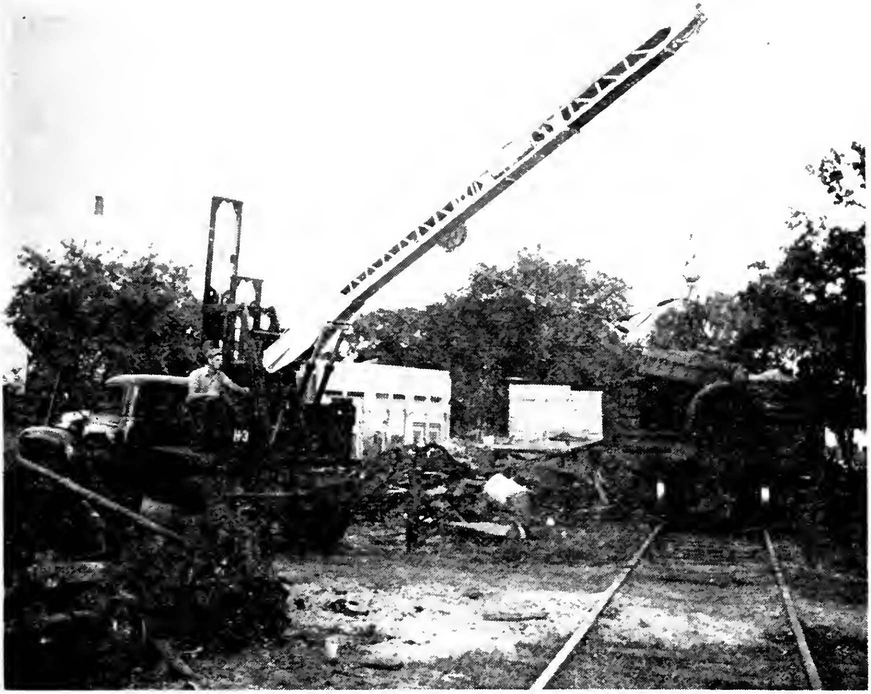


Fig. 21. Hydro-crane.

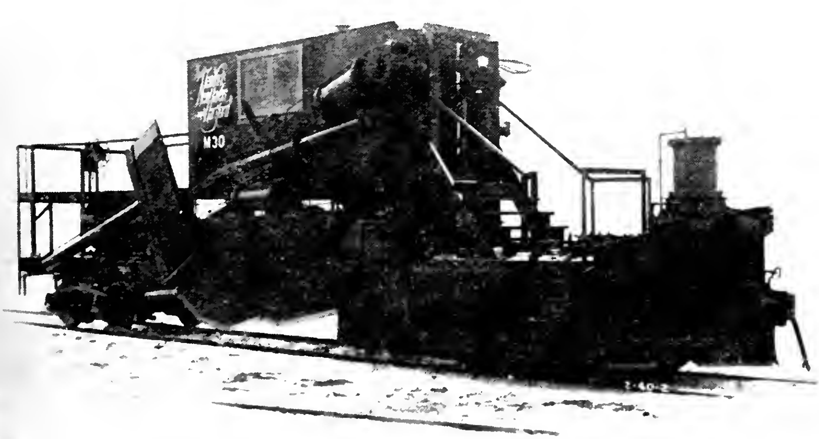


Fig. 22. Spreader-ditcher.

Fig. 23. High-cycle generator.

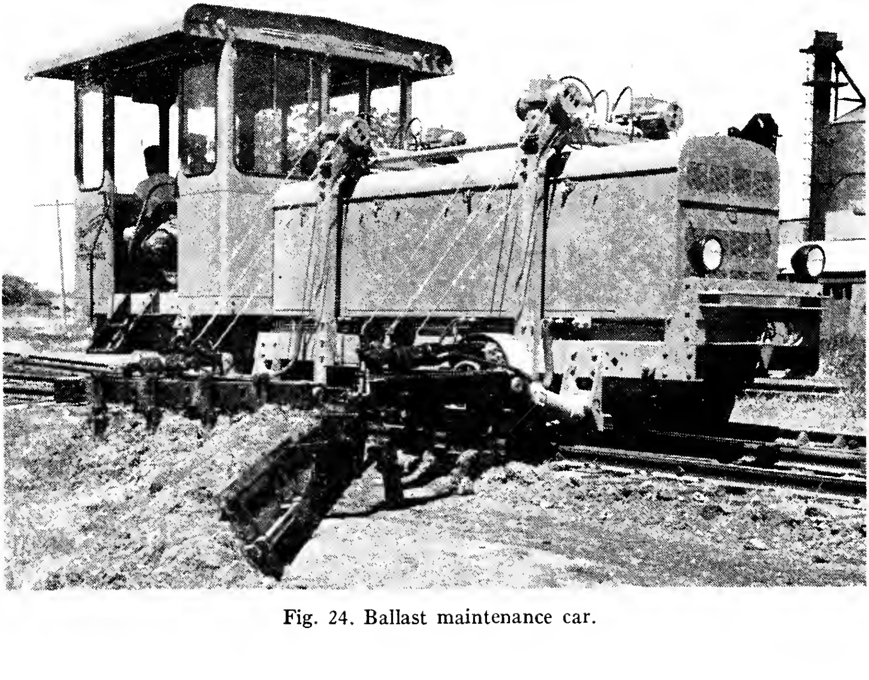


Fig. 24. Ballast maintenance car.

Hydrocrane

A completely hydraulic, motor-truck-mounted crane has been developed in 2 models, of 2-ton and 3-ton capacity. This crane has hydraulic telescoping boom, and revolves, hoists, loads, digs and sets outriggers by hydraulic power. The various attachments permit numerous types of service. The crane is truck-mounted and can be moved readily from job to job at normal highway truck speeds. See Fig. 21.

Spreader–Ditcher

A new track-mounted combination spreader–ditcher has been developed which can be converted rapidly from spreader to ditcher, and vice versa. This machine is designed and adapted particularly for heavy work. The front plow attachment provides at all times a clean running rail and, with the extension wings, permits rapid disposal of material from the center of the track when used for spreading ballast and cleaning tracks. It also has some improved features for spreading material on embankment shoulders or in ditching operations. See Fig. 22.

High-Cycle Generator

A high-cycle generator, gasoline-engine powered, has been developed in two models, each operating on 230-volts, 180-cycle, 3-phase alternating current. These models weigh 125 lb. and 175 lb. per machine, and, it is said, will deliver 2500 watts and 5000 watts, respectively.

This generator is adapted for use with high-cycle tools, such as chain saws, paving breakers, etc. The light weight of the generator makes for flexibility of usage. See Fig. 23.

Ballast Maintenance Car

A track-mounted car developed, but not in general use, provides for scarifiers, disks, ballast equalizing boxes, two sizes of blades, and a center plow. Hydraulic power makes it applicable to a wide range of operations. Additional data on this machine is not available at this time. See Fig. 24.

Report on Assignment 5

New Types of Work Equipment Needed

H. E. Michael (chairman, subcommittee), W. S. Brown, T. F. Burris, W. M. Dunn, F. L. Etchison, W. F. Kohl, W. B. Lee, A. W. Munt, J. L. Starkie, F. E. Yockey.

This is a progress report, presented as information.

In a previous report on New Developments in Maintenance-of-Way Equipment (Proceedings, Vol. 50, 1949, page 353) your committee reported that two of the seven machines suggested for development in its 1942 report had not yet been manufactured, namely:

(1) One-man inspection motor car weighing less than 400 lb.
(2) Signal to warn track and bridge gangs of the approach of trains.

The committee also suggested six other machines that should be developed:

(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 the 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 the installation of ties.

None of these eight machines has as yet been marketed, and the development of all eight is still considered desirable.

In addition to these machines, the following suggestions have been made by railroad representatives for machines, which, in their opinion, should be made available. Each of the representatives, in making his suggestions to the subcommittee, gave his reasons for thinking the equipment would help him in his work, told what the equipment should do and, in some cases, outlined possible ways in which it might be designed to operate. This information has been abstracted into one or more brief paragraphs following the name of each suggested piece of equipment.

Additional Equipment Needed

Adzer—Small

Hand adzing is expensive. It would seem possible to develop a small adzer with a light saw or planer-type head which could swing under a lifted rail base and lightly adz the rail seat for replating or installing new plates.

Air Dump or Hopper Car*

An automatic air dump or hopper car is needed that will unload banking material clear of the ballast section and eliminate the labor now used to move material from the ballast sections by hand. Existing machines satisfy the needs of some roads; perhaps improvements to such machines would satisfy all.

Ballast Cleaner—Portable*

A small, portable ballast cleaning machine that could be used by a small section gang for spot cleaning of some ballast, particularly where it is necessary to clean the ballast on ballast-deck bridges, through switches and interlocking plants, or at locations where the cleaning cannot be done by larger machines. A small vibratory cleaner, made in England, and being used in Canada, is reported to be effective for this work.

Ballast Cleaner and Cribber

Ballast cleaning, whether in cribs, on shoulders, or between tracks, is considered by many to be essential to economical track maintenance. Many machines are now on the market and others are being developed to do this work, but better types are warranted to speed up the operation so that more ballast can be cleaned at lower unit costs. A step in the right direction might consist of a self-propelled, combination cribbing and ballast cleaning machine that could clean entire cribs and both sides of the track simultaneously, return the clean ballast to the track and foul only the track on which it is working.

(*) placed after the name of a machine indicates that there is presently available a machine or device capable of performing at least some of the functions desired in the suggested equipment.

Ballast Distributor*

It is becoming more and more necessary to handle ballast from revenue hopper cars. If a device could be developed to make the efficiency of distributing ballast from such cars comparable to that when using specially designed ballast cars, it would reduce the waste of material as well as the labor of further handling.

Ballast Dresser*

Until such time as an adequate ballast distributor is available, and perhaps afterwards, some type of dressing machine is needed to remove ballast from between the rails and from the tops of ties beyond the rails. This machine should preferably remove the loose stone to a depth of one inch below the top of tie. The value of such a device would be considerably enhanced if it was designed to dress the shoulder and establish a uniform toe line.

Bonding Drill—Special

A bonding drill, or an attachment for existing drills, is needed to drill holes in the webs of rails on bridges and at other points at which guard rails are used. Such a drill should also be adapted to the drilling of frogs.

Brush-Cutting Machine*

Cutting brush along railway right-of-ways is highly desirable but very expensive. Sooner or later it has to be done, and the later it's started the more expensive it becomes. Mechanization of this work would reduce its cost, permit it to be done more often, and to complete it more quickly.

Crib Cleaner—Off Track*

There is a particular need for an off-track crib-cleaning machine that would cost less and be more economical to operate than other types of cribbers presently available. Its popularity would be greater if it was also suitable for small gangs.

Cross Tie Remover and/or Installer*

Greater demand exists for a device or devices to mechanize the renewal of cross ties than for machines to be used in any other track maintenance operation. Enormous savings are possible with any machine that can fulfill all requirements. Some of those requirements vary from a single machine that will adz the shoulder on plate-cut ties, remove old ties, handle new ties from beside the track, and finally insert them in the track—to several machines for the individual operations.

Perhaps one machine could jack up the track on both sides of the tie, remove the tie, and then remove enough ballast to permit a new tie to be installed without undue disturbance to the tie bed.

On some roads it might be desirable to have a machine that would operate off-track and be capable of making only spot renewals. Whatever form these machines might take, they should all have a common requirement that they do not pull the track out of line.

Ditcher—Small*

Under present conditions of high labor costs, it is impossible to justify the small productivity of the wheelbarrow-trackman team in cleaning ditches in cuts. A small loader scraper, pulled by a narrow-gage tractor, could certainly show large savings where this type of work is essential. Perhaps "baby" bulldozers, such as were flown in airplanes during the last war, might suffice.

Ditcher—Loader

There has long been a need for a machine equipped with conveyors for loading dirt in side-dump cars when ditching. Such a machine would save the use of a clamshell-equipped crane and its traffic-delaying fouling orders on multiple track when loading the dirt piled up by spreader-ditchers. It should produce a neater result and at the same time eliminate most, if not all, hand work in dressing ditches.

Earth Auger

To assist in stabilizing roadbeds with sand piles, a special earth-boring machine is needed. This device should be able to bore a hole 6 in. in diameter to a depth of 10 or 12 ft., and then be capable of being raised mechanically out of the hole without disconnecting the shaft. It could be mounted on a tractor. Such a machine would permit damp, pit-run sand to be shoveled into the hole instead of the presently used, more-expensive, dried sand.

Electric Tamper Auxiliary*

A mechanical apparatus is needed to throw up ballast ahead of multiple tampers to relieve the men doing this work with forks at the present time. This new machine should be able to travel at approximately the same speed as the tamper, and should be self-propelled and removable from the track.

Fence-Building Equipment*

Tractor accessories for the transportation and erection of right-of-way or snow fences should effect considerable savings.

Gage Indicator Attachment for Motor Cars*.

An indicator or recorder that will show variations in track gage could be installed on a supervisor's inspection car to relieve section foreman of some work. Such an arrangement has been developed by a roadmaster and was described in an article in Railway Engineering and Maintenance within the past year. If desired, such a device could, no doubt, be designed to spot-paint automatically any point at which the gage happens to be wider than a predetermined amount.

A corollary device could be added to the gage indicator that would show variations in cross-level and thereby add to its utility.

Impact Drill and Wrench—Electric

To eliminate the necessity for using a heavy compressor, there is needed a 60-cycle, 115-volt, impact-type combination drill and wrench having sufficient capacity to set ⅞-in. screw spikes or lag screws in oak timbers, drill 9/16-in. holes and counterbore them 2¼ in. in diameter.

Material Loader—Special

Repairs to road crossings and track-level station platforms could be made quicker and more economically if a machine were available to remove and possibly load the material between the rails. Any loading arrangements provided should be capable of placing the material in either railroad cars or trucks.

Multiple Track Jacks

To obviate the necessity for setting and removing many ordinary track jacks as is now common practice, a machine is needed for jacking track ahead of on-track tampers and holding a true surface until the track is tamped.

Off-Track, Tractor-Tamper

Merit exists in a light-weight, narrow-gage, off-track tractor, such as is being considered for experimental use in transporting a multiple, vibratory tamper along the outside of the roadbed shoulder or along the right-of-way.

Pile Drivers—Diesel Powered

Pile-driving equipment needs to be modernized to keep pace with dieselization. To eliminate the necessity of having a man report for work in advance of the regular gang to fire up the boiler to furnish steam to the propelling gear, pile drivers should be diesel-engine powered. They might be mounted on a car with two trucks, have a traveling speed of 20 m.p.h. on a 1½ percent grade, and have self-raising and lowering leads capable of swinging either through 180 deg. or 360 deg. To supply steam for the pile hammer, the machine should be equipped with an oil-fired vapor heater or boiler. Oil and water-storage tanks should be provided, each with capacity to supply requirements for a 12-hour period.

Pneumatic Crossing Tamper

An existing gasoline-driven, self-contained tamper has pointed the way to the need, under certain conditions, for a similar machine driven by air furnished by a small off-track, portable air compressor. To tamp bituminous mixtures adequately on road crossings and station platforms, such a machine should probably produce an impact at least equivalent to a 10-ton roller.

Power Track Wrench for Use at Guard Rails

A bolting machine is needed to tighten track bolts wherever guard rails make it impossible to use existing machines. Various attachments for such a machine would add to its value.

Rail Drill

A need still exists for a small, efficient, but light-weight rail-drilling machine for boring rails at switches.

Rail Saw

To eliminate the idle manpower that often exists while a rail is being cut, a machine is needed to cut rail faster than any method now existing.

Rail-Laying Machines*

The importance and extent of rail-laying activities deserve the development of lighter, faster types of rail cranes.

Rail Slotting Machine*

A power-operated, light-weight, cross slotter for rail ends is needed that one man could handle easily. Its prime mover should preferably be of the off-track type.

Split-Tie Tightener

Consideration should be given to an off-track machine for compressing the ends of split cross ties to permit the ties to be bored and dowels inserted while the ties are in the track.

Mower—Small*

An off-track, light-weight, narrow-gage tractor, with an attachment mounted immediately in front, for mowing shoulder weeds should be further developed. The position of the operator should be such as to give him a complete view of the cutting blades at all times.

Small Tools*

There are a number of small tools which might be developed for such purposes as gaging track, lining track, removing spikes by hand, and machines for performing some of the dressing up functions after ballasting or tamping operations.

Snow Clearing Machines*

To effect savings in the removal of snow and ice in yards and terminals, several types of machines are needed. One might be a one-man, power-operated machine to clear snow along ladders. Such a machine should be small enough for one man to handle easily in maneuvering it around head blocks.

Another could be used to remove accumulated ice and snow from engine-terminal tracks, fuel and water stations, and along leads and ladders. It should have enough power to dig out ice in which foreign material, such as coal and other spilled lading, is embedded. It should be easily removable from the track or be of the off-track type. It should also be capable of placing removed material where desired for loading.

There is also a need for a machine that can collect and load snow removed from tracks around terminals, including that from small platforms, rip-track areas, and from between platforms at storehouses and freight terminals.

Finally, some of these machines should be so designed, or a new device should be made available, to remove snow from between the rails in turnouts not taken care of by switch heaters.

Spike-Stub Driver

To speed up the all-important head-end operation of rail laying, a self-sustaining unit of some description is needed to drive down old spike stubs ahead of adzing machines, thereby replacing the hammer and punch now used.

Suction Ballast Cleaner

Some type of vacuum cleaner is needed in laying rail to pick up the wood chips scattered by tie adzers.

Tie Handling Machine*

A device designed to load, unload and stock pile ties would reduce the cost of doing this work by hand labor.

Tie-Plugging Machine*

The plugging of spike holes in creosote-treated ties is extremely important both in connection with rail-renewal operations and in the recovery of secondhand ties for reuse. While a relatively small operation, it is extremely costly when done by the usual hand-labor methods. To do this work more economically a magazine-type machine is desired to insert and drive tie plugs, or separate machines to perform the individual operations.

Tie Spacer*

The increasing use of on-track mechanical tie tampers has brought with it a requirement that ties be spaced within specific limits. A machine to do this would assure that no ties need be skipped by the machines and therefore have to be tamped by hand.

Tie Tamper—Multiple, Pneumatic*

A multiple tie tamping machine is desirable, consisting of eight or more tamping units, operated by air. It should be light enough to be lifted from the track by man power and be operated by air furnished by an off-track compressor. The tamping units should be so arranged that they can be used individually through turnouts, crossings, etc.

Tie Unloader*

The unloading and distribution of cross ties should be further mechanized. The tie unloaders illustrated in the Proceedings, Vol. 51, 1950, pages 283–284, are a start in this direction.

Track Cleaner

There is need for a machine for cleaning tracks in restricted areas where the usual type of equipment cannot be used, such as at station terminals, where there are platforms on each side of a pair of tracks and an intertrack fence between tracks.

Track Liner

There is a definite need for a machine to line track on a production basis. Such a machine might have power equipment which can either line track out-of-face as a separate operation or line tangent track in connection with a ballasting operation. Its effectiveness would be increased by the use of modern sighting devices.

Truck Bodies

There is an increasing need developing for truck bodies to meet specific needs in the maintenance-of-way department. A utilitarian chassis and body, designed with seating facilities for 25 to 30 men and compartments for adequate tools for that many workers, and capable of being changed rapidly to handle suitable equipment or emergency material, would be in great demand. If able to haul snow, such trucks would approach indispensability.

Tie-Plating Tool*

An improved tie-plate lining tool would be a very useful piece of equipment, especially if it could be combined with the magnetic pickup device already available.

Weed Cutter—Rotary

It is conceivable that a weed cutter would be a great advantage to the railroads if it could be devised with adjustable rotary heads that could be raised and lowered and operated from a car so that weeds between rails and over the tops of ties could be cut mechanically.

Weed Eradicators*

On minor branch lines, especially in open, flat country where ballast is meagre, heavy weed growth causes considerable trouble while green by blowing across the rail and thus reducing locomotive traction; or, when dead and dry, by causing snow to pile up on the track. Any machine that could eradicate such offending weeds for the entire length of the tie and compete in cost with chemical or burning methods would be well worth while.

If such a machine would remove weeds from both shoulders as well, its worth would be increased.

Yard Cleaner*

A machine designed to clean yard tracks, possibly employing a vacuum arrangement to remove sand and fly-ash from between the tracks, and of such size and so designed as to load material into a following car, would save considerable money.

Improvements Needed For Existing Machines

While making these suggestions for new equipment, the railroad representatives also stated that, although the following machines have been in use for sometime to fill, in principle, a worthwhile need, such use had demonstrated that there still remains an opportunity to improve them.

(1) Creosote sprayer
(2) Cribbing machines
(3) Multiple tampers—electric, mechanical or pneumatic
(4) Pressure welding equipment
(5) Rail-laying cranes

Report on Assignment 6

Equipment for Fence Building

F. H. McKenney (chairman, subcommittee), W. R. Bjorklund, R. E. Buss, Jack Largent, Francis Martin, T. M. Pittman, J. W. Risk, E. E. Turner.

This is a final report, submitted as information.

In developing information on this subject, it was found that most fencing jobs involve the maintenance or replacement of existing fences and are confined to comparatively short sections a considerable distance apart, making it difficult to justify sending special equipment to the job. This work is generally done by local section forces rather than by special fence gangs. Then, too, in many cases farmers make repairs to fences with materials furnished by the railroad company. Nearly all of the work is still done by hand methods due to the limited use that could be made of power equipment.

Standard right-of-way fences are usually wire fences with steel, wood or concrete posts. Stockyard fences and corrals are usually built of wood entirely, with posts of 8-in. by 8-in. timbers set about 5 ft. in the ground. Snow fences may be permanent wood fences, portable wood fences, light slat-type portable fences, and, more recently, fences constructed with steel posts and corrugated steel sheets.

The distribution of fencing materials may be by track motor cars where the fence sites are otherwise inaccessible, or by trucks or tractors. Rough ground usually limits the use of trucks, but both wheel and crawler-type tractors are practical for most work.

Where considerable right-of-way fence is to be built out-of-face, due either to the generally poor condition of the existing fence or to new line construction requiring entirely new right-of-way fence, various units of power equipment can be used for speed and economy.

Trucks for the transportation of men, material and tools may be equipped with power auger, winch, or post driver. Equipment may be mounted so as to operate from the truck power take-off, or it may be skid mounted and driven independently by gas engine (Fig. 1). Hand-operated winches are sometimes used. Tractors of either the wheel

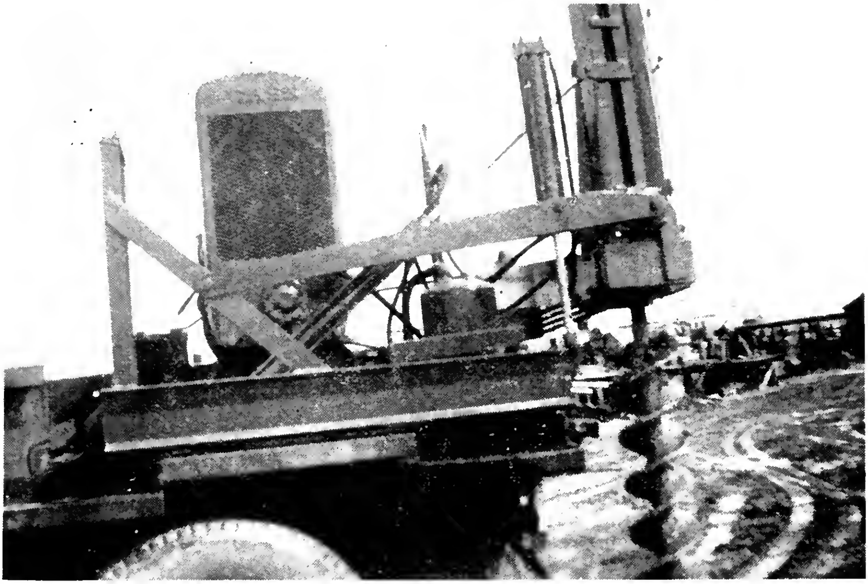


Fig. 1.—Skid-mounted auger on truck.

Fig. 2. Wheel-type tractor with power auger.

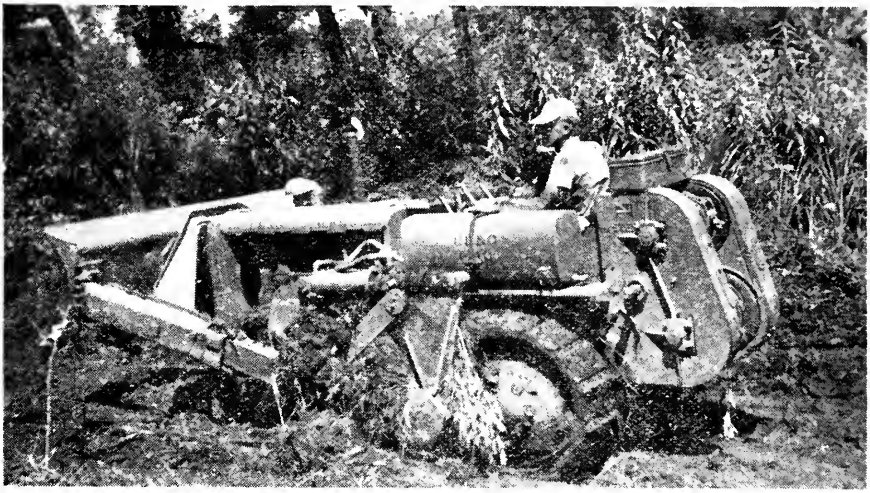


Fig. 3. Crawler tractor with dozer blade and winch for clearing fence line and pulling and stretching wire.

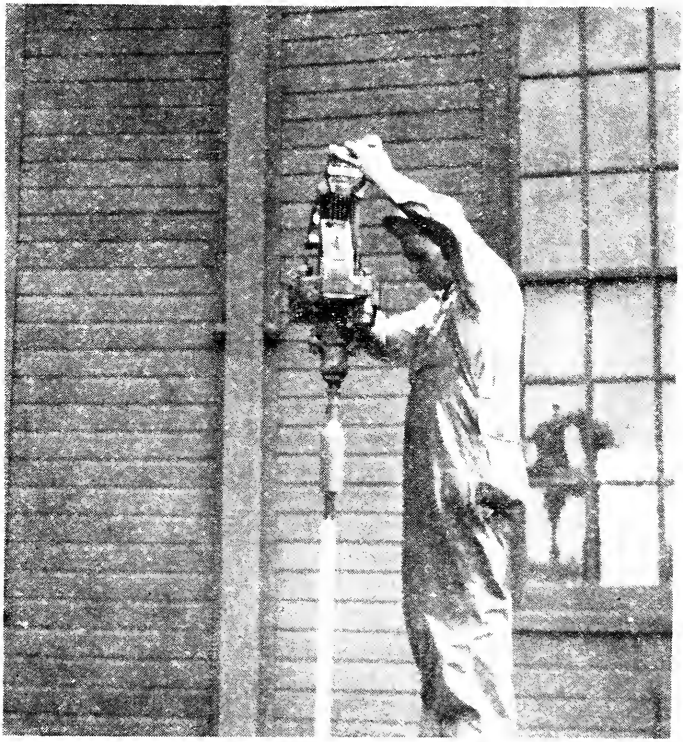


Fig. 4. Unit tamper fitted for driving steel fence posts.

or crawler type are useful. Wheel-type farm tractors equipped with power augers (Fig. 2) will dig a hole per minute in ordinary earth. Crawler-type tractors equipped with dozer blade and winch (Fig. 3) are useful for clearing the fence line, making temporary road for a truck to distribute material or to drive posts, and for pulling in and stretching the fence wire. Power auger attachments are on the market to fit both crawler and wheel-type tractors.

Portable augers are also available, driven by an electric or air motor, if such power is available, as well as an auger attachment for a gasoline-powered, two-man, portable chain saw, which can be quickly converted by detaching the chain saw assembly and attaching the auger assembly.

Power post drivers for driving wood or concrete posts are miniature pile drivers, which may be mounted on the truck bed. Some concrete and wood posts have not proved satisfactory, where the large end of the post was driven into the ground without tamping around the post. This has resulted in loose posts.

Post drivers for steel fence posts may be either hand or power tools. The hand tools consist of a weighted cylinder of a size to slip loosely over the post, with a cap on the top end. Two men grasp the cylinder and use it as a hammer to drive the post to the required depth. One manufacturer makes these in various sizes and weights, which are said to be suitable for driving wood posts up to 5 or 6 in. in diameter in ordinary soil, free from rock or gravel. The heavier cylinders are provided with a parallel rod on each side for convenient hand holds. For driving ordinary steel fence posts of "T" or "L" section, an air hammer or one of the heavier types of unit tie tampers (Fig. 4) may be fitted with a suitable driving head to slip over the top of the post. These may be conveniently used off the back end of a truck, which is about the proper height for a man to stand to operate the hammer.

The construction of wood stockyards and corrals is more of a special job for bridge and building gangs, and power tools may be utilized for most of this work. Power augers can be used for setting posts, which are usually 8-in. by 8-in. timbers set about 5 ft. in the ground. The power saws and tools used in bridge and building work are used in framing lumber for chutes and pens.

The choice of tools and equipment must be made by local officers to fit the work to be done.

Report on Assignment 7

Special Cars for Handling Work Equipment

A. H. Whisler (chairman, subcommittee), R. M. Baldock, R. E. Berggren, W. S. Brown, E. L. Cloutier, Bernard Geier, W. B. Lee, Harry Mayer, W. I. Stadter.

This is a final report, submitted as information.

Study of the subject assigned emphasizes the need for detail planning and the conservation of manpower and materials that can be made by having properly designed equipment to perform specific functions.

Railroad cars specially equipped to handle specific machines or combinations of machines will result in:

1. Minimum number of men the least amount of time to load and unload the equipment.

2. Work being done in the safest manner, fewer personal injuries, and create in the minds of men the benefits to be derived by doing work in a methodical manner.

3. Less material being used to securely block, shore or timber each shipment, and eliminate the wastage of blocking, etc., frequently associated with the use of miscellaneous materials.

4. Less damage to and increased life of car bodies by eliminating the boring, bolting, and nailing normally associated with miscellaneous anchorages.

5. Less damage to and increased life of the work equipment being transported. It will eliminate the damaging shocks and strains frequently subjected to loaded equipment not properly fastened or anchored.

6. Minimum amount of car-inspector time to approve loading for shipment.

Three types of specially equipped railroad cars are used for transporting pieces of work equipment. They are the flat car, the half flat—half box, and the box car.

Flat cars have been designed for and are being used to carry:

Crawler cranes and shovels.
Crawler tractors with the various attachments.
Crane booms, dipper sticks, clamshell and dragline buckets, fuel and oil containers, tool boxes, etc.
Graders.
Material conveyors.
Railroad wheel-mounted, small, self-propelling M.W. cranes.
Welding outfits.
Rail-laying machines and allied power equipment.
Steam ditchers.
Tamping machines, power track jacks, etc.
Trenching machines.

They are also used as idler cars to be coupled to carriers for transporting cranes and shovels with booms or attachments extending beyond ends of the carriers.

Equipping Flat Cars

In equipping flat cars consideration should be given the following:

(a) Cars chosen for special equipping should be of sound physical condition, considering the service life that will be expected of them. They should not be cars that have deteriorated to the state that they are no longer fit for shipment in revenue trains, or such that they will have to be withdrawn frequently from their assigned service and money provided for their repair.

(b) Cars chosen to carry long equipment should, as often as possible, be of a length sufficient to preclude the necessity of using idler cars when shipment is made in revenue trains.

(c) The deck should have guard rails or timbers to act as guides when work equipment is moved onto, on, or off the car.

(d) Blocking timbers, when necessary, should be constructed so they can be swung or moved toward the center of the car without lifting them, and should be of such dimensions as will permit the equipment to be moved over or past them.

(e) Wheel or crawler stops should be constructed of steel, designed to hold a particular machine, and when in place should fit into a receptacle in the car with the minimum amount of bolting, keying, etc. They should be fastened to the car floor by wire rope or chain to prevent their becoming lost when not in place for holding the equipment.

(f) Other fastening or anchoring devices should be made of wire rope, chains, etc., with turnbuckles, and with one end permanently fastened to the car floor or side, and so arranged that when holding the machine or equipment they will result in the minimum amount of strain on the equipment, and insure that the strain is applied at the safest place.

(g) Boom supports should be so constructed that the boom will be as low as possible, and so the crane may pass over them. Where this is not possible, a hinged type of support should be used, made of the lighest angle iron construction consistent with the weight of the boom.

(h) Boom anchorages should be of steel rods or cables and should include turnbuckles for drawing the boom down to the boom support, instead of using the crane boom-hoisting cable to put tension in the anchorages.

(i) Sides or side boards applied to flat cars should be as open as possible to permit trainmen or inspectors walking past the car to notice readily any lack of or damage to anchorages or supports. When equipment such as cranes mounted on the flat car are of a width that will prevent trainmen or workmen from walking between the side of the equipment and the car side, the car side should be topped with a "cat-walk" of not less than eight inches in width, and the equipment should be provided with sufficient handholds to permit the "cat-walk" to be used safely to pass the equipment.

(j) Steel rails used on flat cars to carry equipment having flanged wheels should be secured to the car frame. They should not be fastened to a wood car floor by spiking, bolting or lagging. Where practical, the wood car flooring should provide for an opening of approximately one inch along each side of the steel rail. This arrangement will provide the most rigid construction, permit of easily cleaning the car floor, and will result in a dry floor with maximum service life.

(k) Cars on which any type of shovel or crane will be worked should be equipped with auxiliary side bearings, to void the action of car truck springs while the machine is in use. This arrangement, especially on curved track having superelevation, will provide the maximum stability and safety against overturning or upsetting the car and crane.

(l) Car hand-brake mechanisms should be placed so as not to interfere with end loading or unloading of the equipment. When they are placed where they will interfere, they should be of the type that will permit easy removal and replacement of the wheel and staff.

(m) Unloading and loading ramps should be provided and cars should be so equipped that the ramps can be used at both ends of the car. They should be of the minimum length and of the lightest construction consistent with the weight of the equipment they must carry. Intermediate supports should be used to minimize the weight of ramp runways, so they can be easily handled by several men in the least amount of time. Provision should be made to carry ramp parts under the equipment, and such should be properly secured to the car floor or sides while the car is in transit.

(n) Cars assigned to carry cranes and buckets should provide for easily and quickly securing the buckets to the car floor or deck.

(o) Boxes or chests should be provided along the center line of car floor for the safe and proper keeping of extra anchorage or equipment parts, extra wire rope, etc. These should be of such dimensions that they will not interfere with the passage of equipment over or past them.

(p) Underdeck wells or side bins should be provided for the proper storage or carrying of some fuel and lubricating oil containers, such as are normally associated with each piece of equipment.

(q) Each car should have stenciled on it the number or numbers of the equipment it was designed for and is assigned to carry. Similarly, equipment assigned to be carried on or in a particular railroad car should have stenciled on it the number of the railroad car assigned.

(r) Intercar bridges will save many man-hours, provide the greatest safety and result in the least damage to equipment when several cars are coupled together and it is desired to move equipment from one car to another.

(s) Pivoted equipment should be equipped with swing limit stops to insure that the center line of the boom or other attachments will be held parallel with the center line of its chassis and the center line of the car body.

Equipping Box Cars

In addition to the foregoing, the equipping of box cars should always include consideration of the following:

(A) Under many circumstances, box cars can be used more economically to transport and house the smaller roadway machines, such as rail-end and structural welding outfits, and rail-laying machines, such as powered tie adzers, spike pullers, air compressors, track wrenches, tie borers, etc. When so used, they provide protection from the weather or pilferage, permit minor repairs or adjustments to be made during inclement weather, and provide excellent storage facilities when and if machines are not required between or during working seasons.

(B) End doors should be of a type that requires minimum space when being opened or closed. The overhead-rolling-type or side-hinged, accordion-type will prove most satisfactory.

(C) Sufficient windows should be provided in the doors and car sides to preclude the use of artificial lights in the daytime to secure or loosen equipment or to place or remove spare parts, etc.

(D) Sufficient ventilators should be a part of the car to insure the quick removal from the car of dangerous exhaust or fuel fumes when all doors and windows are closed.

(E) Artificial lights should always be of the electric, explosion-proof types, which is the preferable artificial light because of the fact that gasoline fumes are frequently associated with roadway machines.

(F) Cars for transporting machines such as referred to in (A) should be equipped with rails, blocking, anchorages, etc., as referred to in paragraphs (a), (e), (f), (j), (m), (o), (q) and (r) under items to be considered when flat cars are specially equipped.

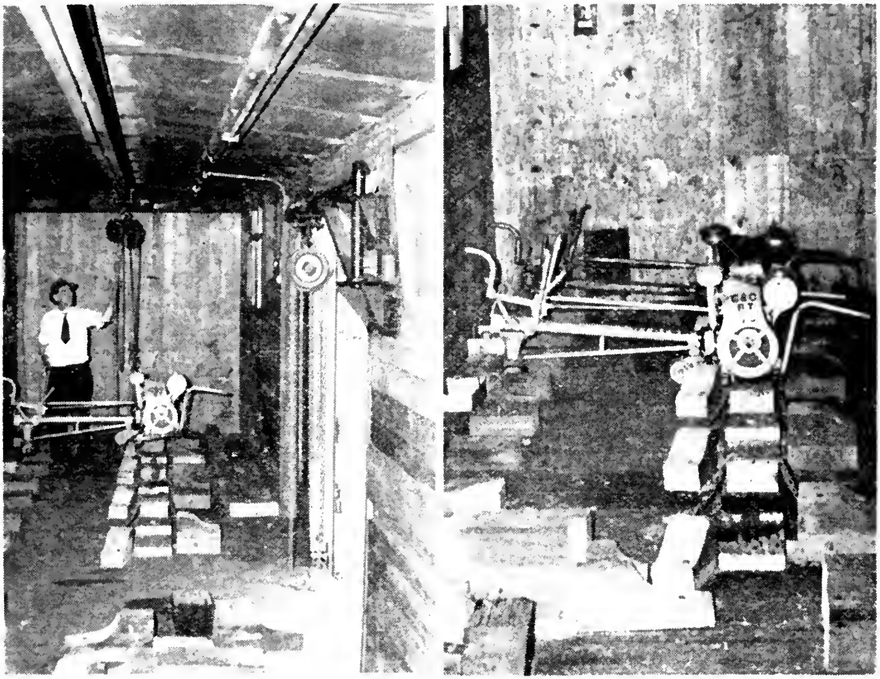
(G) When cars are to be used as repair shops, and heating of them is necessary, heat should be provided by means of steam or electricity generated outside the cars. When it is necessary to use ordinary stoves to supply warm air, they should be housed in a compartment, access to which is only possible from the ground outside the cars.

(H) Small jib or stiff-leg hand-operated cranes should be provided, to be used at the opening of either or both side doors to afford an easy means of loading or unloading heavy machine parts or small machines.

Figs. 1 and 2 indicate the detail planning that should be performed to equip box cars properly for carrying specific machines.

Half Flat—Half Box Cars

Equipping half flat—half box cars requires consideration of the items listed under the equipping of flat cars and box cars. This type of car can frequently be equipped to perform work for which a flat car and a box car were formerly used.



Figs. 1 (left) and 2 right). Interior of specially equipped box car.

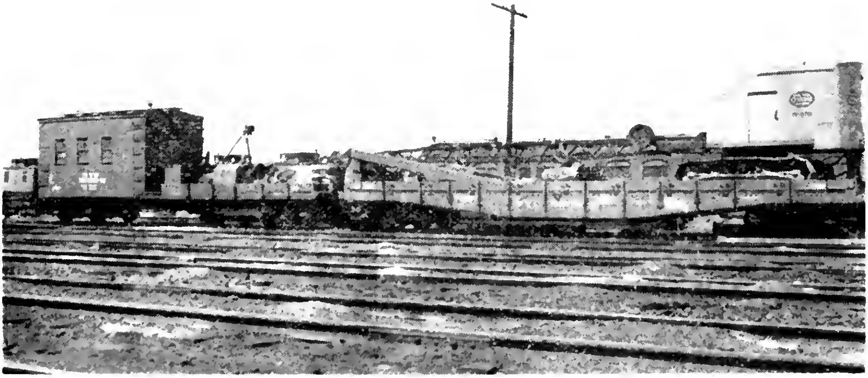


Fig. 3. Half flat—half box, and crane-carrying flat car.

The box portion may be used for living quarters, or to house small parts and materials in quantities, which do not require a standard size box car. See Fig. 3.

Small drawings, approximately 8½ in. by 11 in., each showing the general blocking and anchorage arrangement of some particular type of equipment on or in some particular type of car, can be used to save many man-hours that would otherwise be consumed by men not entirely familiar with the details of each loading, blocking and unloading arrangement. These will permit men charged with the proper anchoring of equipment to intelligently and correctly call for or order the blocking or anchorage parts that are required to replace defective or lost parts. They will insure the blocking and anchorages being made in accordance with approved plans. They should indicate the car numbers of the cars so equipped, as well as the number of the equipment assigned to be carried by each car. Their use will save costs in man-hours and materials far in excess of the cost to prepare and distribute them to interested personnel.

Conclusion

Carefully planned and designed cars for transporting maintenance-of-way equipment will result in savings in both money and time, and also increase the safety performance of maintenance forces.

Report on Assignment 8

Special Attachments for Tractors

W. G. Luebke (chairman, subcommittee), W. R. Bjorklund, C. T. Blume, L. E. Conner, Herbert Huffman, E. H. Ness, J. W. Risk, R. S. Sabins, M. M. Stansbury, E. E. Turner.

This is a final report, submitted as information.

This committee has attempted to segregate the various attachments available, reporting only on those which can be adapted to railroad uses.

Earth Boring Machines

This attachment has much merit as a labor saving device. Models are made which can be attached to both crawler or wheel-type tractors.

One type tractor-mounted earth drilling machine is power-operated and the auger bar, pole derrick and winch are an integral part of the machine. The auger bar and pole may be raised from traveling to working position by power, and the auger will dig at various angles in clay, hard pan, shale or frozen ground. The pole derrick is capable of handling 40 to 45-ft. poles. The auger is adjustable to dig from 6 to 20-in. holes, 7 to ten ft. deep. See Figs. 1 and 2.

Post hole digging attachments for the conventional wheel-type tractors are also available having augers 4 in. to 20 in. in diameter. These will drill holes 54 in. deep. Extension augers 3½ ft. long can be obtained, which can be attached to the auger, permitting the digging of holes 20 ft. deep.

Power-Operated Winches

Various manufacturers have power-operated winches on the market as a standard crawler tractor attachment. These winches are available with various drum sizes, line pulls and speeds, and are made in single-drum, double-drum and three-drum models. The

Fig. 1. (left above) Earth boring machine digging hole.

Fig. 2. (right above) Earth boring machine setting pole.

primary use of these winch attachments is hoisting, towing and skidding, but many and various other uses of these attachments will be apparent when working on the right-of-way.

Winch attachments for wheel tractors are on the market which, while not of the capacity of crawler tractor winches, have proved themselves invaluable in assisting maintenance-of-way crews.

Crane and Boom Attachments

Crane and boom attachments for crawler and wheel tractors are continually proving more popular and versatile. There are many varieties on the market built along similar lines, some of which are as follows:

1. Pipe layer
2. Swing crane
3. Swing crane with electric magnet

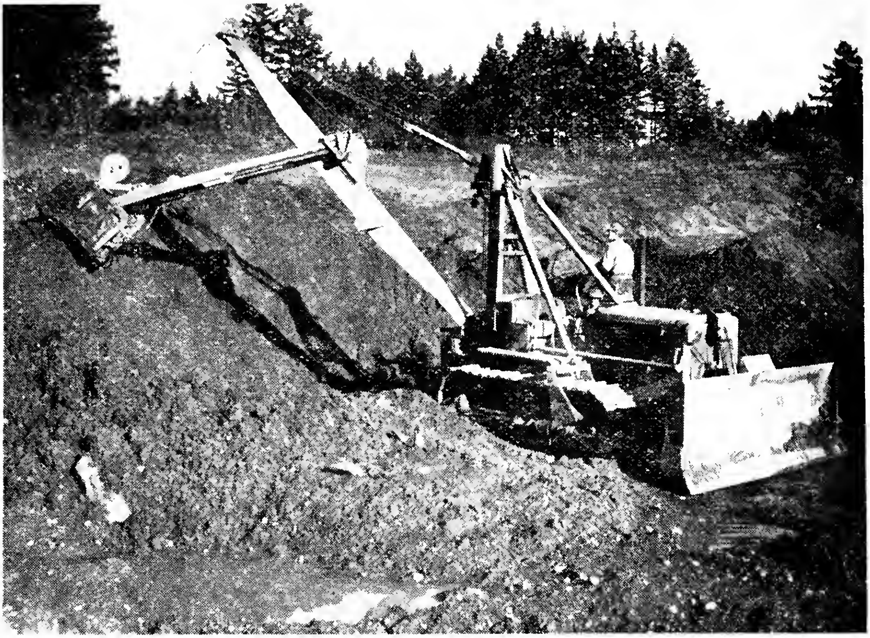


Fig. 3. Shovel attachment in bank sloping operation.

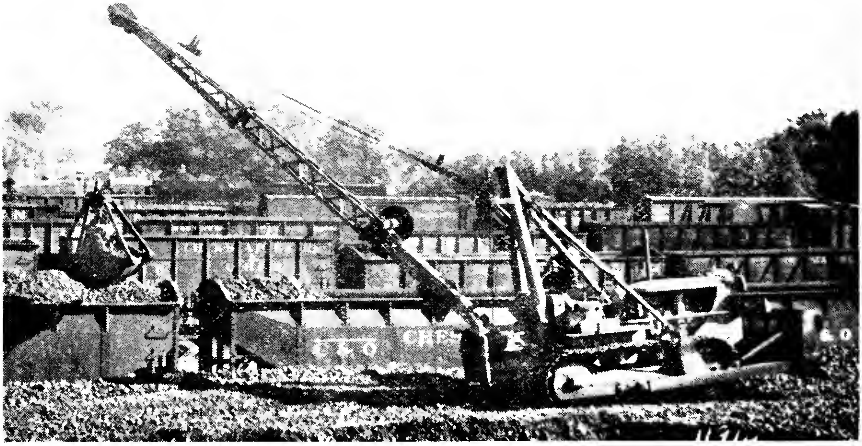


Fig. 4. Clamshell attachment loading storage coal.

Fig. 5. Tie loading attachment lifting ties from roadbed for sorting and loading.

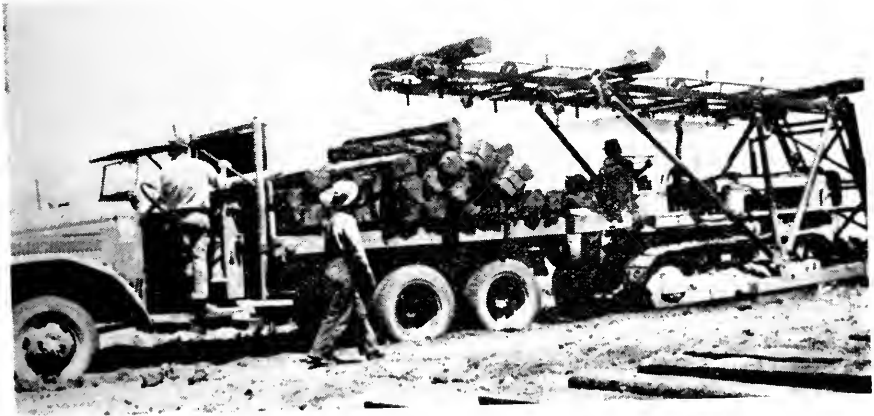
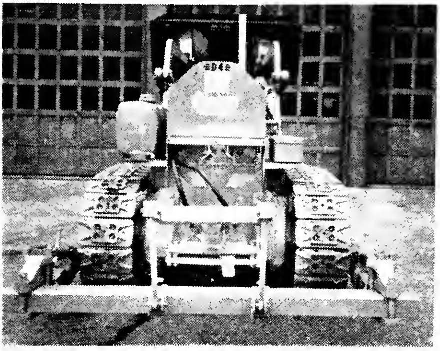


Fig. 6. Tie loading attachment loading ties on truck direct from roadbed.



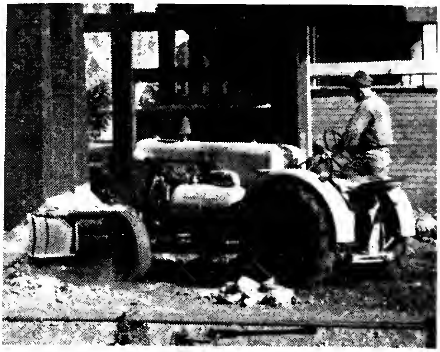


Fig. 7. (left above) Tool bar attachment applied to crawler tractor.

Fig. 8. (below) Tool bar attachment, in operation, equipped with ditcher.

Fig. 9. (right above) Tractor-mounted air compressor operating with backfill blade attachment.

4. Shovel front. (see Fig. 3)
5. Back hoe
6. Dragline
7. Clam bucket. (see Fig. 4)
8. Pile driver

Tie Loading Attachment

This device is suitable for installation on standard-type crawler tractors. It uses a bulldozer-type "C" frame which scoops up the ties. Power for this scoop is obtained through a cable drive from one drum of a double-drum power control unit mounted on the rear of the tractor. The other cable drum controls the position of the towed truck, so the ties may be loaded without manual help. A small gasoline engine-generator set mounted beside the operator furnishes power for the conveyor system. See Figs. 5 and 6.

Trenching Attachments

Trenching attachments for wheel tractors are available which are capable of digging trenches up to 24 in. in width and 52 in. deep. A back-filling blade is included with this attachment, which enables the completion of trenching jobs with the one machine. Speeds range from 2 ft. to 20 ft. per min. while trenching, and the normal road speed of the tractor on which this attachment is mounted can be maintained.

Tool Bar Attachments

Tool bar attachments for crawler tractors are mentioned with the thought in mind that special right-of-way tools may be designed which could be used in conjunction with it. This attachment is a hydraulically-operated crossbar on the rear of the tractor, to which special tilling tools may be attached, such as chisel, ditcher, cultivator, disk, etc. See Figs. 7 and 8.

Tractor-Mounted Arc Welders

Tractor-mounted arc welding machines are made by various manufacturers, which are especially designed for working in railroad yards and which have proven themselves to be labor and time savers. Machines are available in current ranges of 50 to 400 amp., with remote control and a cable reel holding up to 75 ft. of both electrode and ground cable.

Tractor-Mounted Air Compressor

A tractor-mounted air compressor with various attachments is now on the market and in service on many railroads. The air compressor has a 105 cu. ft. capacity and is an integral part of the tractor, which has 4 speeds forward with 1 reverse, and a maximum speed of 35 hp.

The following attachments are available for this machine:

1. Swingloader
2. Backfill blade. (see Fig. 9)
3. Snow plow
4. Power broom

Report on Assignment 10

Portable Lighting Outfits

W. E. Kropp (chairman, subcommittee), R. M. Baldock, R. E. Berggren, C. T. Blume, C. L. Fero, B. Geier, H. H. Main, Francis Martin, P. S. Settle, S. E. Tracy.

This is a final report, submitted as information.

Portable lighting outfits are designed to furnish artificial light wherever it might be needed, and consist principally of a generator to supply the current, one or more floodlights with stands, extension cords, outlets, reflectors, etc., with a suitable mounting. The variety in generators, floodlights, and mountings for these outfits makes it possible to set up a combination suitable to most any maintenance-of-way requirement.

Portable lighting outfits may be classified as follows:

1. Off-track, Wheel-Mounted. These consist generally of a small generator and floodlights mounted on two or four pneumatic-tired wheels. The floodlights may be either permanently mounted, or removable with extension cords. See Fig. 1.
2. On-track, Wheel-Mounted. This type consists usually of a combination motor car-generator with floodlights permanently mounted, or removable with extension cords. They also are sometimes mounted on a push car and towed by a motor car. Permanently mounted, they are customarily used for tunnel inspections, while the types with removable floodlights may be used at any point along the right-of-way.
3. Highway Trailer-Mounted. This type is mounted on two pneumatic-tired wheels, with a hitch for attaching it to an automotive vehicle for movement over highways at normal driving speeds. The floodlights may be permanently mounted, or removable with extension cords. See Fig. 2.

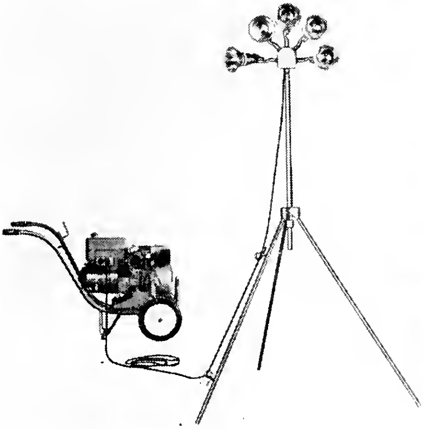


Fig. 1.

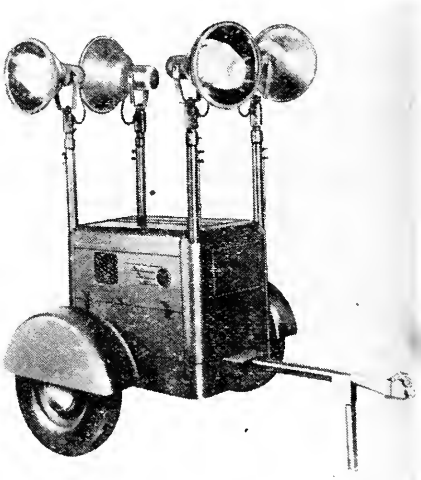


Fig. 2.

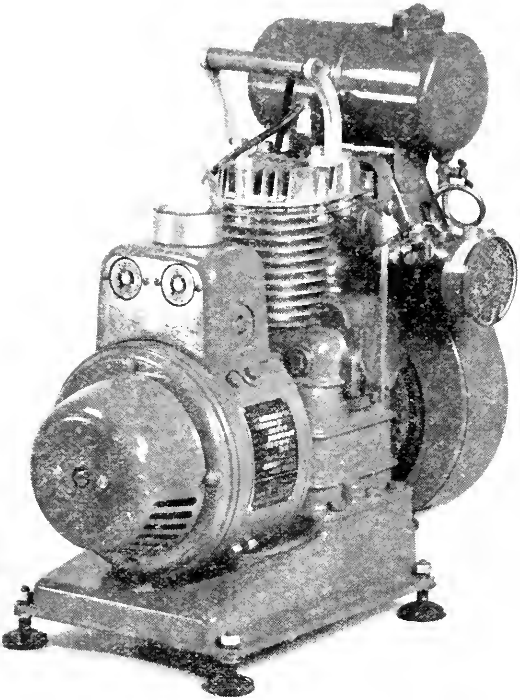


Fig. 3.

4. Carryable. The carryable type of lighting outfit is generally a small size generator capable of being carried by one or two men, mounted on a metal base or skids with electrical outlets for the insertion of extension cords. In some few types provision is made for the direct mounting of a bulb and reflector on top of the generator, but in most cases the floodlights are separate and not mounted on the generating outfit. See Fig. 3.

Generators for use in maintenance-of-way portable lighting outfits are usually powered by gasoline engines and are available in both alternating and direct-current types, 115 and 230 volts; 25, 50 and 60 cycles in the alternating current types. The capacities range from 600 to 3000 watts in the small, wheel-mounted and carryable types; up to 5000 watts in the larger, wheel-mounted outfits; and up to 25,000 watts for those designated as highway trailers.

The floodlights commonly used in the lighting outfits for railroad work range from 1 light on 1 base to a cluster of 5 lights on 1 base, which range in height up to 6 ft. 2 in. The light stands, supports, or tripods are usually adjustable as to beam direction and height.

The type of portable lighting outfit most commonly used for maintenance of way work at derailments, slides, floods, etc., consists of a generator in the 2500 to 5000-watt range, mounted on 2 pneumatic-tired wheels, equipped with floodlights ranging from 350 to 500 watts each. The lengths are supported by a single light stand with the height adjustable to 6 ft., with extension cords approximately 150 ft. in length.

Report of Committee 8—Masonry

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C. A. Whipple
W. Wilbur
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.

   No report.

3. Foundations for masonry structures, collaborating with Committees 1, 6, 7, 15 and 30.

   Report on revision of Specifications for Foundations of Masonry Structures, presented for adoption and publication in the Manual .... page 382

   Report on Steel and Timber Pile Tests on the New Orleans, Texas and Mexico Railway, presented as information .... page 384

4. Earth pressure as related to masonry structures.

   Report on Specifications for Design of Retaining Walls and Abutments, presented as information .... page 384

5. Tunnel linings: Design, construction and maintenance, collaborating with Committees 1, 5, 28 and 29.

   No report.

6. Methods of repairing masonry, including internal pressure grouting.

   No report.

7. Methods of improving the quality of concrete and mortars, collaborating with Committee 6.

   Report on methods of manufacture and control of quality of ready-mixed concrete, presented as information .... page 394

AREA Bulletin 492, January 1951.

8. Specifications for the construction and maintenance of masonry structures.
   No report.

THE COMMITTEE ON MASONRY,
C. B. PORTER, *Chairman.*

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, K. J. Wagoner, E. P. Wright.

Your committee recommends for adoption and publication in the Manual the following revisions of Articles A. General, and B. Design, of Specifications for Pile Foundations, to replace existing material under these Articles on pages 8–87 and 8–88:

[1]PILE FOUNDATIONS

A. GENERAL

1. Scope

These specifications cover the investigation, design and construction of pile foundations, under substructures located below the surface of the ground.

2. Purpose and Necessity

Pile foundations may be used when the bearing power of the soil is insufficient to carry the superimposed loads or where the possibility of scour or other disturbance of the soil may cause a change in the underlying foundation condition.

Depending on subsoil conditions, piles act as columns to carry the supported load to firm substrata, to transfer the load to the soil by skin friction, or to consolidate the soil.

B. DESIGN

1. Loads

Pile foundations shall be designed for that combination of the following forces which produces maximum load and in accordance with Article C. Allowable Load on Piles.

Primary

- (a) Dead
- (b) Live
- (c) Centrifugal force
- (d) Earth pressure
- (e) Buoyancy

Secondary

- (f) Wind and other lateral forces
- (g) Longitudinal forces

2. Increased Load on Piles

When pile foundations are designed for both primary and secondary forces, as defined above, the allowable load on the piles may be increased by 25 percent, but the number of piles shall not be less than is required for primary forces alone. With a group of friction piles, the load on the piles from primary forces shall not be increased by secondary loads beyond the shear value as determined under Article C. Allowable Load on Piles, with a reasonable safety factor.

3. Eccentricity of Loads

The maximum pile load under eccentric load shall not exceed the allowable load as determined under Article C. Allowable Load on Piles. The piles shall be spaced so that the eccentric load on the foundation will be distributed as equally as possible to the piles in the group.

4. Uplift on Piles

In special cases when piles are subjected to continuous uplift, or to uplift from horizontal loads other than earth and hydrostatic pressures, and sufficient bond and anchorage can be provided between the pile and the superimposed structure, the uplift may be considered in the design of the pile foundation. The uplift force considered in the design shall not exceed the value of friction between earth and pile, with an ample safety factor. The ultimate uplift value may best be determined by jacking test piles of identical type and dimension to be used in the design, and measuring the pull required per square foot of embedded area to raise the pile.

5. Spacing of Piles

Piles shall be spaced to equalize their load as far as possible consistent with economical design of footings. The spacing of piles shall depend upon the type of pile; that is, whether friction, end bearing or compaction piles; upon their structural and crushing strength; and upon the type of material sustaining the pile. Compaction piles can be spaced only from test, as provided in Article C. Allowable Load on Piles. Generally, piles should not be spaced less than 2½ diameters or sides of square pile, and in friction bearing materials piles should be spaced 3 to 4½ diameters of the pile depending upon the allowable load determined in accordance with Article C. Piles should be spaced far enough apart to reduce heaving or uplifting of adjacent piles to the minimum. In small pile groups the piles may be battered to enlarge the area sustaining the group, thereby increasing the load carrying capacity of the group without increasing the size of the foundation unreasonably. End bearing piles may be spaced in accordance with the capacity of the pile and the end bearing stratum to carry the design load, but should not be spaced so close as to cause heaving and uplift on piles previously driven.

6. Batter Piles

Piles may be battered to help resist longitudinal and lateral forces inadequately resisted by the footing against the soil. In foundations for piers or bents, in friction pile areas, with not too large a group of piles, the battering of perimeter piles adds to the shear capacity of the group. Where longitudinal or lateral loads are large, a sufficient number of piles should be battered to take these loads. Such piles shall be designed to carry horizontal forces combined with their share of the vertical loads. Where space permits, piles may be added to the group with a batter making a large angle between the pile and the vertical to resist large longitudinal or lateral loads.

Report on Steel and Timber Pile Tests

West Atchafalya Floodway—New Orleans, Texas and Mexico Railway

This report embraces a description and analysis of tests made on hollow steel and timber bearing piles in the swamps of southern Louisiana. The tests were made at the request and expense of the Corps of Engineers, U. S. Army, in accordance with an agreement between the New Orleans, Texas and Mexico Railway and the United States of America. As your committee considered this report to be outstanding and of interest to foundation engineers and all others concerned with foundation problems, it was published in the September–October Bulletin as an advance report of the committee, and will be included in AREA Proceedings, Vol. 52, 1951, page 149.

Report on Assignment 4

Earth Pressure as Related to Masonry Structures

R. B. Peck (chairman, subcommittee), E. E. Burch, H. J. Engel, J. A. Erskine, C. W. Martin, E. A. McLeod, H. Posner, W. Wilber.

Your committee presents as information the following tentative Specifications for Design of Retaining Walls and Abutments with the view of offering it next year for adoption and publication in the Manual to replace material under Articles 310 and 311, pages 8–56 to 8–59, and Appendix B, pages 8–82 to 8–86, inclusive:

SPECIFICATIONS FOR DESIGN OF RETAINING WALLS AND ABUTMENTS

A. DEFINITIONS

1. Types of Retaining Walls and Abutments

A retaining walls is a monolithic or masonry structure used to provide lateral support for a mass of soil which, in turn, may provide vertical support for loads acting on or within the soil mass.

The principal types of retaining walls are as follows:

- (a) The gravity wall, which is so proportioned that no reinforcement is required.
- (b) The semi-gravity wall, which is so proportioned that some steel reinforcement is required along the back and along the lower side of the toe.
- (c) The cantilever wall, which has a cross section resembling an L or an inverted T, and which requires extensive steel reinforcement.
- (d) The counterfort wall, which consists of a reinforced vertical face slab supported laterally at intervals by vertical reinforced counterforts extending into the backfill, and supported by a reinforced base slab which usually projects in front of the face slab to form a toe.
- (e) The buttress wall, which is similar to the counterfort wall, except that the vertical members, called buttresses, are exposed on the face of the wall rather than buried in the backfill.

An abutment commonly consists of a retaining wall that incorporates a bridge seat in its face. It may also be of the spill-through type, however, in which the bridge seat rests on horizontal beams supported by piles or columns, between which the fill is permitted to extend.

B. INFORMATION REQUIRED

1. Field Survey

Sufficient information shall be furnished, in the form of a profile and cross sections or a topographic map, to determine the structural requirements. Present grades and alinements shall be indicated, together with the records of high water, low water and depth of scour, the location of underground utilities and information concerning any structures that may affect or be affected by the construction.

2. Controlling Dimensions

Information shall be assembled concerning clearances, proposed grades, and all other factors that may influence the limiting dimensions of the proposed structure.

3. Loads

Loads to be superimposed either on the wall or abutment or on the backfill shall be indicated.

4. Character of Backfill

Backfill is defined as all material behind the wall, whether undisturbed ground or fill, that contributes to the pressure against the wall.

The backfill shall be investigated and classified with reference to the following soil types:

TYPES OF BACKFILL FOR RETAINING WALLS

1. Coarse-grained soil without admixture of fine soil particles, very free-draining (clean sand, gravel or broken stone).
2. Coarse-grained soil of low permeability due to admixture of particles of silt size.
3. Fine silty sand, granular materials with conspicuous clay content, or residual soil with stones.
4. Soft or very soft clay, organic silt, or soft silty clay.
5. Medium or stiff clay that may be placed in such a way that a negligible amount of water will enter the spaces between the chunks during floods or heavy rains.

5. Character of Foundation

The character of the foundation shall be determined by means of test pits, auger borings or core borings, of a type and to an extent consistent with the magnitude of the project.

If the subsoil is essentially sandy or gravelly in character, the groundwater level shall be ascertained. In addition, the relative density of the material shall be investigated, preferably by means of penetration tests or static load tests. The penetration test shall consist of driving a sampling spoon (2 in. O.D.; 1⅜ in. I.D.) into the material by means of a weight of 140 lb. falling through a distance of 30 in. The relative density is measured by the number of blows N required to obtain a penetration of 1 ft.

If the subsoil consists of clay, it is advisable to obtain intact specimens suitable for determination of the unconfined compressive strength. In the absence of such samples, the consistency of the clay shall be described in the following terms:

CONSISTENCY OF CLAY

Consistency	*Field Identification*	*Ultimate Unconfined compressive strength tons per sq. ft.*
Very soft	Easily penetrated several inches by fist	less than 0.25
Soft	Easily penetrated by thumb	0.25 to 0.50
Medium	Can be penetrated by thumb with moderate effort	0.50 to 1.0
Stiff	Readily indented by thumb but penetrated only with great effort	1.0 to 2.0
Very stiff	Readily indented by thumbnail	2.0 to 4.0
Hard	Indented with difficulty by thumbnail	over 4.0

Where seasonal changes in the consistency of clay subsoils are likely to occur, their influence shall be taken into consideration.

Other procedures for investigating the relative density of sands or the consistency of clays may be used in places of those recommended in the preceding paragraphs, provided such procedures lead to quantitative results.

C. COMPUTATION OF APPLIED FORCES

1. Loads Exclusive of Earth Pressure

In the analysis of retaining walls and abutments, due account shall be taken of all superimposed loads carried directly on them, such as building walls, columns, or bridge structures; and of all loads from surcharges caused by railroad tracks, highways or building foundations supported on the fill back of the walls.

In calculating the surcharge due to track loading, the entire load shall be taken as distributed uniformly over a width of 14 ft. for a single track or tracks spaced more than 14 ft. centers, and as distributed over 14 ft. plus the distance center to center of tracks where tracks are spaced 14 ft. or less.

Impact shall not be considered unless the bridge bearings are supported by a structural beam, as in a spill-through abutment.

2. Computation of Backfill Pressure

Values for the unit weight, cohesion, and angle of internal friction of the backfill material shall be determined directly by means of soil tests or, if the expense of such tests is not justifiable, by means of the following table referring to the soil types defined in Section B4.

Soil Type	*Unit Weight lb. per cu. ft.*	*Cohesion c lb. per sq. ft.*	*Angle of internal friction deg.*
1	105	0	33–41′ (38 for broken stone)
2	110	0	30
3	125	0	28
4	100	0	0
5	120	240	0

The magnitude, direction and point of application of the backfill pressure may be computed to take proper account of the appropriate values of unit weight, cohesion and internal friction; of the actual shape of the ground surface, and of the actual surcharges. The computation can be made by the trial-wedge method as illustrated in Appendix A. Unless the minimum cohesive strength of backfill material can be evaluated reliably, the cohesion shall be neglected and the computation based on internal friction alone.

When the backfill is assumed to be cohesionless; when the surface of the backfill is or can be assumed to be plane; where there is no surcharge load on the surface of the backfill or when the surcharge can be converted into an equivalent earth surcharge, Rankine's or Coulomb's theories can be used under the conditions to which each applies. Tables, charts, or formulas based on these theories and appropriate friction angles may also be used.[1] If the wall or abutment is not more than 20 ft. high and the backfill has been classified according to Section B4, empirical charts may be used.[2] In the computation of backfill pressure the influence of vibrations and of earthquake shocks need not be considered.

If the wall or abutment is prevented from deflecting freely at its crest, as in a rigid-frame bridge or some types of U-abutments, the computed backfill pressure shall be increased 25 percent.

In spill-through abutments, the increase of pressure against the columns due to the shearing strength of the backfill shall not be overlooked. If the space between columns is not greater than twice the width across the back of the columns, no reduction in backfill pressure shall be made on account of the openings. No more than the active earth pressure shall be considered as the resistance offered by the fill in front of the abutment. In computing the active earth pressure of this fill, the negative or descending slope of the surface shall be taken into consideration.

D. STABILITY COMPUTATION

1. Point of Intersection of Resultant Force and Base

The resultant force on the base of a wall or abutment should fall within the midle third if the structure is founded on soil, and within the middle half if founded on rock, masonry or piles. The resultant force on any horizontal section above the base of a solid gravity wall should intersect this section within its middle half. If these requirements are satisfied, safety against overturning need not be investigated.

2. Resistance Against Sliding

The factor of safety against sliding at the base of the structure is defined as the sum of the forces at or above base level available to resist horizontal movement of the structure, divided by the sum of the forces at or above the same level tending to produce horizontal movement. The numerical value of this factor of safety shall be at least 1.5. If the factor of safety is inadequate, it shall be increased by means of a key, by sloping the base upward from heel to toe, or by the use of batter piles.

In computing the resistance against sliding, the passive earth pressure of the soil in contact with the face of the wall shall be neglected. The frictional resistance between the wall and a non-cohesive subsoil may be taken as the normal pressure on the base times the coefficient of friction f of masonry on soil. For coarse-grained soil without silt, f may be taken as 0.55; for coarse-grained soil with silt, 0.45; for silt, 0.35.

If the wall rests upon clay, the resistance against sliding shall be based upon the cohesion of the clay, which may be taken as one-half the unconfined compressive strength. If the clay is very stiff or hard the surface of the ground shall be roughened before the concrete is placed.

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[1] See, for instance, Structural Engineers Handbook, by M. S. Ketchum, or Earth Pressure, Walls and Bins, by Wm. Cain.

[2] See Soil Mechanics in Engineering Practice, by Karl Terzaghi and Ralph M. Peck, pp. 316, 317.

If the wall rests upon rock, consideration shall be given to such features of the rock structure as may constitute surfaces of weakness. For concrete on sound rock the coefficient of friction f may be taken as 0.60.

The factor of safety against sliding on other horizontal surfaces below the base shall be investigated and shall not be less than 1.5.

3. Soil Pressure

The factor of safety against a bearing capacity failure at the toe of the structure is defined as the ultimate bearing capacity of the material beneath the toe, divided by the maximum pressure beneath the toe. The value of this factor of safety shall be not less than 2 if the structure rests on sand and gravel, or 3 if it rests on clay.

The pressure on the foundation shall be calculated by the following formulas (see Fig. 1):

Case 1. Resultant within the middle third.

$$p_1 = (4B - 6a)\ F/B^2$$
$$p_2 = (6a - 2B)\ F/B^2$$
When $a = B/2$, $P_1 = P_2 = F/B$

Case 2. Resultant at edge of middle third.

$$p_1 = (4B - 6a)\ F/B^2 = 2F/B$$
$$p_2 = (6a - 2B)\ F/B^2 = 0$$

Case 3. Resultant outside the middle third.

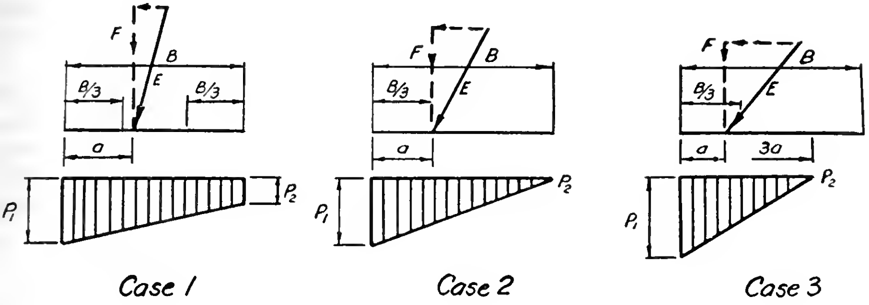
$$p_1 = 2F/3a$$
$$p_2 = 0$$

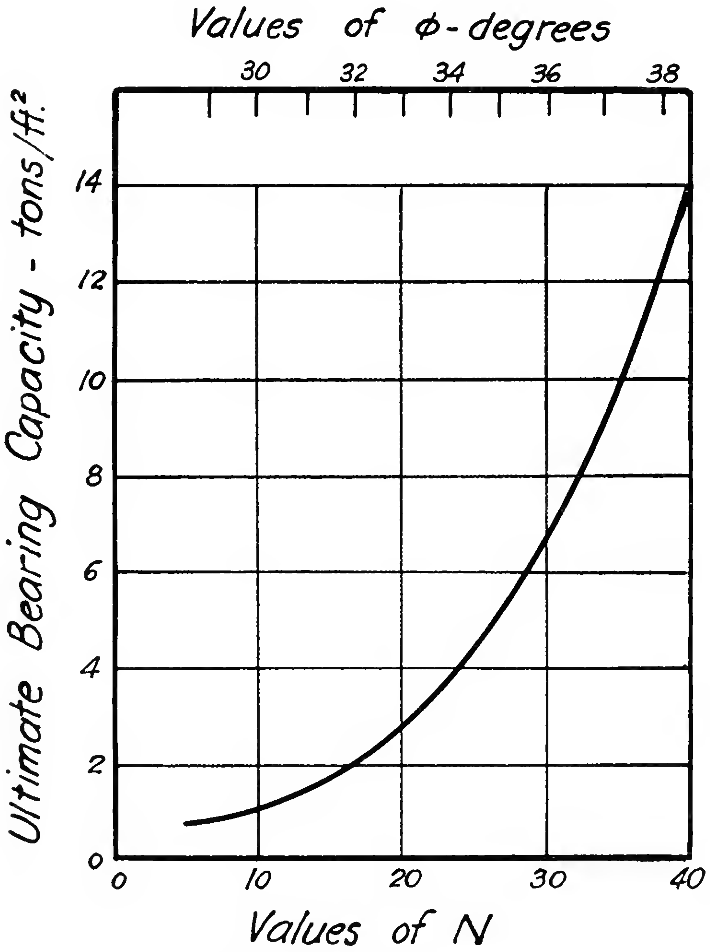
The ultimate bearing capacity of sand and gravel shall be estimated on the basis of the relative density or angle of internal friction Ø of the material. If the relative density has been investigated by means of the penetration test described in Section B5, the ultimate bearing capacity corresponding to the appropriate. N value can be determined by means of the chart, Fig. 2. The same chart can be used if the value of Ø is known. The value of N or Ø shall be the average within the significant depth below the base of the footing. This depth may be taken as equal to the width of the base, unless the upper part of the subsoil is appreciably looser than the lower. In this event, the average value for the looser part shall be used. If groundwater level is closer to the base of the footing than a depth equal to one-half the width of the base, the ultimate bearing capacity shall be taken as one-half the value determined from the chart. For positions of the water table intermediate between the base and a depth equal to one-half the width of the base, the appropriate values may be determined by interpolation.

The ultimate bearing capacity of a clay subsoil may be considered equal to three times the average unconfined compressive strength of the clay within the significant depth below the base of the footing. This depth may be taken as equal to the width of the base unless the upper part of the subsoil is appreciably softer than the lower. In this event, the average value for the softer part shall be used. The position of the groundwater table is immaterial.

4. Settlement and Tilting

The soil pressures determined in accordance with Section D3 provide for adequate safety against failure of the soil beneath the structure. If the subsoil consists of soft clay or silt, it is necessary to determine the compressibility of the soil and to estimate the amount of settlement.





Figs. 1 (above) and 2 (below)

If the compressibility of the subsoil would lead to excessive settlement or tilting, the movement can be reduced by designing the wall so that the resultant of the forces acting at the base of the wall intersects the base near its midpoint.

If the pressure on a subsoil containing fairly thick layers of soft clay or peat is increased by the weight of the backfill, the wall may tilt backward because of the compression of the clay or peat. The tilt may be estimated on the basis of a knowledge of the compressibility of the subsoil. If the tilt is likely to be excessive, it is advisable to use backfill of light-weight material, to replace the backfill by a structure, or otherwise to change the type of construction so as to avoid overloading the subsoil.

5. Progressive Creep or Movement

If the weight of the backfill is greater than one-half the ultimate bearing capacity of a clay subsoil, progressive movement of the wall or abutment is likely to occur, irrespective of the use of a key, a tilted base, or batter piles. In such cases, it is advisable to use backfill of light-weight material, to replace the backfill by a structure, or otherwise to change the type of construction so as to avoid overloading the subsoil.

E. DESIGN OF BACKFILL

1. Drainage

The material immediately adjacent to the wall should be non-cohesive and free draining. Cinders shall not be used. If a special back drain is installed, the grain size of the drain shall be coarse enough to permit free flow of water, but not so coarse that the fill material may ultimately move into it and clog it. Where economical, it is preferable that free-draining material be used within a wedge behind the wall bounded by a plane rising at 60 deg. to the horizontal. Horizontal drain pipes of not less than 8-in. dia. should be installed in such position that they can remove water from the free-draining material. Such drains should be accessible for cleaning.

Weep holes are considered less satisfactory than horizontal drains. If they are used, they shall have diameters not less than 6 in. and shall be spaced not farther than 10 ft. At the inside end of each weep hole shall be installed a pocket of gravel having a volume not less than 2 cu. ft. At least one drain shall be provided for each pocket formed by counterforts.

2. Compaction

The backfill shall preferably be placed in layers not to exceed 12 in. in thickness. Each layer shall be compacted before placing the next, but overcompaction shall be avoided.

No dumping of backfill material shall be permitted in such a way that the successive layers slope downward toward the wall. The layers shall be horizontal or shall slope downward away from the wall.

F. DETAILS OF DESIGN AND CONSTRUCTION

1. General

The principles of design and permissible unit stresses for walls and abutments shall conform to the Specifications for Design of Plain and Reinforced Concrete Members, with the modifications or additions in the following paragraphs.

The base of a retaining wall or abutment supported on soil shall be located below frost line and in no case at a depth less than 3 ft. below the surface of the ground in front of the toe. The base shall be located below the anticipated maximum depth of scour; where this is not practicable the base shall be supported by piles or piers.

To prevent temperature and shrinkage cracks in exposed surfaces, no less than 0.25 sq. in. of horizontal metal reinforcement per foot of height shall be provided, irrespective of the type of wall. Consideration shall be given to providing additional reinforcement above horizontal joints.

The backs of retaining walls and abutments shall be damp-proofed by an approved material.

At horizontal joints between the bases and stems of retaining walls, raised keys are considered preferable to depressed keys. The unit shearing stress at the base of such a key shall not exceed $0.25f'_c$.

Vertical grooved lock joints shall be placed not over 60 ft. apart to care for temperature changes. They shall be protected by membrane waterproofing or non-corrosive metal water stops.

The walls above the footings shall be cast as units between expansion joints, unless construction joints are formed in accordance with the provisions of these specifications.

The heels of cantilever, counterfort and buttress retaining walls shall be proportioned for maximum resultant vertical loads, but when the foundation reaction is neglected the permissible unit stresses shall not be more than 50 percent greater than the normal permissible stresses.

2. Cantilever Walls

The unsupported toe and heel of the base slabs shall each be considered as a cantilever beam fixed at the edge of the support.

The vertical section shall be considered as a cantilever beam fixed at the top of the base.

3. Counterfort and Buttress Walls

The face walls of counterfort and buttress walls and parts of base slabs supported by the counterforts or buttresses shall be designed in accordance with the requirements for a continuous slab, Section E, Specifications for Design of Plain and Reinforced Concrete Members. Due allowance shall be made for the effect of the toe moment on shears and bending moments in the heel slabs of counterfort walls.

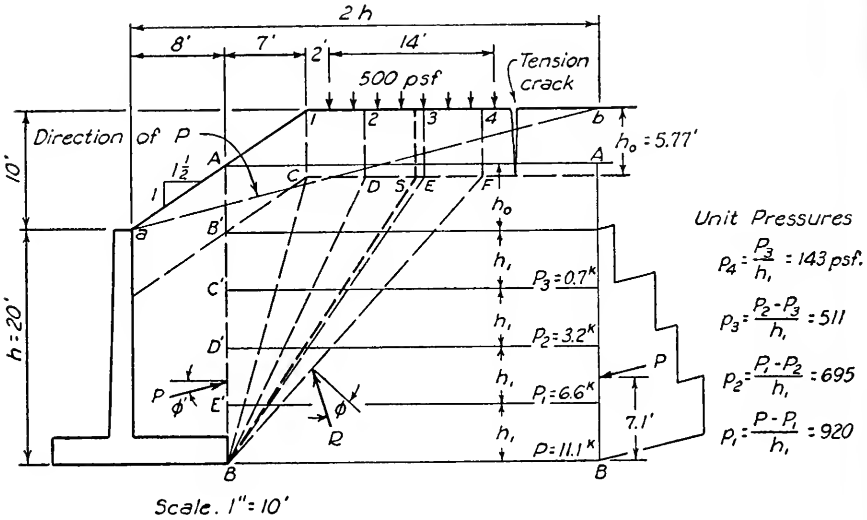
Counterforts shall be designed in accordance with the requirements for T-beams. Stirrups shall be provided to anchor the face slabs and the heel slabs to the counterforts. These shall be proportioned to carry the end shears of the slabs. Stirrups shall be U-shaped with their legs in the counterforts and shall extend as close to the exposed face of face walls and the bottom of base slabs as the requirements for protective covering permit. It is desirable to run reinforcing bars through the loops of the U.

Buttresses shall be designed in accordance with the requirements for rectangular beams.

Appendix A

TRIAL WEDGE METHOD OF EARTH PRESSURE COMPUTATION

The trial wedge method is applicable for backfills of soils possessing cohesion, internal friction, or both; for backfills having any configuration of ground surface; and for surcharges located at any position on the backfill. The procedure, illustrated in Fig. 3, is outlined as follows:



w : Unit weight of soil = 120 pcf.

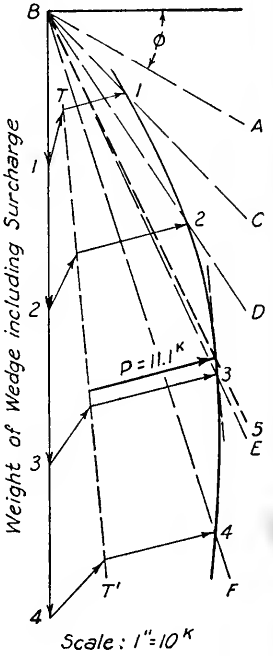
c : Cohesion per unit of area = 200 psf (Should usually be neglected).

ϕ : Angle of internal friction of soil = 30°

$h_o = \frac{2c}{w} \tan(45° + \frac{\phi}{2}) = 5.77'$.

WEDGE VECTORS

Wedge	Area	Σ Area	Σ Wt	Sur-chg.	Total Wt (Kips)
1	$19.56 \times \frac{7}{2} + 5.77 \times 7 = 108.9$	108.9	13.1	0	13.1
2	$24.23 \times \frac{5}{2} + 5.77 \times 5 :$ 89.4	198.3	23.8	1.5	25.3
3	" " : 89.4	287.7	34.5	4.0	38.5
4	" " : 89.4	377.1	45.3	6.0	51.3



COHESION VECTORS

Wedge	Length	Cohesion (Kips)
1	25.2	5.0
2	27.0	5.4
3	29.6	5.9
4	32.7	6.5

TRIAL WEDGE METHOD
EARTH PRESSURE COMPUTATION

A. Computation of Total Pressure

1. Make scale drawing of wall with backfill and any surcharge loads.
2. Locate surface *AB* against which earth pressure is to be computed. For walls with heels use vertical section as shown. For walls without heels use back of wall.
3. Establish direction of earth pressure with respect to line *AB*, by the procedure described under B following.
4. Compute depth h_0 of tension cracks if soil has cohesion.
5. Draw boundaries of trial wedges *BC*1, *BD*2, etc., wherein *BC, BD,* etc. are assumed plane surfaces of sliding.
6. Compute weights of successive wedges *ABC*1, *ABD*2, etc., including any surcharge acting on the ground surface within the limits of each wedge.
7. Lay off weight vectors for successive wedges.
8. Compute total cohesion on each surface of sliding *BC, BD,* etc.
9. Lay off cohesion vectors from lower ends of weight vectors, each parallel to the surface of sliding on which it acts.
10. From end of each cohesion vector draw line parallel to earth pressure *P*.
11. From point *B* in force diagram lay off radial lines *BC, BD,* etc., each making an angle Ø with the normal to its respective surface of sliding (as force *R* on surface *BF*).
12. Locate intersections of vectors *R* with corresponding lines drawn in step 10 and connect intersections with smooth curve. This is the earth pressure locus.
13. Determine maximum distance between line *TT'* and the earth pressure locus, measured parallel to line of action of *P*. This distance represents the active earth pressure *P*.

B. Direction of Pressure *P*

For walls with heels, the following procedure is applicable:

1. Determine height *h* of wall, measured from point *a*.
2. Locate point *b* on the surface of the backfill at a distance 2*h* measured horizontally from *a*.
3. Draw line *ab*.
4. Take direction of resultant earth pressure *P* as parallel to line *ab*.

   For walls without heels, where *AB* is the back of the wall, take angle Ø' equal to 2/3 Ø.

C. Point of Application of Pressure

The point of application of the resultant pressure *P* can be obtained by determining the approximate pressure-distribution diagram, Fig. 3. The procedure is as follows:

1. Subdivide the line *BB'* into about 4 equal parts h_1 below the depth h_0 of tension cracking.
2. Compute the active earth pressures P_1, P_2, P_3, etc. as if each of the points *C'*, *D'*, *E'* etc., were at the base of the wall. The trial wedge method is used for each computation.
3. Determine the average pressures p_1, p_2, etc., over each distance *B'C'*, *C'D'*, etc., as indicated in Fig. 3.
4. Determine the elevation of the centroid of this approximate pressure diagram. This is the approximate elevation of the point of application of the resultant earth pressure *P*.

Report on Assignment 7

Methods for Improving the Quality of Concrete and Mortars, Collaborating with Committee 6—Buildings

M. S. Morris (chairman, subcommittee), M. W. Bruns, W. J. Galloway, J. F. Halpin, J. A. Lahmer, L. M. Morris, G. H. Paris, C. M. Segraves.

Your committee presents, as information, the following report on the methods of manufacture and the control of quality of ready-mixed concrete.

Introduction

In recent years many railroads have found it economical to use ready-mixed concrete on projects where this material is available. It is the purpose of this report to describe some of the features of this product and methods and equipment used in the control of its quality.

The term ready-mixed concrete means any portland cement concrete which is ready to use on arrival at the job. It includes: (1) Concrete produced from a central batching plant, where the materials are proportioned and placed in truck-mixers for mixing enroute to the job or after arrival there, and (2) concrete proportioned and mixed at a central mixing plant and hauled in trucks to the job.

History

Ready-mixed concrete originated many years ago as a means of effecting economies and speeding up production by means of centralizing all operations connected with the mixing of concrete. Prior to 1920, a number of central mixing plants were installed on sizeable jobs in various localities. There were also scattered attempts to sell mixed concrete from central mixing plants. These ventures into ready-mixed concrete were not successful because of the lack of control of proportioning at the central plant, inaccurate water control for the mixture, segregation of aggregates prior to mixing, and in many cases serious segregation of the concrete enroute to the job.

With the advent of improved methods and equipment for the proportioning and control of the ingredients of the concrete, the prevention of segregation of coarse aggregates by division into sizes, and a better understanding of methods for controlling the consistency of concrete mixtures, the ready-mixed concrete industry was revived. Then came the development of special truck bodies which overcame the segregation of concrete during delivery to the job. Some producers are now using the best available equipment and methods, but it should be realized that thorough inspection of equipment, materials, proportioning, and mixing is frequently necessary to obtain satisfactory ready-mixed concrete.

Advantages

The ready-mixed plant, because of its larger volume of production, can afford to adopt more scientific methods and to install better and more accurate equipment for producing concrete than are justified on a job mixing set up for the average project. Closer attention can be given to the following factors: (1) Prevention of segregation of coarse aggregates by separation of sizes, (2) accurate measurement of each ingredient, (3) correction for moisture content of aggregates in water measurements and (4) centralized inspection of concrete materials and concrete manufacturing process.

Quality, economy, and service are the principal considerations which govern the decision as to whether ready-mixed concrete will be used on a given job. Some of the items affecting economy are: (1) Elimination of concrete plant set up on the job, (2) elimination of wastage of material on the job, (3) elimination of mixing crew, and (4) no additional space required for plant set-up and storage of materials.

Items of service to be considered are: (1) Is ready-mixed concrete available for delivery whenever required?, and (2) can the rate of delivery be varied on short notice to meet peak requirements of the job? Usually, with reasonable advance notice, ready-mixed concrete can be furnished faster than the rate of production of a justifiable job plant.

Methods of Manufacture

A ready-mixed concrete plant should be a well-regulated and controlled concrete manufacturing plant capable of producing any desired quality of concrete with the utmost uniformity.

Ready-mixed concrete is generally produced by: (1) Central proportioning method, and (2) central mixing method.

In the central proportioning method the materials are proportioned at a central batching plant and mixed in truck mixers. In some cases the water is placed in the mixer at the batching plant and in other cases it is placed in a separate tank and added as the truck mixer approaches the job or after arrival there. On long hauls it is advantageous to withhold the water for the major portion of the trip.

In the central mixing method the concrete is completely mixed at the plant and hauled to the job in trucks, usually of the agitator type. An advantage of this method is the concentration of the entire control of proportioning of all materials, including water, and the mixing at the central plant. No dependence is placed on the truck operator for water measurement or mixing.

Quality of Concrete

In the absence of an applicable general specification, the quality of the concrete may be specified by one of two alternate methods:

Alternate No. 1.—When the purchaser assumes responsibility for the design of the concrete mixture, he should specify the following:

(1) Minimum cement content in bags per cubic yard of concrete, or equivalent units and type of cement.
(2) Designated size, or sizes, of coarse aggregate.
(3) Maximum allowable water content in gallons per bag of cement, or equivalent units, including surface moisture, but excluding water of absorption of the aggregates.
(4) Slump desired at the point of delivery.
(5) When an air-entrained concrete is used, the maximum and minimum air content of the concrete as determined from samples taken from the transportation unit at the point of discharge.

The manufacturer should furnish a statement to the purchaser giving the proportion by weight (dry) of cement, fine and coarse aggregates, and brand and amount of admixture if any that will be used in the manufacture of each class of concrete ordered by the purchaser. Such proportions should be subject to the approval of the purchaser.

Alternate No. 2.—When the purchaser requires the manufacturer to assume responsibility for the design of the concrete mixture the purchaser should specify the following:

(1) Minimum allowable compressive strength as determined on samples taken from the transportation unit at the point of discharge.

(2) Maximum size of aggregate.
(3) Slump at the point of delivery.
(4) Type of cement.
(5) Maximum water-cement ratio.
(6) When an air-entrained concrete is used, the maximum and minimum air content of the concrete as determined from samples taken from the transportation unit at the point of discharge.

The manufacturer should furnish a statement to the purchaser giving the proportions by weight (dry) of cement, fine and coarse aggregates, brand and amount of any admixture (if permitted by the purchaser), and the amount of mixing water per bag of cement that will be used in the manufacture of each class of concrete ordered. If required, he should also furnish evidence satisfactory to the purchaser that the proportions selected will produce concrete of the quality specified.

Measuring Materials

Once the proper proportions have been determined, it is of utmost importance that the batches be as nearly alike as possible. The only practical way to insure this result is by careful weighing of the ingredients on accurate scales. Measurement of aggregates by volume is unsatisfactory because of the surface moisture which is almost always present and which may increase the volume of sand from 20 to 50 percent. While coarse aggregates do not bulk appreciably, they often contain surface water. The common practice is to weigh them and then to allow for the surface moisture.

Cement, particularly on smaller jobs, is not always weighed. This is because it is bagged by weight. The ASTM Specifications for Ready-Mixed Concrete require that all cement be measured by weight unless the purchaser allows the use of 94-lb. bags. Fractions of a bag should always be weighed.

Water may be measured by volume or by weight.

A tolerance of 1 percent is usually specified in the measuring of all materials. Some specifications allow a tolerance of 2 percent for the larger sizes of coarse aggregates. From the standpoint of strength and yield of concrete, it is as important to weigh the aggregates as accurately as the cement in order to obtain the correct proportion of cement in the total mix. However, it is more important to control the water and cement in order to keep the consistency of the concrete uniform. There is not much advantage in obtaining greater accuracy than the 1-percent tolerance usually specified because other factors can affect the strength of the concrete far more than this weighing tolerance.

Powdered admixtures should be measured by weight, and paste or liquid admixtures by weight or volume, within a limit of accuracy of 3 percent. When admixtures are used in small quantities in proportion to the cement, as in the case of air-entraining admixtures, mechanical dispensing equipment is strongly recommended.

Most plants use a composite batcher for the measurement of all sizes of fine and coarse aggregates in a single hopper and on one set of weighing scales. The cement should be weighed in a separate batcher and on a separate scale. This permits the use of a smaller capacity scale, resulting in more accurate weighing. All weighing hoppers should have steep slopes, should be of welded construction, perfectly smooth inside, and, if rectangular in form, should have rounded corners to insure quick and clean discharge of the materials. Small vibrators attached to the weighing hoppers help to insure rapid and complete discharge. The capacity of all weighing hoppers should be adequate to accommodate the maximum size batch.

The scales may be either the beam type or the springless dial type. Adequate standard test weights should be available for checking accuracy. All exposed fulcrums, clevises and similar working parts should be kept clean. When beam-type scales are used, provision should be made for indicating to the operator that the required load in the weighing hopper is being approached. The device should indicate at least the last 200 lb. of load. The hopper should be so constructed that the operator can conveniently remove any overload in one of several materials.

Weighing batchers are of three general types: (a) Manual, (b) semi-automatic and interlocked, and (c) full automatic with remote control.

The manual type provides for manual filling and discharge. The semi-automatic batchers require manual opening of the filling gates and automatic cut-off when correct weight is reached. Interlocks, either electrical or mechanical, prevent discharge unless the correct weight has been reached, prevent opening the filling gates while discharge gate is open, and prevent closing the discharge gate until the batch is completely discharged. Full automatic batchers include automatic filling, automatic cut-off and automatic power-operated discharge. Automatic batchers are operated by remote control from a panel control board by means of a push button or other controls. The panel board is located so that the operator standing in front of it has all the weighing scales in view. Automatic batchers are operated either electrically with motors or by air. Sometimes a combination of motor-operated filling gates and air-operated discharge gates is employed. Special equipment, such as rotary valves, screw conveyors or vane feeders for feeding the cement into and discharging it from the weighing hopper, is sometimes used with cement batchers.

In recent years many improvements have been made on scales. Hopper types are made in capacities from 100 lb. to 40,000 lb. designed to suspend almost any size or shape of hopper.

Dial heads may be mounted at a distance from the scale, even one or more floors above. Photo-electric cells (the electric eye) are used to effect an automatic cut-off at any predetermined points on the dial. Recording devices, such as strip recorders, chart recorders, and weight printers, preserve a record of each batch and each material. Tolerances as fine as to be 1/10 of 1 percent are claimed to be attained.

The water measuring device should not require watching on the part of the operator to obtain accurate measurement. The inlet and outlet valves should be large enough for rapid operation. They should be frequently inspected and maintained to prevent any leakage. Water measuring tanks of either the weighing or the volumetric type are automatic in operation. Both types have provision for correcting the batch for moisture content of the aggregates. In central mixing plants, the water should be introduced into the mixer slightly in advance of the aggregates and cement; some plants employ automatic means of accomplishing this. When truck mixers are used the water measuring tank is frequently mounted on the truck mixer. In that case the truck tanks are filled at the central proportioning plant and the measured amount of water is admitted to the truck mixer drum during transit. The truck mixer water measuring tanks are usually of the semi-automatic type. The most dependable method is to use an accurate water measuring device on the platform of the central-proportioning plant and put the correct amount of water into the truck mixer water tank or directly into the drum.

Automatic water meters are used also in lieu of water measuring tanks. The meter dial can be set for the quantity of water to be used in the batch, which quantity is measured automatically, without further attention from the operator.

Many ready-mixed concrete producers have found it advantageous to introduce wash water into the drum of the truck mixer on the return trip as an aid in reducing the accumulation of concrete on the blades and interior of the drum. This practice is especially prevalent with long hauls and in hot weather. If the wash water is dumped on the return to the plant, the quantity used need not be measured. But if the wash water is left in the drum as a portion of the mixing water for the next batch, then a known quantity should be used and that amount deducted from the quantity computed for the next batch. Some mixer trucks are equipped with a separate tank for the wash water in order that a known quantity can be loaded at the plant for this purpose, to be introduced to the drum on the return trip.

Allowance For Surface Moisture

Control of the water-cement ratio is fundamental in producing concrete of uniform strength. Since an aggregate seldom remains in the same condition of moisture for any great time, attention to its water content is an important problem in the control of concrete production.

Both fine and coarse aggregates may contain surface moisture, the amount of which must be determined and compensated for through the use of less mixing water. The aggregates may also be so dry that they will absorb water when they are placed in the mixture. The water ratio is computed on the basis of saturated surface dry aggregates. Therefore, a correction must be made when the aggregates contain more or less moisture than they contain in the saturated surface dry condition.

ASTM specifications describe standard tests for the absorption capacity of aggregates and standard tests for surface moisture. There are several other satisfactory methods for determining the amount of surface moisture generally known and acceptable to engineers and it is not deemed necessary to go into detail discussion of them here.

Special equipment is also available to provide quick and accurate means of compensating for moisture present in the materials. One of these is a moisture meter scale, with which a determination can be made in two minutes. The platform-type laboratory scale used is a double purpose scale graduated for both specific gravity and moisture determination. Two pounds of saturated, surface dry material are placed in a metal cup, which is inundated, covered and rolled to eliminate air. The cup is then filled with water, covered and hung on the auxiliary knife edge of the scale. The specific gravity of the sample is read directly on a special segment of the dial. This reading is set on the specific gravity target of the weight of sample scale, and the material being tested is run into the cup until the scale pointer coincides with the target. The sample cup is inundated, rolled to eliminate air, and filled with water and again hung on the knife edge. The percentage of moisture is read directly on the proper segment of the scale.

The correction for moisture contained in the aggregates is made by adding disks corresponding to the determined content, to the poise hangers on the compensator batching scale. This is a beam and dial scale with a separate beam for each material, and it is so constructed that when a poise is moved away from its zero position the indicator follows, showing accurately the setting of the poise. As material flows into the weigh hopper, the indicator moves back to zero. A sealed, automatic graphic recorder records the weight of each material and the moisture compensation made in each.

Another method for determining the moisture content of sand is to read on an instrument the electrical conductivity of the sand and convert this reading into moisture content with the use of a chart or table.

Mixing and Delivery

Concrete must be mixed until all of the particles are thoroughly coated with cement paste. This is efficiently accomplished with modern power mixers.

The mixing time for mixers having a capacity of 1 cu. yd. or less should be not less than 1½. For mixers of larger capacity, this minimum should be increased 15 sec. for each ½ cu. yd. or fraction thereof of additional capacity. Mixing time should be measured from the time all materials are in the drum.

Stationary mixers should be equipped with an acceptable timing device that will not permit the batch to be discharged until the specified mixing time has elapsed. Truck mixers should be equipped with means by which the number of revolutions of the drums or blades may be verified. AREA specifications require not less than 50 nor more than 150 revolutions of the drum or blades at mixing speed for truck mixers; however ASTM specifications limit the maximum number of revolutions to 100. Additional mixing, if any, should be at agitator speed.

Sometimes the concrete is partially mixed in a stationary mixer and the mixing completed in a truck mixer. This is known as "shrink mixing" and permits the use of a somewhat greater capacity of the truck mixer. When this method is used the mixing time in the stationary mixer may be reduced to the minimum required to intermingle the ingredients (about ½ min.).

Ready-mixed concrete may be delivered in truck agitators, truck mixers, or non-agitating truck bodies.

The use of non-agitating equipment may result in segregation and difficulty in dischange. Well proportioned plastic mixtures, short hauls, and smooth roads are favorable for the use of non-agitating transportation equipment. Air-entrained concrete is more adaptable to its use than regular concrete. ASTM specifications permit the delivery of central mixed concrete in non-agitating equipment only when provision for such method is made in the contract and subject to the following limitations.

(a) Bodies shall be smooth, watertight, metal containers equipped with gates that will permit control of the discharge of the concrete. Watertight covers shall be provided for protection against the weather when required.

(b) The concrete shall be delivered to the job in a thoroughly mixed and uniform mass and discharged with a satisfactory degree of uniformity. Discharge shall be completed within 45 min. after the introduction of the mixing water to the cement and aggregates.

(c) Slump tests of individual samples taken at approximately the ¼ and ¾ points of the load during discharge shall not differ by more than 2 in.

The truck mixer is a complete portable concrete mixer arranged for attachment to the truck chassis. The unit usually includes a water measuring tank, water distributing system, charging opening and door, discharge opening and door, revolving mixer drum, power and drive mechanism, revolution counter and frame sub-chassis. There are two general classes of drum-type truck mixers on the market, (1) the horizontal drum and (2) the conical or inclined axis class. The conical drum class has the axis set at an angle with the horizontal to provide a high discharge and is commonly referred to as the "high discharge" mixer. The drum is equipped with spiral blades and greater mixing efficiency is claimed because of the low ratio of length to diameter of the drum in combination with the type of mixing blades used.

The drums of both types normally have a diameter greater than the length. The blades of both types are so arranged that the concrete is conveyed to the front or rear, depending on the direction of rotation. The mixing direction of rotation of the drum causes the materials to be thrown to the front end of the drum; the discharge direction of rotation carries the materials to the rear or discharge end. The drum is revolved at speeds ranging from 4 to as many as 16 rpm. for mixing and discharge. A small centrifugal pump is sometimes introduced into the water distributing system. In the interior of the truck mixer drum the water pipe is located on the longitudinal axis of the drum. The water enters the drum through water bells or spray heads mounted on the water pipe. Special attention must be given to the maintenance of the water equipment and particularly to the valves to assure accurate results.

An open-type truck mixer consisting of a worm or set of paddles revolving in a U-shaped body is also available in smaller sizes (1¼ to 1¾ cu. yd. capacity). This type is not as commonly used and is less desirable than the revolving drum type. One objection to this type is that the concrete is exposed to the sun and rain.

Truck agitators have the same type of drum as the truck mixers. As an agitator is intended to transport pre-mixed concrete, such unit does not require a water tank or a pipe system for introducing water into the drum. However, some operators of agitators do install small flush tanks for carrying wash water. A truck mixer can also be operated as an agitator of central-mixed concrete. The current Standards for Operation of Truck Mixers and Agitators as adopted by the National Ready Mixed Concrete Association recommends that the rated capacity of a unit should not exceed the following percentage of the gross volume of the drum for the respective methods of operation.

(a) Not over 57.5 percent when used for truck mixing.
(b) Not over 70 percent when used for shrink mixing.
(c) Not over 80 percent when used for agitating premixed concrete.

These ratings correspond closely to the standards of the Truck Mixers Manufacturing Bureau. The capacity of a truck mixer or agitator is plainly marked on all modern equipment and the rated capacity of the manufacturer should not be exceeded.

Care must be taken in operating agitator bodies to prevent over agitating the concrete on long hauls or when the discharge of the concrete is unduly delayed. It is only necessary to agitate the concrete sufficiently to keep it in workable condition and prevent segregation. With some cements, and particularly in summer temperatures, over agitation will cause a stiffening of the mix which makes it hard to handle and place on the job. Newer designs of agitators revolve as slowly as 2 rpm. to prevent over agitation. AREA specifications require that the discharge of the concrete from truck mixers or agitators be completed within one hour after the mixing water is added to the cement and aggregates; however ASTM specifications allow 1½ hours for the discharge to be completed. In hot weather, or under conditions contributing to quick stiffening of the concrete, a lesser time should be specified. When a truck mixer is used for the complete mixing of the concrete, the mixing operation should begin within 30 min. after the cement has been intermingled with the aggregates.

Discharging Truck Mixers and Agitators

All of the advantages gained from meticulous control of operations prior to discharge may be lost by careless or improper discharge methods. Unrestricted discharge at full drum speed, with a full discharge opening, is desirable whenever the concrete can be disposed of at the maximum discharge rate. When it is necessary to restrict the rate of discharge, as in loading wheelbarrows or buckets, the best method is to start and stop the discharge by reversing the drum rotation. Although the discharge rate may be controlled by varying the discharge opening, this is one of the principal causes of segregation and is not recommended.

Flat chutes should be avoided unless the concrete is helped along by means of shovels or hoes. Concrete made wet enough to flow of its own accord down a flat chute is not only wasteful of strength and durability, but it tends to segregate. The use of long chutes is to be avoided wherever possible. In discharging concrete through a chute or a spout, the discharge end should be near the surface of the concrete and should be swung back and forth to avoid coning and consequent segregation.

Concrete should be deposited in the forms as nearly as practicable in its final position to avoid rehandling. It should be so deposited as to maintain a plastic surface approximately horizontal. Forms for walls or thin sections of considerable height should be provided with openings or other devices that will permit the concrete to be placed in a manner that will prevent segregation and an accumulation of hardened concrete on the forms or metal reinforcement above the level of the concrete. Under no circumstances should concrete that has partially hardened be deposited in the work.

Cold Weather Concrete

Most commercial ready-mixed concrete plants are equipped to furnish warm concrete in cold weather. Heating is applied by two methods: (1) Using warm mixing water, and (2) heating the aggregates. Steady temperatures may be maintained by means of thermostats. With truck mixers, the warm water is placed in the truck tanks, which are sometimes lagged. If the warm water is charged directly into the drum with the concrete materials, care should be exercised that the water first comes in contact with the aggregates rather than the cement, because water at high temperature may tend to cause "flash" setting of the cement. The temperatures of the various ingredients of the concrete should be regulated so that the temperature of the combined ingredients—cement, aggregates and water—does not exceed about 90 deg. F. or fall below 50 deg. F. The objective should be the delivery at the job of concrete at 70 deg. F. or warmer.

Inspection and Tests

Proper facilities should be provided for the purchaser to inspect ingredients and processes used in the manufacture and delivery of the concrete. The manufacturer should afford the inspector all reasonable facilities for securing samples to determine whether the concrete is being furnished in accordance with the specifications.

ASTM specifications require that samples of concrete for testing be taken in at least three increments uniformly distributed throughout the discharge of the batch. It is suggested that they be secured by passing a bucket or large scoop repeatedly under the discharge stream, and then mixing them with a shovel until the composite sample is homogeneous. If air-entrained concrete is used, care must be taken not to over-mix the sample. For slump tests two samples should be taken, one at the quarter-point and one at the three-quarter point of the load during discharge.

Four test cylinders will generally be made for each class of concrete used in any one day's operation. In special cases this normal number of control specimens may be exceeded when in the opinion of the engineer such additional tests are necessary.

Methods of testing ready-mixed concrete should be in accordance with the following current methods of the American Society for Testing Materials:

(a) Standard Method of Making and Curing Concrete Compression and Flexure Test Specimens in the Field (ASTM Designation C 31).

(b) Standard Method of Test for Compressive Strength of Molded Concrete Cylinders (ASTM Designation C 39).

(c) Standard Method of Test for Weight per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete (ASTM Designation C 138).

(d) Tentative Method of Test for Air Content (Volumetric) of Freshly Mixed Concrete (ASTM Designation C 173)

(e) Tentative Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method (ASTM Designation C 231).

(f) Standard Method of Slump Test for Consistency of Portland Cement Concrete (ASTM Designation C 143).

(g) Standard Method of Sampling Fresh Concrete (ASTM Designation C 172).

General specifications referred to in this report are Standard Specifications for Ready-Mixed Concrete (ASTM Designation C 94).

Report of Committee 28—Clearances

A. R. Harris, *Chairman,*
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J. E. South
O. W. Stephens
J. W. Wallenius
E. R. Word

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, comprising recommended revision .... page 404

2. Clearances as affected by girders projecting above top of track rails, structures, third rail, signal and train control equipment, collaborating with Signal and Electrical Sections, Engineering Division, and with Mechanical and Operating—Transportation Divisions, AAR.

   No report.

3. Clearance diagrams for recommended practice, collaborating with committees concerned.

   No report.

4. Compilation of the railroad clearance requirements of the various states.

   No report.

5. Clearance allowances to provide for vertical and horizontal movements of equipment due to lateral play, wear and spring deflection, collaborating with the Mechanical Division, AAR.

   Progress report, presented as information .... page 404

6. Methods for measuring railway clearances.

   Progress report, presented as information .... page 405

The Committee on Clearances,
A. R. Harris, *Chairman.*

AREA Bulletin 492, January 1951.

Report on Assignment 1

Revision of Manual

J. E. Fanning (chairman, subcommittee), R. A. Emerson, A. R. Harris, W. F. Pfohl, W. E. Quinn, A. M. Weston, E. R. Word.

Your committee recommends the following revision:

Page 28–9, Fig. 9

Add the following note:

> The 4 in. above top of rail is the absolute minimum under any and all conditions of lading, operation and maintenance (wear of axles, wheels and settlement of parts). Allowance must be made for the service conditions in the design of new cars.

Report on Assignment 5

Clearance Allowances to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear, and Spring Deflection, Collaborating with the Mechanical Division, AAR

S. M. Dahl (chairman, subcommittee), C. O. Bird, B. Bristow, F. B. Darling, F. S. Drouet, J. L. Fergus, A. R. Harris, W. F. Hart, C. D. Horton, J. D. Hudson, M. L. Johnson, C. W. Martin, A. G. Neighbour, C. E. Peterson, W. F. Pfohl, A. D. Quackenbush, A. J. Rankin, J. W. Wallenius, A. M. Weston.

This report is presented as information only.

The clearances of equipment on tangent tracks present no difficult problem and have been solved with a reasonable degree of accuracy. However, there appears to be little information available on clearances due to lean and throw of equipment on superelevated tracks. Information on this subject is of greater importance in these days of high speed and new innovations in equipment design, particularly the introduction of the soft steel springs in passenger cars.

Allowances for superelevation and overhang on curves are easily calculated and are taken into account by all clearance engineers. Allowances for wear, play and tilting due to spring deflection have been more or less arbitrary and are not uniform on the various railroads. Your committee feels that a definite method of determining these allowances should be developed.

The accompanying diagram illustrates the various factors entering into lateral and vertical displacements on curves. The information shown was determined from actual tests by a large railroad on a passenger car of recent design.

The horizontal displacement or "throw" from an at-rest position is, of course, a variable involving speed and degree of curve. It is therefore necessary to develop a method of determining this throw for any speed and curvature desired. For this purpose, the following formula has been suggested:

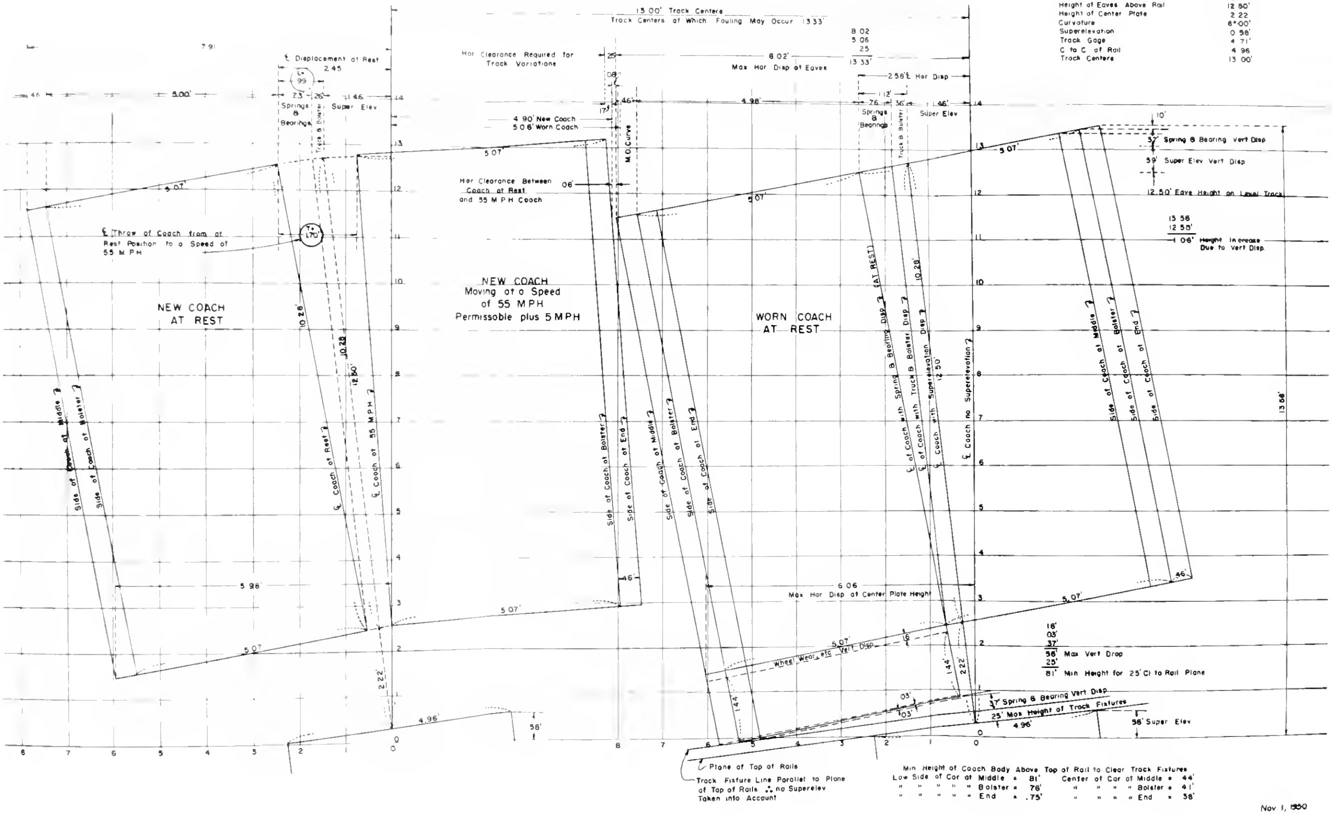
$$T = CV^2D$$


8

HORIZONTAL & VERTICAL DISPLACEMENT
OF A
PASSENGER COACH

REFERENCE DATA

Coach Length	85.00'
Distance Between Trucks	60.00'
Coach Width	10 14
Height of Eaves Above Rail	12 80'
Height of Center Plate	2 22
Curvature	6°-00'
Superelevation	0 58'
Track Gage	4 71'
C to C of Rail	4 96
Track Centers	13 00'



Min Height of Coach Body Above Top of Rail to Clear Track Fixtures

Low Side of Car at Middle	= .81'	Center of Car at Middle	= .44'
" " " " " Bolster	= .76'	" " " " Bolster	= .41'
" " " " " End	= .75'	" " " " End	= .38'

Nov 1, 1950

in which

T = Throw in feet, measured from perpendicular to plane of rails.
V = Any speed in miles per hour.
D = Degree of curve.
C = A constant.

The constant "C" is determined from the formula:

$$C = \frac{L}{V_e^2 D}$$

in which

L = Lean of equipment at rest, in feet, measured from perpendicular to plane of rails
V_e = Equilibrium speed
D = Degree of curve

In practice, the use of this formula will require measurement of the lean at rest of equipment on a superelevated track. For all practicable purposes, one rail elevated six inches will give reasonable accuracy in determining the lean "L" in the equation.

Your committee does not feel that a definite recommendation can be made at this time, but the assignment will be progressed further, until a conclusion can be reached.

Report on Assignment 6

Methods for Measuring Railway Clearances

A. M. Weston (chairman, subcommittee), B. Bristow, W. S. Campbell, J. E. Good, A. R. Harris, C. D. Horton, R. E. Jones, M. V. Kane, C. W. Martin, F. Martin, T. W. Meushaw, W. S. Ray, O. W. Stephens.

Your committee submits the following report of progress as information:

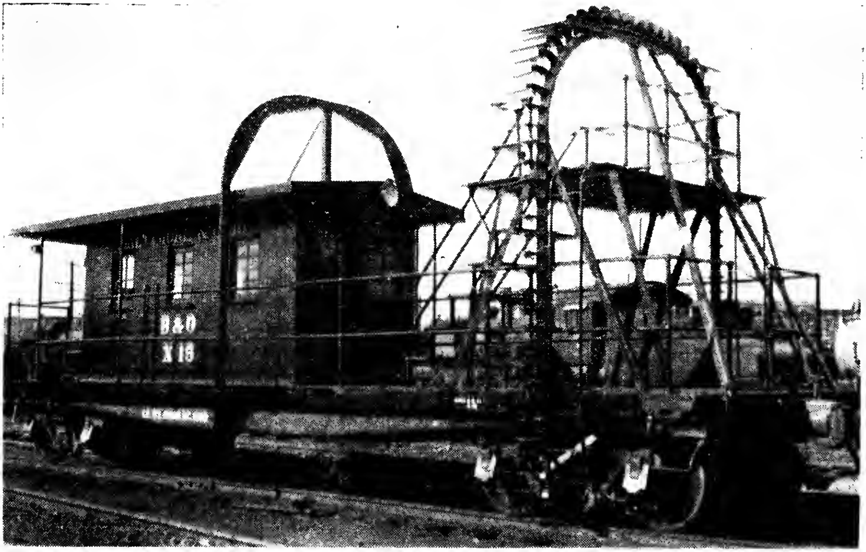
Under this assignment, efforts were directed toward assembling information pertaining to present practices of the railroads in measuring clearances.

A tabulation of the data presented indicated the following methods are being used:

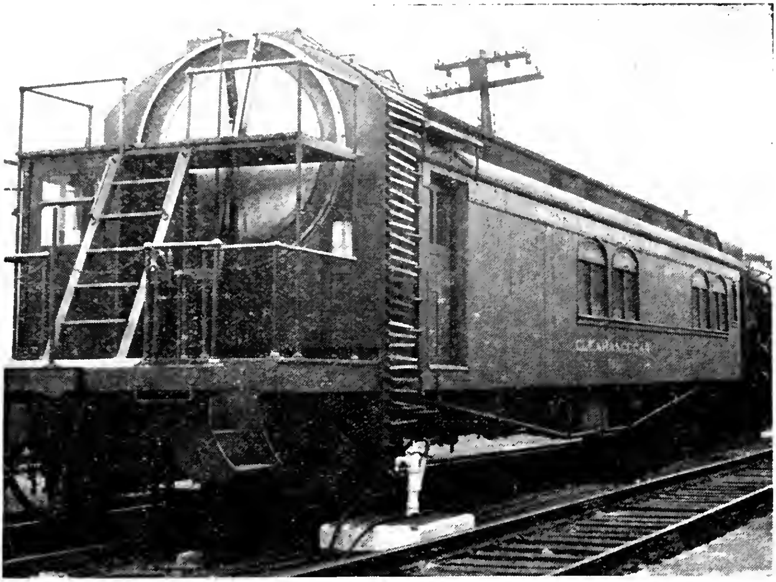
1. Wooden framework mounted on push car.
2. Graduated right angle frame which rests on rails.
   Measurements obtained by these two methods are normal to the plane across top of rails and require no corrections for superelevation or curvature.
3. Vertical and horizontal measurements from rail taken by means of tape and plumb line.
4. Vertical and horizontal measurements from rail taken by means of transit.
   These two methods require correction for superelevation.
5. Clearance Cars
   Illustrations show clearance cars:
   (a) belonging to New York Central System
   (b) belonging to the Baltimore and Ohio Railroad

These cars are similar in that each has a number of feeler arms mounted on a fixed frame. The arms rotate about fixed points and project a certain distance from center line of track and a certain distance above a plane across the tops of rails. The clearance car is pushed by a locomotive, and when the arms meet with an obstruction they retain the deflected position until readings have been recorded.

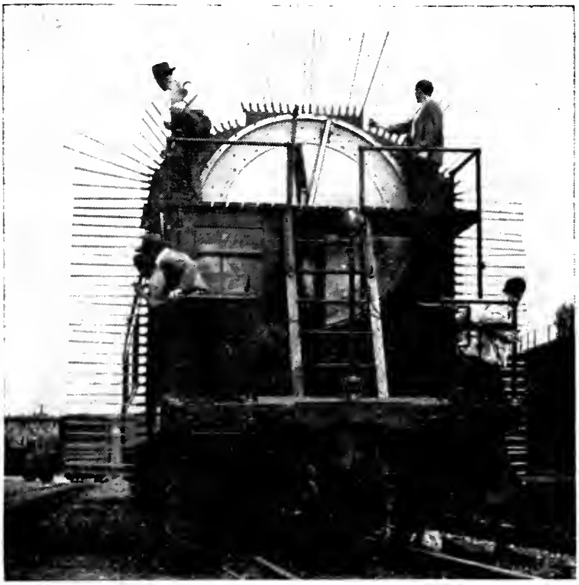
View of Baltimore & Ohio clearance car.



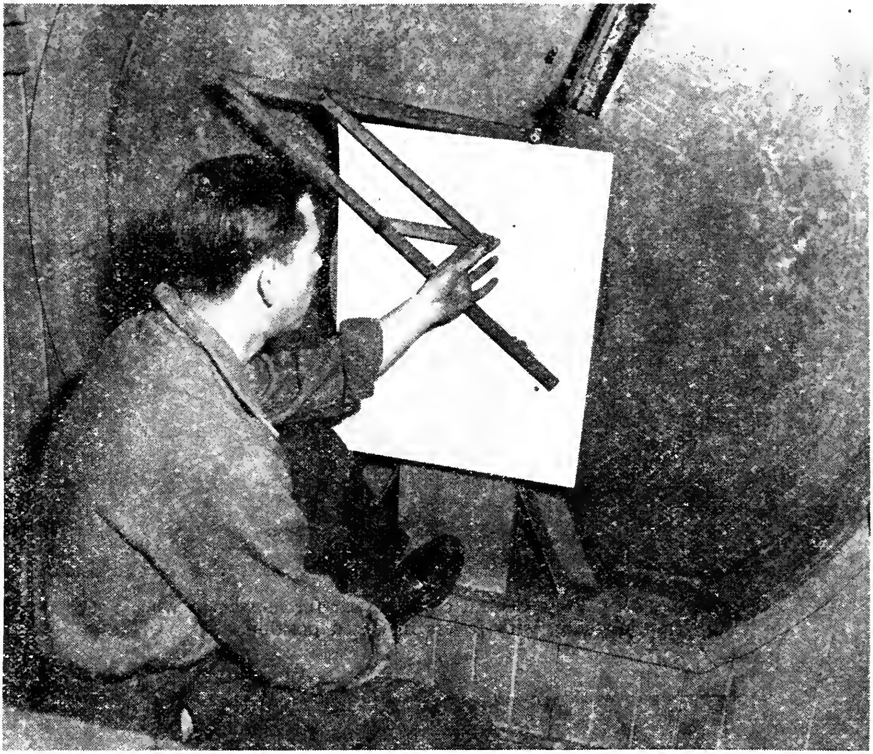
Another view of Baltimore & Ohio clearance car.



View showing New York Central clearance car for movement when not working, with feelers in closed position.



View showing outside pantograph with feelers in position to register outline of a fixed structure—New York Central clearance car.



This view shows the pantograph inside the car where the outline of the fixed structure is registered on a sheet of detail paper.

The New York Central car is equipped with a pantograph connected to a chart board which records proportioned dimensions at a scale 1 in. equals 1 ft.

The Baltimore and Ohio car is equipped with a graduated dial for each arm and when the arms meet with an obstruction they retain the deflected position until the dials have been read and recorded. Dials are graduated to read to the nearest ¼ in.

The frames to which the feeler arms are attached, on both the New York Central and the Baltimore and Ohio cars, are mounted over the center of the truck and require no correction for superelevation or curvature.

Curvature at a point opposite a permanent structure is measured by the string line method and is used to determine the amount of middle ordinate or end overhang to be considered when passing on oversize equipment or shipments.

A number of other railroads use clearance cars similar to the Baltimore and Ohio car and report satisfactory results.

At this time the committee offers no recommendation for a uniform method of measuring railway clearances.

Report of Committee 11—Records and Accounts

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P. J. Schmitz
J. H. Schoonover
R. W. Scott
H. A. Shinkle
J. N. Smeaton
J. R. Traylor
H. C. Wertenberger
J. L. Willcox

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, submitted as information .... page 410

2. Bibliography of subjects pertaining to records and accounts.
   Progress report, submitted as information .... page 410

3. Office and drafting practices.
   Progress report, submitted as information .... page 415

4. Use of statistics in railway engineering.
   Progress report, submitted as information .... page 417

5. Construction reports and property records: their relation to current problems.
   Progress report, submitted as information .... page 418

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), submitted as information .... page 422

7. Revisions and interpretations of ICC accounting classifications.
   Progress report, submitted as information .... page 423

The Committee on Records and Accounts,
Louis Wolf, *Chairman.*

AREA Bulletin 492, January 1951.

Report on Assignment 1

Revision of Manual

J. B. Mitchell, (chairman, subcommittee), F. B. Baldwin, W. C. Bolin, M. A. Bryant, P. D. Coons, Benjamin Elkind, J. P. Ferris, D. E. Field, C. C. Haire, E. M. Killough, W. M. Ludolph, M. F. Mannion, R. M. Nall, S. M. Rodgers, R. L. Samuell, J. H. Schoonover, J. N. Smeaton.

This is a progress report, submitted as information.

Your committee makes no recommendations for revisions in the Manual this year. It is engaged in a general review of the entire subject matter of the committee's chapter of the Manual and has under way a proposed rearrangement of text and forms. It is also working out recommendations for revisions necessary to bring the material up-to-date, supplying an index and making the chapter more readable and usable as a reference.

Report on Assignment 2

Bibliography on Subjects Pertaining to Records and Accounts

A. H. Meyers (chairman, subcommittee), V. H. Doyle, M. M. Gerber, G. B. McMillen, O. M. Miles, B. H. Moore, F. H. Neely, H. L. Restall, E. J. Rockefeller, J. E. Scharper, H. C. Wertenberger, 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 1949 to September 1950.

1. Address delivered at the annual meeting of the Section of Public Utility Law of the American Bar Association at St. Louis, Mo., on September 5–6, 1949, on "Inflation and Depreciation in Public Utility Rate Making" by Charles C. Wine, Chairman, Arkansas Public Service Commission. This is included in issue of November 10, 1949, of Public Utilities Fortnightly, page 686.

2. Article entitled "Weakness and Errors Found in Testimony as to Observed Depreciation", page 523 of October 13, 1949, issue of Public Utilities Fortnightly. This relates to a rate order of the Pennsylvania Utilities Commission which was upheld by the Superior Court of that State.

3. Decision of the New York Public Service Commission re Deer River Power Co. page 20 of October 13, 1949, issue of Public Utilities Fortnightly. The point involved here is accounting for the excess where the purchase price is greater than the original cost of the property, prescribing that the difference be charged to surplus. The Deer River Power decision seems to be in accordance with the U. S. Supreme Court decision No. 55, October Term 1945 in the case of the Federal Communications Commission vs. New York Telephone Co.

4. Depreciation: An Accountant Explains (with reference to British practice) Labor Research, Vol. 39, February 1950, pp. 37–39.

5. Depreciation and Profit Determination. By Sidney Davidson. Accounting Review, Vol. 25, January 1950, pp. 45–47.

6. The Effect of Present Depreciation Allowances Under Income Tax on Economic Development. By A. J. Vandermeulen. In Pacific Coast Economic Association Proceedings, 1948, 1949, pp. 65–67.

7. Keeping Productive Capital Intact (The dangers of under-depreciation and lagging replacement of equipment). Management Review, Vol. 38, September 1949, pp. 499–502. Reprinted from Modern Industry, April 15, 1949.

8. Effects of Depreciation Policy. By J. F. Gaston. National Industrial Conference Board (Studies in Business Economics No. 22) 63 pp. January 1950.

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11. Adjustment of Tax Basis for Depreciation and Depletion: How Present Law Penalizes Taxpayer. By Rollin Browne. Journal of Accountancy, Vol. 89, March 1950, pp. 192–202.

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13. Railroad Construction Indices. Compiled by Engineering Section of the Bureau of Valuation, ICC, August 1, 1950.

14. Analysis of the Effects of Current Policy. Conference Board Study. Management Review, Vol. 39, April 1950, pp. 231–232.

15. Capital Recovery: Examination of depreciation losses on original capital investment incurred in long inflationary periods and some suggested remedies By P. W. Kelly. Dun's Review, Vol. 58, May 1950, pp. 25–26.

16. Construction Equipment Depreciation Schedule. Engineering News, Vol. 144. March 23, 1950, p. 191.

17. Depreciation Problem: Advantages of accelerated depreciation and replacement cost policies. By J. F. Gaston. Commercial and Financial Chronicle, Vol. 171, March 30, 1950, p. 1329.

18. Depreciation Rules Curb Industrial Progress. By G. F. Sullivan. Iron Age, Vol. 165, April 27, 1950, pp. 79–83.

19. Diminishing Depreciation Method Based on a Sine Curve. Works with any scrap value. By H. Benjamin. Journal of Accountancy, Vol. 89, April 1950, pp. 303–309.

20. Needed: Depreciation Reform. By J. S. Morgan. Steel, Vol. 126, May 8, 1950, pp. 53–56.

21. The Demand for Producers Durable Equipment. By S. M. Livingston. Survey Current Business, June 1949, pp. 8–18.

22. Depreciation and High Costs: The emerging pattern; an accelerated depreciation to recover costs of high-priced facilities which have limited economic usefulness. By S. Y. McMullen. Journal of Accountancy, Vol. 88, October 1949, pp. 302–313.

23. Effects of Monetary Depreciation ("LIFO" does not hide profits; it avoids hidden losses). By R. C. Tyson. Robert Morris Associates Bull., Vol. 32, October 1949. pp. 149–152.

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26. The Old and New Depreciation Problems. By J. H. Landman. Taxes, Vol. 27, October 1949, pp. 911–921.

27. The Next Step in Depreciation Accounting: Depreciation as a "Rational and Systematic Allocation". By J. L. Dohr. Journal of Accountancy, Vol. 89, February 1950, pp. 114–119.

28. New Simplified Approach to Mathematically Calculated Reserves for Depreciation for Accounting Purposes. By W. B. Carr. Land Economics, Vol. 25, August 1949, pp. 304–312.

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31. Need to Recognize Changing Price Levels in Determining Depreciation. By H. T. McAnly. Credit & Financial Management, Vol. 51, November 1949, pp. 8–11.

32. Problem of Replacement Cost and Tax Depreciation. By H. R. O'Conor. Public Utilities Fortnightly, Vol. 45, March 16, 1950, pp. 341–343.

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43. To Get New Capital, Railroads Need New Federal Policy. By Elisha M. Friedman. Consulting Economist. Railway Age, Vol. 127, December 31, 1949, p. 1170.

44. Railway Engineers—Where From in the Future. By Lawrence W. Wallace. Comments at seventieth annual meeting of the American Society of Mechanical Engineers, December 1949. Railway Age, Vol. 128, March 11, 1950, p. 469.

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Report on Assignment 3

Office and Drafting Practices

W. M. Ludolph (chairman, subcommittee), B. A. Bertenshaw, V. H. Doyle, Benjamin Elkind, J. P. Ferris, D. E. Field, A. T. Hopkins, W. A. Krauska, A. H. Meyers, A. T. Powell, H. B. Sampson, R. L. Samuell, J. H. Schoonover, H. A. Shinkle, J. R. Traylor.

This is a progress report, submitted as information

Since the last report, the following office and drafting aids have come to the attention of your committee:

Calculator For String Lining Railroad Curves

Probably the most interesting item is a mechanical calculator for determining the throw of the track when string lining railroad curves. The calculator consists of a system of pointers, gears and dials interconnected in such a manner that the corresponding changes in ordinates are automatically made in adjoining ordinates when an ordinate is changed. The machine has a capacity of 32 stations with one setting and will make a graphic record of the curve as it was and as it will be.

Basically, this machine consists of a flat panel on which are located pointers which are set by means of a hand crank on the calculator to indicate the ordinates of the curve as they are before any work is done. When the ordinates are all set on the machine, the calculations are made with a sliding gear box on the left side of the machine which moves the pointers so that they show uniform ordinates or ordinates to meet required conditions, such as meeting the location of station platforms or other fixed objects. The throws are automatically registered on dials.

This calculator is rather expensive and unless a project involves a large number of curves, its use will probably not be economical. Also, this machine is not suitable for use in the field as its full capacity could not be realized and it would be better to have the field notes sent to a central office for calculation.

Photo Copy Machine

Another machine, which is of considerable interest, will photograph long drawings on micro-film and will also produce photo-copies of the drawings photographed at one-half or one-quarter their original size.

This machine is very costly to operate as it is necessary to electronically control the speeds of both the drawing photographed and the film, in order to maintain register; also, when prints are being made it is necessary to control the speed of the paper on which the print is being made. In addition, an auxiliary developing and fixing machine and other apparatus are required.

At the present time, there are only a few of these machines in the United States; however, if one of these machines is available locally, the blue printer can produce small-scale prints of yard layouts, track elevation plans, exhibits, etc., without the necessity of pasting photo-prints together.

Reflex Printing

Reflex printing is receiving considerable attention at the present time for the reason that opaque material can be copied by this method; also, old worn tracings can be reproduced without showing dirt and smudge marks.

This process is used very extensively for copying documents which are printed on both sides; by folding the reproduction paper so both sides of the document are in contact with it, the two sides can be copied in one operation and a copy of both sides is available on one sheet. Pages from books and other similar matter can be readily copied.

The process consists essentially of placing the sensitized side of the reproduction medium next to the material to be copied and exposing it to light from the back of the reproduction medium, developing and fixing in the usual manner. This produces a reversed image or negative which must be printed again to be readable.

New materials have been developed for use with this process of film and paper, as well as with the direct process, that is, black line on a white background. Specially treated tracing cloth is also available for reproducing tracings by this process; however, this process cannot be used where a change of scale is required.

Direct Process Print Papers and Films

Although the ammonia direct process papers have been in use for at least 30 years, and the direct type, which has been used for at least 20 years, and which is developed by the application of a small amount of liquid developer, further advancement has been made in the color and permanency of the image produced, as well as in the application of the developers. Paper of the latter type is produced in five different colors—white, pink, blue, yellow and red—for the purpose of making the various copies distinguishable.

Direct process papers have also been developed for use with photo copy machines, eliminating the necessity of making intermediate negatives.

Machines For Exposing Sensitized Material

Machines for exposing sensitized material now vary from the production-type blue print machine, which is completely equipped to expose, develop, wash and dry blue prints as well as reproduce direct process line and negative silver prints, to the small desk type, which is specially suited for reflex copying. The light source varies from arc lights to small incandescent light bulbs, including photo flood bulbs, mercury tubes, etc.

The newest source of illumination is the cold cathode tube, which starts instantly and produces almost cold light, so that a machine equipped with these tubes can be used indefinitely without fear of overheating and the consequent ruining of the copy or prints.

Duplicating Machine

A duplicating machine based on the original lithographing process has been developed. The master copies can be made on a specially treated material similar to paper or aluminum or zinc sheets furnished by the manufacturer, all of which are flexible enough to be used in a typewriter.

The type of master copy to be used is determined by the number of copies required. That is, if 100 copies or less are required, the master copy similar to paper is used, whereas, if several thousand copies are required, the zinc master copy is used; the aluminum master copy is used for an intermediate number.

The master copy is prepared by typing, ruling or drawing with special ink, or drawing with a crayon supplied for that purpose.

After the master copy has been prepared, it is treated with a solution which repels the ink where no image has been imprinted on the master copy and this process is continued in the machine. The master copy is then put in the machine and after the ink fountain is filled and the rollers inked, the machine is ready for operation.

The latest development in connection with this machine is a light sensitized master copy which can be exposed to light through a photographic film or other negative, and by treatment with special solutions will produce half tones, line drawings, wash drawings or any image of which a proper negative can be made.

Report on Assignment 4

Use of Statistics in Railway Engineering

J. L. Willcox (chairman, subcommittee), S. H. Barnhart, H. T. Bradley, V. R. Copp, Spencer Danby, W. M. Hager, C. C. Haire, C. Jacoby, G. B. McMillen, B. H. Moore, M. G. Pettis, A. T. Powell, S. M. Rodgers, J. E. Scharper, P. J. Schmitz, R. W. Scott, H. G. Wertenberger.

Your committee submits the following report of progress in the revision of forms included in the Manual, pages 11–81 to 11–115.

This review is now in progress, but it is thought that none of the forms should be printed until all of them are ready for publication, including study and revision of all of the text of the pages in question. This revision of the text is to be accomplished jointly by subcommittees 1 and 4.

Study of the general subject assigned to subcommittee 4 has been continued, but we have nothing new to report at this time.

Report on Assignment 5

Construction Reports and Property Records; Their Relation to Current Problems

F. H. Neely (chairman, subcommittee), F. B. Baldwin, H. D. Barnes, B. A. Bertenshaw, W. C. Bolin, V. R. Copp, A. T. Hopkins, W. A. Krauska, M. F. Mannion, O. M. Miles, R. M. Nall, R. W. Scott, H. A. Shinkle, J. N. Smeaton, Louis Wolf.

This report is presented as information.

During the year your subcommittee studied the question of the quality of paper used by railroads for property records. In this, they were aided by an article entitled "Paper in the Railroad Industry" prepared by B. H. Moore, of the staff of the Association of American Railroads.

Mr. Moore's article proved to be very helpful and merits reading, but space does not permit inclusion in its entirety in the subcommittee's report. In the introduction, Mr. Moore states:

> ### Why Talk About Paper?
>
> The raising of a point about such a commonplace material would seem well taken, but when examined in its true perspective, the picture changes. To an industry that spends $65,000,000 yearly for advertising and for stationery and printing, in which the paper alone costs $15,000,000, it would appear essential that the users should know some of the elementals about paper and paper making in order that the most economical grade is selected to produce the best results for the work at hand.
>
> Paper is not all on the expense side of the railroads' accounts. Substantial revenues are derived from the transportation of the inbound raw products from the forests and scrap dealers who pay some $75,000,000 in settlement of railroad freight bills. If the chemicals, oil and coal were included, the amount would be even greater. It has been estimated that it takes four carloads of raw materials and supplies to produce one carload of finished paper. An even greater amount of revenue is received for the movement of the finished products. Over $300,000,000 is received in freight revenue for the transportation of paper and paper products from mill to wholesaler and to jobbers, to printers and ultimate consumers.
>
> Originally paper was designed as a vehicle on which to register and preserve the thoughts and ideas of man, but today the technical and physical uses of paper far outweigh the higher and nobler uses. Paper succeeded the crude stones on which the ancients recorded the history of their civilization.

The article then continues with a description of the processes used in the manufacture of various kinds of paper.

The conclusions reached by Mr. Moore, after a study of the various grades of paper used by carriers for permanent records, are as follows:

> With even the most elemental knowledge of paper making, it is apparent that the user of paper must keep two important factors in mind—(1) That there is a grade of paper made suitable for nearly every requirement, and (2) that the price fluctuates with the quality. Therefore, it is essential to select a grade of paper properly to perform the work that is to be required of it. To go to one extreme is extravagance and to go to the other is the danger of the loss of valuable records through failure of the paper to last the required time or to become mutilated through constant use.

To give a relative idea of the cost of paper suitable for printing or record purposes, beginning with newsprint: This is usually 20 percent chemical fiber (either sulfite or sulfate) and 80 percent groundwood. The price at the mill, in quantity, approximates five cents a pound or $100 per ton. Going to a higher grade, 70 percent groundwood and 30 percent chemical fiber, its cost would be 6¾ cents a pound or $135 per ton; 50 percent each of groundwood and fiber would be $140 per ton; 75 percent chemical fiber would be $160 to $170 per ton; full chemical fiber or 100 percent chemical bond would cost about 12½ cents per pound or $250 per ton. All of these illustrations are fully bleached paper.

Paper made from rag stock has been standardized at 25 percent, 50 percent, 75 percent, and 100 percent and 100 percent plus, rag content with the chemical pulp being mixed with other than all rag content. The rag content paper is the highest grade of paper and the price is fixed accordingly. It is usually surface sized and air dried and run slowly on the paper machine. A 25 percent rag content paper will cost $0.2165 per pound; a 50 percent rag will cost $0.2460 per pound; a 75 percent rag will cost $0.3100 per pound; a 100 percent rag will cost $0.4000 per pound, and Extra No. 1 will cost $0.4600 per pound.

As your committee is primarily interested in permanent records, embracing such reports as AFE's, completion reports and record of property changes, the quality of paper on which these records are prepared is of primary importance. Many complaints have been made that the completion reports and other original valuation records were disintegrating after a number of years of hard usage and storage.

Samples of these reports were furnished by a representative number of carriers and, as nearly as could be determined, the grade of paper used on the completion reports which were taken as representative were divided as follows:

1—100 percent rag content 16 lb.
1—100 percent rag content parchment
3—50 percent rag content
1—25 percent rag content
6—No. 1 sulfite bond 16 lb.
1—No. 2 sulfite bond
1—No. 1 sulfite bond 13 lb.
1—Sulfite bond—manifold

The conclusion to be drawn from this sampling explains the cause for the complaint that after a few years the paper deteriorates. Inferior grades of paper will not last the time required for their retention. It is recommended that not less than a 25 percent rag content paper be used for completion reports where permanence and durability are desired. This recommendation would also apply to the record of property changes and AFE's, particularly where these reports are used by many departments of a railroad.

It is interesting to note that a large paper company, making only 100 percent chemical fiber papers, went outside and purchased a rag content paper for permanent records. While it is true that the rag papers are initially more expensive, in the long run they last the required time and can withstand considerable handling; thus, over a long period are more economical.

The question of preserving documents has been a knotty problem over the years and a solution has long been sought by the Library of Congress, the

Examples of Types of Papers For Use in Railroad Office Work—Description, Standard Sizes, Weights, and the Principal Uses

Type of Paper	*Description*	*Standard sizes (in)*	*Standard Weights or thicknesses (lb. or in.)*	*Principal Uses*
Bond Papers, Rag-Content	A writing and printing paper containing 25, 50, 75 or 100 percent rag or cotton fibers. Has a dense, hard formation and an even finish on both sides of the sheet. Practically all rag-content bonds are surface-sized, air-dried and watermarked. Made with wove or laid formation, in a variety of finishes.	17x22 17x28 19x24 22x34 24x38 28x34 34x44	11 lb. 13 16 20 24 28	Letterheads, legal documents (leases, deeds, writs, etc.) bonds, certificates, policies, business forms, enclosures, pamphlets, envelopes, direct mail advertising.
Bond Papers, Sulfite	A writing and printing paper made of full bleached sulfite pulp or a combination of bleached sulfite and sulfate. Has a dense, hard formation and an even finish on both sides of the sheet. All sulfite bonds are beater sized, the better grades also surface-sized; generally machine-dried. Made with wove or laid formation, in a variety of finishes.	17x22 17x28 19x24 22x34 24x38 28x34 34x44	13 16 20 24	Letterheads, advertising pieces, business forms (invoices, orders, etc.), diaries, price lists, inserts, enclosures, short-term policies, inter-office stationery, pamphlets, envelopes, envelope enclosures, direct mail advertising.
Groundwood Book Papers	Made in 5 standard grades (A-Printing, A-1 Printing, A-2 Printing, B-Printing, B-Publication), the B-Printing grade accounting for the largest tonnage. This is an unbleached sheet containing about 75 percent groundwood fiber, and is made either for letterpress or rotogravure printing.	A Grades 25x38 B Grades 24x36	“A” “B” 21 lb. 30 lb. 23 32 25 35 28 40 31 45 35 40 45 50	Magazines, magazine sections of Sunday newspapers, farm journals, text books, time tables, tariffs, etc.
Ledger Papers, Regular	Semi-stiff, strong, flexible papers with a relatively high degree of durability and permanence. Finished more smoothly and made in a heavier range of weights than bond papers. They have a non-glare finish, good writing, ruling and erasing surface. Made in a variety of grades—from all-rag pulp, sulfite pulp, sulfate pulp, or combinations of these. Colors are white, blue, buff, and green-white tint.	16x21 17x22 17x28 19x24 22x34 24x38 28x34 22½x22½ 22½x34½ 24½x24½ 24½x39	24 lb. 28 32 36	Primarily for bookkeeping systems, but also for various records, policies, legal documents, long-life forms, letterheads, statements, credit cards, price lists, etc.
Ledger Papers, Looseleaf	Principal difference between Loose-leaf and Regular Ledger Papers is the rougher finish which will take direct typing or carbon more readily and which results in less glare. Made in white and a range of pastel colors.	17x22 17½x22½ 19½x24½ 22½x22½ 22½x28½ 22½x35 24½x24½ 24½x28½ 24½x39	24 lb. 28 32 36	Primarily for bookkeeping systems.

EXAMPLES OF TYPES OF PAPERS FOR USE IN RAILROAD OFFICE WORK—DESCRIPTION, STANDARD SIZES, WEIGHTS, AND THE PRINCIPAL USES—Continued

Type of Paper	*Description*	*Standard sizes (in)*	*Standard Weights or thicknesses (lb. or in.)*	*Principal Uses*
Newsprint	An absorbent paper, containing about 70 percent groundwood pulp and 30 percent unbleached sulfite, made on special newsprint Fourdrinier machines, and given a soft, smooth finish on the machine. Uniform in texture and appearance Made in white and such pastel shades as pink, peach, green and salmon.	21x32 22x34 24x36 25x38 28x34 28x42 34x44 36x48 38x50	Ranges from 28½ to 35 lb.	Daily and weekly newspapers; newspaper supplements.
Onionskin and Manifold Papers	Thin, durable lightweight bond-type papers, with good writing and erasing surface. Made in all-rag, rag-content, flax, or all chemical wood pulp grades, and given a cockle, unglazed, or high glazed finish.	17x22 17x26 19x24 17x28 21x32 22x34 24x38 26x34 28x34	Ranges from 7 to 10 lb.	Carbon copies of typewritten material; air mail letterheads and envelopes; envelope enclosures.
Railroad Manila	A groundwood-content paper sized for pen-and-ink writing and available in two grades. No. 1 grade made in sulfur and cream colors only; No. 2 grade in canary, India and white.	17x22 17x28 19x24 22x34 24x38 28x34 34x44	13 lb. 14 16 20	Inexpensive business forms, advertising throw-aways, order blanks, salesbooks, school tablets, second sheets in typing.
Writing Papers	A group of papers which resemble bond papers. Principal differences are that writing papers are usually not as strong and that they have a smooth, flat finish. Hard-sized for pen-and-ink writing, and made with a close, uniform formation.	17x22 17x28 19x24 22x34 24x38 28x34	13 lb. 16 20 24	Stationery, ruled and printed forms; writing tablets.
Map Papers	A rag or chemical wood pulp paper treated to provide high wet-strength. Made with resins to bind the fibers together making them insoluble in water and to withstand rough usage when soaked with oil water, etc., and can be cleaned with soap or gasoline or other solvents.	17x22	Ranges from 16 to 28 lb.	

> Archives, and the Smithsonian Institution. Recently a clear plastic spray was invented which, it has been found, acts as a preservative. The documents are coated with the spray, thus sealing them permanently from air and moisture.
>
> It is suggested that those interested in preserving maps, drawings, photographs, and important documents investigate and experiment with the use of the plastic spray. It has received the approval of many of the governmental departments, and its use in railroad archival work is recommended.

With these conclusions, your subcommittee concurs.

The article also contains an appendix which describes the various classes of paper that might be used in railroad offices, with examples of the various types that have proved to be satisfactory.

This appendix is reproduced herein in tabular form.

Report on Assignment 6 (a)

Current Developments in Connection with Regulatory Bodies and Courts

H. T. Bradley (chairman, subcommittee), M. A. Bryant, P. D. Coons, Spencer Danby, M. M. Gerber, H. N. Halper, L. W. Howard, C. Jacoby, E. M. Killough, G. B. McMillen, J. B. Mitchell, B. H. Moore, H. L. Restall, J. H. Roach, E. J. Rockefeller.

This is a progress report, submitted as information.

Regulatory Bodies

The Interstate Commerce Commission's allocation of its appropriation for the Bureau of Valuation for the year beginning July 1, 1950, was approximately the same as for the previous year when the expenditures amounted to $506,294. This amount is sufficient for the Bureau to maintain the present force with no provision for the restoration of the cuts made in the preceding year when the force was reduced 26 employees. During the year the forces of the Bureau were engaged in railroad and pipeline work. The progress made in railroad work will appear hereafter. The work of bringing the pipeline valuations to date progressed to the extent of the service of 32 tentative valuations out of a total of approximately 75 to be issued. The preparation of the underlying reports has progressed to an even greater extent. The issuance of Valuation Order No. 28 (which requires common carrier pipeline companies, previously valued, to furnish revised inventories and statements of original cost as of dates established by the Director of the Bureau of Valuation) has greatly facilitated the work of the Bureau in the preparation of underlying reports on these companies.

During the year 1949, Class I carriers charged Account 459 Valuation Expenses an amount of $753,044, contrasted with $780,902 for the year 1948. As of October 1, 1950, all Class I carriers (136) had filed 588 returns through the year 1944; 134 through the year 1945; 133 through the year 1946; 124 through the year 1947; 112 through December 31, 1948, and 15 through December 31, 1949. The Accounting Section of the Bureau is now 91 percent current in its field check of these returns.*

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*Based on 8,250,000 mile years from basic valuation dates through 1949.

The Engineering Section of the Bureau, having completed revised inventories for practically all carriers through the year 1932, is engaged in bringing its inventories forward to later dates and, as of October 1, 1950, was approximately 80 percent current (long form method). The work of the Accounting Section in bringing summaries of original cost other than land is 95 percent* current; the original cost of land is 41 percent current. The Land Section in its work of revising land valuations to current dates has completed 77 percent* of its work. From the above figures, it will be noted that the Bureau is just about able to maintain a status quo in its progress and each year sees very little improvement in catching up with the backlog of work. It will be impossible for the Bureau to keep abreast of its work load unless Congress grants an increased appropriation to sustain properly the Bureau's activities.

Elements of Value as of January 1, 1950

The Bureau of Valuation is now completing its work in the preparation of its estimates for the Class I carriers covering the standard elements of value as of January 1, 1950. At the time of the preparation of this report, these figures were not yet available.

Court Decisions

Beginning in 1942 most railroads applied to the Commissioner of Internal Revenue for permission to change from retirement to depreciation accounting for Road Property. In response to this request the Commission issued a mimeograph stating the terms under which such permission would be granted, together with a description of the information that should be furnished by the applicant. Instructions relating to the development of the depreciation base included the following:

> Donated property or contributions or grants in aid of construction from any source must be excluded

Recent decisions of the Supreme Court in the following cases; Detroit Edison Company vs. Commissioner, 319 US 98, 87 L ed 1286, 63 S Ct. 902 (1943) and Brown Shoe Company vs. Commissioner, 94 Law Ed. 746 (May 15, 1950) have suggested the possibility of easing or modification of this important part of the Commissioner's regulations and the matter is now being actively given consideration by the law, accounting, and valuation representatives of the railroads.

Report on Assignment 7

Revisions and Interpretations of ICC Accounting Classifications

H. N. Halper (chairman, subcommittee), H. D. Barnes, S. H. Barnhart, W. M. Hager, B. H. Moore, M. G. Pettis, J. H. Roach, H. B. Sampson, P. J. Schmitz, J. R. Traylor, J. L. Willcox.

This is a progress report presented as information.

Since this committee's last report, Proceedings, Vol. 51, 1950, page 430, the Interstate Commerce Commission issued an Order, effective January 1, 1951, affecting Account 26—Telegraph and Telephone Lines.

Briefly, the order changes the present title and text of Account 26, which now reads: Telegraph and Telephone Lines to Communication Systems. The order gives a representative list of items in this account, which now includes the cost of telegraph, telephone, radio, radar, inductive train communication and other communication systems, including terminal equipment.

Any communication apparatus attached permanently to rolling stock or other equipment is to be included in the same account as the equipment in which it is installed. Communication systems of limited extent, used for special purposes installed within a building or group of buildings, are included in the same account as the building.

The corresponding Maintenance of Way and Structures Account 247 is also changed to read: Communication Systems in place of Telegraph and Telephone Lines, and the Operating Expense Account 407, which is changed from Telegraph and Telephone Operation to Communication System Operation.

Report of Committee 7—Wood Bridges and Trestles

C. V. Lund, *Chairman,*
W. L. Anderson
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A. M. Westenhoff
W. C. Wilder
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, recommending revision and readoption of Manual material . page 426

2. Grading rules and classification of lumber for railway uses; specifications for structural timber, collaborating with other organizations interested.

   Progress report, recommending deletion of Manual material on classification of lumber, etc. .... page 427

3. Specifications for design of wood bridges and trestles.

   Progress report, submitting revisions to specifications for adoption and publication in the Manual .... page 428

4. Improved design of timber trestles.

   Report on performance of glued laminated timbers in service tests .... page 428

5. Instructions for inspection of timber trestle railway bridges.

   Final report, submitted for adoption and publication in the Manual ...... page 430

6. Methods of fireproofing wood bridges and trestles including fire-retardant paints, collaborating with Committee 17.

   No report.

7. Statistics relating to wood bridges and trestles.

   Final report, presented as information .... page 433

8. Specifications for design of wood culverts.

   Progress report, presenting as information, presenting a typical design plan .... page 436

The Committee on Wood Bridges and Trestles,
C. V. Lund, *Chairman.*

AREA Bulletin 492, January 1951.

Report on Assignment 1

Revision of Manual

Nelson Handsaker (chairman, subcommittee), W. W. Boyer, B. E. Daniels, S. L. Goldberg, R. P. Hart. W. E. Heimerdinger, C. S. Johnson, J. V. Johnston, H. J. Kerstetter, W. O. Nelson, W. A. Oliver, W. L. Peoples, W. C. Schakel, B. J. Shadrake, Josef Sorkin, A. M. Westenhoff.

Your committee recommends the following action with respect to its section of the Manual:

Page 7–53:

[1]PILE RECORD FORM

Submitted for reapproval without change, except that the note thereon, which now reads: Bents Numbered from North or East End, be changed to read: Bents numbered in direction in which mile posts increase.

It is also recommended that the following note be added, to follow the pile record form in the Manual:

The size and arrangement of pile driving record forms may be varied to adapt them to the convenience of user, method of filing, and use to be made of the data. The above form embodies the minimum of information for a satisfactory record. Among additional items which may be desirable are: reference to piles other than wood; steam hammer blows per minute; data on batter; reference to jetting; computed bearing value; and other arrangement of data on length between butt, cut-off, ground and point of pile. In conformity with bearing capacity formula it is recommended that the record for piles driven with steam hammers be based on the last 20 blows.

Page 7–63:

[1]RELATIVE MERITS OF OPEN AND BALLASTED DECK WOOD TRESTLES

1925

Submitted for reapproval without change.

Page 7–65

[1]Use of Guard Rails and Guard Timbers for Wood Bridges and Trestles

1920

It is recommended that the material now in the Manual, including the title, be deleted, and that the following be adopted to replace it:

[1]USE OF GUARD RAILS AND GUARD TIMBERS FOR RAILWAY BRIDGES

1951

1. On all open-floor railway bridges, the ties should be held securely in their proper spacing. Guard or spacer timbers, fastened to every tie near its ends, are effective. If such continuous timbers are not placed, blocks or other spacers should be securely fastened between the ties. Lag screws or other suitable fastenings should be used for spacer timber attachment; in fast track it may be advisable also to embed clamping plates or timber connectors between the timbers and ties. Such metal fastenings are

more effective than dapping of the spacer timbers, because of the tendency of the wood to split off between daps.

2. Metal inner guard rails should be placed on all through spans. Except where low speed, alinement, low height or short length make them unnecessary, inner guard rails should be used on all tracks on open-floor deck bridges and on the outside tracks of solid-floor deck bridges. Inner guard rails should be placed on any main track, nearer rail of which is within 10 ft. of the supports of an overhead or adjacent structure.

3. Inner guard rails should preferably be steel track rails. Inner guard rails 5 in. or more in height should not be more than 2 in. lower than the running rails; if less than 5 in. in height they should not be more than 1 in. lower than the running rails. They should not be higher than the running rails. They will normally consist of two rails, spaced about 10 in. inside the running rails, measured between near sides of heads. They should be spiked to every tie and spliced with joint bars, fully bolted; and should be tie-plated when deemed advisable. They must not contact tie plates of tracks carrying electric signal circuits. Where they protect against a hazard on one side only, a single line of rails may be used, adjacent to the running rail further from the hazard.

4. Inner guard rails should extend at least 50 ft. beyond the end of the bridge or other structure. This distance should be increased on curves and on tracks carrying fast trains, and may be decreased on the leaving end where traffic is in one direction. The ends should run to the center of track and be beveled, bent down or otherwise protected against direct impact. A filler block or plate should be provided at the meeting of the converging rails.

5. The guard timbers and the inner guard rails should be so spaced that a derailed truck will strike the inner guard rail and not the timber.

Report on Assignment 2

Grading Rules and Classification of Lumber for Railway Uses; Specifications for Structural Timber,

Collaborating with Other Organizations Interested

C. H. Newlin (chairman, subcommittee), T. J. Boyle, H. M. Church, F. J. Hanrahan, R. P. A. Johnson, A. L. Leach, L. J. Markwardt, T. K. May, W. O. Nelson, W. H. O'Brien, J. R. Showalter, A. M. Westenhoff.

Your committee recommends that the material now appearing in the Manual under the title Classification of the Uses of Lumber and Timber Under American Railway Engineering Association Specifications on pages 7–101 to 7–107, inclusive, be deleted.

The existing text in Chapter 7 of the Manual under the above title presents recommendations for grades of lumber to be used in both railway bridge and building construction. Committee 6—Buildings, has prepared and is presenting for adoption new recommendations for yard grades of lumber for use in building work. To avoid conflicting and superseded material in the Manual, your committee, concurrently with the adoption of the recommendations proposed by Committee 6, recommends deletion of the entire present text in Chapter 7 under Classification of the Uses of Lumber and Timber, and proposes to prepare new and revised recommendations for stress grades of lumber for bridge construction and other structural uses to be offered for adoption a year hence.

Report on Assignment 3

Specification for Design of Wood Bridges and Trestles

J. P. Dunnagan (chairman, subcommittee), W. L. Anderson, T. J. Boyle, E. F. Croxson, S. L. Goldberg, F. J. Hanrahan, W. C. Howe, M. W. Jackson, Milton Jarrell, C. S. Johnson, Jr., R. P. A. Johnson, W. D. Keeney, P. L. Montgomery, J. M. Montz, H. S. Rimington, Josef Sorkin, R. L. Stevens, W. C. Wilder.

At the annual meeting in 1950, your committee presented as information, a table showing the allowable loads in pounds on one common bolt loaded at both ends (three-member joints). The purpose of the table is to supplement basic design data given in paragraph 307 and Tables 707 and 708 of the specifications. The table presents, in convenient form, allowable loads on bolts for the more usual condition of exposure, "occasionally wet but quickly dried"; adjustments for bolts loaded on one end (two-member joints) are given in footnotes to the table.

Your committee recommends that this table be adopted and published in the Manual as Table 709, and that a paragraph be added to section 307, page 7–124, reading as follows:

Table 709 shows bearing values for bolts for the most common condition of exposure —occasionally wet but quickly dried. For locations continuously dry use 4/3 the values in the table, and for locations damp or wet most of the time use 8/9 the values in the table.

Report on Assignment 4

Improved Design of Timber Trestles

F. W. Madison (chairman, subcommittee), F. H. Cramer, E. F. Croxson, E. L. Haberle, F. J. Hanrahan, M. W. Jackson, Milton Jarrell, W. D. Keeney, J. R. Kelly, W. B. Mackenzie, L. J. Markwardt, T. K. May, P. L. Montgomery, J. M. Montz, W. H. O'Brien, A. H. Schmidt, B. J. Shadrake, F. L. Thompson.

Your committee presents as information a progress report on service tests of glued laminated timber in five railroad bridges.

A report on laboratory tests of creosoted, glued laminated stringers appears in the Proceedings, Vol. 46, 1945, pages 186 and 187. The conclusions reached in these tests are that glued laminated beams, creosoted or untreated, incised or unincised, are in general as strong as or stronger than sawed beams.

A previous report on laminated timbers in railroad bridges was published in the Proceedings, Vol. 48, 1947, pages 382 to 385. The timbers had been in service only a few years at the time of that report. This report is presented as additional information.

Texas and Pacific Railway Tests

During October 1944, the Texas and Pacific Railroad installed as a test in service 11 glued laminated 7-in. by 16-in. by 14-ft. stringers in a standard ballasted deck pile bridge on its main line near Woodlawn, Tex.

Five timbers were prepared with scarf-jointed lumber and six beams were made of full length stock. Scarf joints were a 1:4 serrated scarf with the pieces in each lamination varying in length from 4 to 14-ft., resulting in beams 18-ft. long. After gluing, 4 ft. was trimmed from the ends of scarf joint beams for test purposes. The lumber used consisted of kiln-dried southern yellow pine. No edge gluing was done.

All beams were glued with Cascophen LT 67 phenol-formaldehyde resin glue, spread 60 lb. per 1000 sq. ft. of glue line, at a room temperature of 85 deg. F., with a clamping pressure of 150 to 200 psi. After curing, beams were planed to a net width of 7 in. and a net length of 14 ft.

The laminated stringers were treated at Texarkana, using No. 1 distillate creosote with a net retention of 15.5 lb. per cu. ft. No delamination was observed after treatment.

An inspection of the stringers was made in December 1949, some five years after the installation was made. At that time there were no signs of any delamination and the stringers appeared to be in perfect condition.

Southern Railway Tests

The report published in the Proceedings, Vol. 48, 1947, describes the specifications for the gluing and treatment of timbers used in an installation made near Alexandria, Va., in October 1945. The installation consisted of 6 stringers, 8-in. by 16-in. by 27-ft.; 4 caps, 12-in. by 14-in. by 13-ft.; and 16 posts, 12 in. by 12 in. by 12 ft. long.

An inspection of these timbers made in October 1949 disclosed that all timbers, in general, were in excellent condition, with little checking of the timbers or bleeding of the creosote, and only slight opening of the glued joints (similar to small checks) at a few places.

Chesapeake and Ohio Railway Tests

A description of an installation on the Chesapeake and Ohio also appears in the Proceedings, Vol. 48, 1947, page 385. The installation consisted of 2 beams 24 in. by 15 in. by 16 ft., laid flat, and installed in a bridge near Newport News in January 1946.

These stringers were in good condition in the spring of 1950, with the exception of the top 2-in. by 8-in. member of one of the stringers which showed evidence of decay. The defect was noted to a lesser degree when installed, and evidently was in the wood when laminated.

A second installation was made by the Chesapeake and Ohio in the latter part of 1946 in Bridge 312, Ameagle, W. Va. This installation consisted of 8 stringers 7½ in. by 16 in. by 14 ft. long, laminated from 2 in. by 8 in. wide No. 1 Douglas fir dressed to 1⅝ in. by 7½ in. The glue used was a waterproof phenol-resorcinol resin glue; the timbers were treated with Minalith by the full-cell process.

An inspection of these stringers in the spring of 1050 found the beams in good condition and with no defects apparent.

Southern Pacific Railway Tests

In 1946 the Southern Pacific Company constructed a 2-panel ballasted deck pile trestle at Bridge 643.71, near Durnid, Calif., on the Los Angeles Division, in which 3 laminated caps and 14 laminated stringers were used. The location is on the desert in the vicinity of the Salton Sea, at an elevation of 200 ft. below sea level.

The material used in the caps and stringers was kiln-dried Douglas fir of 2-in. nominal thickness, dressed to 1⅝ in. The finished caps were 13½ in. by 14½ in. sections, and were built up of 9 horizontal laminae, each lamina consisting of two boards 4¾ and 8¾ in. wide. The edge joints were preglued and staggered in each lamina.

The finished stringers were 7¼ in. by 17¾ in. by 30 ft. long, requiring 11 horizontal laminae of the 1⅝ in. thick lumber. Splices in the laminae were made by means of 18-in. scarves.

The glue used was Cascophen LT, with a clamp pressure of 100 psi. maintained for 24 hours at a temperature of approximately 70 deg. F.

The fabricated members were treated in the plant of the Southern Pacific, with coal-tar creosote by the full-cell process, without incising. Final retention was believed to have been between 10 and 12 lb. per cu. ft.

The bridge receives frequent inspection and as of the last report (summer of 1950) the caps and stringers were performing satisfactorily.

Report on Assignment 5

Instructions for Inspection of Timber Trestle Railway Bridges

J. R. Showalter (chairman, subcommittee), W. L. Anderson, J. P. Dunnagan, N. L. Flenckenstine, R. E. Jacobus, J. R. Kelly, W. B. Mackenzie, F. W. Madison, C. E. Peterson, Arthur Price, F. W. Small, W. C. Wilder.

Last year your committee presented as information a tentative draft of Instructions for Inspections of Timber Trestle Railway Bridges (Proceedings, Vol. 51, pages 433 to 436) and requested comments and criticisms thereon. These instructions, with minor revisions, are now submitted with the recommendation that they be adopted and published in the manual.

Foreword

It is the purpose of these instructions to describe the manner of inspecting a timber bridge; no attempt is made to set up the organization nor to fix the responsibility or the functioning of the various members of the organization.

1. General

The method of inspecting timber, regardless of its location in the structure, follows:

(a) Make a careful surface inspection of each timber for cross grain, tension or horizontal shear failures that may have developed from uneven bearing, original defects, overstress or other causes. Note whether timber and piling are treated or untreated.

(b) Test each timber and pile for soundness, especially at points of contact with other timbers, ground, or at low water line, and where end grain bears on a sill or cap.

For treated timber, test shall be made by sounding with the knob end of an inspection bar or light-weight hammer, using care to avoid injuring or disfiguring the fiber. If hollow or dead sound results, determine nature and extent of the defect by boring, preferably with an increment borer. Bore holes, where possible, so water can drain, and carefully plug with treated wood.

For untreated timber, test may be made by sounding with the knob end of an inspection bar or light-weight hammer, also by probing with pointed end of inspection bar, using care to avoid any unnecessary injury or disfiguring of the wood. Note the feel and sound when struck by the bar, the appearance of the fiber, and of all decayed or otherwise unsound wood, which should be trimmed away to sound timber.

(c) Make a careful surface inspection of the timber and adjacent ground surface for evidence of termites, carpenter ants, marine borers or other destructive insects.

(d) Make inspection on new work, where timber is treated, of all field cuts for exposed untreated wood.

2. Details of Inspection

The bridge inspector's notes for each bridge shall be written while at the structure after a careful examination has been made covering the following points:

A. IDENTIFICATION

(a) Division or subdivision
Name of inspector and members of inspection party
Date of inspection.

(b) Bridge number
Name of nearest station and mile-post location
Age and type of structure
Total length, height and number of panels.

(c) Number of bents, towers, spans or panels in each bridge in the direction in which the mile post numbers increase, starting with the dump bent as No. 1.

Number the piles in each bent or tower and the stringers in each panel from left to right, when facing in the direction in which the mile post numbers increase.

B. WATERWAY

(a) Observe if the opening appears adequate for drainage area and if free of obstructions, such as drift, vegetation, displaced revetment stone, or old pile stubs. Note whether the channel is stable, filling, deepening or subject to scour, and if public or private improvements have altered the general condition in any way. Measure and record the distance from base of rail to ground line at each bent. Measure and record high water mark if obtainable. If heavy or accumulated drift is troublesome during high water, ascertain the type, such as logs, trees, ice, etc., and observe whether of such intensity as to force the bridge out of line and/or break piling.

(b) Note if protection work is required, or whether cleaning and straightening of the channel are necessary. Note whether bent alinement obstructs or deflects normal flow and if revetment or deflection dikes are needed.

(c) Note evidence that would indicate the presence of any buried cable, conduit, tile or pipe lines crossing under the bridge, giving the panel location, together with size and use.

C. TRACK

(a) State whether track is level or on a grade, and if alinement is tangent or curved. If on a curve, note how superelevation is provided, whether by cutoff in the bents, taper in the caps, or in the ballast section. Note location of track with reference to the chords for uniformity of loading.

(b) Observe condition of embankment at the bridge ends for fullness of crown, steepness of slopes and depth of bulkheads. Note whether track ties are fully ballasted and well bedded.

(c) Record the weight and condition of the track rails and inside guard rails; also the condition of the rail joints and fastenings. Note the size and condition of the tie plates.

(d) Where track is out of line or surface, the location, amount and probable cause should be determined.

D. SUPERSTRUCTURE

(a) Ascertain size, spacing and uniformity of bearing of the ties. Note condition as to soundness, mechanical wear, spike killing and other defects.

(b) Determine the size, condition, and security of anchorage of the guard timber.

(c) Inspect all walks, railings, and refuge bays, noting the condition as to soundness and security of fastening devices.

(d) Note if any members are broken or have moved out of proper position and whether all fastening devices are functioning properly. On ballast deck trestles, note whether ballast is clean and in full section.

(e) Examine all stringers for soundness and surface defects. Note size and kind, and the number used in each panel. Note if bearing is sound and uniform, if all stringers are properly chorded and securely anchored, and if all shims and blocking are properly installed. Note whether packers or separators are used and the condition of all chord bolts.

(f) Note and report presence of any wires, cables, pipe lines or other attachments which are foreign to the bridge structure.

E. SUBSTRUCTURE

(a) Make careful examination of all piles and posts for soundness, noting particularly the condition at points of contact with the caps, girts, bracing, sills, and at the ground or water line.

(b) Examine all bents and towers for plumbness, settlement, sliding and churning, and give an accurate description of the nature and extent of any irregularities. Note particularly whether caps and sills have full and uniform bearing on the supports.

(c) Record number and kind of piles or posts in the bents or towers. Note uniformity of spacing and the location of any stubbed or spliced member, especially if the bridge is on a curve or the bent is more than 15 ft. in height.

(d) Ascertain whether all bents and towers are properly sway, sashed and tower braced, and if girts and struts are applied as needed.

(e) Examine all fastening devices for physical condition and tightness.

(f) Observe action of bridge under movement of trains, where practicable, in order to evaluate better the riding condition and soundness of the structure.

F. FIRE PROTECTION

(a) Note whether surface of the ground around and beneath the structure is kept clean of grass, weeds, drift or other combustible material.

(b) Where rust-resisting sheet metal is used as a fire protection covering for deck members, note condition of metal and fastenings.

(c) Note if any other method of fire protection has been used, such as fire retardant salts, external or surface protective coatings, or fire walls. Record such apparent observations as are pertinent to the physical condition and effectiveness of such protective applications.

(d) Where water barrels are provided, note the number, condition, if filled, and if buckets for bailing are on hand. If sand is used, note whether bins are full and in condition to keep the sand dry.

(e) Note if timber, particularly top surfaces of ties and stringers in open deck bridges, is free from frayed fiber, punk wood, or numerous checks.

3. Notes on Recommended Practices

The inspector's outline of repairs should be based on the following recommended practices:

(a) Safety should be the first consideration.

(b) Posting of the outside piles shall not be permitted on bridges on curves where bents exceed 12 ft. in height or on tangents where bents are over 20 ft. in height.

(c) On high-speed track where traffic is heavy, not more than two posted piles in any one bent shall be permitted. If more than two piles are poor, all piles should be cut off to sound wood below ground line and a framed bent installed, or piles redriven.

(d) All posts should be boxed, in addition to toe nailing, to prevent buckling.

(e) When individual caps, sills, braces or struts have become weakened beyond their ability to perform their intended function, renewal is the only remedy.

(f) When only an individual stringer is materially deteriorated, an additional stringer may be installed, inside or outside of the chord, to aid the weakened member.

(g) Where piles are decayed at the top they may be cut off and double capped; a single pile may be corbelled.

(h) Shimming of stringers to provide proper surface and cross level should be done with a single shim under each chord; if possible avoid multiple shimming.

Report on Assignment 7

Statistics Relating to Wood Bridges and Trestles

A. L. Leach (chairman, subcommittee), W. L. Anderson, J. P. Dunnagan, Nelson Handsaker, W. E. Heimerdinger, C. S. Johnson, W. O. Nelson, J. R. Showalter.

This is a final report, submitted as information.

Under this assignment your committee released a questionnaire to all Class I member railroads requesting information regarding their practices and standards pertaining to timber trestles. The following summarizes replies from 88 railroads reporting; 18 of these reported they had no timber trestle in service, 21 reported having no untreated trestle, and 10 reported having no treated trestle. Some roads did not reply to all items, and replies to a few items contained in the questionnaire were too varied or indefinite to permit tabulation.

Summary

(Replies from 70 railroads, except Item 2, which includes 88 railroads)

(1) Track feet of timber trestles in service:

	Branch Line	*Main Line*	*Total*
(a) Untreated open deck	1,785,314	1,206,781	2,992,095
" except bents	56,111	107,475	163,586
" stringers only	282,424	161,093	443,517
" other	11,640	11,344	22,984
(b) Treated open deck	1,071,214	1,057,454	2,128,668
(c) " ballasted deck	665,460	2,012,967	2,678,427
(d) " protected deck (60 percent reported as sheet metal)	544,693	293,411	838,104
Totals	4,416,856	4,850,525	9,267,381

(2) Mileage of reporting railroads (operated)

United States	193,646
Mexico	9,268
Canada	40,391
	243,305

(86 percent of total in U. S.)
(89 " " " " Mexico)
(95 " " " " Canada)

(3) Types of timber trestles currently used, or considered standard construction:

	Branch Line	*Main Line*
(a) Untreated open deck	15	9
(b) Treated open deck	41	20
(c) Treated ballasted deck	3	22
(d) Treated protected deck	1	1
(e) No standard	8	16

(4) (A) Number of railroads whose policy is to replace untreated timber trestle with:

(a) Untreated timber	5	(On branch lines only, 2 included)
(b) Treated timber	27	(On branch lines only, 2 included) (On main line only, 2 included)
(c) Steel structures	2	
(d) Concrete structures	8	(On main line only, 2 included)
(e) No established policy	16	

(B) Number of railroads whose policy is to replace treated timber trestle with:

(a) Treated timber	27	(On main line only, 2 included) (On branch lines only, 2 included)
(b) Steel structures	3	
(c) Concrete structures	12	(On main line only, 2 included)
(d) No established policy	22	

(5) Number of railroads using following species of bridge timber and piling:

	Timber	*Piling*
Southern pine	18	34
Fir	23	8
Pine and fir	19	4
Fir and oak	4	
Mexican and Oregon pine	1	
Oak and pine		8
Cedar		2
Oak		5
Pine and cypress	1	
Spruce		1
Others	4	5

(6) Number of railroads purchasing bridge timber under the following grading rules:

(a) AREA	10
(b) West Coast Lumbermen's Association	18
(c) Southern Pine Association	11
(d) WCLA and SPA (both)	13
(e) Railroad rules	6
(f) Various	7

(7) Design working stresses currently being used:

	Number of railroads reporting		
(a) Fiber stress in bending:			*Pine and*
psi.	*Pine*	*Fir*	*Fir*
1200	3	3	4
1400	3	5	7
1500	1	1	1
1600	10	1	9
1800	..	2	1
AREA (not otherwise classified)	2	1	5
Other	1	4	6
(b) Horizontal shear:			
psi.			
Under 100	..	2	2
100	7	8	6
120	6	2	13
125–130	3	..	..
140–190	1	1	2
AREA (not otherwise classified)	2	1	5
Other	1	2	5
(c) Compression perpendicular to grain:			
psi.			
Under 240	1	..	3
240–280	5	5	8
280–320	1	3	3
320–400	9	5	5
AREA (not otherwise classified)	2	1	5
Other	1	1	6

(d) Impact used: 55 none, 9 various

(8) (a) Kind of structural failures experienced, not associated with or resulting from decay:

	Number of railroads reporting	
	Stringers	*Caps*
Cross grain and splitting and horizontal shear	33	25
Crushing	12	12
Splitting and crushing	2	12
None	34	33

(b) Most prevalent type of failure, not associated with decay:

	Number of railroads reporting
Crushing	21
Cross grain	5
Caps splitting	5
Stringers splitting	8

(9) (a) Is timber (stringers in particular) inspected at the mill?

	Number of railroads reporting
Yes	54
No	9
Both (mill and at destination)	4

(b) Is this service performed by railroad company inspectors, or by an established inspection bureau?

	Number of railroads reporting
Railroad company inspectors	38
Inspection bureau	15
Both railroad company and inspection bureau	8

(10) (a) Is treatment done at a railroad treating plant or by others?

	Number of railroads reporting
Railroad plant	14
Railroad owned plant operated by others	5
Treatment by others	47

(b) Is timber being incised?	*Number of railroads reporting*
Yes (Fir timber)	37
No (Includes three using fir)	26
Yes (Ties only)	1

Report on Assignment 8

Specifications for Design of Wood Culverts

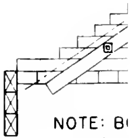
F. E. Schneider (chairman, subcommittee), E. F. Croxson, E. L. Haberle, W. C. Howe, C. S. Johnson, J. C. Korte, W. D. Keeney, J. M. Montz, W. A. Oliver, A. H. Schmidt, R. L. Stevens, W. C. Wilder.

This is a progress report, submitted as information.

Under this assignment your committee has made a study of the design plans of timber culverts submitted by a number of railroads and has prepared a tentative plan for recommended practice.

The plan shows typical design features and details for the range of culvert sizes that would ordinarily be used by railroads, for fill heights up to 15 ft. from flow line to base of rail. The design is based on Cooper E 72 live load, and usual assumptions of earth pressure. The plan includes a table of computed stresses for the principal members under the maximum and minimum fill heights. Practical considerations in the selection of dimensions permit the use of the lower grades of structural lumber in many cases.

Comment and criticism of the tentative plan of recommended practice are invited, with view to offering the plan, as may be revised, for inclusion in the Manual a year hence.



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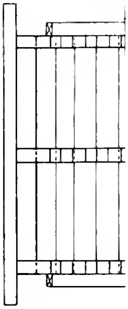
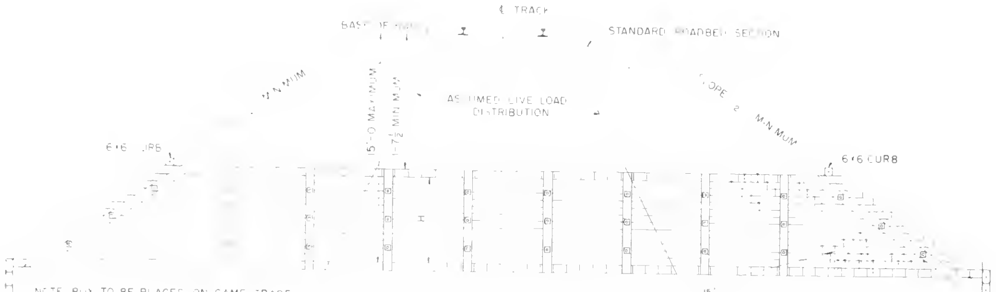
AS ADJ
ON MOR



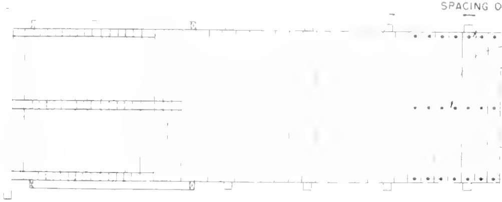
WIDTH W IN FT.-IN	HE F
2'-0	1
2'-0	1
2'-0	
2'-6	
3'-0	
3'-0	
3'-6	
4'-0	
4'-0	
4'-0	
4'-6	
5'-0	
6'-0	



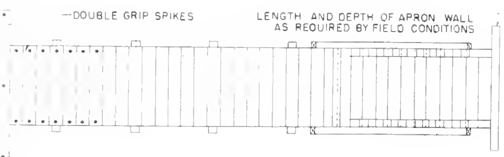
NOTE BOX TO BE PLACED ON SAME GRADE AS ADJACENT GROUND OR RAVINE, BUT NOT ON MORE THAN A TWO PERCENT GRADE

SIDE ELEVATION OF SINGLE AND DOUBLE BOX

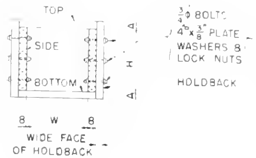
$\frac{15}{16}\phi \times 7$" DOUBLE GRIP SPIKES DRIVEN THRU $\frac{1}{4}\phi \times 6\frac{1}{2}$" PREBORED HOLES FOR TIMBER SIDEWALLS OF 3 AND 4' THICKNESS, AND $\frac{3}{8}\phi \times 10$" DOUBLE SPIKES DRIVEN THRU $\frac{5}{16}\phi \times 9\frac{1}{2}$" PREBORED HOLES FOR TIMBER SIDEWALLS OF 6" THICKNESS



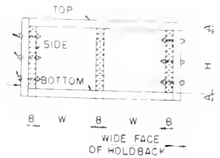
PLAN OF DOUBLE BOX



PLAN OF SINGLE BOX



TYPICAL SECTION THRU SINGLE BOX



TYPICAL SECTION THRU DOUBLE BOX

TABLE OF TYPICAL SIZE BOXES AND UNIT STRESSES

SIZE OF BOXES AND REQUIREMENTS							MAXIMUM STRESS IN TIMBER IN LB PER SQUARE INCH								MAX TENSION IN BOLTS LB PER BOLT	
WIDTH W IN FT-IN	HEIGHT H IN FT-IN	TOP AND BOTTOM A IN INCHES	SIDES B IN INCHES	HOLDBACKS			TOP & BOTTOM BENDING		SIDE WALLS BEARING		CENTER WALL BEARING		HOLDBACKS BENDING			
				SIZE IN INCHES	MAX SPACING FEET	NUMBER OF BOLTS	MIN DEPTH	MAX. DEPTH	MIN. DEPTH	MAX. DEPTH	MIN. DEPTH	MAX. DEPTH	MIN. DEPTH	MAX DEPTH	MIN DEPTH	MAX DEPTH
2-0	1'-0	3	3	NONE			730	990	60	78	135	175				
2-0	1-6	3	4	4 x 4	5	2	785	1040	48	64	105	127	1033	1450	1800	2540
2'-0	2-0	3	4	4 x 6	6	2	785	1020	48	63	105	136	905	1270	2860	4000
2'-6	2'-6	3	4	4 x 6	5	2	1156	1480	57	73	127	163	1128	1565	2930	4130
3'-0	2'-0	4	4	4 x 6	6	2	901	1170	66	86	151	195	975	1370	2860	4020
3'-0	3'-0	4	6	6 x 6	5	3	1000	1240	48	61	105	132	1153	1520	2490	3270
3'-6	3'-6	6	6	6 x 8	6	3	582	702	55	66	121	145	1078	1440	3360	4550
4-0	3-0	6	6	6 x 6	5	3	736	910	61	75	136	169	1217	1650	2390	3240
4-0	4-0	6	6	6 x 8	5	3	736	880	61	72	136	163	1140	1525	3200	4300
4-0	6'-0	6	6	8 x 10	5	4	736	816	61	67	136	154	1165	1470	3280	4650
4-6	4'-6	6	8	8 x 8	6	4	970	1135	53	62	118	138	1273	1680	3260	4320
5-0	5'-0	6	8	8 x 8	5	4	1170	1345	58	66	129	148	1291	1675	3040	3950
6-0	6'-0	8	8	8 x 10	5	4	845	1010	67	74	152	168	1235	1545	3700	4650

GENERAL NOTES

1 TIMBER CULVERTS SHALL BE CONSTRUCTED OF TREATED TIMBER OF STRUCTURAL GRADE CONFORMING TO AREA SPECIFICATIONS FOR STRUCTURAL TIMBER

2 TIMBERS WITH APPRECIABLE WARP, PARTICULARLY WALL TIMBERS SHALL NOT BE USED.

3 TIMBERS SHALL BE CUT TO LENGTH AND BORED BEFORE TREATMENT

4 SURFACES OF TREATED TIMBER UNAVOIDABLY CUT OR DAMAGED IN CONSTRUCTION SHALL BE FIELD TREATED WITH TWO COATS OF HOT CREOSOT OIL AND ONE COAT OF HOT SEALING COMPOUND, OR EQUAL HOLES UNAVOIDABLY BORED IN THE FIELD IN TREATED TIMBER SHALL BE THOROUGHLY SATURATED WITH HOT CREOSOTE OIL AND THE FASTENER IMMEDIATELY PLACED

5 PROTECTIVE COATINGS OR GALVANIZING OF METAL FASTENINGS SHALL CONFORM TO RECOMENDATIONS FOR "USE OF PROTECTIVE COATINGS FOR IRON AND STEEL FASTENINGS FOR WOOD BRIDGES" AREA MANUAL, CHAP 7 DOUBLE GRIP SPIKES SHALL BE DIPPED IN A PRESERVATIVE BEFORE DRIVING

6. LOCK NUT OR SPRING WASHER SHALL BE USED ON ALL BOLTS, AND NUTS TIGHTENED SECURELY

7 BACKFILLING OF CULVERTS SHALL BE BUILT UP UNIFORMLY ON BOTH SIDES, AND EMBANKMENT CONSTRUCTED IN LAYERS, WELL COMPACTED IN ACCORDANCE WITH BEST PRACTICE

DESIGN DATA (TANGENT TRACK)

LIVE LOAD COOPER'S E-72 LOADING AXLE LOADS DISTRIBUTED UNIFORMLY OVER A DISTANCE OF 5'-0 PARALLEL TO TRACK, AND UNIFORMLY OVER A DISTANCE EQUAL TO LENGTH OF TIE PLUS DEPTH OF FILL UNDER TIES PERPENDICULAR TO TRACK

DEAD LOAD. ASSUMED WEIGHT OF MATERIALS FOLLOWS:

TRACK RAILS AND FASTENINGS	200 LBS PER LINEAL FT. OF TRACK
EARTH FILL AND BALLAST	120 LBS PER CU FT
TIMBER	60 LBS. PER CU FT

LATERAL EARTH PRESSURE ACTIVE EARTH PRESSURE EQUAL TO 0.286 WH
WHERE W = 120 LBS PER CU FT
H = DEPTH BELOW BASE OF RAIL PLUS LIVE LOAD SURCHARGE

TIMBER SECTIONS FULL NOMINAL DIMENSIONS WITHOUT REDUCTION FOR BOLT HOLES.

UNIT WORKING STRESSES FOR ALLOWABLE UNIT WORKING STRESSES FOR TIMBER SEE PARAGRAPH 301 AND TABLE 705 OF SPECIFICATIONS FOR DESIGN OF WOOD BRIDGES AND TRESTLES FOR RAILWAY LOADING.

RECOMMENDED PRACTICE
FOR
DESIGN OF WOOD CULVERTS
E-72 LOADING FOR HEIGHTS UP TO 15 FT
BASE OF RAIL TO FLOW LINE

Report of Committee 24—Cooperative Relations With Universities

S. R. Hursh, *Chairman,*
L. L. Adams
J. B. Akers
M. B. Allen
W. S. Autrey
J. B. Babcock
T. A. Blair
Armstrong Chinn
J. B. Clark
H. R. Clarke
R. P. Davis
O. W. Eshbach
P. O. Ferris
E. M. Hastings
W. H. Huffman
Clark Hungerford
J. R. Ivey, Jr.
A. V. Johnston
G. A. Kellow
W. S. Kerr
H. E. Kirby
R. B. Kittredge
T. R. Klingel
N. W. Kopp
B. B. Lewis
F. J. Lewis
H. S. Loeffler
E. E. Mayo
A. A. Miller
C. T. Morris
C. H. Mottier
R. C. Nissen
C. G. Grove,
Vice-Chairman,
L. M. Ogilvie
W. A. Oliver
J. E. Perry
R. B. Rice
J. A. Rust
W. C. Sadler
H. O. Sharp
J. F. D. Smith
R. J. Stone
D. W. Tilman
E. C. Vandenburgh
Barton Wheelwright
R. C. White
A. D. Wolff, Jr.
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 438

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 438

3. The cooperative system of education, including summer employment in railway service.

   Progress report, presented as information .... page 440

The Committee on Cooperative Relations with Universities,
S. R. Hursh, *Chairman.*

AREA Bulletin 492, January 1951.

Report on Assignment 1

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.

J. B. Akers (chairman, subcommittee), M. B. Allen, J. B. Clark, H. R. Clarke, C. G. Grove, E. M. Hastings, Clark Hungerford, G. A. Kellow, N. W. Kopp, F. J. Lewis, C. H. Mottier, R. B. Rice, R. J. Stone, R. C. White, A. D. Wolff, Jr.

This is a progress report, submitted as information.

Arrangements have been made by means of which it is expected to develop through the AAR the reaction of railroad managements to the subject of this assignment, and the extent to which its importance has been recognized by the various railroads. It is hoped that this effort will bring to the attention of railway managements the need for developing this source of future technical and managerial personnel. The data, when assembled, should prove invaluable in convincing educational leaders of the need for courses in railroad transportation, and for interesting qualified undergraduates in the opportunities in the railroad field.

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, W. S. Autrey, T. A. Blair, C. G. Grove, J. R. Ivey, Jr., H. E. Kirby, B. B. Lewis, H. S. Loeffler, E. E. Mayo, C. T. Morris, J. E. Perry, J. A. Rust, W. C. Sadler, H. O. Sharp, J. F. D. Smith, D. W. Tillman, Barton Wheelwright.

This is a progress report, presented as information.

In the past, this subcommittee has emphasized the fact that two of the most effective methods of stimulating an interest in transportation on the part of college and university students is for the railroads to furnish inspiring lecturers to the schools, and also to provide inspection trips for students to interesting activities of the railroads.

Reports received by the subcommittee indicate that perhaps not as many talks have been given during the past year as in previous years. The reason for this is probably that there was less recruiting of engineering graduates during the past year. Many schools avail themselves of an opportunity to have railroad recruiting personnel give talks on some transportation subject, and with a little planning, such talks can be given without loss of time when recruiting is in progress.

Among the talks by railroad representatives during the past year before student groups was that presented by N. W. Kopp, division engineer of the Illinois Central Railroad, entitled "Railway Engineering Maintenance," given to the ASCE student section of the University of Illinois; also, one by Clark Hungerford, president of the St. Louis–San Francisco Railway, entitled "Ladders but No Escalators," given before Theta Tau of the University of Arkansas; one by J. B. Akers, chief engineer of the Southern Railway System, before a student group of the ASCE at the annual meeting of that society in Washington; two addresses by Ray McBrian, engineer standards and research of the Denver and Rio Grande Western Railroad, before the senior engineering class of the University of Utah, in which he discussed railroad engineering problems and research problems; an address by James H. Aydelott, vice-president of the Association of American Railroads on the subject, "Railway Employment for the Graduate Engineers," given before a student group of the University of Illinois; and an address by W. H. Huffman, division engineer, Chicago and North Western Railway, entitled "Railway Engineering—Past and Present," before the Wisconsin Chapter of the ASCE.

L. K. Sillcox, executive vice president of the New York Air Brake Company, gave five addresses during the year. The first, entitled "Geared to Gain," was given at Princeton University; the second, entitled "Struggle to Succeed," was given at Purdue University; the third, entitled "Tugging for Traffic" was given at Harvard University; the fourth, entitled "Two Years After," was delivered at Yale University; and the fifth, entitled "High Speed Horses," was delivered at M.I.T.

John W. Barriger, president of the Chicago, Indianapolis and Louisville Railway, gave four addresses during the year; one at the Amos Tuck School of Business Administration, Dartmouth College, the second before the senior students in Engineering Administration at M.I.T., the third at the School of Business, Northwestern University, and the fourth at the Business School of Indiana University.

Among the inspection trips arranged for student groups by the railroads may be mentioned the one by J. B. Akers of the Southern Railway System, where a group of students attending an ASCE meeting at Washington visited the Potomac yard, the test labroatory and the diesel shop at Alexandria of that railroad. Three inspection trips for students of the University of Minnesota were arranged by railroads during the year—one by the Chicago, Milwaukee, St. Paul and Pacific Railroad to inspect its track layout and other facilities in the vicinity of its passenger depot at Minneapolis, one by the Minneapolis and St. Louis Railroad for the inspection of the new diesel shop at its Minneapolis terminal, and one by the Soo Line Railroad at which students inspected and rode several miles on the AAR magnetic-type rail detector car. The Chicago and North Western Railway, through its chief engineer, E. C. Vandenburgh, recently arranged for a group of engineering seniors of Iowa State College to visit the yards and freighthouse facilities at Proviso, Ill.

Quoting from a letter from C. H. Mottier, vice president and chief engineer of the Illinois Central Railroad: "On November 11, twelve students studying terminals under Professor W. W. Hay at the University of Illinois were our guests for an inspection trip to Markham yard, near Chicago, Ill. The students were shown the hump classification operation, arrangement of yard tracks, car repair facilities, yard office and clerical procedures, and engine service facilities. The overall operation of the yard was explained by the operating personnel. A booklet, 'Description of Markham Yard and Its Operation,' was distributed to the students. Their inspection trip has been an annual event for the past several years."

Your subcommittee wishes to call attention to a possible source of stimulation of interest on the part of student groups in transportation problems which may easily be overlooked—a reference to the large amount of research now being done at several schools through the cooperation of the AAR. A typical example is Purdue University, where the official AAR draft gear laboratory is located. Other research includes a number of investigations in the field of steel railway bridges and in railway timber fatigue. For many years the AREA has used very extensively the research facilities of such other schools as the University of Illinois and Northwestern University, as well as many others. The results of this research have proved extremely valuable in the work of the technical committees, but it is questionable whether sufficient publicity has been given these research projects to arouse the interest of undergraduate student groups in the general field of transportation.

On May 12 and 13, 1950, the AREA, representing the Engineering Division of the AAR, participated in the Second Engineering Exposition at Michigan State College, Lansing, Mich. The Engineering Division exhibit included the Association's extensive dynamic strain gage equipment, which was mounted in a new truck recently purchased to facilitate movement from one test location to another, and was accompanied by two representatives from the AAR Research Laboratory. It was estimated that approximately 400 students and others at the Exposition viewed the AAR exhibit.

Attention is directed to the very attractive pamphlet put out by the Baltimore and Ohio Railroad entitled "Technical Graduate Training Course," which describes the training program recently inaugurated by that railroad. This booklet will be of interest to all senior students contemplating railroad work, and if widely distributed, may arouse the interest of those who have not thought of entering railroad work.

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, E. M. Hastings, A. V. Johnston, W. S. Kerr, T. R. Klingel, A. A. Miller, R. C. Nissen, L. M. Ogilvie, J. E. Perry, E. C. Vandenburgh.

In previous years the committee has reported on the participation of the railroads in the cooperative system of education, summer employment, and in the reaction of college students to their work. During the past year the Korean War and the defense program have created a critical situation which will not only affect cooperative education and part-time employment, but what is more important, will affect the constant supply of technical graduates for the railroads. A summary of the situation was presented at the October meeting of the committee, and upon the recommendation of the committee the following report was approved by the Board of Direction for publication in the December issue of the AREA News.

The railroads, like industries generally, have an important stake in this matter, for under even the most favorable conditions that can be anticipated, they will be faced during the next decade with keen competition to fill even their minimum requirements for engineering graduates. At the present time it appears that there is no majority consensus as to how the situation should be met. It is probable that the proposal on Selective Service regulations herein discussed will be modified, but even with modifications, the situation can hardly be expected to change materially.

COMPARISON OF BIRTHS IN CHICAGO
RECORDED FROM 1930 TO 1949

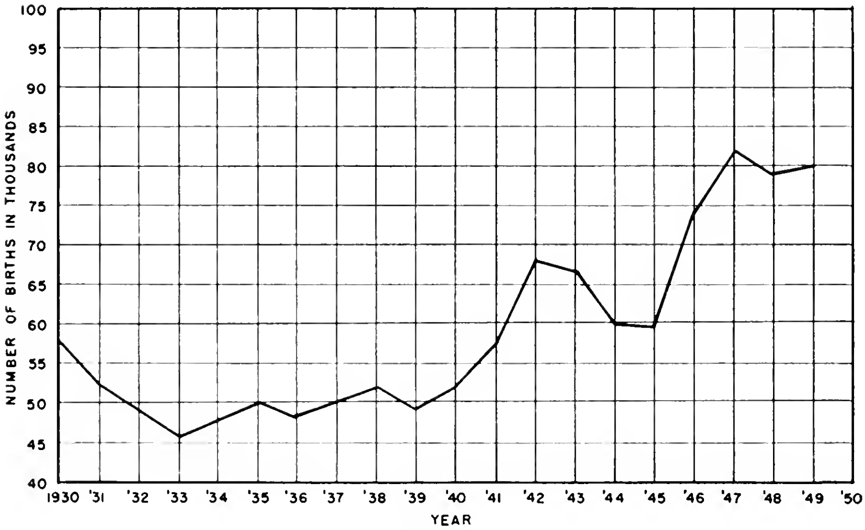


Chart I.

REPORTED PAST AND PREDICTED FUTURE
FRESHMAN ENGINEERING ENROLLMENTS FROM 1925 TO 1961
IN THE UNITED STATES

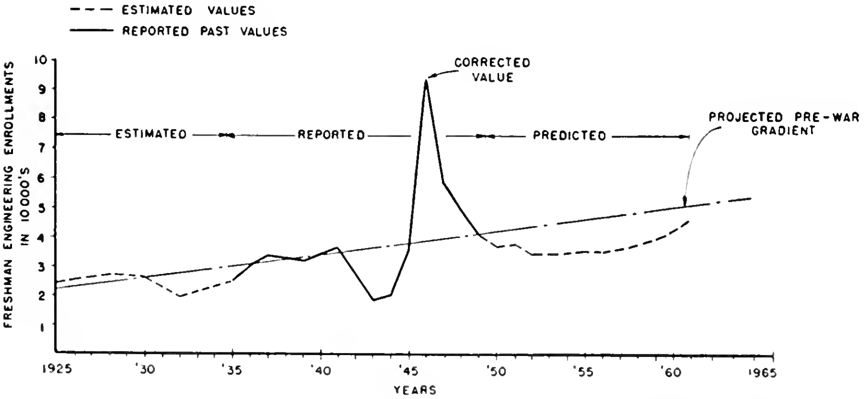


CHART COMPILED BY
A. PEMBERTON JOHNSON
EDUCATIONAL TESTING SERVICE
PRINCETON, NEW JERSEY
JUNE 12, 1950

Chart II.

On October 5, 1950, Dr. M. H. Trytten, chairman of the Scientific Advisory Committee, appointed by the director of Selective Service of the Selective Service System, submitted a report which, in principle, was endorsed by a meeting of approximately 600 college presidents and administrators, and the director of Selective Service. The report was published and was given wide circulation, in part for the purpose of receiving constructive suggestions prior to the enactment of legislation in the coming Congressional sessions and the establishment of administrative regulations.

It is pertinent at this time to review the implications of the recommendations contained in this report as they affect perhaps the most critical of all special situations—specifically, the supply of engineering talent to both the armed forces and our productive industry. Specific recommendations of the committee which have bearing upon this problem are, briefly, as follows:

(a) For any college student to be eligible for a classification which would permit him to continue his studies, he must have a score on a general aptitude test equivalent to 120 or above on the Army General Classification Tests.

(b) To continue in this special classification, the student must, as a sophomore, have maintained a scholastic record which placed him above the fiftieth percentile of his first year class. As a junior he must have maintained a scholastic record placing him above the thirty-third percentile of his class; as a senior or a fifth-year student, he must have maintained a scholastic record which placed him above the twenty-fifth percentile of the class; and as a graduate student, he must have been above the fiftieth percentile of his graduating class.

Recommendation is also made that students completing their program be given a period of four months in which to be placed in an occupation vital to the defense. No differentiation is made on the basis of program of study. The committee recognized that the current manpower needs of the military may require the induction of a large portion of the student age groups and estimated that their proposal of deferring certain individuals to meet the scientific, professional, and specialized needs for personnel would result in the deferment of not more than three percent of the men in any age group.

While the principles set forth are, on the surface, appealing in their reasonableness, because of certain unusual conditions, their application will result in a very critical situation in the supply of engineers for military and civilian needs. This situation is as follows:

Although enrollment in engineering after the close of World War II was abnormally high, the prospects for the next ten years are abnormally low. Two factors which have contributed to this situation are: (1) The low birth rate in the depression days of the Thirties, which will supply an engineering enrollment of less than pre-World War II days, as shown in Charts I and II, and (2) the popular opinion that engineering is in danger of being overcrowded, which has reduced the percentage of high school students selecting engineering. The combined result of these two factors would reduce the number of engineering graduates in 1954 to about 16,000, whereas the industrial needs are variously estimated at 20,000 to 25,000 annually, and in an emergency situation may be as high as 30,000. The prospects are that the numbers graduating from engineering schools will fail to meet even industrial needs for a period of at least ten years.

The adoption of the Scientific Advisory Committee's report to the director of Selective Service would probably reduce the inadequate supply about 50 percent. Thus, if a critical situation actually exists three or four years from now, it may be anticipated that less than one-third of the engineering talent needed for a strong military and production program will be available. It is most important that the military and industrial leaders who must rely on a reasonable supply of technical talent appreciate the significance of this situation before it is too late.

In its report, the Scientific Advisory Committee recognized the importance of a strong and well-balanced economy in the successful prosecution of a war. In fact, a strong productive economy, rather than the number of men in uniform, is America's greatest asset in protecting the civilization of our allied countries.

One of the most serious civilian implications in the application of the committee's recommendation is its influence upon our private educational institutions, the financial stability of many of which is sensitive to student enrollment.

It is recognized that the decisions to be made are not easy. The urgent problem from a defense standpoint is the training of a large number of reservists and the development of an adequate supply of technically trained men for production and military service. To place undue emphasis upon the need for men in uniform may not be in the national interest. To withdraw engineering talent from industry when it is important to step up development and production for military purposes needs careful consideration.

It should be recognized, however, that somewhat the same factors affecting the supply of engineers make it difficult to maintain a military force of 3,000,000 men. For example, between the ages of 19 and 25, there are approximately 8,000,000 men. Under the recently proposed "service credit" and point system it appears that it is not possible to maintain 3,000,000 men in training without reducing the lower age limit to 18 years and establishing a universal military training program which would require about 1,000,000 inductees a year. When it is considered that not more than 1,250,000 students will be graduated from high school annually during the next eight years and that half of them are girls, the situation is indeed serious. Not until 1960 will it be possible to support the combined military and industrial needs now contemplated, nor may educational institutions anticipate student enrollment approaching that of the recent postwar period or comparable to their physical capacities.

Report of Committee 15—Iron and Steel Structures

J. L. BECKEL, *Chairman*,
P. E. ADAMS
H. A. BALKE
F. BARON
J. E. BERNHARDT
E. S. BIRKENWALD
R. T. BLEWITT
M. BLOCK
H. F. BOBER
F. H. BOULTON, JR.
R. N. BRODIE
V. R. COOLEDGE
R. P. DAVIS
W. E. DOWLING
W. N. DOWNEY
C. E. EKBERG
E. M. GLAROS
G. V. GUERIN, JR.
O. E. HAGER
SHORTRIDGE HARDESTY
A. R. HARRIS
S. C. HOLLISTER
N. E. HUENI
M. L. JOHNSON
JONATHAN JONES
R. L. KENNEDY
J. C. KING
W. B. KUERSTEINER
M. B. LAGAARD
C. T. G. LOONEY
F. H. LOVELL
F. M. MASTERS
D. V. MESSMAN
K. L. MINER
N. W. MORGAN
CORNELIUS NEUFELD
N. M. NEWMARK
B. J. ORNBURN
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R. E. PECK
J. F. MARSH, *Vice-Chairman*,
A. G. RANKIN
W. S. RAY
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G. E. ROBINSON
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C. E. SLOAN
C. B. SMITH
H. F. SMITH
G. L. STALEY
H. C. TAMMEN
J. P. WALTON
C. EARL WEBB
A. J. WILSON
W. M. WILSON
L. T. WYLY
R. W. YOUNG, JR.
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Revisions of Rules for Rating Existing Iron and Steel Bridges and other parts of Chapter 15, submitted for adoption and publication in the Manual .... page 446

   Revisions of Specifications for Movable Railway Bridges, presented as information .... page 447

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:
   (a) Floorbeam hangers;
   (b) Counterweight trusses of bascule bridges.

   No report.

5. Design of steel bridge details.
   Progress report on Fatigue Tests of Beams in Flexure, published in Bulletin 489, Vol. 52, pages 111 to 129, inclusive .... page 111

6. Preparation of steel surfaces before painting.

   No report.

7. Specifications for cold riveted construction.

   No report.

AREA Bulletin 492, January 1951.

8. Specifications for design of corrugated metal culverts, including corrugated metal arches.

   Progress report as information .... page 478

9. Use of high strength structural bolts in steel railway bridges.

   No report.

10. Substitutes for paint for preservation of steel bridge structures.

    No report.

The Committee on Iron and Steel Structures,
J. L. Beckel, *Chairman.*

Report on Assignment 1

Revision of Manual

E. S. Birkenwald (chairman, subcommittee), J. L. Beckel, R. P. Davis, Jonathan Jones, J. F. Marsh, Cornelius Neufeld, C. H. Sandberg, G. L. Staley.

Rules for Rating Existing Iron and Steel Bridges

The Association last year adopted revised rules which did not include Article 106a and which stated that Article 112 was the same as Article 114 of the current rating rules prior to the adoption of the revised rules in 1950. Consequently, it is necessary for the Association to adopt and publish the following revisions to the presently published Rules for Rating Existing Iron and Steel Bridges:

Page 15–122. Delete Article 106a.

Page 15–124, Article 112.

Change the present text to read:

The application of the live load and the impact to multiple-track bridges shall be as specified in the AREA Specifications for Steel Railway Bridges.

The following is new material, which the committee recommends for adoption and publication in the Manual:

[1]BLAST AND FUME PROTECTION

On bridges over tracks operated with steam locomotives, overhead structures 24 ft. or less above the rail should be protected from locomotive blast or fumes, if likely to be injured thereby. In deciding on the need for such protection and the kind of protection, consideration shall be given to the number of locomotives passing daily, and to other operating conditions affecting the force and extent of blast and possible corrosion by fumes.

In design of overhead structures it is desirable to avoid pockets of poor air circulation above the track. If the design requires such pockets, special protection against the action of fumes and moisture shall be provided for the structural steel. The simplest protection against fumes is an excess of material beyond structural requirements, built into the structure. When this form of protection is used, the corrosion allowance shall be plainly stated on each member, on the plans. Properly designed concrete encasement of steel is satisfactory, but it shall be removed and replaced if any lack of bond develops.

Blast plates shall be of corrosion-resisting metal or metal plates with protective coating.

Blast plates shall be not less than 4 ft. wide, and long enough to completely protect the structure. The plates shall project not less than one foot beyond the edge of the structure or exposed part. The axis of the blast plate shall coincide with the center of stack, superelevation being considered. If superelevation is four inches or more, and clearance permits, the plane of the blast plate shall be normal to the inclined axis of the track. The blast plates shall be so detailed and placed that they do not deflect the blast against other parts of the structure.

Blast plates shall be designed so as to be readily replaceable. Fastenings, framing angles and hangers shall be of corrosion-resisting metal. It is desirable to have hangers attached by welding or such other arrangement as will leave no part of bolts, rivets or weld exposed to direct blast. On account of probable corrosion, all dimensions of blast plates and their supports shall be considerably in excess of structural requirements. The following minimum dimensions are recommended:

	In.
Corrosion-resisting low alloys	3/16
Stainless steel	1/8
Wrought iron	3/8
Cast iron	3/4
Bolts and rivets	¾

The material following is submitted as information this year, and for the purpose of soliciting comments and criticism prior to submission next year of the completely revised specifications for adoption and publication in the Manual. The revisions and additions relate to the partial draft of the specifications which appeared in AREA Proceedings, Vol. 51, 1950, pages 445–469; reference is also made to Manual pages 15–49 to 15–92, incl., for text not included in Vol. 51.

Revisions of

SPECIFICATIONS FOR MOVABLE RAILWAY BRIDGES

INFORMATION TO BE FURNISHED

(See Proceedings, Vol. 51, 1950, p. 446.)

In the first line, change the word "drawings" to "plans".

I PROPOSALS AND GENERAL REQUIREMENTS

(See Proceedings, Vol. 51, 1950, pp. 447–451.)

104. Machinery Drawings

Add the following paragraph:

The contractor shall make a drawing showing all bearings and other elements of the bridge which require lubrication, and designating the lubricants to be used and the frequency of lubrication.

113. Classification of Parts

Change line (d) to read as follows in order to make it consistent with paragraph (d) of Art. 114:

(d) Counterweight sheaves, shafts, and bearings, by the pound.

Change line (f) to read as follows:

(f) Tread plates and castings, by the pound.

114. Parts Included in Classes

Under (a) *Structural Carbon Steel,* add to the end of the first paragraph, "except structural steel parts that function as machinery parts, which shall be classified under (c) *Machinery.*"

In second line of second paragraph, delete "shim plates for adjustment of machinery."

Under (c) *Machinery,* add to the list of items "Gear covers and guards" after "Worm gearings," and "Shims" after "Wrenches."

Change (f) to read as follows:

(f) *Tread Plates and Castings.*—Tread plates and castings for segmental girders and track girders for rolling lift bridges, together with their connecting bolts.

Under (i) in the first line, after the words "scrap metal," add the words "or steel punchings."

Under (j) add the words "or steel punchings" at the end of the paragraph.

II GENERAL FEATURES OF DESIGN

(See Proceedings, Vol. 51, 1950, pp. 451–454.)

209. Materials Used

In second paragraph from the bottom of the page, change heading *Treated Steel* to *Hardened Steel.*

In second paragraph, under *Weldments,* in the 5th line after the word "machined," add the words "unless otherwise stipulated."

Change the last paragraph of Art. 209 to read as follows:

Cast Iron.—Cast iron shall be used only for the parts of motors, engines, and standard manufactured articles that are usually made of cast iron, for balance chains for vertical lift bridges, and for counterweights.

III LOADS, UNIT STRESSES, AND PROPORTIONING OF PARTS

(See Proceedings, Vol. 51, 1950, pp. 454–464.)

306. Power Requirements and Machinery Design

In the first line of Paragraph C, omit the words "unequal arm."

307. Machinery Resistances

Omit italics for the words, "For trunnion friction."

Substitute the following for lines (a) and (b) under the heading "For trunnion friction."

(a) Sliding bearings, one or more complete rotations	0.135	0.09
(b) Sliding bearings, less than one complete rotation	0.18	0.12
(c) Roller bearings	0.004	0.003

308. Machinery Losses

Item reading "For efficiency of worm gearing, collar friction included" should read, ".... collar friction not included."

309. Brakes, and Machinery Design for Braking Forces

Add the following to the last paragraph on page 458: Under this condition, the normal unit stresses may be increased 50 percent.

313. Unit Stresses in Machinery Parts

In the next to last line of the table at the top of page 459, change "Grade 25" to "Class No. 25"; also in the last line change "Phosphor-bronze, Class D" to "Bronze—Alloy D."

In the third line from the end of Art. 313 change the equation so as to read as follows:

$$K_3 = 1.1 + 0.033\sqrt{n}$$

314. Bearing Pressures

Change to read as follows:

The following maximum bearing pressures on the diametral projected area, in pounds per square inch, for rotating and sliding surfaces shall be used:

(a) For intermittent motion and for speeds not exceeding 50 ft. per min.:	
Pivots of swing bridges, hardened steel on Alloy A bronze discs	3,000
Pivots of swing bridges, hardened steel on Alloy B bronze discs	2,500
Trunnion bearings and counterweight sheave bearings, rolled or forged steel on Alloy B bronze	1,500
Shaft journals, rolled or forged steel on Alloy C bronze	1,000
Wedges, cast steel on cast steel or structural steel	1,500
Acme screws which treatment motion, rolled or forged steel on Alloy D bronze	1,500
(b) For speeds exceeding 50 ft. per min.:	
Shaft journals, rolled or forged steel on Alloy C bronze	600
Shaft journals, rolled or forged steel on babbitt metal	400
Shaft journals, rolled or forged steel on cast iron	400
Thrust collars, rolled or forged steel on Alloy C bronze	200
Cross-head slides (speed not exceeding 600 ft. per min.)	50
Step bearings for vertical shafts	
Hardened steel shaft end on Alloy B bronze	1,200
Hardened steel shaft end on Alloy C bronze	600

The maximum pressures for the various bearings named in paragraph (b) above also shall not exceed those specified in Art. 315.

For slow-moving journals, as on trunnions, counterweight and deflector sheave bearings, and operating drum bearings, the bearing area shall be taken as the net area, the effective areas of oil grooves being deducted from the gross bearing area.

For crank pins and similar joints with alternating application and release of pressure, the bearing values given above may be doubled.

Replace Art. 315, Journal and Pivot Bearings, by the following:

315. Heating and Seizing

To avoid heating and seizing at high speeds, the bearing pressures on shaft journals, step bearings for vertical shafts, thrust collars, and Acme thread power screws shall not exceed:

a. Shaft journals, rolled or forged steel on bronze .... $p = \frac{250{,}000}{nd}$

b. Step bearings, hardened steel on bronze .... $p = \frac{60{,}000}{nd}$

c. Thrust collars, rolled or forged steel on bronze .... $p = \frac{50{,}000}{nd}$

d. Acme screws, rolled or forged steel on bronze .... $p = \frac{220{,}000}{nd}$

p = pressure in pounds per square inch of projected area.
n = number of revolutions per minute.
d = diameter of journal or step bearing, or mean diameter of collar or screw in inches.

For crank pins and similar joints with alternating application and release of pressure, the bearing values given by the foregoing formulas may be doubled.

Where pressures given by the foregoing formulas exceed those specified for similar parts in Art. 314, the values in the latter article shall be issued.

The pressures given by the foregoing formulas shall not be exceeded under the overload provisions of Art. 319.

316. Pressure on Rollers

Change "Tool steel" to "Hardened steel, 53,000 min. yield point in tension."

Change "Hardened tool steel" to "Hardened steel, 63,000 min. yield point in tension."

Add the following paragraph:

For rollers of trunnion and counterweight sheave roller bearings, the permissible pressure in pounds per linear inch of roller shall be 3,000 d, where d is the diameter of the roller in inches. One fifth of the rollers shall be taken as effective in carrying the load.

317. Shafts

In the first two equations change the term "d^3" *to* "πd^3".

In the last two formulas, change the reference from Art. 311 to Art. 313.

IV DETAILS OF DESIGN

(See Manual pages 15–61 to 15–65, incl., for original text of paragraphs 401 to 463, incl.)

(a) General

401. Rail End Connections

Designs for rail and connections will be furnished by the engineer.

If the connections are of the sliding-rail lock type, the ends of the bridge rails shall be fixed, cut square, and connected with the approach rails by sliding sleeves or joint bars, to carry the wheels over the openings between the rail ends. The distance from the center of the track to the inside of the rail lock wheel tread shall be not less than 2 ft. 6 in., and not more than 2 ft. 6½ in., the heads of the rails being planed off on the outside if necessary.

If the connections are of the miter type, the two sections shall be held positively in a transverse direction by guides, to prevent spreading at the miter joint.

Provisions shall be made so that the rail locks can be closed only when the span is seated and the rail end sections properly engaged.

The edges of all drilled holes in rail locks and in the rail ends adjacent thereto shall be chamfered approximately 1/16 in. All reentrant angles in these appurtenances shall be filleted.

402. Air Buffers

Air buffers to aid in seating the movable span shall be provided as elsewhere herein specified.

The inside diameter of the cylinder of the air buffer shall be not less than 10 in., and the travel of the piston not less than 24 in.

There shall be three cast iron packing rings for each piston.

Each air buffer shall be provided with a needle valve and a check valve, and these shall be suitable for sustaining for short intervals air pressures of 1000 psi. and temperatures of 800 deg. F.

403. Counterweights

Counterweights usually shall be of concrete, supported by a steel frame or, preferably, inclosed in a steel box. Boxes shall be rigidly braced and stiffened to prevent warping or bulging. All surfaces of the boxes in contact with the concrete shall be provided with open holes (about 1 sq. in. to each 10 sq. ft. of surface) to permit escape of water from the box as the concrete dries out.

Counterweights not inclosed in steel boxes shall be adequately reinforced.

Counterweights shall be made so as to be adjusted easily for variations in the weight of the span and in the unit weight of the concrete. Usually this shall be done by adding or taking off properly located cast iron or concrete balance blocks. Pockets shall be provided in the counterweights to house the balance blocks necessary to care for not less than 3½ percent underrun and 5 percent overrun in the weight of the span. Each completed counterweight shall contain not less than one percent of its weight in balance blocks, arranged so as to be readily removable for future adjustment. Additional blocks for future adjustment in the amount of 0.5 percent of the weight of the counterweight shall also be provided and shall be stored at the site as directed by the engineer. All balance blocks shall be firmly held in place so that they will not move during the operation of the bridge. Balance blocks for future adjustment shall be provided with recessed handles and shall weigh not more than 100 lb. Balance blocks shall be furnished only as necessary to meet the specified requirements for future adjustment and to secure the required balance of the span and counterweights.

Pockets in counterweights shall be provided with drain holes not less than two in. in diameter. The pockets shall be covered. The cover, its fastenings and frame shall be of metal. The cover shall be weatherproof.

404. Concrete

Concrete, unless otherwise stipulated, shall conform to the Specifications for Concrete and Reinforced Concrete Railroad Bridges and Other Structures of the AREA, shall be made with Type II cement, and shall be proportioned as directed by the engineer, with not more than 6 gal. of water per sack of cement. Where heavy concrete is required for counterweights, the coarse aggregate shall be trap rock, magnetic iron ore, or other heavy material, or the concrete may consist of steel punchings or scrap metal, and mortar composed of 1 part of cement and 2 parts of fine aggregate. The maximum weight of heavy concrete shall be 315 lbs. per cu. ft. and preferably not more than 275 lbs. per cu. ft. Heavy concrete shall be placed in layers and consolidated with vibrators or tampers. Methods of mixing and placing shall be such as to give close control of the unit weight of the concrete and uniformity of unit weight throughout the mass. Counterweights containing punchings or scrap metal or iron ore aggregates shall be inclosed in steel boxes.

Concrete counterweights of the revolving type shall be poured continuously if practicable.

For ascertaining the weight of the concrete, test blocks having a volume of not less than 4 cu. ft. for ordinary concrete, and 1 cu. ft. for heavy concrete, and 1 cu. ft. for the mortar for heavy concrete, shall be cast at least 30 days before concreting is begun. Two test blocks of each kind shall be provided, and one weighed immediately after casting and the other after it has seasoned.

405. Machinery Design

The machinery shall be simple and substantial in design, and easily erected, inspected, adjusted, painted, and taken apart. The fastenings shall be adequate to hold the parts in place under all conditions of service. If practicable, each group of machinery shall be mounted on a self-contained cast steel frame or base; otherwise on a rigid structural steel support.

406. Location of Machinery

The location of the machinery shall be such as to allow easy access, and room for ample size of machinery parts.

407. Bearings

Bearings shall be placed close to the points of loading and located so that the unit bearing pressure will be as nearly uniform as possible.

Journal bearings shall be of the split type with one half recessed into the other half. The length of a bearing shall be not less than its diameter. The base half of bearings for gear trains and for mating gears and pinions shall be in one piece. The caps of bearings shall be secured to the bases with turned bolts with square heads recessed into the base and with double hexagonal nuts. The cap bolts shal have a close body fit in the holes and the nuts shall bear on finished bosses or spot-faced seats.

Provision shall be made for the alining of bearings during erection by means of shims and for the adjustment of the caps by means of laminated liners or other effective device, where it is obvious that such alining and adjustment will be necessary.

Large bearings shall be provided with effective means for cleaning without dismantling the parts.

408. Linings

Bearings carrying heavy loads shall have phosphor bronze linings; for other bearings the lining may be phosphor bronze or babbitt metal. For split bearings, the lining shall be in halves and shall be provided with an effective device to prevent its rotation under load. The force tending to cause rotation shall be taken as 1/16 of the maximum load on the bearing and as acting at the outer circumference of the lining. There shall be ¼ in. clearance between the lining of the cap and the lining of the base into which laminated liners shall be placed. The inside longitudinal corners of both halves shall be rounded or chamfered, except for a distance of ⅜ in. from each end or shaft fillet tangent point.

Linings for solid bearings shall be in one piece and shall be pressed into the bearing bore and effectively held against rotation.

409. Step Bearings

The bearing ends of vertical shafts running in step bearings shall be of hardened steel, and shall bear on bronze discs.

410. Roller Bearings for Heavy Loads

Roller bearings shall be used, when so specified, to support the trunnions of bascule bridges, the counterweight sheave shafts of vertical lift bridges, and similar shafts carrying heavy loads. Each roller bearing shall be of a type, or shall be so mounted, that the deflection of the shaft will produce no overloading of any part of the bearing or housing. The bearing rollers shall be relatively short for their diameter, shall be closely spaced in bronze cages, and shall run between hardened-steel races, mounted in the housing and on the shaft. The bearing mountings on each shaft shall be such that the shaft will be restrained from axial movement by one mounting, and shall be free to move in the other mounting.

Each roller bearing shall be mounted in an oil- and water-tight steel housing, which shall be provided with means for replenishing the lubricant and arranged for convenient access for thorough cleaning of the operating parts.

Rollers, rolls, and races shall be of hardened steel having a Brinell hardness not less than 600. Bearings shall be made by a manufacturer of established reputation who has had bearings of comparable size of the same materials and type in successful service for at least ten years.

411. Lubrication

Provision shall be made for effective lubrication of sliding surfaces, and of roller and ball bearings. Lubricating devices shall be easily accessible.

Each sliding bearing requiring lubrication shall have a high-pressure grease fitting, containing a small receiving ball or cone check valve, made of steel, that will receive the grease and close against back pressure. These fittings shall be connected to the linings of bearings by means of brass pipe, which shall be screwed into the lining through a hole in the cap. If the bearings are not readily accessible, the fittings shall be placed where they will be accessible, and shall be connected to the bearings by means of brass pipe.

Grease ducts shall be so located that the lubricant will tend to flow, by gravity, toward the bearing surface. Grooves shall be provided, wherever necessary, for the proper distribution of the lubricant.

The grooves for trunnion bearings may be cut in either the shaft or the lining. Such grooves shall be straight, parallel to the axis of the shaft, and for large bearings no fewer than three; they shall be so located that the entire bearing surface will be swept by lubricant in one movement of opening or closing the bridge, or in 90 deg. rotation of the shaft, whichever is less. Each such groove shall be served with lubricant by a separate pressure fitting. The grooves shall be of such size that a 5/16-in. diameter wire will lie wholly within the groove; their bottoms shall be rounded to a ¼-in. radius. The grooves shall be accessible for cleaning with a wire.

The grooves for counterweight sheave bearings may be in accordance with the requirements of the foregoing paragraph, or they may be spiral grooves cut in the lining and served with pressure fittings. A cleanout hole shall be provided in the bearing base and connected to the lowest point of the spiral grooves so that the journal surface can be cleaned and the grooves flushed out.

In disk bearings, straight grooves shall be cut in the upper of the two rubbing surfaces in contact. The grooves shall be not less than ¼ in. wide and deep, and the corners shall be rounded to a radius not less than half the width of the groove. The corners at the bottom of the grooves shall be filleted so there shall be no sharp corners.

Small bearings with light bearing pressures and slow or intermittent motion, and not readily accessible, may be lubricated with self-lubricating bushings. Bushings shall be of a character which will not be injured by the application of oil, and the bearings shall be provided with oil holes for emergency lubrication, and oil holes to be fitted with readily removable screw plugs.

Hand-operated grease guns having a capacity of 12 oz. shall be provided to service all lubrication fittings. There shall also be provided portable loaders of 25-lb. capacity and a loader for use with 100-lb. grease drums. All necessary adapters shall be provided for the equipment.

Two guns shall be furnished for each swing and bascule span, and three guns for each lift span. One portable loader and one drum loader shall be furnished for each movable bridge.

412. Shafts

For shafts supporting their own weight only, the unsupported length of the shaft shall not exceed $L = 80\sqrt[3]{d^2}$ in which $L =$ length of shaft between bearings in inches; $d =$ diameter of shaft in inches.

Shafts likely to be thrown out of line by the deflection of the supporting structure shall be made in non-continuous lengths, and the arrangement preferably shall be such that only angular misalinement need be cared for by the couplings, offset misalinement being cared for by a floating shaft. Each length of shaft preferably shall rest in not more than two bearings.

Shafts shall be proportioned so that the angular deflections will not exceed the following limits:

(a) For ordinary service, as in the operating gear trains, 1 deg. in a length equal to 20 times the diameter of the shaft.

(b) For special cases where more positive action is desirable, as in shafts driving end-lifting devices, 0.08 deg. per lin. ft. of shaft.

Line shafts connecting the machinery at the center of the bridge with that at the ends shall be designed to run at fairly high speed, the speed reduction being made in the machinery at the end. The maximum speed of line shafts shall not exceed 2/3 of the critical speed of any section of the shaft.

Shafts transmitting power for the operation of the bridge, and shafts 4 ft. or more in length forming part of the operating machinery of rail locks and bridge locks, shall be not less than 2½ in. in dia.

Journals on cold-rolled shafting shall not be turned down. Pinions may be forged integral with their shafts.

413. Shaft Couplings

So far as practicable, all couplings used in connection with the machinery shall be standard manufactured couplings. The couplings shall be close to the bearings.

Couplings between machinery units shall preferably be of the gear type, providing for angular misalinement or for both angular and offset misalinement.

Couplings connecting machinery shafts to electric motor or internal combustion engine shafts shall be flexible couplings, transmitting the torque through metal parts and providing for both misalinement and shock.

Machinery shafts so supported and assembled as to avoid any misalinement between the shafts may be connected by flange couplings. The bolt heads and nuts shall be seated in recesses or protected by flanges. The couplings shall be cylindrical.

All couplings shall have pressed fits on their shafts and shall be keyed to the shafts. The couplings shall in all cases be fitted to their shafts in the shop, the couplings after manufacture being shipped to the manufacturers of the shafts as necessary to accomplish this result.

414. Longitudinal Thrust

Wheels and similar parts shall be securely fastened, to prevent longitudinal movement, by set screws through the hub, or by clamps around the shaft. Provision shall be made to hold bevel gears and worm wheels against movement along the shaft. The axial thrust from bevel gears shall be taken by the shaft bearing with a loose bronze washer between the gear hub and the face of the bearing, or with an equivalent means to carry the thrust load to the bearing.

415. Collars

Collars shall be provided wherever necessary to prevent the shaft from moving lengthwise. There shall be at least two set screws, 120 deg. apart, in each collar. The set screws shall have cone points, and the shafts shall be counterbored for the set screws. The edges of the holes shall be peened over the set screws after the collars are adjusted. If a shaft or trunnion receives a longitudinal force, there shall be a thrust bearing to prevent longitudinal movement.

416. Gear Teeth

Gear teeth, unless specifically stipulated otherwise, shall be machine cut, shall be of the involute type, and shall have a pressure angle of 20 deg. Gears in general shall have straight spur teeth of full depth. For special applications, stub teeth may be used. For tooth speeds over 1200 ft. per min., and for tooth speeds over 500 ft. per min., where quiet operation is desired, herringbone gears preferably shall be used. Herringbone gears shall be assembled in a common frame, shall be fully enclosed in metal housing, and shall run in oil; they shall be assembled so that one gear of each pair of mating gears may have a slight axial movement to permit operation at the correct location relative to the other gear. Unless otherwise stipulted, all gear teeth shall be cut from solid rims.

For full-depth spur gear teeth, the addendum shall be not more than 0.3183 of the circular pitch and the tooth thickness measured on the pitch circle shall be 0.495 of the circular pitch. For stub teeth, the addendum shall be not more than 0.2546 of the circular pitch.

The face width of a spur gear shall be not less than 1½ times the circular pitch. The face width of a bevel gear shall be not more than 1/3 of the slant height of the pitch cone, nor more than 3 times the circular pitch at the middle section of the tooth.

The circular pitch of spur gears, other than motor pinions, transmitting power for moving the span, shall be not less than 1 in. The circular pitch for main rack teeth shall be not less than 1½ in.

Pinions shall have not less than 15 teeth. Rack pinions shall have not less than 17 teeth. Motor pinions preferably shall have not less than 19 teeth.

Herringbone gear teeth shall be cut to the same normal profile as spur gear teeth. The helical angle shall be not less than 23 deg. and not more than 30 deg. The net width of face, measured parallel to the axis of the bore, shall be not less than 3 times the circular pitch nor more than 1½ times the pitch diameter of the pinion.

417. Strength of Gear Teeth

In the design of spur gears, bevel gears, and herringbone gears, the load shall be taken as applied to only one tooth.

The tooth profile for spur, bevel and herringbone gears shall be the 20 deg., full depth or stub, involute and shall be of the proportions stated in Art. 416.

The allowable load on gear teeth shall conform to the following formulas:

(a) Spur Gears and Bevel Gears

For full depth involute teeth

$$W = psf\left(0.154 - \frac{0.912}{n}\right)\frac{600}{600 + V}$$

For stub involute teeth

$$W = psf\left(0.178 - \frac{1.033}{n}\right)\frac{600}{600 + V}$$

(b) Herringbone teeth, full depth

$$W = 0.7psf\left(0.154 - \frac{0.912}{n}\right)\frac{1200}{1200 + V}$$

In the above formulas

W = allowable tooth load, in pounds.
p = circular pitch, in inches.
s = permissible unit stress, in psi.
f = effective face width, in inches.
n = number of teeth in gear.
V = velocity of pitch circle, in feet per minute.

The effective face width for spur and bevel gears shall be the full face width up to three times the circular pitch; for greater face widths, the effective width shall be three times the circular pitch but not less than one-half the full width.

The effective face width for herringbone gears shall be the net active width of face measured parallel to the axis of the bore.

For calculating the strength of bevel gear teeth, the middle section of the tooth shall be taken. The number of teeth "n" in the above formulas for bevel gear teeth shall be the formative number which, for the pinion, is determined as follows:

$$n = np\sqrt{1 + \left(\frac{np}{ng}\right)^2}$$

Where np = actual number of teeth in pinion.
ng = actual number of teeth in gear.

The permissible stresses in pounds per square inch for cut gear teeth of all types shall be:

Bronze	9,000
Cast steel	16,000
Class C forged carbon steel	20,000
Class E forged carbon steel	22,500
Forged alloy steels	60 percent of yield point in tension, but not more than 1/3 of ultimate strength in tension.

The permissible stress in pounds per square inch for machine molded teeth shall be:

Cast steel	8,000

For racks and their pinions and for all other mating gears and pinions which are not supported in and shop-assembled in a common frame, the permissible unit stresses shall be decreased 20 percent.

418. Worm Gearing

Except for the end lifts and center wedges of swing bridges, worm gearing preferably shall not be used for transmitting power. In calculating the strength of worm gear teeth, the load transmitted shall be taken as equally distributed between two teeth.

Worm gear reducers for transmitting power, except for end lifts of swing bridges, preferably shall be commercial units which shall be selected on the basis of their rating under the American Gear Manufacturers Association recommended practice. The helix angle of the worm shall be not less than 20 deg. The worms shall be heat-treated alloy steel forgings and the gear shall be bronze. The thread of the worm shall be ground and polished, and the teeth of the gear shall be accurately cut to the correct profile. The worm and gear-thrust loads shall be taken by anti-friction bearings, mounted in water and oil-tight housings. The unit shall be mounted in a cast-iron or cast-steel housing and the lubrication shall be continuous while in operation.

Worm gear units, that are used for end lifts and center wedges of swing bridges, shall be self-locking.

419. Screw Gearing and Cams

Except for end lifts and center wedges of swing bridges, screw gearing preferably shall not be used for transmitting power.

Screws and nuts for transmitting power shall be cut with 29-deg. general-purpose Acme thread. Anti-friction bearings shall be provided to carry all thrust loads. The unit shall be mounted in an oil and watertight housing and provided with continuous lubrication. The screw and nut shall be made of dissimilar metals, preferably steel and bronze.

Cams and similar devices transmitting power by line or point contact shall not be used.

420. Hubs

If practicable, the length of all wheel hubs shall be not less than the diameter of the bore, and for gear wheels also not less than 1.25 times the width of the teeth. The thickness of the hub, preferably, shall be not less than 0.4 of the diameter of the bore.

Unless otherwise specified, all hubs shall have pressed fits on their shafts, and shall be provided with keys designed to carry the total torque to be transmitted to the shaft.

Bascule trunnion hubs that are to fit tightly into structural parts shall have shrink fits therein, and shall be secured against rotation by keys or bolts.

421. Keys and Keyways

Keys for securing machinery parts to shafts shall be parallel-faced, square or flat. Tapered keys may be used to meet special requirements. All keys shall be fitted into keyways sunk into the hub and shaft. Preferably, the keyways in the shaft shall have closed ends, which shall be milled to a semi-circle equal to the width of the key. Keyways shall not extend into any bearing.

Keys that are not set into closed-end keyways shall be held by safety set screws, or other effective means; in vertical shafts, collars clamped about the shafts, or similar devices, shall be used.

In hubs of spoked wheels, the keyways shall be located in the centers of the spokes. If two keys are required, they shall be placed 120 deg. apart.

All keys shall have a width not greater than ¼ of the shaft diameter and the thickness of flat keys shall be approximately ¾ of their width; the dimensions shall be such that the allowance unit stresses in shear and bearing will not be exceeded.

422. Capacity of Keys

The foregoing requirements for keys and keyways are for machinery parts, whose use is intended to develop the full torsional strength of the shaft. For minor parts, the keys and keyways shall be proportioned for that size of shaft whose torsional strength would be developed by such parts.

For trunnions and similar parts which are designed chiefly for bending and bearing, the keys and keyways shall be proportioned simply to hold the trunnion from rotating. The force tending to cause rotation shall be taken as 1/5 of the load on the trunnion, and as acting at the circumference of the trunnion.

423. Bolts and Nuts

All bolts for connecting machinery parts to each other or to supporting steelwork shall have turned shanks, cut threads, and semi-finished, washer-faced, hexagonal heads and nuts. The finished shanks shall be 1/16 in. larger in dia. than the diameter of the thread which shall determine the head and nut dimensions.

The dimensions of all bolt heads and nuts shall be in accordance with the heavy series, and the threads shall be in accordance with the coarse thread series of the American Standards.

All bolt heads and nuts shall bear on seats square with the axis of the bolt. On castings, except where recessed, the bearing shall be on finished bosses or spot-faced seats. Bolt heads which are recessed in castings shall be square.

All nuts shall be secured by effective locks. If double nuts are used, both nuts shall be of standard thickness.

424. Set Screws

Set screws shall not be used for transmitting torsion; they may be used for holding keys or light parts in place. They shall be safety-type headless set screws with cone points, set in counterbored seats. Unless otherwise ordered, they shall be secured in position by peening over the holes, or by welding.

425. Tap Bolts and Stud Bolts

Tap bolts and stud bolts shall be used only by special permission of the engineer.

426. Springs

Springs preferably shall not be used to actuate any moving part. For electric parts, preference will be given to those having the fewest springs.

427. Equalizers

The net section back of the pin hole in equalizing levers shall be not less than the required net section in tension to carry the load on the pin. The net section through the pin hole shall be not less than 140 percent of the required net section in tension.

428. Covers

Dust covers shall be provided wherever necessary to protect the sliding and rotating surfaces and prevent dust from mixing with the lubricant.

Safety gear guards shall be provided for all gears in the machinery houses.

If gears or sheaves are located where falling objects may foul them, they shall be protected by metal covers easily removed.

Counterweight sheave rims shall be covered to protect them from the weather.

429. Safety Guards

Safety guards for the protection of persons shall be installed. All safety regulations shall be observed.

430. Drain Holes

At places where water is likely to collect, there shall be drain holes not less than 1 in. in dia.

431. Compressed Air Devices

Mechanical devices using power transmitted by compressed air may be used for the operation of center wedges, and lifts, centering devices, and sliding rail locks.

(b) Special for Swing Bridges

432. Center Bearing

Center-bearing swing bridges shall be so designed that when the bridge is swinging, the entire weight of the moving span is carried on a center pivot, and when the bridge is closed. the trusses rest at the center on wedges. Adjustment for height shall be provided.

433. Rim Bearing

The load on the rim girder of a rim-bearing or commercial rim- and center-bearing swing bridge shall be distributed equally among the bearing points. The bearing points shall be spaced equally around the rim girder.

Rigid struts shall connect the rim girder to a center pivot, firmly anchored to the pier. A strut shall be attached to the rim girder at each bearing point, and at intermediate points when required. No fewer than eight struts shall be used in any case.

The rim girder shall be so designed that the load will be properly distributed over the rollers. For calculating stresses in the girder, the loads shall be assumed to be distributed equally to all rollers. The span length shall be taken as the developed length of the girder between adjacent bearing points. This part of the girder shall be considered fixed at both ends. The girder shall be designed in accordance with the requirements for plate girders.

The lower track shall be strong enough to distribute the load on the rollers uniformly over the masonry.

434. Combined Bearing

In a combined rim and center-bearing swing bridge, a definite portion of the load, not less than 15 percent, shall be carried to the center by radial girders attached rigidly to the center and to the rim.

435. Shear over Center

In swing bridges having a center truss panel, this panel shall be so designed that shear will not be carried past the center. The web members of such panel shall be strong enough, however, to make the bridge secure against longitudinal wind pressure when it is open.

436. Air Buffers

Power-operated skew bridges shall be equipped with air buffers to aid in stopping the span smoothly. One air buffer shall be provided at each end of the bridge.

437. End Lift and Center Wedges

The end lifting apparatus of swing bridges shall be arranged to center the bridge accurately when closed, unless a separate device is used to center the bridge. The end-lift and center wedges shall be so designed that the action of the moving load cannot cause displacement of the end supports and wedges in case of failure or disconnection of the mechanism which actuates the end lift. The end lifting apparatus and center wedges shall be so designed as to permit adjustment. The center and end wedges may be operated by the same mechanism.

438. Rim Girders

Rim girders shall be provided with stiffeners, with fillers on both sides of the web at points of concentrated loading. These stiffeners shall fit close against both flanges. The distance between adjacent intermediate stiffeners shall not exceed 2 ft. On rim girders exceeding 5 ft. in depth, alternate intermediate stiffeners may extend only ½ the depth of the girder, unless required to be of full depth to stiffen the web. The thickness of the outstanding legs of stiffener angles shall be not less than ⅛ of their width. The tread plate for the rollers shall be securely fastened to the rim girder and shall be from 2 to 3 in. thick, depending on the weight of the bridge. The rim girder flange angles shall be not smaller than 6 in. by 4 in. by ¾ in.

439. Center Pivots

Center pivots shall consist of disks bearings, upon which the span revolves, and supporting pedestals. Disc bearings shall consist of two discs, one of phosphor bronze and one of hardened steel.

Center pivots shall be so designed that the disks may be taken out and replaced while the bridge is closed, without interfering with the operation of trains over the bridge. The disks shall be so anchored that sliding will take place only at the surface of contact of the disks.

440. Balance Wheels

For power-operated center-bearing bridges, no fewer than eight wheels, running on a circular track, shall be provided to limit the tilting of the bridge and to carry the wind pressure to the track while the bridge is swinging. The balance wheel bearings shall be adjustable for height, preferably by shims between the superstructure and the seats of the bearings. For short, single-track, hand-operated bridges, four wheels may be used.

When wheels are not cast integral with their axles, they shall have pressed fits thereon. The axles shall rotate in bronze-lined bearings, which shall be provided with means for lubrication.

441. Rack and Track

The rack and track of swing bridges shall be made in sections, preferably not less than 6 ft. long. The track shall be deep enough to insure good distribution of the balance wheel or roller loads to the masonry, but in no case shall the depth for rim-bearing bridges be less than 4 in. If a cast track is used and the loads are light, as in center-bearing bridges, the rack and track segments preferably shall be cast in one piece. In rim-bearing bridges, the rack shall be cast separate from the track, so that the parts may be easily removed for repairs. The joints in the rack and track shall be staggered. The track shall be anchored to the masonry by bolts not less than 1½ in. in diameter, extending at least 12 in. into the masonry, and set in portland cement mortar or grout. The track of hand-operated, center-bearing bridges shall have an ample number of anchor bolts so that the mortar or grout in which they are set will not be crushed by the tractive force developed when turning the bridge. When center-bearing bridges are operated by mechanical power, the track shall be anchored down by bolts, and the tractive force developed when turning the bridge shall be taken by lugs extending from the bottom of the track downward into the masonry and set in cement mortar, grout or concrete.

442. Main Pinion Shaft Bearings

When two rack pinions are used they shall be placed diametrically opposite, and when four pinions are used, they shall be placed in pairs which shall be diametrically opposite.

Each main pinion shaft shall be supported in a double bearing, which shall be cast in one piece and provided with bolted caps, split linings, and liners, to permit easy removal of the pinion shaft, and to provide adjustment for wear. A bronze thrust collar shall be provided at the top bearing to carry the weight of the pinion, shaft and gear. Means shall be provided for holding the pinion against movement along the shaft. The double bearing shall be of ample strength for the maximum pinion load and shall be adequately braced and attached to the rim girder or superstructure.

Sufficient shims shall be provided between the bearing base and the steelwork to care for any necessary adjustment in position of the bearing. If practicable, the bearings shall be shipped assembled to the steelwork, with the shims in place.

443. Equalizing Devices

In power-operated swing spans there shall be no fewer than two rack pinions. The shafts of these pinions shall be connected by mechanical devices which will equalize the turning forces at the pinions, unless such equalization is provided by other means acceptable to the engineer.

(c) Special for Bascule Bridges

444. Rail End Connections

If the rail end connections are of the sliding-lock type, the sliding locks at the heel end of the bridge shall be on the approach.

445. Centering Devices

The bridges shall be equipped with self-centering devices at the toe end. Transverse centering shall be accomplished by a device preferably located on the center line of the bridge, as near the track level as practicable, with a clearance not to exceed 1/16 in.

446. Locking Devices

There shall be a locking device at the end for each girder or truss to force down and hold down the toe end to its seats.

447. Air Buffers

Power-operated bridges shall be equipped with air buffers to aid in seating the span smoothly. For single-track bridges having girders or trusses not more than 10 ft. center to center, there shall be one air buffer at the toe end of the bridge. For all other bridges, there shall be two air buffers at the toe end of the bridge.

448. Segmental Girders and Track Girders

The flanges of segmental and track girders of rolling lift bridges shall be symmetrical about the central planes of the webs. The central planes of the webs of the segmental girders shall coincide with the central planes of the webs of the track girders. The treads attached to the segmental girders and track girders shall be steel castings or rolled steel plates, and shall not be considered as part of the flanges of these girders.

The permissible load per linear inch of line bearing between treads for segments having a diameter of 120 in. or more shall not exceed

$$(1200 + 80D)\frac{(P - 13000)}{20000}$$

in which D is the diameter of the segment in inches, and P is the yield point strength of the material in tension in pounds per square inch.

The thickness of solid tread plates shall be not less than 3 in. plus 0.004 D. The effective length of line bearing for solid tread plates shall not exceed the thickness of the web of the segmental or track girder, including the effective thickness of the side plates, plus 1.6 times the thickness of the tread plate. The edge of the web and the backs of the flange angles shall be machined so as to bear continuously on the tread.

The thickness of the web, including the effective thickness of the side plates, shall be such that the quotient obtained by dividing the load by the area of a portion of the edge of the web whose length equals twice the least thickness of the tread, shall not exceed one-half of the yield point of the material in tension. Flange angles shall not be considered as transmitting any load from the web to the treads, and the bearing value of side plates shall not exceed the strength of those rivets connecting them to the web which are included between diverging lines in the plane of the web that intersect in the line contact between the treads and that make an angle with the normal to the rolling surfaces at that point whose tangent is 0.8. The load, as used in this paragraph, shall be the weight of the structure, no addition being made for rolling impact.

Tread plates may be flange-and-web castings instead of solid plates. The rolling flanges of such castings shall have a thickness not less than specified for solid tread plates. The castings shall be designed as pedestals to distribute the pressure from the web to the line of contact between treads.

Solid tread plates on segmental girders shall have a radius slightly smaller than the segmental girders in order to facilitate the securing of tight contact with the girders throughout their length when drawn up with the attaching bolts.

When not otherwise stipulated on the plans, all tread plates shall be made as long as practicable. When tread plates are made in segments, the faces of the tread plates at the joints between the segments shall be in planes at right angles to the rolling surface and preferably at an angle of 45 to 60 deg. with the longitudinal center line of the tread plate.

Those portions of the segmental and track girders, which are in contact when the bridge is closed, shall be designed for the sum of the dead load, the live load, and an impact equal to the live load. Under this loading, the permissible live loading given herein may be increased 50 percent.

The segmental and track girders shall be fully reinforced with stiffeners and diaphragms.

449. Location of Machinery

The machinery shall preferably be located on the stationary part of the bridge.

450. Equalizing Devices

There shall be mechanical devices on bascule bridges to equalize the forces at the two rack pinions, unless such equalization is provided by other means acceptable to the engineer.

(d) Special for Vertical Lift Bridges

451. Centering Devices

Bridges shall be equipped with self-centering devices at each end. Transverse centering shall be accomplished by devices located on the center line of bridge, as near the track level as practicable, with a clearance not to exceed 1/16 in. For truss bridges these centering devices shall be supplemented by close transverse centering of the unloaded chords, to be accomplished by special centering devices or by the span guides.

452. Locking Devices

Bridges shall be equipped with locking devices to hold the span down to its seats after it has been forced down to its seats by the operating machinery. At each end there shall be a locking device on the center line of bridge for single track bridges, and a locking device at each outside girder or truss for multiple track bridges.

453. Span Guides

The lift span and its counterweights shall be held in position transversely and longitudinally during their movement by means of guides engaging guide flanges on the towers. Truss spans shall have transverse guides at both top and bottom chords. The guides may be of either the sliding or the rolling type. The ends of guide flanges shall be planed smooth. The guides shall be adjustable, and shall preferably be set to provide a normal running clearance of ¾ in., except for the span guides for the seated position of the span where the clearance shall not exceed ⅛ in.

454. Air Buffers

Power-operated bridges shall be equipped with air buffers to aid in seating the span smoothly. For single-track bridges having girders or trusses not more than 10 ft. center to center, there shall be an air buffer at each end of the bridge. For all other bridges there shall be two air buffers at each end of the bridge.

Power-operated bridges shall also be equipped with air buffers to aid in stopping the moving span and counterweights without damage to the structure, in the event that the span is accidentally raised above the prescribed limit.

455. Counterweights

The balance block pockets shall be placed as near the ends of the counterweights as practicable, in order to aid in securing the required balance between the lift span and the counterweights at each of the four corners of the span.

456. Clearance below Counterweights

The counterweights shall clear the track rails by not less than 5 ft. when the span is fully open. In computing this clearance the counterweight ropes shall be assumed to stretch one percent of their length.

457. Equalizing Devices

On vertical-lift spans operated through pinions engaging racks on the counterweight sheaves, there shall be devices to equalize the forces at the rack pinions when two counterweight sheaves and two pinions are used at a corner of the span. Equalizing pinions shall not be used between pinions at opposite sides of the span; but adjusting devices shall be provided between such pinions, to permit leveling of the span.

458. Counterweight Sheaves

For main counterweight ropes, the pitch diameter of the sheave, center to center of ropes, shall be not less than 72 times the diameter of the rope, and preferably not less than 80 times. For auxiliary counterweight ropes, the pitch diameter of the sheave shall be not less than 60 times the diameter of the rope.

Counterweight sheaves shall have shrink fits on their shafts, and shall be secured by driving-fit dowels set in holes drilled after the sheave is shrunk on the shaft.

The shape of the grooves shall conform as closely as feasible to the rope section so that while the ropes shall run freely in the grooves, the sides of the grooves shall prevent the ropes from flattening under static loads, as when supporting counterweights. The distance center to center of grooves shall be not less than ¼ in. more than the diameter of the rope.

459. Operating Drums and Deflector Sheaves

For operating ropes, the diameter of the drums and deflector sheaves shall be not less than 45 times the diameter of the rope, and preferably not less than 48 times, except for deflector sheaves with small angles of contact between rope and sheave.

Operating drums shall have pressed fits on their shafts, and in addition shall have keys designed to carry the total torque to be transmitted to the shafts.

The shape of the grooves on operating drums shall conform as closely as feasible to the rope section. The distance center to center of grooves shall be not less than ⅛ in. more than the diameter of the rope.

Deflector sheaves shall generally have the same diameter as the drums. Intermediate deflector sheaves shall be provided as necessary to prevent rubbing of the ropes on other parts and to avoid excessive sag of the ropes. When operating ropes have small angles of contact with deflector sheaves, the sheaves shall be supported on roller or ball bearings and shall be designed as light as practicable to insure easy turning and minimum rope slippage in starting and stopping.

All deflector sheaves shall have deep grooves to prevent displacement of the ropes.

460. Built Sheaves

In built sheaves, there shall be enough rivets connecting the flanges of the cast rim with the web to carry into the web all of the load coming on the rim. The rim shall be strengthened by transverse ribs, or shall be thick enough to carry the load.

461. Counterweight Ropes

The connections of the counterweight ropes to the lift span and counterweights shall be so made as to permit ready replacement of any one rope without disturbing the other ropes. Provision shall also be made for replacement of all the ropes simultaneously, preferably by supporting the counterweights from the towers.

On the lift span side, the counterweight ropes shall be separated sufficiently to prevent objectionable slapping of the ropes against each other while the span is in the closed position. This may be accomplished either by use of widely spaced grooves on the sheaves, by using deviations of the ropes from a vertical plane, or by other approved means.

The transverse deviation of a counterweight rope from a vertical plane through the center of the groove on the sheaves, shall preferably not exceed one-half the spacing of the grooves, and shall be the same for all the ropes on a sheave. In no case shall it exceed 1 in 40. The longitudinal deviation of a counterweight rope leading from the sheave, measured from a vertical plane tangent to the pitch diameter of the sheave, shall not exceed 1 in 30, and shall be the same for all the ropes on a sheave. These deviations shall not be exceeded on the span side for the lift span in its highest possible position, and on the counterweight side for the span in the closed position.

The connections of all ropes shall be made in such manner as to give equal loads on the several ropes of a group either by adjustment of the tension in the ropes during erection, by fabrication of the ropes in the shop to the exact required lengths without tolerance with provision for future adjustment of the tension if required, or by use of equalizers.

The connections of all ropes shall be so made that the center line of the rope above the socket is at all times at right angles to the axis of the socket pin for pin sockets and to the bearing face of the socket for block sockets. Rope deflector castings or plates or equivalent devices shall be provided near the sockets, as necessary, to accomplish this result.

462. Operating Ropes

The transverse deviation of a rope from a plane through the groove of a drum or sheave at right angles to the axis of the shaft of the drum or sheave shall not exceed 1 in 30, and preferably shall not exceed 1 in 40.

There shall be at least two full turns of the rope on the operating drum when the span is in the fully open or closed position and, in addition, the end of the rope shall be rigidly clamped to the drum, the attachment being such as to avoid sharp bends in the wires.

There shall be take-ups, consisting of turnbuckles or other devices, for taking up slack in the ropes. The take-ups shall be such as to prevent any rotation of the ropes about their axes. They shall be readily accessible for operation by one man.

463. Balance Chains

Cast iron chains for balancing counterweight ropes shall be made of cast iron links, connected by rust-resistant steel pins, placed in bored or reamed holes. The holes shall be of uniform size, carefully located, and at right angles to the length of the links. The chains shall hang freely in vertical planes without twists. The pins shall be fitted with washers and round cotter bars.

V WIRE ROPES AND SOCKETS

(See Proceedings, Vol. 51, 1950, pp. 465–469, incl.)

503. Construction

Change to read as follows:

All wire ropes shall be made of improved plow steel wire. All operating ropes shall be preformed wire rope.

All wire ropes shall be of 6 × 25 filler wire construction with hard fiber core. Each strand shall consist of 19 main wires and 6 filler wires fabricated in one operation, with all wires interlocking. There shall be four sizes of wires in each strand; 12 outer wires of one size, 6 filler wires of one size, 6 inner wires of one size, and a core wire.

Ropes shall be laid in accordance with the best practice. Every effort shall be made to obtain ropes of uniform physical properties. The ropes shall be fabricated in the greatest lengths practicable, and all similar ropes for any one bridge shall be cut from ropes manufactured with one setting of one stranding machine and one setting of one closing machine.

508. Ultimate Strength

Revise the first three lines to read as follows:

In order to demonstrate the strength of the rope and its fastenings, test pieces with a length between the sockets equal to not less than 25 rope diameters, and preferably not less than 50 rope diameters, shall be cut, and shall have sockets, selected at random from those to be.

511. Sockets

Substitute the following paragraph for the first two paragraphs:

All sockets used in connection with wire ropes shall be Class C1 forged steel, normalized, and shall be forged, without welds, from solid steel. They shall be neatly finished to the exact dimensions shown on the plans. All socket pins shall be Class C1 normalized steel forgings. In every case the dimensions of the sockets shall be such that no part under tension shall be stressed higher than 48,000 psi. when the rope is stressed to its specified ultimate strength. The sockets shall be attached to the ropes by using zinc of a quality not less than that defined for Intermediate Grade in the current Specifications for Slab Zinc (Spelter) of the American Society for Testing Materials. Serial Designation B 6, and using a reliable method that will not permit the rope, when stressed to 80 percent of its specified ultimate strength under the test specified in Art. 508, to slip more than 1/6 the nominal diameter of the rope. If a greater movement should occur, the method of attachment shall be changed until a satisfactory one is found.

513. Length

Change to read as follows:

The length of each counterweight rope from inside of bearing to inside of bearing of sockets shall be determined, and a metal tag having the said length stamped thereon shall be securely attached to the rope. While being measured, each rope shall be twisted to the correct lay, it shall be supported throughout its length in a straight line at points not more than 25 ft. apart, and it shall be under a tension of 12 percent of its ultimate strength. (This corresponds approximately to the direct load on the rope.) A variation from the required length of not more than ¼ in. in 100 ft. will be allowed. For block sockets which provide for the direct load on the rope to be transmitted by bearing on the front face of the socket, this permissible variation from the required length shall be corrected in the shop by permanently fastening steel shims to the bearing face of one socket so that the length from bearing face of one socket to bearing face of shim at the other socket corresponds exactly to the required length. No shim shall be less than ⅜ in. thick.

The contractor shall verify the exact lengths to which the counterweight ropes shall be manufactured.

Each rope shall have a stripe painted on one side along its entire length at the time the measurement of length is made, to assure the correct twist of the rope during the erection of the bridge.

Ropes shall be suitably marked or tagged for identification for proper erection.

514. Operating Ropes

Substitute the following for the last sentence:

Length of operating ropes to be furnished shall be determined by the contractor.

515. Shipping

Delete the last sentence.

VI POWER EQUIPMENT

(See Manual pages 15–72 to 15–85, incl., for original text of paragraphs 601 to 667.)

Page 15–72

601. Kind of Power

Change to read:

If the bridge is to be operated by mechanical power, the kind of power to be used will be stipulated by the company. The internal combustion engine, electric motor, or other prime mover that may be stipulated, shall be of ample capacity to move the bridge at the required speed. The type of prime mover and the name of the manufacturer shall be given in the proposal if the design is made by the contractor.

602. Man Power

Change to read:

If the bridge or parts thereof are to be operated by hand, the number of men and the time of operation shall be calculated on the following bases:

(a) The force which a man can exert continuously on a capstan lever is 40 lb. while walking at a speed of 160 ft. per min.

(b) The force which a man can exert continuously on a crank at a radius of 15 in. is 30 lb. with rotation at 15 rpm.

For calculating the strength of the machinery parts, the force of one man applied to extreme end of either a lever or a crank shall be assumed as 150 lb. Under this condition, the normal unit stresses may be increased 50 percent.

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603. Machines

Change to read:

Machines which are of the usual manufactured types, such as gasoline engines, electric motors, pumps, air compressors, etc., shall be tested for the specified requirements to the satisfaction of the engineer, and shall be guaranteed by the contractor to fulfill these requirements for one year.

604. Torque of Motors

Change to read:

The motors shall be capable of exerting, through successive cycles of bridge operation extending through 30 min., the torques shown on the torque curves for the loads specified in Art. 308; and for 15 min. one and one-quarter times those torques. A cycle is defined as an opening and a closing of the bridge without a period of rest between closing and opening, and without a change of wind in amount or direction. Successive cycles shall be taken without periods of rest.

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(c) Internal Combustion

Add the following article before Art. 614:

613a. Engine Torque for Span Operation

The ratio of the rated engine torque to the maximum bridge starting torque shall be not less than the following:

(a) Four cylinders or more 1.33
(b) Less than four cylinders 1.50

The rated engine torque, as referred to above, shall mean the rated torque of the engine at the speed to be used for operation, measured at the flywheel, with all metal housing in place, and with radiator, fan, and all other power-consuming accessories in place, and shall be taken at not more than 85 percent of the rated torque of the stripped engine.

Replace Art. 625, "Starting Torque," by the following:

625. Maximum Torque for Span Operation (A.C. Slip-ring Induction Motors)

The maximum starting and running torques of a motor shall be not less than 2 and 2.5 times, respectively, the rated full load torque.

The rated full load torques of the motors shall be as follows:

(a) One motor installation:

The rated full load torque of the motor shall be not less than 80 percent of the maximum bridge starting torque, and the maximum torque peaks that occur when the bridge is accelerated to the required speed, using the specified bridge control, shall not exceed 90 percent of the maximum starting torque of the motor, nor preferably 180 percent of the rated full load torque of the motor.

(b) Two motor installation, with no provision for operation of the bridge with a single motor:

The two motors jointly shall meet the requirements given in paragraph (a) for one motor.

(c) Two motor installation, with provision for operation of the bridge in emergency with one motor in not more than 1.5 times the times of openings specified in Art. 306:

The rated full load torque of one motor shall be not less than 65 percent of the maximum bridge starting torque, nor 80 percent of the maximum bridge running torque, not including inertia, and the maximum torque peaks that occur when the bridge is being accelerated to the required speed, using the specified bridge control, shall not exceed 90 percent of the maximum starting torque of the motor, nor preferably 180 percent of the rated full load torque of the motor.

VII MATERIALS

(See Manual pages 15–85 to 15–88, incl., for original text of paragraphs 701 to 717, incl.)

Delete all articles up to and including 717 and insert the following:

701. Cast Steel

Steel for castings shall conform to the Specifications for Steel Railway Bridges of the American Railway Engineering Association, except as provided otherwise herein.

A test to destruction on three castings selected from a lot may be substituted for the tensile test, in the case of small or unimportant castings. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from the same melt or blow annealed in the same furnace charge.

Large castings shall be hammered all over while suspended. If cracks, flaws, defects, or weaknesses appear, the casting shall be rejected.

702. Cast Iron

Cast iron shall conform to the Specifications for Steel Railway Bridges of the American Railway Engineering Association.

703. Carbon Steel Forgings

Except as otherwise specified in this section, carbon steel forgings shall conform to the requirements of the current specifications of the ASTM, Designation A 235, and shall be Class C1, E, or G, as specified.

The chemical composition shall conform to the following table:

	Percent
Manganese, max.	0.90
Phosphorus, max.	0.05
Sulfur, max.	0.05

The tensile test requirements are as follows:

	Solid Diameter or thickness In.		*Tensile strength min. psi*	*Yield point min. psi*	*Elongation in 2 in. min. percent*	*Reduction of area min. percent*
Class	*Over*	*Not Over*				
C1		12	66.000	33,000	23	36
	12	20	66,000	33,000	22	34
E		8	75,000	37,500	24	40
	8	12	75,000	37,500	22	35
	12	20	75,000	37,500	20	32
	20		75,000	37,500	19	30
G		4	90,000	55,000	20	39
	4	7	85,000	50,000	20	39
	7	10	85,000	50,000	19	37

The crosshead speed of the testing machine, after a stress of ½ the specified yield point is attained and during determination of yield point, shall not exceed 1/16 in. per min. per in. of gage length; and during determination of ultimate strength shall not exceed ½ in. per min. per in. of gage length.

704. Alloy Steel Forgings

Except as otherwise specified in this section, alloy steel forgings shall conform to the requirements of the current specifications of the ASTM, Designation A 237, and shall be Class A.

The chemical composition shall conform to the following table:

	Percent
Phosphorus, max.	0.05
Sulfur, max.	0.05

The tensile test requirements are as follows:

Tensile strength, min., psi.	80,000
Yield point, min., psi.	50,000
Elongation in 2 in., min., percent	
Solid diameter or thickness	
not over 12 in.	24
over 12 to 20 in., incl.	22
Reduction of area, min., percent	
Solid diameter or thickness	
not over 12 in.	40
over 12 to 20 in. incl.	38

The crosshead speed of the testing machine, after a stress of ½ the specified yield point is attained and during determination of yield point, shall not exceed 1/16 in. per min. per in. of gage length; and during determination of ultimate strength shall not exceed ½ in. per min. per in. of gage length.

705. Hardened Steel

Unless otherwise stipulated, hardened steel for disks for swing spans and for bearing ends of vertical shafts running in step bearings shall be forged carbon steel conforming to the requirements of Art. 703, and shall be Class G.

706. Bronze

Bronze for disks for swing spans, for linings for bearings, for gears, worm wheels, and nuts, and for similar parts, shall be cast bronze conforming to the requirements of the current specifications of the ASTM, Designation B 22, and shall be Alloy A, B, C, or D, as specified.

707. Babbitt Metal

Unless otherwise stipulated, babbitt metal shall conform to the requirements of the current specifications of the ASTM, Designation B 23, and shall be Grade No. 2.

VIII WORKMANSHIP

(See Manual pages 15–88 to 15–91, incl., for original text of paragraphs 801 to 825, incl.)

(a) General

Delete all articles and insert the following:

801. Machinery Manufacture in General

The machinery shall be manufactured, finished, assembled, and adjusted in approved manner and according to the best machine shop practice. The limits of accuracy, which are to be observed in machining the work and the allowances for all metal fits, shall be placed on the contractor's working drawings. These drawings shall show separately the working allowance for the journals and their bearings, so that the total differences between journal and bearing diameters shall be within the prescribed limits.

Parts of the machinery in contact with other parts or with supports shall be machined so as to provide even true bearings, and surfaces in sliding or rotating contact with other surfaces shall be finished true to dimensions and highly polished. Castings shall be clean and all fins and other irregularities shall be removed so that they will have clean, smooth surfaces, suitable for this class of work. Unfinished edges of flanges and ribs shall be neatly made with rounded corners. All inside angles shall have suitable fillets. Drainage holes of suitable sizes shall be drilled so as to drain all places where water might collect.

Finished rubbing surfaces shall be coated as soon as possible after being accepted with an approved rust-inhibitive grease before removal from the shop. Other surfaces shall be cleaned and painted in the shop as specified for structural metal. All finished rubbing surfaces which are not assembled in the shop for shipment shall be adequately protected during shipment by wrapping with burlap or canvas which shall be secured by wooden bats securely wired together. All grease holes shall be adequately plugged for shipment. Careful attention shall be given to the protection of all machinery parts during shipment.

802. Racks

When racks are built in segments, the segments shall be fitted together accurately. Particular care shall be taken to have the pitch of the teeth at the joints accurate. The periphery of rack teeth shall be planed. The pitch line shall be scribed on both ends of the teeth.

The backs of racks which bear on metal surfaces and the surfaces in contact with them shall be planed.

803. Shafts

All shafts shall be straight, true to gage, and turned or otherwise well finished throughout their lengths. All shafts shall be made with fillets where abrupt changes in section occur.

All shafts more than 8 in. in dia. shall have a hole bored lengthwise through the center. The diameter of the hole shall be about 1/5 of the diameter of the shaft.

804. Journals

Journals shall have accurate machine finish and shall be polished. Particular care shall be taken to secure a high polish on the journals of trunnion and counterweight sheave shafts.

Unless otherwise specified, all machinery journals and those of trunnion and counterweight sheave shafts shall have the corners at their ends rounded and, except for cold rolled shafts, shall be of slightly less diameter than the remainder of the shaft.

805. Linings

Linings shall be bored, finished smooth, and scraped to a true fit so that the journals will run without excess friction or heating.

The total differences between journal diameters and lining diameters shall be within the following limits:

(a) For machinery journals having both bearings in one unit frame with shafts and bearings finally assembled and alined in the shop:

Maximum difference .... 0.003″ plus 0.00085 d
Minimum difference .... 0.001″ plus 0.0007 d

(b) For all other machinery journals, for trunnion journals, and for counterweight sheave shaft journals:

Maximum difference .... 0.005″ plus 0.00085 d
Minimum difference .... 0.003″ plus 0.0007 d

The edges of oil grooves and the edges of linings shall be rounded.

806. Bearings

The rubbing and bearing surfaces and the joints between cap and base of bearings shall be finihsed. The holes in cap and base shall be drilled. The holes in bearings for bolts fastening them to their supports shall be drilled.

807. Couplings

The faces of flange couplings shall be machined to fit.

808. Hubs

The holes in all hubs including hubs of sheaves, drums, gears, pinions, and all other wheels shall be bored concentric with the pitch circle or rolling surface and, unless otherwise specified, so as to give a pressed or shrink fit on the staft. All such hubs shall be properly keyed to the shafts. If the hub performs the function of a collar, the end next to the bearing shall be faced.

Unless otherwise specified, the total difference in diameter between hole and shaft for pressed or shrink fits for hubs on shafts having a diameter of 2 in. or more shall be such that there will be an interference of metal and shall be within the following limits:

Maximum difference	0.0005 d plus 0.001″
Minimum difference	0.0005 d minus 0.001″

but not less than 0.0005″

where d is the diameter of the shaft in inches.

809. Gears

The teeth of gears, unless specifically stipulated otherwise, shall be machine cut. The periphery and the ends of teeth and gears shall be turned. The pitch circle shall be scribed on both ends of the teeth.

810. Bevel Gears

The teeth of bevel gears shall be cut by a planer having a rectilinear motion in lines through the apex of the cone. Rotating milling cutters shall not be used for making bevel gears.

811. Machine Molding

Uncut teeth shall be machine molded.

812. Worms and Worm Wheels

Threads on worms shall be machine cut and the teeth of worm wheels shall fit the worm accurately with surface or line contact.

813. Keys and Keyways

Keys shall be planed and keyways machine cut. The finish of the keys and keyways shall be such as to give the key a driving fit on the sides. Tapered keys shall bear on the top, bottom and sides; parallel faced keys on the sides only.

814. Bolt Holes and Turned Bolts

Bolts for the connection of minor machinery parts, to each other or to their supports, may be unfinished bolts, the holes for which shall be drilled or reamed not more than 1/16 in. larger in dia. than the bolts. All other bolts for connection of machinery parts to each other or to their supports shall be turned bolts having the shank 1/16 in. larger in dia. than the threaded portion. The turned bolts fastening trunnion and counterweight sheave bearings to their supports, and all turned bolts which carry shear shall have a driving fit in their holes, which shall be of the same diameter as the bolts. Other turned bolts shall have holes 1/32 in. larger in dia. than the bolt.

815. Assembling Machinery in Frames

All shafts, gears, pinions, and other parts supported by machinery frames shall be assembled in the shop in their several frames, tested by operation, and shipped to the field ready to be set in place. Each assembly shall be operated continuously for a period of not less than four hours in the shop before shipment; the speed of operation shall be not less than that of the assembly under normal bridge operation.

816. Balancing of Gears

In order to reduce the noise of operation to a minimum, the gears shall be assembled in the shop on their shafts with their keys in place, and each shaft assembly shall be balanced for any position of rotation of the shaft. Gears shall be so cast that compensation can be obtained after assembling.

817. Assembling Machinery on Structural Supports

When so stipulated on the plans, machinery parts shall be assembled on the supporting members in the shop. They shall be alined and fitted, and holes in the supports shall be drilled with the members in correct relative position. The members shall be match-marked, both to the supports and to each other, and erected in the field in the same relative positions.

When the foregoing assembly is not stipulated, the holes in the machinery parts shall be drilled in the shop and the holes in the supports shall be left blank and drilled in the field after the machinery parts are assembled and alined. If any small size placement holes are provided to aid in field alinement of the machinery, they shall be reamed to fit the permanent bolts after all other holes have been drilled and their bolts placed.

818. Grooves in Journals and Linings

The lubrication grooves in the surface of shaft journals and bearing linings shall be machine cut. Small inequalities may be removed by chipping and filing. The grooves shall be smooth, including the rounded corners.

819. Air Buffers

The workmanship on air buffers shall be so accurate that the weight of the cylinder and its attachments will be sustained by the confined air for six minutes, with a piston travel not more than that which occurs during the closure of the bridge. The valves must be closed and the buffers balanced so that the whole weight is carried by the piston rod.

(b) Special for Swing Bridges

820. Rim Girders

In the bottom flanges of the rim girders of rim-bearing swing spans, the edges of the webs and side plates and the backs of the flange angles shall be so planed that full bearing on the tread plates will be secured.

821. Rack and Track

Track segments shall be planed on the top and bottom and at the ends. Surfaces on which conical rollers bear shall be planed to the true bevel. The center line shall be scribed on the surface.

The rack and track shall be completely assembled in the shop to their correct center lines, fitted, drilled, and the parts match-marked.

822. Bearings for Rack Pinion Shafts

The bearings for rack pinion shafts shall be bolted to the bracket supporting them and bored while so fastened to insure perfect alinement.

823. Rollers

The faces and sides of rollers and balance wheels shall be finished, the corners rounded, and the center line of the rollers and balance wheels scribed on the faces. The hubs shall be bored accurately and faced on both ends.

824. Pivots

Pivot stands and center castings of swing bridges shall be finished and fitted accurately. The base shall be faced truly at right angles to the axis and shall be turned on the circumference concentric with the axis.

825. Disks

Steel disks shall be fitted accurately, finished to gage, and ground accurately to the final finish. The sliding surfaces of steel and phosphor-bronze disks shall be polished. Disk centers shall be assembled, fitted accurately and match-marked.

826. Assembling Centers

For a rim-bearing swing span, the complete center, including rim girders, center pivot, radial members, rack, track and rollers, shall be assembled, alined, fitted, drilled, and the parts match-marked in the shop.

(c) Special for Bascule Bridges

827. Segmental Girders and Track Girders

In rolling lift bridges. the bottom flanges of segmental girders and top flanges of track girders shall have the edges of the web and side plates and the backs of the flange angles so planed that full bearing on the tread plates will be secured. Flanges of the segmental girders shall be so accurately bent to the required radius that planing will not reduce their thickness more than 1/8 in.

828. Racks

When stipulated on the plans, all circular racks shall be assembled in the shop on their supporting members, including all parts up to and including the trunnion shaft or its supporting member, the parts then alined and adjusted so that the pitch of the rack throughout its length is at the prescribed radius from the center of the trunnion shaft, the holes drilled, and the parts match-marked. If any temporary radial members are required to properly aline the rack, they shall be furnished and match-marked for use in erection.

829. Tread Plates

In rolling lift bridges, the top and bottom surfaces of the tread plates shall be planed. When tread plates are built in segments, their ends shall be faced.

Tread plates shall be assembled in the shop with their segmental girders and track girders, alined, fitted, drilled, and the parts match-marked.

830. Assembly of Trunnion Shafts and Bearings

Each trunnion shaft shall be assembled in the shop with its bearings, and the linings shall be scraped to a true fit with the journals.

(d) Special for Vertical Lift Bridges

831. Sheaves and Drums

The grooves in sheaves and drums shall be turned. Particular care shall be taken to secure uniformity of pitch diameter for all of the grooves of a counterweight sheave. The variation from the required diameter shall not exceed plus or minus 0.01 in.

Built sheaves shall be assembled and permanently riveted before the grooves are turned.

832. Assembly of Counterweight Sheave Shafts and Bearings

Each counterweight sheave shaft shall be assembled in the shop with its bearings, and the linings shall be scraped to a true fit with the journals.

Page 15–91

Delete all articles under, "IX Erection," and insert the following:

IX ERECTION

(See Manual pages 15–91 and 15–92 for original text of paragraphs 901 to 911, incl.)

901. General Specifications

The Specifications for the Erection of Steel Railway Bridges of the American Railway Engineering Association shall apply to the erection of movable bridges, with additions specified herein.

902. Erection of Machinery

The installation and adjustment of all machinery shall be by competent machinists, experienced in this class of work. They shall be provided with all necessary gages, straight edges, and other precision instruments to insure accurate installation.

The final alinement and adjustment of machinery parts, whose relative position is affected by the deflection or movement of the supports under full dead load, or of the span under full dead load, shall not be made until such deflection or movement has taken place.

Machinery parts assembled in the shop on their supporting members, with all holes for connections drilled in the shop, shall be erected according to the match-marking diagrams. Machinery frames carrying machinery assemblies, individual bearings, and other machinery parts, which have not been assembled with their supports in the shop, shall be assembled in the field and adjusted to proper elevation and alinement on the supporting steel parts, by the use of full-length shims, the holes through the supporting steel parts for the connecting bolts to be drilled while the parts are so assembled. If any small size placement holes are provided to aid in field alinement of machinery, they shall be reamed to fit the permanent bolts after all other holes have been drilled and their bolts placed.

Careful attention shall be given to the protection of all machinery parts during unloading and while stored before erection. Before erection, all finished surfaces which were coated in the shop with a protective rust-inhibitive grease shall have such grease thoroughly washed off with gasoline or benzine.

903. Erection of Trunnion Bearings and Counterweight Sheave Bearings

Trunnion bearings and counterweight sheave bearings shall be alined with the utmost accuracy. After they have been adjusted to proper elevation, alinement and position on the supporting steel parts, with due allowance for movements of the bearings which may result from the dead load to be placed on the bearings, by the use of full length shims, the holes through the supporting steel parts for the connecting bolts shall be drilled through the holes in the bearings which were previously drilled in the shop.

The exact methods to be used in securing the required alinement of trunnion and counterweight sheave bearings shall be shown on the contractor's working drawings.

For counterweight sheaves, before the ropes are placed over the sheave, the bearings shall be lubricated and the sheave shall be turned to see that the shaft turns freely in the bearings. If the shaft does not turn freely, the alinement of the bearings must be corrected, as necessary, to accomplish this.

904. Protection of Parts

Parts which are protected from the weather in the finished structure shall be protected in the field during erection by housing or equivalent means. This applies in particular to electrical parts.

Wire ropes shall be housed and stored at least 18 in. above the ground. The ropes shall be kept free from dirt, cinders, and sand.

905. Lubrication

The contractor shall furnish at his own expense grease, oil, fuel and all other things necessary for satisfactory operation of the movable span until it has been accepted by the company, excepting only that for electric motor operated spans the company will pay for electric current obtained from the power line. Greases and oils must be suitable for the operating service and pressures and shall meet the approval of the engineer.

After the movable span is in operating condition, the contractor shall thoroughly clean all counterweight ropes and operating ropes of foreign material and shall furnish and apply hot, when wheather conditions are suitably dry and warm, one coat of approved wire rope dressing. The dressing shall not be applied in an atmospheric temperature below 40 deg. F.

906. Erection of Wire Ropes

Wire ropes shall be carefully removed from reels and coils by revolving them, and shall be so erected as to avoid any sharp kinks or bends. They shall not be pulled through dirt.

Operating ropes for vertical lift spans shall be adjusted to equal tensions at the four corners of the span, and in such manner as to give only slight tension in the slack side of the rope.

Counterweight ropes, when not fabricated to exact lengths without any variation, and when not connected by equalizers, shall be adjusted in the field so as to secure equal loads on all of the ropes at a corner of the span. The stripe painted on each rope in the shop shall be straight after the rope is erected.

907. Painting

Surfaces of machinery parts, except rubbing surfaces, shall be cleaned and painted in the field as specified for structural metal.

Exposed concrete surfaces of counterweights shall be coated with approved waterproofing material.

908. Counterweights

The contractor shall prepare calculations showing the required dimensions and weights of counterweights based on weights computed from the shop drawings of structural steel and machinery, and on estimated unit weights of concrete, timber, and other parts of the span. These calculations shall be submitted to the engineer, in form, for verification. These calculations shall include summarized tabulations showing, for each kind of material, the total quantity of the material, its estimated unit weight, and its total estimated weight. Before pouring the counterweights, the contractor shall verify these estimated and computed weights by comparison with shipping weights of steel. and by weighing suitable portions of non-metal parts, and shall submit to the engineer, supplemental summarized tabulations based on these actual weights.

The contractor shall adjust and correct the counterweights, shall provide the required balance blocks, and shall secure the required balance of the counterweights and span. Approval of any balance tabulations or of any materials or processes, by the engineer, shall not relieve the contractor of the entire responsibility for securing such balance.

909. Testing of Machinery

Before the main operating machinery is connected for transmitting power, it shall be given an idle run of four hours.

910. End Lifting Devices for Swing Spans

The end lifting devices shall be adjusted to produce a lift equal to the deflection caused by the negative end reaction of the live load and impact, plus 25 percent of their sum.

911. Bridge Operator

For a power-operated bridge, the contractor shall provide, at his own expense, competent men to supervise the operation of the bridge for a·period of 14 calendar days after the span is completely operable; and for an additional 14-day period, he shall provide one man. These men shall be competent to operate the bridge, to supervise its operation, and to make any adjustments or corrections that may be required in the mechanical or electrical equipment of the bridge. They shall instruct and qualify the employees of the company in the operation of the bridge. Any adjustments or corrections required during the two 14-day periods shall be at the expense of the contractor.

912. Channel Lights

During erection and in taking down the old span, the contractor shall place and maintain navigation lights and signals, in accordance with the government requirements for the protection of the falsework, as well as navigation.

Report on Assignment 8

Specifications for Design of Corrugated Metal Culverts, Including Corrugated Metal Arches

J. F. Marsh (chairman, subcommittee), F. Baron, H. F. Bober, F. H. Boulton, Jr., R. N. Brodie, V. R. Cooledge, C. E. Ekberg, N. E. Hueni, D. V. Messman, C. Neufeld, O. K. Peck, C. E. Sloan, H. F. Smith, G. L. Staley.

This is a progress report, submitted as information, dealing with the verification or modification of the design data (gage tables for pipe) in the Specifications for Corrugated Structural Plate Pipe and Arches as adopted by Committee 1 in 1944 and as now printed in the Manual.

The closing paragraph of the committee's 1950 report, Vol. 51, pp. 504 to 505, contained the following interim paragraph to be added to the present specifications as an aid to the engineer, and which was adopted by the Association:

Art. 12, page 1–12.84, of the specification shall be amended by adding the following paragraph:

Alternate structural units having a depth of more than 1½ in., may be used in lieu of the plates specified herein under the following conditions:

(a) The section modulus shall be equal to or greater than that of the plate specified. (b) The bolts shall be ¾ in. in dia. (c) The number and arrangement of the plates and the size of the structures shall be recognized manufacturer's standards. (d) The minimum gage of side and top plates shall be as follows:

Dia. of Pipe: *in.*	*Gage of plates*
60 to 90	10
91 to 120	8
121 to 150	7
151 to 180	5

The committee was hopeful that the final report of the Lansing, Michigan tests, which have been conducted by the AASHO, would be available for this report, but results have not yet been officially disclosed. It has been reported by one of the members of that committee that final results will confirm the above interim paragraph adopted by the Association. Meanwhile, the results of field measurements are being tabulated and it is anticipated that the committee will soon be in a position to verify or modify the design data adopted in the present specifications.

Report of Committee 1—Roadway and Ballast

H. W. Legro, *Chairman,*
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C. R. Bergman
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F. E. Short
F. H. Simpson
W. C. Swartout
H. M. Tremaine
W. O. Trieschman
C. D. Turley
G. C. Vaughan
Stanton Walker
C. E. Webb
Charles Weiss
C. S. Wicker
A. A. Winter
R. C. Young
W. L. Young

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, with recommendations for reapproval .... page 481

2. Physical properties of earth materials:

   (a) Roadbed. Load capacity. Relation to ballast. Allowable pressures.
   Third progress report on study of soils, presented as information ..... page 482

   (b) Structural foundation beds, collaborating with Committees 6 and 8.
   No report.

3. Natural waterways. Prevention of erosion.

   No report.

4. Culverts:

   (a) Conditions requiring head walls, wing walls, inverts and aprons and requisites therefor.
   No report.

   (b) Installation of culverts.
   Progress report, presenting specifications as information for the purpose of soliciting comments and criticisms prior to submission a year hence for adoption and publication in the Manual .... page 492

5. Roadway drainage: Critical review of recommended practice.

   No report.

AREA Bulletin 493, February 1951.

6. Roadway: Formation and protection:

    (a) Roadbed stabilization

    Sixth progress report on investigation of roadbed stabilization work, presented as information .... page 494

    Third progress report on laboratory investigation of roadbed stabilization, presented as information .... page 497

    First progress report on investigation of stabilization of fills, presented as information .... page 499

    (b) Construction and protection of roadbed across reservoir areas; specifications.

    No report.

    (c) Chemical eradication of vegetation.

    Progress report, presented as information .... page 503

7. Tunnels: Construction and maintenance.

    No report.

8. Fences:

    (a) Corrosion-resisting fence wire, collaborating with Committee A-5 on Corrosion of Iron and Steel, ASTM.

    No report.

    (b) Electric shock fences and their adaptability to railroad requirements, collaborating with the Electrical Section, Engineering Division, AAR.

    No report.

    (c) Instructions for maintenance inspection of fences.

    Final report, presented as information .... page 505

9. Signs.

    Progress report, presented as information .... page 505

10. Ballast:

    (a) Tests.

    No report.

    (b) Ballasting practices.

    Progress report, presented as information .... page 506

    (c) Special types of ballast.

    Progress report, presented as information .... page 512

THE COMMITTEE ON ROADWAY AND BALLAST,
H. W. LEGRO, *Chairman.*

Report on Assignment 1

Revision of Manual

A. P. Crosley (chairman, subcommittee), F. W. Biltz, L. H. Bond, B. H. Crosland, J. W. Demcoe, A. T. Goldbeck, L. V. Johnson, Paul McKay, J. A. Noble, A. W. Schroeder.

Your committee has made a study of its chapter in the Manual and recommends the following:

Pages 1–27 to 1–36.1, incl.

401. SPECIFICATIONS FOR THE FORMATION OF THE ROADWAY

1941

A. Alinement, Grade, Cross Section
B. Clearing and Grubbing
C. Grading
D. Work in Vicinity of Operated Tracks
E. General Conditions

402. RECOMMENDATIONS

Widths and Slopes

1939

A. Widths of Roadbed
B. Slopes
C. Settlement of Embankments

Submitted for reapproval without change.

Pages 1–87 to 1–89, incl.

IX SIGNS

1939

901. Roadway Signs Required
902. Principles of Design and Rules for Use
903. Economy of Various Materials

Submitted for reapproval without change.

Page 2–15

CINDER BALLAST

1921

Submitted for reapproval without change.

Report on Assignment 2 (a)

Physical Properties of Earth Materials

Roadbed. Load Capacity. Relation to Ballast. Allowable Pressure

J. W. Demcoe (chairman, subcommittee), J. P. Datesman, J. G. Gilley, L. H. Jentoft, W. T. Johnston, J. W. Poulter.

This is the third progress report on the study of soils being conducted by the Engineering Division research staff of the Association of American Railroads for this committee.

Third Progress Report on Soil Pressure Cells—1951

Synopsis

The tests for soil pressures under rail traffic described in the following report were performed under the New York Central track near Trenton, Mich., in 1950. The test installation includes 12 pressure cells placed 4 ft. below the bottoms of the ties over a 16-ft. section. Five of these cells are placed to record vertical pressure, four to record transverse horizontal pressure, one for longitudinal horizontal pressure, and two for pressure at an angle of 45 deg. transverse and downward. Tie loads on five ties, the center one directly over the cells, were obtained by a system of shims and strain gages under the tie plates. All data were recorded by oscillographs under normal traffic. The installation was made near the center of a ballast pocket, three rails in length, which was treated by pressure grouting after the first 20 test runs were obtained. Following grouting, an additional 22 runs were recorded. The cells are remaining in place for additional runs in 1951.

The present report is preliminary and does not include full analysis of all data. Presented is a comparison of recorded pressures to theoretical or calculated pressures for the tie loads involved. Very good correlation was obtained prior to grouting between the recorded and theoretical for vertical pressures. Grouting was not found to change the relationship of load to calculated pressure intensity, but the recorded data indicate a decrease of approximately 9 percent in measured pressure intensity.

For horizontal pressures under the ties, the recorded values exceed the theoretical appreciably, but the reverse is true for locations 8 ft. from centerline. In all cases, however, the apparent effect of grouting is to reduce the pressure intensities.

The close agreement of the recorded and theoretical vertical values indicates the cells are performing excellently and that the divergence of the horizontal data is caused by other factors.

Introduction

This is the third progress report on the measurement of subgrade soil pressures from normal rail traffic by means of soil pressure cells. The work was conducted with committee sponsorship under the general direction of G. M. Magee, research engineer of the Engineering Division, AAR, and Dr. R. B. Peck, research professor of soil mechanics of the Engineering Experiment Station of the University of Illinois, by Rockwell Smith, roadway engineer, and M. F. Smucker, assistant electrical engineer, of the research staff. The pressure cells in use are of AAR design. The last previous report is in the Proceedings, Vol. 51, 1950, starting on page 710.

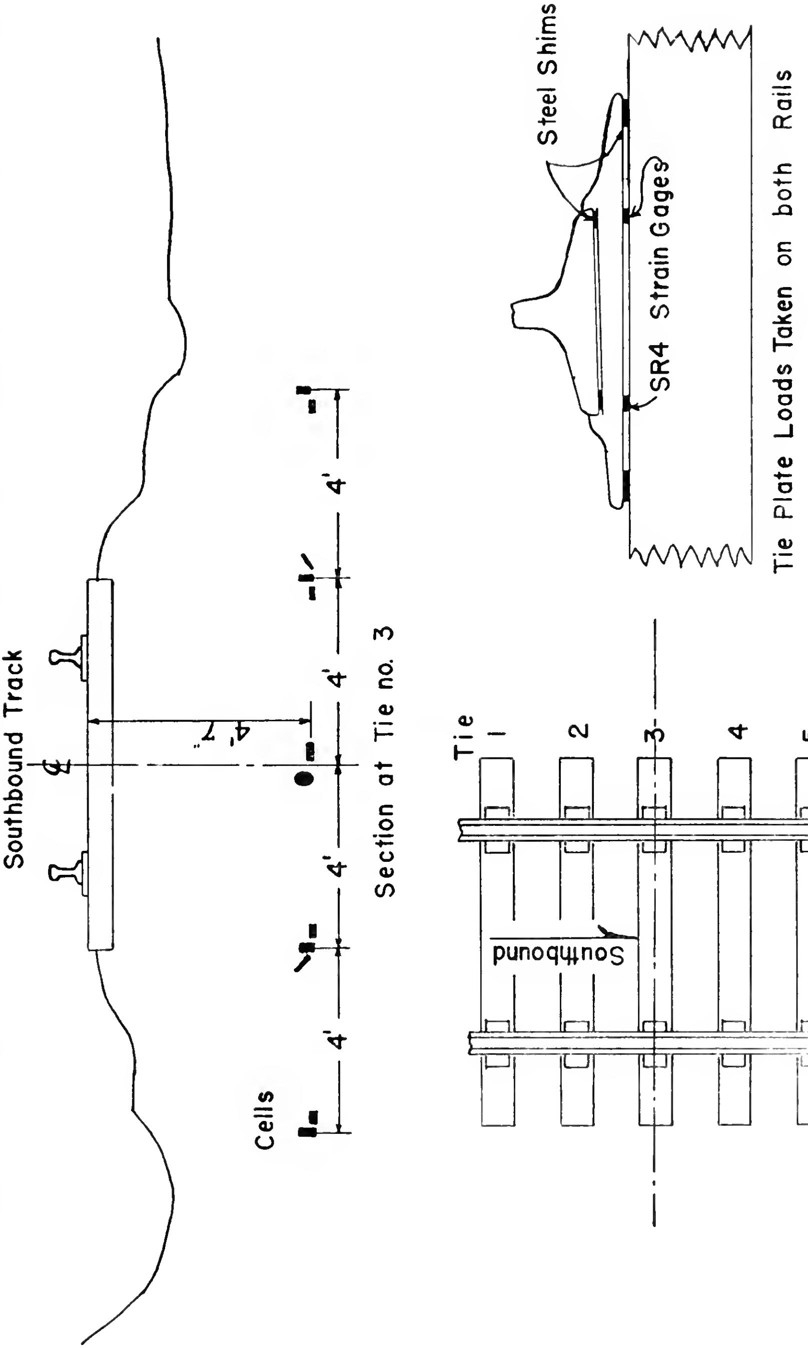


Fig. 1. General layout of pressure cell installation.

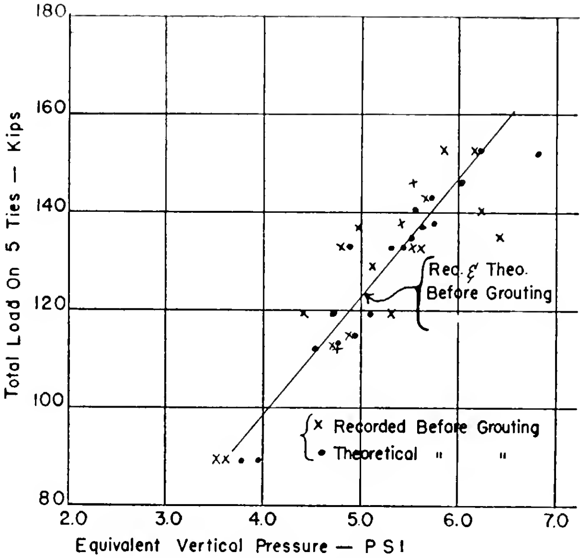


Fig. 2. Before grouting.

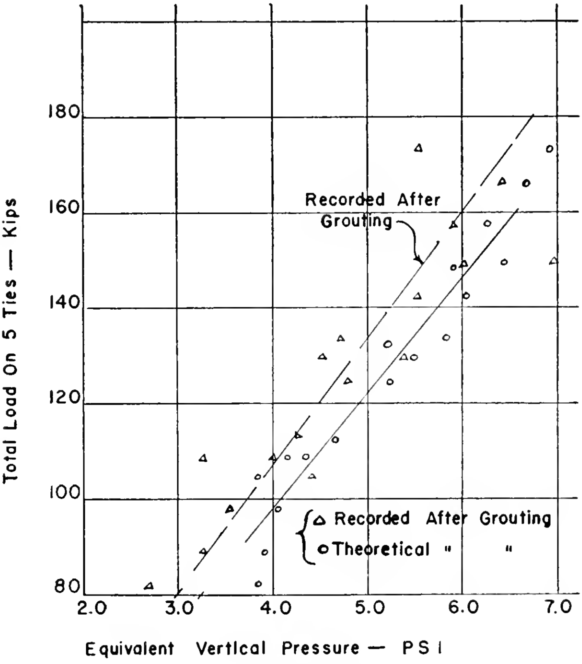


Fig. 3. After grouting.

Relationship between load and vertical pressure.

The installation of pressure cells for this year's tests was made under the New York Central southbound track near Trenton, Mich., about 18¾ miles south of Detroit. The cells were placed near the center of a water-carrying ballast pocket approximately three rails in length. With the aid of rail supports, a trench 9 ft. in width was excavated through the track section extending 12 ft. right and left of centerline. The cells were placed along the center of this trench at various intervals as shown in Fig. 1. Under the ends of the ties the ballast pocket was 3½ ft. in depth underlain by plastic lacustrine clay. The cells were so placed that their centers are all 4 ft. below the bottom of the ties. The native clay soil of the subgrade, hand placed, was used to provide a cover for the first 6 in. above the cell centers. This clay was of normal subgrade consistency, compacted to a density approximately equivalent to that of the undisturbed subgrade. The remainder of the trench above the 6 in. was refilled with the broken stone ballast removed from the trench.

For this year's work the electric circuits for the tie plates were so arranged that it was possible to obtain loads on 10 tie plates, or the total load on 5 ties. The center tie of this group of 5 was directly over the section through the pressure cells. See Fig. 1.

The cell installation was made on July 7, 1950, and the first records were obtained October 12. After the first series the roadbed was treated by the standard method of the New York Central for stabilization by pressure grouting, using a sand-cement slurry. As these tests were not completed until about November 1, full study and analysis of the data have not been possible, but a number of interesting features are apparent and are discussed briefly in this report. The records were read to give the maximum vertical load on the center pressure cell and simultaneously the load on the 5 ties. Records were obtained from 42 runs, 20 before and 22 after grouting.

Discussion

In order to compare recorded pressures with theoretical pressures as determined from Newmark charts, (Influence Charts for the Computation of Stresses in Elastic Foundations, Nathan M. Newmark, Bulletin Series 338, University of Illinois Engineering Equipment Station) for the tie loads involved both the theoretical and the recorded pressures were integrated graphically for the 16-ft. width covered by the cell installation and the average values of the equivalent vertical pressure obtained. These are plotted as abscissae in Fig. 2 against the total load on the 5 ties computed from the oscillograph records. For theoretical pressures the total load on each tie was assumed to be uniformly distributed over the bottom. Ties are 7 in. by 9 in. by 8½ ft. From this graph it can be seen that the proportionality, represented by the straight line, between total tie loads and equivalent vertical pressure is reasonably good for the recorded pressures and very good for the theoretical pressures. For recorded pressures the variation is greater, but the same relationship is apparent. Any variation of the theoretical pressures from the average plotted line is caused by the proportion of the total tie load carried by each tie, which varied from run to run. The fact that the theoretical pressures do check closely to a straight line is an indication that this method of equating total tie load to pressure is not greatly in error for soil pressures at a 4-ft. depth.

Several of the points for recorded pressure that are most widely divergent from the straight line proportionality may be caused by speed effects or other effects from track or locomotive. Further detailed study of the records is required for additional elaboration.

The data for the runs after grouting are plotted in Fig. 3. The solid line in Fig. 3 is the same line that appears in Fig. 2 and represents the theoretical relationship. The dash

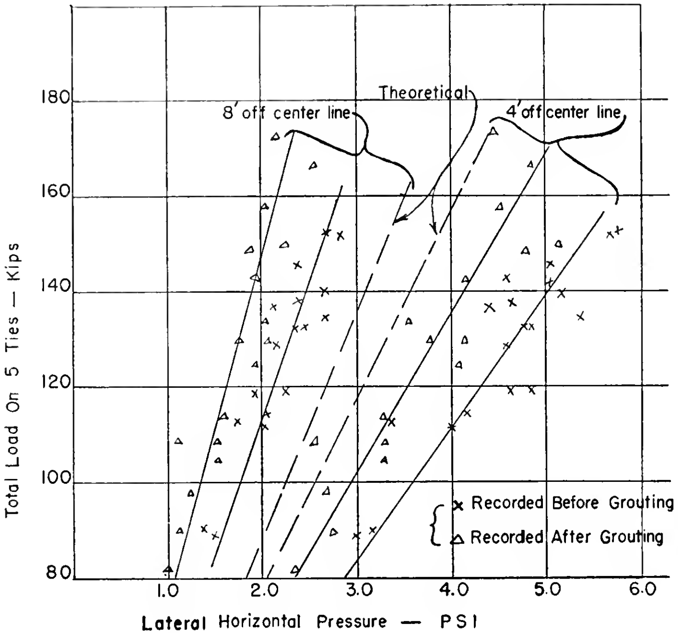


Fig. 4.

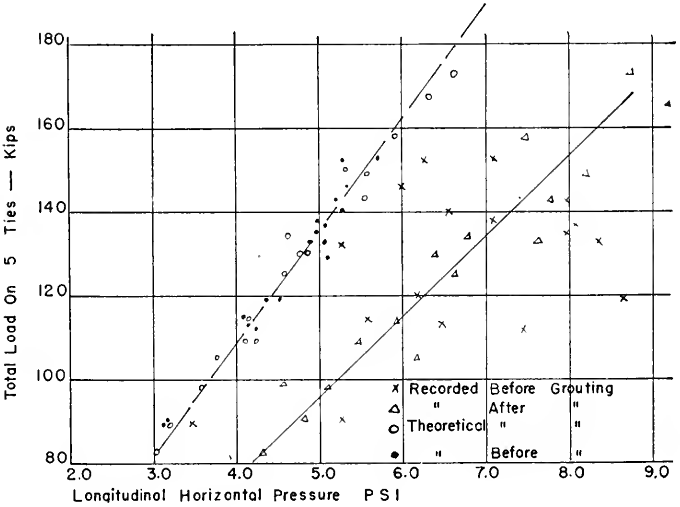
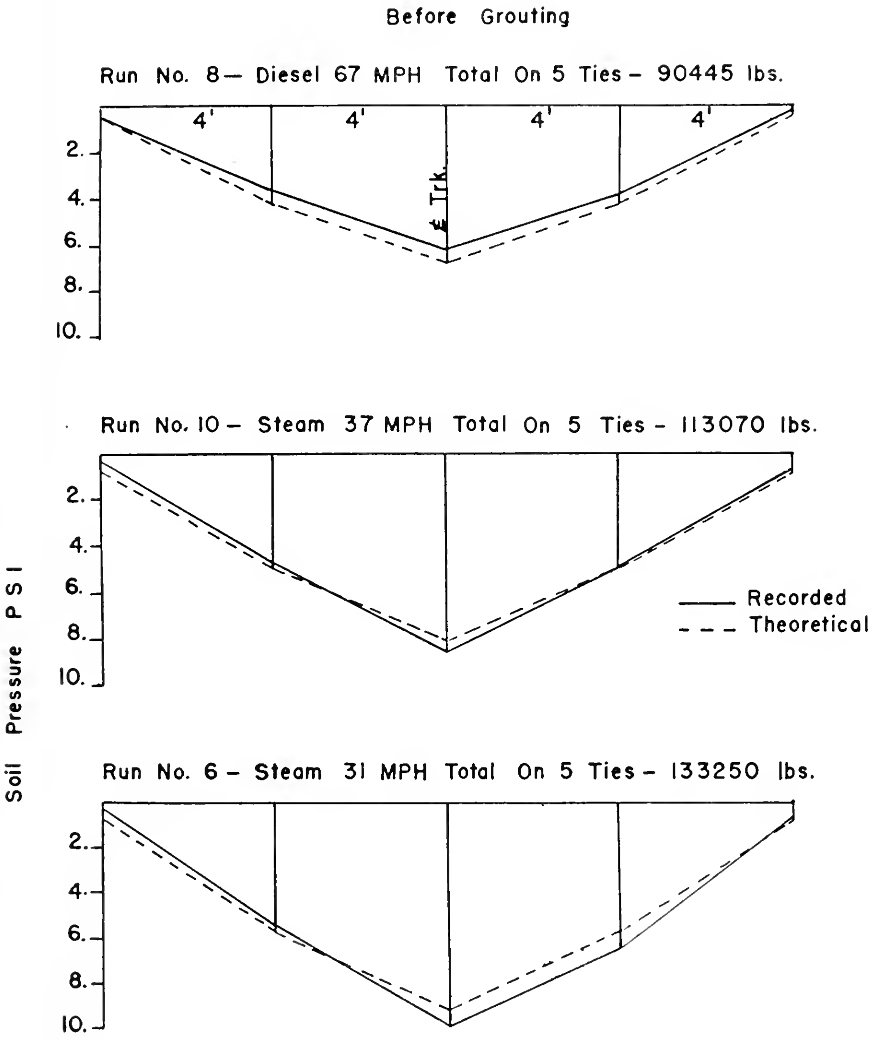


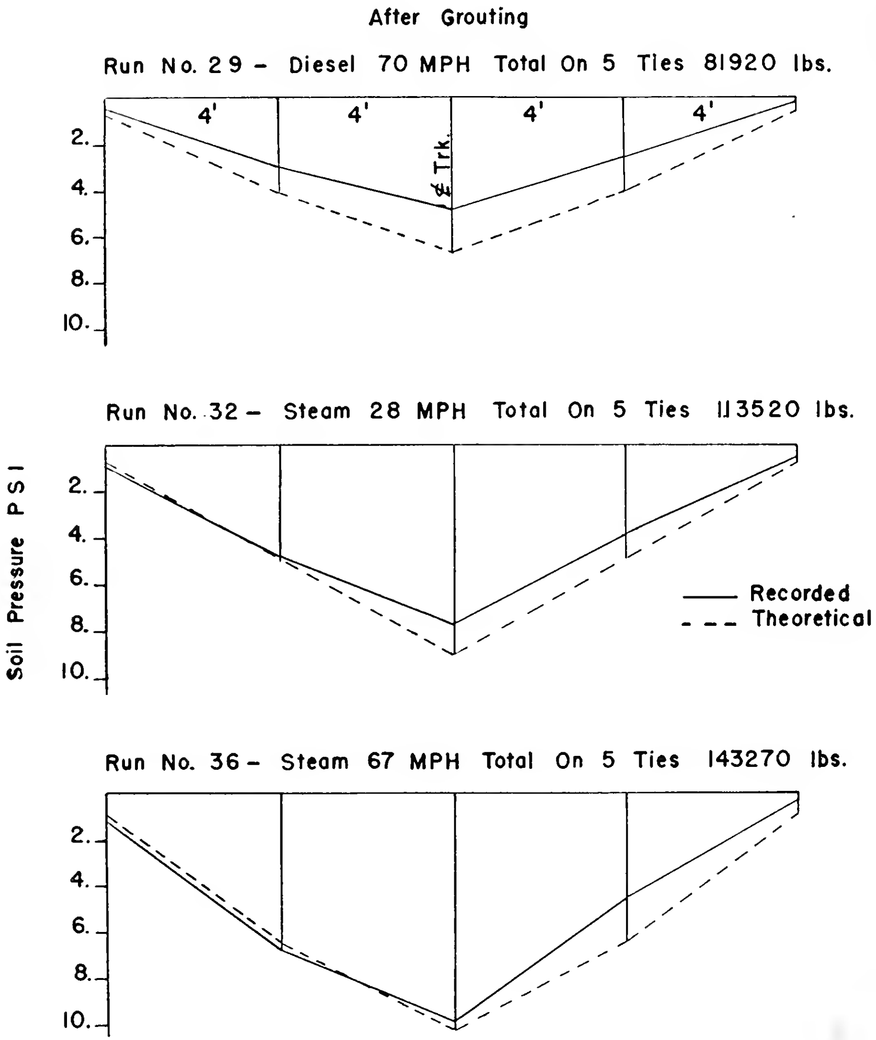
Fig. 5.

Relationship between load and horizontal pressure in both lateral and longitudinal directions.



Vertical Pressure Distribution At Section Through Pressure Cells

Fig. 6



After Grouting

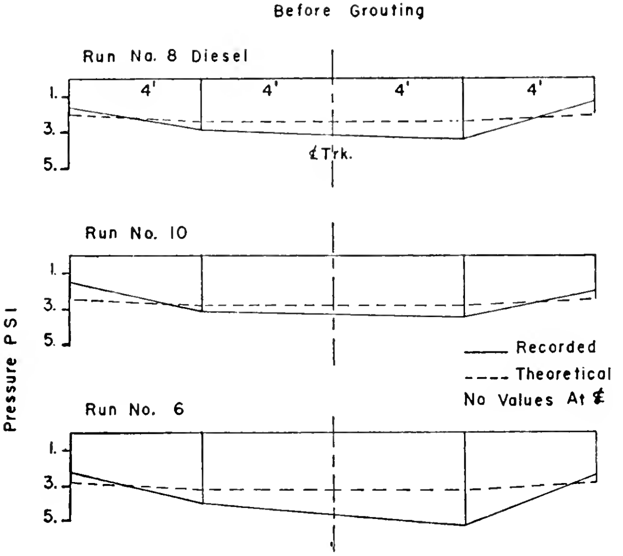
Run No. 29 – Diesel 70 MPH Total On 5 Ties 81920 lbs.

Run No. 32 – Steam 28 MPH Total On 5 Ties 113520 lbs.

Run No. 36 – Steam 67 MPH Total On 5 Ties 143270 lbs.

Vertical Pressure Distribution At Section Through Pressure Cells

Fig. 7



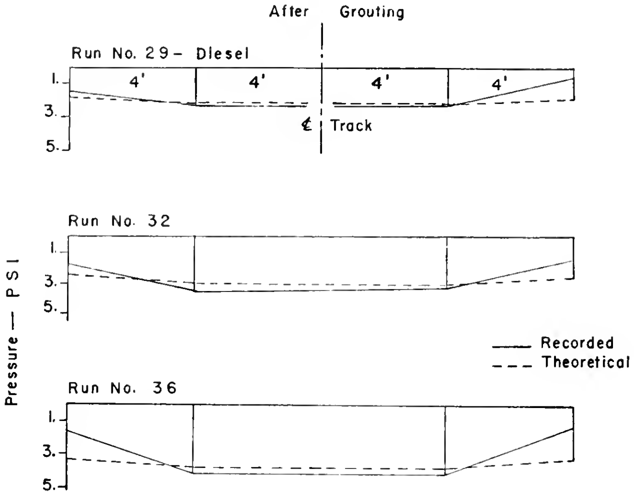
Lateral Horizontal Pressure Distribution At Pressure Cells

Fig. 8.

line, however, appears most closely to indicate the relationship between load and recorded equivalent vertical pressure after grouting. This dash line indicates for equal loads a decrease of approximately 9 percent in the indicated equivalent pressure after grouting.

While the indications of recorded vertical pressure on horizontal planes closely check theoretical considerations, the distribution of horizontal pressure on vertical planes is somewhat at variance with the theoretical pressures. Fig. 4 shows the relationship between recorded pressure before grouting and theoretical pressures for the cells 4 ft. and 8 ft. from centerline. Newmark's charts for a Poisson's ratio of 0.5 were used for computation of the theoretical horizontal pressures. For the recorded pressure the average of the cell records right and left is used for the curves. For the theoretical pressures these values are equal. It will be noted from Fig. 4 that the theoretical pressures 4 ft. off centerline are appreciably less than the recorded pressures, especially before grouting, but after grouting these values are in considerably closer agreement. For the pressures 8 ft. off centerline the theoretical pressure is appreciably greater than recorded pressures and the effect of grouting is to make this variation even greater. In both cases, however, the effect of grouting is to reduce the amount of pressure recorded for equal tie loads. The theoretical curves appearing on Fig. 4 are plotted from the values obtained both before and after grouting, but there is close agreement in the two sets of values and the points are not shown on the graph.

On Fig. 5 are plotted similar data for horizontal pressure at centerline on a plane normal to the centerline of the track; that is, the horizontal pressure is parallel to the track. For the recorded pressures before grouting there is very wide divergence from any average line that may be drawn to represent the points. The solid line on the right represents recorded values after grouting and is in fairly close agreement with the data.



Lateral Horizontal Pressure Distribution At Pressure Cells

Fig. 9.

This line also can be considered as representing a fair average for the recorded values before grouting. The theoretical pressure is indicated by the dash line on the left for values both before and after grouting, for which there is very good agreement. From this graph, grouting appears to have little or no effect on the recorded pressures at the centerline in a direction parallel to the track. The stabilization process has narrowed the spread of variation considerably, but the recorded pressures are greatly in excess of the theoretical values. In determining theoretical values for this pressure, it was necessary to include 8 additional ties in the system. Loads on these additional ties were taken to be the same as the average for the 5 ties on which the load was actually weighed. For the lateral horizontal pressures 4 ft. and 8 ft. off centerline, 4 additional ties were used in computing theoretical pressures using the average tie load as explained above. For vertical pressures the 5 tie loads recorded in all cases would account for approximately 98 percent of the theoretical pressures.

The distribution of vertical pressure over the section on which pressure cells were installed is indicated in Figs. 6 and 7. On these plotes the recorded pressure is indicated by a solid line and the theoretical by a dash line. The close agreement between theoretical and recorded prior to grouting is shown on Fig. 6. On Fig. 7 the same values indicate similar distribution, but with an indicated lessening of recorded pressures after grouting. The 6 runs shown on these 2 graphs are fairly typical of the 42 runs recorded.

Similar graphs for the lateral horizontal pressures are indicated in Fig. 8 and Fig. 9. These runs plotted on these two figures are the same as those plotted in Fig. 6 and Fig. 7. Prior to grouting theoretical pressures in all three cases are noticeably less than the recorded values, except for the cells 8 ft. from centerline, where the theoretical values are slightly greater. After grouting these latter values remain greater, but over the center of the section the theoretical values are less than the recorded values although in closer agreement than for the data prior to grouting. No data on lateral pressure at centerline were obtained. Theoretical values can be computed.

The data include pressures measured on a plane at 45 deg. from the vertical and at 90 deg. to the plane of the cross section, and these data will permit full analysis of principal stressess, direction of stressess and shear stresses. This material involves considerable lengthy computation and the results will be incorporated in succeeding reports if data of value are obtained.

Pressures recorded after grouting were obtained within a few days after the stabilization process and the effect on pressure intensities may not be of permanent duration. However, the cells will remain in place and additional runs will be obtained during 1951, and further consideration of these points will be made at that time.

Summary

The trench 9 ft. in width excavated for the installation appears sufficient to eliminate any significant arching effect for cells at this depth. Action of the track over the backfilled trench appeared normal.

The results of the data so far analyzed indicate that the vertical pressures recorded are very close to the range indicated by theoretical considerations, which lends confidence both in the method of calculation and in the method of pressure-cell measurement. Pressure grouting stabilization changes the values of recorded pressures, but it does not destroy the proportionality between load and pressure. For these tests the effect of the stabilization is to reduce the indicated pressure. The data are not sufficient to indicate that this reduction of pressure intensity is the result of a wide distribution of the load, but a consideration of statics would so indicate.

For horizontal pressures there is greater divergence of the recorded values from the theoretical values. A decrease in Poisson's ratio to 0.4 would increase this divergence. Stabilization reduces the recorded values of the lateral horizontal pressure intensity. After grouting the plotted points are more closely in agreement with a straight-line proportionality between load and pressure. Recorded values both before and after grouting at 4 ft. from the centerline are greater than the theoretical, but at 8 ft. off centerline the recorded values before and after grouting are less than the theoretical. There is no reason to suspect that the horizontal cells are not registering as faithfully as the vertical cells, and it appears tentatively that the basic elastic assumptions for computing theoretical pressures are not strictly tenable for the horizontal values. A number of considerations may be involved, such as track effects, passive resistance of the soil, strains, and a possible nonisotropic condition. Much additional study and analysis of available data are required in consideration of these elements.

While grouting usually decreases the pressures for equivalent load, the amount of such decrease does not seem sufficient to explain the good results received by pressure grouting. A decrease of 10 percent in the vertical pressure intensity would hardly prevent the development of pockets. Reduction of pressure and consequent increase of the pressure-bearing section is much to be desired, but previous investigations have shown that, in pocketed conditions, thin layers of soil through moisture accumulation are reduced to very low strength. The above reduction of pressure is far too small to reduce unit stresses below the soil strengths. It seems very probable, therefore, that the action of the cement slurry is also beneficial in some other way, such as waterproofing the subgrade, with a consequent prevention of moisture absorption and reduction in strength.

Report on Assignment 4 (b)

Culverts

Installation of Pipe Culverts

A. W. Schroeder (chairman, subcommittee), W. T. Adams, T. F. de Capiteau, G. W. Miller, W. C. Swartout, W. O. Trieschman, A. A. Winter.

This is a progress report, presented as information for the purpose of soliciting comments and criticism prior to submission next year for adoption and inclusion in the Manual.

INSTALLATION OF PIPE CULVERTS

Inspection

All material used in the construction of pipe culverts shall be subject to inspection by a representative of the railroad at the fabricating plant or at the site of the work. Material rejected by the railroad's inspector shall be removed by and at the expense of the contractor; it shall be replaced with acceptable material without additional cost to the railroad.

Handling

Pipe culverts shall be shipped and handled in such manner as to prevent damage to pipe or injury to the pipe coating. Pipes shall not be dropped or dragged over the ground. They shall be handled with skids, rolling slings or cranes. If pipes are bituminous coated, all spots on the pipes where the bituminous coating has been injured or destroyed shall be painted with two coats of approved hot asphaltic paint or approved cold bituminous paint prior to installation.

Installation

For installation of corrugated structural plate culverts, see specifications, AREA Manual, pages 1–12.81 to 1–12.88, inclusive.

For installation of concrete culvert pipe, see specifictions, AREA Manual, pages 8–123 to 8–127, inclusive.

Installation may be by open trench excavation, tunneling, jacking, threading, or a combination of such methods, depending upon local conditions, except where the method of installation has been specified in advance by the engineer or is shown upon the plans. The minimum gradient should be 0.5 percent.

(a) Preparation of foundation.—The foundation shall be of uniform density and shall be carefully shaped to fit the lower one third of the outside circumference of rigid pipe; the foundation should be shaped to permit tamping under the pipe. The foundation shall conform to the grade and camber established by the engineer.

Where a trench is required, it shall be excavated only to a width sufficient to permit thorough tamping of the backfill material under the haunches and around the pipe as hereinafter specified, but the trench shall not exceed the external diameter of the pipe by more than 12 in. on each side, except where unsuitable material is encountered.

Where, in the opinion of the engineer, the foundation at the established grade is unstable, the unstable material shall be removed for a depth equal to the pipe diameter up to a maximum of 3 ft., for the full length of the pipe, and for a width of at least one diameter on each side of the pipe, and the excavation backfilled with a well compacted granular material. When indicated on the plans or when directed by the engineer, rigid pipe shall be bedded in concrete, reinforced when required, and in accordance with the direction of the engineer.

If ledge rock or boulder formations are encountered at the established grade, such rock shall be excavated to a minimum of 1 ft. below the lowest extremity of the pipe and the excavation backfilled with an earth material placed in compacted layers, each having a thickness of not more than 6 in. (loose measure).

(b) Laying Pipe.—Each culvert shall be laid true to the established line and grade, except where camber is specified, and shall have a firm bearing throughout its entire length.

If two or more lines of pipe are to be laid parallel to each other, they shall be spaced to permit thorough tamping. Pipes up to 72 in. in diameter shall be separated by a distance of at least one half of the diameter of the pipe, with a minimum of 1 ft. Larger sizes shall be separated a minimum of 3 ft.

Riveted corrugated metal pipe shall be laid with outside laps of the circumferential joints pointing upgrade, and with the longitudinal joints on the sides. The ends of the sectons shall be spaced approximately ¾ in. apart and connected with bands bolted firmly into place. Riveted corrugated metal pipe having a diameter of 48 in. or more shall be strutted in a manner to increase the vertical axis approximately 5 percent. The struts shall remain in place until the backfill has consolidated around the pipe.

Rigid pipe shall be laid with the groove or bell end of each section upgrade and with the tongue or spigot firmly inserted into the groove or bell. Recesses shall be excavated for all bells. Unless otherwise specified, all joints shall be sealed in a manner approved by the engineer. The outside of the joint shall be filled with sufficient mortar to form a bead around the pipe. The inside of the pipe shall be wiped clean and finished smoothly. After initial hardening of the mortar, the outside of the pipe shall be protected from the weather.

Backfill

As rapidly as the condition of the pipe will permit, selected material, free from large or frozen lumps, clods or rocks, shall be deposited in layers not exceeding 6 in. in depth (loose measure), and thoroughly compacted so that on each side of the pipe there shall be a berm of thoroughly compacted or undisturbed soil at least as wide as the external diameter of the pipe or to the trench sides. Each layer, if dry, shall be moistened and then compacted by rolling or tamping with a mechanical tamper, or hand tamper weighing not less than 20 lb. and having a tamping face not larger than 6 in. by 6 in. Special care shall be taken to compact the soil under the pipe and on the side thereof. This method of placement shall be continued until the top of the pipe is covered with at least 12 in. of soil. Cinders shall not be used for backfilling.

General Conditions

(a) Precautions for Safety of Trains and Track.—The work shall be so arranged that there will be minimum interference with the operation of trains beyond the schedule established by the engineer. Regardless of the method used, the track must be adequately supported during the installation. Whenever the work as authorized affects the safety of trains or tracks, the railroad may require such precautions as it deems advisable to insure safety, and the cost thereof shall be charged to the contractor.

(b) Cleaning Up.—Before the work is finally accepted, the contractor shall, at his own expense, clear away from the railroad's property and from the channel of the stream or ditch all rubbish and excess material and all contractor's tools, equipment and other property.

Report on Assignment 6

Roadway: Formation and Protection

B. H. Crosland (chairman, subcommittee), R. H. Beeder, J. C. DeJarnette, Jr., W. P. Eshbaugh, R. A. Gravelle, G. B. Harris, R. R. Manion, G. W. Payne, C. S. Robinson, F. H. Simpson, C. E. Webb, W. L. Young.

Your committee has three subassignments under its general assignment, each of which is studied by a section of the subcommittee with its own section chairman.

Reports on two of the subassignments are presented below.

Report on Assignment 6 (a)

Roadbed Stabilization

F. H. Simpson (chairman, subcommittee section (a)), R. H. Beeder, R. R. Manion, **W. L. Young.**

The following report, presented as information, was prepared by the Engineering Division research staff of the Association of American Railroads. Upon the recommendation of your committee the report this year is limited to tabulations of costs and savings effected by pressure grouting and by pole and tie driving, the latter for the first time Considerable additional data, both factual and technical, have been obtained in the course of the investigations, but in view of the detailed reports previously submitted your committee feels that publication of this information can best be postponed until such time as the data permit the drawing of more definite recommendations. Work along these lines will be continued.

The cost and maintenance data appearing in the research report are worthy of study. Judicious use of roadbed stabilization can result in appreciable savings. The committee expects to report similar data in the future on various other types of stabilization.

Subjects of allied interest very closely related to roadbed stabilization are reported under the assignment of subcommittee 2 (a) Physical Properties of Earth Materials.

Sixth Progress Report of the Investigation of Roadbed Stabilization—1951

This investigation has been conducted under the 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, directed the work. Rockwell Smith, roadway engineer, research staff, performed the field work and prepared this report.

General

The investigation in 1950 continued the study of the different methods of stabilization in use. In addition, considerable attention was given the investigation of areas of evident or incipient instability to determine the underlying causes and the most effective treatments. The results of this work are described generally under the assignment of Subcommittee 2 (a).

Data on maintenance costs have been brought to date for pressure grouting (Tables 1 and 2), and limited cost data and maintenance savings for tie and pole driving are

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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 Trk.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	7th Year	8th Year	Average	Avg. Sav Man Hou Per Mil Per Yea
Thatcher, Colo. MP 595-603 Four Locations	5/42 to 9/42	3.4	1/8-1/40	1.42	0.535	7359	4463	2544	3742	2860	2670	2652	1525	1267	2715	4644
Maxwell, N.M. MP 684-685	12/42 to 8/43	1.0	1/4-1/8	1.26	0.68	3614	1803	1424	846	1169	1218	720	736		1131	2473
Dermott, Texas MP 748-749	2/43	1.0	1/8	1.45	0.56	2952	731	1443	2015	1718	304	234	266		959	1993
Maxwell, N.M. MP 682-683	7/43	1.0	1/8	1.05	0.65	2743	2927	1746	555	216	856	402	466		1024	1719
Edgerton, Kans. Curve 47	11/43	0.218	1/6	3.17	1.46	6595	1464	2840	3574	2935	2546	1921	1569		2407	4188
Taiban, N.M. MP 704-709	5/44 to 7/44	5.0	1/10	2.18	0.50	1813	321	606	630	798	815	710			647	1166
Onava-Azul, N.M. MP 761-762	7/45	1.0	1/16	3.95	1.58	6750	2541	1415	1813	428	1128				1465	5285
Texico, N.M. MP 649-652 Double Track	12/45 to 7/46	4.0	1/16	6.21	2.43	2535	1581	629	1064	1580					1213	1322
* Snyder, Texas MP 775-776	7/46	1.0	1/32	2.5	0.52	806	622	328	549	424					481	325
* Near Alvin, Texas MP 42-43	9/45 to 11/45	1.0	1/12	1.48	0.72	2236	1155	1050	1100	855					1040	1196
Avg. of Water Pocket Test Sections		18.618				3740	1761	1403	1589	1298	1362	1106	912	1267	1308	2431
						SLIDING FILL										
* Brenham, Texas MP 126 plus Sliding Embankment	9/46 to 3/47	0.354	1/16	35.14	8.89	6215	424	234	373						344	5871

* A.R.E.A. designated test sections.

NEW YORK CENTRAL - GROUT TEST SECTIONS
WATER POCKETS & SOFT TRACK

						Dollars per year per mile	Dollars per year per mile									Dollar
Monroe, Mich.	1941	0.362	1/1	1.25	0.65	7800	245	212	1875	1570	314	431	215		695	7105
Port Clinton, O.	1942	0.555	1/1	1.50	0.90	14600	862	829	304	0.0	0.0	0.0	0.0		333	14267
Canada Division	1943	0.827	1/1	2.77	1.60	10500	1038	1410	1760	922	1320	880			1222	9278
(" ") (Welland, Ontario)	1945	1.482	1/1	5.75	2.78	6354	994	418	275	203					473	5881
Hillsboro, Ill.	1945	0.615	1/1	4.54	1.07	13365	5760	160	660	285					1716	11649
Corunna, Ind.	1946	0.488	1/1	5.62	2.95	5450	211	0.0	0.0						70	5380
Average of water pocket sections -						9678	1518	505	812	596	545	437			752	8926
						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	12.96	0.0			11.04			2848
M.P. 33.16 Near Weisburg, Ind.	1947	400 feet Double tr.	1/1	15.0	9.60	228	0.0	0.0					0.0			228

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Chicag
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TABLE NO. 2 — GROUTING AND MAINTENANCE DATA

Railroad and Location	Year	Length of Section Reported Feet	Grout Acceptance cu.ft. per tr. ft.	Grout Mixture Cu. Ft.				Character of Track	Dollar Total	Cost of Grouting		Maintenance Data Before Grouting	After	Savings		Period of Record Yrs.		Remarks
				Cement	Sand	Fly-Ash	Gal. Asphalt	Ballast Type & Type Instability Max Cut & Fill		tr.ft.	cu.ft.	Man Hrs. per Year		Man Hrs. Per Year	Percent	Before	After	Grouting Equipment & Type of Work
Baltimore & Ohio																		
Baltimore E.E. & Toledo Divs.	1946	13,191	5.92	1	14	-	-	Crushed stone, soft track, unstable fills.	35,491	2.69	0.455	11,042	5,160	5,882	53	1	1	Hydraulic, track & fill.
				1	10	-	-	Cinders, squeezes, ballast pockets.										
					14	1	1,240 ft.											
Baltimore E.E. Akron,St.L. Divs.	1947	31,619	4.40	1	7,8,14	-	-	Crushed stone, slag, soft track.	59,472	1.88	0.426	38,910	12,672	26,238	68	1	1	" " "
" " " " " "	1948	23,204	4.98	1	7,12,16	Used on some portions only.		Unstable fills.	61,375	2.64	0.531	24,538	11,444	13,094	53	1	1	" " "
Canadian National																		
Stevensville, Ont.	1945	(1,232)	2.01	1	1.5	-	-	Crushed stone & gravel. 10' max fill.	2,895		(1.14)	3,440	541	2,899	84	1	4	Pneumatic, track only.
		(520)	1.67	1	1	-	-		1,118		(1.29)		Eliminates shims					
M.P. 58.7 Cayuga Subdivn.	1949	2,142	4.4	1	2	-	-	Crushed rock - side slips.	6,030	2.82	0.64	4,800	Est. 600	4,200	87	5	3 mos.	" track and fill.
				1	7	1	-	4' to 12' fill.										
CB&Q - Burlington																		
M.P. 123.19 Beardstown, Ill.	1946	269	14.58	1	7	1/2	2/3	Cinders - 50' sliding fill.	1,662	6.18	0.42	$2,107.28	$ 5.75	$2,101.53	99	1	3	Hydraulic, track & fill.
Alliance Div. M.P.438-439.2	1946	6,336	7.85	1	7	1/2	2/3	Crushed rock. Unstable low fill, heavy clay.	13,939	2.20	0.28	$2,366.00	$ 16.76	$2,349.24	99	1	3	" " "
" " " 458.8-459.05	1947	1,320	5.76	1	7	1/2	2/3	" " " " " " "	3,379	2.56	0.44	$2,867.80	Normal	$2,867.80	100	1	3	" " "
St. Joseph " 129.5-130.04	1947	2,884	5.23	1	4	-	-	Chatt - Unstable low fill, heavy clay.	7,441	2.58	0.49	$2,671.44	108.12	$2,671.44	98	1	3	Pneumatic, track only.
Chicago & North Western																		
Near Nondamin, Ia.	1945	10,560	4.2	1	7	-	1	Cinders - Unstable 7' fill.	16,790	1.59	0.39	5,608	1576	4032	71	1	5	Hydraulic, track only.
" Council Bluffs, Ia.	1946	12,500	4.1	1	7	-	1	Cr. stone,gravel,cinders.Unstable 10' fill.	23,625	1.09	0.46	2,085	522	1563	75	6 mos.	4	Hydraulic & pneu.track only.Welded
" Clinton, Ia.	1946	325	27.9	1	3	-	0.5	Cr. stone & cinders. Sliding 30' fill.	5,206	16.02	0.43	2,545	247	2298	90	1	4	Hydraulic, track & fill.
" Salix, Ia.	1947	6,500	4.0	1	7	-	1.5	Cinders, soft track, unstable 4' fills.	-	-	-	3,360	2298	1068	31	1	3	" " "
CMStP&P - Milwaukee																		
Near Owega, Ia.	1945	16,297	1.65	1	4	-	-	Gravel, cinders - pocketed Tr. 6' fill.	22,164	1.36	0.83	3,540	550	2990	83	1	4	Contract pneumatic, track only.
Delaware & Hudson																		
Whitehall, N.Y.	1947	(524)	2.00	1	1 1/2	-	-	Stone ballast on timber mat on wet clay.	1,593	3.04	(1.52)	1,129	37	1092	97	1	3	Pneumatic over mat.
		(335)	4.78	1	1 1/2	-	-	" " " " " " " "	3,312	6.93	(1.45)							" under "
Smith's Basin, N.Y.	1948	2,841	3.60	1	1 1/3	-	-	" " ,pockets, 6' cut to 10' fill.	9,517	3.35	0.93	2,366	264	2102	89	1	2	" track only.
Great Northern																		
Near Glasgow,Mont.	1946-47	8,012	4.51	1	6	-	1	Gravel, pockets & splitting 10' fills.	13,861	1.73	0.44	11,930	364	11,566	97	1	3	Pneumatic track & fill.
												1570 c.y. bal.	None					
" Fargo, N. Dak.	1947	10,545	5.36	1	5	-	1	" , soft track, 4' fills.	19,824	1.88	0.35	15,015	3,350	8,315	55	1	3	" track only.
												800 c.y. bal.	25 c.y.bal.					
" Wahpeton, N. Dak.	1947	19,701	2.65	1	5	-	2	" " " " "	22,065	1.12	0.36	15,428	2,188	11,052	72	1	3	" " "
												5800 c.y. bal.	None					
" " " "	1948	10,880	4.34	1	5	-	2	" " " " "	13,056	1.20	0.28	10,680	1,280	9,400	88	1	2	" " "
												1500 c.y. bal.	None					
" Noyes, Minn.	1948	815	45.88	1	5	-	1 1/2	" , pockets & slipping 12' fill.	14,662	17.99	0.39	3,448	0.0	3,448	100	1	2	" track & fill.
												350 c.y. bal.	None					
Illinois Central																		
Robb, Ill. Tunnel No. 2	1945	3,215	1.90	Cement only			-	Crushed rock, tunnel, mud boils	13,085	4.07	2.13	6,192	384	5,808	94	1	5 1/2	Hydraulic on track equipment.
Chicago Terminal	1944	80	13.90	1	4	1	-	" " soft track dbl.slip switch.	674	8.42	0.61	100	20	80	80	1	6	Pneumatic, track only, fill ground
Carbondale, Ill., Yard	1946	3,577	1.48	1	7	1	-	Cinders, squeezes, soft track.	1,359	0.38	0.26	2,178	120	2,058	94	1	4	Hydraulic on track equipment.
Near Elmford, Ill.	1947	1,521	23.30	1	7	1	-	Crushed slag, cinders, sliding fill.	12,442	8.18	0.35	1,248	120	1,128	90	1	3	" track & fill.
Louisville & Nashville																		
Duckers, Ky. M.P. 74	1947	400	3.6	1	2	-	-	Limestone	1,292	3.23	0.90	$1,136.	$ 10.45	$1,125	99	1	3	Hydraulic.
" " " "	1948	600	6.03	1	2	-	-	"	3,348	5.58	0.92	$4,543.	$ 30.02	$4,513	99	1	2 1/2	"
Ravenna, Ky. M.P. 232	1948	1,156	3.76	1	2 1/2	-	-	Cinders	2,682	2.32	0.62	$1,762.	$288.00	$1,474	83	1	2 1/4	"
MStP&SSM - Soo Line																		
Near Borea, Wis.	1946	4,313	2.01	1	5.2	-	-	Pit run gravel 10' unstable fill.	3,321	0.77	0.39	$1,169	$325.	$ 844	72	8 mos.	3	Hydraulic, track only.
	1947	11,468	1.92	1	6.7	-	-	" " " 8-10' " "	7,798	0.68	0.36	$2,478	$656.	$1,822	73	2	2	" " "
	1948	24,006	1.08	1	5.8	-	-	" " " 2-12' " "	12,723	0.53	0.49	$2,779	$710.	$2,069	74	3	1	" " "
Mo-Kan-Texas																		
Moran-Savonburg, Kan.	1945	8,941	3.74	1	8	-	1	Chatt,pockets & soft track 10' cut & fills.	21,905	2.45	0.65	3,731	est. 520.	3,211	86	1	4 3/4	Hydraulic contract, track only.
Nickel Plate																		
Wheeling & Lake Erie Dist.																		
Near Baltic, Ohio M.P. 100	1948	600	38.48	1	2	-	-	Slag on cinders, sliding 40'-50' fill.	13,512	22.52	0.586	$3,000.	0.0	$3,000	100	1	2	Pneumatic fill grouting.
" " " M.P. 99.56	1949	429	42.69	1	2	-	-	" " " " 30'-40' "	9,592	22.36	0.524	-	0.0	-	100	-	1	" " "
" " " M.P. 99.31	1949	147	12.27	1	2	-	-	" " " " 5'-10' "	989	6.73	0.548	-	0.0	-	100	-	1	" " "
Northern Pacific																		
Bathaway, Mont. M.P. 100	1945-47	7506	2.0	1	6	-	1.2	Crushed stone. ater pockets on low fill.	11,259	1.50	0.75	$1,400	$167	$1333	95	1	3	Hydraulic, track.
Tacoma-Portland, Ore.	1948	4660	17.7	1	6	-	1	Cr. Stone. ater pockets,slipping 15'fill.	45,668	9.30	0.55	$7,520	$1000	$6520	87	1	1	" " & fill.
	1948	1130	16.0	1	6	-	-	" " " " " 12'fill.	8,396	7.43	0.46	$170	0.0	170	100	1	1	" " " "
Pennsylvania																		
North Point, Md.	1936	75	Av. for Western Region	-	-	Pulv. Limestone	-	ater pocket.	700	9.33	-			1,400	-	1	14	
										Av. est. Region								
Four Divisions	1945	7408	1.29	1	-	2	-	Gravel, settlement.	10,075	1.36	1.044	16,250	1,735	14,515	89	2 1/4	3 1/4	Hydraulic.
Ft. Wayne, Ind. Div.	1945	137	1.29	1	-	2	-	Crushed stone, settlement.	186	1.36	1.044	1,315	266	1,049	80	2 1/3	3 1/3	"
Toledo, Ohio Div.	1945	7300	1.29	1	-	2	-	Gravel "	7,928	1.36	1.044	12,350	495	11,855	96	2 1/4	3 1/4	"
Chicago Terminal	1945	2388	1.29	1	-	2	-	" "	3,248	1.36	1.044	4,410	520	3,890	88	2	3	"
Bedford, Ohio	1946-47	6416	5.02	1	1	2	-	Crushed stone, soft track, 20' cut.	16,928	2.64	0.53	2,431	127	2,304	94	1	4	"
Virginian																		
Westgate, Va.	1949	540	26.8	1	4	-	-	Cinders,crushed stone,sliding 65' fill.	8,040	11.89	0.555	$8,500	$ 64	$8,432	99	1	1	Pneumatic, track & fill.

TABLE 3. TIE AND POLE DRIVING—MAINTENANCE DATA

Location	*Year treated*	*Length of section track ft.*	*Cost*		*Maintenance Data man-hrs. per yr*		*Savings*		*Period of record*	
			track ft.	*total*	*before treatment*	*after treatment*	*man-hrs. per year*	*Percent*	*before*	*after*
A.T.&S.F. Poles										
Near Alvin, Tex.	1943	5470	$0.803	$ 4,400	1312	640 Avg.	672	51	1	6
Baltimore & Ohio Poles										
Caseyville, Ill.	1946	600	$7.40	$ 4,438	1456	506	950	65	1	1
Caseyville, Ill.	1947	2711	$5.77	$15,658	3204	214	2990	93	1	1
Niles Jct., Ohio	1948	2257	$7.52	$16,970	5452	1169	4283	79	1	1
Mo. Pac. Cull ties										
Wichita, Kans.	1931	1900	$0.98	$ 1,862	Not Available	Est.	3 daily 750 per year	----------	1	16

reported for the first time (Table 3). It is hoped that similar data for other types of stabilization can be obtained during 1951.

Cost Data

The data in Table 1 for the Santa Fe and the New York Central show yearly maintenance savings obtained during periods up to eight years after grouting. There is no general trend toward higher maintenance cost with the age of the project. If any trend is apparent, it is toward reduced expenditures with years. For the Santa Fe, the average savings obtained for all projects reported amount to 2403 man-hours per mile per year, based on the more than 18 miles as tabulated. When it is projected on this basis to the more than 800 miles treated by this road, the yearly saving is considerable. It is interesting to note that the savings obtained from the stabilization at Thatcher, Colo., are the highest reported. This grade was built in 1936 and had not received the benefit of the years of continuing maintenance obtained by the other projects built between 1900 and 1911.

The annual savings shown in Table 1 for the New York Central are considerably higher than those for the Santa Fe. These values are projected to a mile basis for direct comparison, but most of the sections reported are less than this distance. Also, a number of the projects reported include a number of small sections making up the total track feet. It is the policy of the New York Central to treat short sections showing the greatest maintenance costs; thus, stabilization of these sections results in greater savings than the out-of-face treatment of the Santa Fe. On the basis of the New York Central's analysis, stabilization of approximately 20 miles of track has resulted in a maintenance saving of over $750,000, and a net saving after deducting the cost of grouting of about $500,000 during the last eight years. Gross savings during 1949 alone amounted to almost $200,000. These figures are from a complete analysis and are not projected from the data in Table 1.

Table 2 shows similar data in less detail for 14 railroads. Results are comparable to those obtained by the roads listed in Table 1. Average maintenance costs for the period of record, one to seven years, are shown, with the annual savings and percent of reduction these savings represent of the costs prior to stabilization. This percent of saving varies from 45 to 100. The saving of 100 percent is not to be construed as reducing all maintenance to zero. It is rather to indicate that excess maintenance over that required on good, stable track has been eliminated. It has been noted usually that the reduction in so-called excess maintenance has also been attended by a reduction in basic maintenance, such as savings in ballast and out-of-face surfacing. With the exception of one road, the Great Northern, the data and records in Table 2 do not permit the evaluation of this item.

Another factor which is not directly assessable is the saving obtained from the raising of speed restrictions or the elimination entirely of slow orders. A considerable number of the railroads reported restrictions prior to stabilization and removal thereafter, the most noteworthy of which were the elimination of a 12 mph. order on the Westgate fill on the Virginian, and a 10 to 25 mph. order on the Northern Pacific between Tacoma, Wash., and Portland, Ore. Without these additional benefits, the least favorable project reported in Table 2 is self amortizing, without interest, within approximately 11 years. The most favorable project returns the cost of stabilization in less than one year. Most of the projects listed, which are considered a representative cross section of stabilized roadbed areas, will return the original expenditure within five years.

The benefits from roadbed stabilization are not limited to sections treated through pressure grouting. Table 3 shows the results obtained by three railroads on sections treated by pole and tie driving. The section on the Santa Fe, near Alvin, Tex., has for six years shown an average saving of 15 percent in maintenance, which returns the cost of installation in about six years. The Missouri Pacific installation gives similar results. The Baltimore and Ohio installations are on higher fills requiring larger and more expensive poles. While the cost of these installations greatly exceed those of the other two railroads, the original cost is returned in effected savings within five years. Details of this project are as yet not available. The details of the Santa Fe and the Missouri Pacific projects have been reported in the Proceedings, Vol. 49, 1948, pages 528–529.

The Santa Fe project is within eight miles of the grouted section reported in Table 1, near Alvin, Tex. The original cost of the grouting and the pole driving is closely equal, and the percent of maintenance savings is also very similar. The prior-to-treatment maintenance cost for the grouted section, however, is about double that for the section with poles, resulting in a greater annual saving. Conditions of roadway and subgrade on the two sections are very similar, and it is reasonable to assume that poles on the section grouted would have produced equal results. On other sections on other railroads inspected during this investigation, pole and tie installations have been very successful on low fills over wet areas. In most cases these installations, using 8 to 12-ft. poles, have been placed for costs ranging from $0.65 to $1.00 per track foot. Estimated grouting costs for similar areas have ranged from $0.60 to $1.50.

Third Progress Report of a Laboratory Investigation of Roadbed Stabilization—1951

Introduction

This is the third progress report of a laboratory investigation for studying the factors that cause soft spots in roadbeds. The first report appeared in the AREA Proceedings, Vol. 50, 1949, and the second in Vol. 51, 1950.

The investigation is part of the research work of the Engineering Division, AAR. It is being conducted 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 Dr. R. B. Peck. The tests described in this report were conducted by E. Rosenblueth and T. S. Fry, and constitute a continuation of those started on Material II, a plastic clay with properties described in the second report.

Test Program

A summary of the tests performed in 1950 is given in Table 1, together with the properties of the material as placed in the simulated roadbed. The largest series consisted of 13 tests with ballast and 2 without ballast to extend the range of initial water contents used in the 1949 tests. Tests No. 38 and 42 were carried out to check similar tests in last year's program. Tests 39, 40 and 41 were made to investigate whether or not the presence of a thin layer of sand between ballast and subgrade would be beneficial.

With a few exceptions, the test specimens were subjected to repeated loads at the placement moisture content for a period of 500 min. and the deformation of the subgrade was observed. Thereafter, the subgrade was flooded and the test continued until the penetration of the test plate into the ballast became excessive.

Tests Without Ballast or With Ballast Only

This series comprises tests 23 to 37, inclusive, which were conducted for the most part on materials placed at low moisture contents.

TABLE 1. 1950 REPEATED LOAD TESTS ON MATERIAL II

Test no.	*Description*	*Initial Conditions*		
		w,%	q_u, *tons/ft.*^{2}	*dry density lb./ft.*^{3}
23	ballast; flooded*	15.4	2.27	88.8
24	ballast; not flooded	8.0	0.00	—
25	ballast; not flooded	11.3	1.25	90.5
26	ballast; not flooded	12.0	1.45	89.6
27	no ballast; not flooded	11.0	1.11	86.4
28	ballast; not flooded	10.9	1.09	—
29	no ballast; not flooded	11.6	1.32	88.8
30	ballast; not flooded	12.7	1.66	89.1
31	ballast; not flooded	15.2	2.24	88.2
32	ballast; not flooded	16.7	2.45	88.0
33	ballast; not flooded	17.7	2.56	90.5
34	ballast; not flooded	18.0	2.58	—
35	ballast; flooded	17.0	2.49	87.5
36	ballast; flooded	26.5	1.18	91.8
37	ballast; flooded	28.8	0.91	89.0
38	ballast and wire mesh	26.9	1.12	92.0
39	ballast and ⅜-in. sand layer	27.0	1.10	92.8
40	ballast and 3/16-in. sand layer	27.1	1.07	92.7
41	ballast and ¾-in. sand layer	27.3	1.05	96.3
42	ballast and 3/16-in. mortar layer	27.0	1.08	91.5

*Flooded tests were started at initial water content and flooded after 500 min.

Before flooding, the penetration was negligible for a range of water content between 8 percent and about 24 percent. Samples with moisture contents higher than 24 percent experienced an increase in penetration corresponding to the data in Fig. 17 of the 1949 report. On the other hand, the penetration after flooding was found to decrease with increasing water content up to a water content of about 24 percent. Above a water content of 26 percent, the penetration increased with increasing water content.

These results would seem to indicate that the rate at which soft spots may develop is likely to be a minimum for a water content intermediate between a fairly wet and a fairly dry condition. It is known that compacted clays placed at a water content appreciably below the optimum value are likely to be quite pervious because fairly large and continuous voids may exist between the chunks. As the initial or placement water content increases, the plasticity of the clay also increases. Therefore, the size of the voids and the permeability tend to decrease. Thus, as the water content increases, the time required for the penetration of water and the formation of soft spots also increases. On the other hand, if the initial water content is appreciably above the optimum value, the clay is already in such a soft condition that instability can develop very rapidly.

These considerations suggest that the most suitable water content for compaction of a new fill to prevent the rapid development of ballast pockets is a few percent above the Standard Proctor optimum.

Tests With Wire Mesh and Grout

Test No. 38 was an exact duplicate of that reported last year, in which wire mesh was inserted between ballast and subgrade. The results were similar and it appears that the tensile strength of the wire mesh is of substantial value in preventing the development of soft spots.

Test No. 42 was intended to be a duplicate of the 1949 test in which a thin layer of cement mortar was inserted between the ballast and the subgrade. However, the check test did not confirm the results of the original test and the mortar layer failed and permitted rapid penetration of the subgrade about 20 min. after flooding. This would appear to indicate that the beneficial effects observed in the field from cement grouting are not the result of a blanketing effect caused by the layer of grout.

Tests With Sand Layers

Tests 39, 40 and 41 were made with a layer of sand between the ballast and the subgrade. Three thicknesses of sand were used, namely $\frac{3}{16}$ in, $\frac{3}{8}$ in. and $\frac{3}{4}$ in. Prior to flooding, the sand layer had the effect of slightly reducing the penetration after a given number of load applications. However, after flooding, the penetration was no less rapid than in the tests without any sand layers. Therefore, it seems evident that the frictional resistance of the sand layers, or any corresponding frictional strength that a grout layer might have, is not responsible for the beneficial effects of track grouting. Moreover, any supposed effect of the sand in reducing stress concentrations in the upper part of the subgrade also appears to be non-existent.

Conclusion

The continued series of tests on Material II has demonstrated that the development of soft spots could probably be retarded by compacting embankments originally at a moisture content a few percent above the optimum value.

The studies made in 1949 and 1950 seem to demonstrate that the beneficial effects of track grouting are not the result of physical-chemical reactions between the soil and cement, nor are they due to the strength or frictional resistance of the grout. It is possible that some of the benefit may derive from the ability of the grout to waterproof the upper part of the subgrade, although this is not yet certain.

These comments lead to the conclusion that the benefit of the grout may be associated with its injection under pressure into the upper part of the subgrade and the corresponding squeezing of water from some of the pockets in the subgrade. Various techniques have been tried for accomplishing the pressure injection of grout in the laboratory tests but, as yet, it has not been possible to inject the small-scale model in a manner comparable to that in the field.

Future Program

A sufficient quantity of highly active clay has been obtained from the M–K–T relocation near Denison, Tex. (Proceedings, Vol. 50, 1949, page 719, Part II) to permit the performance of an extensive series of tests on this material. The characteristic properties of the material have been investigated and the tests can be inaugurated in the near future.

Further attempts will be made to develop a technique for injecting grout into the model subgrades.

First Progress Report on Investigation of Stability and Methods of Strengthening Existing Fills—1951

Introduction

During the past five years an increasing number of slides in fills have come to the attention of the research staff. Most of these slides have occurred in fills 25 or more years old, although a few are of recent construction. Grouting by portland cement—sand mixtures has often been found highly effective in stabilizing such fills in which failure seemed incipient. There appears to be little question that grouting is an economical and satisfactory method under many conditions.

It has also become apparent that one of the most important problems in connection with fill stabilization is the detection of those embankments in which instability is imminent. On one railroad, several slides have occurred in fills along one section of the line. Unstable conditions were noted and grouting equipment was made avaliable for use on what appeared to be the most dangerous of the fills. However, in at least two instances, major slides occurred in fills that were believed to be slightly more stable than those upon which the stabilization was being done. Had it been possible to determine accurately which of the fills was least stable, and to carry out stabilization in the order of increasing inherent strength, much time and expense could have been saved.

If unstable conditions are to be predicted before they manifest themselves in slides, it will be necessary to obtain a better knowledge of the strength of fills placed under conditions common in railroading. It appears that this can best be done by obtaining detailed information concerning certain fills that have become unstable and for which satisfactory information concerning the conditions during and after placement can be determined. In addition, it seems advisable to study certain other fills that, in accordance with present knowledge, would appear inherently weak, but are in reality stable.

Some information of this type has already been published in preceding reports; in particular, on the Chicago, Burlington & Quincy, near Beardstown, Ill., (1948 report, page 510), and on the Missouri–Kansas–Texas, at Denison, Tex., (1949 report, page 665).

Because of the wide variety of conditions encountered in embankments, it is desirable that the problem of stability be studied on as broad a basis as possible. Fortunately, both the U. S. Army Engineers and the U. S. Bureau of Reclamation have initiated studies similar to those being carried out by the Association of American Railroads. The AAR investigation is keeping informed of developments made by others.

The following summaries present the results of some of the 1950 investigations.

The field work was performed by R. B. Peck, H. O. Ireland, T. H. Thornburn, and T. S. Fry—all of the staff of the University of Illinois.

Nickel Plate Road.—An investigation of an unstable fill was made at Kiger Hollow, near Silverwood, Ind. The fill, which was built in 1942, is about 54 ft. high at the deepest spot in the hollow, and was constructed with slopes of about 1.6:1 to replace a girder bridge from which the girders were removed but the piers left in place. Most of the material was obtained from a borrow pit containing a sandy or gravelly glacial clay with a liquid limit of about 30 percent. It was placed in layers with tractors and scrapers and an attempt was made to achieve uniform compaction, except around the existing masonry.

Three major slides have occurred since construction, the first in January 1950, and the latest in July 1950. In each instance the north side of the fill dropped and the lower part of the slope moved more or less horizontally. It does not appear that the foundation material was involved.

Three borings were made in August 1950, two in the slide material and one in the adjacent, unaffected fill. It was found that the fill is composed primarily of silty, sandy or gravelly clay, although pockets and layers of sand and gravel and small deposits of organic material were found in each boring. The average unconfined compressive strength for samples from Borings 1 and 2, in the slide material, was 1.1 tons per sq. ft., and the water content about 20 percent. The samples from Boring 3, in the stable fill, were somewhat stronger, but the water content was about the same. Assuming no frictional resistance, the shearing strength should be equal to one-half the unconfined compressive strength, or to at least 0.5 ton per sq. ft. Stability computations on this basis indicated that the factor of safety of the fill against sliding was at least 1.25. Nevertheless, the fill failed.

At the time of failure the average shearing resistance along the real surface of sliding must have been on the order of 0.4 ton per sq. ft. It appears most likely that the fill consisted of chunks of material of higher strength surrounded by weaker and more pervious soils through which water could percolate. The last failure occurred after a period of extensive rainfall. Probably, the chunks were gradually softened on the outside by the action of the water and the quality of the fill gradually deteriorated. In testing the samples, only those materials that would remain intact could be subjected to tests. Hence the softer materials between the chunks would not be represented. It appears that only eight years were required for the moisture in the fill to accumulate and soften the material sufficiently to reduce its strength to the point of failure.

Burlington Railroad.—A slide occurred in a fill east of Creston, Iowa, early in 1950. The fill at this point was part of the original construction of the railroad; it was about 50 ft. high and approximately 50 years old. It was originally built for single track, but was widened for double track in about 1909. In 1949 the slope was flattened and dressed to slopes of about 2½:1. Beneath the highest part of the fill there is a masonry culvert, evidently constructed before the fill was enlarged to its present width. Therefore, the culvert is short and the slopes immediately adjacent to the head wall are a steep as 1:1.

The failure, which localized at the culvert, involved a considerable part of the slope. Much of the material that moved consisted of that added during 1949. Moreover, there was no evidence of base failure.

Soil conditions were explored by means of two borings, which revealed that the fill consists almost entirely of sandy silty yellow clay derived from the Kansan Drift found extensively in the locality. It contains moderately stiff chunks separated by softer, less cohesive materials. As in the case of the fill at Kiger Hollow, the only samples suitable for compression tests were those cut from the chunks more or less intact. The average unconfined compressive strength was about 1.5 tons per sq. ft., and the corresponding computed factor of safety is approximately 1.3. Here again, the slope failed, and it is obvious that the strength of the fill was appreciably less than that of the compacted chunks contained in it.

One of the borings was completed to a depth of about 32 ft. at the end of a working day. The water level at that time was near the bottom of the boring. By next morning the water level had risen to about 26 in. below the ground surface. This boring was located in the stable part of the fill. The rise of the water indicates both the very pervious nature of the fill and the presence of a considerable amount of free water in the voids.

This fill had exhibited instability for a great many years, as evidenced by the necessity for widening and flattening at various times. It is likely that the strength gradually deteriorated due to the presence of water in the larger voids in a manner similar to that a Kiger Hollow.

An extensive series of borings with a 4-in. auger was made prior to grouting this fill. On the basis of the borings, it was concluded that the fill should be stabilized, but the fill failed while the grouting program was in its initial stages.

Canal Dike Near Montreal.—In September 1950, an existing dike adjacent to the power plant along the canal at Beauharnois was investigated. For about 1000 ft. from its outlet the Beauharnois Power Canal is confined between two rolled earth dikes, constructed in 1931. These dikes, of Laurentian clay, have a maximum height of about 65 ft. above the normal ground level, or about 85 ft. above the underlying bedrock. The top width is 40 ft. and the side slopes are about 3:1. The parts of the dikes near the water line have been protected by riprap to reduce the damage caused by wave action.

The riprap rests directly on the clay, without any intermediate blanket or filter; otherwise, there is no slope protection. Compaction of the dikes was accomplished by driving trucks over the fill. Rollers and moisture-content control were not used.

The fill material has a liquid limit of about 60 percent, and a plastic limit of 27 percent. The borrowed material was primarily the desiccated gray and yellow upper crust of a very fine-grained clay deposited in salty waters during a post-glacial marine incursion of the St. Lawrence Valley. The clay mineral is predominantly illite, but some montmorillonite is present.

The optimum moisture content of the fill material is about 29 percent and the maximum dry density (Standard Proctor test) about 92.0 lb. per cu. ft. The clay was placed at a water content of about 37 percent, at a dry density of about 88 percent of the maximum, nevertheless, its unconfined compressive strength was about 1.5 tons per sq. ft., and no softening, sloughing or other deterioration had been observed prior to removal of the dike at the time of the investigation in September 1950.

Although the fill consisted of very impermeable clay chunks, the permeability of the fill as a whole was relatively great. This was demonstrated by bailing the water out of an observation well on the land side of the dike, over 100 ft. from the canal. The diameter of the well was 2.5 in. The water level was lowered 4 ft.; in 6 min. the level had risen 8.5 in. and in one hour it had risen 20 in. Probably the relatively free drainage of the clay facilitated the development of frictional resistance and accounts for the strength of the material.

Inspection of the soil in a test pit excavated in the dike near the water's edge demonstrated that the fill consisted of stiff, fairly brittle chunks that had been mashed together at their contacts and had split into smaller fragments near these contact points. The interstices were filled with the split-off material, which was rather soft and had a granulated appearance. Water was able to seep slowly through the cracks formed in the chunks when they had split.

Conclusion

This report contains two examples of fills constructed by ordinary procedures and consisting of materials with properties generally considered satisfactory for embankment construction. Both fills failed after a period of years. In the 1948 report was given the history of an investigation on the M–K–T, near Denison, Tex. Fills in this locality were constructed by the latest and most approved procedures, including moisture content control and compaction, but they failed in numerous places within a few years after construction. The failure has been attributed to the presence of nontronite, a rather unusual clay mineral that imparts undesirable characteristics to the clay.

On the other hand, the present report contains a brief summary of an investigation of an earth dike in Canada composed of clay having a high liquid limit and containing appreciable amounts of montmorillonite, also generally regarded as an extremely active and undesirable clay mineral. Moreover, the dike was inadequately compacted and was placed at a moisture content about ten percent above the optimum value. Thus, it might be anticipated that the dike should have behaved in an unsatisfactory manner comparable to that of the fill at Denison. Yet, it has stood for about 25 years with no slope protection, in contact with water, to a height of 65 ft., and showed no signs of weakening or deterioration at the time of its removal. These experiences demonstrate strikingly the inadequacy of present knowledge concerning the fundamental characteristics of fills in the field.

Experiences at the dike and at numerous other railroad fills have indicated that auger borings and undisturbed samples taken with 2-in. Shelby tubes provide considerable information about the characteristics of the material, but that, as yet, the information has not been definite enough to permit evaluating the urgency of stabilization. It is believed that interpretation of the auger borings is hampered by lack of knowledge of the true conditions in the interior of the soil mass. Hence, it is recommended that full-scale excavations be arranged to determine the actual structure of the materials in some of the older fills. Once the pattern of the structure is understood, it should become more feasible to interpret the results of borings and tests. Furthermore, it is recommended that additional explorations be made in fills that have been stabilized by grouting in order to determine the pattern of the injected material. This should not only provide a better conception of the manner in which the grout accomplishes stabilization, but it should help determine the optimum quantity of grout to be injected, and it should give some indication of the original distribution of the voids in the fill. The principal purpose of the investigation, however, would be to determine techniques for selecting those fills that should be stabilized because of the probability of slides in the near future.

Report on Assignment 6 (c)

Chemical Eradication of Vegetation

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This is a progress report, presented as information.

Clearing grass and weeds from track and ballast, clearing miscellaneous vegetation, vines and brush from the berm, ditches and right-of-way have engaged railway track forces from the earliest days.

The section foreman and his gang originally carried the entire responsibility for "clean track." Cheap labor costs were not accurately divided with respect to grassing and weeding. Supervisory instructions varied according to territorial weed conditions and labor budgets. However, when wheels slipped on grassy rails, or when foul ballast and clogged ditches caused pumping ties and soft track, the section gangs bore the criticism and managed the job.

Beginning in 1910, weed control methods were tried on railroad track. Sodium arsenite water solutions were sprayed from tank cars; weed burners, steamers and mowers were used. Accurate appraisals of the effectiveness of these methods were, however, difficult to obtain as track labor continued to carry its responsibility and regarded these devices as aids rather than complete substitutes for hand weeding. Dependable and self-sufficient track weeding was not obtained with chemicals or mechanical means to last a full growing season.

Budget approval for chemical weed control expenditures was justified as an aid to labor in order that it might devote more time to essential maintenance of the track structure, surface and alinement, and not as a basis for reducing labor forces.

Today track labor has been reduced as the result of labor-saving improvements to the extent that it is no longer available, and is entirely too costly for weed eradication or brush control.

The railroads now desire a self-sufficient and dependable chemical method of weed and brush control which includes the full track section, and in many cases the entire right-of-way. Apparently the day is gone when deficient chemical processes will be used to kill the vulnerable growth and labor will be used to clean up the resistant types. Such ineffectual methods cause the resistant types to spread due to lack of competition.

In attempting to improve chemical weed control to a self-sufficient and dependable standard, two methods have been followed:

A. To use more frequent applications within the growing season.
B. To increase the quantities or dosage of chemicals applied per mile.

Experience has shown that the older type chemicals, such as arsenic and chlorate, when used in ordinary top-kill or contact dosage, fail to provide root kill on many perennial types of weeds and grasses, and that soil poisoning to reach the roots frequently requires ten or more times the top-kill or contact dosage.

Experience has also shown that soil poisoning with mass quantities may result in chemical waste during periods of excessive rainfall, or where soil constituents cause fixation of arsenic into non-toxic forms, or where chlorates are decomposed.

The new hormone type chemicals completely kill certain plants and roots; however these new chemicals are limited in specific action. For example, 2,4–5–T kills many resistant woody vines, creepers and shrubs; 2,4–D kills many broadleaved weeds; trichloroacetic acid kills many of the most resistant grasses. These chemicals are also available in several derivative forms, which permit combinations in water solutions and others in oil solutions.

Recent experience provides evidence that combinations may be made whereby each constituent chemical not only performs its peculiar function, but also combines to aid other constituents to perform their duties. In this manner it appears that the railroad objctive of an all-purpose, dependable weed control may be evolved.

The complexity of this development naturally makes modern weed control a science. It is no longer a rule of thumb, hit-or-miss practice. Too many dollars may be misspent or fail to produce a full return unless weed control is based on scientific study and appraisal.

Many thousands of dollars are expended annually for weed control on the railways. Under present conditions the use of chemicals for such control appears to have great possibilities for effectiveness and economy. For the most part, however, the railroads, for lack of specific information, find it necessary to use the formulations commercially available. These formulations, while successful for many conditions, are designed principally for agricultural purposes. It is to meet railroad requirements that research is proposed.

This committee proposes to conduct research with such appropriations as may be made available for the purpose, in accordance with the following program:

To undertake through the Association of American Railroads research staff a contract with an educational institution already equipped with a laboratory and presently carrying on related investigations. The initial stages of the special railroad investigation would be in a three-year period and would provide for the establishment near the laboratory of test plots containing various types of vegetation to be controlled. These plots would be treated with various types of chemical weed killers now available. In addition, it is proposed to develop in the laboratory new chemical combinations which may be more effective and better meet the several specific requirements of the railroads.

Appraisal and classification by the committee of the results of the research should precede and lead to conclusions or specifications with respect to formulations, dosage and use in various sections of the country and under varying climatic conditions.

Report on Assignment 8 (c)

Fences

Instructions for Maintenance Inspection of Fences

L. V. Johnson (chairman, subcommittee), J. W. Poulter, C. R. Shaw, L. R. Shellenbarger, R. C. Young.

This is a final report, presented as information.

Maintenance of right-of-way and other fences may be of considerable importance on some railroads, while on many others it constitutes a relatively minor item of maintenance of way. Study by the committee indicates little demand or need for standardization of maintenance or inspection. Statutory and other requirements for fencing are so varied with respect to the railroads generally as to make the preparation of standard instructions impractical.

Report on Assignment 9

Signs

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This is a progress report, presented as information.

Roadway signs are primarily for use by employees who work on their territories by day and by night. The ordinary painted sign, carrying its message easily read in daytime, becomes a land mark at night with its message fixed in the mind of the observer from constant familiarity. Its first cost is low, and maintenance every two or three years, in the routine progress of a painting crew over the territory, is relatively inexpensive. It is not easily damaged by vandalism.

With some exceptions, the reflectorization of signs of all types would result in unnecessary expense, which cannot be justified. Certain types may be reflectorized where distinct warnings of special conditions are considered necessary by night as well as by day. Some of these are as follows:

Speed limit signs.
Drawbridge approach signs.
Yard limit signs.
Snow plow and flanger signs.
Spring switch signs.
Motor car indicator signs.

The reflectorization of signs may be accomplished by means of reflector buttons, reflectorized coatings of prepared materials fastened by adhesives, reflectorized plastic material, and reflectorized paint—some of these materials being in the experimental stage.

Report on Assignment 10

Ballast

A. T. Goldbeck (chairman, subcommittee), Stanton Walker (chairman, subcommittee section (a)), F. H. Simpson (chairman, subcommittee section (b)), C. D. Turley (chairman, subcommittee section (c)), J. E. Armstrong, Jr., E. W. Bauman, J. E. Chubb, L. B. Craig, A. P. Crosley, H. W. Jensen, G. L. Morrison, C. S. Wicker.

(b) Ballasting Practices

Reballasting and Resurfacing Track

This is a progress report, submitted as information. One of the assignments for the Subcommittee on Ballasting Practices involves a study of reballasting and resurfacing track. In order to secure information on this subject a questionnaire containing 10 questions was sent to 41 railroad members of Committee 1, representing 27 railroads. Replies were received from 35 individuals, representing 22 railroads. The answers received showed a great variation on the different railroads.

To the first question, as to whether single, double or multiple tracks were involved, two answers covered single track only; eight, double track only; nine, single and double track; six, single and multiple track and one, multiple track only.

The size of ballast used varies greatly. The predominant sizes of stone ballast are 2½ in. to ¾ in., 2½ in. to 1 in., and 2 in. to ¾ in. For gravel ballast, 1¼ in. to No. 10 sieve, and 1½ in. to No. 4 sieve predominately.

Stone ballast of the following types was involved: Trap rock; granite; quartzite; limestone; and dolomite.

Gravel ballast consists of pit run, washed gravel and crushed gravel. Also reported were Pueblo slag, copper smelter slag and blast furnace slag, volcanic cinders, and chats from zinc workings.

Reports of wear tests on stone ballast disclosed the following:

Trap rock:	Deval test, 2.3 to 4.5 percent
	Los Angeles abrasion test, 8 to 18 percent
Granite:	Deval test, 13.6 percent
	Los Angeles, 19.5 to 25 percent
Quartzite:	Deval, 2 to 3.6 percent
Limestone:	Deval, 2.8 to 5 percent
	Los Angeles, 12.9 to 27 percent.

The amount of lift reported varies greatly, due to physical characteristics of the properties of the reporting roads, and ranges as follows:

Trap rock:	3 in. to 5 in. for reballasting
	2 in. for resurfacing
Granite:	4 in. to 6 in. for reballasting
	1½ in. to 2 in. for resurfacing
Quartzite:	Not shown
Limestone:	4 in. to 8 in. for reballasting
	1¼ in. to 2½ in. for resurfacing
Dolomite:	Not shown
Pit run gravel:	4 in

Washed gravel: 5 in. to 6 in. for reballasting
1 in. to 2½ in. for resurfacing
Crushed gravel: 4 in. to 6 in. for reballasting
1 in. to 3 in. for resurfacing
Pueblo slag: 4 in. for reballasting
Copper smelter slag: Not shown
Blast furnace slag: 4 in. to 6 in. for reballasting.

The tools and machines used by the different roads varies considerably. One road reported using spades and tamping bars. Other tools are hand electric tampers and hand pneumatic tampers, with machines having capacity for operating from 4 to 16 tools each. Various types of power ballasters were also reported.

The question involving the force used was answered with great variation. For neumatic tampers the force ranges from gangs of 7 or 8 men to 70 men, depending on the number of tools being operated. Electric tamper gangs were reported in about the same range. One road reporting hand tamping, with spades or bars, uses gangs of 35 to 45 men. Another, doing hand tamping, uses 79-man gangs on the first raise and 26 men for the final raise. Another road uses hand gangs of 27 on the first raise and 13 on the final raise. Roads reporting the use of power ballasters of different types utilized gangs varying from 30 to 78 men per machine.

Production per day per machine or gang also varies greatly; in fact, to such an extent that it is very difficult to give any detailed report. The replies for hand tamping with gangs of 20 to 45 men gave production ranging from 440 ft. to 1,600 ft. per day. For electric tampers with gangs of 20 to 70 men, production varies from 475 ft. to 3500 ft. per day. Pneumatic tamper gangs of 15 to 70 men show a production range varying from 950 to 2600 ft. per day. Various types of power ballasters are used with gangs ranging from 45 to 78 men. The resulting amount of track raised ranges from 2000 ft. to 4000 ft. per day.

Another question involved the approximate cost per mile of track, divided, if possible, into labor, material, and rental of equipment not owned. Five roads reported no cost data available. The reports for work done with electric tampers varied from $1250 to $4900 per mile, depending on the amount of lift, ranging from 2½ in. to 6 in. Two roads reported equipment rental—one of $114, and the other of $320 per mile. Costs for resurfacing with pneumatic tampers varied from $900 to $1650 per mile for a lift of 3 in. to 4 in. Labor costs for reballasting with power ballasters varied from $950 to $1375 per mile with lifts of 3 in. to 6 in. Costs for reballasting with tamping forks varied from $1100 to $3800 per mile for lifts of 3 in. to 8 in. One road reported 825 ft. of track reballasted at a labor cost of $2012 per mile with a 2-in. to 4-in. lift.

All roads reported negligible breakage of stone, with one exception. That one road stated that there was appreciable breakage using pneumatic tampers, especially where the amount of lift was less than the maximum size of stone used. With one exception, all roads reporting prefer machine tamping over hand tamping. The opinion of roads using electric and pneumatic tampers was divided as to the merits of the two types of machines. Roads employing power ballasters reported that this type of machine puts up better track than hand tools.

Due to the wide variation of the replies, the values of the report is difficult to assess, but the subject of reballasting and resurfacing is very active and several new types of power ballasting machines are being offered by different manufacturers. We expect that further reports concerning such machines will be made.

Ballast Cleaning Practices

This report is offered as information.

One of the assignments for the Subcommittee on Ballasting Practices was to make a study of ballast cleaning practices. To get information in this regard, a questionnaire containing 12 questions was sent to 41 railroad members of Committee 1, representing 27 railroads. Replies were received from 35 members, representing 22 railroads.

The answers to the first question asked, concerning kinds of ballast used and sizes of particles, as well as the answers to all other questions, varied widely on the different railroads. Some of the requirements as regards sizes specified are as follows:

Crushed limestone:	2½ in. to 1 in.; 1½ in. to ½ in.; 2½ to ¾ in.; 2 in. to ¾ in.
Crushed granite:	2½ in. to ½ in. first lift; 1½ in. to ½ in. granite ledge rock; 2 in. to ⅜ in. granite boulders
Trap rock:	2½ in. to 1¾ in.; 2½ in. to 1 in.
Slag:	1½ in. to ¾ in.; 2 in. to ⅝ in.; 1½ in. to ½ in.; 2 in. to 1 in.
Lead and zinc mine chats:	½ in. to No. 30 screen

Does Your Road Clean Ballast?

Seven of the reporting railroads stated that they do not clean ballast at all. Most of the roads in this category did not indicate what type of ballast is being used. Four roads reported the ballast is cleaned only to a limited extent, one of these stating that it conducts out-of-face ballasting programs every 6 to 10 years because of center-bound track and that stone ballast is cleaned only at isolated locations, using forks. Another stated that its ballast cleaning work is confined to hand cleaning in station areas. The third said that it cleans ballast only on grades where the material has become fouled with engine sand, using forks and screens for this purpose. The fourth road reported that it had cleaned ballast in 1948 for the first time. Twelve of the reporting railroads said that they do considerable ballast cleaning. On all of the roads cleaning ballast, the work is confined to crushed materials, namely, limestone, granite, trap rock and slag.

A great variation in frequency of cleaning ballast exists, not only on different railroads, but on individual or separate territories of the same system. One road said that it cleans its crushed rock ballast annually; on 2 others the ballast is cleaned on an average of every 4 years; and on others it was stated that the cleaning cycle is from 4 to 12 years, 3 to 6 years, 1 to 5 years, and 2 to 4 years, the exact frequency at any specific location depending on local conditions. Others simply stated that the frequency of cleaning varies considerably, depending on conditions. One road said that it had cleaned ballast once in the last 20 years.

Answering a question regarding methods and machines used for cleaning ballast, six of those that do this kind of work indicated that mole-type ballast cleaners are the only machines used, and on one of these roads it was stated that such machines are used in connection with cribbing machines. On another road all ballast cleaning work is done with large on-track equipment, under contract, but on all others, various combinations of methods and machines are used. One road uses mole-type and large mechanical cleaners. Another says it uses several large gasoline-electric machines, plus mole-type units. Still another uses one or more large, locomotive-hauled ballast cleaning machines, as well as mole-type cleaners, and one road, in addition, is using a home-made machine. One railroad said that it cleans its ballast annually and reported that this work is done by hand, using ballast forks and screens.

During the working season of 1949, several new ballast cleaning machines were introduced and several roads are contemplating building machines of their own design. While there is great promise in these new machines, none of the roads submitting answers to the questionnaire had had sufficient experience with any of them to give any information.

A question as to whether cribs, center ditches, shoulders (all or any) were cleaned, also brought forth a variation in answers. Of the roads that clean ballast more or less regularly, four do not clean the cribs. Of those roads that do clean crib ballast a great majority remove the ballast from the cribs by hand, placing it on the shoulders or in the intertrack space, where it is picked up and cleaned by mechanical equipment. One road reported that it has been using cribbing machines for this purpose, and another road said that it has only recently started the use of such equipment. As is the case with ballast cleaning machines, several new developments in crib cleaners and crib excavators have been made, but these have not been in use long enough to get anything definite on their performance.

One question was with regard to the production per machine. Generally, the amount of ballast cleaned with the mole-type machines was in the range of 650 ft. to 1200 ft. per day, although one road reported a production of as little as 350 ft. per 10-hour shift with this type of equipment. Two roads gave production figures for these machines operating in both center ditches and on the shoulders. On one of these the production is 750 ft. per day in center ditches and 1200 ft. on the shoulder; on the other the output was 900 ft. per day in the center ditches and 1000 ft. on the shoulders. One road said that it averaged 100 ft. per hour with the mole-type machines, while another reported that the production with these machines is from 0.9 to 1.25 miles per week.

The reported output per day with the large, on-track machines also varied rather widely. For instance, the production achieved with one type of equipment, operated under contract, was reported to be 6 miles per day on one road, 15,000 ft. per 10-hour day on another, 11,246 ft. of single track per day on a third, and a mile an hour on a fourth. A railroad that uses another type of such equipment obtains a production of $0.055 per foot of shoulder and $0.06 per foot of intertrack space. With equipment reported a production of 1600 ft. of track per hour. One road, not mentioning the make of equipment, says it gets a production of 40,000 ft. per day with a rented machine, and that it cleans ballast at the rate of 24,000 to 36,000 ft. per day with a company machine. Another road, using a home-made ballast cleaner, reports production of 1800 ft. per 10-hour day. The railroad reporting the use of mechanical cribbing equipment says that cribs are cleaned at the rate of 900 ft. per day, while the one which does all of its ballast cleaning by hand says that its production by this method is 16 ft. per man per 8-hour day.

As regards the personnel for each machine or each method of ballast cleaning, the number of men with each mole-type machine ranges generally from 4 to 7; 5 being the most common. On several of the railroads it was indicated that the organization used with each such unit varies slightly, depending on various conditions, and on whether the shoulder or intertrack ballast is being cleaned. For instance, one road stated that it uses 5 men on each such machine in cleaning shoulder ballast and 6 men when cleaning intertrack space ballast. The road that uses one of the large on-track cleaners says that it uses 22 men with this equipment.

Where ballast is cleaned under contract by large on-track machines, the necessary force, according to the answers to the questionnaire, is furnished by the contractor. One road that apparently uses a machine of its own design says that it has 3 foremen and 13 laborers with each unit; another road that also uses home-made equipment employs 1 foreman and 9 laborers with each of its machines. The road that reported using a rented machine, but not specifying its exact nature, said it uses 4 foremen and 19 laborers with this equipment. The road that uses the cribbing machines has 5 men with each machines. Several roads that clean ballast by hand said that the number of men used varies somewhat. depending on the conditions encountered. The one road that does all its ballast cleaning by hand said that this work is done either by section gangs of 8 men or extra gangs of 30 men.

One of the questions asked for data on the cost of cleaning ballast per mile of track, separated between labor and material, and rental of equipment not owned. Here again, wide disparity was revealed in the cost figures for similar equipment. For instance, the figures given for the cost of cleaning ballast with mole-type machines varied within a wide range. Among the figures given on the cost of cleaning a mile of track with these machines were the following:

$1025 double track; $900, an estimated 85 percent of which represents labor; $987 for labor and $205 for material; $270 for labor; $848 for the intertrack ballast and $627 for the shoulder ballast; $335 for labor and $19 for material. One road that gave figures in dollars per foot said that the cost of cleaning ballast with these machines was $0.055 per foot of shoulder and $0.06 per foot of intertrack space. With equipment worked under contract, the reported figures per mile of track were as follows:

$512; $780 for the intertrack space and $390 for the shoulder; approximately $425. One road using this equipment gave figures to indicate that the amount paid to the contractor was $348 per mile and that, in addition, the road spent $109 per mile for work done with its own forces. The road that uses another of the large on-track types of machines reported the total cost per mile was $576, while the line that uses still another type of large on-track equipment reported that the cost was $502 per mile of intertrack space and $385 on the shoulder. Of the two roads that use home-made ballast cleaning equipment, one said that the cost is $375 per mile, of which 85 percent represents labor; while the other road said that the cost was $372 for labor and $97 for material. The line that uses the rented machine reported the cost was $395 per mile, of which an estimated 85 percent represents labor.

One of the two roads that cleans ballast in the cribs by hand said that the cost was $1700 per mile, while on the other the cost ranges between $1250 to $1500 per mile. The road that uses cribbing machines gave a cost of $328 per mile for labor and $41 for material. The one railroad that does all its ballast cleaning by hand reported the total labor cost of doing this work was $3000 a mile.

One of the questions inquired whether new ballast is added after cleaning, and if so how much is placed per mile. Two roads stated definitely that new ballast is not added to the track after cleaning, and another said that it is felt to be unnecessary. One road reported that new ballast is added as required, but gave no specific figure, and another, explaining that the practice followed depends on local conditions, said that a small amount is generally needed. All other roads said that new ballast is added after cleaning, and gave specific figures as follows:

Fifty tons per mile; 500 cu. yd. when the track is surfaced; 250 to 300 tons per mile if no lift is made; 1100 tons per mile for an average raise of 2 in. to 4 in.; 7 to 10 cars per mile; 1 to 1½ cars per mile when necessary. A road which uses two of the large on-track types of ballast cleaners reported, that it adds 113 cu. yd. of new ballast per mile when one of the machines is used and 282 cu. yd. per mile when the ballast is cleaned by the other type of machine. One road adds 640 tons of ballast per mile where the track is resurfaced, 1050 tons where a 3 in. raise is made. and 1550 tons where a 5 in. raise is made.

Fourteen of the railroads replying gave answers to a question requesting an expression of opinion regarding the relative merits of cleaning and wasting foul ballast. Seven of these roads made it clear that they consider the cleaning of ballast the more economical practice. Several of these amplified their viewpoints in various respects. One, first explaining that wasting ballast would result in increased cost, said that its territory does not have sufficient width of right-of-way to permit continuous wasting. Another said that experience of many years has shown large economies in cleaning. Still another said that the cleaning of stone ballast pays dividends under certain conditions. A fourth reported that it saves considerable money by cleaning and will continue this practice. A fifth said that it was more economical to clean ballast even if it had to be done with hand labor. Only two of the reporting roads expressed the opinion that the wasting of ballast was a more economical practice. One of these said that until ballast cleaning machines are improved, the wasting of ballast gives the best results. The other merely expressed the opinion that it was more economical to waste foul ballast. The other five roads answering the question on cleaning versus foul ballast wasting qualified their replies in various respects. One of these, stating that the answer depends on the economy and cost of ballast, said that where subgrades are narrow, foul ballast is wasted to strengthen the embankment. Another said that it is more economical to clean ballast when it is dry, but better to waste it when it is wet. A third said that it recommends the cleaning of stone ballast, but feels that this practice is not economical if the ballast is too foul. A fourth said that the answer depends largely on the size of the ballast and whether or not it is dry enough to clean. A fifth, indicating that it favors the cleaning of ballast, reported that ballast is wasted on some short sections, but offered no explanation of this practice.

In the final question, the roads answering the questionnaire were asked to submit any other ideas or suggestions they might have relative to the matter of cleaning ballast. A number of comments were offered in answer to this question. One railroad expressed the opinion that when drainage can be improved by the use of ballast diskers, the cleaning of the ballast may be deferred until resurfacing of the track becomes necessary. Another road said that, while it has no machines for cribbing track, it is in favor of having such work done prior to cleaning the ballast. The road that uses a homemade ballast cleaner expressed the opinion that this machine is cheaper to operate than other types. The road using one of the large on-track units said that this unit holds all dirt removed from the ballast, while others deposit it along the track. It was pointed out that this is an important consideration in localities where dirt must be removed entirely.

One of the answers expressed the opinion that the question of cleaning or wasting ballast should be left open, pending future developments in the design and manufacture of machines. This road believes that the use of machines is becoming more inviting, due to the increased cost of labor and ballast. Another answer expressed the opinion that, if ballast were to be cleaned by programmed cleaning at proper time cycles, effective drainage of the roadbed would result and the development of muddy track would be prevented. Another road believes that it is a good idea to clean ballast before surfacing work is done, to prevent the development of churning track.

The response to the questionnaire was very gratifying, and we wish to thank the members of Committee 1 for the time spent in gathering and transmitting the information shown above. Due to the wide variation of the replies, the value may be questioned;

but this subject of ballast cleaning is extremely active in the light of the increased cost of labor and the five-day week, and many of the roads and many manufacturers of equipment are going a long way towards attempting to solve the problem and to give satisfactory answers to the questions involved.

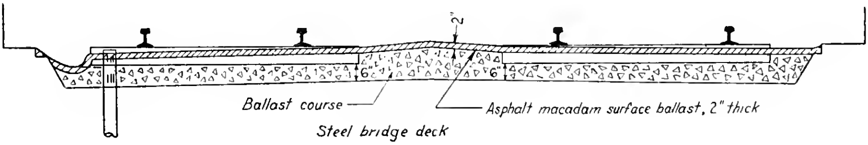
Report on Assignment 10 (c)

Special Types of Ballast

This is a progress report, presented as information, and covers the deck waterproofing, reballasting, and the application of an asphalt covering over the ballast, of the New York Central's Niagara River arch bridge at Niagara Falls, Ont., during the late summer of 1947.

The Niagara river arch bridge, with its approaches, was constructed in 1924, and was completed and put in service in February 1925. It carries the two main line tracks of the New York Central (Michigan Central Railroad) over the Niagara river, between Niagara Falls, Ontario, and Suspension Bridge, New York, and is composed of a 640-ft. steel arch, with a 125-ft. steel approach span at the east end, a 100-ft. steel approach span at the west end, and a 112.5-ft. concrete span over Front Street, Niagara Falls, Ont. The total width of the bridge is 31 ft. which includes a 3-ft. precast concrete slab sidewalk on each side, providing a ballast section of 25 ft.

The entire structure has a ballasted steel deck, with approximately 6 in. of stone ballast under the ties. This ballast had been in place since the erection of the bridge in 1924. It had become very badly fouled, due primarily to the use of sand by locomotives hauling transfer runs in both directions at slow speeds, to allow the checking of cars by the customs.



Typical section of bridge deck.

The waterproofing on the deck of the bridge consists of an asphalt mastic over the entire deck plate, varying in thickness from 1¾ in. to 1 in., to provide a grade for drainage to down pipes. This mastic is covered with a saturated 2-ply membrane, ½ in. thick, which is covered with an asphalt mastic 1½ in. thick.

The drainage for the east and west approach spans consists of down pipes spaced approximately 10 ft. apart on the center line of each track. These pipes are 2 in. in diameter and extend from the top of the ballast, through the deck, to below the steelwork of the bridge. These pipes are slotted at the top end, and also immediately above the waterproofing on the deck of the bridge, to allow surface water to enter as well as the water that seeps through the ballast to the deck of the bridge.

The deck over the arch consists of 16 "pans", or floor sections, each 40 ft. long, which are connected by expansion joints, leaving each section to be drained separately. The mastic waterproofing on the deck of each panel is sloped toward each corner of the panel, at which points there is a 5-in. down pipe that extends from the top of the ballast, through the deck, to a point below the steelwork of the arch. There are slots on these down pipes at the top of the ballast, as well as immediately above the waterproofing on the deck, to allow water to enter.

The Front Street span is drained in a manner somewhat similar to the drainage system of the arch span—the down pipes being on the outside of the tracks along the sidewalks.

The track layout at each end of the bridge was well adapted to the diverting of trains over the bridge, and it was, therefore, not necessary to construct any temporary crossovers. The eastward track was put out of service first and later the westward track.

The work consisted of removing each track, cleaning off all the old ballast, repairing and renewing the down pipes, waterproofing the deck, placing new stone ballast and sawed ties, and then applying asphalt paving over the ballast, with a waterproof spray top coat of bitumen and a coating of sand.

The first operation consisted of the removal of all the excess ballast on the bridge, as well as the cribbing out of the old ballast in both tracks to approximately half the depth of the ties. This excess ballast was thrown between the tracks, and from there was loaded into hopper cars by a work train handling a light crane. The teeth on the bucket of the crane were removed and extreme care was exercised in handling the bucket so as not to injure the waterproofing on the deck.

The old ballast removed from the bridge was not wasted, but was dumped on the Niagara branch, where a sag in the track was lifted. When the removal of the excess ballast was completed, the eastward track was taken out of service and its removal, together with the double guard rails in this track, was started at the east end of the bridge. All ballast and other material were handled with the light crane.

When the first section of track was removed and the old ballast was cleaned off the deck, it was found that the ballast directly under the ties was imbedded in the mastic on the deck of the bridge. Therefore, it was necessary to use air guns equipped with regular tamping bits that had been slightly chisel-pointed at the ends, to remove these imbedded stones. These bits loosened up the imbedded ballast very well. They did not injure the waterproofing mastic as would have occurred if picks had been used.

After the ballast had been removed from a section, the surface was swept and then air blasted with nozzles made for this purpose. These nozzles were made from ½-in. pipe about 42 in. long. The nozzle end had been brazed and a ⅛-in. hole bored in it. Shut-off valves on these nozzles controlled the flow of air. It was necessary to have the deck surface free of dirt and dust before applying the new waterproofing coat. These nozzles worked very satisfactorily, not only in removing the dirt from the uneven surface, but also since they tended to dry up any moisture.

As it was necessary to have a dry surface before applying the waterproofing to the deck, two oil-flame burners were used to advantage in places where moisture was evident.

As the eastward track was cleaned, old ties from the eastward track were laid along the inside ends of the ties on the westward track to prevent dirt and ballast from the westward track fouling the cleaned surface.

When the work of cleaning the deck had progressed sufficiently, the bridge gang started applying the waterproofing. This gang had set up two heating kettles on lorries at the east end of the bridge and, as each section was cleaned, they applied a mop coat of soft penetration oxidized asphalt to the deck. As soon as this work had progressed sufficiently, the light crane was used to unload sufficient stone to provide a depth of 4 in. under the ties, and the track was relaid, using all new ties.

As the work of cleaning off the deck and waterproofing progressed across the bridge, the construction of the new track followed closely, and the track was surfaced up to approximately 1 in. below the final grade. After the eastward track was relaid to the west end of the bridge, it was tamped with electric tie tampers and was brought up to final grade.

When the guard rail had been replaced on the eastward track, this track was put in service and the westward track was taken out of service. Then the work on the westward track was started at the east end of the bridge, and was progressed westward, following the same procedure as was used on the eastward track. Extreme care was used in removing the old ballast from the westward track to prevent fouling the new ballast on the eastward track.

When the westward track was replaced, it was brought up to grade, tamped with electric tie tampers, and put in service.

The eastward track was then air tamped and again brought up to its final grade, as it was found that after the electric tamping had been done, the track had settled approximtely ½ to ¾ in. under traffic. The track was then carefully lined and the stone ballast surface was formed 2 in. below the proposed finished grade of the asphalt paving. This was accomplished by the use of templates that were provided for forming the finished top of the paving.

The asphalt paving material was then unloaded by the light crane in the area between the tracks. This paving mix consisted of 60 percent ¼-in. aggregate and 40 percent aggregate from ⅛ in. to 200 mesh, to which were added for each ton 10 Imperial gallons of 91–100 penetration asphalt, and 3 Imperial gallons of diesel fuel oil as a cut-back. This material was readily handled by shovels and was spread over the stone ballast to a depth of 1 in. above the finished top of the paving. This was then compacted to grade, providing a 2-in. surfacing over the stone ballast.

The grade on the paved surface was constructed to drain surface water from the center between tracks to gutters at the outer ends of the ties. From here it is guttered to the down pipes by suitable grades.

After the eastward track was paved, the westward track was air tamped and prepared for paving similar to that over the eastward track.

Special hand tamping tools were made for compacting the aspalt. Tamping tools made from old air tamping bits were used in the air tamping guns. These tamping bits worked very successfully when some of the weaknesses were overcome by welding different shape plates on to them for tamping heads.

Extreme care had to be used in finishing the surface of the asphalt to maintain a grade to the gutters; care also was required to grade the gutters to the various down pipes, as the available fall from the high point of the paving to the down pipes was slight.

The guard rails were removed and replaced as the paving progressed, since all of the paving was done under traffic. It was found that without the air tampers it was very difficult to compact the asphalt under the running rails, as the top of the paving was only 1 in. below the tops of the ties at the inside ends, and 2 in. below the tops of the ties at the outside ends.

After the paving was completed, the paving, ties, guard rails and running rails were given a spray coat of bitumen, and a coating of sand was applied to the ties and paved surface. The sand was a fine, sharp lake sand, the same as is used in grouting soft spots in roadbed. It was applied immediately after the spray coat, and was brushed in, since it tended to hold the bitumen from draining toward the gutters.

The spraying of the entire deck was carried on in one continuous operation, working from east to west. A motor car was used to haul a drop-frame lorry, on which was mounted a heating kettle equipped with a power sprayer; it also hauled a lorry on which the sand was carried.

Before the bitumen was applied, the entire surface to be sprayed was cleaned and air blasted to remove any cinders, dirt, etc., so as to have a clean surface for the spray coat.

Compression-type rail anchors were applied, two to a tie, except joint ties, alternately inside and outside the rail.

Recent field inspection of the waterproofed deck indicates that performance to date is quite satisfactory. Surface water is drained away quickly, the ballast remains clean, the steel deck of the bridge is protected against corrosion, and maintenance costs should be greatly reduced.

Report of Committee 5—Track

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C. R. Strattman
C. E. Weller
Troy West
J. B. Wilson
M. J. Zeeman
Committee

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* Died December 10, 1950.

** Died January 9, 1951.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
Progress report, offering revisions in Manual material .... page 518

2. Fastenings for continuous welded rail, collaborating with Committee 4.
No report.

3. Track tools, collaborating with Committees 1 and 22, and with Purchases and Stores Division, AAR.

   Progress report, offering revised plan as recommended practice .... page 519

4. Plans for switches, frogs, crossings, spring and slip switches, collaborating with Signal Section, AAR. (For plans see supplement to Bulletin 493—Part 2)

   Progress report, offering revised and new plans and revised specifications as recommended practice .... page 520

   Appendix 4-a—Service tests of designs of manganese castings in crossings at McCook, Ill., presented as information .... page 528

   Appendix 4-b—Service tests of solid and manganese insert crossings supported by steel T-beams and longitudinal timbers, presented as information .... page 529

   Appendix 4-c—Crossing frog bolt tension tests, presented as information .. page 532

5. Prevention of damage resulting from brine drippings on track and structures, collaborating with Committee 15, and Mechanical Division, AAR.
No report.

AREA Bulletin 493, February 1951.

6. Design of tie plates, collaborating with Committees 3 and 4.

   Report on special design of tie plate for curves, offering plans of tie plates as recommended practice .... page 553

   Progress report on tie plate service test measurements .... page 556

7. Hold-down fastenings for tie plates, including pads under plates; their effect on tie wear, collaborating with Committee 3.

   Progress report, submitted as information .... page 563

8. Effect of lubrication in preventing frozen rail joints.

   Progress report, submitted as information .... page 564

9. Field measurement of forces resulting from rail anchorage.

   No report.

10. Critical review of the subject ot speed on curves as affected by present-day equipment.

    Progress report, submitted as information .... page 576

THE COMMITTEE ON TRACK,
F. J. BISHOP, *Chairman*.

Report on Assignment 1

Revision of Manual

C. R. Strattman (chairman, subcommittee), L. L. Adams, C. A. Anderson, T. H. Beebe, F. J. Bishop, J. A. Blalock, M. H. Dick, C. T. Jackson, H. F. Kimball, M. J. Zeeman.

Your committee offers for approval and publication in the Manual the following material:

Glossary—page 29.

Add under definition of TIE PLATE:

TIE PLATE ECCENTRICITY.—The horizontal distance between the midlength of the plate and the center of the bottom of the rail base when resting against the outer shoulder.

Page 5–20.5.

Delete the fifth paragraph under LAYING, and substitute the following therefor:

Standard metal, fiber or wood shims shall be placed between the ends of the adjacent rails to insure space allowance for expansion as indicated in the following table:

Delete the sixth paragraph and substitute therefor the following:

Shims shall be removed within 12 rail lengths of the laying.

Report on Assignment 3

Track Tools

Collaborating with Committees 1 and 22, and with Purchases and Stores Division AAR

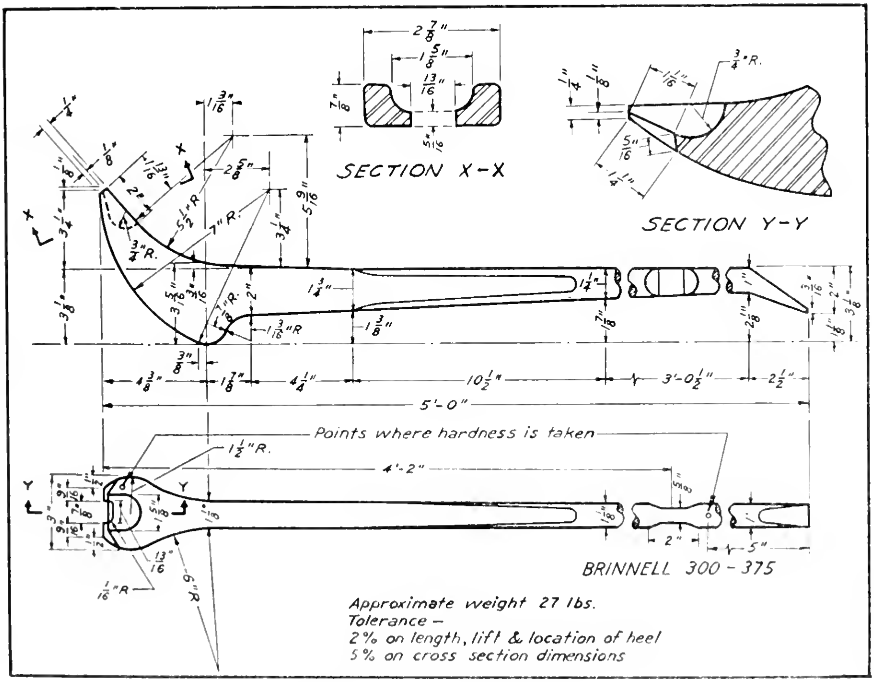
Troy West (chairman, subcommittee), L. L. Adams, L. E. Bates, F. J. Bishop, J. A. Blalock, H. J. Bogardus, E. W. Caruthers, W. E. Cornell, L. W. Deslauriers, C. E. R. Haight, C. L. Heimbach, T. R. Klingel, E. E. Martin, W. N. Myers, M. P. Oviatt, C. E. Peterson, R. C. Slocomb, J. B. Wilson.

Your committee presents the following recommended practice for adoption and publication in the Manual:

On page 5–54.1, II Plans for Track Tools, under Recommended Limits of Wear for Tools to be Reclaimed, add the following clause:

For reclaiming alloy track tools, company forces should be limited to grinding methods; where it is advisable to reclaim them by heating methods, due to the numerous and continuous changes in alloy they should be returned to the manufacturer who is familiar with their precise metallurgical content.

Revise AREA Claw Bar Plan 11–50 to show location of hardness points.



Approximate weight 27 lbs.
Tolerance —
2% on length, lift & location of heel
5% on cross section dimensions

Plan 11–51. AREA Claw Bar.

The committee offers the following as information:

An investigation was made to substitute steel for malleable iron in the web of the snath. Since malleable iron will resist rust better than steel, it is the opinion of the committee that steel should not be considered as a substitute.

A reversible tie tong was considered for inclusion in the Manual. It was demonstrated that such a tool could not be used safely, so it was decided that, due to this objection, such a tie-tong should not be used.

Members of the committee reported favorably on the use of aluminum track tools; therefore, the committee will watch developments of such tools and will report later.

Report on Assignment 4

Plans for Switches, Frogs, Crossings, Spring and Slip Switches

Collaborating with Signal Section, AAR

M. J. Zeeman (chairman, subcommittee), L. L. Adams, J. C. Aker, C. A. Anderson, T. H. Beebe, F. J. Bishop, J. A. Blalock, T. E. Bliss, C. W. Breed, H. F. Busch, E. W. Caruthers, W. E. Cornell, E. D. Cowlin, P. H. Croft, L. W. Deslauriers, J. W. Fulmer, W. E. Griffiths, A. E. Haywood, A. B. Hillman, A. F. Huber, W. G. Hulbert, C. T. Jackson, C. H. Johnson, T. R. Klingel, R. E. Miller, G. A. Peabody, C. E. Peterson, S. H. Poore, J. A. Reed, R. D. Simpson, G. J. Slibeck, R. C. Slocomb, C. R. Strattman, J. B. Wilson.

Your committee has prepared revisions of a large number of the trackwork plans to include several widely used details on which the patents have expired and other improvements outlined here. (For plans see supplement to Bulletin 493—Part 2)

1) *Curved Split Switches.* All of the radii and two of the lengths of the present switches are revised to provide a better balance between the switch curvature and the lead curvature so that the deflection through the switch will not be the limiting factor in calculating by existing formulas, the permissible turnout speeds, and to effect in several of the turnouts a sizable decrease in length.
2) *Tie Layouts for all Split Switches.* A minimum tie spacing of 19½ in. is provided to permit more thorough tamping, and the plans now show the tie layout for interlocked switches which was approved in March 1949.
3) *Switch Point Planing.* The inverted "V" type of switch point, known generally by the trade name "Samson," is recommended for the turnout point in curve switches and is presented as an alternate for straight switch points. For these switch points, an undercut stock rail is specified.
4) *Location of Holes in Split Switches.* Uniform horizontal hole locations (except joint drilling) in all switch lengths is presented for economy in production and to permit the application of roller bearings without redrilling switches at locations requested by the AAR Signal Section. For rails over 110 lb., the vertical distance from the base of the switch rail to the center of the rod clip holes is increased to 2⅞ in. to improve the vertical stability of the switch point.
5) *Hook Twin Tie Plates.* The hook design of twin tie plate is substituted for the plain flat design to provide a more positive shoulder against the rail base. The plans for graduated riser switches and all the frog plans are affected by this substitution.
6) *Railbound Manganese Steel Insert Frogs.* Plan No. 600–51 presents an improved construction at the flare blocks and also permits the use of straight unattached ribs in the castings.

Your committee offers the plans listed below with the recommendation that they be adopted as recommended practice for publication in the Portfolio of Trackwork Plans and that the previous issue of each plan be withdrawn from the Portfolio.

Plan 111–51 16′6″ Straight Split Switch with Uniform Risers
Plan 112–51 16′6″ Straight Split Switch with Graduated Risers
Plan 113–51 11′0″ Straight Split Switch with Uniform Risers
Plan 114–51 11′0″ Straight Split Switch with Graduated Risers
Plan 115–51 22′0″ Straight Split Switch with Uniform Risers
Plan 116–51 22′0″ Straight Split Switch with Graduated Risers
Plan 117–51 30′0‴ traight Split Switch with Uniform Risers
Plan 118–51 30′0″ Straight Split Switch with Graduated Risers
Plan 121–51 13′0″ Curved Split Switch with Uniform Risers
Plan 122–51 13′0″ Curved Split Switch with Graduated Risers
Plan 123–51 19′6″ Curved Split Switch with Uniform Risers
Plan 124–51 19′6″ Curved Split Switch with Graduated Risers
Plan 125–51 26′0″ Curved Split Switch with Uniform Risers
Plan 126–51 26′0″ Curved Split Switch with Graduated Risers
Plan 127–51 39′0″ Curved Split Switch with Uniform Risers
Plan 128–51 39′0″ Curved Split Switch with Graduated Risers
Plan 181–51 Spring Switches
Plan 209–51 Numerical and Classified Index of Detail Numbers Covering Switch Equipment
Plan 221–51 Details for Switch Points
Plan 222–51 Switch Rods and Clips
Plan 241–51 Details and Typical Applications of Hook Twin Tie Plates
*Plan 322–51 No. 4, No. 5 and No. 6 Bolted Rigid Frogs
*Plans 323–51 No. 7, No. 8 and No. 9 Bolted Rigid Frogs
*Plan 324–51 No. 10, No. 11 and No. 12 Bolted Rigid Frogs
*Plan 401–51 No. 10 Spring Rail Frog
*Plan 405–51 No. 10 Spring Rail Frog—Short Spring Rail Type
*Plan 407–51 No. 9, No. 11 and No. 12 Spring Rail Frogs
*Plan 408–51 No. 9, No. 11 and No. 12 Spring Rail Frogs—Short Spring Rail Type
Plan 600–51 Data and Sections for Rail Bound Manganese Steel Frogs
*Plan 611–51 No. 4 and No. 5 Rail Bound Manganese Steel Frogs
*Plan 612–51 No. 6, No. 7 and No. 8 Rail Bound Manganese Steel Frogs
*Plan 613–51 No. 9, No. 10 and No. 11 Rail Bound Manganese Steel Frogs
*Plan 614–51 No. 12, No. 14 and No. 15 Rail Bound Manganese Steel Frogs
*Plan 615–51 No. 16, No. 18 and No. 20 Rail Bound Manganese Steel Frogs
*Plan 622–51 No. 6. No. 7 and No. 8 Rail Bound Manganese Steel Frogs for Rails 112-lb. and Heavier
*Plan 623–51 No. 9, 10 and No. 11 Rail Bound Manganese Steel Frogs for Rails 112-lb. and Heavier
*Plan 624–51 No. 12, No. 14 and No. 15 Rail Bound Manganese Steel Frogs for Rails 112-lb. and Heavier
*Plan 625–51 No. 16, No. 18 and No. 20 Rail Bound Manganese Steel Frogs for Rails 112-lb. and Heavier

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* The revision on these plans consists only in the tables thereon, showing the quantities of hook twin tie plates to be furnished. For ready reference this information is combined on a single sheet Plan No. 241A, Quantity of Hook Twin Tie Plates for Frogs, and if approved by the Association, the tables on the individual plans will be corrected and issued in the 1951 Supplement to Trackwork Plans.

*Plan 641–51 Solid Manganese Steel Self Guarded Frogs
*Plan 670–51 Solid Manganese Steel Frogs
Plan 920–51 Turnout and Crossover Data for Curved Split Switches

Due to lack of time, your committee was not able to correct the detail on Plans 912–41 and 921–41 to correspond to the revised lengths and curvatures being presented for Curved Split Switches and recommends the temporary withdrawal of Table B and Table D on Plan 912–41 and the entire Plan 921–41. The committee intends to correct these plans in next year's work.

On Plan 768–50, as published for the Portfolio of Trackwork Plans, the phrase For Rails less than 6″ in height was omitted, and it is recommended that this plan be republished with the correct title reading as follows:

Plan 768–51—Manganese Steel Insert Crossings Angles 14°15′ to 8°10′ for Rails less than 6″ in height.

Your committee has completely edited the Specifications for Special Trackwork—Appendix A in the portfolio of Trackwork Plans to bring it up to date as far as references to specifications sponsored by other associations, and to clarify the intent of the requirements. As a result of this review your committee recommends that the following paragraphs in Appendix A 1942 be revised as stated herein and that previous corresponding paragraphs be withdrawn.

The collaboration of the Standardization Committee of the Manganese Track Society in the drafting of the plans and in the review of the specifications presented in this report is gratefully acknowledged.

APPENDIX A

SPECIFICATIONS FOR SPECIAL TRACKWORK

For Rails 90-lb. and Heavier

DIVISION I

GENERAL INSTRUCTIONS

4. The drawings shall be part of the specifications. Anything that is not shown on the drawings, but which is mentioned in the specifications, or vice versa, or anything not expressly set forth in either, but which is specified on the order or contract, shall be furnished. Should anything be omitted from the drawings or specifications that is necessary for a clear understanding of the work, or should any error appear in either the drawings or specifications affecting the work, the Manufacturer shall notify the Purchaser and shall not proceed with the work until instructed to do so.

DIVISION II

WORKMANSHIP

42. Painting

No paint, tar, or other covering shall be used unless specified by the order or contract. When so specified, such covering shall not be applied before final inspection.

43. Welding

No welding shall be permitted on rails or surfaces of other parts exposed to wheel wear. Where welding is permitted on other portions, as shown by the drawings or by the detail material specifications, such welding shall be done by an approved process.

DIVISION III

MATERIALS

PART 1. INSPECTION, TESTS AND CLAIMS

55. Inspection, Tests and Claims

(c) Chemical and physical tests covered by the specifications as optional requirements shall be required by the Purchaser only when specified on the order or contract. For materials originally manufactured by the special trackwork Manufacturer for a specific order, such tests shall be made at the expense of the Manufacturer when the amount of the particular kind of material is 50 tons or more; if less than 50 tons the Purchaser shall pay for the expense of such tests, unless the material fails to meet the specifications, in which case the Manufacturer shall bear the expense.

(d) For materials or parts of the work taken from stock or purchased from other manufacturers, the special trackwork Manufacturer, when specified by the order or contract, shall certify that the material conforms with these specifications. If the Purchaser desires any chemical or physical tests of such materials he shall pay the expense of such tests, unless the materials fail to meet the specifications, in which case the special trackwork Manufacturer shall pay the expense. For the rails used in the work the Manufacturer, when specified by the order or contract, shall supply the Purchaser with a certificate of inspection from the rail Manufacturer.

PART 2. DETAIL MATERIAL SPECIFICATIONS

Article 2. Open-Hearth Steel Girder Rails of the Plain, Grooved and Guard Types

202. Manufacture

Unless otherwise specified by the Purchaser, the rails shall be manufactured according to the current ASTM Specification A 2 for Girder Rails. Where the class of the rail is optional, the special trackwork Manufacturer may use either class.

Article 4. Manganese Steel Track Castings

403. Chemical Requirements

(b) An analysis of each heat of steel shall be made by the Manufacturer to determine the percentages of the elements specified in paragraph 403 (a). This analysis shall be made from drillings taken at least ¼″ beneath the surface of a test ingot obtained during the pouring of the heat. When specified by the order or contract, the chemical composition thus determined shall be reported to the Purchaser or his representative.

405. Physical Requirements and Tests

(a–2) When bend tests are specified, the test specimens shall stand being bent cold, without breaking, through an inside diameter of 1″, to an angle of 150°. The bending may be done by any method preferred by the Manufacturer.

(b) In the case of castings weighing not over 50 lb. and if satisfactory to the Manufacturer and Inspector, a test to destruction may be made as an alternative to bend tests when the latter are specified. For this test the castings shall be grouped in lots, each lot containing castings from the same heat and from the same heat-treating charge. From each such lot the Inspector shall select one casting to represent the lot. The representative casting shall be tested to destruction by pressure or by blows. This test shall show the material to be tough and ductile, and suitable for the purpose intended. The cost of all such test castings shall be provided for in the purchase order.

(d–1) When bend tests are specified, one such test shall be made from each heat of steel in each heat treatment charge.

(e) If the results of the bend tests for any lot do not conform to the requirements specified, such lot may be reheat treated, but not more than twice. Retests shall be made as specified in paragraph 405 (a–2). In the case of reheat-treatment and retest, two bend tests from a lot, instead of one as specified in paragraph 405 (d–1), shall be required, both of which shall conform to the requirements specified in paragraph 405 (a–2).

406. Bend Test

A bending test demonstration from the test specimen, if specified by the order or contract, shall be made in the presence of the Purchaser's representative at the foundry where the castings are made.

407. General Conditions

(b) The bottom part of castings which rest on plates or ties shall be reasonably straight and out of twist and shall be free from lumps or such imperfections as would prevent a good bearing. It shall be without sharp corners, having a minimum radius of ¼" at the intersections of the inside of the vertical wall and the bottom, and a minimum radius of ⅛" at the intersection of the vertical outside edge and the bottom.

Article 5. Carbon Steel Castings

501. Material Covered

(a) Steel castings for general service in trackwork for which no physical or heat treatment requirements are specified, except as otherwise provided for in Section 505, including appurtenances and fittings, corner braces, rail braces, washers, spring housings, separator and end blocks for guard rails, adjusting wedges for guard rail clamps, parts for switch stands, and other parts not exposed to wheel wear, designated as "Grade N–3" castings.

502. Manufacture

(b) The castings shall conform in general character to the latest revision of ASTM specification A 27, and should comply with the following requirements:

503. Chemical Composition

(a) Grade N–3 Castings

	Percent	
	Min.	*Max.*
Carbon	...	0.45
Manganese	...	1.00
Phosphorus	...	0.05
Sulfur	...	0.06

(b) Grade H–1 Castings

Carbon	0.45	0.55
Manganese	...	1.00
Phosphorus	...	0.05
Sulfur	...	0.06
Silicon	0.15	0.60

504. Check Analysis

A chemical analysis may be made by the Purchaser from a broken tension test specimen or from a casting representing each heat. Drillings for analysis shall be taken not less than ¼" below the surface, and in such manner as not to impair the usefulness of any casting selected for such check analysis. The chemical composition thus determined shall conform to the requirements specified in Section 503 above.

505. Physical Requirements

(a) Grade N–3 Castings. No test for physical properties shall be required unless otherwise specified on the order or contract.

507. Tension Tests and Alternative Tests

When tension tests are required by the order or contract, such tests shall be made in accordance with the latest revision of ASTM Specification A 27.

508. Annealing and Heat Treatment

(a) Grade N–3 castings with carbon content not over 0.30 percent need not be heat treated unless so specified by the order or contract. A heat treatment, either by annealing or normalizing shall be applied to all castings of Grade N–3 when their carbon content exceeds 0.30 percent.

(b) Grade H–1 castings shall receive a heat treatment, either by being annealed, normalized, normalized and tempered, or quenched and tempered, at the option of the Manufacturer in accordance with latest revision of ASTM Specification A 27.

511. Welding

Minor defects which do not impair the strength or wearing qualities of the castings, except those located on the tread surface within 1½" of the gage line, may be welded by an approved process. Defects shall be considered minor when the depth of the cavity prepared for welding is not greater than 20 percent of the actual wall thickness, but in no case greater than 1". Defects other than minor may be repaired with the consent of the Purchaser by welding with an approved process. All major welds shall be given a suitable stress-relief or heat treatment.

Article 6. Gray Iron Castings

603. Chemical Composition

It is the intent of these specifications to subordinate chemical composition to physical properties. The quantities of any chemical elements in the cast iron may be specified by agreement between the Manufacturer and the Purchaser.

604. Physical Properties and Tests

(a) For "General" gray iron castings, no test for physical properties shall be required.

(b) For "High Test" gray iron castings, when transverse tests are specified by the order or contract, they shall be made in accordance with and meet the requirements of, the latest revision of ASTM Specification A 48, Class 30.

Article 7. Malleable Iron Castings

702. Manufacture

(c) When specified by the purchase order or contract, the castings shall be manufactured in accordance with latest revision of ASTM Specification A 47.

703. Physical Properties and Tests

(b) When so specified by the Purchaser on the order or contract, the castings shall be subject to the test prescribed by the specifications of the ASTM referred to in Paragraph 702 (c) and shall conform to the following minimum requirements as to tensile properties:

Tensile strength, psi.	50,000
Yield point, psi.	32,500
Elongation in 2 in., percent	10.0

Article 8. Steel Forgings

801. Material Covered

(a) Forgings of mild carbon steel for corner braces, fillers, and other parts of trackwork and track specialities not exposed to wheel wear.

(b) Forgings of high carbon steel for riser blocks, switch tongues, and other parts of trackwork which are exposed to wheel wear, also for parts of trackwork and track specialties not exposed to wheel wear at the option of the Manufacturer. Such forgings may also be made from rail steel of the respective qualities specified for open-hearth steel T-rails of standard sections.

803. Chemical Composition

The steel shall conform to the following chemical requirements, except when made from rail steel:

	Mild Carbon Steel Percent		*High-Carbon Steel Percent*	
	Min.	*Max.*	*Min.*	*Max.*
Carbon	0.20	0.35	0.35	0.60
Manganese	...	0.90	...	0.90
Phosphorus	...	0.05	...	0.05
Sulphur	...	0.05	...	0.05

804. Heat Treatment

(a) Forgings of mild carbon steel need not be heat treated unless so specified by the order or contract.

(b) Forgings of high carbon steel, may be heat treated by annealing, normalizing, normalizing, and tempering, or quenching and tempering in accordance with current ASTM Specification A 235 to meet the properties specified in Paragraph 805.

805. Tensile Properties

When specified by the order or contract, except when made from rail steel, forgings shall conform to the following minimum physical properties:

	Mild carbon steel	*High carbon steel*
Tensile strength, psi.	60,000	80,000
Yield point, psi.	30,000	40,000
Elongation in 2 in. percent	22	15
Reduction in area, percent	35	30

806. Tests

When tension tests are specified by the order or contract, such tests shall be made in accordance with latest revision of ASTM Specification A 235.

807. Hardness

Hardness tests shall be required only upon agreement between Manufacturer and Purchaser, and when specified by the order or contract.

Article 9. Rolled Mild Steel

901. Material Covered

Rolled mild steel bars and shapes hammered, pressed or machined for fittings and appurtenances, reinforcements, switch rods, clips, braces, slide and turnout plates, base and special tie plates, hold down housings, stops, heavy joint bars for the internal joints of solid manganese steel crossings, corner braces, etc., but not including standard tie plates.

902. Manufacture

(a) When made from bar stock, the same shall be of open-hearth steel conforming in general with the latest revision of ASTM Specification for Commercial Quality Hot-Rolled Bar Steel, A 107.

905. Tests

All tests, when required by the order or contract, shall be made in accordance with the respective specifications referred to in paragraphs 902 (a) and 902 (b).

Article 10. Rolled Steel Frog Fillers

1003. Chemical Composition

The steel shall comply with the following chemical requirements:

	Percent	
	Min.	*Max.*
Carbon	0.35	0.60

1004. Heat Treatment

When specified by the order or contract the bars shall receive a suitable heat treatment to provide the physical properties specified herein.

1005. Physical Properties

When specified by the order or contract, the bars shall conform to the following:
Brinell hardness No. .... 277 minimum

1006. Workmanship and Finish

The bars shall be smooth, straight and within the following permissible variations and dimensions.

(a) The fishing heights of the fillers shall not vary from that called for by the rail section by more than $\frac{1}{64}$″ over or $\frac{1}{32}$″ less than the nominal dimensions.

(b) Width of fillers between rail webs shall not be more than $\frac{1}{16}$″ over or under the dimensions called for.

(c) Depth of the flangeway groove may be $\frac{1}{16}$″ under or $\frac{1}{8}$″ over dimensions called for.

Article 11. Heat-Treated Rail for Special Trackwork

1102. Heat Treatment

The rails shall be heat treated in accordance with the Trackwork Manufacturer's current approved specifications.

Subsequent to heat treatment the rails shall not be heated to such a temperature that the properties resulting from the original heat treatment are altered.

1103. Physical Properties

The rails in completed work shall conform to the following:

	Min.	*Max.*
Brinell hardness number	300	375

1104. Test

(a) The Brinell test shall be made on the rail head. Before making the impression, any decarburi/ed metal shall be removed from the point selected for measurement. The surface of the rail at the point selected for measurement shall be properly prepared to permit accurate determination of hardness.

(b) Brinell hardness determinations shall be made on a minimum of 10 percent of the rails in each normalizing or quenching charge represented in each tempernig charge. except when the rails are treated with the assembly a sufficient number of test pieces representative of the lots treated shall be tested in accordance with these requirements.

(c) If all the rails tested meet the requirements of Paragraph 1103, all of the rails represented shall be accepted.

(d) If any rail tested fails to meet the requirements of Paragraph 1103, it shall be checked by making two additional hardness measurements, one on each side of the point first measured and each approximately 1″ from that point. If both of these check measurements meet the requirements of Paragraph 1103, the rail shall be considered to have met these requirements.

(e) If any of the rails tested fail on check test to meet the requirements of Paragraph 1103, each rail in the lot shall be tested and those showing a hardness meeting the requirements of Paragraph 1103 shall be accepted.

(f) Any rail failing to meet the requirements of Paragraph 1103 may be retreated, but not more than three additional times unless authorized by the Purchaser, and resubmitted for test in accordance with Paragraph 1104.

Article 12. Helical Springs

1202. Manufacture

The springs shall be manufactured in accordance with ASTM Specification for Heat-Treated Steel Helical Springs A 125, latest revision, except for springs less than $\frac{1}{2}$″ diameter when made of pretempered or cold-drawn wire.

1203. Chemical Requirements

The steel for bars ½" diameter and larger shall conform to the chemical requirements of ASTM Specification A 68, latest revision.

The steel for bars less than ½" diameter may also conform to above requirements unless otherwise specified, or a cold-drawn or pretempered wire meeting ASTM Specifications A 228 and A 229, latest revisions, respectively, may be furnished.

1204. Workmanship and Finish

Unless otherwise specified, the tests, permissible variations and finish required by the latest revision of ASTM Specification A 125 shall apply.

Article 13. Joint Bars

1304. Tests

Tests when specified by the order or contract, shall be made in accordance with the specifications under which the joint bars are manufactured or in case of special joint bars, according to the test required for the material from which they are made.

Appendix 4–a

Service Tests of Designs of Manganese Castings in Crossings at McCook, Ill.

This report is offered as information.

This investigation, which was last reported in the Proceedings, Vol. 51, 1950, page 653, has been continued by observing the service performance of some of the five original castings and the shot-peened frog placed in service in 1949.

Inspection of September 1950

Shot-Peened Casting

This frog is of the same pattern as the Morden–Ramapo design originally tested, except that the flangeways were shot peened by the American Wheelabrator Equipment Corporation, as described in last year's report. After 17-months' service in the test corner where the stress measurements were made, a crack 1¾ in. long had developed in the Santa Fe flangeway adjacent to the B. & O. receiving—Santa Fe leaving corner. This crack, which clears the apex of the corner by 1¼ in., was first discovered after 12 months' service but had not progressed in length five months later. Otherwise, this casting was in good condition. The original Morden–Ramapo casting, without shot peening, after a service period of one year in the test corner, had developed small cracks around the B. & O. receiving corner and also the Santa Fe receiving corner.

Revised Taylor–Wharton Casting

This casting was in the position opposite to the test corner, the same as last reported. The flangeway cracks observed after four years' service consisted of one 5½ in. long (5 in. in the Santa Fe flangeway) which was adjacent to the B. & O.–Santa Fe receiving corner, one ¾-in. long at the guard rail junction on the Santa Fe side, and another 5½-in. crack at the B. & O. leaving corner which extended 3 in. in the Santa Fe flangeway and 2½ in. along the B. & O. side.

Carnegie–Illinois Casting

After three years' service this design of casting was removed and retired September 15, 1950, because of extensive cracks in the flangeways and base of the casting. It was in a location corresponding to the test corner but in the Santa Fe westbound—B. & O. southbound crossing, the same as previously reported. A long flangeway crack extended around the B. & O.–Santa Fe receiving corner between the guard rail junctions, except for a 2-in. gap in the B. & O. flangeway near the guard rail junction. The base of the casting was cracked entirely across the bottom transversely to the length of the three long openings near a line passing through the casting offsets for the guard rails.

Original Taylor–Wharton Casting

After 1½ years' service this design was damaged in a derailment and removed from the track in December 1948. Last winter it was repaired by straightening a wing and restored to service in a position opposite to the test corner, but in the Santa Fe eastbound—B. & O. northbound crossing. There was a short flangeway crack, 1 in. to 1¼ in. long, at each of the guard rail junctions. At the Santa Fe–B. & O. receiving corner, a 9½ in. flangeway crack extended toward the Santa Fe guard rail junction. This same crack also extended 3¼ in. toward the B. & O. guard rail junction, making a total length of 12¾ in. A 1-in. crack was observed at the apex of the Santa Fe leaving corner. This casting has had approximately two years' service.

Summary

Five different designs of castings were included in the service tests for observation. The Morden–Ramapo design was removed in 1949 after being in service for 4½ years. The Bethlehem design was removed after eight months, and the Carnegie–Illinois design after three years. The original Taylor–Wharton design is still in service after two years, but now has extensive flangeway cracks. The revised Taylor–Wharton design is still in service after four years, and will probably be serviceable for another six months or a year. Those designs having a base plate with a web between this plate and the running tread have given the best service performance in track.

Appendix 4–b

Service Tests of Solid and Manganese Insert Crossings Supported By Steel T-Beams and Longitudinal Timbers

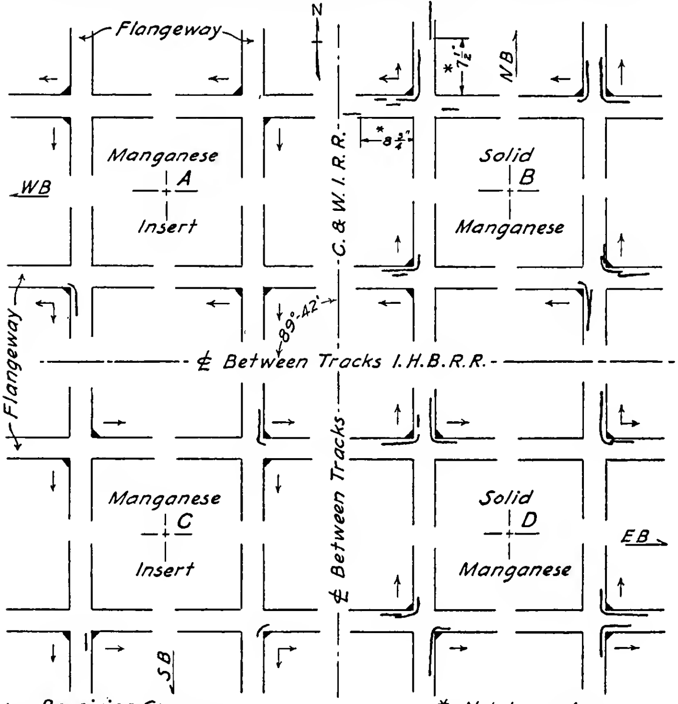
This is a progress report, submitted as information.

Installations in 1946

Four crossings were installed October 14, 1946, in the double-track main lines of the Indiana Harbor Belt Railroad and the Chicago and Western Indiana Railroad near 55th Street and Cicero Avenue, Chicago, Ill., for the purpose of investigating the service performance of two types of crossings supported on a steel T-beam substructure and bolted longitudinal timbers under all rails.

These crossings are maintained by the I.H.B.. and are generally raised two to three times a year, regardless of the type of support or ballast. However, for each raise of the crossings on the steel support and asphaltic concrete ballast, it is necessary to give them the second and sometimes the third lift during one to two weeks in order to have them hold the desired grade. Ballast forks have been used for ramming the asphaltic concrete

Crossings A and B have structural steel T-section supports.
Crossings C and D have bolted longitudinal timber supports.



◣ - Receiving Corner * Not to scale
Inspection made Sept. 15, 1950 Crossings installed October 14, 1946.

Fig. 1. Flangeway cracks in four crossings of the C. & W. I. R. R. and I. H. B. R. R., near 55th St. and Cicero Ave., Chicago, Ill.

ballast under the T-beam flanges. In order to improve the distribution and the compaction of the asphalt ballast placed under the plates, a new tool for ramming the ballast is being developed. It will have a blade 5 in. wide by 12 in. long by ⅜ in. thick, with a bent handle which will be more effective in placing additional ballast under the plates.

Fig. 1 is presented to show the extent of the flangeway cracks as of September 15, 1950, and also general information regarding type of crossing frogs and supports. The length of cracks in the figure is shown to the same scale as used for the flangeway width. The cracks in both of the solid manganese crossings (B and D) have progressed in length and number to a moderate extent since the last report, and the type of support has had little influence on the development of these cracks.

The two insert crossings (A and C) have continued to give good performance as to the occurrence of flangeway cracks. Crossing A on the steel support had a crack in only one corner while crossing C on longitudinal timbers had a short crack at two corners and a longer one at another corner. With this type of crossing, the castings have developed fewer cracks on the T-beam support, but the difference is not yet significant.

The insert castings are in good condition, while the solid frogs showed some batter. In the four years of service no welding has been done on any of the depth-hardened castings of the four crossings except in the NE corner of crossing B where the Chicago and Western Indiana receiving corner—I.H.B. leaving corner, broke out and was built up during the summer of 1950. All four crossings had recently been surfaced in connection with general surfacing of the two north and south tracks.

Installations in 1949

These two solid manganese crossings (AREA Plan 771–40) were placed in the same C. & W. I. tracks (operated by the Belt Ry.), shown in Fig. 1, and the Eldson Branch track located about 40 ft. south of the I.H.B. eastbound track, and were described in detail in last year's report. The northbound track has the improved T-beam support, while the southbound crossing has timbers laid transversely to the southbound track with two ties under each of the east and west crossing plates.

These crossings were last inspected on September 15, 1950, and at that time flangeway cracks had developed at the NE and NW corners of the crossing on the steel substructure. The two longer cracks were 3½ in. and 4½ in. in length. Shorter cracks were observed at all four corners of the crossing on timbers, the longer ones being 2¼ in. and 2 in. in length. The aggregate length of the cracks was greater in the crossing on the steel support. During the latter part of September 1950, the corners on the crossing with the T-beam support were built up by welding, and the metal flow in the flangeways was ground out. No welding was done on the timber-supported crossing.

The Belt Railway has furnished a record of the cost of maintaining the crossing for the first year's service. The total cost for the steel and timber-supported crossings, respectively, was $70.79 and $32.11. The foregoing figures include 43 man-hours for two surfacings of the steel-supported crossings and 15 man hours for one surfacing of the other crossing. Seven clip bolts were renewed in the crossing with the steel support. During the next five-month period, from May through September 1950, additional maintenance expenditures were $184.65 (including $126.00 for welding) and $41.90 for steel and timber-supported crossings, respectively. During the 17-month period the total maintenance costs were $255.44 and $74.01. In the five-month period, 40 man-hours were charged for surfacing the steel-supported crossing four times as compared with 30 man-hours for surfacing the other crossing twice. More recently, the steel-supported crossing was raised by the trowel method by letting the traffic compact the new ballast placed under the T-beam flanges. For one lift, 10 man-hours were required for the steel support and 15 for the timber support.

The steel-supported crossing required more frequent surfacing on the stone ballast than the original crossing with T-beam support installed in 1946 with asphaltic concrete ballast. It is evident that stone ballast without a binder is not suitable for supporting the T-beam construction because of the large impacts which vibrate the stones out of place and cause the crossing to settle. It is believed that the stones imbed into the bottom of wood ties and are less easily displaced than they are under the hard smooth underface of the T-beam. It is proposed to apply hot asphalt to the stone ballast by the penetration method to endeavor to reduce the cost of keeping the steel-supported crossing in line and surface. This will be done in the fall of 1950.

Appendix 4–c

Crossing Frog Bolt Tension Tests

This is the first report of progress on the spring washer tests and is presented as information.

Foreword

This investigation is for the purpose of determining the reactive characteristics required of spring washers for more economical and efficient maintenance of adequate bolt tension in crossing and turnout frog bolts. Bolt tension tests are being conducted on three types of crossing frogs: solid manganese, manganese insert and heat-treated bolted rail construction. All three types are in slow to moderate speed territory with mostly freight traffic and the bolted rail type is also in high-speed main line service.

Test Procedure

The field work involves measurements of bolt tension with a specially designed caliper extensometer to accommodate long bolts and the amount of pull-in or wear of the assembled crossings with a new out-to-out gage. Nut back-off gage readings were taken to detect any back-off of the nuts. Prior to the summer of 1950, the initial bolt tension used in all six crossings and one turnout frog was 40,000 lb., which stresses the root area of the 1⅜-in. frog bolt about the same as a 20,000-lb. load on a 1-in. track bolt. In general, two men are required to wrench the bolts to 40,000 lb. For the summer cycle in 1950, all crossings were reset to 25,000-lb. initial bolt tension to represent the practice of one-man bolt tightening. Several weights of washers having different reactive properties are being tested. Previous discussion of the test procedure and operating conditions at the several crossings may be found in the Proceedings, Vol. 50, 1949, page 577, and Vol. 51, 1950, page 658.

Spring Washers Used

Several designs of single-coil washers and two types of plate washers were included in these tests to cover a wide range of reactive spring pressures and check their performance as to retention of bolt tension. Fig. 1 shows the release curves of three kinds of single-coil spring washers for 1¼-in. bolts used in the three crossings at 55th Street and Cicero Avenue, Chicago, Ill. Similar information is given in Fig. 2 for the spring washers used on the 1⅜-in. bolts. The first washer listed in each figure was originally an experimental spring washer made by the Reliance Division, Eaton Manufacturing Company, but was later included in their line of Improved Frog and Crossing Hy-Crome spring washers. Hubbard & Company also developed an experimental washer for 1⅜-in. bolts. The Electric Railway Improvement Company furnished two designs of plate washers for 1⅜-in. bolts: the Type D–5 compression washer and the S–300 washer. Type D–5 consists of five ⅛-in. plates, 3 in. square and cemented together, and the S–300 consists of one plate 0.30 in. thick. Each of the plate washers has a spherical shape. The Reliance Division also developed another experimental single-coil washer made of ¾-in. square cross-section for 1⅜-in. bolts and designated with a (d) in Fig. 2. This washer is designated as "Heavy-Duty Hy-Chrome" by the sponsor. It will be observed that the reactive pressure of the coil washers for 1⅜-in. bolts at a release of 0.030 in. from an initial load of 40,000 lb., ranged from 2200 lb. to 15,700 lb., and the corresponding value of Type D–5 was 19,900 lb. Table 1 is included to give the dimensions and other physical properties of the washers. The Pennsylvania Railroad specifica-

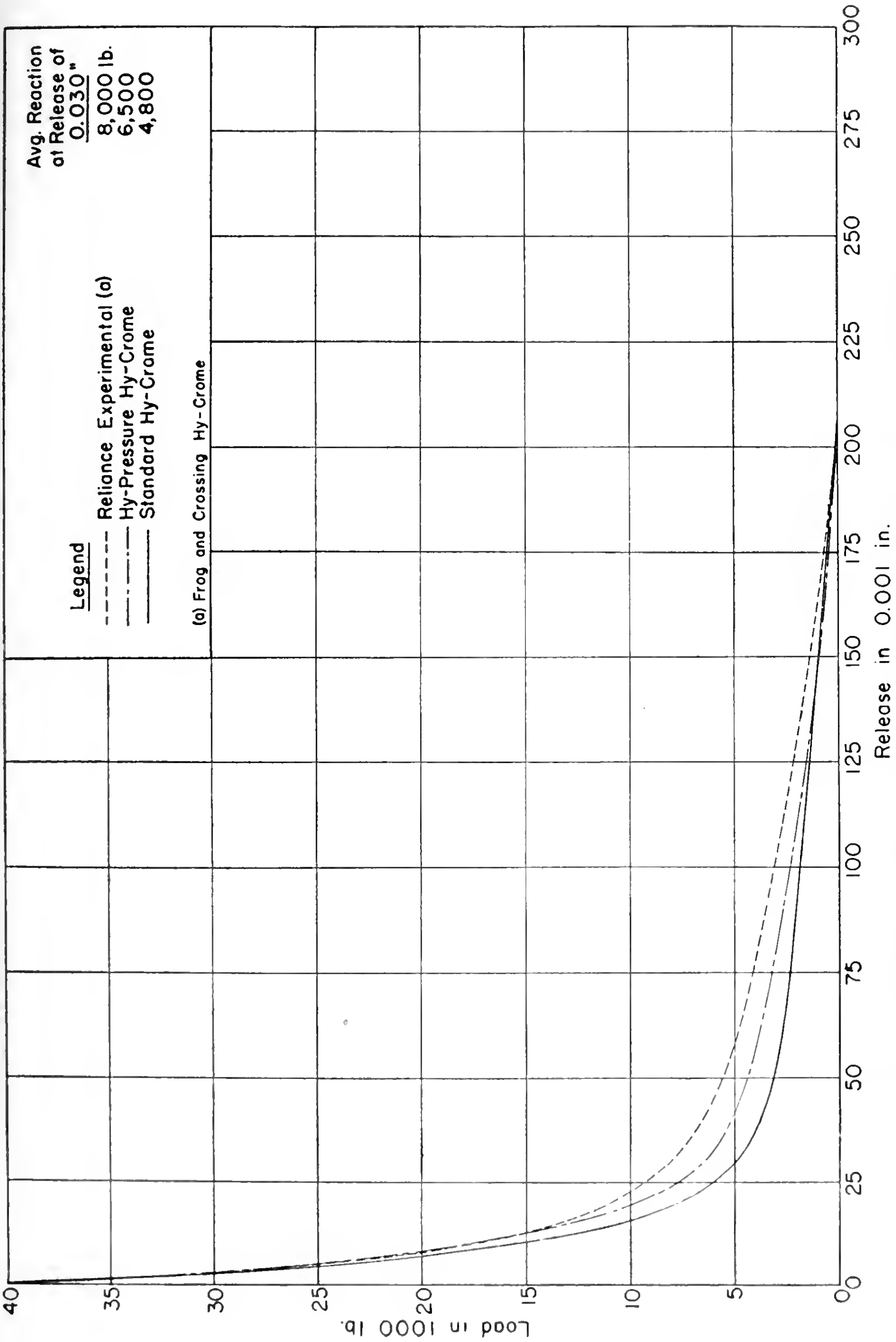


Fig. 1. Mean reactive spring pressure curves of spring washers for 1¼-in. frog bolts.

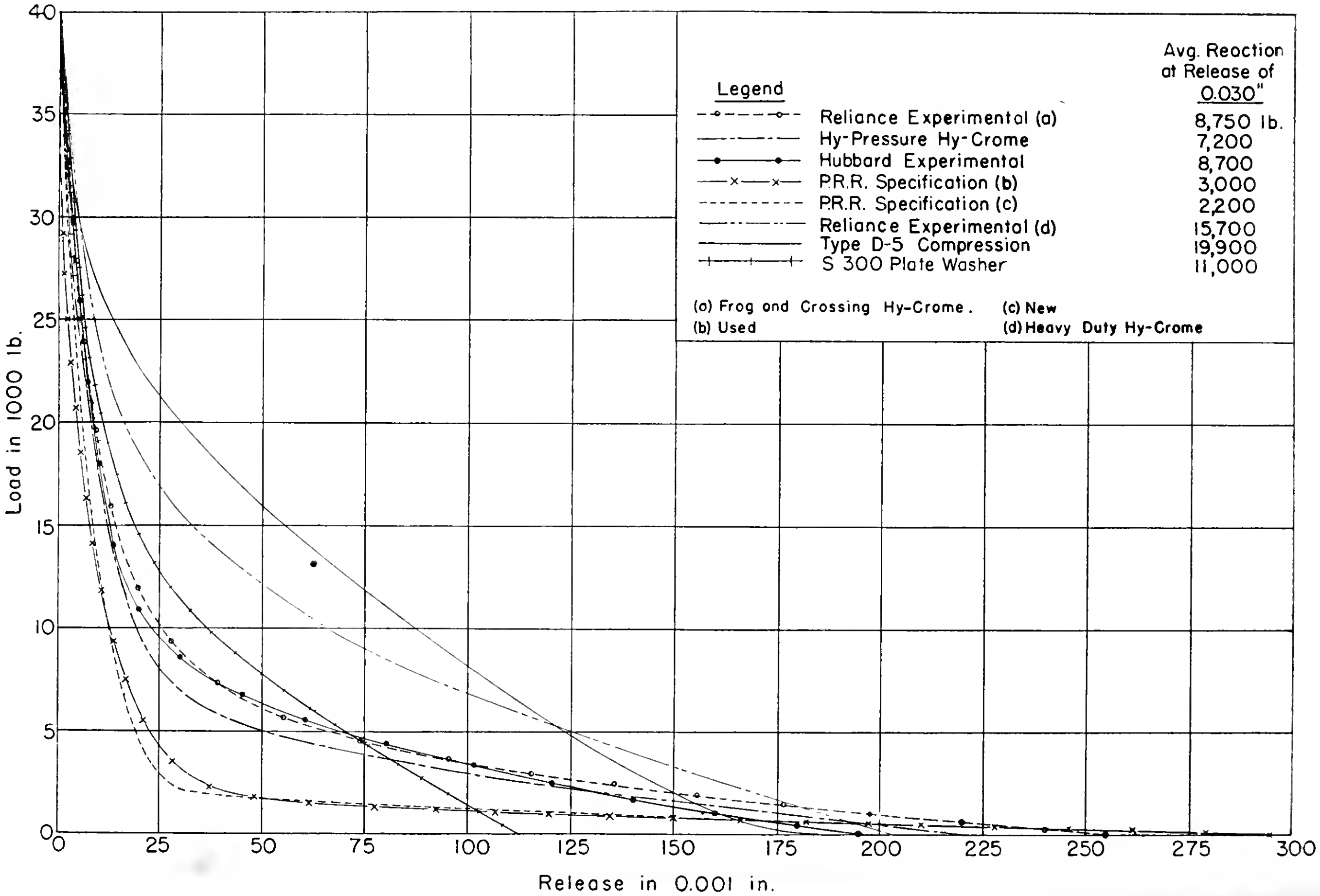


Fig. 2. Mean reactive spring pressure curves of spring washers for 1⅜-in. frog bolts.

TABLE 1. - SUMMARY OF SEVERAL PHYSICAL CHARACTERISTICS OF SPRING WASHERS FOR FROG BOLTS

Designation of Spring Washer	Number of Washers Tested	+Avg. Reaction at 0.030 in. Fourth Release (lb.)		xTotal Deflection Fourth Release (in.)	Nominal Dimensions of Cross Sections		Approx. Weight per 1000 pcs. (lb.)
					Width (in.)	Thickness (in.)	
		For 1-1/4" Diameter Bolts					
S.H. Reliance Standard Hy-Crome	4	4,800		0.21	1/2	7/16	295
Reliance Frog and Crossing Hy-Crome	4	8,000		0.22	13/16	7/16	575
S.H. Reliance Hy-Pressure Hy-Crome	4	6,500		0.19	17/32	15/32	361
		For 1-3/8" Diameter Bolts					
PRR Specification	4	2,200		0.27	1/2	3/8	290
S.H. PRR Specification	4	3,000		0.29	1/2	3/8	290
S.H. Reliance Hy-Pressure Hy-Crome	4	7,200		0.22	9/16	1/2	435
Hubbard Experimental	4	8,700		0.19	17/32	21/32	605
Reliance Frog and Crossing Hy-Crome	4	8,750		0.25	7/8	15/32	725
S-300 Plate Washer	4	11,000		0.11	3 x 3	19/64	630
Reliance Heavy-Duty Hy-Crome	4	15,700		0.22	3/4	3/4	1000
Type D-5 Compression	2	19,900		0.18	3 x 3	5/8(5-ply)	1800

Notes:

\+ Average reactive spring pressure at fourth release from 40,000 lb.

x Deflections measured between loads of 40,000 lb. and 100 lb.

tion for 1¼-in. and 1⅜-in. spring washers stipulates a reactive spring pressure of 300 lb. when the washers are released from a 60,000-lb. load, 0.15 in. and 0.17 in., respectively.

Main Track Crossing at Warsaw, Ind.

The test crossing is located about 110 miles east of Chicago, Ill., in the eastward main of the double-track line of the Pennsylvania Railroad and a single-track branch line of the New York Central System. The P. R. R. traffic, approximating 18 million gross tons per annum, consists of both passenger and freight traffic operated at high speed; and the branch line is slow-speed operation of light density. Most of the passenger trains and some of the freight trains are hauled by multiple-unit diesels on the P. R. R. Some large steam power of the duplex type (4–4–6–4), having four cylinders, divided drive and rigid frame, are operated on the P. R. R., while the N.Y.C. uses moderate sized steam locomotives, principally of the Mikado type. Some of the P. R. R. passenger trains run 80 mph. and freights up to 65 mph.

The crossing frog is of the three-rail bolted type with heat-treated 131 RE rail and flangeway fillers. It is supported on longitudinal timbers under the P. R. R. rails and stone ballast. Both tracks are straight and the crossing has been in service since May 1948. The track gage is about ¼ in. tight on both sides of the crossing. The test included the 48 main bolts, 1⅜ in. by 14 in., and was set up as shown in Fig. 3 for the second test

TABLE 2. - SUMMARY OF THE FIRST CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R.R. AND A SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT **WARSAW, IND.**

Construction and Location	*Bolt Position	Avg. Bolt Tension (1000 lb.)			Percent Tension Lost	Avg. Pull-in (in.)
		Initial	Final	Lost		
N.W. Corner P.R.R. Spec. Spring Washer	1 2 3	42.5 41.0 40.4	18.0 21.9 26.4	24.5 19.1 14.0	58 47 35	0.013 0.008 0.007
	Avg.	41.3	22.1	19.2	46	0.009
N.E. Corner Hubbard Experimental Spring Washer	1 2 3	39.9 38.5 40.5	17.9 21.9 27.6	22.0 16.6 12.9	55 43 32	0.023 0.016 0.012
	Avg.	39.6	22.4	17.2	43	0.017
S. E. Corner SH PRR Spec. Spring Washer	1 2 3	39.6 41.1 40.2	18.5 26.6 15.8	21.1 14.5 24.4	53 35 61	0.012 0.009 0.009
	Avg.	40.3	20.3	20.0	50	0.010
S. W. Corner Type D-5 Compression Washer	1 2 3	41.3 40.8 38.7	23.1 27.2 27.3	18.2 13.6 11.4	44 33 30	0.022 0.018 0.013
	Avg.	40.3	25.9	14.4	36	0.018

* Each corner of the crossing has 12- 1 3/8-in. x 14-in. main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one and the No. 3, the farthest from the intersection.

These results cover the period from July 12, 1949 to November 9, 1949.

cycle. The first test cycle was the same, except that in the SE corner SH P. R. R. washers were used because the Reliance Heavy-Duty Hy-Crome washers were not ready.

Discussion of Test Results

Table 2 and Fig. 4 cover the first cycle of loss in bolt tension, and Table 3 and Fig. 5 show the results of the second cycle for the periods shown. Figs. 4 and 5 give a graphical record of the loss in bolt tension with respect to pull-in or wear of the crossing assembly. The nut back-off readings indicated that none of the nuts backed off during the two test cycles. An analysis of loss in bolt tension indicated there was no significant difference in the performance of bolts with or without the special locknuts as shown in Fig. 3. In Fig. 4 the plotted points, except for some scatter, are in fair agreement with the combined release curves of the spring washer and bolt. Table 2 gives a summary of the first test cycle and is subdivided as to bolt position and crossing corners. The bolt positions are numbered 1, 2 and 3 in each arm starting from the flangeway intersection of each crossing corner. In general, the No. 1 bolts lost the greatest percentage of bolt tension and the No. 2 and 3 bolts had lower losses in tension. The type D-5 washer performed well in holding the tension loss to 36 percent.

TABLE 3. - SUMMARY OF THE SECOND CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R.R. AND A SINGLE TRACK-BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, IND.

Construction and Location	*Bolt Position	Avg. Bolt Tension (1000 lb.)			Percent Tension Lost	Avg. Pull-in (in.)
		Initial	Final	Lost		
N.W. Corner P.R.R. Spec. Spring Washer	1 2 3	40.8 40.3 40.3	10.5 17.3 18.9	30.3 23.0 21.4	74 57 53	0.011 0.010 0.011
	Avg.	40.5	15.5	25.0	62	0.011
N.E. Corner Hubbard Experimental Spring Washer	1 2 3	39.1 39.1 38.5	14.2 18.9 24.9	24.9 20.2 13.6	64 52 35	0.019 0.015 0.009
	Avg.	38.9	19.3	19.6	50	0.014
S.E. Corner Reliance Heavy-Duty Hy-Crome	1 2 3	39.2 39.4 36.6	13.3 19.7 22.8	25.9 19.7 13.8	66 50 38	0.015 0.011 0.006
	Avg.	38.4	18.6	19.8	52	0.011
S.W. Corner Type D-5 Compression Washer	1 2 3	40.8 40.2 40.3	18.3 21.5 24.5	22.5 18.7 15.8	55 47 39	0.012 (4)X 0.011 (2) 0.006 (3)
	Avg.	40.4	21.4	19.0	47	0.010

* Each corner of the crossing has 12- 1 3/8-in. x 14-in. main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one and the No. 3, the farthest from the intersection.

X Number of washers having one or more broken layers at end of test cycle. These results cover the period from November 9, 1949 to June 5, 1950.

The second cycle (Fig. 5 and Table 3) was the first one in which the Reliance Heavy-Duty Hy-Chrome spring washer with a ¾-in. square cross section was tested. In Fig. 5 the plotted points were mostly below the combined release curves, except with the Hubbard Experimental Washer. At the end of the second cycle, 9 out of 12 type D-5 washers were broken, and this explains the decline in the bolt tension retention capacity of the laminated washer. These washers were removed and replaced with a single plate washer 0.30-in. thick for the third test cycle. The performance of the Reliance Heavy-Duty Hy-Chrome washers was adversely affected by crushing of the wall of the nuts at the minimum section. There was evidence that the crushing or abrasion was progressive in that the wall of the nut on one side only, was crushed two to three times deeper than on the other three sides. Crushing of the nut wall at the cut in this high reaction single-coil washer will release the bolt tension, and this crushing or abrasion is not reflected in pull-in measurements as they are taken on the outer face of the corner braces.

The P. R. R. specifies for heat-treated frog bolts the ASA regular series nut of medium carbon (high strength). Because of the excessive crushing and abrading of the

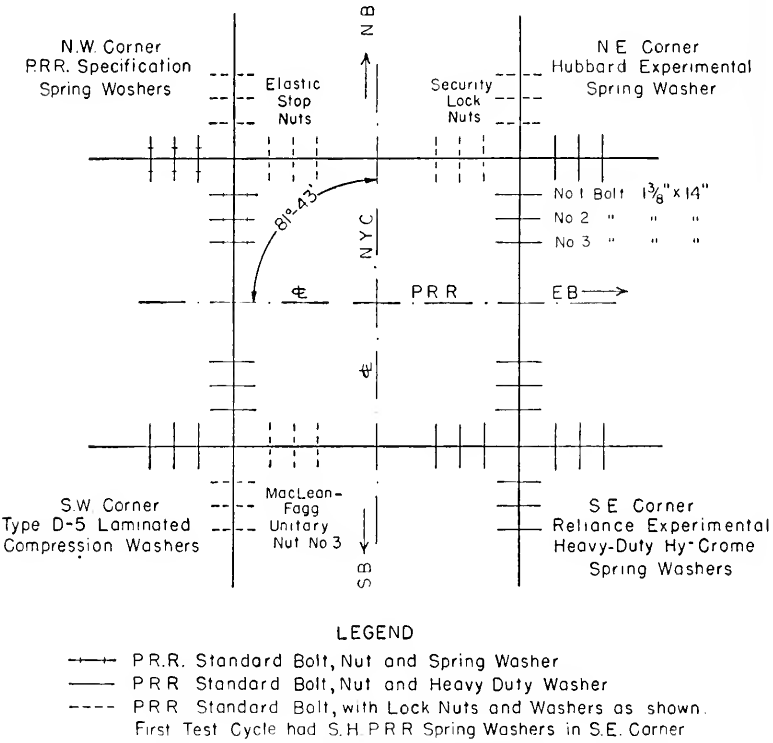


Fig. 3. Plan of P. R. R.—N. Y. C. crossing at Warsaw, Ind., showing position of bolts, washers and locknuts.

nuts at Warsaw, hardness readings were taken on eight of the P. R. R. nuts used in the tests. For these nuts the Brinell readings ranged from 123 to 152, with an average of 140. From these data it is judged that some of the nuts have the hardness of low carbon nut steel; since, generally, the medium carbon nut has a Brinell hardness of 145 or greater. Future tests at Warsaw will be made with the ASA heavy series square nuts of medium carbon. This will conform more nearly to the general practice of the majority of the railroads, except that many of the lines use nuts ¼ in. thicker.

For the third test cycle the ASA heavy series nut of medium carbon was used with the Heavy-Duty Hy-Crome washers to replace the smaller nuts in order to endeavor to eliminate the dissipation of bolt tension caused by crushing of the wall of the nut.

Pennsylvania Railroad—Gulf, Mobile and Ohio Railroad Crossings at Chicago, Ill.

The two test crossings are of construction similar to the bolted rail diamond at Warsaw, Ind., except the rail is the 130 P.S. section. They are in the Pennsylvania eastward "Panhandle" track and the double-track main line of the Gulf, Mobile and Ohio near 37th Street and Campbell Ave., Chicago. Ill. The P. R. R. traffic, amounting to about 4 million gross tons per annum, consists of yard freight movements between their

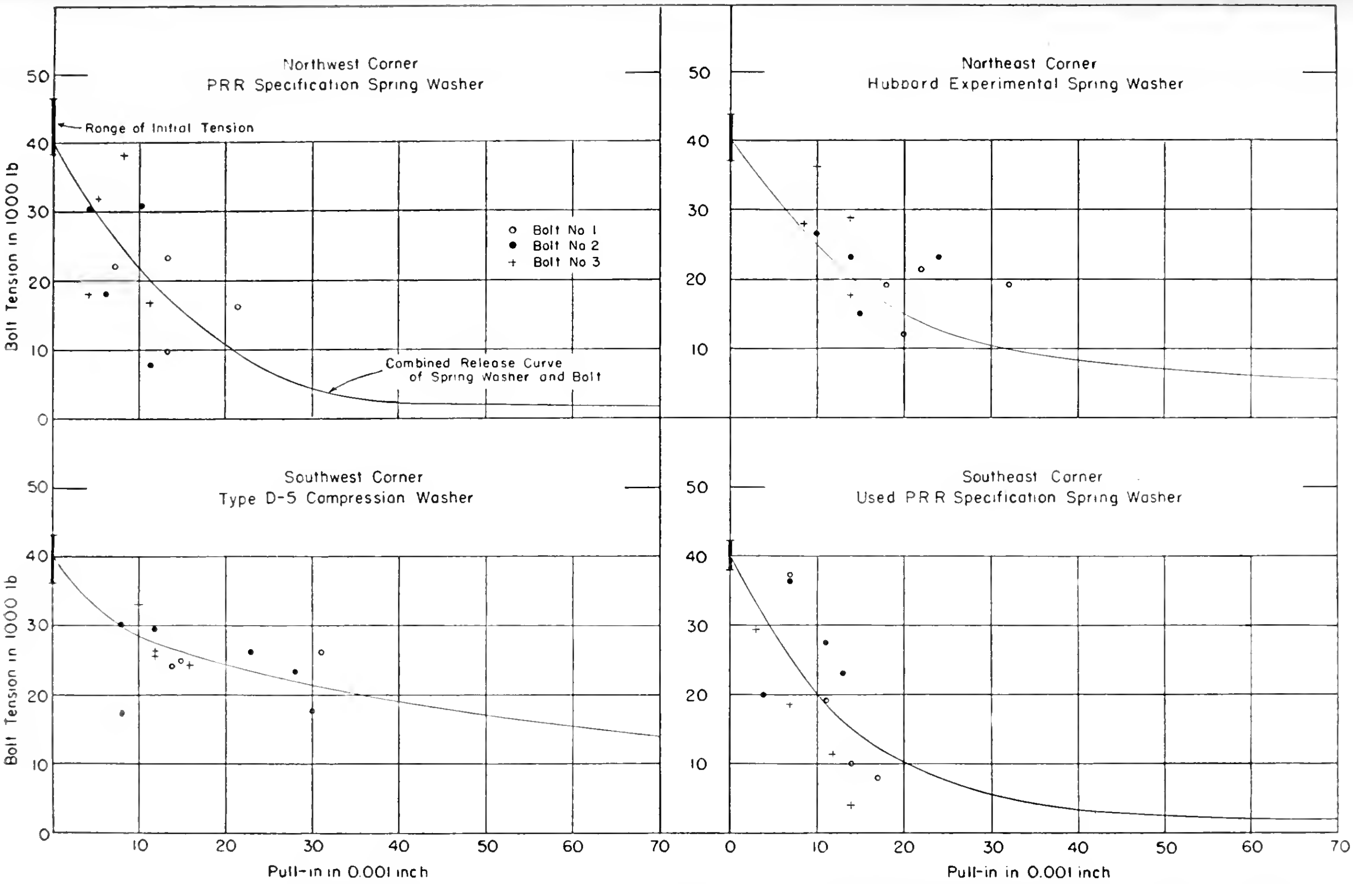


Fig. 4. Bolt tension and pull-in of main bolts in P. R. R.—N. Y. C. crossing at Warsaw, Ind. (First cycle 7–12–49 to 11–9–49).

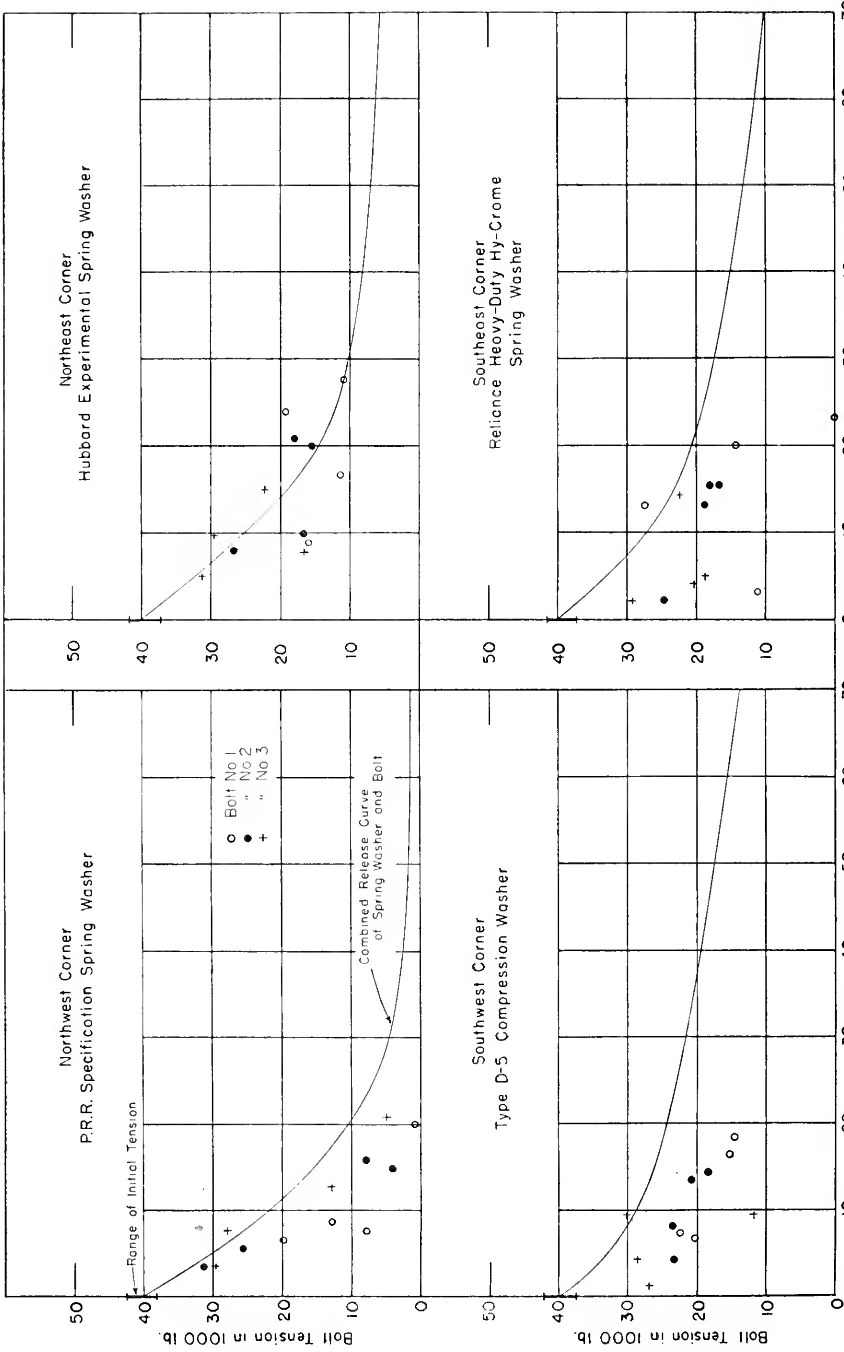
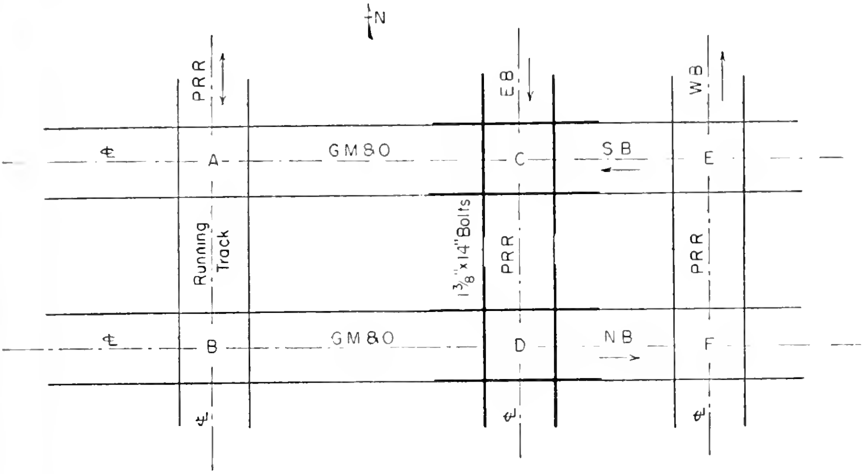


Fig. 5. Bolt tension and pull-in of main bolts in P. R. R.—N. Y. C. crossing at Warsaw, Ind. (Second cycle 11–9–49 to 6–5–50).



Note: Test Crossings are Crossings "C" and "D".
West Half of Both Test Crossings Contains Used PRR Specification Spring Washers.
East Half of Crossing "C" Contains the Hubbard Experimental Spring Washer
East Half of Crossing "D" Contains the Reliance Experimental Frog and Crossing Hy Crome Spring Washer

Fig. 6. Plan of P. R. R.—G. M. & O. crossings at 37th St., and Campbell Ave., Chicago, Ill., showing location of test crossings and direction of traffic.

59th Street yard and various industries and interchange points. The G. M. & O. traffic, which is lighter than the P. R. R. for either track, includes passenger trains and yard freight movements. The G. M. & O. trains are hauled by diesels, and both diesel and steam switchers operate on the P. R. R. track. Most of the traffic is slow speed by virtue of the stop-and-proceed operation controlled by a towerman. However, some of the G. M. & O. passenger trains operate up to 30 mph. The crossings have longitudinal bolted oak timbers under the P. R. R. rails and stone ballast. The frogs were placed in service September 1944.

Discussion of Test Results

In Fig. 6 a general plan of the two test crossings is shown. In crossing C the Hubbard Experimental washer is being compared with the P. R. R. specification washer, while in crossing D, a similar test is underway with the Reliance Improved Frog and Crossing Hy-Crome spring washer. Fig. 7 and Table 4 cover the first test cycle of loss in bolt tension for a four months' service period which was not of sufficient duration to dissipate the bolt tension as much as desired for the purpose of these tests. Only a few bolts (Fig. 7) had a final tension of less than 10,000 lb. and about one-third of the bolt tension was lost in each crossing. The average tension loss ranged from 32 to 36 percent (Table 4), which was too small to utilize the best portion of the washer release curves (Fig. 2).

TABLE 4. - SUMMARY OF THE FIRST CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF TWO CROSSINGS BETWEEN THE EASTWARD TRACK OF THE PENNSYLVANIA R.R. AND THE DOUBLE TRACK MAIN OF THE GM&O R.R. 37th STREET AND CAMPBELL AVE., CHICAGO, ILL.

Construction and Location	*Bolt Position	Avg. Bolt Tension (1000 lb.)			Percent Tension Lost	Avg. Pull-in (in.)
		Initial	Final	Lost		
Crossing "C"						
East half of N.W. Crossing Hubbard Exp. Spring Washer	1	40.2	24.2	16.0	40	0.015
	2	40.4	26.4	14.0	35	0.009
	3	41.3	32.6	8.7	21	0.006
	Avg.	40.6	27.7	12.4	33	0.010
West half of N.W. Crossing P.R.R. Spec. Spring Washer	1	41.9	17.0	24.9	59	0.011
	2	44.9	31.9	13.0	29	0.006
	3	39.5	32.9	6.6	17	0.004
	Avg.	42.2	27.2	15.1	36	0.007
Crossing "D"						
East half of S.W. Crossing Reliance Exp. Spring Washer	1	38.7	21.1	17.6	45	0.017
	2	42.8	29.5	13.3	31	0.011
	3	41.9	33.1	8.8	21	0.008
	Avg.	41.1	27.9	13.2	32	0.012
West half of S.W. Crossing P.R.R. Spec. Spring Washer	1	43.1	20.4	22.7	53	0.015
	2	41.3	28.1	13.2	32	0.013
	3	40.2	30.1	10.1	25	0.009
	Avg.	41.5	26.2	15.1	36	0.012

* Each half of a crossing has 24- 1 3/8-in. x 14-in. main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of each corner, the No. 2 position the next nearest one and the No. 3, the farthest from the intersection.

These results cover the period from June 15, 1949 to October 12, 1949.

Table 5 and Fig. 8 give the results for the second test cycle covering the period from October 1949 to June 1950. From Fig. 8 it will be observed that several bolts had dropped to 10,000 lb. or less tension, and the fewest number in that category were in the half of the crossing C having the Hubbard Experimental washer. In each crossing the bolts with the heavier washers lost 53 percent tension as compared with 61 to 62 percent for the P. R. R. washers.

It will be observed that in these crossings the bolts in the No. 1 position lost the greatest tension, the same as in the crossing at Warsaw. The No. 2 bolts lost a lesser amount of bolt tension than those in position No. 1, and the No. 3 bolts, in general, showed a smaller drop in tension than the other two positions.

It is proposed to transpose the two heavier designs of washers to determine what effect, if any, the different service conditions of the two crossings have on the performance of the spring washers.

TABLE 5. - SUMMARY OF THE SECOND CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF TWO CROSSINGS BETWEEN THE EASTWARD TRACK OF THE PENNSYLVANIA R.R. AND THE DOUBLE TRACK MAIN OF THE GM&O R.R. 37th STREET AND CAMPBELL AVE., CHICAGO, ILL.

Construction and Location	*Bolt Position	Avg. Bolt Tension (1000 lb.)			Percent Tension Lost	Avg. Pull-in (in.)
		Initial	Final	Lost		
Crossing "C"						
East half of N.W. Crossing Hubbard Exp. Spring Washer	1	39.6	12.6	27.0	68	0.031
	2	39.9	18.7	21.2	53	0.023
	3	38.8	24.9	13.9	36	0.017
	Avg.	39.4	18.7	20.7	53	0.024
West half of N.W. Crossing P.R.R. Spec. Spring Washer	1	39.3	10.1	29.2	74	0.022
	2	39.8	19.9	19.9	50	0.021
	3	41.0	17.2	23.8	58	0.021
	Avg.	39.9	15.3	24.6	62	0.021
Crossing "D"						
East half of S.W. Crossing Reliance Exp. Spring Washer	1	37.5	11.8	25.7	69	0.019
	2	37.6	20.5	17.1	46	0.013
	3	38.2	20.9	17.3	45	0.012
	Avg.	37.8	17.7	20.1	53	0.015
West half of S.W. Crossing P.R.R. Spec. Spring Washer	1	40.1	5.2	34.9	87	0.027
	2	39.7	17.4	22.3	56	0.018
	3	35.9	20.5	15.4	43	0.015
	Avg.	38.6	14.9	23.7	61	0.019

* Each half of a crossing has 24- 1 3/8-in. x 14-in. main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of each corner, the No. 2 position the next nearest one and the No. 3, the farthest from the intersection.

These results cover the period from October 12, 1949 to June 21, 1950.

Chicago and Western Indiana Railroad and Indiana Harbor Belt Railroad Belt Line Crossings at Chicago, Ill.

Bolt tension tests are being conducted on three of the four crossings installed near 55th Street and Cicero Avenue in October 1946, for making a service test of the original design of structural steel T-beam substructure as compared with the bolted longitudinal timber supports. These three crossings, together with the kind of spring washers used, as well as other details, are shown by the heavy lines in Fig. 9. Spring washer D is now known as the Reliance Improved Frog and Crossing Hy-Crome spring washer. Because of an error in shipment, washer D for the test cycle reported was for 1⅜-in. bolts instead of 1¼-in. bolts actually in the crossing. This was corrected in July 1950.

Crossings A and C (Fig. 9) are of the reversible manganese insert type with 105 Dudley rail. Crossing D is the solid manganese type, 6 in. high, with the external wings cut square for a four-hole joint and having six-hole internal joints. Crossing A is on asphalt ballast and crossings C and D are ballasted with crushed rock.

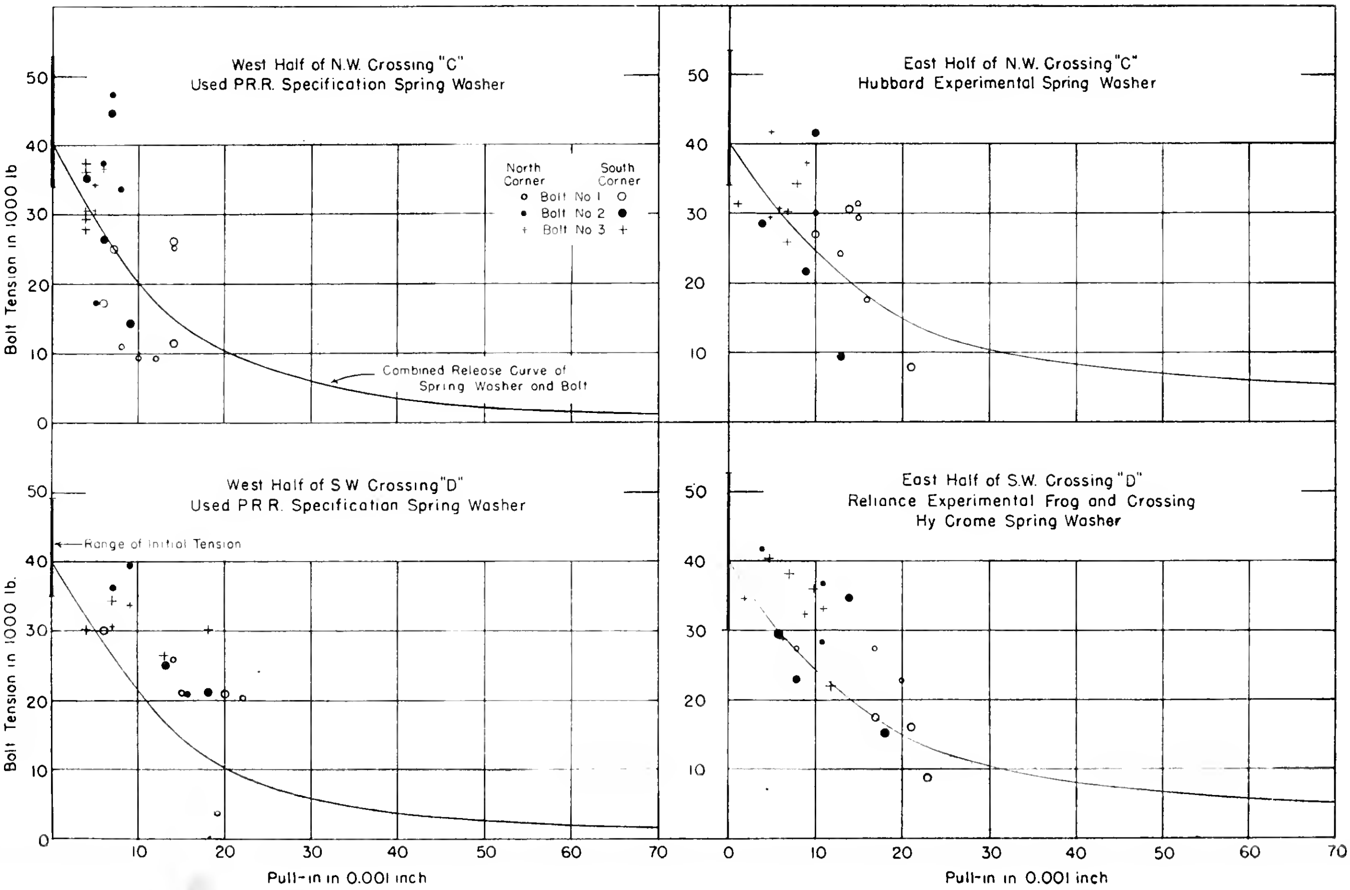


Fig. 7. Bolt tension and pull-in of main bolts in P. R. R.—G. M. & O. crossings at 37th St. and Campbell Ave., Chicago, Ill. (First cycle 6–15–49 to 10–12–49).

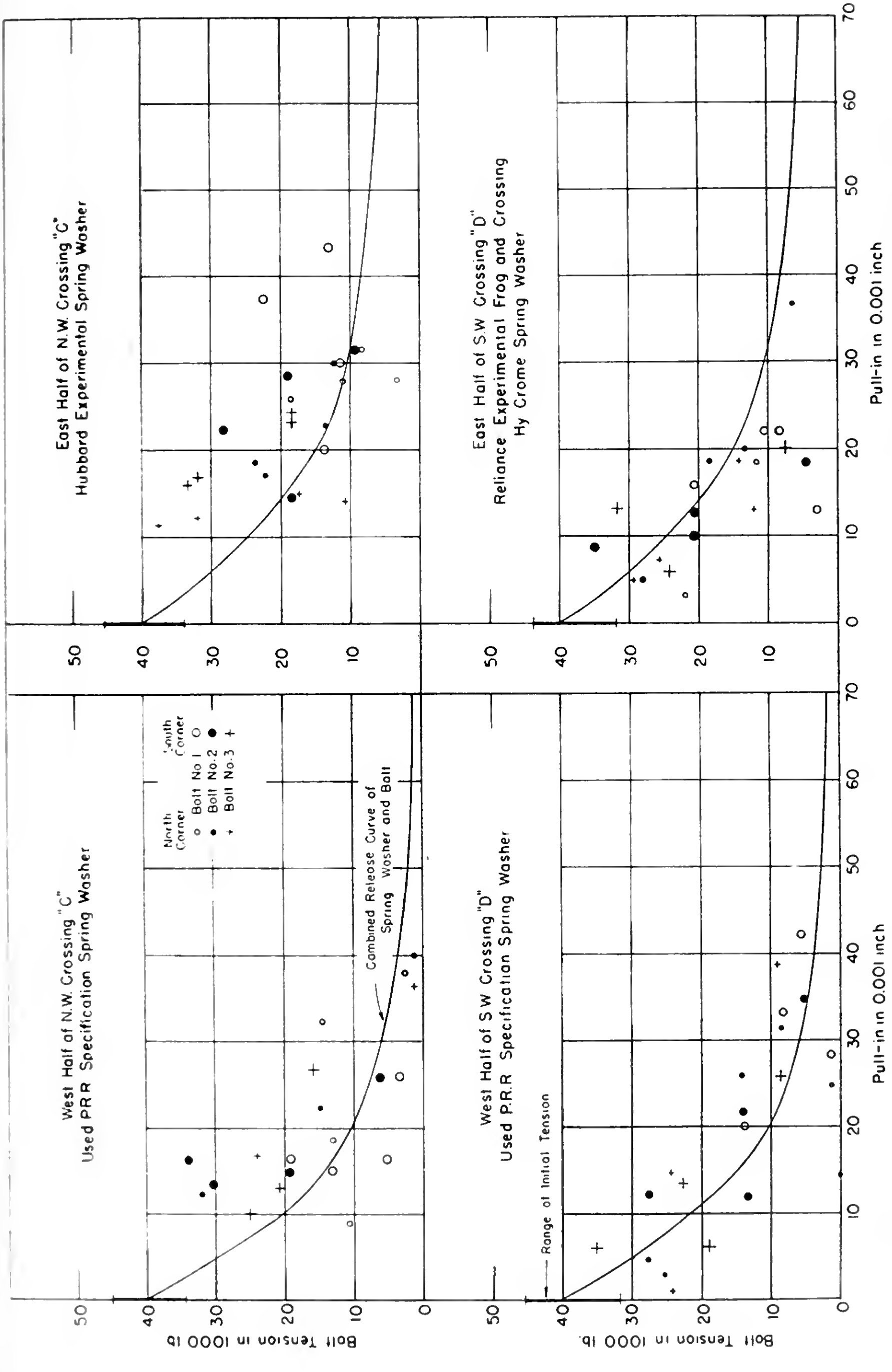
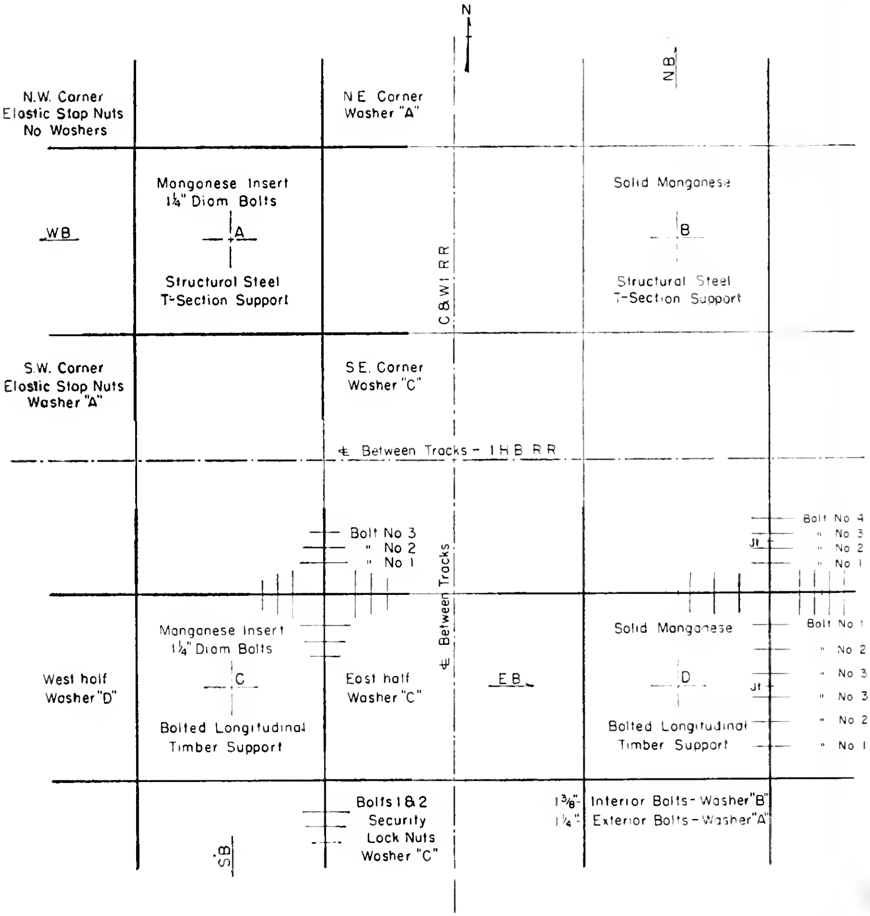


Fig. 8. Bolt tension and pull-in of main bolts in P. R. R.—G. M. & O. crossings at 37th St., and Campbell Ave., Chicago, Ill. (Second cycle 10–12–49 to 6–21–50).

All traffic is freight and is hauled by diesel power on both belt lines, except that some steam power is operated on the C. & W. I. The crossing is interlocked and train speeds are under 30 mph.

Discussion of Test Results

Two cycles of bolt tension loss have been conducted on the three crossings. The first cycle, covering the period from June 1949 to November 1949, was of insufficient duration to dissipate the bolt tension to low values, which are required to bring out the differences between the reactive characteristics of the several weights of washers, and



Note: Washer "A" Reliance Hy-Pressure Hy-Crome Spring Washer for 1¼" Bolts
Washer "B" Reliance " " " " " " for 1⅜" Bolts
Washer "C" Reliance Standard Hy-Crome Spring Washer for 1¼" Bolts
Washer "D" Reliance Experimental Hy-Crome Spring Washer for 1¼" Bolts

Fig. 9. Plan of I. H. B.—C. & W. I. R. R. crossings near 55th St. and Cicero Ave., Chicago, Ill., showing the location of bolts, washers and locknuts, type of crossing and support, and direction of traffic.

TABLE 6. - SUMMARY OF THE SECOND CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE CROSSING BETWEEN THE SOUTHWARD TRACK OF THE C.& W.I. R.R. AND THE WESTWARD TRACK OF THE I.H.B. R.R. 55th AND CICERO AVE., CHICAGO, ILL.

Construction and. Location	*Bolt Position	Avg. Bolt Tension (1000 lb.)			Percent Tension Lost	Avg. Pull-in (in.)
		Initial	Final	Lost		
Crossing "A" - Manganese Insert on T-Beam Support						
N.W. Corner Elastic Stop-Nuts - No Washers	1	39.9	5.5	34.4	86	0.009
	2	41.7	35.1	6.6	16	0.005
	3	40.4	36.8	3.6	9	0.001
	Avg.	40.7	22.1	18.6	46	0.006
S.W. Corner Elastic Stop-Nuts - Hy-Pressure - Hy-Crome Spring Washers	1	39.9	12.0	27.9	70	0.009
	2	39.8	25.1	14.7	37	0.003
	3	40.6	29.9	10.7	26	0.006
	Avg.	40.1	21.3	18.8	47	0.006
N.E. Corner Std. Nuts Hy-Pressure Hy-Crome Spring Washers	1	40.0	12.3	27.7	69	0.015
	2	39.1	27.8	11.3	29	0.008
	3	40.1	34.0	6.1	15	0.006
	Avg.	39.7	22.8	16.9	42	0.010
S.E. Corner Std. Nuts Std. Hy-Crome Spring Washers	1	39.5	9.8	29.7	75	0.012
	2	38.2	20.8	17.4	46	0.004
	3	39.7	33.2	6.5	16	0.003
	Avg.	39.2	21.3	17.9	46	0.006

* Each corner of the crossing has 12- 1 1/4-in. main bolts, 4 each of 3 lengths. The No. 1 bolt position is the one nearest the flangeway intersection in the four arms, the No. 2 position the next nearest and the No. 3, the farthest from the intersection.

These results cover the period from November 18, 1949 to July 17, 1950.

will be omitted. The second cycle extended from November 1949 to July 1950, and the results are considered typical for the test conditions.

Manganese Insert Crossings

Graphic records of the bolt tension vs. pull-in for crossings A and C are shown in Figs. 10 and 11. Release curves are shown for each of the three lengths of bolts. The upper curve is for the longest bolt in position 1, the next lower curve is for the No. 2 bolts; and the lowest curve gives the theoretical release for the shortest bolts in position No. 3. The data for these two crossings are summarized in Table 6 and the upper portion of Table 7. In crossings A and the easthalf of C, there were a few No. 1 bolts well below 10,000 lb. at the end of the cycle. This test cycle was made as long as possible in order to ascertain if the No. 2 and 3 bolts would reach a tension in the lower range where the difference in the spring washer release curves is greater. It will be observed in Fig. 1 for the 1¼-in. spring washers, that the curves are grouped closely from loads of 40,000 lb. to 20,000 lb. Obviously, it is necessary to have several values of final tension below the latter amount in order to develop the bolt tension retention

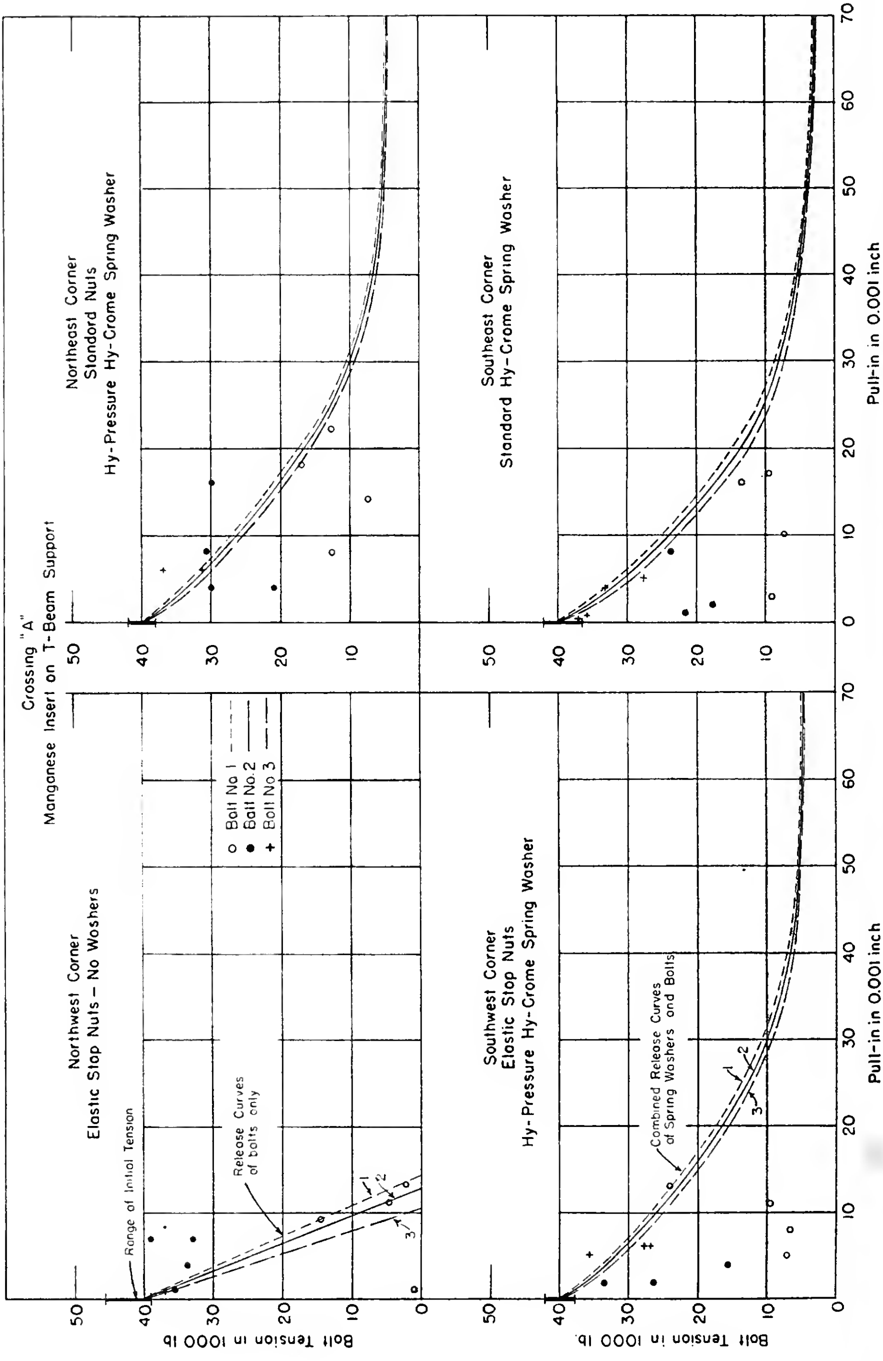


Fig. 10. Bolt tension and pull-in of main bolts in C. & W. I. R. R.—I. H. B. R. R. crossing at 55th St. and Cicero Ave., Chicago, Ill. (Second cycle 11–18–49 to 7–17–50).

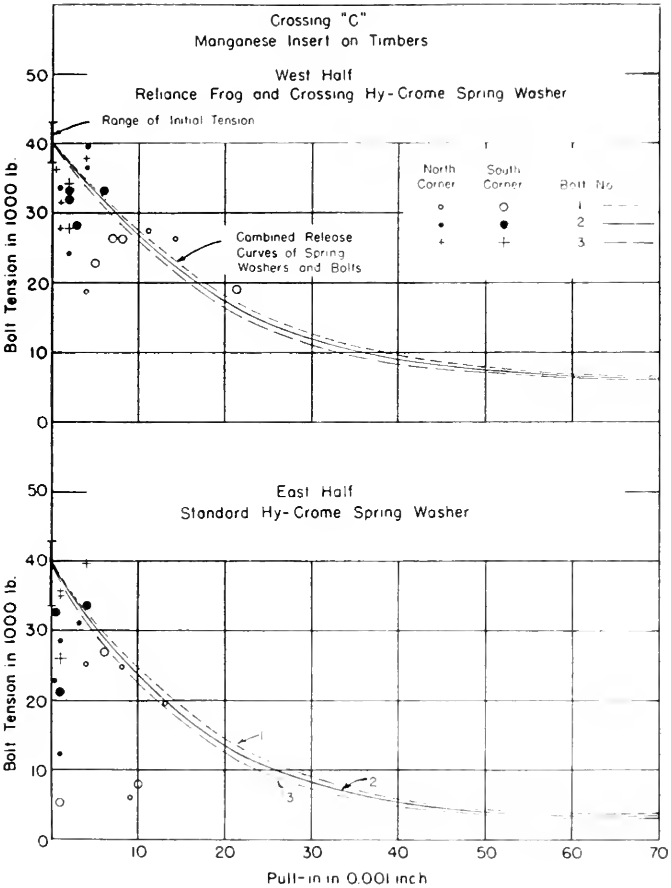


Fig. 11. Bolt tension and pull-in of main bolts in C. & W. I. R. R.—I. H. B. R. R. crossing at 55th St. and Cicero Ave., Chicago, Ill. (Second cycle 11–18–49 to 7–17–50).

TABLE 7. - SUMMARY OF THE SECOND CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF CROSSINGS "C" AND "D" BETWEEN TRACKS OF THE C.& W.I. R.R. AND THE I.H.B. R.R. NEAR 55th STREET AND CICERO AVENUE, CHICAGO, ILL.

Construction and Location	*Bolt Position	Avg. Bolt Tension (1000 lb.)			Percent Tension Lost	Avg. Pull-in (in.)
		Initial	Final	Lost		
Crossing "C" - Manganese Insert on Timbers						
East half Std. Hy-Crome Spring Washer	1 2 3	39.6 37.9 39.5	16.5 26.0 34.0	23.1 11.9 5.5	58 31 14	0.007 0.001 0.002
	Avg.	39.0	24.1	14.9	38	0.004
West half Reliance Frog and Crossing Hy-Crome Spring Washer	1 2 3	39.6 39.8 39.1	23.7 32.2 32.3	15.9 7.6 6.8	40 19 17	0.010 0.003 0.002
	Avg.	39.5	29.4	10.1	26	0.005
Crossing "D" - Solid Manganese on Timbers						

Construction and Location	*Bolt Position	Avg. Bolt Tension (1000 lb.)			Percent Tension Lost
		Initial	Final	Lost	
1-3/8 in. Interior Bolts-Hy-Pressure Hy-Crome Spring Washers	1 2 3	40.0 39.8 40.5	27.3 23.3 19.8	12.7 16.5 20.7	32 41 51
	Avg.	40.0	23.3	16.7	42
1-1/4 in. Exterior Bolts-Hy-Pressure Hy-Crome Spring Washers	1 2 3 4	40.4 40.1 39.1 40.5	23.8 25.2 23.9 27.1	16.6 14.9 15.2 13.4	41 37 39 33
	Avg.	40.0	25.0	15.0	38

* Crossing "C" is identical to Crossing "A". See Note on Table 6. Crossing "D" - Each external arm has four main bolts for connecting the rails to the casting and the bolts are numbered from the flangeway intersection to the far end of the connecting joint. Each interior side of the casting has a six-hole joint. Bolt position 3 includes the two middle bolts of the joint, position 2, the intermediate bolts, and No. 1, the end bolts of the internal joints.

These results cover the period of November 18, 1949 to July 17, 1950.

characteristics of the several weights of spring washers. There is considerable scatter in the plotted points in Figs. 10 and 11, and the values of pull-in were generally lower than in the bolted rail crossings at Warsaw and 37th Street and Campbell Ave. The Reliance Frog and Crossing Hy-Crome washers in the west half of Crossing C (Fig. 11) performed well in that there were only two bolts with tension slightly under 20,000 lb. after eight months' traffic. Table 6 shows data for each of the four corners of Crossing A, in which two weights of washers and the Elastic Stop Nuts were used. In the two corners with Elastic Stop Nuts, there was little difference in the loss in bolt tension with or without Hy-Pressure Hy-Crome spring washers. In the upper portion of Table 7 for the manganese insert crossing on timbers, the Reliance Frog and Crossing Hy-Crome washer had an average of 26 percent loss in tension against 38 percent for the standard Hy-Crome spring washer. Crossing C on timbers lost an average of 32 percent tension as compared to 45 percent for Crossing A on the T-beam support. Although there were differences in the washers and the traffic over the two insert crossings, it does not appear that the steel support has been of benefit in the maintenance of the proper bolt tension with the least cost.

Solid Manganese Crossing

The solid manganese crossing (D) is covered by the lower part of Table 7. No graph of the bolt tension and pull-in is being presented since the values of pull-in obtained in the field were quite small, and questionable. Further investigation seems necessary to explain the 40 percent loss in bolt tension for such a small pull-in. In this crossing the interior 1⅜-in. bolts lost 42 percent tension as compared to 38 percent for the 1¼-in. exterior bolts. The No. 1 interior bolts are the end bolts of the 6-hole internal joints, the No. 2 bolts the intermediate positions, and the No. 3 bolts the middle bolts of the joints. The percentage loss in bolt tension is the greatest in the middle bolts (No. 3) and progessively decreases at the No. 2 and 1 positions. The exterior bolts in the 4-hole connecting joints are numbered outward from the flangeway intersection, and positions 2 and 3 are the middle bolts of the joints. The tension loss, in general, gradually decreased from positions 1 to 4.

It will be noted that the bolt tension by positions in either the external or internal joints of the solid manganese crossing drops more uniformly than in the three positions of the insert and bolted-rail type crossings. Therefore, in the last two mentioned types of crossings, the No. 1 bolts will require more frequent wrenching to maintain adequate bolt tension, whereas in the case of the solid crossing, the bolt tension loss pattern is similar to that of rail joints with the same number of bolts.

From Table 7, Crossing D, it cannot be concluded that for this design of solid manganese crossing the interior bolts normally lose the larger amount of tension. For a tension of 40,000 lb., the 1¼-in. external bolts were stretched 0.0126 in. as compared to 0.0104 in. for the 1⅜-in. internal bolts, and the excess deformation of the smaller bolts may have aided in holding up the tension. The same make of spring washer was used on both sizes of bolts, but the one used with the 1⅜-in. bolts had only 700 lb. more reactive spring pressure at 0.030 in. release from a 40,000-lb. load. It is judged that with identical size of bolts and spring washers, the loss in bolt tension in the external joints would be greater than in the internal joints because the latter have better support by the longitudinal timbers.

Turnout Frog Tests

In order to broaden the scope of this investigation a turnout frog has been included in the bolt tension tests. The frog selected is in the westward main and cross-over of the P. R. R. near the crossing at Warsaw, Ind. The first cycle was started in June 1950, on a No. 15—25-ft. rail-bound manganese frog with 140 P.S. rail which had been installed new in the spring of 1949. All of the 18 bolts, 1⅜ in. in diameter, (5 bolts being ahead of the point of frog and 13 behind) were set to approximately 40,000-lb. tension. All bolts have the P. R. R. specification washer, the same as used on the crossing frog at Warsaw. Initial pull-in measurements and nut back-off data were taken in addition to the bolt tension readings. Thirteen of the bolts were replaced by longer ones with extra threaded length, in order to reduce the number of lengths from nine to three for the purpose of simplifying the field work. The first cycle will extend over a period of several months to allow sufficient time for the bolt tension to drop appreciably.

Summary

In this study to determine the characteristics required of spring washers for use with turnout and crossing frogs, field observations have included measurements on a bolted heat-treated rail crossing in high-speed territory, and on this type of crossing together with a manganese insert, and a solid manganese type in slow-speed territory. Measurements have extended over two service periods of from four to eight months for each crossing. For each service period, the bolts were initially set to a tension of approximately 40,000 lb., and the remaining tension determined at the close of the period.

Loss of Bolt Tension

The measurements have indicated that loss in bolt tension was not due to the nuts backing off. Also, no indication has been found that the bolts have been stretched beyond their yield point by the additional dynamic loads produced under traffic. Loss of tension is evidently due to wear, which permits the faces, against which the head of the bolt and the nut bear, to move closer together, in addition to other factors which will be more fully discussed later. The rate of bolt tension loss was found to be considerably more on the bolted rail type of construction than on either the manganese insert or solid manganese types of crossing. There was no definite pattern for tension loss found consistently throughout with respect to either the internal or external arms of the crossing frogs. It is also rather difficult to find any consistent relation between the rate of bolt tension loss and the line carrying the heavier or faster traffic over the crossing. It was quite definitely indicated, however, that the bolts in what has been termed position 1, or nearest to the flangeway intersection, lost tension at a much more rapid rate than the bolts in position 2, and still more than those in position 3, except in the solid manganese crossing.

Pull-In Measurements

Loss in bolt tension has been shown with reference to the amount of pull-in at each respective bolt position. These data have not formed as good patterns as was expected; and in many instances more loss in bolt tension was found than the pull-in measurements, when related to the reactive characteristics of the spring washer would explain. Further study is necessary to more fully understand this variation, but it is believed that it is due to some extent, in the embedding of the spring washer both in the face of the crossing and into the nut. In some cases, there was evidence of a crushing of the nut wall from the high bearing pressure of the spring washer. More data are also needed to establish the monthly rate of pull-in that should be provided for in the design of the spring washer.

Performance of Spring Washers

In general, the high reaction types of spring washers have shown better ability to maintain bolt tension over the test period than the low reaction types. However, the effectiveness of the high reaction types has not been as much as anticipated in several instances, and it is believed this is due to the above-mentioned conditions of embedding of the washers together with, perhaps, crushing of the nut wall.

Locknut Performance

The tests included three types of locknuts: Elastic Stop, Security, and the MacLean-Fogg Unitary Nut No. 3, all being made of low carbon steel. None of the locknuts has backed off during the test period. The standard nuts have not backed off except in a few instances where the No. 1 bolts had lost all tension. None of the locknuts had become frozen at the end of the second test cycle for each crossing. None of the locknuts showed any benefit in maintaining bolt tension.

Measurements of Shock Load on Main Bolts

In August 1950, the shock load or dynamic variation in the bolt tension under traffic was measured in 12 main bolts of the SE corner of the westward crossing at Warsaw, Ind. The test bolts were made of standard heat-treated 1⅜-in. by 14-in. bolts by turning down a short section of the body next to the head to accommodate SR-4 wire resistance strain gages and drilling two holes through the head and body for the wiring. The two gages on a bolt were placed on a bolt diameter and so connected to be additive in the oscillograph channel. Two series of tests were conducted; one with 40,000-lb. initial tension, the other with 25,000-lb. tension. A few records were taken with the bolt tension set at 10,000 lb. From a cursory examination of some of the oscillograms for the series with 40,000-lb. tension, the No. 1 bolts had a moderately large increase in tension under the heavy loads while there was a very slight dynamic load shown for the No. 2 and 3 positions. A report on these dynamic measurements will be made in 1951.

The bolt tension tests will be continued for another year to obtain additional information on the use of 40,000-lb. bolt tension and also to include some test cycles with 25,000-lb. initial bolt tension.

Acknowledgment

The Association is indebted to the Pennsylvania, the Indiana Harbor Belt, the Belt Railway Company of Chicago, and the Baltimore & Ohio Chicago Terminal for their cooperation and assistance in conducting the various tests, and extends its appreciation to the manufacturers for their interest and valuable assistance in making these investigations.

Report on Assignment 6

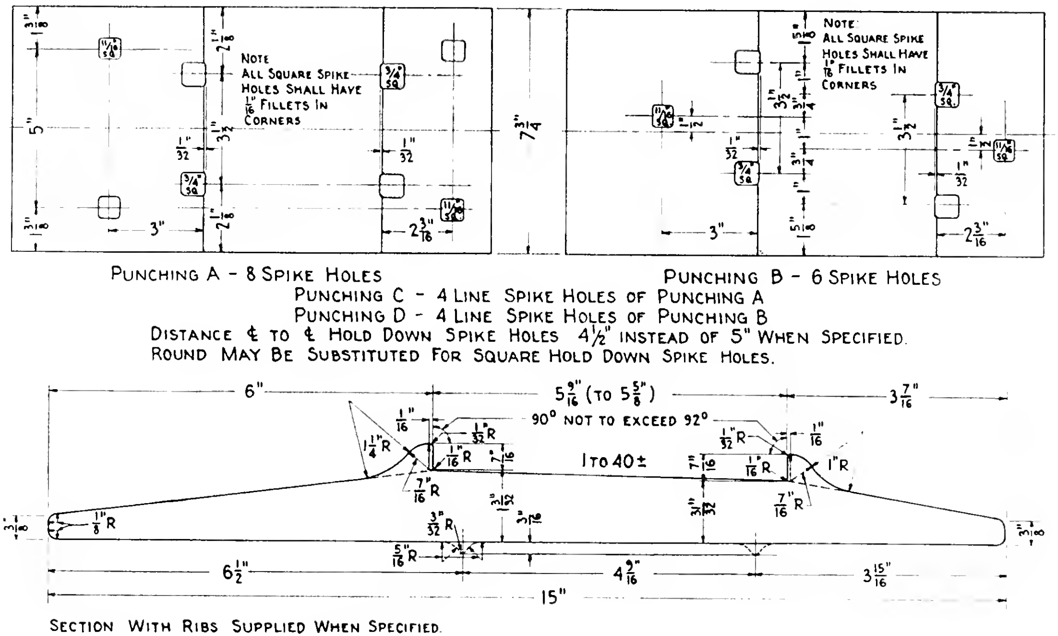
Design of Tie Plates

Collaborating with Committees 3 and 4

J. de N. Macomb (chairman, subcommittee), L. L. Adams, E. D. Billmeyer, F. J. Bishop, Blair Blowers, A. E. Botts, M. D. Carothers, E. W. Caruthers, F. W. Creedle, J. W. Fulmer, B. F. Handloser, A. E. Haywood, J. P. Hiltz, J. W. Hopkins, C. T. Jackson, J. A. Reed, R. D. Simpson, C. E. Weller, M. J. Zeeman.

Your committee submits its report in two parts, as follows:

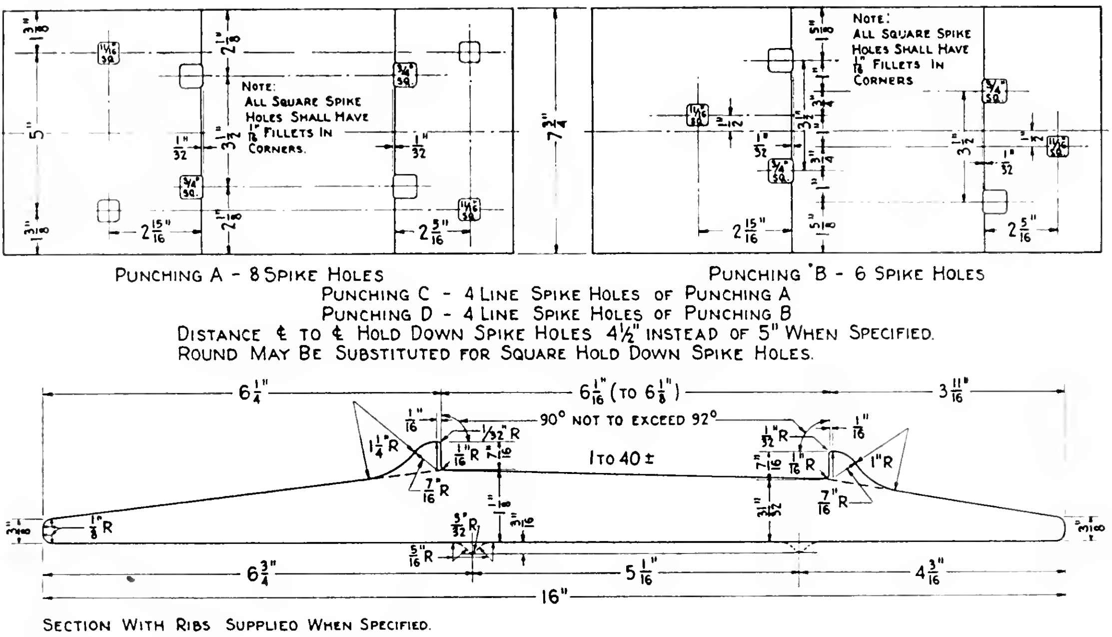
> The first part covers, for use on curves only, where needed, two special tie plate designs, which are recommended by the committee for adoption and publication in the Manual as recommended practice.



* ESTIMATED WEIGHTS

PER FOOT——————43.96 LB.
PER 7¾ IN——————28.39 LB
PUNCHED 8 SPIKE HOLES——27.22 LB
PUNCHED 6 SPIKE HOLES——27.40 LB
PUNCHED 4 SPIKE HOLES——27.58 LB.
* ADD 0.34 LB. TO FOOT WEIGHT AND 0.22 LB. TO FINISHED WEIGHTS WHEN SUPPLIED WITH RIBS.

Fig. 1. AREA 15-in. tie plate for 5½-in. rail base width for curves only. Size and location of spike holes to be optional, with a maximum of eight. This design of tie plate is for use on **either or both rails** of curves, including a portion of the spirals, where observations of the tie plate cutting or past experience indicate that one or both rails cant outward sufficiently to require too frequent readzing and regaging. This design must not be used on **tangent track.**



Punching A - 8 Spike Holes

Punching *B - 6 Spike Holes

Punching C - 4 Line Spike Holes of Punching A

Punching D - 4 Line Spike Holes of Punching B

Distance ℄ to ℄ Hold Down Spike Holes $4\frac{1}{2}$" instead of 5" When Specified.

Round May Be Substituted for Square Hold Down Spike Holes.

Section With Ribs Supplied When Specified.

* ESTIMATED WEIGHTS

PER FOOT	47.57 LB
PER $7\frac{3}{4}$ IN.	30.72 LB
PUNCHED 8 SPIKE HOLES	29.53 LB
PUNCHED 6 SPIKE HOLES	29.71 LB
PUNCHED 4 SPIKE HOLES	29.89 LB

* ADD 0.34 LB. TO FOOT WEIGHT AND 0.22 LB. TO FINISHED WEIGHTS WHEN SUPPLIED WITH RIBS.

Fig. 2. AREA 16-in. tie plate for 6-in. rail base width for curves only. Size and location of spike holes to be optional, with a maximum of eight. This design of tie plate is for use on either or both rails of curves, including a portion of the spirals, where observations of tie plate cutting or past experience indicate that one or both rails cant outward sufficiently to require too frequent readzing and regaging. This design must not be used on tangent track.

The second part concerns a service test of seven designs of tie plates for a rail base width of 5½ in., and is offered as information.

1. Special Tie Plates for Curves

Extensive measurements of tie plate cutting by the AAR research staff on several railroads during the past five years have shown that it would be advantageous, in the interest of reducing the cost of maintaining curved track, to have specially designed tie plates with a large eccentricity, which would prevent or greatly reduce the outward canting of the rails on curves and thus avoid the frequent regaging and readzing necessitated by unequal plate cutting. A tie plate eccentricity of 1¼ in. was selected as being the most suitable for the largest mileage of the sharper curves, ranging from 4 deg. to 6 deg., inclusive. These special plates are for use on curves where observations of plate cutting or past experience indicate that one or both rails cant outward sufficiently to cause too frequent readzing and regaging. A more complete report covering the investigation and use of these tie plates was published in the Proceedings, Vol. 51, 1950, page 664.

Fig. 1 is presented to cover the 15-in. tie plate with 1¼ in. eccentricity for use with rails having a base width of 5½ in. The punching for this design is the same as that shown on Manual Plan No. 7 for the 13-in. length plate and same rail base. The 16-in. tie plate, having an eccentricity of 1¼ in., for the 6-in. rail base, is shown in Fig. 2. Punching for this design of plate is the same as given on Manual Plan No. 12 for the 14 in. length and same rail base.

Your committee has approved these two designs of tie plates and recommends that the tie plate plans shown in Figs. 1 and 2 be adopted, for use on curves where needed, as recommended practice and published in the Manual.

2. Service Test Measurements

Foreword

This report of progress covers the service performance of seven designs of tie plates under 112 RE rail in a 4-deg. curve and section of tangent track, with creosoted oak and pine ties, in the southward main of the Illinois Central Railroad near Curve and Henning, Tenn. The test plates were installed on new ties and slag ballast (fine on the curve and moderately coarse on tangent), in October 1944, and the total traffic carried by the track to May 1950 was 105 million gross tons. All trains over the test track are hauled by steam locomotives, except that two streamlined passenger trains have multiple-unit diesels. The curve has approximately 4 in. elevation. and some of the freight trains operate over it at speeds as low as 20 mph.

Tie Plate Penetration

These measurements show the total depth of plate cutting into the tie for the 67-month test period ended in May 1950, and are summarized in Table 1. The most significant increase in plate cutting since the last progress report (Vol. 50, 1949, page 589), which covered the service period ended in July 1948, was at the field end of the tie plates on the inner rail of the portion of the 4-deg. test curve with pine ties, where the average penetration ranged from 0.5 in. to 0.7 in. Individual values ranged as high as 1½ in. on the joint ties. On the curve in both the hardwood and softwood sections, plate cutting was appreciably less under the 13-in. tie plates than under the 11-in. plates. However, in the tangent test sections there were no important differences in tie plate penetration with respect to plate length. This is attributed to the absence of damaging

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 May 1950 in 0.001 in. - 105 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	169	110	140	84	148	116	128
419-Z	7 3/4 x 11 x 27/32	Flat	268	149	208	139	175	157	183
419-Y	7 3/4 x 11 x 11/16	Flat	281	112	197	108	225	167	182
419-X	7 3/4 x 11 x 9/16	Flat	285	157	221	167	257	212	217
366	8 x 11 x 23/32	Beveled	306	115	210	102	173	137	174
400	7 3/4 x 11 x 23/32	Rolled Circular	296	58	177	122	166	144	161
3170	8 1/2 x 11 x 3/4	Pressed Circular	309	153	231	115	227	171	201
			4° Curve - Creo. Pine Ties						
419	7 3/4 x 13 x 27/32	Flat	465	125	295	142	202	172	234
419-Z	7 3/4 x 11 x 27/32	Flat	609	158	384	204	271	238	311
419-Y	7 3/4 x 11 x 11/16	Flat	541	115	328	207	258	232	280
419-X	7 3/4 x 11 x 9/16	Flat	696	158	427	272	244	258	342
366	8 x 11 x 23/32	Beveled	670	210	440	154	269	211	326
400	7 3/4 x 11 x 23/32	Rolled Circular	639	195	417	181	264	223	320
3170	8 1/2 x 11 x 3/4	Pressed Circular	654	148	401	219	194	206	304
			Tangent - Creo. Oak Ties						
419	7 3/4 x 13 x 27/32	Flat	177	247	212	192	145	168	190
419-Z	7 3/4 x 11 x 27/32	Flat	187	214	201	217	169	193	197
419-Y	7 3/4 x 11 x 11/16	Flat	185	206	195	187	152	170	183
419-X	7 3/4 x 11 x 9/16	Flat	190	195	193	182	145	163	178
366	8 x 11 x 23/32	Beveled	157	191	174	154	177	166	170
400	7 3/4 x 11 x 23/32	Rolled Circular	195	203	199	217	155	186	193
3170	8 1/2 x 11 x 3/4	Pressed Circular	159	203	181	219	161	190	186
			Tangent - Creo. Pine Ties						
419	7 3/4 x 13 x 27/32	Flat	207	245	226	235	147	191	209
419-Z	7 3/4 x 11 x 27/32	Flat	204	302	253	301	159	230	242
419-Y	7 3/4 x 11 x 11/16	Flat	159	287	223	242	136	189	206
419-X	7 3/4 x 11 x 9/16	Flat	191	273	232	252	145	199	215
366	8 x 11 x 23/32	Beveled	185	279	232	288	181	234	233
400	7 3/4 x 11 x 23/32	Rolled Circular	174	251	212	266	163	215	214
3170	8 1/2 x 11 x 3/4	Pressed Circular	167	253	210	223	132	177	194

All tie plate designs have 3/8-in. eccentricity except No. 3170 has 1/2-in.

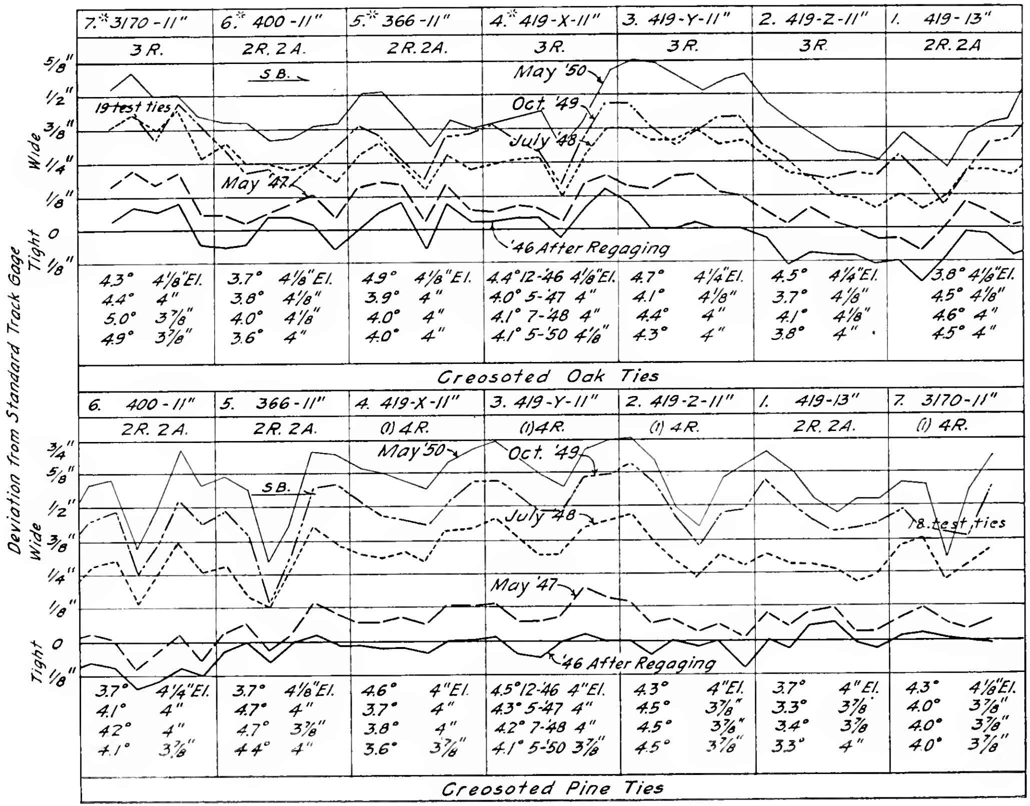
pressures on the ties in the tangent section. Since July 1948, the test track has carried approximately one-half as much traffic as was reported then, and the increase in penetration in the tangent sections was also about 50 percent. However, during the past service period, plate cutting on the curve has increased 100 percent and 80 percent on oak and pine ties, respectively.

A few statistics based on the average penetration for the five designs of 11-in. tie plates, having an eccentricity of ⅜ in., may be of interest.

1. Plate cutting under the inner rail of the curve for oak and pine ties has exceeded the corresponding value for the outer rail by 25 and 70 percent, respectively.

2. Tie plate penetration on the curve for pine ties was 70 percent more than for the oak ties, and the corresponding value for tangent track was only 20 percent more.

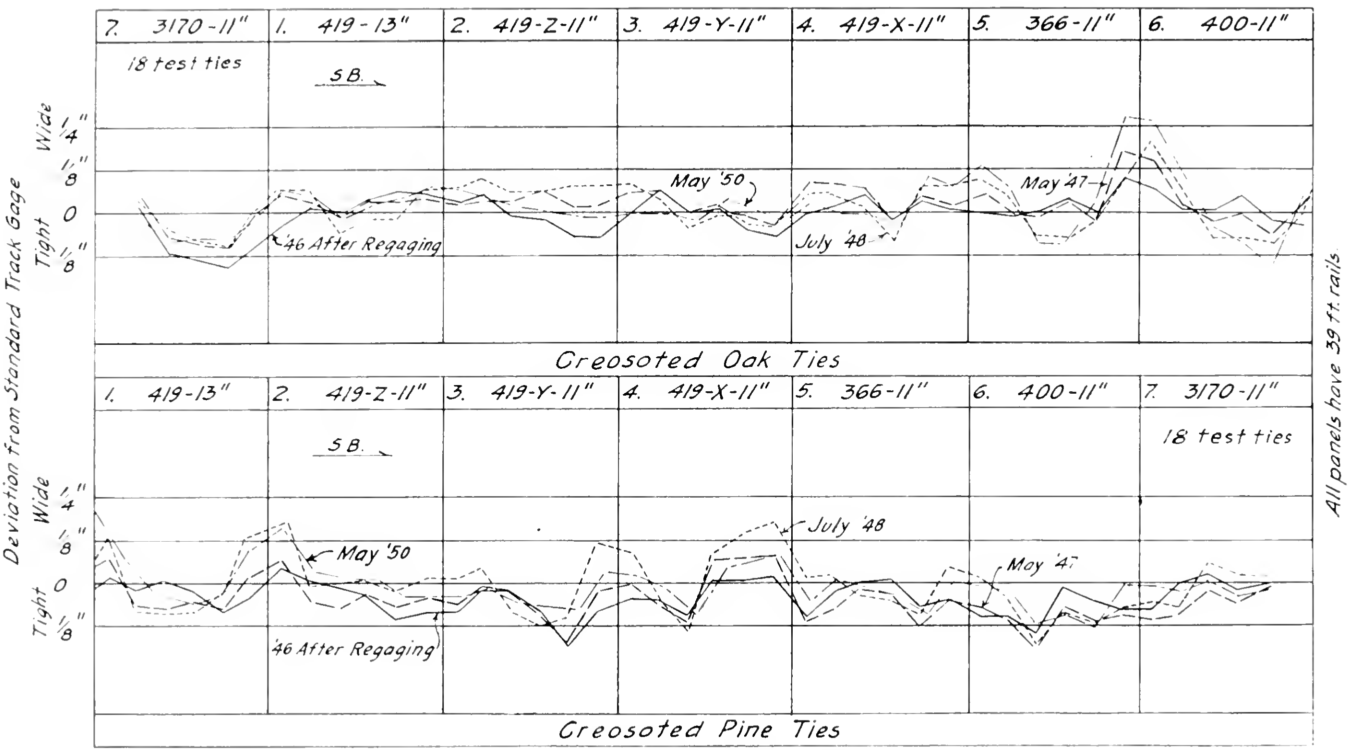
3. The average oak tie wear on tangent was the same as that for the curve, while with the softwood ties the plate cutting was 40 percent greater on the curve.



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

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 plate.

Fig. 3. 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. 4. Gage of each panel of test track on tangent at Henning, Tenn., I. C. R. R.

4. The centroid of the average tie plate load, as calculated from the penetration data for 10 panels of track on the curve, was 1.3 in. and 0.7 in. outside of the centerline of rail base for the inner and outer rails, respectively.

Tie Plate Bending

These measurements were taken to determine if the shoulder extensions of the test plates had been bent upward during the test. The data taken in May 1950 indicated that four 419–X tie plates in the inner rail of the panel on the curve, with pine ties, had bent up moderately. In connection with making a change in the test (which will be described later), the test plates on the inner rail with pine ties were removed. It was found that the four 419–X plates bent had offsets of 0.21, 0.19, 0.14 and 0.13 in. at the field end, as measured from a straight-edge placed on the tie plate bottom along its longitudinal centerline and contacting the straight portion adjacent to the gage end. It is believed that after the oak ties have had a few additional years of service, with further acceleration of the rate of plate cutting, some of the 419–X design of plates (which is ⅛ in. thinner than AREA Plan No. 4 tie plate) may become bent.

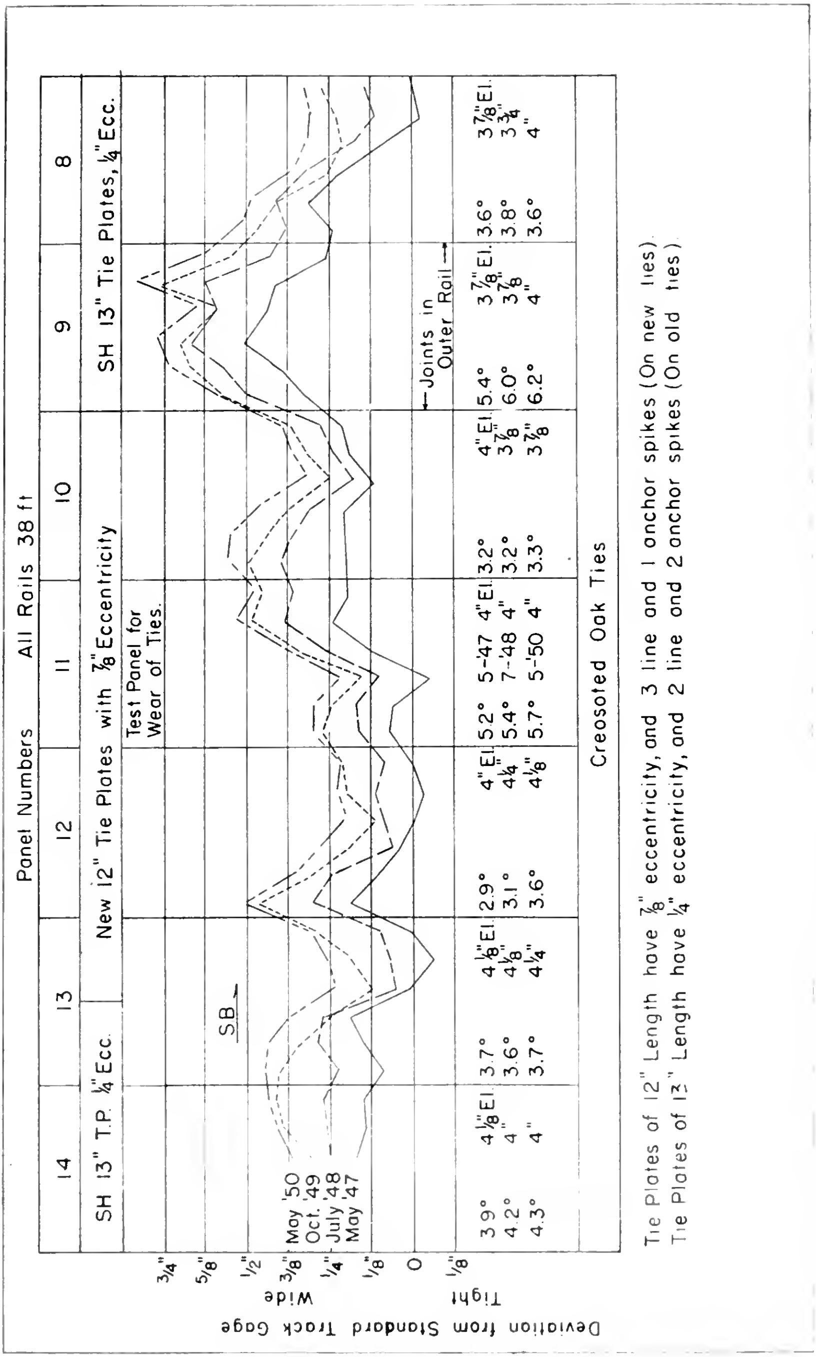
Gage of Track

In this test the track gage was measured at six points in each panel, with none of the points opposite a joint. Fig. 3 gives a graphical record of the gage on the test curve from the fall of 1946, after the first regaging, to May 1950, at which time the gage was wide and irregular on both the pine and oak ties. Flange wear at track gage level on the outer rail since regaging in 1946 is estimated to be not over ⅛ in. Because the inner rail had canted outward considerably on the pine ties, these ties were readzed when the curve was regaged and relaid on the low side in July 1950. In Fig. 4 a record is shown for the track gage of the tangent test sections. Most of the gage is within + or — ⅛ in. of standard gage, except where some of the irregularities have been increased by the traffic.

Revision of Original Test Installation

When the curve was checked in July 1948, it was evident that it would be necessary to readze and set up the inner rail on the pine ties in about two years; also, that a repetition of the test on the inner rail with six designs of 11-in. tie plates and one of the 13-in. length would not contribute any significant information that had not been developed in the first cycle of plate cutting. With the foregoing in mind, it was decided to retire the test plates on the inner rail on pine ties in connection with the readzing and regaging, and to replace them with special 15-in. tie plates for curves, similar to Fig. 1, this report.

During the last week in July 1950, the entire inner rail of the curve (42 rails) was relaid with No. 1 relay 112 RE rail. The ties in the pine section were machine adzed to provide a level seat for the 15-in. plates, replacing the 11-in. and 13-in. lengths. The pine ties were regaged on the inner rail and oak ties were regaged on the outer rail, thus leaving undisturbed the seven tie plate designs on the inner rail of the oak tie section. For purposes of economy, the 15-in. tie plates, with 1¼ in. eccentricity, were made 8 in. wide instead of 7¾ in. and were 1 in. thick along the entire length, except for the planing required for the 1:40 cant rail seat. Bars were welded on the plates to serve as shoulders. This design of plate was placed on the low end of 156 ties, and each was spiked with three SH cut line spikes, which had been applied new in October 1944. In addition, two ⅝-in. round by 4½-in. Racor studs were applied as anchor spikes in the south 50 plates, 2 Tie Plate Lock Spikes were used in the next north 50 plates, and the remain-



Tie Plates of 12" Length have 7/8" eccentricity, and 3 line and 1 anchor spikes (On new ties)

Tie Plates of 13" Length have 1/4" eccentricity, and 2 line and 2 anchor spikes (On old ties)

Fig. 5. Gage, curvature, and elevation of 4-deg. curve with tie plates of two eccentricities, Mile L-333, I. C. R. R.

ing 56 tie plates were spiked with 2 SH cut spikes for anchors. The third line spike was used because of throat cutting of the SH cut spikes, and also because of the readzing of the softwood ties, which ranged from 1 in. to 1½ in. in depth. Two special types of hold-down fastenings were placed in the test to check their effectiveness in reducing mechanical wear of ties and in avoiding gage widening brought about by outward movement of the tie plates on the ties.

Test of 12-in. Tie Plates, with ⅞-in. Eccentricity

In January 1947, 12-in. tie plates with ⅞-in. eccentricity were placed in 3½ panels of track on new 7-in. by 9-in. by 8-ft. 6-in. creosoted oak ties in the 4-deg. test curve north of the original installation made in 1944. The plates were made by shearing 1 in. off the gage end of the 13-in. tie plates. Each plate was spiked with two inside and one outside cut line spikes and one anchor at the field end.

The tests in 1946 with the dynamometer tie plates showed that the position of the centroid of the tie plate loads on the curve was 1.4 in. and 0.5 in. outward from the center line of the rail base for the inner and outer rails, respectively, resulting in a mean value of approximately 15/16 in. It was believed that a tie plate with a compromise eccentricity of ⅞ in. for both rails would be beneficial in reducing gage widening caused by unequal plate cutting. In one panel of track tie plate penetration measurements have been recorded since May 1947. This test was checked in July 1948, but was not reported because the plate cutting was very slight and several of the plates had not become fully seated on the new oak ties, as evidenced by readings indicating uplift of the plates.

The following table gives the average tie plate penetration in inches for the 12-in. plates, as measured in May 1950, after approximately three years' traffic.

Inner Rail			*Outer Rail*			*Avg.*
Field end	*Gage end*	*Avg.*	*Gage end*	*Field end*	*Avg.*	*both rails*
0.083	0.031	0.057	0.064	0.073	0.069	0.063

The average penetration of 1/16 in. is about in line with that of the 13-in. tie plate on oak ties in the same curve for the first three years' traffic. The relative penetration of the two ends of the plates for each rail has not yet stabilized at the values anticipated. In other words, the field end of the plates for both rails had greater penetration than expected. However, the small variations that have occurred during seating of the plates will probably be masked out as the penetration progressively increases in the next few years.

Fig. 5 is presented to show a record of the track gage for the 12-in. tie plates during the three-year test. So far, these tie plates have not demonstrated much superiority for holding the gage of the curve. However, the gage widening caused by unequal penetration was only 0.03 in., which is a minor part of the gage widening.

Summary

The 13-in. length tie plate has effected a reduction in tie wear of 26 to 30 percent on the curve where damaging pressures have occurred. The thinnest, 11-in., tie plate, design 419–X, was in the upper part of the range of plate cutting on the test curve, but these minor differences are not significant. This design of tie plate developed some permanent bending. Little tie plate bending would be expected on relatively new preadzed ties, as the tie wear must progress to the extent of "dishing" out the bearing area on the wood under the rail base. The 11-in. plates include flat, beveled, rolled circular crown, and pressed camber rail seats, but none was effective in reducing tie wear. In previous reports it has been shown that the rolled circular crown rail seat caused much higher stresses in the rail base edges than the flat seat. The data show that the flat seat does not cause more plate cutting than the other shapes of seats.

There are no substantial differences in tie wear of the 8½-in. by 11-in. tie plate (design 3170) and the other 11-in. plates with lesser width. Design 3170 has a 1/16-in. pressed camber and does not become fully seated until the tie wear amounts to 1/16 in. This feature may possibly have prevented the tie wear from being less with the 3170 plate, which has approximately 10 percent more area than the 7¾-in. by 11-in. plates.

A service period of possibly five more years may be required to develop conclusive data.

Acknowledgment

The committee and the Association are indebted to the Illinois Central for its fine cooperation and assistance in conducting these tests.

Report on Assignment 7

Hold-Down Fastenings for Tie Plates, Including Pads Under Plates; Their Effect on Tie Wear

Collaborating with Committee 3

Blair Blowers (chairman, subcommittee), L. L. Adams, C. A. Anderson, L. E. Bates, F. J. Bishop, M. C. Bitner, J. A. Blalock, H. J. Bogardus, A. E. Botts, E. W. Caruthers, H. B. Christianson, E. D. Cowlin, H. F. Fifield, J. W. Fulmer, C. E. R. Haight, J. P. Hiltz, J. W. Hopkins, A. F. Huber, J. de N. Macomb, E. E. Martin, W. N. Myers, J. A. Reed, M. K. Ruppert, C. E. Weller, Troy West, J. B. Wilson, M. J. Zeeman.

Your subcommittee submits the following report as information.

The investigations being made for this assignment consist of observations of two service tests of hold-down fastenings and tie pads. The objective is to determine the more economical and effective methods for extending the service life of ties by minimizing tie plate cutting.

The major test installation is located in the northward main of the Louisville & Nashville Railroad near London, Ky. This test has been described in detail in previous reports. In July and November 1950, 11 new test sections were added. Installations made in tangent track consisted of two sections each, of Koppers No. 16 sealing compound, and the Dayton Rubber Company's special tie plate with a raised rubber insert pad. Each type of construction was with both new and existing hardwood ties. Seven new test sections were installed in a 5-deg. curve at East Bernstadt, Ky., about one mile north of the original long test curve. Five of the test sections had tie pads as follows: Achuff sisal fiber, Johns-Mansville rubber-asbestos fiber, Taylor Fibre Company's rubber-vulcanized fiber, Fabco with cements, and Dume's ⅛-in. rubber pads. Another section had standard construction with two each of cut line and anchors to serve as the basis of comparison. The seventh section had two Racor studs for anchor spikes. All sections on the 5-deg. curve had the 14-in. AREA tie plate for the 6-in. rail base and new creosoted oak ties.

A general inspection and the first check of the tie plate penetration was made. A full report covering the installations, about 1¼ miles of track, will be presented in the June-July 1951 Bulletin.

A supplemental test on seven arrangements of hold-down fastenings is being conducted on the Illinois Central Railroad, north of Manteno, Ill. This installation was last checked in 1949, and will be reported upon again in 1951.

Report on Assignment 8

Effect of Lubrication in Preventing Frozen Rail Joints

C. W. Breed (chairman, subcommittee), L. L. Adams, E. D. Billmeyer, F. J. Bishop, Blair Blowers. H. F. Busch, E. D. Cowlin, M. H. Dick, H. F. Fifield, W. E. Griffiths. C. L. Heimbach, J. W. Hopkins, C. T. Jackson, T. R. Klingel, J. de N. Macomb. E. E. Martin, W. N. Meyers, M. K. Ruppert, J. B. Wilson.

This report, submitted as information and consisting of two parts, covers the fifth service period performance of the rail joint lubrication test installation on the Chicago, Burlington & Quincy Railroad and a brief description of the second test installation made in June 1950, on the Illinois Central Railroad.

Test on the Burlington

Foreword

This test has been conducted in five miles of the Burlington's westward main track laid with 131 RE rail in July 1945, near Earlville, Ill. The fifth test period includes 10⅔ months, ended June 30, 1950, in which the traffic amounted to 13.3 million gross tons, of which 9.9 million gross tons were freight. During the 5-year test period the test track carried 81.2 million gross tons. This test was last reported in the Proceedings, Vol. 51, 1950, page 689. The location of the test sections and other essential details are given in Fig. 1.

Discussion of Test Data

Rail Joint Gap

Measurements of joint gap openings were taken in both winter and summer, but since they showed no significant differences from the last report they are not given this year. Previous reports have demonstrated conclusively that, either without lubrication or with lubricants having a wide range of chemical composition and physical characteristics, there was no condition tested that was effective in bringing about a superior uniformity of rail gap width, particularly in cold weather.

Joint Bar Pull-In

Out-to-out measurements for determining joint bar pull-in, or wear of all the joints, were taken in June 1950, but showed no important changes from the last report. From previous measurements there was no indication that any of the lubricants reduced joint wear, and the pull-in for the two test sections without lubrication was quite comparable with that of several stretches in which a lubricant was used. It is proposed to conclude these measurements in 1951.

Bolt Tension

Bolt tension measurements were repeated in the middle 15 joints of each of the 20 test sections and are summarized in graphical form in Fig. 2. For the fifth service period the average initial tension in the 1-in. track bolts for the 10 test sections in the north rail with headfree bars ranged from 19,300 lb. to 21,400 lb., and the corresponding figures for the south rail with reformed head-contact bars were 19,300 lb. to 21,300 lb., resulting in an average for the north and south rails of 20,400 lb. and 20,300 lb., respectively. The larger losses in percentage of applied bolt tension in the north rail were in the sections with RMC plastic packing and without a lubricant; in the south rail the greater losses were in the no lubricant and Crater 1-X sections. The lowest value of tension loss in the north rail was in the Petrolatum section. In the south rail the lower values were in the sections with Petrolatum and Texaco No. 904 grease (standard construction). In the 5-mile test the average loss in bolt tension was 50 and 49 percent for the north and south rails, respectively.

In Fig. 2 the 5-year average percentage loss in bolt tension is shown for each test section. It is significant to note that, although the percentage differences were not great, there was an indication that both of the sections without a lubricant had tension losses in the upper range of values. The average loss in bolt tension in the 5 track miles during the 5-year test period was 46 percent for the north rail with headfree bars and 47 percent in the south rail with reformed head-contact bars. Regardless of the differences in the design of the two types of joint bars, neither showed superiority for holding up the bolt tension.

Table 1 is presented to show for each test section the percentage of bolts having less than 5000 lb. tension at the end of the fifth service period. The information in the table covers 15 joints in each test section in which bolt tension measurements were made. As in previous reports, the north rail with headfree joints had the larger percentage of bolts with less than 5000 lb. tension. This amount of tension is considered the mini-

TABLE 1. PERCENTAGE OF BOLTS IN 15 JOINTS OF EACH TEST STRETCH WITH BOLT TENSION LESS THAN 5,000 LB. FOUND AT THE END OF THE FIFTH TEST PERIOD AFTER 10 2/3 MONTHS TRAFFIC.

South Rail H.C. Joints Percent	M.P. to M.P.		Lubricant	North Rail H.F. Joints Percent
7	67	67½	No- Ox- Id "A" Special	16 (a)
2	67½	68	Petrolatum (Dark)	11
13	68	68½	Crater 1-x Compound	19
11	68½	69	No Lubricant	22 (a)
1	69	69½	Leadolene No. 385	12
6	69½	70	Texaco No. 904 Grease	12
2	70	70½	R.M.C. Plastic Packing	23 (b)
4	70½	71	Meropa No. 8	19 (b)
9 (a)	71	71½	Texaco No. 904, Recessed nuts, no spring washers	9 (a)
1	71½	72	Liquid Asphalt Rail coating	15 (b)
6			Average	16

(a) Includes one loose bolt.
(b) Includes two loose bolts.

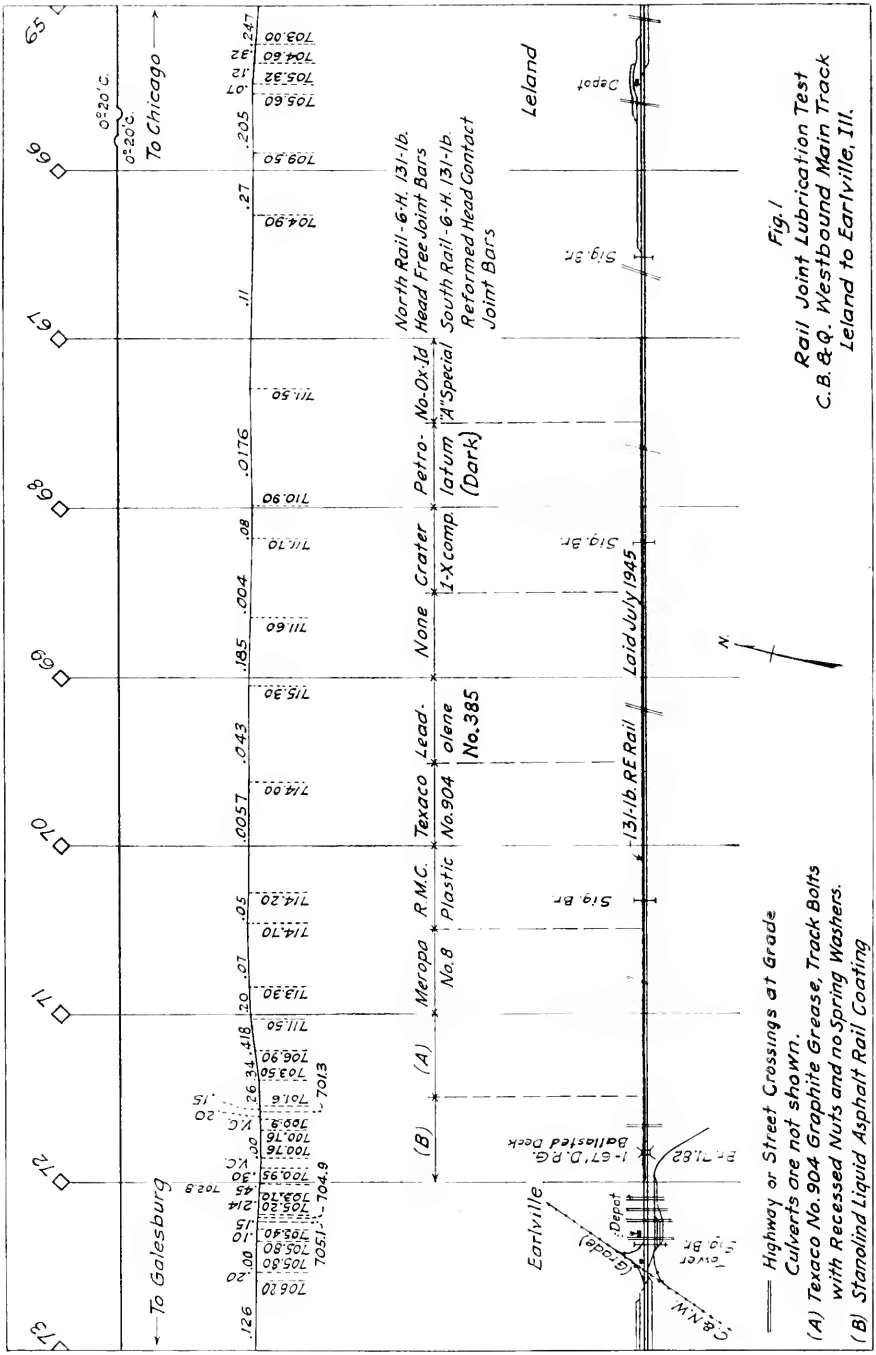
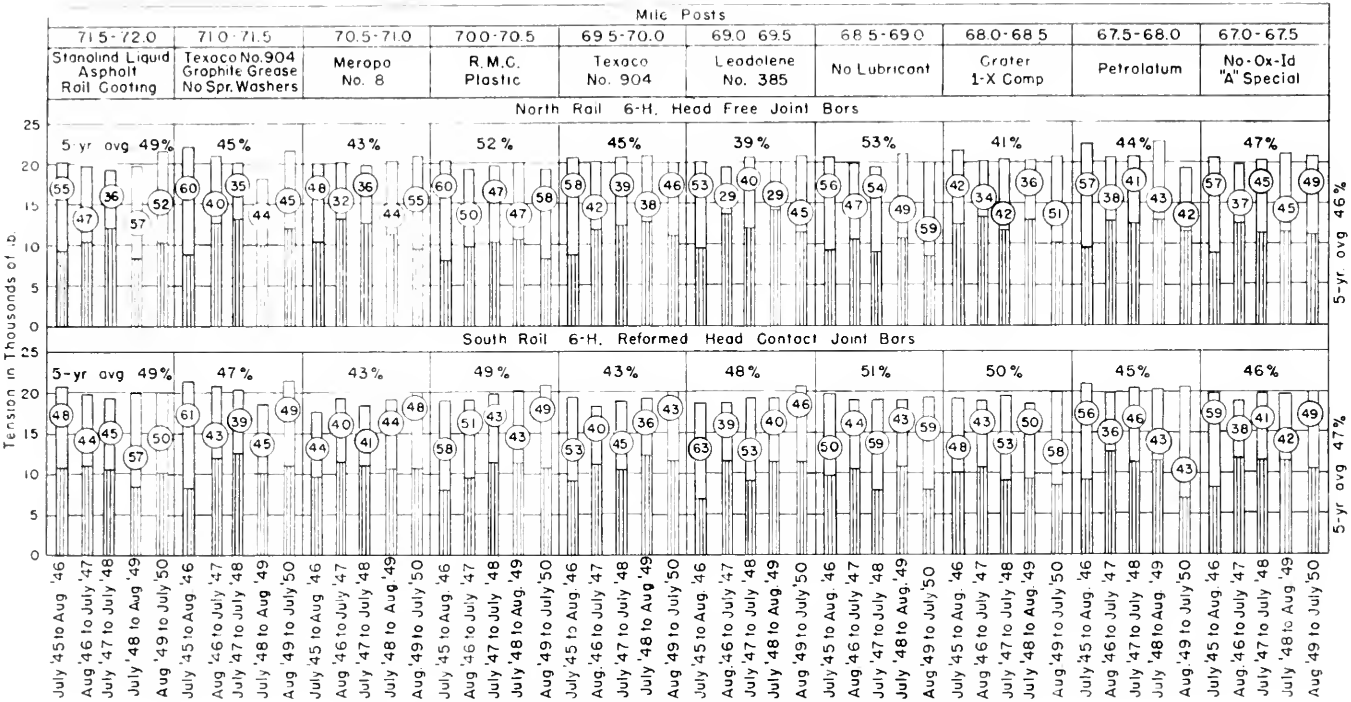


Fig. 1
Rail Joint Lubrication Test
C.B.&Q. Westbound Main Track
Leland to Earlville, Ill.

— Highway or Street Crossings at Grade
Culverts are not shown.
(A) Texaco No. 904 Graphite Grease, Track Bolts with Recessed Nuts and no Spring Washers.
(B) Stanolind Liquid Asphalt Rail Coating



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. 2. Bolt tension—C. B. & Q. R. R., Leland to Earlville, Ill.

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 10, 1949 TO JULY 1, 1950.

South Rail					North Rail		
H.C. Joints					H.F. Joints		
No. of Bolts					No. of Bolts		
Loose	Broken	Total	MP to MP	Lubricant	Loose	Broken	Total
0	0	0	67 67½	No- Ox- Id "A" Special	1	0	1
0	0	0	67½ 68	Petrolatum (Dark)	0	0	0
0	0	0	68 68½	Crater 1-x Compound	0	4(a)	4
0	0	0	68½ 69	No Lubricant	1	0	1
0	0	0	69 69½	Leadolene No. 385	0	4(a)	4
0	0	0	69½ 70	Texaco No. 904 Grease	0	0	0
0	0	0	70 70½	R.M.C. Plastic Packing	2	2	4
0	0	0	70½ 71	Meropa No. 8	2	3	5
1	0	1	71 71½	Texaco No. 904, Recessed Nuts, No Spring Washers	1	2	3
0	0	0	71½ 72	Liquid Asphalt Rail Coating	2	1	3
1	0	1	Totals		9	16	25

* Also includes loose bolts (shown in Table 1) found by AAR Research Staff when checking bolt tension in July, 1950.

(a) Includes one stripped joint.

mum required for the proper functioning of the symmetrical type of bars. For the 5-year test period, the average percentage of the bolts having less than 5000 lb. remaining tension per year was 8 and 12 for the south and north rails, respectively.

Maintenance of Way Report

For the fifth service period the roadway forces of the Burlington have maintained a record of loose and broken bolts and stripped joints for each test section. This information is summarized in Table 2. Except for one loose bolt in the south rail, all of the loose and broken bolts and stripped joints were in the north rail with headfree joint bars. There was a stripped joint in each of the sections in the north rail with Crater 1-X Compound and Leadolene No. 385. Last year's report also included one stripped joint in the last mentioned section, making a total of three stripped joints for the five-year test period, all being in the rail with the headfree bars. So far, there have been remarkably few stripped joints, and these did not occur in the sections without a lubricant. It is possible that good rail anchorage, brought about by the use of an adequate number of anchors properly spaced, could have a greater influence on the frequency of occurrence of the stripped joints than the kind of lubricant used.

Inspection of Dismantled Joints

Original Test Installation

This inspection was made in August 1950, and was attended by six representatives of four manufacturers, two railroad representatives, and G. M. Magee and H. E. Durham of the research staff.

Sixteen dismantled joints with head-contact bars in the south rail were examined to ascertain the condition of the lubricant, the extent of corrosion, etc. Photographs were taken of one joint with each kind of lubricant or rust preventive. The joints inspected had not previously been dismantled for these observations.

Figs. 3 and 4 are photographs showing the condition of No-Ox-Id "A" Special, and Petrolatum (Dark), respectively. These two lubricants after five years of service have begun to harden, flake off and weather away. They have deteriorated appreciably since last year's inspection, at which time they had not suffered much from the elements. Three joints with No-Ox-Id "A" Special and two with Petrolatum (Dark) were examined, and all showed the protective coatings had weathered away to some extent on the joint bar fishings, and particularly on the lower rail fillets and fishings. In previous years there had been an accumulation of the grease on the lower part of the rail. In these joints the condition of No-Ox-Id "A" Special was a little better than the Petrolatum (Dark). There were no hard rust layers formed in the lower rail fillets near the joint bar ends with either lubricant.

Leadolene No. 385 (Fig. 5) had weathered away on the fishings, lower rail web and fillets, and around the bolt hole at the receiving end of the joint bars. This lubricant was not in as good condition as the two petrolatum compounds. Some rust slabs had formed in the lower rail fillet near the ends of the bars.

All of the other brushed-on lubricants, viz., Crater 1–X Compound, Texaco No. 904 Graphite Grease, Meropa No. 8, and Liquid Asphalt Rail Coating were in poor condition, and photographs of them have been omitted. These compounds had weathered away badly and were no longer effective in protecting the rail web and fillets from corrosion. Hard layers of rust were found in the lower rail fillets in many of the joints.

Two joints with RMC joint packing were inspected, and a photograph of one is shown in Fig. 6. The lower rail fishings were partly lubricated but to a lesser extent than last year because the grease cakes had become drier. In one joint there was some moisture on the web of the receiving rail, between the rail end and the first bolt, where the rail web had a gray colored etched appearance. The other joint had one moisture pocket, and the loose material had formed round balls. The grease cakes protect the bolts well and keep out the sand, dirt and debris but not the moisture or free water which enters at the joint gap. After five years' service the material had dried out to such an extent that there was little evidence of fresh bleeding at the bolt holes. There were no rust slabs in the lower rail fillets.

This year two joints without a lubricant were examined. One joint was remarkably clean inside and had no rust slabs, while the other one had a hard layer of rust in the lower rail fillet on the gage side at the receiving end of the joint bar. In the joints without lubrication the bolt threads were not greased, and considerably more effort was required to back off the nuts. In the lubricated sections, regardless of the kind of compound used on the bolts, the nuts backed off easier; and the grease was spread over the threads. The recessed nuts were the most effective as to retaining thread lubrication.

Only one bolt was found to have battered threads. Lubrication on the top fishings was practically all dissipated except in the No-Ox-Id "A" Special and Petrolatum (Dark)

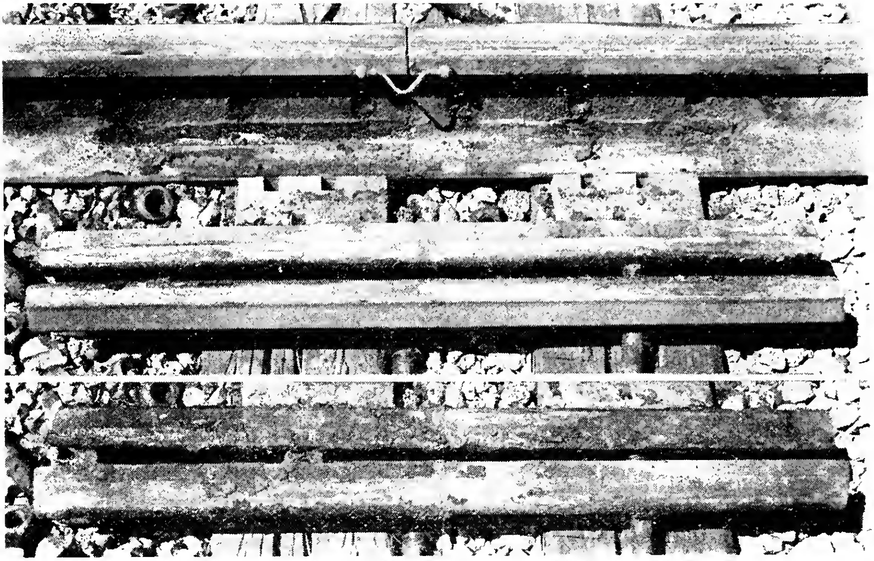


Fig. 3. No-Ox-Id "A" special.

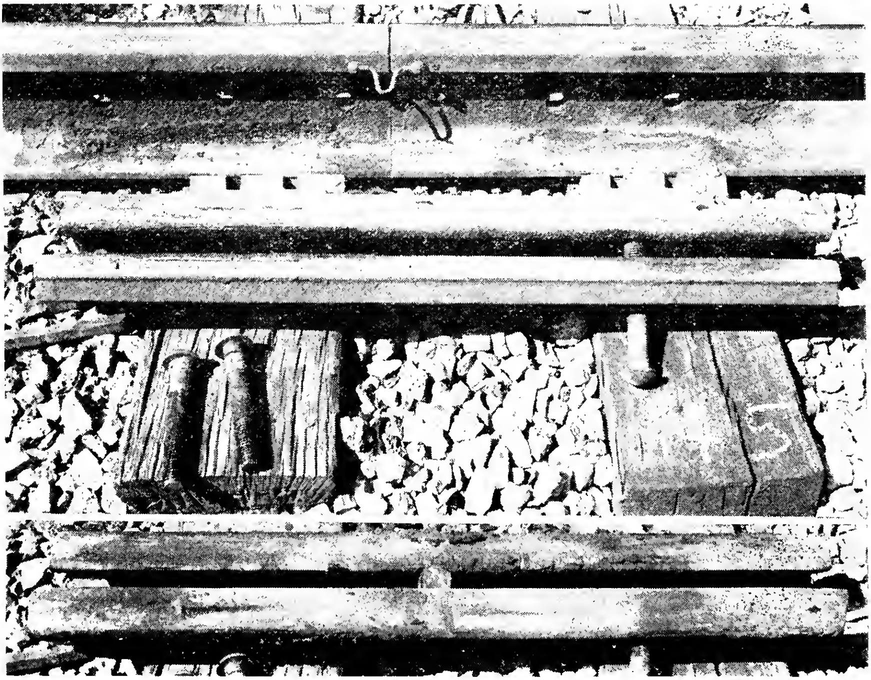


Fig. 4. Petrolatum (dark).

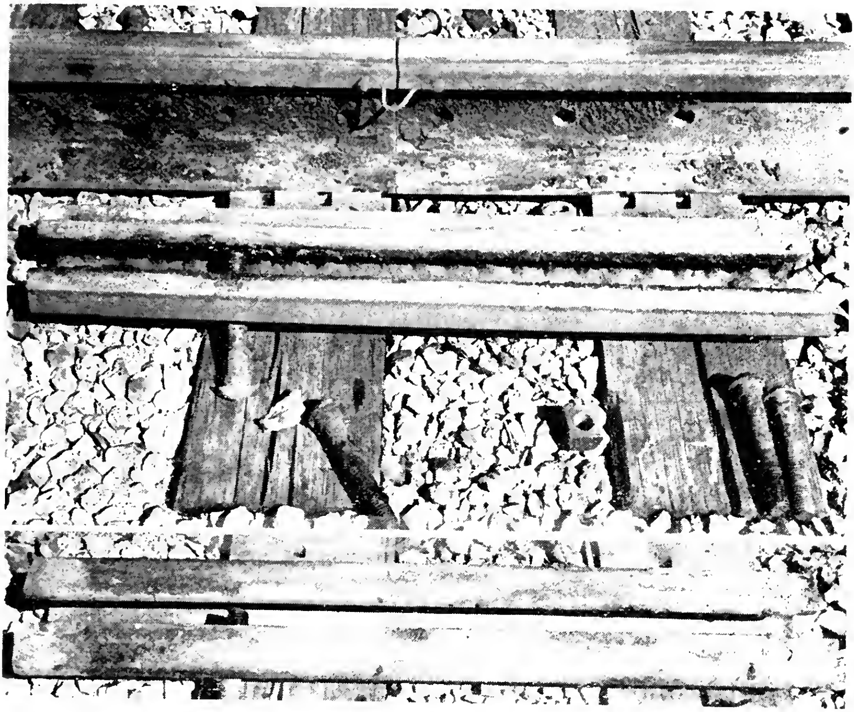


Fig. 5. Leadolene No. 385.

Fig. 6. R. M. C. plastic joint packing.

Fig. 7. No. 3208 graphite grease slabs

sections. In the RMC joints there was generally more lubricant on the bottom fishings than in the other test sections. Obviously, the greases have squeezed out where there has been good contact between the fishings, and the remaining grease functions more as a rust preventive than a lubricant. As mentioned in last year's report, the rust slabs found in the lower rail fillets will reduce the available joint bar take-up and possibly shorten the service life of the bars. Suitable end plugs extending from the ends of the bars to the end bolt should effectively reduce or eliminate the hard layers of rust from forming. Joint packing or end plugs that work out beyond the end bolts will expose the areas where the rust slabs form and may be of little benefit in the prevention of the hard layers of corrosion.

In the original application of the brush-on lubricants, only the rail was coated. This service test has demonstrated the difficulty in keeping a lubricant on the fishings, especially the top ones. It seems desirable to coat the bar fishings, since grease applied with a brush will have a better bond with the steel than that which is transferred from the rail to the bars when the joints are assembled.

No. 3208 Graphite Grease Slabs

Last year six joints with head-contact bars were packed solid with these lime soap graphite grease slabs. Fig. 7 shows one of these joints after a year of service. It will be observed that the application was not effective in the lubrication of either fishing surface. The grease slabs were in good condition as to weathering, but they did not bleed in hot weather because of the high melting point of 215 deg. F. This material had flaked out at the ends of the bars, and the Burlington advised that this had occurred during the winter. The grease slabs protected the inner areas of the joints and the bolt shanks, except where the grease worked out at the ends of the joints.

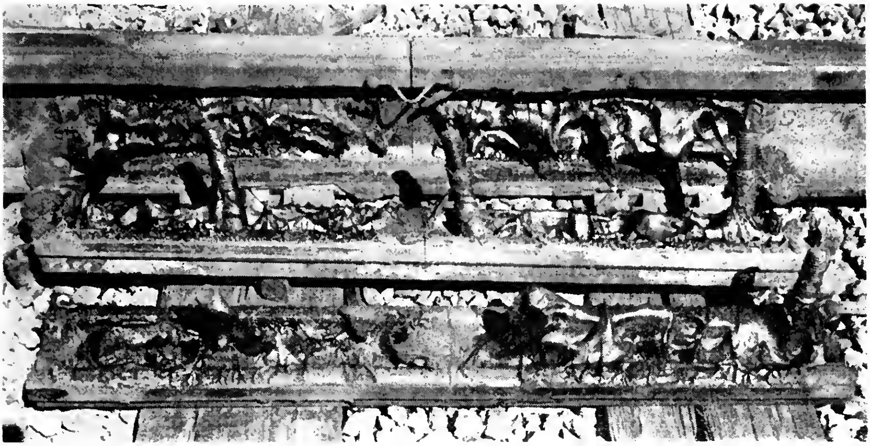


Fig. 8. Solvated Sealz joint packing.

Solvated Sealz Joint Packing

Six head-contact joints were packed with Solvated Sealz slabs in 1948, and one of the joints is shown in Fig. 8. When the joint bars were removed after two years' service, the rubber slabs pulled apart and had a good bond with the rail web, except at the rail gap where the material adhered to the joint bars. This indicates that the slabs may break bond with the rail web between the middle bolts. If this develops, moisture or free water may be held against the rail web for long periods and possibly cause corrosion fatigue failures to occur in the rail. This material had one water pocket, but it was not near the rail gap. The slabs covered the lower fishings well but were deficient on the upper fishings. The packing was in good condition and protected the inside of the joint and bolt shanks well, except for the water pocket. Solvated Sealz slabs are made of reclaim rubber and natural and synthetic resins. It has no lubricating properties but is intended to keep the inside of the joints protected from sand, debris and the elements.

Relubrication

In the laboratory tests of rail joint lubrication, which were conducted with the joint slippage machine and reported in the Proceedings, Vol. 48, 1947, page 589, it was developed that lubrication of a new rail joint was beneficial for about 500 cycles of opening and closing of the rail gap, while in the case of regreasing a joint, the lubrication was effective for a greater number of cycles. In order to develop information on the relative merits of initial lubrication and regreasing, 47 joints with head-contact bars were regreased in the Petrolatum (Dark) section with the same lubricant. The bars and rails were thoroughly cleaned before applying a brush coat on the rail web and fishings and the bar fishings. Because of moderately cool weather in August 1950, the Petrolatum was stiff, and 1.7 lb. per joint were used. The application was made with two-knot roofing brushes. If the weather had been warm or the grease heated, less than 1 lb. per joint would have been required.

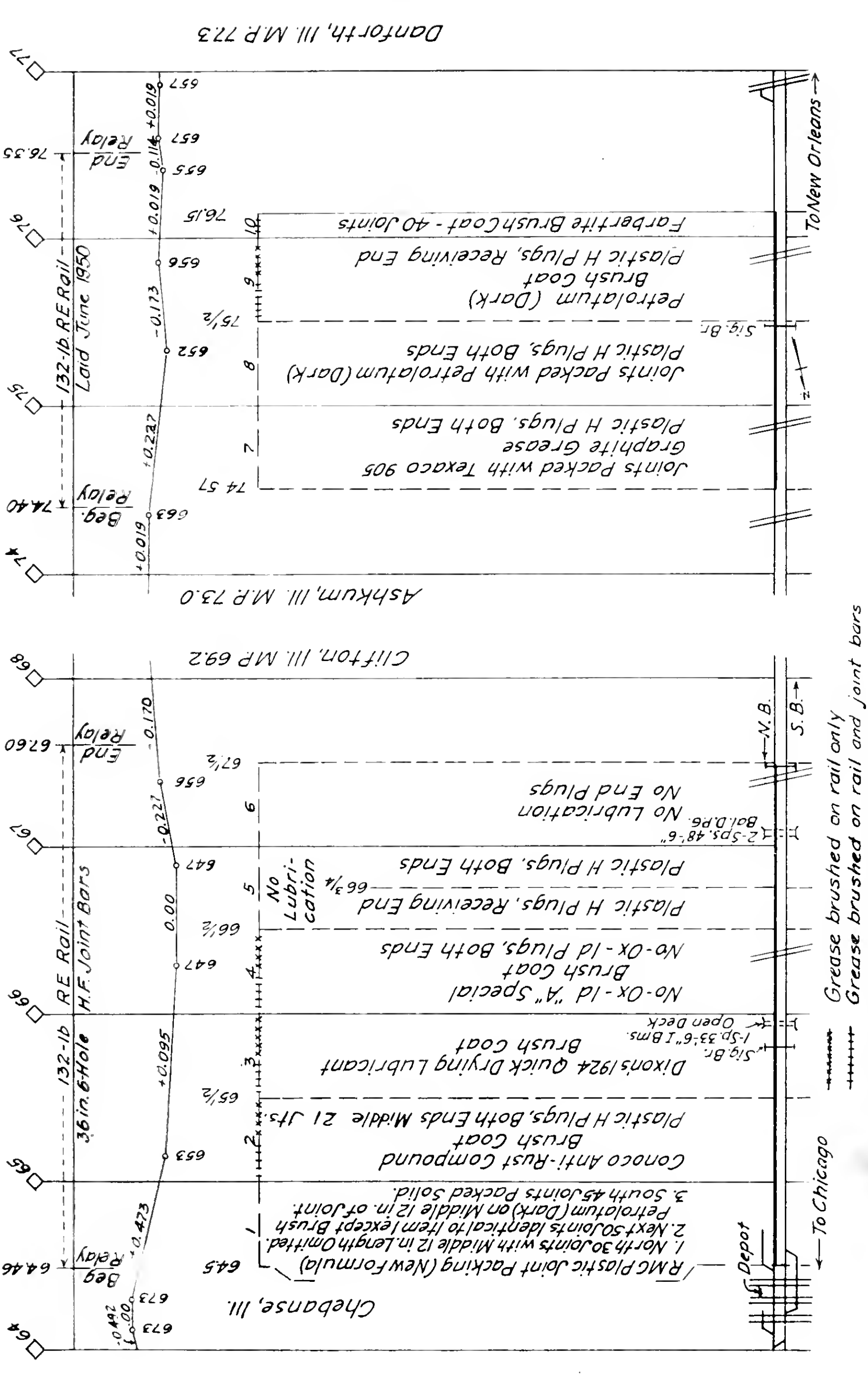


Fig. 9. Rail joint lubrication service test in I. C. R. R. northward main track between Chebanse and Danforth, Ill.

Summary

Of the brushed-on lubricants, No-Ox-Id "A" Special and Petrolatum (Dark) were superior as to weather resisting properties. However, in the fifth year of service these greases had begun to dry out and weather away. Leadolene No. 385 was in the second best class as to resisting the elements. For four years it had protected the rail web and fillets well, except at the receiving end of the bars. After five years' service it was also deficient in the lower rail fillet.

In five years the RMC packing had become dry but had protected the inner surfaces of the joint and the bolt shanks well, except for some corrosion on the rail web each side of the joint gap.

None of the lubricants has shown a superiority for effecting a reduction in joint wear or for bringing about a good uniformity of joint gap width. Three stripped joints in five miles of track for a service period of five years are too few in number to judge the effectiveness of the lubricants. None of the stripped joints occurred in the two sections without lubrication.

Observations of the dismantled joints have shown the difficulty in keeping lubrication on the fishings, particularly the top ones. The value of lubricants seems to be for rust prevention rather than for joint lubrication. The results have shown that all brushed-on lubricants have a relatively short service life.

From the results so far, it is evident that a longer service life of the compounds for the prevention of corrosion is definitely needed. It seems necessary, for more effective and lasting protection against corrosion of the rail, bars and bolts, to use end plugs with a brushed-on lubricant or to pack the joint with a material that will stay in place and not hold water or moisture against the rail web at the rail ends.

This is the final report on the bolt tension measurements. Rail gap and pull-in measurements will be concluded next year, except for the regreased section. Future inspections will be made of some of the sections as may be justifid from the results obtained from year to year.

Test Installation on the Illinois Central Railroad

Foreword

This test was planned for the purpose of investigating the service performance of new types of rust preventives or lubricants, different methods of application, greases with end plugs, and also end plugs without a lubricant. In the tests on the Burlington, near Earlville, Ill., many deficiencies developed in less than three years with most of the brush-on lubricants; and it is the desire of the subcommittee to develop information leading to more effective and economical methods for preserving joints over a much longer service period.

General Description

The Illinois Central very kindly offered to place this test in its northward main of the double-track line between Chebanse and Danforth, Ill., where about five miles of track in two stretches were scheduled for relay with 132 RE rail and the Rail Joint Company's 6-hole headfree joint bars in June 1950. The test track carries high-speed passenger and freight trains and an annual traffic density of about 29 million gross tons. The track has color-light signals for operation in both directions, and a few trains each day are operated against the current of traffic. Fig. 9 is presented to show the location of the 10 test sections as installed in June 1950. In connection with next year's progress report, a complete description of the various sections will be given.

Acknowledgment

The committee and the Association are indebted to the Burlington and the Illinois Central for their splendid cooperation and assistance in conducting these tests.

Report on Assignment 10

Critical Review of the Subject of Speed on Curves as Affected by Present Day Equipment

J. W. Fulmer (chairman, subcommittee), L. L. Adams, J. C. Aker, T. H. Beebe, E. D. Billmeyer, F. J. Bishop, M. C. Bitner, J. A. Blalock, T. E. Bliss, C. W. Breed, E. W. Caruthers, M. H. Dick, A. E. Haywood, C. T. Jackson, E. E. Martin, W. N. Myers, E. R. Murphy, C. E. Peterson, Troy West.

Preliminary Test to Correlate Passenger Ride Comfort on Curved Track with Lateral Accelerations

Summary

This report gives a description and the results of tests made in May 1950, on the Louisville & Nashville Railroad to obtain data for re-examining the present practice of establishing maximum comfortable speed on curved track on the basis of 3 in. unbalanced elevation. Special arrangements were made with the railroad to apply accelerometers to the Chesapeake & Ohio Railway track inspection car on a regular inspection run, measurements being obtained on sections of the L. & N. main line containing many curves of various degrees of curvature between Cincinnati, Ohio, and Bowling Green, Ky. Twelve observers rode in the test car and recorded their impressions of the riding condition on each curve. These observations were then correlated with the measured lateral acceleration and calculated unbalanced elevation for each curve. The detailed results obtained are given in the accompanying tables and diagrams. This was a preliminary test, principally with the objective of establishing methods of measurement and correlation of ride impressions to form the basis for securing more extensive measurements later. However, much valuable data were obtained from this test and the more important conclusions are as follows:

1. The 3-in. unbalanced elevation gives a very satisfactory riding condition and it appears likely that further study may justify increasing this to perhaps 4 or 4½ in.
2. The tests have demonstrated that the amount of tilting of the car body on the springs is a very important factor because it reduces the effectiveness of the elevation and increases the acceleration on the passenger. With the type car used in the tests this increase amounted to 80 percent.
3. The tests have greatly clarified the future course that needs to be followed to establish a satisfactory method of speed limitation based on scientific measurements.

1. Acknowledgment

The opportunity to make the tests here discussed was afforded by L. L. Adams, assistant chief engineer of the L. & N. Mr. Adams invited the research staff to install such special equipment as was required on the C. & O. track inspection car during its yearly trip over the L. & N., and gave extensive assistance in the arrangements and

preparations for the tests. The C. & O. and S. H. Poore, assistant engineer in charge of the inspection car, also gave helpful assistance during the preparations for the tests while the car was in the Huntington, W. Va. shops. The tests were run May 10, 1950, between Cincinnati, Ohio, and Bowling Green, Ky.

Twelve members of the Track committee and representatives of interested commercial companies contributed their time and expenses to go on the test run and acted as observers to record their impressions of the ride. The tests were under the general direction of G. M. Magee, research engineer, and were in the charge of Randon Ferguson, electrical engineer, assisted by M. F. Smucker, assistant electrical engineer, and W. G. Heilman, electrical assistant. This report was prepared by Mr. Ferguson.

2. Origin of the Problem

The present speed limitations on curved track as now given in the AREA Manual are based on the consideration that the maximum comfortable speed on a curve is one which would require 3 in. additional elevation for balanced load on the inner and outer rail. This criterion of 3-in. unbalanced elevation is applied to all degrees of curvature, regardless of the amount of elevation or length of spiral.

This criterion was established in 1914 by a special committee and was based upon the personal observation and experience of the committee members. Introduction of diesel trains operating at higher speeds with passenger cars having reduced center of gravity height and extensive changes in truck design, including more flexible springs, snubbers and stabilizers, have made it desirable to review this criterion, making use of electrical instrumentation now available to establish a more scientific basis of speed limitation.

The characteristics of a ride can be measured in terms of various physical quantities, the usual ones being displacement, velocity, acceleration and frequency. Acceleration is perhaps the most widely accepted criterion of ride quality being proportional to the force acting on the body under acceleration. The frequency is also an important factor and must be known to evaluate the effects of the acceleration.

Extensive tests have been made to obtain a correlation between the effect of vibrations on persons and these measurable physical quantities, such as acceleration. The most reliable and extensive of these tests[1] were analyzed and condensed for use in the report on Effect of Wheel Unbalance, Eccentricity, Tread Contour and Track Gage on Riding Quality of Passenger Cars.[2] Here a quantitative term "Ride Index" was introduced to give absolute values to ride quality and the thresholds between the degrees of sensation used. However, the above tests covered vibrations in the range from a little over 1 cps. to 60 cps. with the data rather meager in the extreme low range. The type of acceleration given the passenger riding around a curve is of a very low frequency since it will be practically constant, except for discontinuities in the alinement or oscillations of the trucks, during the whole time of traversing the curve, a matter of many seconds. There being little if any experimental work on the effects of acceleration on people in this frequency range, it was decided to run an exploratory test to correlate the impressions of passengers under this type of acceleration with the measured lateral acceleration to aid in formulating a program when a full-scale set of tests could be made.

3. Relevant Analytical Discussion

The AREA Manual[3] states that safety and comfort limit the speed on curves and that experience has shown that comfort may be maintained if the speed is limited to a value such that 3 in. more elevation is required to give a balanced condition (equal loads on the inner and outer rails and centrifugal force balanced by the elevation of the track). The formula for the balanced condition given in the Manual is

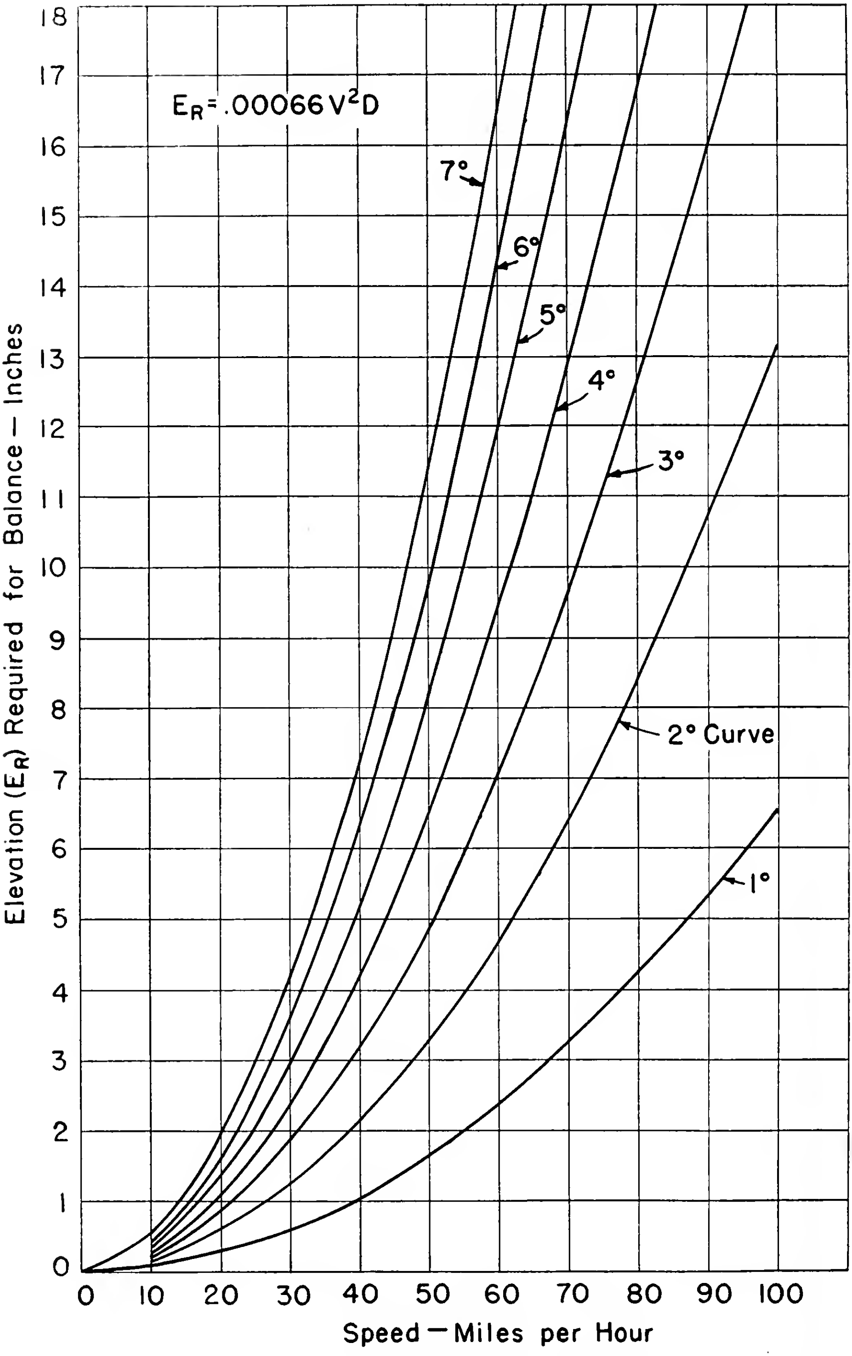


Fig. 1. Elevation required for various speeds and degrees of curvature.

$$E_R = .00066\ V^2D$$

where E_R is the elevation required for balance in inches, V, the speed in miles per hour, and D, the curvature in degrees. This equation is plotted for curves of 1 deg. to 7 deg. and speeds to 100 mph. in Fig. 1. These curves permit determination of the unbalanced elevation for a given speed by subtraction of the actual elevation present from that needed for balanced speed.

The unbalance is directly proportional to the lateral acceleration and force on any object affected. The centrifugal force, F, going around a curve has been derived as[4]

$$F = \frac{W\ V^2D}{85{,}800} \qquad \text{(Formula slightly modified)}$$

where W is the total weight. The component, H, of the weight W in the plane of the inclined track will be

$$H = \frac{W\ E_A}{60}$$

E_A is the actual elevation and 60 the distance between bearing points of the wheels on the rails in inches. The unbalanced force, F_U, will be

$$F_U = F - H = \frac{W\ V^2D}{85{,}800} - \frac{W\ E_A}{60}$$

$$F_U = \frac{W}{60}\ (0.00066\ V^2D - E_A)$$

Substituting E_R and calling the unbalanced elevation E_U

$$F_U = \frac{W}{60}\ (E_R - E_A) = \frac{W}{60}\ E_U$$

The weight W may be the weight of the car itself or an object within the car. Further

$$F_U = Ma = \frac{W}{g}\ a$$

where M is the mass of the body under consideration; a is the acceleration; and g the acceleration of gravity.

Equating the two above values for F_U

$$\frac{W}{60}\ E_U = \frac{W}{g}\ a$$

and

$$a = \frac{E_U}{60}\ (g)$$

Expressing the acceleration in terms of g

$$a = \frac{E_U}{60} = 0.0167\ E_U$$

If $E_U = 1$ in., $a = 0.0167\ g$, or for a 3-in. unbalance $E_U = 3$ in.

$$a = 0.0501\ g$$

The active axes of the accelerometers were placed parallel and perpendicular with respect to the car floor to measure the accelerations in those directions. The vertical (perpendicular) measurements were of only incidental interest. The lateral (parallel) component tells the effect of the speed, curvature and elevation. The lateral accelerometer is also subject to effects other than the centrifugal force and elevation. These are mainly variations in curvature, oscillations of the trucks and rolling of the car body on the springs. The elevation inclines the car so the component of gravity parallel to the car floor aids in balancing the centrifugal force at speeds greater than the balance speed. Since the center of gravity of the car body is above the point of support, the body will tend to roll outward on the springs and reduce the angle of inclination due to the elevation, thus causing a lessening of the balancing component of gravity and decreasing the effectiveness of the elevation. In effect, this means that the accelerometer (or passenger) is subject to a greater acceleration than indicated by calculated unbalanced elevation. This will be discussed further in the presentation of the results.

4. The Test Car, Apparatus and Procedure

The AAR equipment was set up in the C. & O. track inspection car adjacent to the recording table for the regular inspection equipment. This car is not representative of new type equipment nor is it exactly representative of standard older equipment because of some of the special features required by the track inspection devices. However, the objective was not to test the equipment but to correlate ride impressions with measured quantities representing the ride, and it will be apparent from the analysis of the test data that this correlation was satisfactorily obtained with the type of equipment used. The car was the last car of the train, which caused some lateral oscillations. Before starting the test run, the observers were asked to record their impressions of the general throw of each curve and ignore oscillations or lurches due to unusual track irregularities. Speed was limited to 70 mph. because of the effect on the track inspection devices.

The car was equipped to record various characteristics of the track surface and alinement, the most pertinent to this test being the degree of curvature and elevation. These two values were also supplied by the L. & N. engineering department, but in cases of apparent discrepancies the car record was used for a check.

The accelerations of the car, vertical and lateral, were measured by two Statham accelerometers of $\pm 2g$ range and recorded by a two-channel Brush pen writing oscillograph driven by two Brush carrier wave amplifiers. The accelerometers were placed at about the middle of the car on the floor, being mounted on a steel block weighing about 25 lb., which, in turn, rested upon a rubber pad that absorbed some of the irrelevant high frequency vibrations from the floor, but suitably transmitted the accelerations affecting riding comfort. A sensitivity of about $0.01g$ per millimeter deflection was used. The paper record traveled at 5 mm. per second, which is about 0.20 in. per second. An event marker on the oscillograph was operated in parallel with the mile post indicator on the inspection car record, and mile post numbers, speeds and other data were written on the record of acceleration.

The passengers (observers) were supplied with a table listing the curves for the stretches of track selected for test. This table also listed the degree of curve and direction, and had a vacant column for each of the four degrees of sensation previously established for vibratory tests. These were "Not Perceptible," "Perceptible," "Strongly Noticeable" and "Uncomfortable." Each curve was called by mile post and letter designation over a specially installed address system as the curve was entered. The passenger then checked the appropriate description of the ride on the curve. All these individual impressions were summed up and tabulated in Table 1, together with a weighted Ride Index for each curve, derived as later explained.

5. Results of the Tests

A sample record of the accelerations recorded by the Brush oscillograph is shown in Fig. 2. The record of the lateral acceleration is at the upper part of the figure. It will be noted that the record indicates a vibration superimposed on the general pattern of throw due to unbalance. The larger vibrations were at approximately one second intervals, and in a few cases were quite severe and definitely unpleasant. However, these vibrations have no bearing on the acceleration due to curve unbalance, which is represented by a mean value of the vibrations. In the example shown this value was taken as 0.09*g*.

This record also shows a characteristic that was present on several short curves. The acceleration is inward entering the curve and leaving it, and of considerable amount, and reverses to an outward value in between. It was stated by the engineering department of the railroad that it is necessary in some cases to place part of the elevation on the tangents. This gives an acceleration component due to gravity having the same effect as running below the speed of elevation on the curve. This condition gives the passenger two rather quick reversals of acceleration and the effect may be uncomfortable. This phase of the problem was not foreseen at the time of the test, so no special observations were made to determine the effect of this condition on passenger comfort.

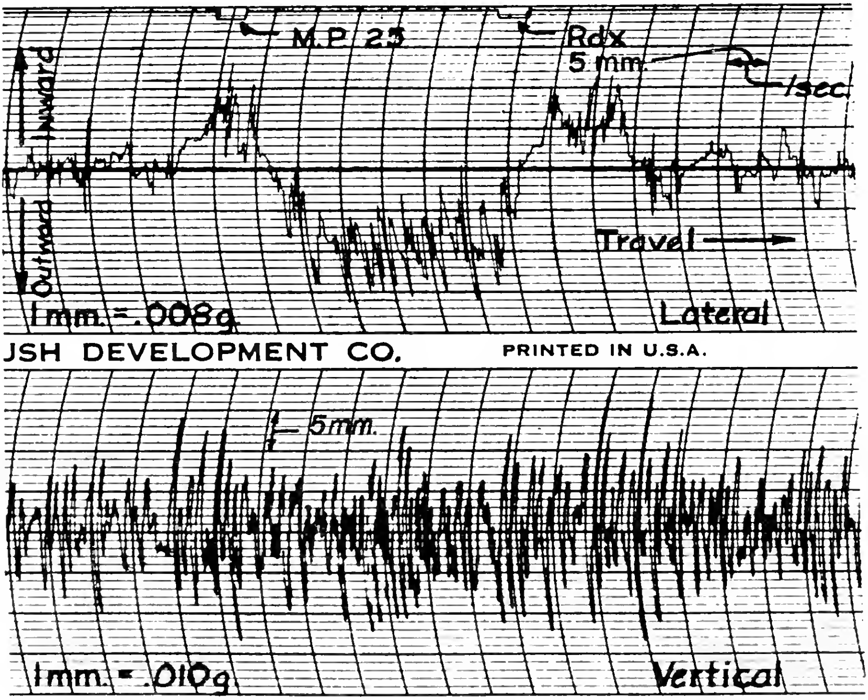


Fig. 2. Typical record of vertical and lateral acceleration on a 3-deg. curve with 4½ in. elevation. Speed—62 mph.

Table 1. Curve Ride Data
Louisville and Nashville R.R. Co. - Cincinnati to **Bowling Green**

Speed mph.	Ride Impression Summation					Elev. (In.)	Unbal. Elev. (In.)	Lat. Accel. (g)	Vert. Accel. (g)
	Not Perceptible	Perceptible	Strongly Noticeable	Unconfort-able	Weighted Ride Index				
7° Curves									
45	3	6			1.2	6	3	.08*	.08
43	4	5			1.1	6 1/4	2 1/4	.04	.07
43	4	6			1.1	6 1/2	2	.04	.07
42	7	4	1		1.0	6	1 1/2	.07	.08
40	1	8	3		1.7	5 1/2	2	.06	.09
36	10	2			.7	4 1/4	1 3/4	-.03	.07
26	9	1			.6	3	0	-.02	.02
6° Curves									
45		10			1.5	5 1/2	2 1/2	.06	.05
38	8	2			.7	5 1/2	0	0	.03
33	4	5	1		1.2	4	1/2	.05	.03
32	5	4			.9	6	-2	-.03	.04
32	3	6	1		1.3	6	-2	-.05	.04
40	2	7	1		1.4	5 1/2	1	.07	.08
42		9			1.5	6	1	.07	.10
46		7	2		1.7	6	2	.08*	.10
48	1	6	1	1	1.7	5 1/2	3 1/2	.07	.07
48	1	7	1		1.5	6 1/4	2 3/4	.06	.06
46	1	6	2		1.6	6 1/2	1 1/2	.06	.08
45	2	7			1.3	6	2	.08	.07
44	2	7	1		1.4	6	1 1/2	.04	.07
42	2	8			1.3	6	1	.06	.05
45	2	9	1		1.4	6	2	.06	.04
40	7	4			.9	6 1/4	1/4	-.01	.07
37	6	5			1.0	5	1/2	-.01	.03
44	4	6	1		1.2	6	1 1/2	.07	.07
34	5	7			1.1	5	-1/2	-.05	.05
43	2	8	2		1.5	5	2 1/2	.08	.09
43	2	8	1		1.4	6	1 1/2	.08	.07
#50		1	8	3	2.8	4	5 1/2	.12	.10
47	1	10	1		1.5	5 1/2	3	.08	.07
43	1	9	2		1.6	5 1/2	1 1/2	.07*	.12
40	10	2			.7	5 1/2	1	.06	.07
42	2	10			1.3	5 1/2	1 1/2	.07	.09
6° Curves (Continued)									
44	2	7	3		1.6	5 1/2	2	.09	.09
46	1	4	6	1	2.1	5 1/2	2 1/2	.13*	.07
42	1	9	2		1.6	4	3	.06	.09
35	8	3	1		.9	6	-1	-.02	.04
34	8	3	1		.9	5	-1/2	-.01	.07
34	9	2			.7	5	-1/2	-.02	.07
33	6	6			1.0	5 1/2	-1	-.02	.06
34	5	6	1		1.2	5 1/2	-1	-.04*	.08
35	9	3			.8	5 1/2	-1/2	-.05	.06
36	7	3	1		1.0	5 1/2	-1/2	.02	.05
40	7	3	1		1.0	5 1/2	1	.04	.10
46	2	8	1		1.4	5 1/2	2	.06	.05
48	4	5	1		1.2	5 1/2	3 1/2	.07	.05
43	10		1		.7	5 1/2	1 1/2	.04	.06
42	8	2	1		.9	5 1/2	1 1/2	.05	.06
41	8	3	1		.9	5	1 1/2	.03	.05
38	9	2	1		.8	5	1/2	0	.07
35	8	2			.7	4	1	.03	.02
33	7	2			.7	3	1 1/2	.03	.02
31	7	3			.8	3 1/4	3/4	.04	.02
28	8	2			.7	3 1/4	-1/4	-.05	.02
26	8	2			.7	2 3/4	-1/4	.02	.02
26	8	2			.7	3 1/4	-3/4	-.02	.02
26	9	1			.6	3	-1/2	-.02	.02
5° Curves									
45	2	8			1.3	5	1 1/2	.05	.07
42	6	4			.9	4 1/2	1	.05	.08
42	7	5			.9	6 1/8	-1/8	-.02	.08
49		9	2		1.7	6	2	.10	.05
48	8	3	1		.9	6	1 1/2	.08	.07
45	7	5			.9	5 1/2	1	.03	.05
30	8	2			.7	3 3/4	-3/4	-.04	.02
26	8	2			.7	2 1/4	-1/4	.02	.02
26	9	1			.6	2 3/4	-3/4	-.04	.01

Table 1. Curve Ride Data (Continued)
Louisville and Nashville R.R. Co. - Cincinnati to **Bowling Green**

Speed mph.	Ride Impression Summation					Elev. (In.)	Unbal. Elev. (In.)	Lat. Accel. (g)	Vert. Accel. (g)
	Not Perceptible	Perceptible	Strongly Noticeable	Uncomfort-able	Weighted Ride Index				
4° Curves									
40	8	2			.7	5 1/2	-1 1/2	-.06	.04
33	6	4			.9	6	-2	-.03	.04
43	5	4			.9	4 1/2	1/2	.03	.10
47	10	1			.6	3 3/4	2 1/4	0	.05
45	10	2			.7	5	1/2	.02	.08
40	11	2			.7	2 1/2	2 1/2	-.01	.05
41	12				.5	5 1/4	-3/4	0	.04
38	10	3			.7	4	0	0	.06
54	1	10	1		1.5	5 1/2	2	.09	.06
54		4	7	1	2.3	4	3 1/2	.09	.14
60		5	6	1	2.2	5 1/2	4	.09	.12
38	10	2			.7	3 1/2	1/2	.02	.06
36	8	4			.8	3 1/2	0	-.02	.07
35	10	2			.7	4 1/2	-1 1/2	-.03	.06
33	3	8	1		1.3	5 1/2	-2 1/2	-.08	.05
58		1	8	3	2.7	3 1/2	5 1/2	.15	.12
49	8	4			.8	5 1/2	1	.03	.07
42	11	1			.6	4 1/2	0	0	.07
58	1	9	2		1.5	5 1/2	3 1/2	.10	.11
60	2	6	1		1.4	6	3 1/2	.06	.03
50	6	4	1		1.0	7	-1/2	-.05	.06
42	6	3	1		1.0	6 1/4	-1 3/4	-.06	.02
38	8	2			.7	4 1/2	-1/2	-.02	.02
55	4	4			1.0	6	2	.04	.05
52	5	3			.9	4	3	.04	.05
53	6	2			.8	5 1/2	2	.05	.07
53	5	3			.9	5 1/2	2	.03	.04
56	5	2			.8	5 1/2	2 1/2	.06	.07
3° Curves									
44	9	1			.6	4 1/4	-1/4	0	.06
47	9	3			.8	4 1/2	0	0	.06
40	8	4			.8	4	-1	-.03	.02
41	6	7			1.0	2 3/4	3/4	.02	.04
53	11	1			.6	4 1/4	1 1/4	.03	.06
3° Curves (Continued)									
49	9	3			.8	3 5/6	7/8	.01	.05
42	10				.5	4 1/4	-3/4	-.02	.03
49	5	6			1.0	4	1/2	.03	.05
49	9	2			.7	3	1 1/2	0	.03
56	5	6	1		1.2	4	2	.06	.04
54		4	7	1	2.3	3 1/2	2	.09	.10
57	2	8	1		1.4	4	2 1/2	.07	.06
45	11				.5	3 1/4	3/4	0	.08
35	11				.5	2 1/4	1/4	-.02	.08
40	11	1			.6	3	0	0	.07
50	1	9	2		1.6	3 1/2	1 1/2	.15	.12
48	9	3			.8	4	1/2	.02	.19
47	8	3			.8	4	1/2	0	.07
46	11	1			.6	-	-	-	-
60		10	2		1.7	4	3	.10	.15
54	9	3			.8	4 1/4	1 1/4	.04	.09
50	11	1			.6	4 1/2	1/2	.02	.09
45	11	1			.6	4	0	0	.07
	5	1			.7	3 1/2			
10	8	1			.6	1 1/2	-1	-.03	
30	5	6	1		1.2	2 1/2	-1/2	-.04	.04
62		6	4	2	2.2	4 1/2	3	.09	.12
63	2	6	3	1	1.8	5 1/2	2 1/2	.10	.15
62	6	6			1.0	5	2 1/2	.06	.07
31	5	5			1.0	5	-3	-.07	.03
50	6	2			.8	2 1/2	2 1/2	.10	.05
52	3	5			1.1	3	2 1/2	.07	.07
58	6	2			.8	5 1/4	1 1/4	.05	.06
2° Curves									
45	10				.5	2 1/4	1/4	.02	.10
47	8	3			.8	3	0	0	.08
44	10	2	1		.8	3 1/2	-1	-.05	.09
45	8	4			.8	2	1/2	.01	.06
40	10	2			.7	2 1/2	-1/2	-.05	.07

Table 1. Curve Ride Data (Continued)
Louisville and Nashville R.R. Co. - Cincinnati to Bowling Green

Speed mph.	Ride Impression Summation					Elev. (In.)	Unbal. Elev. (In.)	Lat. Accel. (g)	Vert. Accel. (g)
	Not Perceptible	Perceptible	Strongly Noticeable	Unconfortable	Weighted Ride Index				
				2° Curves (Continued)					
37	7				.5	2			
52	11	1			.6	2 1/2	1	.03	.10
56		10	2		1.7	2 1/2	1 1/2	.07	.12
60	2	8	2		1.5	3 1/2	1 1/2	.07	.10
53	11	1			.6	2 1/2	1	.02	.07
32	10	2	1		.8	2 1/2	-1	-.03	.07
39	8	4			.8	1 1/4	3/4	.03	.10
56	8	3	1		.9	1 1/2	2 1/2	.06	.10
45	9	3			.8	3	-1/2	-.03	.07
46	12				.5	2 3/4	1/4	-.02	.06
61	11	1			.6	3 1/2	1 1/2	.04	.05
61	9	1			.6	3 1/4	1 3/4	.05	.05
62	8	3	1		.9	3 1/4	1 3/4	.04	.07
37	9	1			.6	3	-1	-.02	.02
26	6	4			.9	3 1/4	-2 1/4	-.05	.02
67	3	5			1.1	5 1/2	1/2	-.04	.07
65	3	5			1.1	3	2 1/2	.10	.10
61	7	1			.6	3	2	.02	.07
38	5	2	1		1.0	4 1/2	-2 1/2	-.09	.02
				1° Curves					
37	9	1			.6	1 3/4	-3/4	-.02	.02
27	10				.5	2	-1 1/2	-.05	.01
60	9	1			.6	2 1/4	1/4	.02	.05
65	7				.5	2 1/2	1/2	.05	.10
55	5	2			.8	2 3/4	-3/4	-.04	.05
68	6	1			.6	2 1/2	-1/2	-.05	.08
71	7	1			.6	3 1/2	0	.02	.05
67	8				.5	2 1/2	-1/2	.03	.05
69	8				.5	2 1/2	1/2	.04	.07
66	5	3			.9	2	1	.02	.05
37	4	3	1		1.1	3	-2	-.04	.02

* Violent Oscillation
\# 6° & 4°

The vertical oscillations shown at the bottom of Fig. 2 have a frequency of about 2 cps., which is probably the natural frequency of the car body on the springs.

The lateral accelerations and unbalanced .elevations are plotted with reference to the Ride Index previously mentioned in Figs. 3 and 4, respectively.

The Ride Index is an arbitrary numerical representation of ride quality that was first devised for the vibratory conditions found in the before mentioned wheel balance tests. The value 1.0 is a threshold of the perceptible sensation; 2.0, of the strongly noticeable; 3.0, of the uncomfortable. Of course, the degree of sensation is not the sort of thing that can be defined with a high degree of accuracy, but this method makes it feasible to weight the various opinions of the observers and then plot the weighted value. The method of weighting was to consider, for example, that the middle of the perceptible region was at a value of 1.5, and if there were 8 people who had this opinion the product of the two was 12.0. Other opinions were multiplied by the proper value and the average obtained and used as the Ride Index for that curve. It may be seen that there is some scatter in the plottings, but even so there is a definite trend which is represented approximately by the solid lines drawn through the plotted points. Variations in opinions are to be expected due to differences in physiological and psychological makeup and previous experience of the individual.

The curve representing the trend of the plotted points in Fig. 4 has been added on Fig. 3 as a dashed curve to facilitate comparison of the measured lateral accelerations and the calculated unbalanced elevation. It is apparent that there is an important difference between these two curves. One way of describing the difference is to state that acceleration equivalent to the calculated unbalanced elevation does not accurately describe the acceleration given the accelerometer (or passenger). Another way of looking at the difference is that the acceleration required for a given ride sensation is larger than would be indicated by the calculated unbalanced elevation. The greater scatter of the points in Fig. 4 for the calculated unbalance also suggests that the agreement of that calculation with passenger reaction is not as consistent as with the measured accelerations.

The cause of the above difference was stated in Art. 3. Relevant Analytical Discussion in regard to the effect of tilting of the car body on the springs as a result of the unbalanced centrifugal force. If the car body tilts outward of the curve on the springs, the effectiveness of the elevation in counteracting the outward centrifugal force will be decreased and the accelerometer (or passenger) will be subjected to a greater acceleration than would be indicated by consideration of only the elevation, curvature and speed.

It is seen from the above discussion that the action of the equipment is an important factor in the lateral accelerations, and characteristics of the various types of equipment such as springing, swing hangers, and snubbing must be considered.

Reference to Fig. 3 indicates that the threshold of the perceptible region is at about 0.05 *g*. This acceleration is much higher than given for the same condition in the purely vibratory case discussed under the wheel balance tests. There the threshold of the perceptible (there called "Easily Perceptible") was as low as 0.003 *g* acceleration though there was a wide variation with frequency and the value for 1 cps. was 0.023 *g*. The body is apparently less sensible to a slowly changing acceleration than to a rapidly changing acceleration.

A survey of the passenger reactions and other data given in Table 1 indicates that in general this test had mostly a moderate ride condition. There are few cases where the ride was classed as uncomfortable or where the unbalanced elevation exceeded 3 in., so there is a paucity of points in the upper regions of the curves of Figs. 3 and 4. It is

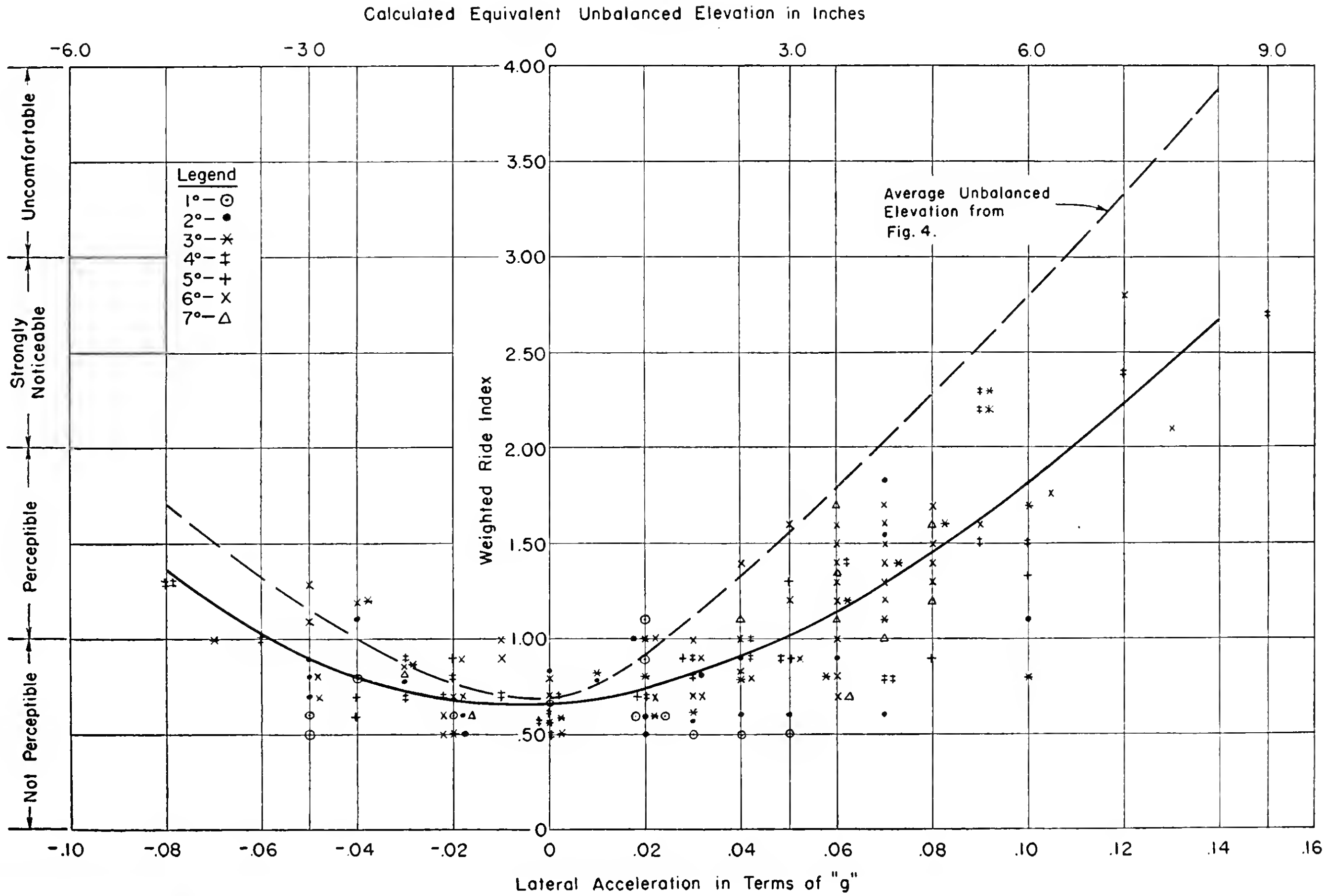


Fig. 3. Relation of weighted ride index to lateral acceleration of car body.

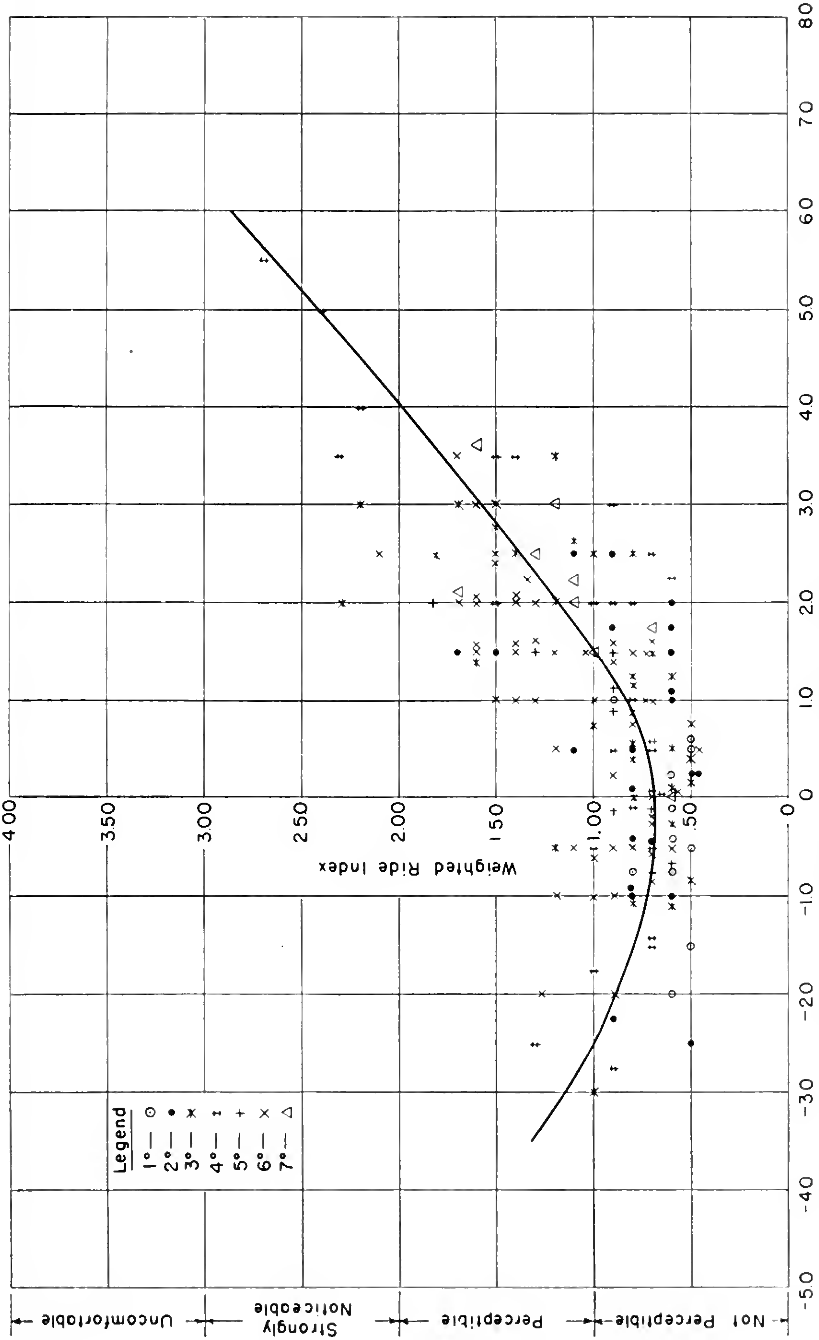


Fig. 4. Relation of weighted ride index to calculated unbalanced elevation.

highly desirable that conditions of greater unbalance should be obtained to determine whether the speeds are being unduly restricted from the standpoint of comfort.

6. Conclusions and Recommendations

It is believed that the test here reported is one of the first in this range of acceleration and frequency. Though the data is far from extensive, it shows good correlation. Several conclusions and recommendations may be stated from these tests and analyses.

1. The 3-in. unbalanced elevation with the type of car used in the tests gave an agreeable ride of moderate acceleration, and it appears further investigation might determine that this could be increased to perhaps 4 or 4½ in. without undue discomfort.

2. The tests have demonstrated that the amount of tilting of the car body on the springs is a very important factor because it reduces the effectiveness of the elevation and increases the acceleration on the passenger. With the type car used in the tests this increase amounted to 80 percent.

3. For this reason the unbalanced elevation is not a very accurate criterion of the ride quality. This is further evidenced by the wide vertical scatter of the points in Fig. 4.

4. The correlation between ride quality and lateral acceleration of the car body indicates that the acceleration is a reliable criterion of ride quality.

5. A given amount of lateral acceleration due to unbalanced elevation produces less passenger discomfort than the same amount of acceleration of a vibratory nature.

6. Other factors also affect the acceleration and ride quality on curves. The most important of these are probably uniformity of the curvature, surface, elevation, length of spiral, and action of the car trucks.

7. There was no indication that the degree of curvature had any effect on the relation of unbalanced elevation or lateral acceleration to ride quality.

8. No consideration has been given in this study to the safe speed on curves because experience and calculations show that the safe speed on curves is considerably greater than the comfortable speed.

9. A further series of passenger observer tests, especially including higher amounts of unbalanced elevation, should be made to more adequately establish the Ride Index relation between lateral acceleration and passenger comfort. This would then provide a basis for evaluating measurements of lateral accelerations on various types of equipment operating over various degrees of curvature through a range of speeds. From these data is is believed that a satisfactory method may be established for determining speed restriction on curves.

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Report of Special Committee on Continuous Welded Rail

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Committee

To the American Railway Engineering Association:

This is a new committee organized on the recommendation of the Board of Direction, under the guidance of the chairmen of the Committees on Economics of Railway Labor, Rail and Track at a meeting held on May 17, 1950. Authorized by the Board on August 4, 1950, the new committee is composed of approximately equal representation from each of these three committees.

The committee's overall assignment is defined specifically as follows:

> That the subject of continuous welded rail be studied and investigated in the broadest and most comprehensive manner possible at the present time, from the processing of the rail and welds in fabrication to final disposition of the rail as scrap, and that this cradle-to-grave treatment should, so far as is practicable, reflect the most desirable processes and practices of welding, and best methods of transporting, laying and relaying; also develop information on failures, repair, auxiliary or supplemental operations and practices necessary or desirable with this type of track construction, and include a comprehensive study of its economic worth

At the first meeting of the new committee, on November 2, 1950, plans and methods for carrying out the committee work were discussed and the following study assignments were set up and subsequently approved by the Board Committee on Outline of Work.

Your committee reports on the following assignments:

1. Fabrication—encompassing such matters as methods of welding, space and facilities required; organization, procedure and costs from the unloading of rails for welding, to and including loading of the strings of welded rail into cars.

2. Laying—encompassing necessary preparation of track, transportation to site and distribution of long rails, installation in track, temperature considerations, closure welds, disposition of rail when continuous welded rail is replaced by continuous welded rail, length limitations; procedure at insulated joints, switches, railroad crossings, and draw-bridges; cost data.

3. Fastenings—encompassing rail expansion, types and number of anti-creeping devices required throughout the length of welded sections and adjacent jointed track, type of joint bar at ends of welded sections, tie plate and spike requirements; cost data.

4. Maintenance—of rail, track fastenings, ties and ballast; out-of-face resurfacing and reballasting; repair or rail renewal; cost data.

5. Economics—of continuous welded rail versus jointed track.

Your committee presents the following bibliography on continuous welded rail for use by the committee and others who are interested. This is to bring up to date (October 1950) the bibliography prepared by R. E. Cramer to March 1939 and published in AREA Proceedings, Vol. 40, 1939, pages 711–713.

THE SPECIAL COMMITTEE ON CONTINUOUS WELDED RAIL,
H. B. CHRISTIANSON, *Chairman.*

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Report of Committee 4—Rail

RAY MCBRIAN, *Chairman,*
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H. F. WHITMORE
BARTON WHEELWRIGHT
R. P. WINTON
J. E. YEWELL
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions .... page 596

2. Conditions affecting service life of rail, causes of rail failures and defects, in collaboration with AISI Technical Committee on Rail and Joint Bars.
   Progress report, presenting 1951 report on the rails investigation, Appendix 2–a .... page 605

3. Rail failure statistics, covering (a) all failures; (b) transverse fissures; (c) performance of control cooled rail.
   Progress report on entire assignment presented as information .... page 617

4. Rail end batter; causes and remedies.
   Progress report, presented as information .... page 629

5. Economic value of various sizes of rail.
   Progress report, presented as information .... page 633

6. Continuous welded rail, collaborating with Committees 5 and 22.
   No report (Special Committee authorized by Board of Direction to make study of this subject)

7. Service tests of various types of joint bars.
   Progress report, presented as information .... page 634

8. Joint bar wear and failures; revision of design and specification for new bars and bars for maintenance repairs.
   Ninth progress report of the rolling-load tests of joint bars, presented as information, Appendix 8–a .... page 647
   Service tests of joint bars on the Burlington of different metallurgics, presented as information, Appendix 8–b .... page 659

AREA Bulletin 493, February 1951.

THE COMMITTEE ON RAIL,
RAY MCBRIAN, *Chairman.*

Report on Assignment 1

Revision of Manual

C. J. Code (chairman, subcommittee), C. H. Blackman, W. J. Burton, R. A. Emerson, J. L. Gressitt, R. L. Groover, G. F. Hand, E. M. Hastings, C. C. Lathey, Ray McBrian, L. T. Nuckols, E. E. Oviatt, R. E. Patterson, E. F. Salisbury, A. A. Shillander, G. L. Smith, H. F. Whitmore, Barton Wheelwright.

As a result of conferences with representatives of the steel manufacturers continuing over the past three years, certain revisions in the Specifications for Open-Hearth Steel Rails, Manual pages 4–1 to 4–6, have been agreed upon, and are recommended for adoption.

The articles affected are given below in their proposed form.

The change in Art. 201 separates chemical analysis of rails 70 to 90 lb. per yard into two groups, 70 to 80 and 81 to 90, assigning a lower carbon range to the rails 70 to 80 lb.

Change in Art. 203 authorizes use of average analysis from three ingots, conforming with present mill practice.

Change in Art. 405 places the entire $\frac{1}{16}$-in. tolerance in bolt size on the plus side, eliminating bolt holes less than standard size.

Paragraph (d) is added to Art. 407 to permit stamping CC instead of branding on rails 100 lb. per yd. and lighter, except 100 RE.

The change in Art. 408 fixes more exactly the position of the thermocouple at the end of a rail in the middle tier.

'SPECIFICATIONS FOR OPEN-HEARTH STEEL RAILS

201. Chemical Composition

The chemical composition of the steel, determined as prescribed hereafter, shall be within the following limits:

Constituents	*Nominal Weight in Lb. per Yd.*			
Percent	70–80	81–90	91–120	121 and over
Carbon	0.55–0.68	0.64–0.77	0.67–0.80	0.69–0.82
Manganese	0.60–0.90	0.60–0.90	0.70–1.00	0.70–1.00
Phosphorus, max.	0.04	0.04	0.04	0.04
Silicon	0.10–0.23	0.10–0.23	0.10–0.23	0.10–0.23

203. Analyses

Separate analyses shall be made from drillings taken from ladle test ingots representing one of the first three and one of the last three applied full ingots of the heat to determine the percentage of carbon, manganese, phosphorus, sulfur, and silicon. The average analysis of the ladle test ingots shall conform to the chemical requirements. A portion of the drillings shall be furnished to the inspector upon request for check analysis.

405. Drilling

Circular holes for joint bolts shall be drilled to conform to the drawings and dimensions furnished by the purchaser. A variation of nothing under and $\frac{1}{16}$ in. over in the size of the bolt holes will be permitted. A variation of $\frac{1}{32}$ in. in the location of the holes will be permitted.

407. Branding

To be added:

(d) Control cooled rails of sections heavier than 100 lb. nominal weight per yd. shall be identified by the letters CC contained in the brand. Control-cooled rails of sections 100 lb. nominal weight per yd. and lighter (except rail section 100 RE) may be identified either by the letters CC in the brand or hot stamped in the web of the rail.

408. Control Cooling

(f) The container shall be so protected and insulated that the control temperature shall not drop below 300 deg. F. in 7 hours for rails 100 lb. per yd. in weight or heavier, from the time that the bottom tier is placed in the container, and 5 hours for rails of less than 100 lb. per yd. in weight. If, for unavoidable mill conditions, this time temperature cycle is not met, the rails shall be considered control cooled, provided the temperature at a location not less than 12 in. from the end of a rail at approximately the center of the middle tier does not drop below 300 deg. F. in less than 15 hours.

Page 4–12

Beveling or Slotting of Rail Ends

1939

Submitted for reapproval, without change.

Pages 4–21 to 4–23, incl.

As a result of conference with steel manufacturers, and after thorough consideration and recommendation by Subcommittee 8, revision of Specification for Quenched Carbon Steel Joint Bars, Manual pages 4–21 to 4–23, is recommended for adoption. The changes in the specification in proposed form are given below.

Except for Art. 5 and 12, the changes are of a minor value. Art. 5 permits a higher manganese content in order to give the manufacturers greater leeway, while Art. 11, (formerly Art. 12), calls for a greater number of tests, which it is believed will give improved control over the quality of the finished product.

[1]SPECIFICATIONS FOR QUENCHED CARBON-STEEL JOINT BARS

1951

2. Process

The steel shall be made by either or both of the following processes: open-hearth or electric-furnace.

5. Chemical Composition

The steel shall conform to the following requirements as to chemical composition:

Carbon	0.35 percent to 0.60 percent
Manganese	Not over 1.00 percent
Phosphorus	Not over 0.04 percent

6. Ladle Analysis

An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, and sulfur. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser or his representative, and the percentages of carbon, manganese, and phosphorus shall conform to the requirements specified in Section 5.

7. Check Analysis

An analysis may be made by the purchaser from a finished joint bar representing each heat. The percentages of carbon and manganese thus determined shall conform to the requirements specified in Section 5, and the phosphorus content shall not exceed that specified by more than 25 percent.

8. Tensile Properties

(a) The material shall conform to the following requirements as to tensile properties:

Tensile strength, min., psi.	100,000
Yield point, min., psi.	70,000
Elongation in 2 in., min., percent	12
Reduction of area, min., percent	25

9. Bending Properties

(a) Bend Test.

The bend test specimen specified in Section 10 shall stand being bent cold through 90 deg. without cracking on the outside of the bent portion around a pin the diameter of which is equal to three times the thickness of the specimen.

(b) Optional Bend Test.

If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that described in paragraph (a): A piece of the finished bar shall stand being bent cold through 45 deg. without cracking on the outside of the bent portion around a pin the diameter of which is equal to three times the greatest thickness of the section.

10. Test Specimens

Tension and bend test specimens shall be taken from the middle of the head at the center of the finished joint bars. Tension test specimens shal be machined to the form and dimensions shown in Fig. 4. Bend test specimens may be ½ in. square in section or rectangular in section with two parallel faces as rolled and with corners rounded to a radius not over $\frac{1}{16}$ in.

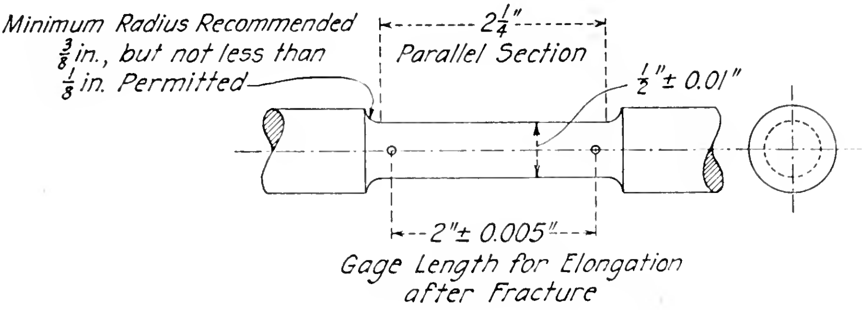

Fig. 4. Standard Round Tension Test Specimen with 2-in. Gage Length.

Note: The gage length, parallel section. and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial.

11. Number of Tests

(a) One tension test and one bend test shall be made from each lot of 1000 bars or fraction thereof, but not less than one test for each heat on each day on which bars are heated and quenched.

12. Retests

If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

13. Workmanship

The joint bars shall be smoothly rolled, true to template and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching and slotting shall conform to the dimensions specified by the purchaser. A variation of plus or minus $\frac{1}{32}$ in. from the specified size of holes, or plus or minus $\frac{1}{16}$ in. from the specified location of holes, and of plus or minus $\frac{1}{8}$ in. from the specified length of joint bar will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The camber in either plane shall not exceed $\frac{1}{32}$ in. in 24-in. bars and $\frac{1}{16}$ in. in 36-in. bars.

14. Finish

The material shall be free from injurious defects and shall have a workmanlike finish.

15. Marking and Stamping

The name or brand of the manufacturer, the section designation, and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars, and a portion of this marking shall appear on each finished joint bar. A serial number representing the heat shall be hot stamped on the outside of the web of each bar, near one end.

17. Rejection

(a) Unless otherwise specified, any rejection based on tests made in accordance with Section 7 shall be reported to the manufacturer within five working days from the receipt of samples by the purchaser.

(b) Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

18. Rehearing

Samples tested in accordance with Section 7 that represent rejected material shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

Pages 4–29 to 4–32, incl.

As a result of tests conducted by R. P. Winton, and studies by him and C. B. Bronson, incidental to the work of a committee of the American Standards Association, revision of Specification for Heat-treated Carbon-Steel and Alloy-Steel Track Bolts, is recommended for adoption. The changes in the specification as proposed are given below.

Editorial changes have been made throughout the specification. The term "medium carbon nuts" has been substituted for the term "high strength nuts."

In Art. 6, the two grades of carbon steel have been combined into one, having the superior physical properties generally of the Grade 2, except that the ductility requirements of the Grade 1 are retained, which are sufficient and give the manufacturers greater latitude.

Art. 9 has been revised to give more specific and more rigid strip test requirements.

Art. 13 has been revised to add a maximum tightness requirement for the bolts with free fit, and to emphasize the free fit as the prevailing type with the wrench turn fit as an alternative.

[1]SPECIFICATIONS FOR HEAT-TREATED CARBON-STEEL AND ALLOY-STEEL TRACK BOLTS

1. Scope

These specifications cover heat-treated carbon-steel, also alloy-steel track bolts.

Chemical Properties and Tests

3. Chemical Composition

(b) The steel for the nuts shall conform to the free-cutting grades of the Specifications for Hot-Rolled Carbon-Steel Bars, (ASTM Designation A 107), except that the minimum carbon percentage of the open-hearth grade shall be 0.15.

(c) When medium carbon nuts are specified, the steel for same shall conform to a carbon range of minimum 0.40 to maximum 0.55 percent.

4. Ladle Analysis

(b) An analysis of each heat of open-hearth or electric-furnace steel shall be made to determine the percentage of carbon, manganese, phosphorus, and sulfur; also any alloy element when used.

PHYSICAL REQUIREMENTS

6. Tension Tests

(a) Tension test specimens shall be taken from the finished bolts and shall conform to the following minimum requirements as to tensile properties:

	Carbon steel	*Alloy steel*
Ultimate tensile strength, psi.	110,000	115,000
Yield point, psi.	80,000	85,000
Elongation in 2 in., percent	12	15
Reduction of area, percent	25	40

9. Strip Test

The threads of the nut shall not "strip" or the bolt break when the bolt, with the nut fully mounted, is tested in tension to the following loads for the diameter and grade ordered:

		Nominal Strength Lb.	
Nominal dia. bolt in.	*Stress area* sq. in.*	*carbon steel 110,000 psi.*	*alloy steel 115,000 psi.*
3/4	0.3340	36,740	38,410
13/16	0.4011	44,120	46,130
7/8	0.4612	50,730	53,040
15/16	0.5395	59,340	62,040
1	0.6051	66,560	69,590
1 1/16	0.6942	76,360	79,830
1 1/8	0.7627	83,900	87,710
1 1/4	0.9684	106,520	111,370

* The stress area is the assumed area of a circle having a diameter equal to the average of the mean pitch and minor diameters with Class 3 tolerances shown on page 16, ASA B1.1—1949.

DESIGN AND TOLERANCE

11. Tolerance

The bolts and nuts shall conform to the plans specified by the purchaser, subject to the following variations:

(a) The nominal size of bolts shall be the over-all diameter of the threads.

MANUFACTURE

12. Finish

The bolts and nuts shall be neatly formed and free from fins or nicking. The head of the bolt shall be concentric with the shank, with the under side at right angles to the axis of the bolt. The bolts and nuts shall be free from injurious defects and shall have a workmanlike finish.

13. Threads and Thread Fit

The threads on bolts may be rolled or cut. The threads on bolts and nuts shall conform to the American National Form of Thread as shown in the American Standard Screw Threads ASA B 1.1—1949, or any later revision thereof. A free fit shall be furnished unless otherwise specified by the purchaser in accordance with the following provisions:

(a) Free fit.—The threads of the bolts and nuts shall conform as nearly as practicable to the American Standard limits for Coarse Thread Series Free Fit (Class 2) screws and nuts. The maximum tightness shall be 5 lb. pull applied to the end of a 24-in. wrench.

(b) Wrench turn fit.—The nut shall have a free fit for at least two threads in starting on the bolt and when fully engaged and for the remainder of the screw length shall show the following minimum and maximum resistance to turning as expressed by pounds pull applied to the end of a 24-in. wrench.

	Min. lb.	*Max. lb.*
Low carbon nuts (3b)	5	45
Medium carbon nuts (3c)	5	55

Before packing, nuts shall be screwed on the bolts enough turns to hold them in place until used.

MARKING AND INSPECTION

14. Marking

(a) A letter or brand indicating the manufacturer, together with the initial A if alloy bolts, shall be pressed on the head of the bolt when it is formed.

(b) All containers shall be marked by the manufacturer as follows:

1. Name of manufacturer.
2. Material (carbon or alloy).
3. Size of bolt (diameter and length).
4. Weight.

Pages 4–33 to 4–35 incl.

As a result of several years of painstaking study by a committee of the American Standards Association, in which Messrs. Bronson and Winton of the Rail committee took an active part, there have been presented revised tables of dimensions of track bolts which currently appear as Figs. 414 and 415 and Tables 401 and 402 on Manual pages 4–33 to 4–35, incl. A revision of Fig. 416 and of Table 403 had also been prepared;

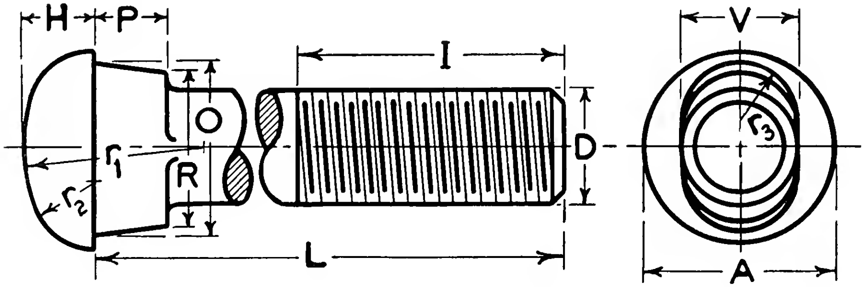

Fig. 1. Oval Neck Track Bolts.

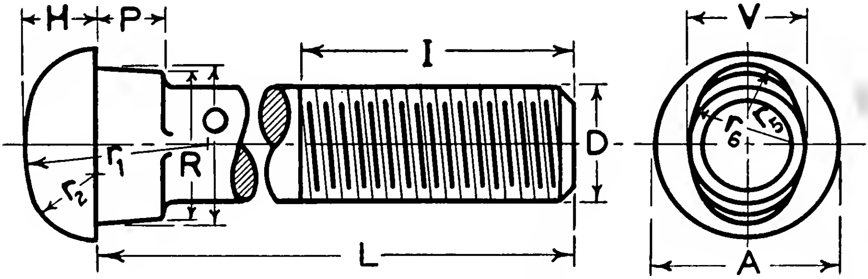

Fig. 2. Elliptic Neck Track Bolts.

TABLE 1. OVAL NECK TRACK BOLTS

D	A	H	r_1	r_2	O	R	P	r_2	V	L	I	
Nominal Dia. Over Thread *Notes 1 & 2*	*Head*				*Neck*					*Length Under Head*	*Min. Thread Length*	*Threads Per In.*
1/2	7/8	5/16	11/16	9/32	5/8	19/32	5/16	½ body diameter of bolt	Same as body diameter of bolt	Under 7 in. by steps of ¼ in	1 1/8	13
5/8	1 5/64	25/64	59/64	23/64	13/16	25/32	3/8				1 1/4	11
3/4	1 9/32	15/32	1 5/32	7/16	1 1/16	1 1/32	7/16				1 3/4	10
7/8	1 31/64	35/64	1 25/64	33/64	1 7/32	1 3/16	1/2				2	9
1	1 11/16	5/8	1 5/8	19/32	1 3/8	1 11/32	9/16			From 7 to 10 in. by steps of ½ in.	2 1/4	8
1 1/8	1 57/64	45/64	1 55/64	43/64	1 17/32	1 1/2	5/8				2 1/2	7
1 1/4	2 3/32	25/32	2 3/32	3/4	1 11/16	1 21/32	11/16				2 1/2	7
Additional Sizes Now in Use But Not Recommended For New Design												
13/16	1 9/32	15/32	1 5/32	7/16	1 1/16	1 1/32	7/16	Same as above	Same as above	Same as above	1 7/8	10
15/16	1 31/64	35/64	1 25/64	33/64	1 7/32	1 3/16	1/2				2 1/8	9
1 1/16	1 11/16	5/8	1 5/8	19/32	1 3/8	1 11/32	9/16				2 3/8	8

All dimensions given in inches.
Tolerances: Length (L) plus or minus 1/8 in.
Neck (O and R) plus or minus 1/32 in.
Head (A and H) plus or minus 1/16 in.

Screw Threads: The screw threads on track bolts shall conform to the American Standard Coarse thread series with fit as specified. They may be formed by cutting or rolling.

Note. In ordering bolts specify the nominal diameter "D", over the threads and not the body diameter.

TABLE 2. ELLIPTIC NECK TRACK BOLTS

D	*A*	*H*	r_1	r_2	*O*	*R*	*P*	r_5	r_6	*V*	*L*	*I*	*Threads Per In.*
Nominal Dia. Over Thread	*Head*				*Neck*						*Length Under Head*	*Min. Thread Length*	
3/4	1 9/32	15/32	1 5/32	7/16	63/64	61/64	7/16	9/32	41/64	Same as body dia. of bolt	Under 7 in. by steps of ¼ in. From 7 to 10 in. by steps of ½ in.	1 3/4	10
7/8	1 31/64	35/64	1 25/64	33/64	1 3/16	1 5/32	1/2	1/2	51/64			2	9
1	1 11/16	5/8	1 5/8	19/32	1 3/8	1 11/32	9/16	3/8	15/16			2 1/4	8
1 1/8	1 57/64	45/64	1 55/64	43/64	1 1/2	1 15/32	5/8	7/16	1			2 1/2	7
1 1/4	2 3/32	25/32	2 3/32	3/4	1 5/8	1 19/32	11/16	1/2	1 1/16			2 1/2	7

Additional Sizes Now in Use But Not Recommended For New Design

13/16	1 25/64	33/64	1 9/32	31/64	1 1/8	1 3/32	15/32	19/64	25/32	Same as above	Same as above	1 3/4	10
15/16	1 19/32	19/32	1 33/64	9/16	1 7/32	1 3/16	17/32	23/64	27/32			2	9
1 1/16	1 51/64	43/64	1 3/4	41/64	1 7/16	1 13/32	19/32	25/64	31/32			2 1/4	8

All dimensions are given in inches.
Tolerances: Length (L) plus or minus 1/8 in.
Neck (O and R) plus or minus 1/32 in.
Head (A and H) plus or minus 1/16 in.

Screw Threads: The screw threads on track bolts shall conform to the American Standard coarse thread series with fit as specified. They may be formed by cutting or rolling.

Note. In ordering bolts specify the nominal diameter "D", over the threads and not the body diameter.

however, this revision failed to obtain the required two-thirds affirmative vote of the Rail committee when submitted to letter ballot, and is, therefore, not included in the recommendations for adoption.

Figs. 1 and 2, as well as Tables 1 and 2, presented herewith, are offered for inclusion in the Manual, replacing the tables and figures currently appearing on Manual pages 4–33 to 4–35 incl., excepting Fig. 416. Track Bolt Nuts on page 4–35, which will be given further study by the committee.

Report on Assignment 2

Conditions Affecting Service Life of Rail, Causes of Rail Failures and Other Defects

In Collaboration with AISI Technical Committee on Rail and Joint Bars

Ray McBrian (chairman, subcommittee), C. B. Bronson, E. E. Chapman, H. R. Clarke, C. J. Code, L. S. Crane, J. L. Gressitt, L. T. Nuckols, W. C. Perkins, R. P. Winton.

A progress report on the Rails Investigation, comprising a cooperative project conducted at the Engineering Experiment Station of the University of Illinois, at the joint expense of 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

By R. E. Cramer

Special Research Associate Professor of Engineering Materials, University of Illinois

Organization and Acknowledgment

This investigation is financed equally by the Association of American Railroads and the American Iron and Steel Institute.

Student assistants, D. R. Yeager and Daniel Kennedy have worked for this investigation on a part-time basis during the past year.

Examination of Control-Cooled Rails Which Failed in Service

Twenty-three failed control-cooled rails were sent to the laboratory by the engineers of 16 railroads. Reports were prepared on each rail for these engineers, the rail manufacturers, and the rail engineer of the AAR.

Table 1 gives a summary of these failures and Table 2 lists each rail separately.

Table 1.—Summary of Rail Failures

Transverse fissures from shatter cracks	3
Transverse fissures from hot torn steel	8
Detail fractures from shelling	7
Detail fracture from head check	1
Web crack from spike maul blow	1
Base break from welded electric bond	1
Web crack possibly from seam	1
Lap on rail tread	1

The transverse fissures from shatter cracks were from two mills which had not previously had such failures in their control-cooled rails. As shown in Table 2, the Ensley failure was in a rail rolled in March 1936, only one month after the beginning of control cooling at this mill and before a temperature recorder was in use on the control-cooling container in which this raii was cooled.

Report of Trip to Algoma Steel Mill

The other two transverse fissures from shatter cracks were in rails rolled at the Algoma mill in February 1939 and January 1946, both winter months. In order to investigate the probable cause of these two rails developing transverse fissures from shatter cracks, the following observations were made at the Algoma mill.

The cooling containers were in good shape and appeared to be tight at the bottom, but no insulation on the walls was used as has been added at some United States mills. However, the lids were of light construction and the ends were bent up in some cases, leaving an air space between the lids and containers of two to three inches. Experience at some mills, when cooling curves were made, has shown that the top rails in a container cool very rapidly when the lid does not fit properly and the containers are subjected to strong air currents. Because of these findings, it has been recommended that there be a good seal between the lids and containers, and some mills have even insulated the lids for better control cooling. It was also observed that the thermocouples are not placed between the outside two rails in the bottom tier in the containers, as is the recommended practice. However, it is thought the poorly fitting lids on containers subjected to strong air currents would be the most likely cause of shatter cracks developing in the top rails in the cooling containers.

It was also found at the Algoma mill that some purchasers of rail are adding requirements not contained in the recommended practice for control cooling adopted by the Joint AREA and AISI rail committees. It was probably thought that added safety was obtained by the requirement that the lids stay on the containers until the rails have cooled to 250 deg. F. This requirement prevents the mills from insulating the fastest cooling parts of the containers and discourages tight fitting lids. Research has proved, as published in the AREA Proceedings, that seven hours of holding the rails at a reasonably high temperature will allow the hydrogen, which forms the internal shatter cracks, to escape, so that drastic cooling after that time, as quenching in ice water, cannot produce shatter cracks. It is much easier for the hydrogen to escape from the steel in the range of 900 to 500 deg. F., so it is very desirable to set up conditions to hold the rails even for a shorter time near this range. It was for this reason that the insulating of certain portions of exposed containers was recommended, and that after ten hours, if desired by the mill, the lids could be removed in order not to hold up mill production.

The Algoma mill had found it necessary to leave some space between the containers and the lids in order to meet the purchasers' requirements that the rails not be removed

TABLE 2. FAILED CONTROL-COOLED RAILS EXAMINED BETWEEN OCTOBER 1, 1949, AND OCTOBER 1, 1950

D.F. = detailed fracture; T.F. = transverse fissure

Source of failed rail	*Laboratory failed rail No.*	*Size of rail*	*Mill*	*Heat No. rail letter and ingot*	*Date rolled*	*Classification of failure*
C.N.	621	85	Dominion	7082–F–4	4–1937	D.F. from shelling
R. F. & P.	622	140	Steelton	87552–B–1	11–1948	T.F. from hot torn steel
C. & O.	623	132	Steelton	83393–E–15	6–1949	Laps on rail tread
C.M.St.P. & P.	624	131	Inland	15346–E–11	1944	T.F. from hot torn steel
Algoma Central	625	85	Algoma	2514–B–3	----	Spike maul blow on web
A.T. & S.F.	626	112	Steelton	87029–B–15	1–1937	T.F. from hot torn steel
B. & O.	627	131	Steelton	83563–D–9	11–1946	T.F. from hot torn steel
S. P.	628	113	Colorado	4510–G–11	1942	D.F. from shelling
S. P.	629	112	Steelton	82260–D–5	12–1936	D.F. from shelling
C. P.	634	100	Algoma	21466–B–13	1–1946	T.F. from shatter crack
C. P.	635	100	Algoma	5378–C–8	2–1939	T.F. from shatter crack
S. P.	636	112	Ensley	878579–B–20	3–1936	T.F. from shatter crack
A. C. L.	637	131	----	----	1948	Base break from welded bond
S. P.	638	112	Steelton	87513–B–11	1936	T.F. from hot torn steel
B. & O.	639	131	E. Thomson	210512–A–20	11–1941	D.F. from shelling
B. & M.	640	112	Lackawanna	6289–C–19	6–1945	D.F. from shelling
S. P.	641	112	Steelton	81063–C–13	11–1939	T.F. from hot torn steel
F. E. C.	642	115	Ensley	819088–A–5	12–1949	Web crack at seam
D. & H.	645	112	Steelton	83209–C–5	1940	D.F. from shelling
S. P.	646	112	Colorado	16556–E–8	2–1937	D.F. from shelling
S. P.	647	112	Steelton	88220–D–7	5–1938	T.F. from hot torn steel
N.Y.C. & St. L.	648	110	E. Thomson	06H156–F–6	4–1949	D.F. from head check
N.Y. N.H. & H.	649	131	Steelton	83469–B–1	9–1943	T.F. from hot torn steel

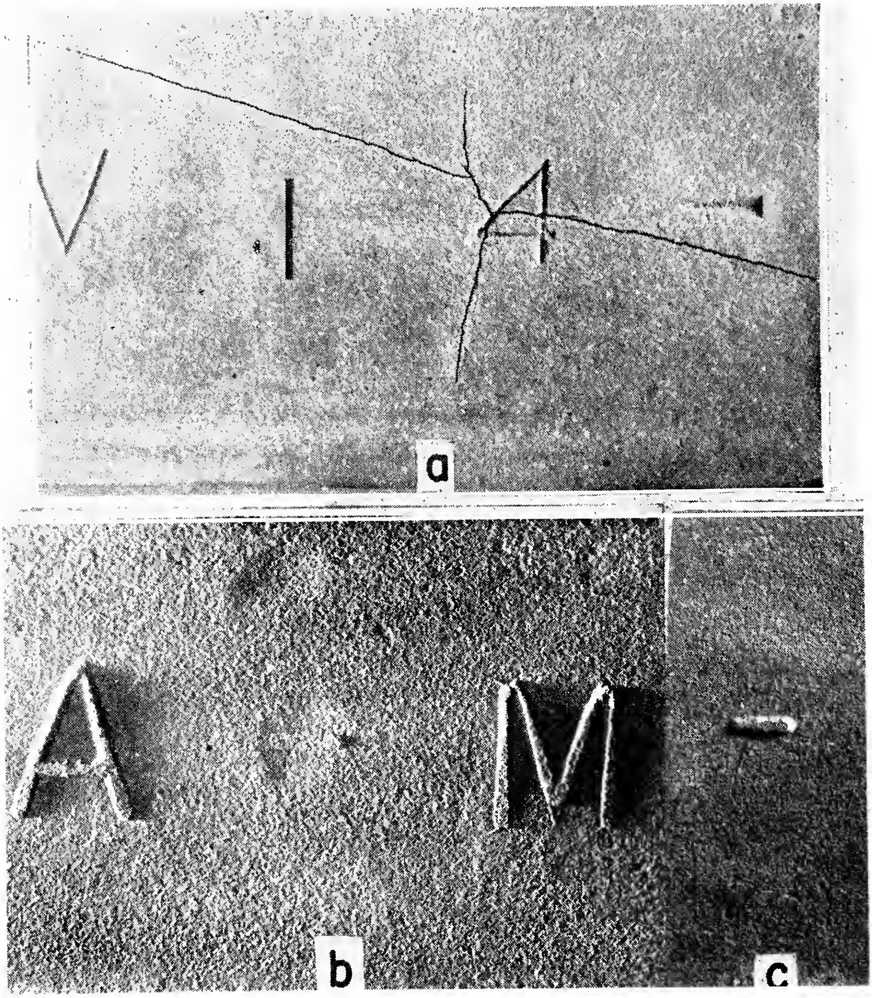

Fig. 1. Web fractured with spike maul.

(a) Web cracks starting at stamped number.
(b) Spike maul marks opposite crack in (a).
(c) Raised dash, similar to where spike maul struck in (b).

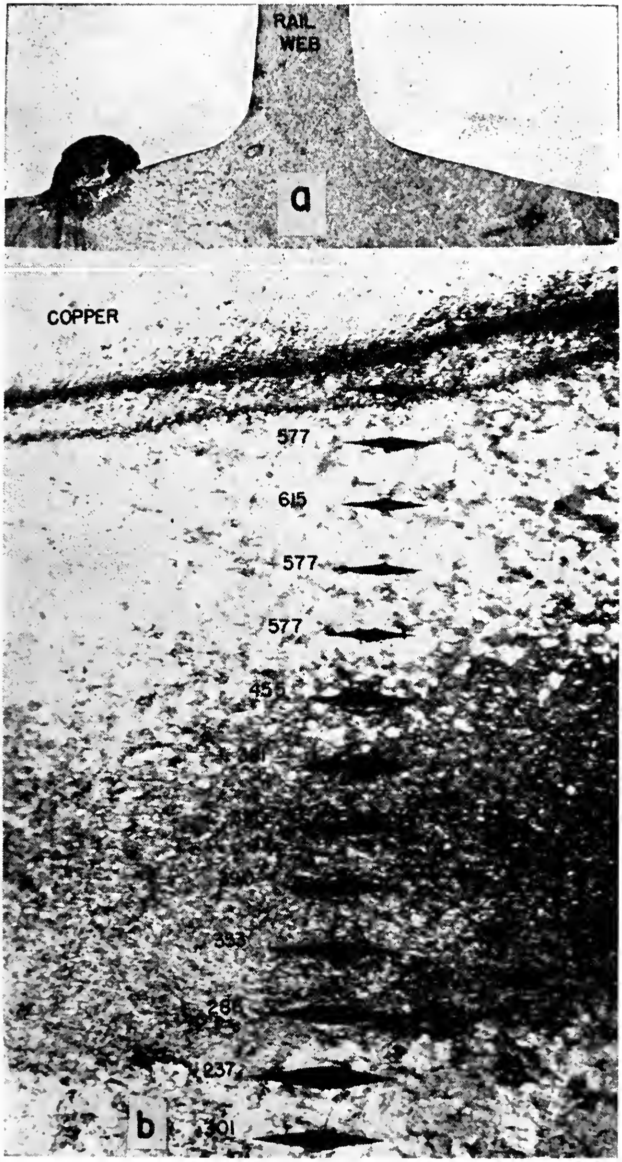

Fig. 2. Bond weld on rail base caused rail failure.

(a) Fractured rail base showing welded bond. Note fatigue area below copper bond.

(b) Photomicrograph adjacent copper bond. Magnification 75X. Etched in 2-percent nital.

White grains are martensite. Diamond marks indicate hardness. Numbers are standard Brinell hardness.

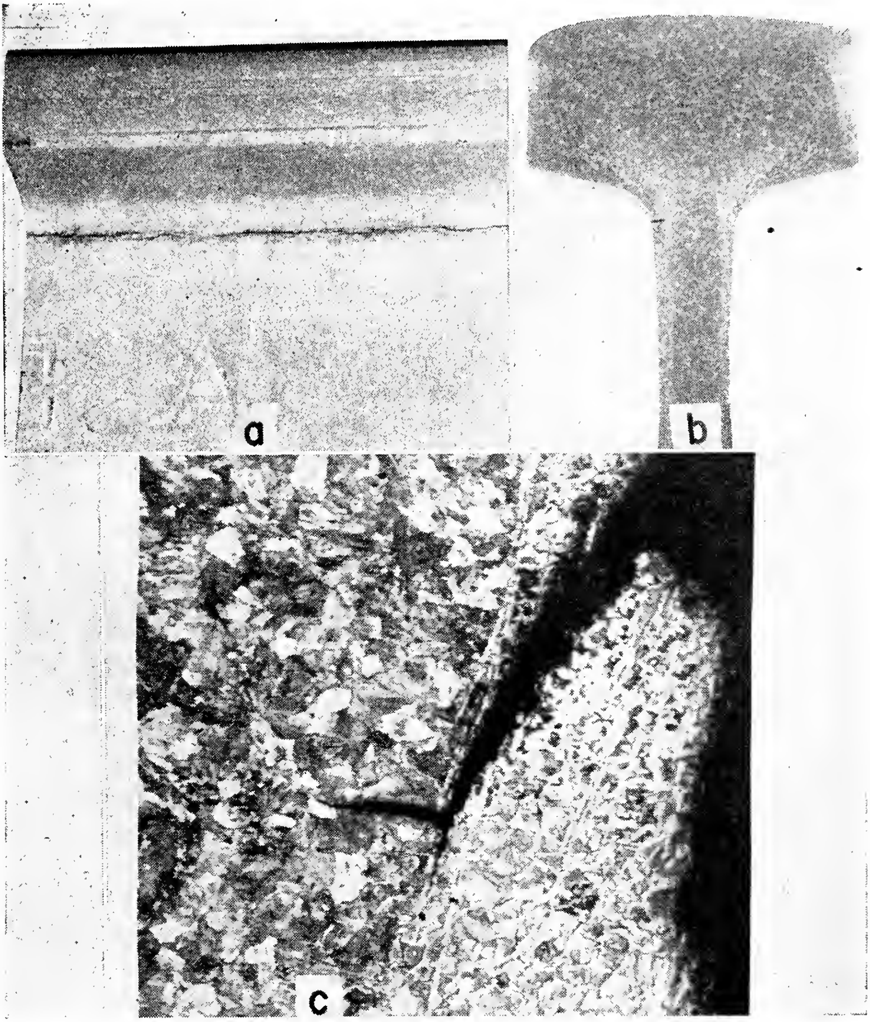

Fig. 3. Fillet cracks in Wabash 110-lb. rails.

(a) Side View. Specimen etched in hot hydrochloric acid.
(b) Cross section. Specimen etched in hot hydrochloric acid.
(c) Photomicrograph. Magnification 70X. Specimen etched in 2-percent nital.

from the containers until they had cooled to 250 deg. F. with the lids in place. It is likely that some changes will be made in the control-cooling practice at the Algoma mill in the near future.

Transverse Fissures from Hot Torn Steel

The transverse fissures from hot torn steel occurred in one rail rolled in each of the following years: 1936, 1937, 1938, 1939, 1943, 1944, 1946, and 1948. This shows that hot tearing of the steel has not been completely stopped in recent rail rollings. However, the total number of hot torn rails found in the past two years has dropped to about one-third of the number found three or four years ago, and are a very small number in more than a million railis produced each year.

Web Failure from Spike Maul Blows

Fig. 1a shows the web fracture caused at a stamped number. Fig. 1b shows two spike maul marks on the opposite side of the rail web. The lower mark hit on a raised dash like the one shown in Fig. 1c. This dash was directly opposite the stamped Fig. 4 where the web crack started.

Base Failure from Welded Electric Bond

Fig. 2a shows the fracture of a rail starting at a Cadwell-type bond on the left side of the rail base. A small dark fatigue area developed directly under the bond in the rail base; then the rail fractured suddenly, under traffic. A photomicrograph at 75× mag. is shown in Fig. 2b, with Tukon hardness impressions in the steel from directly under the copper bond down through the area in the rail steel that was hardened when the bond was melted onto the rail. The hardness readings converted to standard Brinell hardness numbers are also shown. In the white area adjacent to the copper, which is a Martensite structure, several Brinell readings were 577 to 615. This hard brittle steel cannot withstand the bending to which all rail bases are subjected, thus producing the failure. Another similar rail failure from a Cadwell "bootleg" bond on a rail base has been reported by W. D. Simpson of the Seaboard Air Line Railroad. It seems inadvisable to make any type of welded bonds on the bases of railroad rails.

Failure of Rails with Fillet Cracks

Four rail specimens representing many failures in 14 miles of 110-lb. rail rolled in 1930 were supplied by the engineers of the Wabash Railroad. Fig. 3 shows typical pictures of these failures in their early stages of development. Fig. 3a shows that the cracks along the head and web fillet are not continuous but a series of short cracks. Fig. 3b is an etched cross section, showing that the crack has penetrated only about ⅛ in. Fig. 3c is an etched micrograph at 70× magnification, which is typical of many cracks examined. All the micro specimens showed that the cracks were starting at decarburized seams or laps in a narrow area of the fillet, as indicated by the white ferrite grains in the micro. No cracks were found in areas where the decarburization was shallow or normal for rail steel.

The R. W. Hunt Company furnished the survey of the failures in 2 of the 14 miles of failures made by the division engineer and shown in Table 3.

The R. W. Hunt Company reports: "All of the failures occurred on the brand side of the rails, regardless of whether the brand side was laid to the field or to the gage. It has never been the practice for the Wabash to pay any attention to whether the brand was on the field or gage side. Rails from another steel mill were laid at the same time in this same section of track and are not developing any fillet cracks."

TABLE 3. FILLET CRACKS IN TWO MILES OF RAIL

Analysis of Failures Between Mile Post 121 and 122

North or south rail	*No. of rails*	*No. cracked*	*No. O.K.*	*No. O.K. with brand on gage side*	*No. O.K. with brand on field side*	*No. cracked with brand on gage side*	*No. cracked with brand on field side*
South	137	56	81	36	45	54	2
North	137	24	113	8	105	1	23
Failures Between Mile Post 122 and 123							
South	139	51	88	72	16	51	0
North	140	18	122	8	114	0	18
Totals	553	149	404	124	280	106	43

This information on this large group of fillet crack failures indicates that some unusual condition of the rolls in the rail mill caused more than the usual amount of decarburized metal to be located in the head and web fillet. The same condition also produced seams or laps in the fillet of these rails on the brand side, which resulted in service failures.

Report on Assignment 3

Rail Failure Statistics

Ray McBrian (chairman, subcommittee), C. B. Bronson, C. J. Code, G. F. Hand, J. G. Roney, A. A. Shillander.

These statistics present the rail failures reported to December 31, 1949 and are submitted as information. They include the failures reported in practically all of the main line railway mileage in the United States and Canada. They were prepared by Kurt Kannowski, rail engineer of the AAR Engineering Division Research Staff, under the general direction of G. M. Magee, research engineer.

Transverse Fissure Failures

As in previous years Table 1 has been continued to show the number of service transverse fissures and detected transverse defects in the main line trackage in 61 railroads for the years 1939 to 1949, inclusive. The total service and detected failures for these same roads are also shown in Fig. 1 for each year from 1919 to 1949, inclusive. The considerable increase in the number of detected transverse defects has resulted in a lowering in the number of service transverse fissures after 1943. However, there are still a considerable number of transverse fissures occurring in service which are not picked up by detector cars due either to lack of adequate detection by the car or to lack of testing or insufficient frequency of testing.

The increase in number of detected transverse defects in 1947 appeared inconsistent with expectations from the continually increasing mileage of control-cooled rail being placed in service. Beginning January 1, 1947 many roads began classifying as "transverse defects" all detected failures having transverse components, such as transverse fissures,

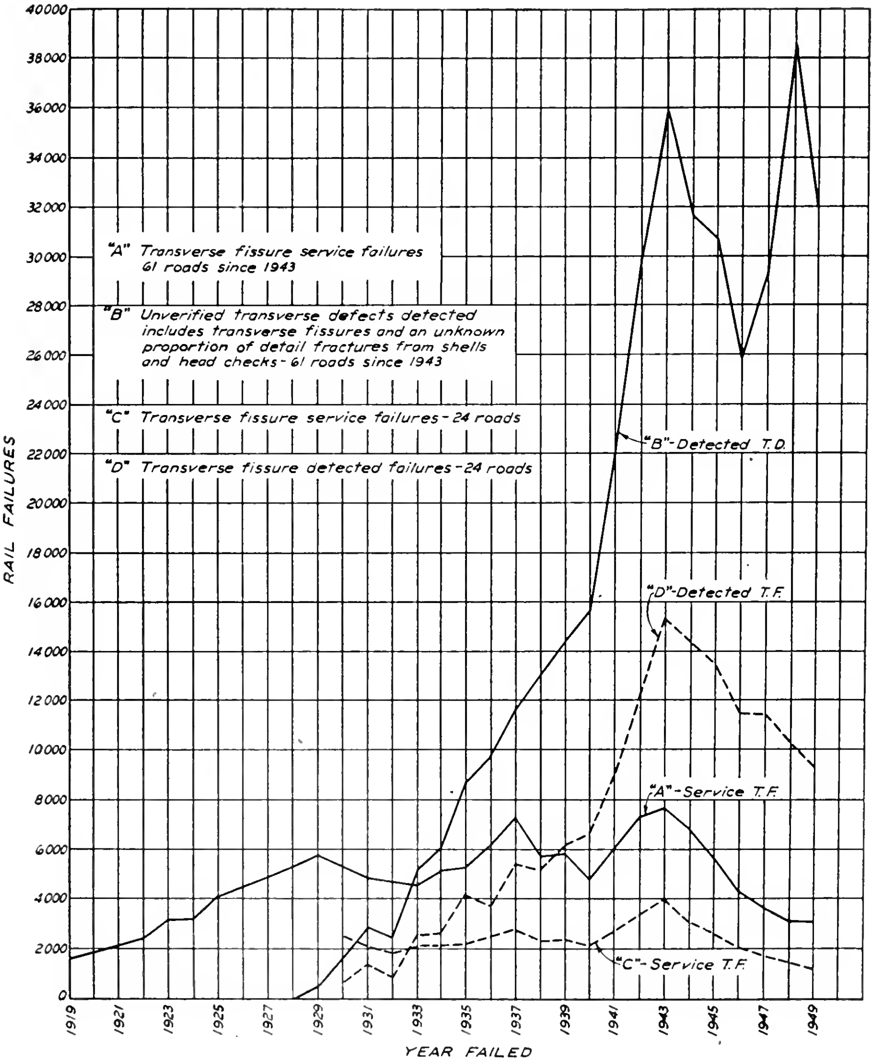

Fig. 1. Annual service rail failures due to transverse fissures and to detected transverse defects as reported by all roads.

TABLE 1. SERVICE FAILURES FROM TRANSVERSE FISSURES AND DETECTED FAILURES FROM TRANSVERSE DEFECTS, BY RAILROADS AND BY YEAR FAILED—ALL ROLLINGS BY ALL PROCESSES

	Service Failures											Detected Failures										
Year Failed	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	Total	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	Total
AT&SF	111	140	341	455	307	141	157	112	92	103	1959	377	275	566	831	647	538	580	388	1358	1449	7009
ACL	114	121	250	218	267	50	51	43	14	7	1135	118	288	809	1220	870	1302	924	1120	1491	919	9061
Ban. & Aroos.	0	0	3	3	4	3	1	2	0	0	16	0	0	0	0	0	0	49	0	26	16	91
B&OCT	-----	-----	-----	-----	2	0	0	12	9	5	28	-----	-----	-----	-----	0	0	0	0	2	15	17
B&LE	-----	-----	-----	-----	10	6	9	3	5	3	36	-----	-----	-----	-----	0	0	0	0	0	0	0
B&M	11	20	20	42	64	17	11	26	31	16	258	927	785	661	884	276	695	315	212	379	300	5434
B&O	341	459	588	425	367	332	205	209	177	100	3203	609	797	1421	1269	780	844	978	801	713	780	8992
CP	225	501	425	381	238	274	214	184	181	131	2754	2011	3813	5201	5964	5064	4957	3105	4338	3546	3787	41786
C. of Ga.	77	109	62	77	61	58	31	40	31	18	564	130	248	223	407	179	157	184	0	426	275	2229
C. of N. J.	87	81	77	77	71	48	45	61	65	-----	612	0	0	0	0	0	0	3	0	0	-----	3
C&EI	15	23	31	48	51	62	57	42	33	41	403	96	120	138	271	352	304	338	316	317	320	2572
C&O—Ches. Dist.	93	100	123	107	71	57	68	88	64	37	808	533	539	417	540	393	458	465	559	1108	845	5857
C&O—PM Dist.	2	0	9	15	4	1	1	0	0	0	32	20	14	111	124	87	27	23	0	11	5	422
C&NW	62	78	162	168	160	135	137	168	149	118	1337	631	820	1463	1495	1578	1641	1176	1461	976	1159	12400
CB&Q	161	199	272	323	287	244	141	152	144	65	1988	668	747	774	1733	1245	1342	1408	885	954	975	10731
CI&L	-----	-----	-----	-----	12	16	8	6	7	0	49	-----	-----	-----	-----	19	21	57	2	114	77	290
CMStP&P	73	77	119	136	136	132	79	87	89	61	989	311	340	684	468	1062	1083	1069	1173	914	1080	8184
CRI&P	91	115	158	247	183	168	123	127	83	47	1342	269	136	390	605	645	643	527	552	596	620	4983
C&S	-----	-----	-----	-----	26	21	3	10	3	5	68	-----	-----	-----	-----	28	47	82	17	189	72	435
D&H	-----	-----	-----	-----	67	31	14	19	12	12	155	-----	-----	-----	-----	192	196	114	111	314	508	1435
DL&W	56	85	96	23	27	29	36	22	17	8	399	140	0	1089	369	333	300	303	375	319	186	3414
D&RGW	-----	-----	-----	-----	203	212	159	22	31	15	642	-----	-----	-----	-----	114	254	190	14	695	373	1640
Erie	110	129	210	207	177	99	98	87	58	43	1218	238	599	405	1133	971	549	666	619	776	570	6526
Fla. E.C.	-----	-----	-----	-----	152	92	67	86	55	39	491	-----	-----	-----	-----	367	119	164	279	182	243	1354
GN	232	224	225	261	243	247	266	175	175	†102	2150	171	150	258	366	430	535	516	430	1531	936	5323
GM&O—So. Rgn.	62	85	57	48	29	54	-----	26	35	-----	396	0	0	28	298	306	60	-----	265	274	-----	1231
GTW	-----	-----	-----	-----	43	43	13	20	27	19	165	-----	-----	-----	-----	112	112	83	89	110	123	629
IC (Sys.)	474	556	699	534	311	197	64	65	59	69	3028	727	471	1483	2000	1925	1907	1314	1418	1650	1284	14179
KCS	-----	-----	-----	-----	14	21	4	0	10	8	57	-----	-----	-----	-----	178	66	94	0	94	73	505
L&HR	11	2	10	1	8	0	0	4	0	0	36	22	0	24	0	24	13	12	6	0	0	101
L&NE	4	1	8	3	5	2	7	2	5	0	37	26	0	27	12	4	15	16	13	36	4	153
LV	30	30	79	41	33	49	22	22	14	6	326	6	150	171	128	189	156	67	127	55	126	1175
L&N	130	139	202	217	160	159	116	133	115	60	1431	530	561	925	800	747	684	648	653	933	864	7345
Me. Cen.	-----	-----	-----	-----	12	15	14	0	0	7	48	-----	-----	-----	-----	21	63	50	0	0	74	208
MStP&SSM	-----	-----	-----	-----	13	49	23	30	21	17	153	-----	-----	-----	-----	39	24	96	90	95	73	417
MKT	66	110	81	131	92	57	28	31	30	24	650	132	4	455	249	515	214	141	118	576	532	2936
Mo. Pac. R.R.	-----	-----	-----	228	-----	-----	-----	-----	-----	-----	228	-----	-----	-----	1328	-----	-----	-----	-----	-----	-----	1328
Mo. Pac. Lines	-----	-----	-----	68	25	24	31	42	4	24	218	-----	-----	-----	502	728	399	462	507	553	518	3669
NC&StL	35	48	39	57	58	43	32	19	9	9	349	115	110	126	218	172	184	68	84	104	59	1240
NYC (Sys)*	357	462	617	652	406	344	225	202	173	165	3603	352	428	623	844	559	1119	750	724	1484	1508	8391
NYC&StL	-----	-----	-----	192	86	47	29	45	37	21	457	-----	-----	-----	392	318	199	215	172	128	118	1542
NYC Transit	-----	-----	-----	-----	3	3	6	2	15	-----	29	-----	-----	-----	-----	0	0	0	0	0	-----	0
NYNH&H	28	30	34	24	21	14	3	5	4	2	165	58	98	121	268	136	74	86	68	172	79	1160

TABLE 1. Continued

	Service Failures											Detected Failures										
Year Failed ------	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	Total	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	Total
NYO&W	20	20	32	16	62	6	1	24	24	12	217	0	0	0	0	53	0	56	2	0	0	111
N&W	10	7	9	2	3	1	5	3	2	3	45	53	63	49	34	40	40	58	17	129	84	567
NP	147	217	241	317	310	288	289	188	129	90	2216	227	326	470	589	440	471	702	475	431	473	4604
PRR**	323	425	440	517	365	415	290	259	255	430	3719	1158	1048	858	799	1026	909	646	644	1865	1166	10119
P&LE	-----	-----	-----	-----	4	0	3	0	1	0	8	-----	-----	-----	-----	4	6	1	5	36	22	74
Reading	148	283	267	172	173	70	49	47	0	0	1209	0	0	0	0	367	735	287	321	1236	404	3350
RF&P	5	16	27	28	31	27	20	12	10	6	182	37	186	168	238	228	207	176	106	514	195	2055
Rutland	2	2	1	1	3	1	2	1	0	0	13	0	0	8	0	0	0	0	9	0	0	17
Seaboard	-----	-----	-----	-----	49	23	24	21	11	18	146	-----	-----	-----	-----	197	159	299	440	412	299	1806
S.P. (Pac. Lines)	347	356	452	426	445	267	209	179	162	98	2941	709	1424	1610	2002	1536	1377	1362	909	1243	1012	13184
Sou. (Sys.)	258	256	337	311	278	277	246	188	171	98	2420	1101	2151	2454	3541	2360	1955	1835	1998	2643	2009	22047
StLSF	-----	-----	-----	-----	111	142	102	101	74	52	582	-----	-----	-----	-----	573	655	415	532	664	639	3478
T&NO	-----	-----	-----	-----	239	186	123	66	112	99	825	-----	-----	-----	-----	795	924	837	739	951	1006	5252
Tex. & Pac.	-----	98	93	160	128	124	72	71	46	22	814	-----	760	758	839	869	582	524	0	393	173	4898
UP (Sys.)	481	395	447	389	226	241	176	172	55	19	2601	3022	4226	4479	3045	1587	1356	1148	4957	4149	3613	31582
Virginian	30	27	16	12	11	13	10	4	6	1	130	126	90	173	114	114	0	0	0	152	24	793
W. Md.	53	43	48	35	26	27	14	33	25	3	307	82	148	228	152	184	133	144	224	418	302	2015
W&LE	-----	-----	-----	-----	3	3	5	1	0	3	15	-----	-----	-----	-----	0	3	3	0	8	5	19
All Roads	4882	6069	7407	7795	6976	5707	4238	3801	3166	2361	52402	15732	21915	29848	36071	31978	30813	25831	29364	38445	32371	292368

--No report received.
*Including IHB failures.
**Including LI RR & PRSL 1940 to 1948 Incl.
†Includes Burn Fractures.

TABLE 2. VERIFIED DETECTED TRANSVERSE FISSURE FAILURES BY RAILROAD AND BY YEAR FAILED REPORTED BY ROADS WHICH BREAK THEIR DETECTED RAILS ALL ROLLINGS BY ALL PROCESSES

	Detected Failures																				
Year Failed	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	Total
AT&SF	-----	0	0	13	17	121	59	247	194	326	377	275	566	831	647	538	580	388	298	488	6025
Ban. & Aroos.	-----	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49	0	26	11	86
CP	-----	351	214	372	834	899	999	1501	1239	1780	2011	3813	5201	5946	5064	4957	3105	4338	3545	3787	49974
C&EI	-----	59	0	74	43	65	29	65	77	89	96	120	138	271	352	304	338	316	312	320	3068
CB&Q	-----	-----	-----	174	322	315	447	413	602	662	668	747	774	1733	1245	1342	1408	885	887	884	13508
CMStP&P	-----	49	0	156	179	247	197	357	288	285	311	340	684	468	1062	1083	1069	1173	734	901	9583
C&S	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	28	47	82	17	56	37	267
Erie	7	4	0	75	0	165	0	166	264	350	238	599	405	1133	971	549	666	619	595	469	7275
GTW	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	112	112	83	89	106	123	625
GN	25	0	0	6	144	114	88	69	92	142	171	150	258	366	430	535	516	430	631	599	4766
L&N	165	0	0	358	19	341	488	577	530	408	530	561	925	800	747	684	648	653	662	554	9650
Long Island*	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	25	25
MKT	12	29	76	31	98	74	77	167	169	61	132	4	455	249	515	214	141	118	280	264	3166
NC&StL	2	0	0	0	40	45	17	42	70	42	115	110	126	218	172	184	68	84	87	58	1480
NYC System	107	83	182	253	114	191	322	428	430	562	352	428	623	844	559	1119	750	724	690	693	9454
NYC&StL	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	392	318	199	215	172	128	116	1540
NYNH&H	67	159	106	101	100	82	60	101	92	110	58	98	121	268	136	74	86	68	132	60	2079
N&W	20	0	5	0	74	0	0	84	45	44	53	63	49	34	40	40	58	17	29	28	683
NP	-----	0	0	81	19	324	173	292	246	310	227	326	470	589	440	471	702	475	355	441	5941
PRR	260	576	403	851	440	1073	690	757	857	920	1158	1048	858	799	1026	909	646	644	404	16	14335
P&LE	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	4	6	1	5	0	0	16
RF&P	-----	0	0	36	0	67	44	53	52	61	37	186	168	238	228	207	176	106	147	49	1855
Rutland	0	0	7	0	0	3	0	0	0	0	0	0	8	0	0	0	0	9	0	0	27
Va.	-----	0	0	0	0	0	0	0	0	0	126	90	173	114	114	0	0	0	1	0	618
WMd.	-----	0	0	0	106	0	0	86	0	72	82	148	228	152	184	133	144	224	210	141	1910
Total	665	1310	993	2581	2609	4126	3690	5405	5247	6224	6742	9106	12230	15463	14394	13707	11531	11554	10315	10064	147956

*Included in PRR prior to 1949.

TABLE 2A. SERVICE TRANSVERSE FISSURE FAILURES—ALL ROLLINGS BY ALL PROCESSES—SAME ROADS AS IN TABLE 2

	Service Failures																				
Year Failed	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	Total
AT&SF	142	114	84	64	46	35	46	92	43	85	111	140	341	455	307	141	157	112	92	103	2710
Ban. & Aroos.	7	2	1	1	0	0	0	0	0	0	0	0	3	3	4	3	1	2	0	0	27
CP	138	109	90	103	113	121	134	138	114	164	225	501	425	381	238	274	214	184	181	131	3978
C&EI	18	18	28	39	23	14	18	22	23	15	15	23	31	48	51	62	57	42	33	41	621
CB&Q	-----	-----	-----	165	152	214	164	167	134	151	161	199	272	323	287	244	141	152	144	65	3135
CMStP&P	26	45	105	125	99	71	74	53	46	45	73	77	119	136	136	132	79	87	89	61	1678
C&S	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	26	21	3	10	3	5	68
Erie	156	175	181	179	187	171	167	229	123	133	110	129	210	207	177	99	98	87	58	43	2919
GTW	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	43	43	13	20	27	19	165
GN	189	141	126	128	143	179	246	276	215	246	232	224	225	261	243	247	266	175	175	102	4039
L&N	285	268	220	182	215	181	253	229	178	178	130	139	202	217	160	159	116	133	115	48	3608
MKT	31	32	30	17	20	33	39	30	35	80	66	110	81	131	92	57	28	31	30	24	997
NC&StL	22	50	42	58	20	19	50	36	19	30	35	48	39	57	58	43	32	19	9	9	695
NCY System	340	306	299	306	272	318	381	361	389	433	357	462	617	652	406	344	225	202	173	165	7008
NYC&StL	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	192	86	47	29	45	37	21	457
NYNH&H	40	25	24	40	59	34	37	48	39	31	28	30	34	24	21	14	3	5	4	2	542
N&W	43	41	29	50	33	23	38	36	22	21	10	7	9	2	3	1	5	3	2	3	381
NP	131	171	160	126	169	168	171	259	213	185	147	217	241	317	310	288	289	188	129	90	3969
PRR	717	426	345	345	430	414	544	672	513	442	323	425	440	517	365	415	290	259	255	430	8567
P&LE	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	4	0	3	0	1	0	8
RF&P	-----	1	3	5	4	4	2	4	3	2	5	16	27	28	31	27	20	12	10	6	210
Rutland	3	1	0	1	0	1	1	1	1	2	2	2	1	1	3	1	2	1	0	0	24
Va.	7	24	24	28	33	30	23	36	34	39	30	27	16	12	11	13	10	4	6	1	408
WMd.	255	148	94	94	62	87	116	70	133	50	53	43	48	35	26	27	14	33	25	3	1416
Total	2550	2097	1885	2056	2080	2117	2504	2759	2277	2332	2113	2819	3381	3999	3088	2702	2095	1806	1598	1372	47610

compound fissures, detail fractures, and engine burn fractures. Roads using this classification which do not break the detected transverse defects for visual inspection are unable to report the number of "detected transverse fissures" separately. To obtain further information on this, the transverse fissure statistics were compiled separately for 24 roads which do break their detected transverse defects. The results from these 24 roads are shown on the same figure as curves C and D. It will be observed that curve C, service transverse fissures for this select group, approximately parallels curve A, service transverse fissures for all 61 reporting roads. However, curve D, the detected transverse fissures for the select group, shows in general a continuing decrease in number after 1943. It is, therefore, apparent that the increase in number of detected transverse defects in the years 1947, 1948 and 1949 for all 61 roads includes a substantial number of other types of transverse defects than true transverse fissures.

The service failures reported by individual roads and shown in Table 1 are of interest in showing the extent to which each railway has been able to lower its number of service failures by rail replacement with control-cooled rail and by the use of detector cars. This information may be of value to individual railways in scheduling the operation of detector cars and determining the required frequency of testing.

Use of Control-Cooled Rail

The track miles of control-cooled rail laid in 1948 as reported by 64 railroads were somewhat less than in 1947, but still represent approximately 2.3 percent of the main line mileage of the reporting roads. Including the control-cooled rail laid in 1937 and 1938, which is not shown in this table, there have been laid approximately 68,761 track miles of control-cooled rail, or approximately 24 percent of the total main line mileage of the reporting roads. It is evident that with this substantial mileage of control-cooled rail and the almost total lack in development of transverse fissures in it, its influence on the rate of transverse fissure failures should henceforth be strongly noticeable.

Mill Performance

Maintenance of rail failure statistics on almost the entire main line mileage of United States and Canada affords an excellent proving ground for comparing service failures of each year's rolling of rail. Table 4 is prepared to afford this comparison up

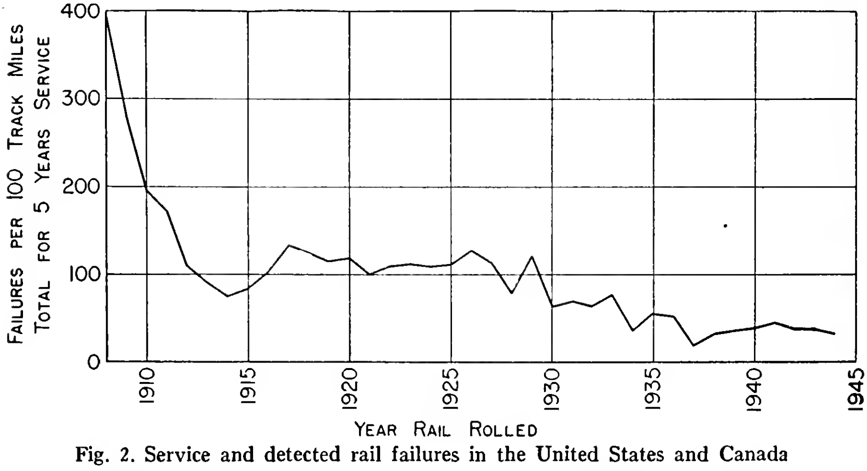

Fig. 2. Service and detected rail failures in the United States and Canada

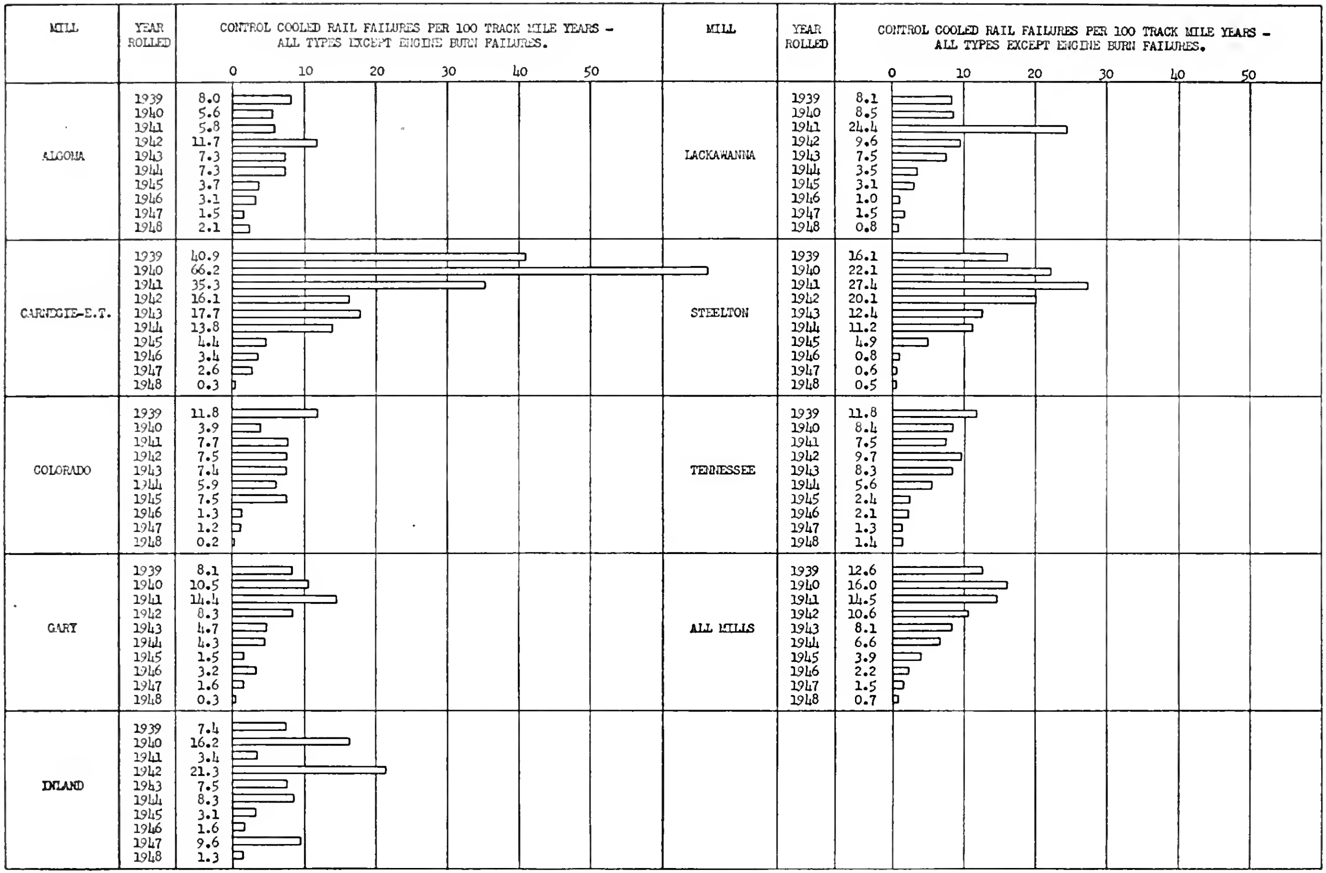

Fig. 3. Control-cooled rail failure rates to December 31, 1949 by mills—all types except engine burn failures—service and detected.

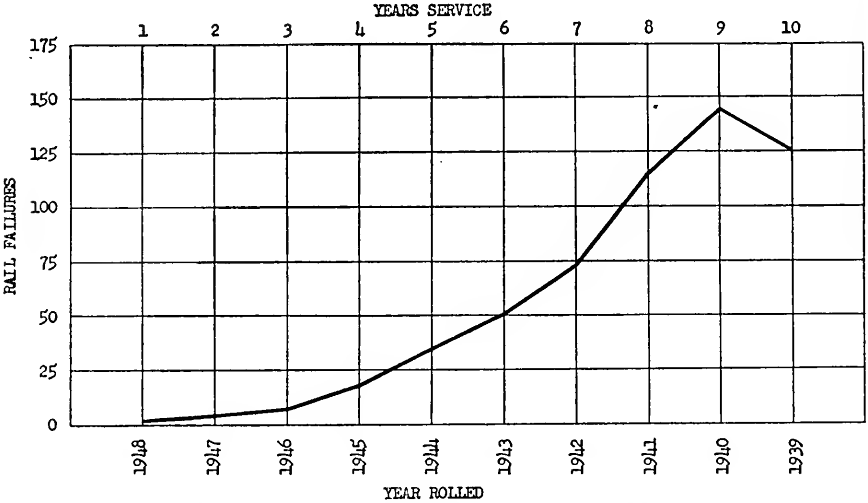

Fig. 4. Control-cooled rail failures to December 31, 1949, per 100 track miles—all types excluding engine burn fractures-service and detected.

to ten years of service for the rollings from all mills for the years 1939 to 1948, inclusive. The same information is presented graphically in Fig. 4. It will be observed that the rate of failures runs quite low for the first three years and then increases more rapidly than in a straight line relation thereafter. For this year's report the maximum rate is reached in the ninth year, decreasing in the tenth year. The same trend, with a decrease in the tenth year, was shown in the Rail committee report for last year. It will be interesting to see whether this pattern continues and if so to determine the reason for the decline in the tenth year of service.

Fig. 2 is also of interest in checking mill performance. This figure shows the failures per 100 track miles for the various years' rollings occurring in the first five years of service after being laid. The rate of failures has steadily decreased since 1941 and the performance for the 1944 rolling is quite good but not yet as low as that for the 1937 rolling. Since 1944 is one of the war years, when the mills were operating under unusual conditions, it is to be expected that a still further decline will be shown in the rollings for the postwar years.

Table 5 shows the track miles of control-cooled rail in the rollings from 1939 to 1948, inclusive, by individual railroads and by individual mills, together with the number of failures occurring in the year 1949. In Table 6 this information has been totalled and shown for each mill separately, broken down by types of failure. It will be observed from this table the failures per 100 track mile years are reasonably uniform for all the mills except for Carnegie (ET) and Steelton. Observation of Table 7 showing the same information, but separated by the various reporting railroads, indicates that the reason for the high rate for both mills is the large number of web failures reported by one railway.

Several railways are experiencing a considerable number of cracks at the first bolt hole and in the upper fillet at the rail ends, and if rails removed for this type of defect are reported, it seems certain that the influence of this type of failure will have a marked effect on the rail failure record.

TABLE 3-TONS OF RAILS AND TRACK MILES OF EACH YEAR'S ROLLINGS 1939 - 1948, INCL., INCLUDED IN THESE STATISTICS. REPORTED BY 64 RAILROADS.

YEAR	OH CONTROL COOLED ONLY		BRUNORIZED AND OTHER PROCESS		TOTAL	
ROLLED	TONS	TRACK MILES	TONS	TRACK MILES	TONS	TRACK MILES
1939	634459	3435.47	54128	309.72	688587	3745,19
1940	860592	4880.64	52846	316.44	913438	5197.08
1941	1048261	5595.43	40414	232.09	1088675	5827.52
1942	1082175	5844.69	14129	95.61	1096304	5940.30
1943	1257635	6829.39	11443	77.24	1343043	6906.63
1944	1536809	8390.38	7845	54.12	1544654	8444.50
1945	1520038	8305.15	0	0	1520038	8305.15
1946	1206611	6346.71	0	0	1206611	6346.71
1947	1394419	7207.20	0	0	1394419	7207.20
1948	1193972	6180.90	0	0	1193972	6180.90
TOTAL	11734971	63015.96	180805	1085.22	11989741	64101.18

TABLE 4 - SERVICE AND DETECTED FAILURES OF ALL TYPES EXCEPT ENGINE BURN FAILURES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1949 PER 100 AVERAGE TRACK MILES, CONTROL COOLED RAIL ONLY, IN ALL ROLLINGS, FROM ALL MILLS.

Year Rolled	Years of Service									
	1	2	3	4	5	6	7	8	9	10
1938	-	-	-	-	28.5	39.6	51.9	65.2	83.4	85.1
1939	-	-	-	15.0	21.4	40.4	70.4	102.6	131.5	126.9
1940	-	-	12.5	17.5	34.3	67.9	92.9	119.8	144.3	
1941	-	4.2	9.3	24.3	46.3	66.1	90.6	116.1		
1942	2.3	6.0	11.6	24.9	37.7	54.8	74.8			
1943	3.4	8.4	16.5	23.9	34.9	48.7				
1944	3,6	7.2	13.8	19.4	33.3					
1945	1.4	4.1	8.6	15.7						
1946	1.2	2.9	6.6							
1947	0.9	3.1								
1948	0.7									

Note: - indicates figures are not available.

TABLE 5–TRACK MILES AND 1949 FAILURES, ALL TYPES, IN ROLLINGS 1939 TO 1948, INCL.,
OPEN-HEARTH CONTROL-COOLED RAIL ONLY

ROAD	TRACK MILES BY MILL											1949 FAILURES ONLY	
	ALG.	CARN	COLO	DOM	GARY	INL'D	LACKA	MD	STLTN	TENN	TOTAL	EBFS EXCL	EBFS ONLY
AT&SF			3138		905	96			46		4185	128	0
ACL		93							483	693	1269	23	5
B&O		976			508	23	207		498		2212	274	138
B&AROOST		3							117		120	0	0
B&O-CT					19	18					37	1	0
B&LE		111									111	2	0
BOS&ALB					8		195		5		208	6	0
B&M		178					185		110		473	17	0
CP	3905			87			146				4138	360	0
C of GA.										360	360	15	14
C&O, E REGN					1074	504			196		1774	189	130
C&O, PM.DIST.	95				192	95	62				444	0	0
C&EI					258	50					308	12	15
C&NW					799	185	67				1051	299	0
CB&Q			1030		837	143					2010	20	1
CCC&StL.					879		46				925	62	10
CI&L					108						108	0	0
CMSt.P&P					1301	367					1668	13	0
CRI&P			451		1232	358					2041	56	0
C&S			47								47	0	0
D&H									488		488	275	10
DL&W		78					333				411	2	0
D&RGW			581								581	79	0
ERIE		752			269	33	142				1196	30	8
FEC		11							50	414	475	0	5
GTW					317	78	18				413	10	0
GN*			51		689	172	268				1180	171	0
IC					1379	549				432	2360	136	6
IHB						29					29	1	0
KCS					398	59			10		467	5	0
L&HR									29		29	0	0
LONG ISL.									117		117	0	0
L&NE		3							37		40	2	0
LV							291				291	3	0
L&N					197					1667	1864	209	4
Me. CEN.							67				67	0	0
MICH.CEN.	355				285						640	11	8
MSt.P&SSM					101	49	93				243	11	0
MKT			183		447	84					714	3	1
MPRR			1155		506	218				101	1980	47	2
MP LINES		15	350							152	517	13	4
NC&StL					5					448	453	57	0
NYC-E					58		1245				1303	268	7
NYC-W					606	87	144				837	461	18
NYC&StL					486	102	178				766	34	0
NYNH&H		355							344		699	38	2
N&W		983							355		1338	90	20
NP			446		909	70	435				1860	60	17
PRR		1386			844	138	40		1391		3799	2115	97
R&E						21					21	0	0
P&LE		165									165	9	15
READING									437		437	1	0
RF&P									139		139	77	4
RUTLAND							3				3	1	0
SAL									759	550	1309	27	2
St.L SF					10	50				727	787	21	0
SP			3016						184	315	3515	356	52
SOUTHERN					115				730	1341	2186	121	18
T&NO			648						48	37	733	20	2
T&P			542							188	730	24	0
UP			2254		1103	172					3529	1468	0
Va.		125					5		249		379	29	0
W Md.		81							106		187	16	0
W&LE		250									250	24	2
	4355	5565	13892	87	16844	3750	4170		6928	7425	63016	7804	617

* Oreat Northern RR includes the engine burn fractures under the column headed "Compound Fissures and Detail Fractures".

TABLE 6 - ACCUMULATED FAILURES AND FAILURES PER 100 TRACK MILES, IN ROLLINGS 1939 TO 1948, INCLUSIVE, FROM DATE ROLLED TO DECEMBER 31, 1949, SERVICE AND DETECTED, BY MILL AND TYPE OF FAILURE.

OH CONTROL COOLED RAIL ONLY

MILL	ACCUMULATED FAILURES TO DECEMBER 31, 1949 (EXCL. EBFs)										TRACK MILES	TRACK MILE YEARS	FAILURES PER 100 TRACK MI. YEARS
	TF VER UofI	CF & DF	VSH	HSH	OTHER HEAD	BROKEN	WEB		BASE	ALL TYPES			
							IN JT.	OTHER					
ALGOMA	3	4	259	15	195	60	289	53	457	1335	4355	20507	6.59
CARNEGIE (ET)	-	331	98	103	107	233	4725	1376	7	6980	5565	26610	26.23
COLORADO	-	1765	549	598	404	117	139	646	25	4243	13892	64412	6.58
DOMINION	-	-	2	1	8	0	3	5	2	21	87	516	4.07
GARY	-	1644	220	128	347	318	2465	596	97	5815	16844	83583	6.95
INLAND	5	294	61	20	41	162	672	286	35	1576	3750	18792	8.33
LACKAWANA	6	232	36	32	82	127	931	68	152	1666	4170	19868	8.38
MARYLAND	-	-	-	-	-	-	-	-	-	-	-	-	
STEELTON	37	1840	43	149	170	495	1020	487	7	4248	6928	30144	14.09
TENNESSEE	-	204	247	564	260	463	693	423	107	2961	7425	39757	7.44
ALL MILLS	51	6314	1515	1610	1614	1975	10937	3940	889	28845	63016	304189	9.48
FAILURES 100 TR. MI. YEARS	.02	2.07	.50	.52	.53	.65	3.59	1.29	.29	9.48			

TABLE 7 – ACCUMULATED FAILURES OF ALL TYPES OF OH CONTROL COOLED RAIL ONLY, IN ROLLINGS 1939-1948, INCL., ACCUMULATED TO DECEMBER 31, 1949, SEGREGATED BY ROADS AND MILLS, FROM TABLE 6, EXCLUSIVE OF ENGINE BURN FRACTURES SHOWN SEPARATELY FOR 1949 ONLY AND TOTAL ACCUMULATED 1943-1949, INCL.

ROADS	TF Ver UofI	CF & DF	VSH	HSH	Other Head	Broken	Web		Base	FAILURES TOTALS			
										EBFs Excl.		EBFs Only	
							In Jt.	Other		Accum. Total	1949	1943 1949	1949
ALGOMA													
CP	3	4	258	13	194	59	282	51	453	1317	344	0	0
C&O-PM	–	–	1	–	–	–	–	–	1	2	–	–	–
Mich. Cent.	–	–	–	2	1	1	7	2	3	16	6	2	2
Total	3	4	259	15	195	60	289	53	457	1335	350	2	2
CARNEGIE (ET)													
B&O	–	56	38	17	55	14	262	156	–	598	142	131	49
B&LE	–	6	–	1	–	–	1	–	–	8	2	–	–
B&M	–	–	–	1	6	3	–	23	–	33	3	–	–
DL&W	–	–	1	1	–	–	–	–	–	2	–	–	–
ERIE	–	12	6	3	4	4	14	22	2	67	11	24	8
FEC	–	–	–	–	2	–	5	–	–	7	–	–	–
L&NE	–	–	1	–	–	–	–	–	–	1	–	–	–
NYNH&H	–	14	15	11	–	5	31	1	1	78	20	8	1
N&W	–	106	3	29	2	–	37	48	–	225	69	51	16
P&LE	–	12	2	2	4	–	–	4	–	24	9	15	15
PRR	–	96	25	25	19	71	4362	1081	2	5681	668	199	48
Va	–	28	1	4	–	95	1	8	–	137	14	–	–
WMd	–	1	–	1	–	13	–	6	–	21	9	–	–
W&LE	–	–	6	8	15	28	12	27	2	98	24	2	2
Total	–	331	98	103	107	233	4725	1376	7	6980	971	430	139
COLORADO													
AT&SF	–	143	71	61	13	36	23	32	4	383	111	–	–
CB&Q	–	1	27	18	4	5	2	1	1	59	11	1	1
CRI&P	–	3	20	1	5	21	8	–	6	64	19	–	–
D&RGW	–	191	26	24	10	6	35	22	–	314	79	–	–
MKT	–	–	3	4	1	1	–	2	–	11	–	–	–
MP LINES	–	–	5	3	2	5	1	–	–	16	5	4	4
MP	–	6	50	10	53	8	35	20	3	185	22	–	–
NP	–	2	6	–	5	5	3	7	–	29	5	12	9
SP	–	20	268	293	209	22	16	411	6	1245	214	38	21
T&NO	–	4	11	14	17	5	–	24	–	75	20	2	2
T&P	–	–	4	–	1	2	9	2	–	18	5	–	–
UP	–	1395	58	170	84	–	7	125	5	1844	857	2	–
Total	–	1765	549	598	404	117	139	646	25	4243	1348	59	37

TABLE 7 - Continued

ROADS	TF Ver UofI	CF & DF	VSH	HSH	Other Head	Broken	Web		Base	FAILURES TOTALS			
										EBFs Excl.		EBFs Only	
							In Jt.	Other		Accum. Total	1949	1943 1949	1949
INLAND													
AT&SF	1	-	-	-	-	-	1	-	-	2	1	-	-
B&O	-	1	-	-	-	-	3	-	-	4	-	4	4
B&O CT	-	1	-	-	-	1	-	-	-	2	1	-	-
C&O PM	-	1	2	-	-	-	-	-	1	4	-	-	-
C&O	-	54	1	-	1	-	-	-	-	56	56	45	45
C&EI	-	-	2	-	1	1	2	4	-	10	2	3	-
C&NW	-	4	7	-	3	29	21	2	5	71	24	-	-
CB&Q	-	1	3	1	1	2	-	1	-	9	1	-	-
CMStP&P	1	1	4	1	4	40	7	2	4	64	5	1	-
CRI&P	-	1	3	1	4	19	4	3	5	40	10	-	-
ERIE	-	1	-	-	-	2	1	2	-	6	2	-	-
GTW	-	-	1	-	3	28	-	-	6	38	4	-	-
GN*	-	-	6	1	7	-	4	-	3	21	9	-	-
IC	-	19	16	2	-	5	42	11	1	96	44	2	-
IHB	-	-	-	-	-	6	9	2	-	17	1	-	-
MStP&SSM	-	-	-	-	1	8	-	1	5	15	5	-	-
MKT	-	1	4	2	2	-	-	3	-	12	1	1	1
MP	-	4	2	5	8	7	17	92	-	135	10	1	1
NYC-W	-	3	2	-	-	1	166	5	-	177	17	2	2
NYC-StL	-	3	1	-	2	2	8	3	2	21	5	-	-
NP	-	-	1	-	-	2	-	-	2	5	1	-	-
PRR	.	11	1	3	2	9	385	136	-	547	63	6	5
UP	3	188	5	4	2	-	2	19	1	224	74	-	-
Total	5	294	61	20	41	162	672	286	35	1576	336	66	58
LACKAWANNA													
B&O	-	20	1	-	4	2	18	11	-	56	12	33	9
Bos. & Alb.	-	1	3	-	-	1	4	2	3	14	5	-	-
B&M	-	-	2	-	5	12	1	1	2	23	5	-	-
CP	-	-	2	1	26	-	5	5	30	69	13	-	-
C&NW	-	-	-	-	1	-	-	-	1	2	2	-	-
CCC&StL	-	-	1	-	6	1	1	5	-	14	3	-	-
C&O PM	-	-	-	-	-	1	-	-	2	3	-	-	-
DL&W	-	2	4	4	2	-	5	2	10	29	2	1	-
ERIE	-	15	-	-	-	2	-	8	1	26	8	1	-
GN*	-	19	3	1	11	-	13	2	6	55	24	-	-
LV	2	5	1	-	-	12	7	20	21	68	3	-	-
Me. Cent.	-	-	-	-	1	-	-	-	1	2	-	-	-
MSt.P&SSM	-	-	-	-	-	4	-	-	2	6	2	-	-
NYC-E	3	97	6	22	6	14	337	3	5	493	232	12	7
NYC-StL	1	-	-	-	10	2	6	6	-	25	7	-	-
NYC-W	-	6	4	1	6	-	465	1	1	484	241	11	2
NP	-	1	8	1	4	34	4	2	55	109	20	4	-
RUTLAND	-	-	-	-	-	12	-	-	14	26	1	-	-
PRR	-	66	1	2	-	34	65	-	-	168	24	1	-
Total	6	232	36	32	82	127	931	68	152	1666	602	63	18

TABLE 7 - Continued

										FAILURES TOTALS			
										EBFs Excl.		EBFs Only	
ROADS	TF Ver UofI	CF & DF	VSH	HSH	Other Head	Broken	Web		Base				
							In Jt.	Other		Accum Total	1949	1943 1949	1949
DOMINION													
CP	-	-	2	1	8	-	3	5	2	21	3	-	-
Total	-	-	2	1	8	-	3	5	2	21	3	-	-
GARY													
AT&SF	-	-	13	1	1	3	7	-	-	25	5	-	-
B&O	-	1	6	2	9	1	111	8	5	143	59	57	16
B&O-CT	-	-	-	-	-	-	1	-	-	1	-	-	-
Bos.& Alb.	-	-	-	-	-	-	1	-	-	1	-	-	-
C&O	-	77	1	1	5	-	-	8	-	92	92	81	81
C&O PM	-	2	-	-	-	-	-	-	-	2	-	-	-
CCC&StL	-	6	5	5	26	2	37	37	2	120	59	12	10
CMStP&P	-	-	5	-	-	44	1	8	8	66	8	-	-
CRI&P	-	-	16	2	21	70	8	7	14	138	27	-	-
C&EI	-	-	4	-	6	-	22	7	-	39	10	18	15
C&NW	-	6	10	5	31	49	267	7	5	380	273	-	-
CB&Q	-	6	8	4	5	3	4	3	2	35	8	-	-
ERIE	-	8	1	-	-	4	4	10	1	28	9	1	1
GTW	-	1	3	1	7	55	5	4	39	115	6	-	-
GN*	-	185	20	1	76	1	17	-	-	300	138	-	-
IC	-	21	30	12	8	9	94	13	4	191	59	4	3
KCS	-	34	14	4	-	4	2	14	1	73	5	12	-
L&N	-	2	-	-	-	-	-	1	-	3	1	-	-
MKT	-	-	6	2	5	-	11	1	-	25	2	-	-
MP	-	4	3	5	3	4	8	77	-	104	6	2	1
Mich. Cent.	-	8	21	-	9	-	5	5	-	48	5	19	6
MStP&SSM	-	-	4	-	1	3	-	1	3	12	4	-	-
NC&StL	-	-	1	-	-	-	1	1	-	3	-	-	-
NYC-W	-	41	8	3	35	-	175	-	-	262	203	37	14
NYC-E	-	38	2	5	5	-	37	-	-	87	36	1	-
NYC&StL	-	2	1	2	20	9	40	35	1	110	22	-	-
NP	-	8	10	1	18	33	11	8	9	98	34	14	8
PRR	-	41	9	4	2	21	1585	264	1	1927	582	36	21
SOUTHERN	-	1	-	-	-	3	1	3	1	9	2	-	-
StL&SF	-	-	-	-	1	-	-	-	1	2	-	-	-
UP	-	1152	19	68	53	-	10	74	-	1376	537	3	-
Total	-	1644	220	128	347	318	2465	596	97	5815	2192	297	176

TABLE 7 - Continued

										FAILURES TOTALS			
												EBFs Only	
							Web			EBFs Excl.			
ROADS	TF Ver UofI	CF & DF	VSH	HSH	Other Head	Broken	In Jt.	Other	Base	Accum. Total	1949	1943 1949	1949
STEELTON													
AT&SF	-	2	-	-	-	7	8	-	-	17	11	-	-
B&O	5	27	5	7	19	5	39	52	2	161	61	127	60
BAN&AROOS	-	-	1	-	-	1	-	-	-	2	-	-	-
Bos. & Alb.	-	-	-	-	-	1	-	-	-	1	1	-	-
Bos. & Me.	2	2	2	1	6	10	1	6	1	31	9	1	-
C&O	-	34	-	1	-	-	-	6	-	41	41	4	4
D&H	2	397	6	78	24	9	18	176	-	710	273	26	10
FEC	-	-	-	1	-	-	-	-	-	1	-	-	-
KCS	-	-	-	-	1	-	-	5	-	6	-	4	-
L&NE	-	-	-	-	1	-	1	-	-	2	2	-	-
NYNH&H	5	22	1	2	-	2	19	-	-	51	18	7	-
NW	5	77	-	5	1	-	5	12	-	105	21	25	4
PRR	-	696	5	15	64	364	909	12	-	2065	778	39	23
RFP	1	346	6	5	2	-	7	-	-	367	77	12	4
READING	-	-	-	-	-	7	-	1	-	8	1	1	-
SOUTHERN	2	185	2	3	2	14	2	-	-	210	34	26	1
SAL	3	7	1	2	-	34	3	2	1	53	5	-	-
SP	3	5	10	27	48	4	-	198	2	297	28	25	20
T&NO	-	-	-	-	-	-	-	1	-	1	-	-	-
Va	9	40	1	2	1	31	8	15	1	108	15	-	-
WMd	-	-	3	-	-	7	-	1	-	11	7	-	-
Total	37	1840	43	149	170	495	1020	487	7	4248	1382	297	126
TENNESSEE													
ACL	-	2	12	3	-	3	22	5	4	51	23	6	5
C of Ga.	-	2	1	11	9	13	46	1	6	89	15	14	14
FEC	-	1	-	1	1	3	8	-	2	16	-	7	5
IC	-	3	15	5	2	6	83	8	3	125	35	3	3
L&N	-	133	76	190	53	70	305	65	27	919	208	27	4
MP LINES	-	1	2	2	2	1	3	-	16	27	8	-	-
Mo P	-	-	2	7	7	6	13	7	2	44	9	-	-
NC&StL	-	10	40	87	42	28	143	57	19	426	57	-	-
StL&SF	-	17	21	10	26	43	6	37	1	161	21	1	-
SAL	-	6	7	13	1	59	4	2	12	104	22	6	2
SP	-	12	60	201	54	31	17	209	5	589	114	18	11
SOUTHERN	-	16	8	33	61	198	19	31	9	375	85	33	17
T&P	-	1	3	1	2	2	24	1	1	35	19	1	-
Total	-	204	247	564	260	463	693	423	107	2961	616	116	61
ALL MILLS	51	6314	1515	1610	1614	1975	10937	3940	889	28845	7800	1329	617

* Great Northern RR includes the engine burn fractures under the column headed "Compound Fissures and Detail Fractures".

TABLE 8. ACCUMULATED TRANSVERSE FISSURE FAILURES IN CONTROL-COOLED RAIL AS VERIFIED BY LABORATORY INVESTIGATION, BY ROAD, MILL AND YEAR ROLLED TO OCTOBER 1, 1950

Roads	*Mills*	*1935*	*1936*	*1937*	*1938*	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*1948*	*Total*
CP	Algoma					1(a)	1						1(a)			3
PM	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
Wabash	Gary			1(a)												1
AT&SF	Inland							1								1
C&O	Inland	1	4(c)	3	2			6			1	1				18
CMStP&P	Inland										1					1
GN	Inland					1(e)										1
UP	Inland					3	3									6
LV	Lackawanna								1	1						2
NYC	Lackawanna								1	1	1					3
NYC&StL	Lackawanna								2							2
AT&SF	Steelton			3												3
B&O	Steelton							1	2	1			1			5
B&M	Steelton						2									2
C of NJ	Steelton									1						1
C&O	Steelton	4		1	4		1									10
D&H	Steelton				1	2	1(f)			1						5
MP	Steelton			1												1
N&W	Steelton					1	1		4							6
NYNH&H	Steelton			3		2	1		1	2						9
PRR	Steelton		2													2
RF&P	Steelton			1			1								1	3
SAL	Steelton							2		1						3
SoRy	Steelton							1								2
SP	Steelton		17	2	6	4										29
Va.	Steelton						1									1
SP	Tennessee		1(a)													1
Total		5	31	17	14	16	14	11	11	9	3	1	2		1	135
	Algoma					1	2						1			4
	Carnegie(ET)			1		1										2
	Colorado	*														
	Dominion															
	Gary		7	2	1	1	1									12
	Inland	1	4	3	2	4	3	7			2	1				27
	Lackawanna								4	2	1					7
	Maryland	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Steelton	4	19	11	11	9	8	4	7	7			1		1	82
	Tennessee		1													1
Total		5	31	17	14	16	14	11	11	9	3	1	2		1	135

*No CC rail rolled.

Note: (a) TF from shatter cracks due to use of improper cooling box covers. (b) TF from welded engine burns. (c) One TF from welded engine burn. (d) TF from silicate inclusion. (e) TF from small hole near welded joint. (f) TF from inclusion. SUMMARY—11 TF's from shatter cracks, 5 TF's from welded engine burns, 2 TF's from inclusions, 1 TF from mall hole near welded joint, 116 TF's from hot torn steel.

Fig. 3 shows the same information for each mill separately in graphical form. As previously stated, the high number of failures for the Carnegie (ET) mill is due primarily to the number of web failures reported. It will be observed that although the diagram for the total rollings of all mills shows a decline in rate of failures on the tenth year, this same pattern is not reflected in the reports for each individual mill.

Types of Failure

Table 6 is also of value in indicating the types of more prevalent failures. It will be observed that the compound fissure and detail fracture classification, together with the web failures, comprises about 75 percent of all failures reported, and the web failures within the limits of the joint bar represent 38 percent of all failures reported. It seems probable that the detail fractures to a large extent have developed from shelly spots, one of the research projects which is receiving special attention. The web failures reported within joint bar limits may be expected to be reduced by the new design of rail sections and the new bolt hole spacing. It is also to be expected that the work on lubrication and prevention of corrosion may have important possibilities in lowering this failure rate.

As shown by Table 8, the performance of control-cooled rail with respect to development of transverse fissures continues to be almost perfect. It is also gratifying to note that the number of transverse fissures from hot torn steel has been reduced from 19 in the 1936 rollings to only 2 in the rollings from 1946 to 1948, inclusive. This indicates that the action taken by the mills in correcting this condition has been effective.

Report on Assignment 4

Rail End Batter; Causes and Remedies

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This is a final report on the tests of various methods of building up rail ends by welding on the Richmond, Fredericksburg and Potomac Railroad near Penola, Va. in May 1941, which were mentioned in the Proceedings, Vol. 43, 1942, page 591.

It was desired to make the tests in a territory of heavy traffic. Several locations were inspected, but in some cases there was insufficient batter to justify welding. Finally a location on the southbound track on the R. F. & P., near Penola, Va., 30 miles north of Richmond, was selected. The traffic was about 14,000,000 gross tons per year at this site. Some of the rail was 130 PS and some 130 PS headfree. It was claimed that 75 percent of the rail ends had 0.020 in. or more batter, with quite a few having 0.030 to 0.040-in. batter. Unfortunately, it was found later that the poor surface was caused largely by loose bolts and worn joint bars rather than by actual batter of the rail ends. Some of the joint bars were shimmed and the bolts were tightened before the welding tests were started. Profiles made by the Graham magnified tracing instrument just before welding showed so little batter that the welding required was too little for a satisfactory test.

Nine railroads and one contract welder were invited to weld 50 joints each, using the procedures in use on their own railroads. Seven of the panels were welded by the oxyacetylene process, three panels by the d.c. electric arc process, and one panel by the a.c. electric arc process. The location of the test panels is shown in Fig. 1.

The welding was started on May 5, 1941, and was completed on May 12, 1941. One of the members of the subcommittee observed each welder and made a record of the net time required by the welder and helper to do the welding, and the amount of welding rod, oxygen and acetylene or gasoline used.

The procedure used on each panel was as follows:

Panel 1—Process A—AC Arc

No preparatory cleaning was done. The rail was preheated to 675 deg. F. by means of a propane-air heater. The power was furnished by a gasoline engine-driven alternating current generator, through a cable to a transformer at the welder, where the voltage was stepped down to give a welding current of 425 amp. Heavy-coated $\frac{1}{4}$-in. electrode was used. Immediately after welding, the rail was postheated by means of a propane-air heater to 1100 deg. F., and an asbestos shield was placed over the joint to keep it from cooling too fast. The surface was ground by a 4-cylinder gasoline engine-driven grinder using a 12-in. by $1\frac{1}{2}$-in. straight grinding wheel. The ends of the rails were slotted with a $\frac{5}{32}$-in. grinding wheel.

Panel 2—Process B—Gas

An Oxweld W–24 welding torch with No. 70 welding tip was used. The rail was heated up and upset with a hot-cut chisel. Oxweld MW $\frac{1}{4}$-in. by 36-in. welding rod was used. The weld was finished with a flatter.

Panel 3—Process C—DC Arc

Chips and laminations were ground out. The rail was preheated by a small portable propane heater to 400 deg. F. Power was furnished by an R. F. & P. 300-amp. gasoline engine-driven d.c. welding generator. Bare $\frac{1}{4}$-in. high-carbon alloy electrode with 300 amp. was used. The weld was started at the end of the rail with transverse beads tapering off at the end of weld. The surface was rough-ground with a Nordberg BG gasoline engine-driven grinder immediately after welding, and finish ground the next day by a Nordberg "Midget" grinder. The ends were slotted with a $\frac{3}{16}$-in. by 8-in. grinding wheel.

Panel 4—Process D—DC Arc

The rails were preheated by a kerosene-compressed air furnace to 600 deg. F. Power was furnished by the R. F. & P. 300-amp. gasoline engine-driven d.c. welding generator. Bare $\frac{3}{16}$-in. by 18-in. high-carbon electrode was used. The current was 220 amp. One bead was welded across the end of the rail, followed by several longitudinal beads. The surface was rough-ground with a Nordberg BG grinder and finish-ground with a Nordberg "Midget" grinder, and the ends were slotted with an 8-in. by $\frac{1}{8}$-in. grinding wheel.

Panel 5—Process E—DC Arc

Chips and laminations were ground out. No preheat was used. Power was furnished by the R. F. & P. 300-amp. gasoline engine-driven d.c. welding generator. Heavy mineral-covered electrode $\frac{7}{32}$-in. by 18-in. was used. The current was 250 amp. Longitudinal beads were welded across the joint when the ends were tight and the weld was cross slotted shortly after welding to prevent a crooked break. The surface was rough-ground with a Nordberg BG grinder and finish ground with a Nordberg "Midget" grinder, and the ends slotted with an 8-in. by $\frac{1}{8}$-in. grinding wheel.

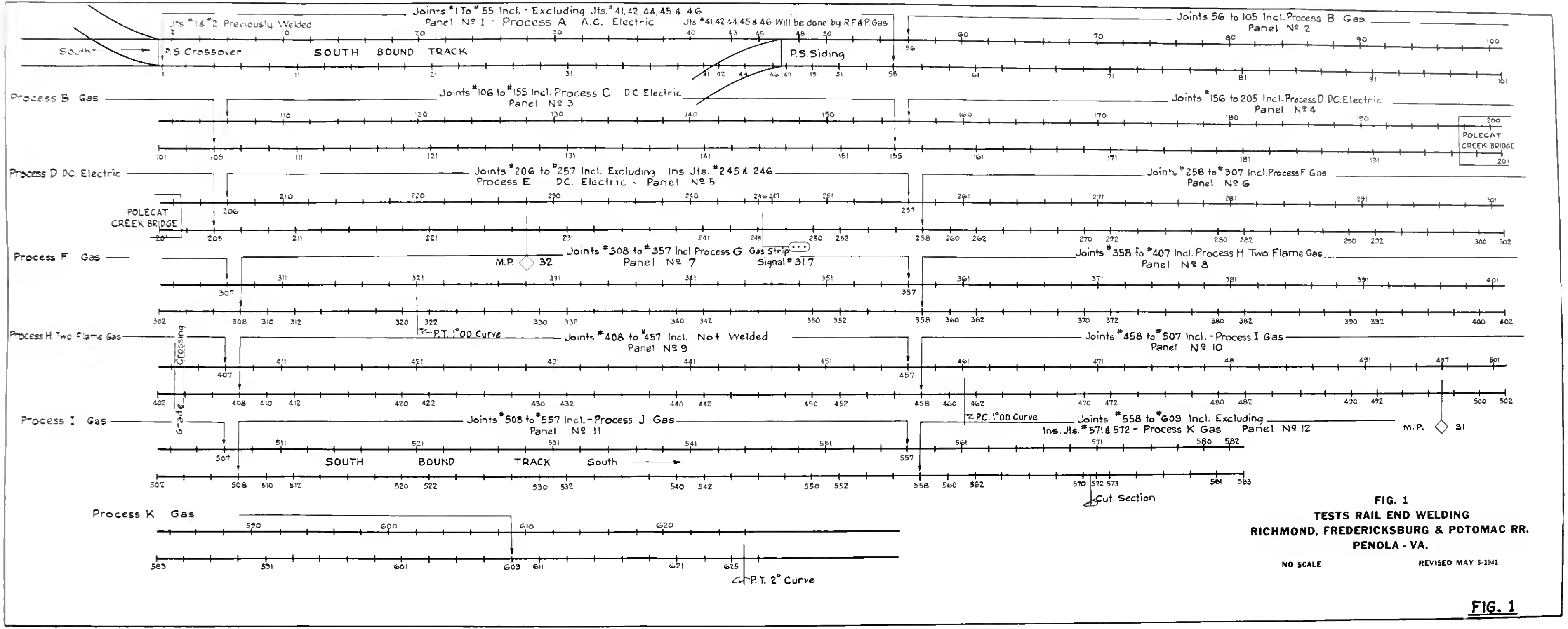

FIG. 1
TESTS RAIL END WELDING
RICHMOND, FREDERICKSBURG & POTOMAC RR.
PENOLA - VA.

NO SCALE

REVISED MAY 5-1941

FIG. 1

Panel 6—Process F—Gas

An Airco 9700 welding torch with No. 10 tip was used. The welding was done with Airco ¼-in. by 36-in. RR welding rod. The weld was rough-finished by hand hammering. The ends of the rail were heated with a torch and quenched with water from a sprinkling can to about 200 deg. F., and then tempered with the torch to about 650 deg. F. The surface was finished by a Nordberg CG cup-wheel grinder and slotted by a flexible-shaft attachment with a $\frac{3}{16}$-in. by 8-in. grinding wheel.

Panel 7—Process G—Gas "Strip Weld"

An Oxweld W-24 welding torch with a No. 70 tip was used. Three acetylene cylinders and one oxygen cylinder were mounted on a self-propelled cart, which saved labor in moving the cylinders. The exhaust of the gasoline engine kept the acetylene cylinders warm in winter to permit getting the maximum amount of acetylene out of the cylinders. The welding was done with ¼-in. by 36-in. Oxweld MW welding rod. No attempt was made to remove laminations, and some of the welds chipped at the ends later. A strip 1¼-in. wide was welded rapidly in the center of the head. The theory was that rapid welding on a cold rail would give a harder weld. However, the measured hardness was only 362 BHN, which was very little harder than the full-width gas welds made by the Process B. The welds were so thin that the wheels bore over the whole width of the head a short time after the welding. The surface grinding was done with a Railway Track-Work Company grinder with an 8-in. by 1¼-in. grinding wheel on the side, and an 8-in. by ⅛-in. grinding wheel, for slotting, on the other side.

Panel 8—Process H—Two-Flame Gas

Standard Airco equipment with a special two-flame tip was used. The welding rod was bare high-carbon flat strip ¾-in. by $\frac{1}{16}$-in. The welding was somewhat faster than with a single-tip, but it was more difficult to control the puddle. The oxygen and acetylene used were greater than with the other single-flame torches. The hardness of the welds was lower than produced by any of the other processes. The surface was ground free hand, with an angle-spindle cup-wheel flexible-shaft grinder. The surface was not as accurate as procured with the other grinders, which have guide wheels on the rail. The ends were slotted free hand, with an 8-in. by ⅛-in. grinding wheel on a straight hand piece with the same flexible shaft. The cross grinding was so poor that the ends had to be reslotted.

Panel 9—(Not Welded)

Panel 10—Process I—Gas

An Airco 9700 torch with a No. 10 tip and ¼-in. by 36-in. Airco RR welding rod was used. The rail was heated and the ends were upset with a hot-cut chisel, and the sides upset with a flatter. The surface was finished with a flatter so that only a very small amount of welding rod was used. The rail was heated and quenched with water from a sprinkling can, and was then tempered with the torch to 650 deg. F. The surface was not ground nor were the ends slotted. In some cases there was a hollow about 3 in. from the end of the receiving rail. The rail was heated and hammered so many times that the total cost of labor and material was nearly the same as for the other panels where the rail ends were welded without upsetting. The hardness of the weld was about the same as in Process B, which was not heat treated.

Panel 11—Process J—Gas

An Oxweld W-24 welding torch with No. 70 tip was used. The welding rod was ¼-in. by 36-in. Oxweld MW. The rail was heated and the ends upset with a hot-cut chisel and hammered some on the sides. The remainder of the batter was built up the desired amount by welding. The surface was finished and slotted by a Nordberg CG grinder.

Panel 12—Process K—Gas

An Airco 9700 torch with No. 10 tip was used. The welding rod was ¼-in. by 36-in. Airco RR. The rail was heated and upset considerably with a hot-cut chisel and a flatter. Very little welding rod was used. The surface was finished with a flatter. The rail was heated to 1400 deg. F. and was quenched with a measured amount of water from a sprinkling can down to 200 to 250 deg. F. The metal was not tempered with a torch, but the residual heat in the rail heated the surface to a temperature of 450 to 500 deg. F., giving an average hardness of 407.4 BHN.

Profiles were drawn by a Graham profile machine (which magnifies the vertical distance 50 times) at 10 joints of each panel before and after welding. These profiles are misleading as some of the joints sagged due to the impact of the train wheels after they were welded and ground.

TABLE 1

Process		*Avg. length in.*	*Avg. lb. rod*	*Avg.* welding time, min.*	*Avg. BHN*	*Defects June 19, 1946,*		
						Small	*Large*	*Total*
A	AC elec.	7.06	0.550	3.08	368.1	1	0	1
B	Gas	4.49	0.053	11.20	355.5	8	0	8
C	DC elec.	5.40	0.440	3.38	353.4	10	1	11
D	DC elec.	8.03	0.600	6.44	321.9	3	7	10
E	DC elec.	7.00	0.530	4.48	345.3	22	4	26
F	Gas	7.66	0.130	20.40	435.1	6	1	7
G	Gas strip	8.20	0.135	7.60	362.2	7	1	8
H	Gas	6.61	0.200	8.68	301.0	9	0	9
I	Gas	6.50	0.024	17.00	356.0	3	1	4
J	Gas	5.40	0.130	17.46	326.4	5	0	5
K	Gas	3.74	0.030	16.66	407.4	11	0	11

* Does not include grinding time

All of the joints were inspected on July 15, 1942, October 3, 1944, and June 19, 1946. Notes were made of defects and profiles were made of 10 joints of each panel by a 10-in. batter gage of the type shown on page 4-53 in the AREA Manual. No definite conclusions on the relative wear of the various methods of welding can be made from these measurements as low joints, worn joint bars, and loose bolts affected the profiles. The defects found at the inspection on June 19, 1946, are shown in Table 1. The spalling of Process D—d.c. electric welds—was probably caused by improper welding technique. The large number of chips in the Process E—d.c. electric welds—probably were caused by not preheating. Some of the chips in the Process K welds may have been caused by improper heat treatment.

A record was made of the net time required to weld the 50 joints in each panel and of the pounds of welding rod and supplies. The grinding equipment used in some panels was not the same as ordinarily used by the particular railroad. No accurate costs of interest, depreciation and repairs on the electric welding equipment could be obtained.

The conditions of the test and some of the welders were not representative of the railroads involved. Therefore, no estimate of the costs is given in this report.

Conclusions

The following general conclusions seem to be justified:

(1) Satisfactory welding can be done by either the oxyacetylene or electric arc process.

(2) The cost of labor and fuel is higher for the oxyacetylene process than the electric arc.

(3) The investment in equipment for the oxyacetylene process is less than that for the electric arc process.

(4) The cost of reconditioning rail ends by heating and forging is nearly the same as that of building up by welding by the oxyacetylene process.

(5) There is no advantage of multiflame oxyacetylene tips.

(6) The rail should be preheated before electric welding.

(7) Grinding produces a better surface than finishing by forging.

(8) The skill of the welder is a very important factor.

Report on Assignment 5

Economic Value of Various Sizes of Rail

A. A. Shillander (chairman, subcommittee), C. H. Blackman, W. J. Burton, B. Chappell, C. M. Chumley, C. J. Code, R. A. Emerson, J. L. Gressitt, G. F. Hand, C. B. Harveson, E. M. Hastings, W. B. Leaf, E. E. Mayo, Ray McBrian, B. R. Meyers, R. E. Patterson, J. G. Roney, E. F. Salisbury, W. D. Simpson, G. L. Smith, H. F. Whitmore, Barton Wheelwright.

Your committee submits the following report of progress as information. It is a continuation of maintenance charges in Study A for last year, computed to show average for six years.

Study A

RESULT OF STUDY OF ILLINOIS CENTRAL RAILROAD

Test Sections of 112-lb. and 131-lb. Rail

112-lb. Rail	
M.P. 163.68 to M.P. 172.73 (Laid in 1942)	
M.P. 152.24 to M.P. 163.68 (Laid in 1943)	
(Station 10142+58 to Station 11224+95)	
Total track miles maintained (108,173 track ft.)	20.48
No. turnouts maintained	18
No. railroad crossings maintained	1
No. public grade crossings maintained	22
No. private grade crossings maintained	2

131-lb. Rail	
M.P. 132.00 to M.P. 152.24 (Laid in 1944)	
(Station 11224+95 to Station 11293+98)	
Total track miles maintained (106,747 track ft.)	20.21
No. turnouts maintained	21
No. railroad crossings maintained	3
No. public grade crossings maintained	22
No. private grade crossings maintained	6

BOTH TEST SECTIONS COMPUTED AT 1944 PRICES

Average annual traffic density—28,000,000 gross tons

Rail and Other Track Material		*Investment Charges Per Mile*
Gross Cost	$12,643	$14,413
Less est. salvage	Cr. 4,284	Cr. 5,011
Net cost	8,359	9,402
Total cost to lay	1,338	1,473
Total cost to place	9,697	10,875
Estimated life-years	15	25
Annual Cost		
Rail and other track material	$ 557	$ 376
Laying	89	59
Interest at 6%*	839	953
Total annual cost	$1,485	$1,388
Percent decrease in investment cost		Cr. 6.5

AVERAGE OF SIX YEARS

Maintenance Charges Per Mile
112 lb. *131-lb.*
Annual Cost *20.48 Mi.* *20.66 Mi.*†

Annual Cost	*Maintenance Charges Per Mile* *112 lb.* *20.48 Mi.*	*131-lb.* *20.66 Mi.*†
Labor hours	1111	861
Cost at $.90	$1,000	$ 775
Cross ties	284	210
Cost at $2.60	$ 738	$ 547
Ballast (slag)	328 cu. yd.	227 cu. yd.
Cost at $.781	$ 257	$ 178
Total maintenance	$1,995	$1,500
Percent saving		Cr. 24.8
Total annual cost	$3,480	$2,888
Saving by use of 131-lb. material		$ 592
Percent saving		17.0

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* On gross outlay for material and labor.

† Adjusted for 3 additional turnouts; 2 additional railroad crossings, and 4 additional highway crossings by data in AREA Manual, p. 22-15.

Report on Assignment 7

Service Tests of Various Types of Joint Bars

T. A. Blair (chairman, subcommittee), J. B. Akers, H. B. Barry, W. J. Burton, E. E. Chapman, C. M. Chumley, C. J. Code. L. S. Crane, P. O. Ferris, R. L. Groover, S. R. Hursh, L. R. Lamport. W. B. Leaf, E. E. Mayo, Ray McBrian, E. H. McGovern, R. A. Morrison, Embert Osland, R. E. Patterson, W. C. Perkins, J. C. Ryan, W. D. Simpson.

This is a progress report, presented as information. The field work, analysis of data and report of measurements covered in this report were carried out by the Engineering Division research staff of the Association of American Railroads, under the direction of G. M. Magee, research engineer, by Olaf Froseth, assistant track engineer, M. F. Smucker, assistant electrical engineer, and Kurt Kannowski, rail engineer, assisted by other staff members.

Description of the 1948 Service Test Installations

The report of the committee last year described the two service test installations of various designs of joint bars for the new 115 and 132 RE rail sections. Actual cross-section designs of the joint bars were not included in the report, however, and it was thought desirable to give these data this year as a matter of information. Fig. 1 shows the cross section and essential mechanical properties of the joint bars included in the 132 RE test on the Atchison, Topeka & Santa Fe Railway and Fig. 2 shows similar information for the 115 RE test on the Chicago & North Western Railway. The Santa Fe test includes the new AREA design of joint bar, headfree type, as shown in the Manual, page 4–28, with three different bolt spacings: the old AREA spacing, the new AREA spacing, and an experimental spacing using 4 bolts only in a 36-in. bar. It also includes, with the old AREA spacing, the Rail Joint Company K–42 design of short-toe bar and the K–44 design of long-toe or angle bar.

The North Western test includes the new AREA headfree design of joint bar for 115 RE rail as shown in the Manual, page 4–27, with two different bolt spacings: the new AREA spacing, and the experimental spacing, using 4 bolts only in a 36-in. bar. In addition, and using only the new AREA spacing, is included the R. J. Co. heavy design of short-toe bar (K–4), the light, design of short-toe bar (K–22), and the long-toe or angle bar design (K–24). All bars are 36 in. long except the angle bar, which is 39 in.

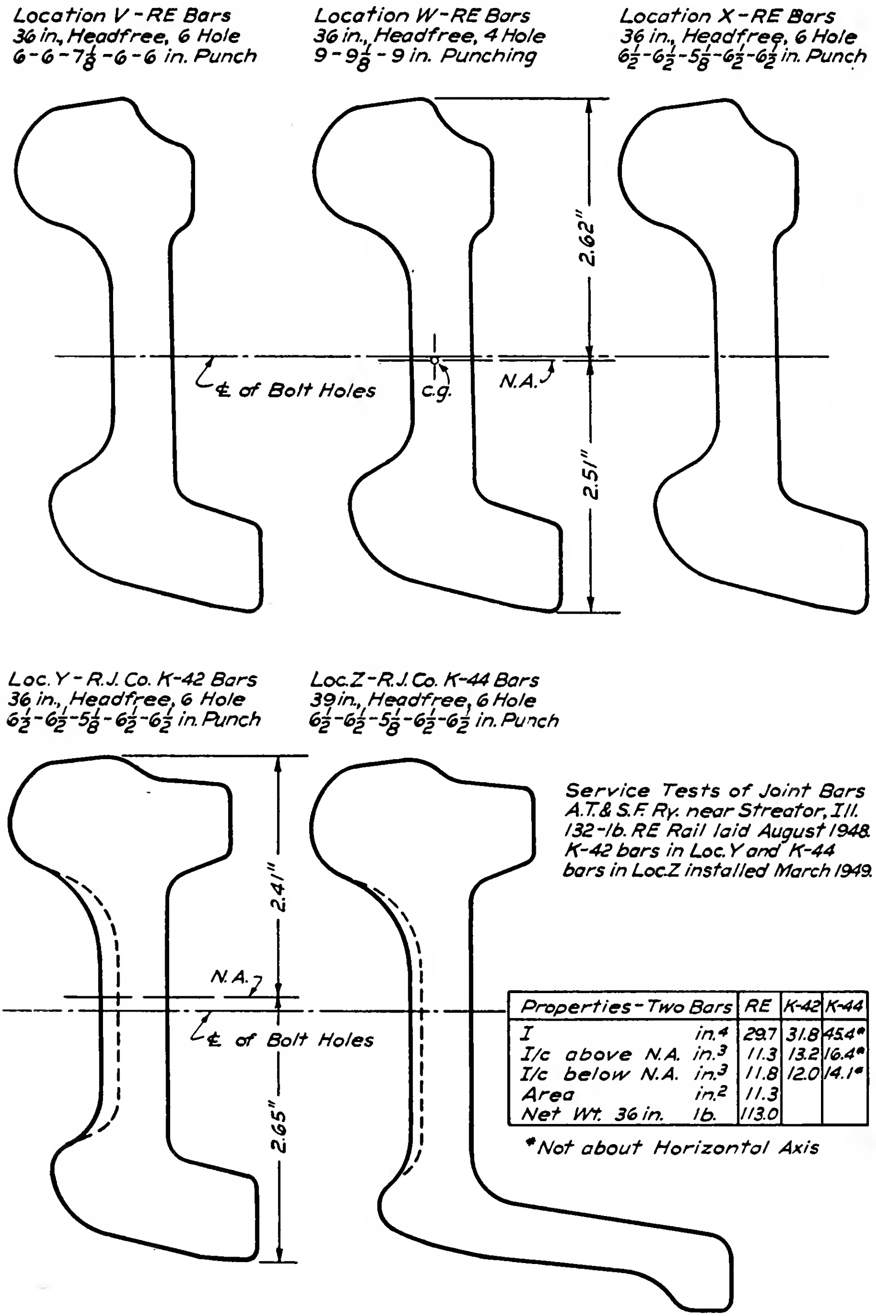
The report last year included an analysis of stress measurements made on the Santa Fe test under regular traffic during November 1948. Similar stress measurements were made on the North Western test in May–July 1949, and the results obtained in these measurements are presented herewith.

Description of the North Western Stress Measurements

As described in last year's report, the test sections for the new 115 RE rail were installed on the westbound main track of the Chicago & North Western Railway near Sterling, Ill., 106 miles west of Chicago on the Omaha line. Each test section includes 100 joints and is approximately 2000 ft. long. Location EE, the long-toe or angle bar design, was added in May 1949, the other sections having been placed in November 1948. This test installation, as shown in Fig. 3, now includes the following sections, all on tangent track:

Location AA—115 RE headfree. 36 in. 9–9⅛–9 in. punching, 4-hole bars.
Location BB—115 RE headfree, 36 in. 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars.
Location CC—115 R. J. Co. K–22, headfree, 36 in., 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars.
Location DD—115 R. J. Co. K–4, headfree, 36 in., 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars.
Location EE—115 R. J. Co. K–24, headfree, long-toe design, 39 in., 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars.

In order to facilitate the field work and minimize expense, the test house was set up at the juncture between Locations AA and BB. Stresses were measured in the 4-hole bars of the 6 rail joints at the extreme east end of Location AA; 3 joints on both the north and south rails. Then stresses were measured in the 6 adjacent rail joints at the extreme west end of Location BB with the original 6-hole BB bars. Later, these bars were removed and successively stresses were measured in 6 pairs of bars from Locations CC, DD and EE installed in the same 6 rail ends at Location BB.

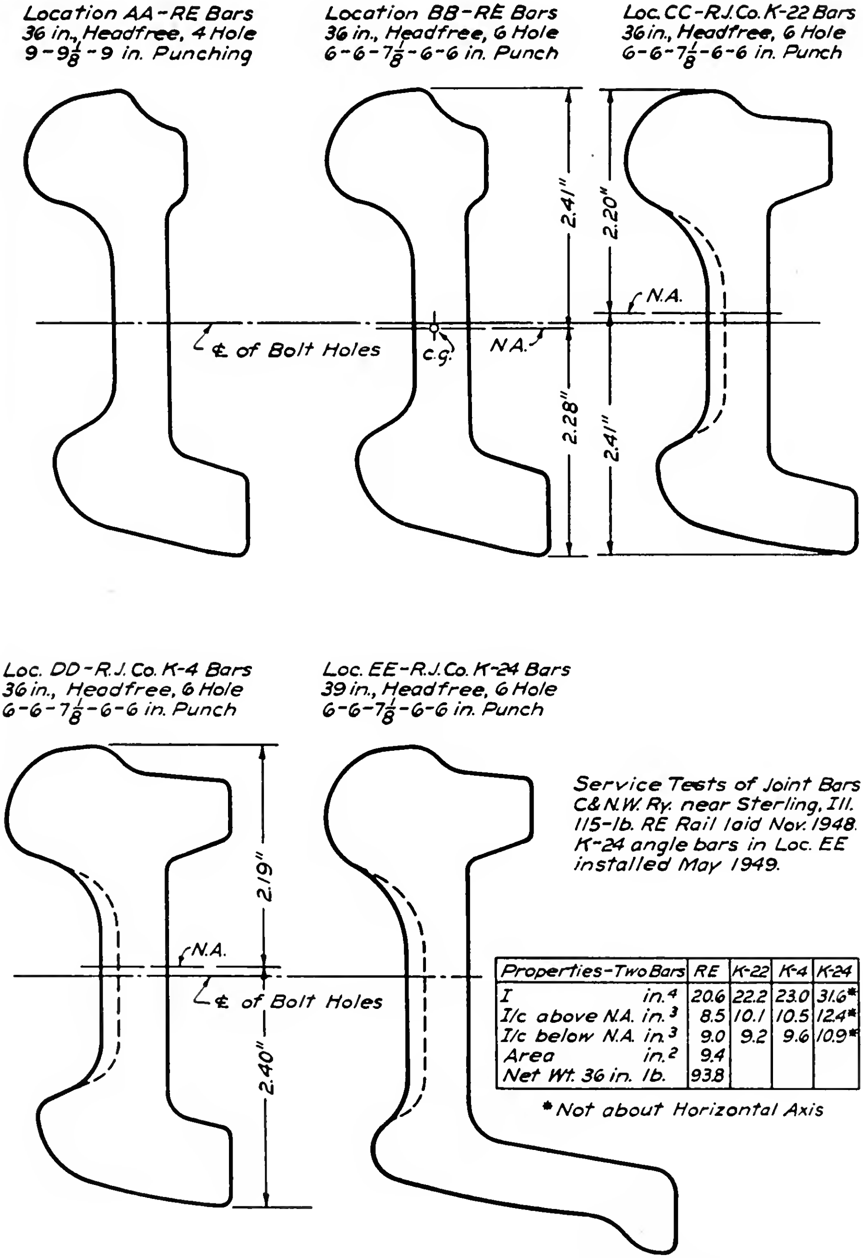


Service Tests of Joint Bars
A.T.& S.F. Ry. near Streator, Ill.
132-lb. RE Rail laid August 1948.
K-42 bars in Loc. Y and K-44
bars in Loc. Z installed March 1949.

Properties - Two Bars		RE	K-42	K-44
I	in.^{4}	29.7	31.8	45.4*
I/c above N.A.	in.^{3}	11.3	13.2	16.4*
I/c below N.A.	in.^{3}	11.8	12.0	14.1*
Area	in.^{2}	11.3		
Net Wt. 36 in.	lb.	113.0		

*Not about Horizontal Axis

Fig. 1. Cross sections of joint bars included in service tests, A. T. & S. F. Ry., near Streator, Ill.



Location AA-RE Bars
36 in., Headfree, 4 Hole
9-9$\frac{1}{8}$-9 in. Punching

Location BB-RE Bars
36 in., Headfree, 6 Hole
6-6-7$\frac{1}{8}$-6-6 in. Punch

Loc. CC-R.J. Co. K-22 Bars
36 in., Headfree, 6 Hole
6-6-7$\frac{1}{8}$-6-6 in. Punch

Loc. DD-R.J. Co. K-4 Bars
36 in., Headfree, 6 Hole
6-6-7$\frac{1}{8}$-6-6 in. Punch

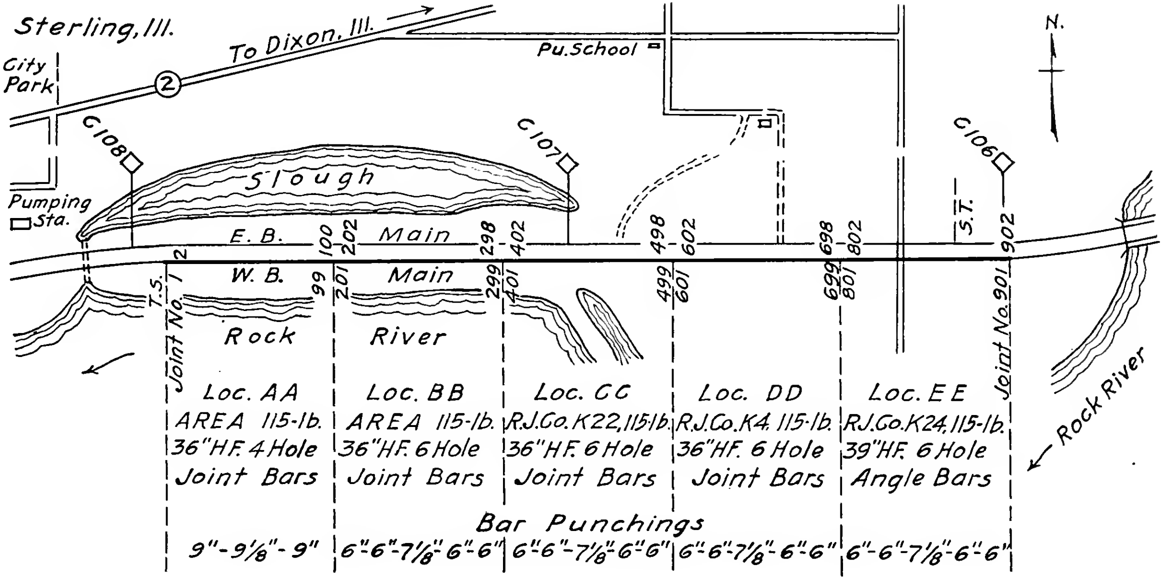
Loc. EE-R.J. Co. K-24 Bars
39 in., Headfree, 6 Hole
6-6-7$\frac{1}{8}$-6-6 in. Punch

Service Tests of Joint Bars
C&N.W. Ry. near Sterling, Ill.
115-lb. RE Rail laid Nov. 1948.
K-24 angle bars in Loc. EE
installed May 1949.

Properties-Two Bars	RE	K-22	K-4	K-24
I in.^{4}	20.6	22.2	23.0	31.6*
I/c above N.A. in.^{3}	8.5	10.1	10.5	12.4*
I/c below N.A. in.^{3}	9.0	9.2	9.6	10.9*
Area in.^{2}	9.4			
Net Wt. 36 in. lb.	93.8			

* Not about Horizontal Axis

Fig. 2. Cross sections of joint bars included in service tests, C. & N. W. Ry., near Sterling, Ill.



Notes: 115-lb. RE Rail in West Bound Main Track laid in November 1948.
R. J. Co. K24, Angle Bars in Location EE installed in May 1949.

Fig. 3.— Service Test of Joint Bars, C. & N. W. Ry. at Sterling, Ill.

Because of the variability in stress from joint to joint in railway track, it was decided to increase the number of joints tested of each design to six rather than to test only two, as was done in the Santa Fe test. Also, it did not appear that any information of value beyond that already obtained would be secured by measuring stresses at other locations on the bar than at midlength where the bending stresses are a maximum. Accordingly, two stress measurements were made with SR–4 strain gages on each bar placed at midlength, one gage being placed to measure the bending stress at the top extreme fiber of the bar and the other as near to the bottom extreme fiber as possible. Fig. 10 shows the position on the cross section at which the gages were located, gage position 2 being at the top and gage position 5 at the bottom.

Effect of Train Speed

In order to show the effect of train speed on the joint bar stresses, Figs. 4 to 8 have been prepared. Fig. 4 shows the maximum dynamic stress obtained for each run for locomotives and cars with respect to speed for the test joint of Location AA that showed the highest stress of the six test joints. Figs. 5 to 8 show the same information for the other test locations.

It will be observed that the stress values do not seem to be appreciably affected by the train speed in any of these five figures. The magnitude of stress is generally about the same throughout the speed range included in the tests on tangent track. This corresponds with the results found in the Santa Fe tests, as reported last year.

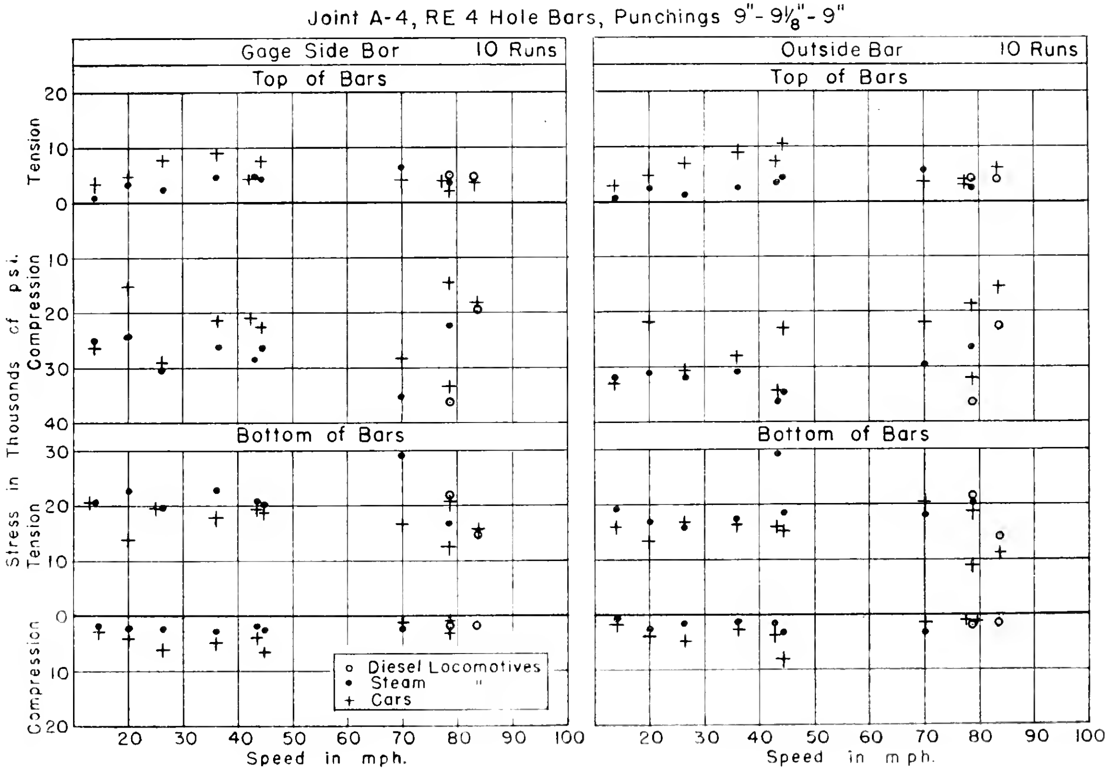
Range of Dynamic Stresses

A comparison of the average maximum stresses and single maximum stresses obtained at the six test joints for the five different test locations is shown in Fig. 9. It was hoped by increasing the number of test joints to six that the variability from joint to joint could be rather well averaged out. However, this was not found to be true because it happened that for Location AA two of the six joints had stresses considerably above the other four, and Location BB had one joint with stresses much higher than the other five. For Locations CC, DD and EE the stresses were reasonably uniform in all six joints and below what would be expected. Since the bars for these locations were temporarily placed on the test rail ends at Location BB in order to measure the stresses, it seems probable that they did not have an opportunity to become well seated, and accordingly were not affording the joint support and developing the resisting movement that they would otherwise have developed.

Fig. 9 does serve, however, to give an idea of the range of bending stresses developed in the 115 RE joint bars in service for comparison with the range of stress applied in the fatigue tests in the rolling-load machines. The stress values for Locations AA and BB are probably representative because the test bars for these joints had been well seated by traffic. There seems to be no important difference in stress between the four and six-hole bars of these two locations. It remains to be determined whether there will be any difference in joint batter and droop from reducing the number of bolts from six to four. The range of average maximum stresses at the top of the bars in these two locations varies from about 8000 psi. tension to 22,000 psi. compression; at the bottom of the bars from 5000 psi. compression to 15,000 psi. tension.

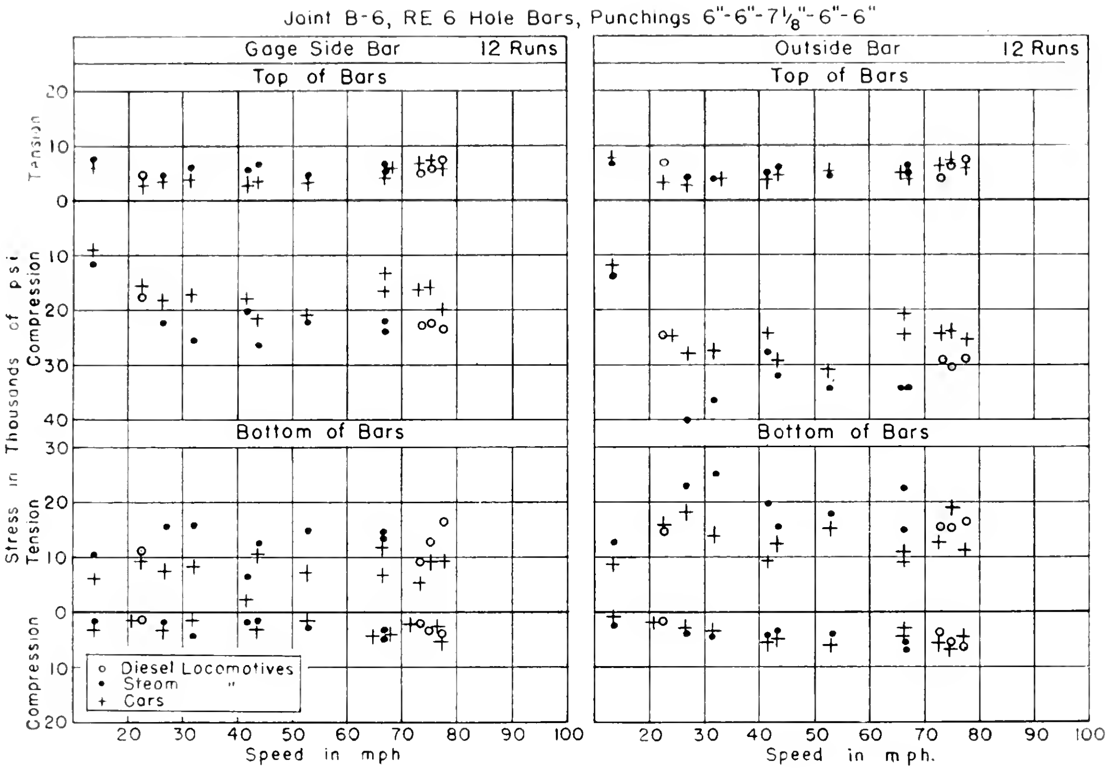
Frequency of Stress Occurrence

The fatigue life of joint bars will depend upon the frequency with which high stress ranges are developed under traffic. Accordingly, for joint B–6 of Location BB, which showed the highest stresses for any of the 6 joints of this location, the 12 test runs were



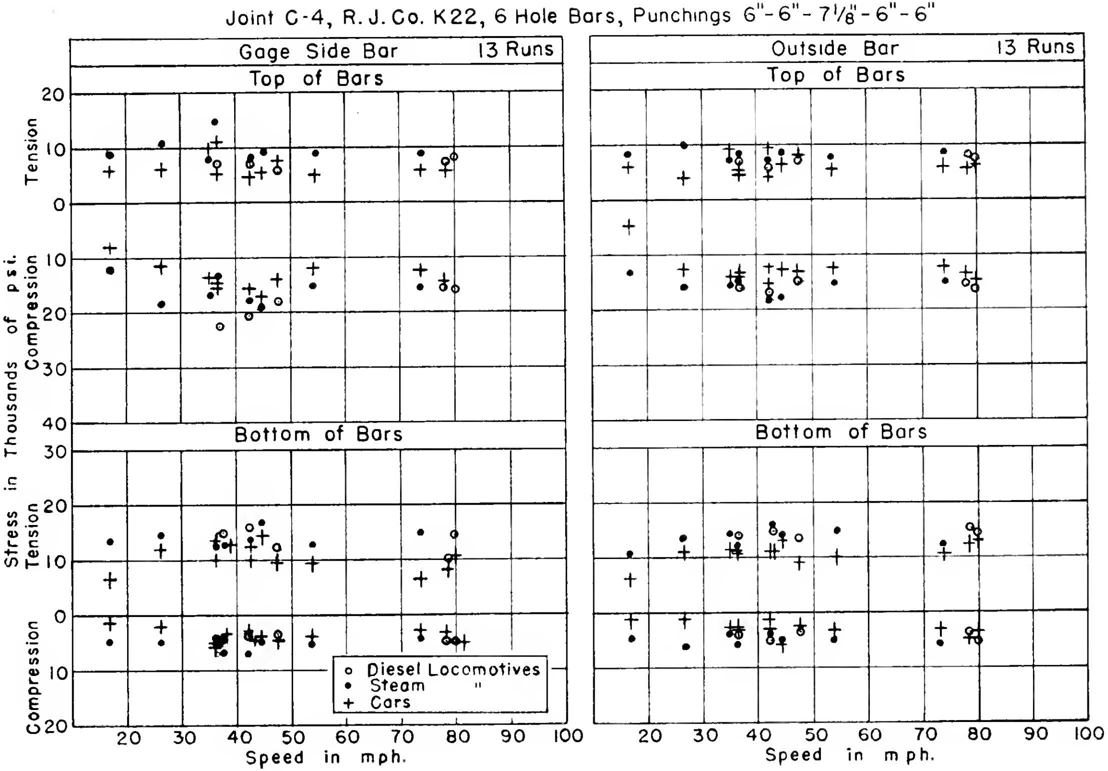
Note:
Position of SR 4 Strain Gages Shown on Fig. 10

Fig. 4. Maximum dynamic stresses at middle of 115-lb. 36 in. H.F. Joint bars, Location AA. C. & N. W. Ry.



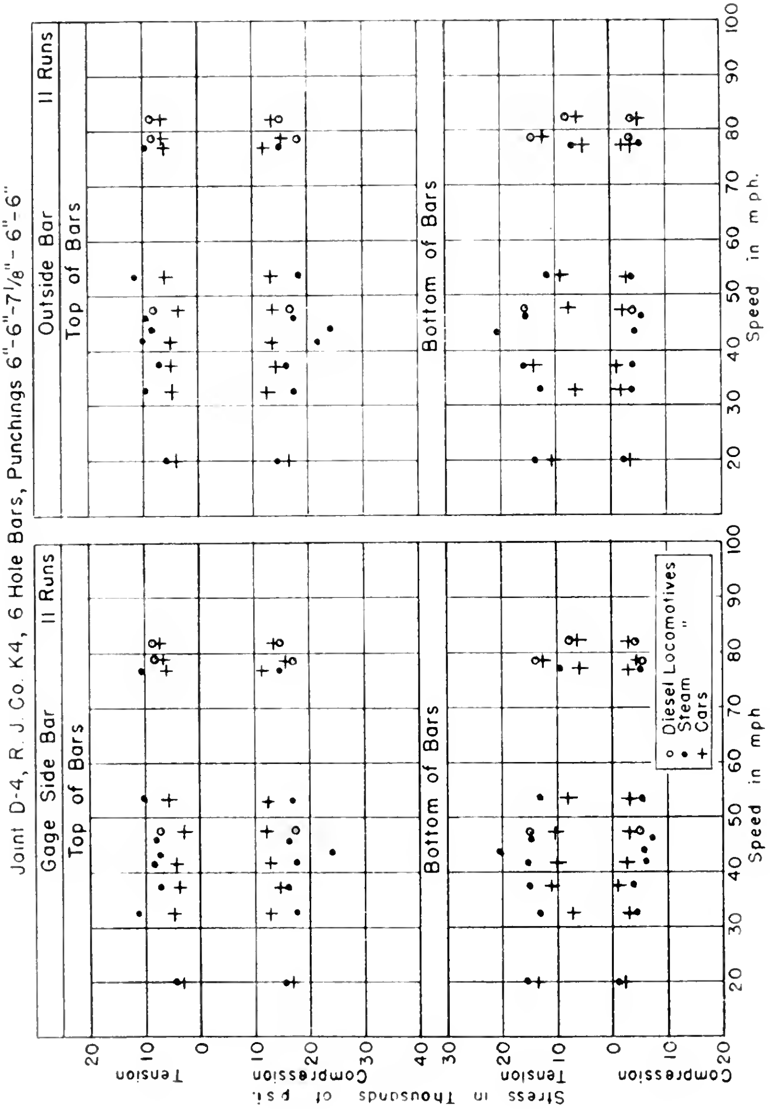
Note:
Position of SR 4 Strain Gages Shown on Fig 10

Fig. 5. Maximum dynamic stresses at middle of 115-lb. 36 in. H.F. Joint bars, Location BB, C. & N. W. Ry.



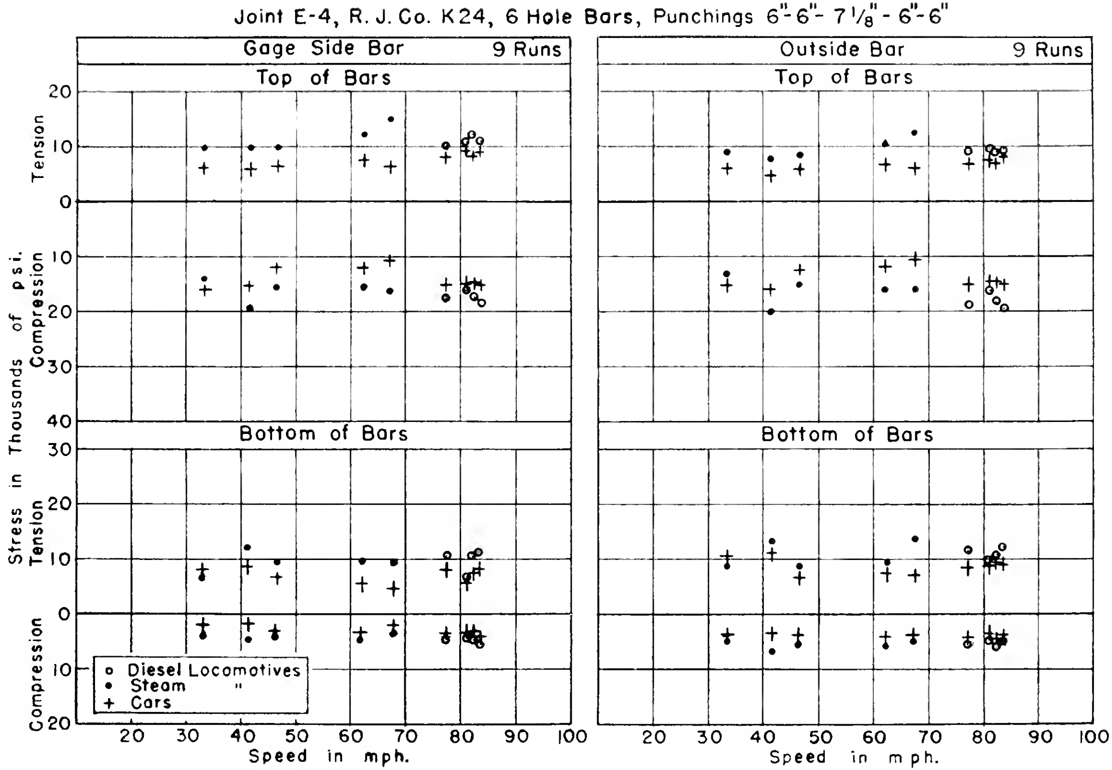
Note:
Position of SR 4 Strain Gages Shown on Fig. 10

Fig. 6. Maximum dynamic stresses at middle of 115-lb. 36 in. H.F. Joint bars, Location CC, C. & N. W. Ry.



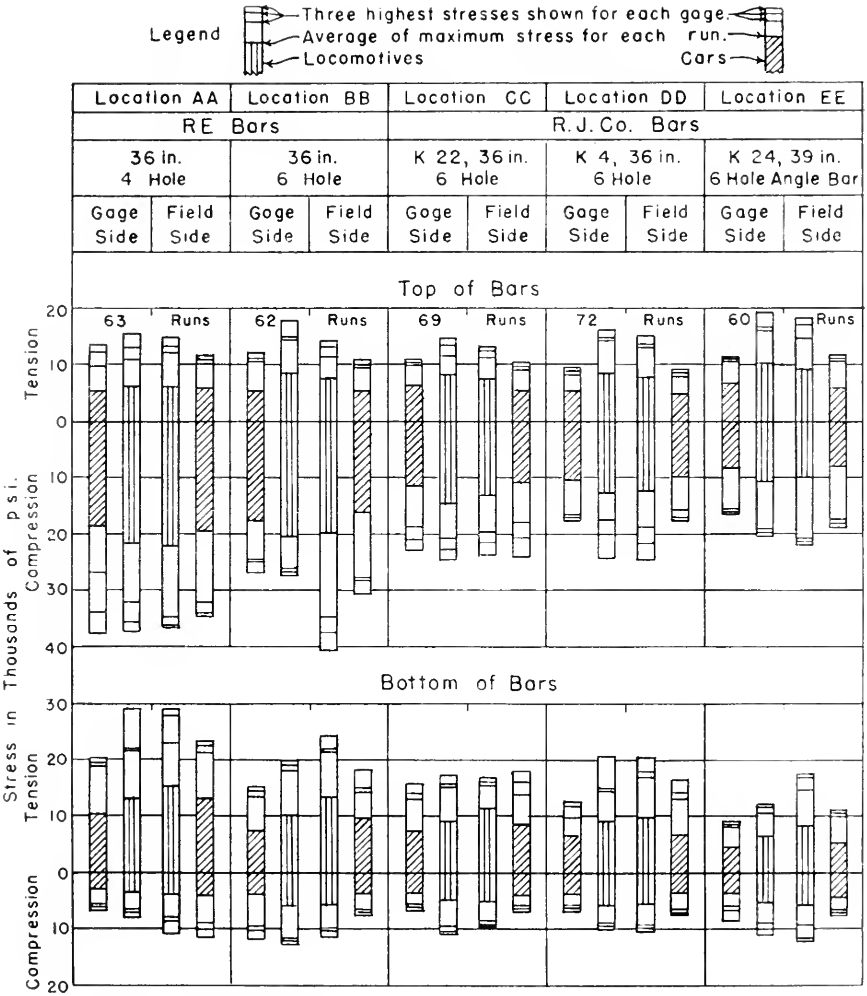
Note
Position of SR 4 Strain Gages Shown on Fig.10

Fig. 7. Maximum dynamic stresses at middle of 115-lb. 36 in. H.F. Joint bars, Location DD, C. & N. W. Ry.



Note:
Position of SR 4 Strain Gages Shown on Fig. 10

Fig. 8. Maximum dynamic stresses at middle of 115-lb.39 in. H.F. Angle bars, Location EE. C. & N. W. Ry.



Notes: Stresses measured from records of runs over six rail joints
Position of SR-4 Strain Gages shown on Fig. 10

Fig. 9. Dynamic stresses at middle of 115-lb. H.F. Joint bars, C. & N. W. Ry.

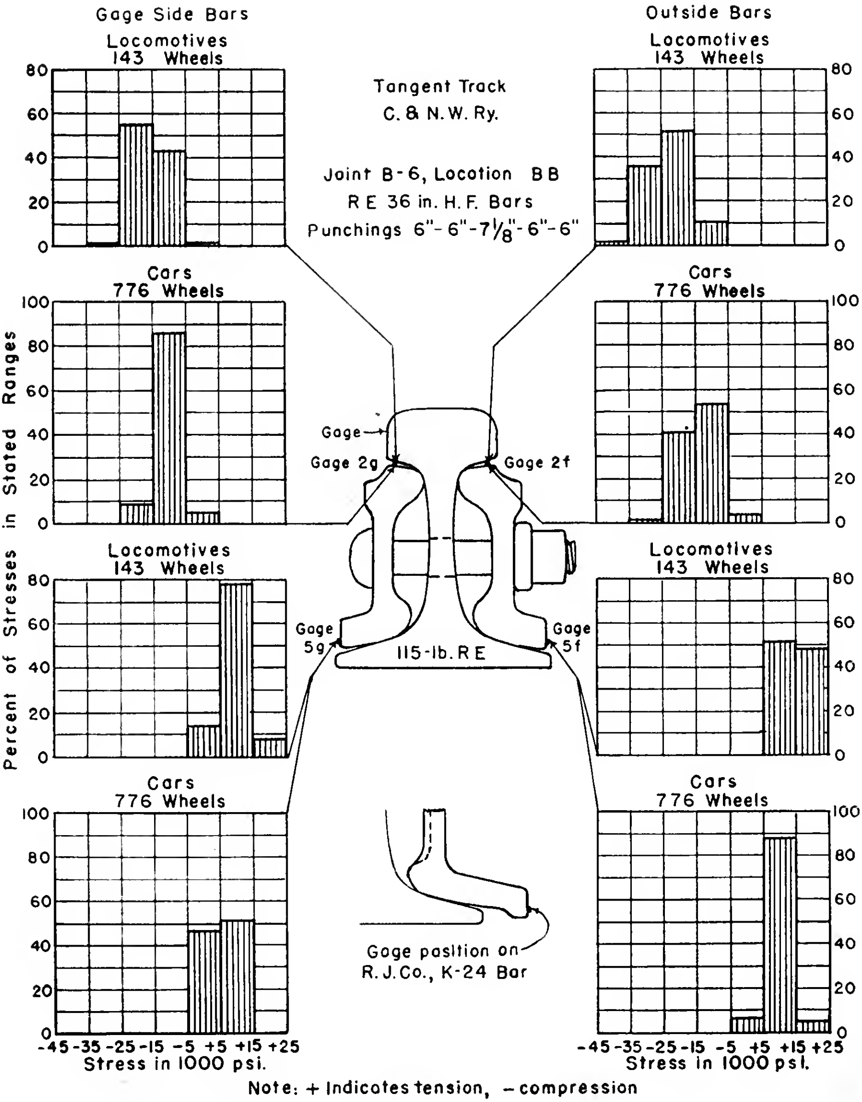


Fig. 10. Frequency of occurrence of stresses at middle of joint bars.

analyzed, and in Fig. 10 the measured stresses are shown with reference to their frequency of occurrence. For this joint, which had unusually high stresses, the range of stresses developed in service appears to be well within the fatigue strength as determined by the laboratory rolling-load tests. Stresses measured at the bottom of the bars are the best index for comparison with the laboratory tests, because they are not affected by localized bearing pressures to the same extent as the stresses measured at the top. It will be observed that the maximum tension stress under locomotives does not exceed 25,000 psi. This stress applied to the section modulus of 9.0 for two joint bars gives an applied bending moment in service of 225,000 in.-lb., whereas 400,000 in.-lb. is applied in the laboratory rolling-load machines.

Annual Observations of Rail Joint Performance

The yearly measurements of rail surface profile, joint camber and out-to-out distances of bars were made on the Santa Fe and the North Western installations during the summer of 1950. These data are not reported because to date no significant results have been obtained.

Conclusions

The same conclusions can be drawn from these tests on 115 RE joint bars as were given in the committee report last year for the 132 RE joint bars. The results obtained in these tests on tangent track indicate that the stresses developed in service in the new AREA headfree design and the Rail Joint Company K–4, K–22, and K–24 designs of joint bars for 115 RE rail are well within the fatigue strength of the bars as determined by laboratory tests. It may be expected that the stresses will be higher on curved track, but the reserve appears sufficient to give assurance that these designs of joint bar will give satisfactory service from the standpoint of development of fatigue failures.

Report on Assignment 8

Joint Bar Wear and Failures; Revision of Design and Specifications for New Bars and Bars for Maintenance Repairs

E. E. Chapman (chairman, subcommittee), J. B. Akers, H. B. Barry, T. A. Blair, W. J. Burton, C. M. Chumley, C. J. Code, L. S. Crane, W. J. Cruse, P. O. Ferris, R. L. Groover, S. R. Hursh, L. R. Lamport, E. E. Mayo, Ray McBrian, E. H. McGovern, R. A. Morrison, Embert Osland, R. E. Patterson, W. C. Perkins, J. C. Ryan, W. D. Simpson.

This is a progress report, submitted as information, including in Appendix 8–a a progress report on rolling-load tests of joint bars being conducted at the University of Illinois under the direction of R. S. Jensen, and in Appendix 8–b, a progress report of the service test of 112-lb. joint bars of four metallurgies on the Burlington Railroad, near Fort Morgan, Colo.

One meeting was held by this subcommittee during the year. At this meeting it was decided to follow up the recommendations made by Subcommittee 8 in March 1945, in Summary Paragraph 4 at end of its report, which reads as follows: The hardness of joint bars generally bears a consistent relation to the fatigue life, the harder bars having the longer fatigue life and vice versa, within the range of hardness encountered in the tests.

To date, no test joint bars, rolled, heated, punched and quenched had been made from the same heat and the exact conditions observed from the open hearth to the finished bar. Therefore, arrangements were made to have observations made on two sets of joint bars made up as follows:

1. Thirteen sets of rolled joint bars for 132 RE rail, to be heated to the proper temperature, so that the physical properties will be well above that required in the joint bar specification.

2. Thirteen sets of rolled joint bars for 132 RE rail, to be quenched at a temperature sufficiently low, so that the physical properties will not meet specification requirements for tensile and yield strengths.

3. In addition, 50 sets of joint bars will be held in bar form from the same heat for possible future tests, all of these to be of the new 132 RE headfree design, 36 in. in length, with new bolt hole spacing for 1 in. diameter track bolts.

Arrangements were made to have R. E. Cramer, metallurgist, present during the rolling, forming, punching and heat treating of these bars and also to collect the necessary data on the complete process, including the heat-treating data.

Physical, chemical and metallurgical tests will be made, as well as rolling-load tests, on these two sets of differently treated bars.

On recommendation of this subcommittee, revisions to the Joint Bar specifications are presented in the report of Subcommittee 1—Revision of Manual.

To round out the complete test, a rolling-load test, and also various physical, chemical and metallurgical tests, will be made on 12 bars of the Rail Joint Company's K–22 design and 12 bars of the Rail Joint Company's K–4 design for the new 115 RE rail section.

Appendix 8–a

Ninth Progress Report of the Rolling-Load Tests of Joint Bars

By R. S. Jensen

Research Assistant Professor of Engineering Materials, University of Illinois

Introduction and Acknowledgment

This report covers 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. Joint bar wear and failures; revision of design and specifications for new bars and bars for maintenance repairs. E. E. Chapman, mechanical assistant to assistant to vice president, Atchison, Topeka and Santa Fe Railway. is chairman of the subcommittee for this assignment. The work is sponsored and financed by the Association of American Railroads.

Acknowledgment is made of the services of Lewis Franklin and Elmer Hunt, mechanicians in the Talbot Laboratory shops, and Burton Davis, graduate assistant.

Testing Machines and Test Specimens

Joint bar tests were made in three 33-in. 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 Proceedings, Vol. 44, 1943, page

TABLE 1. PHYSICAL PROPERTIES OF JOINT BARS

Bar type	Joint No.	Brinell hardness cross section	Tensile strength psi.	Yield strength psi.	Reduction of area percent	Elongation 2 in G.L. percent
131K4 HF	168N	276	132,200	86,800	45.0	17.0
" "	169S	275	136,300	93,000	23.4	12.0
" "	170N	274	133,000	88,200	41.9	16.0
" "	171N	281	133,000	87,100	42.8	15.5
" "	172N	245	116,200	74,300	39.3	17.0
" "	173S	268	132,500	86,800	37.7	15.0
" "	186S	280	132,300	87,200	40.8	16.0
" "	187S	271	130,000	87,400	33.2	14.0
" "	188S	283	135,500	90,600	36.8	14.5
" "	189N	265	129,500	84,500	37.8	16.0
" "	190N	268	131,500	85,500	39.3	17.0
" "	191N	272	131,500	86,000	41.5	16.0
115K22 HF	192N	207	111,700	69,600	48.4	20.0
" "	193S	186	99,200	61,400	55.9	24.0
" "	194S	201	105,500	64,400	49.3	21.0
" "	195N	176	98,800	61,400	53.2	24.0
" "	196S	213	108,600	71,700	49.5	21.0
" "	197N	176	95,600	58,300	52.7	24.0
" "	198N	179	95,400	59,200	54.8	25.0
" "	199S	194	106,500	66,100	49.1	20.0
" "	200N	202	112,000	78,600	41.1	20.0
" "	201N	196	105,000	60,900	41.6	22.0
" "	202S	170	94,800	52,200	46.3	25.5
" "	203N	188	97,900	61,500	55.6	24.0

The chemical analysis for the heat from which the 115 K22 were rolled is as follows:
Heat 11390, carbon 0.48, manganese 0.71, phosphorous 0.012, sulfur 0.030.

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.

Results of Rolling-Load Tests

Twenty-four tests on joint bars have been completed since the last annual report was published; these include 12 tests on 131 K4 headfree 39-in., long-toe bars, and 12 tests on 115 K22 headfree 36-in. bars. The 131 K4 bars had a lateral center overfill of 1/64 in. over an 8 in. length. Unfortunately, these bars, which were rolled in 1945, contained no stamped serial number, and consequently the heat analysis could not be located. However, tensile specimens were cut from each failed bar, and the physical properties as determined from these tensile tests are tabulated in Table 1. The 115 K22 bars had a pressed easement of 1/64 to 1/32 in. over a length of approximately 1 in. of the upper fishing surface.

Data on these 24 joints are tabulated in Tables 1 and 2.

Hardness Tests on Joint Bars

Both Brinell and Rockwell B hardness readings were taken on upper and lower fishing surfaces of all bars before testing. For the 131 K4 bars the Brinell hardness ranged from 232 to 342, with an overall average of 286 for the 24 bars. Rockwell B readings on the fishing surfaces converted to equivalent Brinell averaged 52 points lower, indicating some decarburization of the bar surfaces. Brinell readings were also taken on a cross section of each failed bar and were found to be slightly lower than surface hardnesses for the majority of the bars.

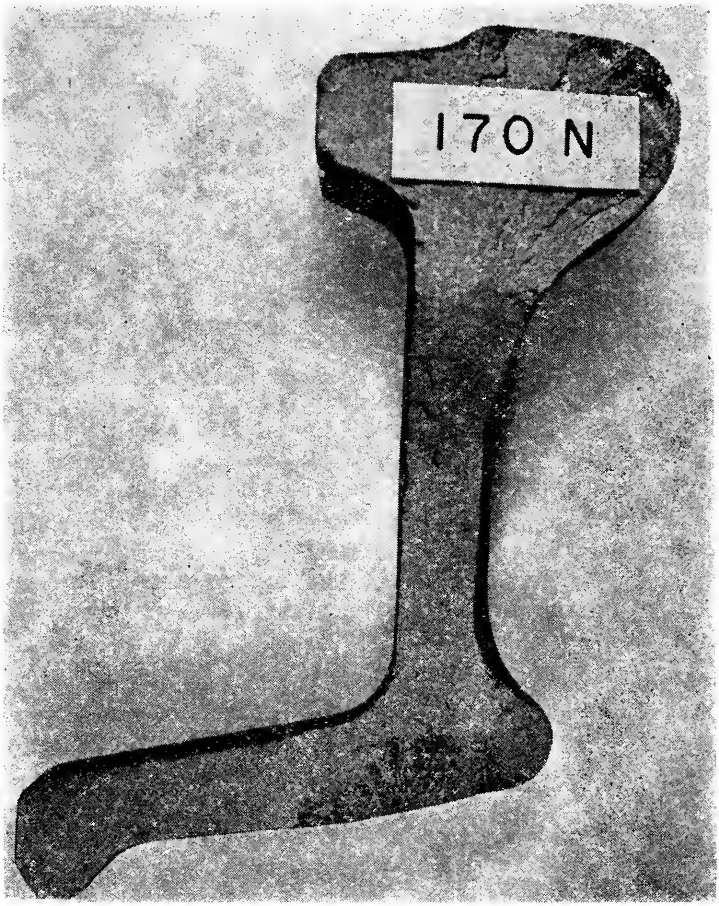


Fig. 1. Fatigue failure of 131–K4 headfree angle bar. Fatigue crack started on lower fishing surface.

For the 115 K22 bars Brinell readings on the fishing surfaces ranged from 175 to 228, with an overall average of 199 for the 24 bars. Rockwell B readings averaged 28 points lower on the fishing surfaces. Brinells on the cross sections of failed bars were slightly lower in most cases.

Rolling-Load Tests of 131 K4 Headfree Bars

Results of 12 tests of 131 K4, 39-in., 6-hole, headfree bars are given in Table 2. Two of the joints, Nos. 168 and 169, ran to 2,000,000 cycles without failure, although cracks had started from the corners of the spike slots on one bar of each joint. The north bar of joint 170 failed from the base at a gouge caused by a rail end and broke completely through before the machine automatically stopped. This fracture, which is shown in Fig. 1, revealed a small fatigue area approximately 1⅛ in. long by ½ in. high and is the only failure in this group which occurred at the center of bar length.

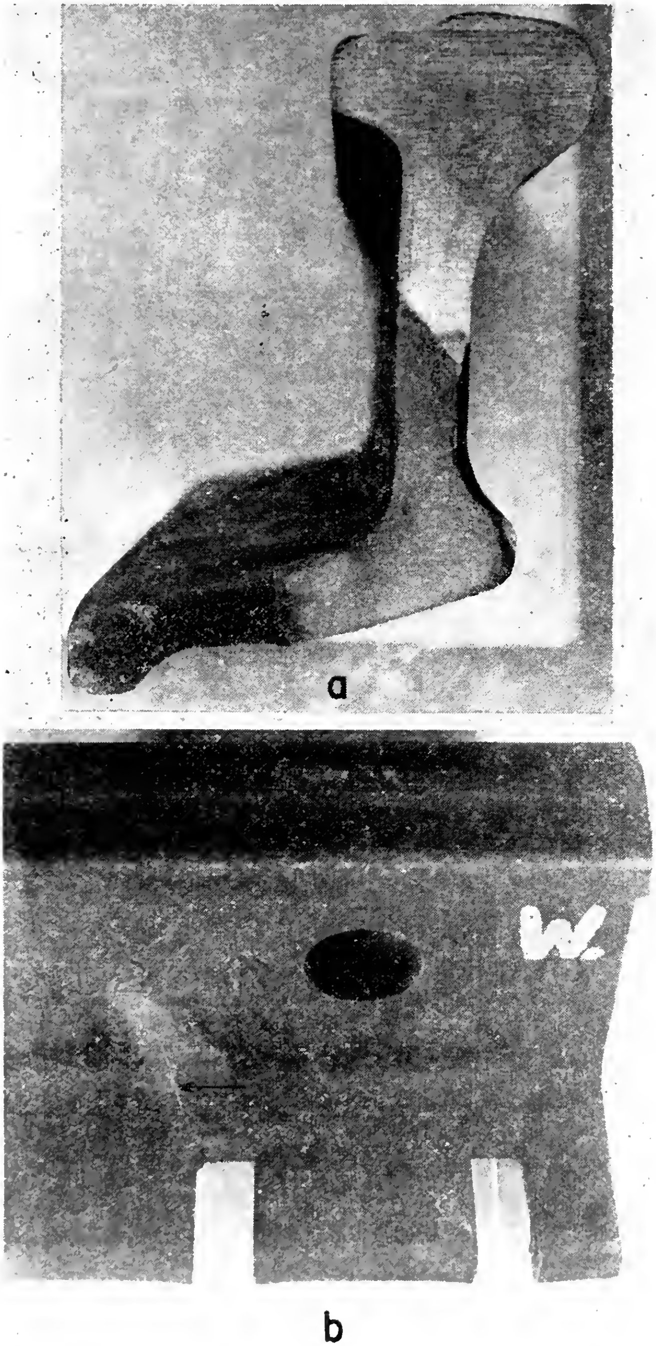


Fig. 2. Fatigue failures from spike slots in long toe bars.
(a) Cross section of bar 171N showing fatigue area.
(b) Crack extends from corner of slot in bar 191N.

TABLE 2. ROLLING LOAD TESTS OF JOINT BARS

Maximum Positive Bending Moment: 55,500-lb. Load—500,000 in. lb. for 131-lb. bars
Maximum Positive Bending Moment: 44,400-lb. Load—400,000 in. lb. for 115-lb. bars
Maximum Negative Bending Moment is 50 Percent of Positive Moment
Bolt Tension: 15,000 lb. Bolts 1 in. Diameter, Heat Treated, Prestressed

Joint No.	*Cycles for failure*	*Bar failure* *N = North* *S = South*	*Surface hardness failed bar BHN*	*Hardness on cross section BHN*	*Depth of decarb. from micrograph in.*	*Rail ends* *H = hot sawed* *C = cold sawed*	*Pinching on failed bar in.*	
							Top	*Base*
		Bars: 131-K4 39-in. Headfree Long Toe Bars No Serial Number						
168	2,000,000	No Failure—N. 1-in. crack in spike slot	N-300	276	0.008	C	----	----
169	2,000,000	No Failure—S. 1½-in. and ⅞ in. cracks in spike slots	S-269	275	0.009	C	----	----
170	622,200	N. base—rail end	277	274	Slight	C	----	----
171	1,173,600	N. base—spike slot	275	281	0.008	C	----	----
172	1,495,700	N. base—spike slot	275	245	0.012	C	----	----
173	1,831,200	S. base—spike slot	249	268	0.005	C	----	----
186	791,700	S. base—spike slot	298	280	0.008	H	0.000	0.001
187	1,146,000	S. base—spike slot	284	271	0.007	H	0.000	0.001
188	733,200	S. base—spike slot	289	283	0.010	H	0.000	0.001
189	1,119,600	N. base—spike slot	232	265	0.012	H	0.000	0.000
190	1,692,300	N. base—spike slot	300	268	0.015	H	0.000	0.001
191	750,000	N. base—spike slot	336	272	Slight	H	0.001	0.000
	1,279,600	Average for 12 joints						
		Bars: 115-K22 36-in. Headfree Serial D9						
192	733,900	N. top—at rail end	205	207	0.024	H-Milled	0.000	0.000
193	692,000	S. top—at rail end	219	186	0.020	H-Milled	0.000	0.001
194	569,600	S. top—at rail end	216	201	0.021	H-Milled	0.000	0.000
195	746,200	N. top—at rail end	194	176	0.013	H-Milled	0.000	0.001
196	649,700	S. top—at rail end	196	213	0.010	H-Milled	0.001	0.001
197	348,300	N. top—at rail end	183	176	0.030	H-Milled	0.000	0.000
198	829,400	N. top—at rail end	182	179	0.021	H-Milled	0.000	0.000
199	747,400	S. top—at rail end	192	191	0.017	H-Milled	0.000	0.002
200	409,000	N. top—at rail end	208	202	0.021	H-Milled	0.000	0.002
201	750,000	N. top—at rail end	182	196	0.021	H-Milled	0.000	0.002
202	636,700	S. top—at rail end	189	170	0.017	H-Milled	0.000	0.002
203	675,200	N. top—at rail end	228	188	0.015	H-Milled	0.000	0.001
	648,950	Average						

The remaining nine joints all failed from a fatigue crack originating in the corner of a spike slot near the end of the bar. Two spike slots are punched near each end of the bar through the toe; the slots are ¾ in. wide and 1⅝ in. deep and are spaced 1-5/16 in. and 4-13/16 in. from the end of the bar. The corners of the slots had a ⅛ in. radius. Fatigue cracks originated in the corner of the slot farthest from the end of the bar and progressed across the toe and upward through the web. Fig. 2a shows a typical failure from such a crack and Fig. 2b shows the crack outlined by Magnaflux extending from the corner of a slot.

Cracks at the spike slots were detected with Magnaflux powder on several bars at 300,000 to 500,000 cycles, but due to the low bending stresses on the bars near the ends, crack growth was slow. One joint ran 753,000 cycles from the time the crack was first detected until it had reached mid-height of the bar. Other joints required numbers of cycles varying from 173,000 to 728,000 to propagate the crack to mid-height after detection. The average number of cycles for failure for the 12 joints was 1,279,600.

Six companion bars developed cracks, extending from the corners of the slots, which ranged in length from ¼ in. to 2 in. On two bars, cracks developed in slots at both ends of the bars.

Since tightening of the bolts was noted to bend the bars laterally at mid-length, lateral deflection readings were taken on both bar flanges of each joint before bolting, after bolting, and at regular intervals during the progress of each test. The amount of bending varied with individual bars, but as the unbroken bar recovered to its original shape upon release of bolt tension, it was apparent that this bending was elastic.

Lateral deflection readings on the bars indicated that at 100,000 cycles the centers of the bars were bowed outward from 0.002 to 0.036 in. in elastic bending measured on the upper flanges, with an average of 0.016 in. Bending on the lower flanges ranged from 0.011 in. outward to 0.015 in. inward, with an average of 0.002 in. outward.

Out-to-out measurements, that is, the distance between the outer bar flanges, indicated that at 100,000 cycles the lower flanges of the bars had moved inward from 0.023 to 0.063 in. at the center of bar length, with an average of 0.041 in., and from 0.007 to 0.058 in. at the ends, with an average of 0.027 in. At the same time the upper flanges had moved inward at the center of bar length from 0.006 to 0.042 in. with an average of 0.019 in., and from 0.005 to 0.070 in. at the ends, with an average of 0.019 in.

Micrographs were taken on sections from all failed bars and the depth of decarburization measured from the micrograph. Decarburization ranged in depth from less than 0.001 in. to 0.015 in. A fine grain sorbitic structure was revealed on nine of the failed bars and a coarser pearlitic structure was found on three of the bars.

It may be of interest to note that of 131 long-toe bars which failed in service and were sent to our laboratory for examination, 128 had failed from fatigue cracks extending from spike slots. These failed bars were mainly for 100-lb. rail.

Rolling-Load Tests of 115 K22 Headfree Bars

Results of the 12 tests on joints with 115 K22 Headfree 36-in. bars are given in Table 2. Rail 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 12 tests was 648,950. All of the bars failed from the top surface at the rail end, the fatigue crack starting either in the gouge mark caused by the rail end or in an area of heavy bearing within ⅝ in. of the rail end.

Fig. 3 shows fatigue failures of three of the 115 K22 bars.

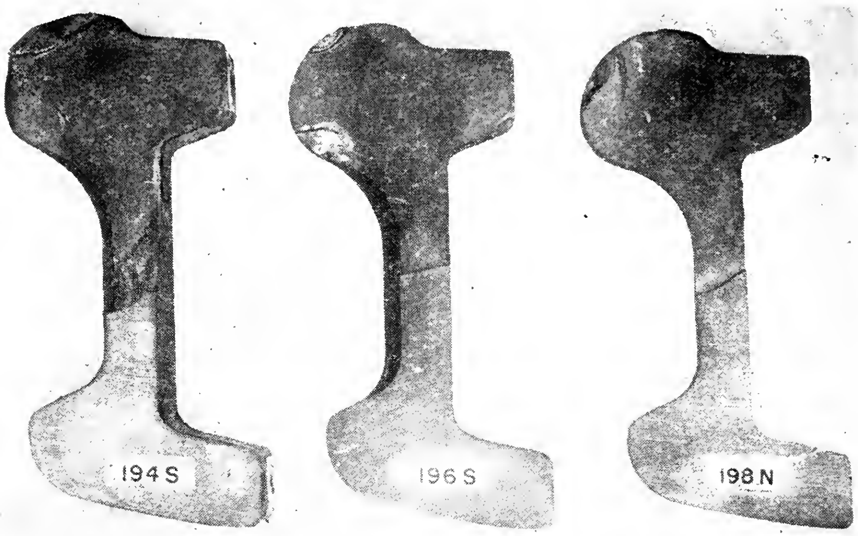


Fig. 3. Fractures of 115 K22 headfree bars.

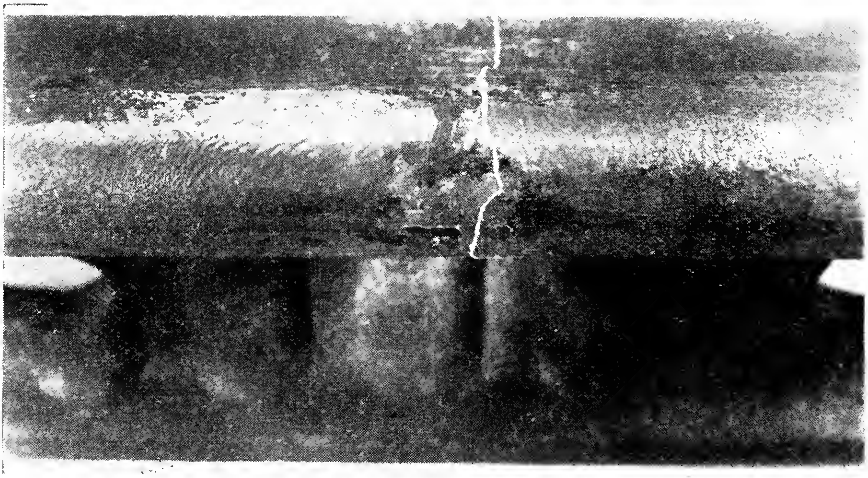


Fig. 4. Crack outlined by Magnaflux on top surface of bar 194S.

Magnaflux examination revealed additional cracks from 3/16 in. to 1¼ in. long on the top surfaces of seven of the failed bars and seven of the companion bars. These cracks occurred in the gouges caused by the rail ends and also in heavy bearing areas near the center of the bar, usually within 2 in. of the joint gap.

Fig. 4 shows the top bearing surface of bar 194S, with the fatigue crack outlined by Magnaflux powder. The pressed easements on these bars greatly reduced gouging by the rail ends, but did not entirely eliminate the gouging since some bearing of rail on bar occurred above the easements on all of the bars. Either increasing the size of the easements or pressing them in slightly higher up on the bars would probably eliminate gouging altogether.

Lateral deflection readings indicated that at 100,000 cycles the center of the bars had deflected from 0.014 in. inward to 0.022 in. outward in elastic bending measured on the upper flanges, with an average of 0.004 in. outward deflection. Elastic bending for lower flanges had approximately the same range for most bars, ranging from 0.021 inward to 0.018 in. outward, with an average of 0.003 in. inward.

Out-to-out measurements indicated that at 100,000 cycles the lower flanges had moved inward from 0.038 to 0.061 in. at the center of bar length, with an average of 0.049 in., and from 0.011 to 0.041 in. at the ends, with an average of 0.024 in. The upper flanges moved inward at the center of bar length 0.001 to 0.004 in., with an average of 0.002, and at the ends the movement ranged from 0.004 in. inward to 0.022 in. outward, with an average of 0.003 in. outward.

Micrographs taken on specimens from all failed bars revealed depths of decarburization from 0.010 to 0.030 in. A fine grain pearlitic structure was revealed on ten of the bars and a coarse grain structure on two of the bars. None of the bars revealed a fine grain sorbitic structure, such as is frequently found on bars of higher Brinell hardness.

Failed Bars from Service

Brinell hardness measurements have been taken on 242 pieces of failed bars from service sent to the laboratory for examination. The range of hardness was 175 to 291. Table 3 lists the number of bars falling in each range of Brinell hardness 10 numbers apart and the percentage (to the nearest whole number) of bars in each range. The Brinell readings were taken near the center of bar length on the top fishing surface after grinding off 1/32 in. to 1/16 in.

TABLE 3. RANGE OF BRINELL FOR FAILED BARS FROM SERVICE

Range of Brinell	*No. of bars*	*Percent*
170–179	2	1
180–189	3	1
190–199	5	2
200–209	19	8
210–219	11	5
220–229	24	10
230–239	19	8
240–249	31	13
250–259	47	19
260–269	39	16
270–279	34	14
280–289	7	3
290–299	1	..
Total	242	100

TABLE 4. BRINELLS AND PHYSICAL PROPERTIES OF FAILED BARS FROM SERVICE

Lab. No	*Hardness near top surface BHN*	*Hardness on cross-section BHN*	*Tensile strength psi.*	*Yield strength psi.*	*Reduction of area percent*	*Elongation 2 in. G.L. percent*
B 150	175	155	82,800	41,500	47.8	25.5
B 7	210	190	93,800	56,800	48.6	23.5
B 61	206	194	99,100	67,400	62.7	26.5
B 33	272	195	96,100	63,900	45.5	22.0
B 53	187	195	99,200	66,100	59.1	25.0
B 77	219	197	105,700	64,900	48.9	21.0
B 56	225	203	106,000	63,300	41.1	19.5
B 47	236	204	99,500	62,200	52.4	23.0
B 2	228	204	102,700	67,500	59.1	24.5
B 49	245	205	103,300	64,900	52.4	23.0
B 9	238	205	105,600	63,000	38.5	18.0
B 51	217	208	102,000	61,500	49.5	22.0
B 128	203	208	110,800	62,800	37.1	18.5
B 16	248	211	103,000	64,400	57.7	23.5
B 4	255	212	104,300	65,100	55.3	23.0
B 48	257	213	113,600	76,400	46.9	19.5
B 81	233	216	113,300	68,700	43.9	19.0
B 3	263	236	116,300	73,900	45.8	19.0
B 98	270	238	118,300	74,500	45.4	18.0
B 67	284	251	124,900	83,100	26.7	13.0
E 52	211	165	98,300	55,300	40.8	21.5
E 31	201	170	97,800	55,300	40.8	21.0
E 1	218	171	90,500	48,100	38.0	17.0
E 38	202	176	99,200	56,000	42.0	21.0
E 26	199	181	99,600	57,100	42.8	21.0
E 6	210	185	78,900	54,800	42.8	21.0
E 21	204	187	100,000	55,500	43.5	21.0
E 5	204	190	100,100	51,200	30.2	19.0
E 30	198	194	93,100	47,100	36.4	19.0
E 49	229	194	104,200	64,200	49.8	21.0
E 48	231	195	105,300	66,000	51.5	22.5
E 15	227	203	106,400	62,700	45.2	21.0
E 29	221	206	106,000	61,500	44.4	20.5
E 7	250	207	112,000	75,500	52.6	21.5
E 13	240	213	111,500	73,100	51.7	22.0
E 3	266	216	116,100	73,100	50.7	21.0
E 4	244	217	115,800	77,000	51.7	21.0
E 8	250	218	112,500	72,200	51.9	21.5
E 19	283	229	121,800	76,500	56.5	22.5
E 54	291	246	130,500	85,500	49.3	19.5
E 27	275	250	131,000	85,200	48.0	18.0
E 17	279	255	131,500	86,500	49.0	18.5

Of the 242 failed bars, 188 were received from the Northern Pacific Railway through the courtesy of G. L. Smith, system engineer of track. These bars were mainly for 100-lb. and 112-lb. rail and represented rollings from 1929 to 1947. Included in this group were 131 long-toe bars, 128 of which failed from a fatigue crack starting in the corner of a spike slot on the base. The remaining bars failed from the top surface at a gouge caused by a rail end. These bars were assigned laboratory numbers from B1 to B188.

A second group of 54 failed bars were received from the Canadian National Railways through the courtesy of W. E. Griffiths, engineer of track. All bars of this group were head contact bars for 100 RA–A rail section and were from 1945, 1946, and 1947 rollings. Failure in each case was from the top surface at a rail end. These bars were numbered E1 to E54.

Tensile specimens were cut from 42 bars, and the physical properties as determined from these tensile tests are tabulated in Table 4. With few exceptions, Brinells on the cross sections near the center of the head of the bars were considerably lower than the hardness near the bar surface. The data of Table 4 indicate that 29 of the 42 bars tested, or 69 percent, met the specification of minimum tensile strength of 100,000 psi.,

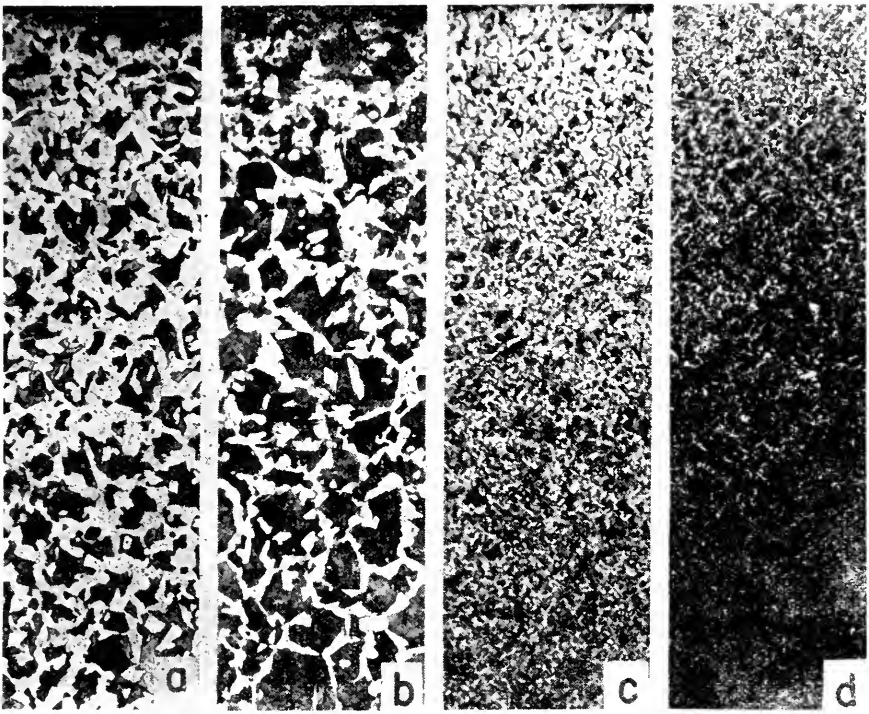


Fig. 5. Micrographs of joint bars which failed in service.

(a) Bar No. E1, Brinell (cross section) 171, coarse grain structure.
(b) Bar No. E5, Brinell (cross section) 190, coarse grain structure.
(c) Bar No. E4, Brinell (cross section) 217, fine grain structure.
(d) Bar No. E17, Brinell (cross section) 255, fine grain structure.

while 13 of the 42, or 31 percent, met the specification of minimum yield strength of 70,000 psi.

Fig. 5 shows micrographs from four of the failed bars with cross section Brinell hardness ranging from 171 to 255. In general, bars with hardness below 200 Brinell show a pearlitic grain structure, often coarse, while bars above 200 Brinell usually reveal a fine grain microstructure.

Tensile strength and yield strength vs. Brinell hardness are plotted in Fig. 6. It appears that for this group of tensile tests, specimens which met the requirement of 100,000 psi. minimum tensile strength had a Brinell hardness of at least 187; specimens between 187 and 204 Brinell fell on both sides of the 100,000 psi. line; and specimens above 204 Brinell had a tensile strength above 100,000 psi.

Specimens which met the yield point specification of 70,000 psi. minimum had a Brinell hardness of at least 207; specimens from 207 to 216 Brinell overlapped the 70,000 psi. line; and all specimens above 216 Brinell were above the 70,000 psi. yield point.

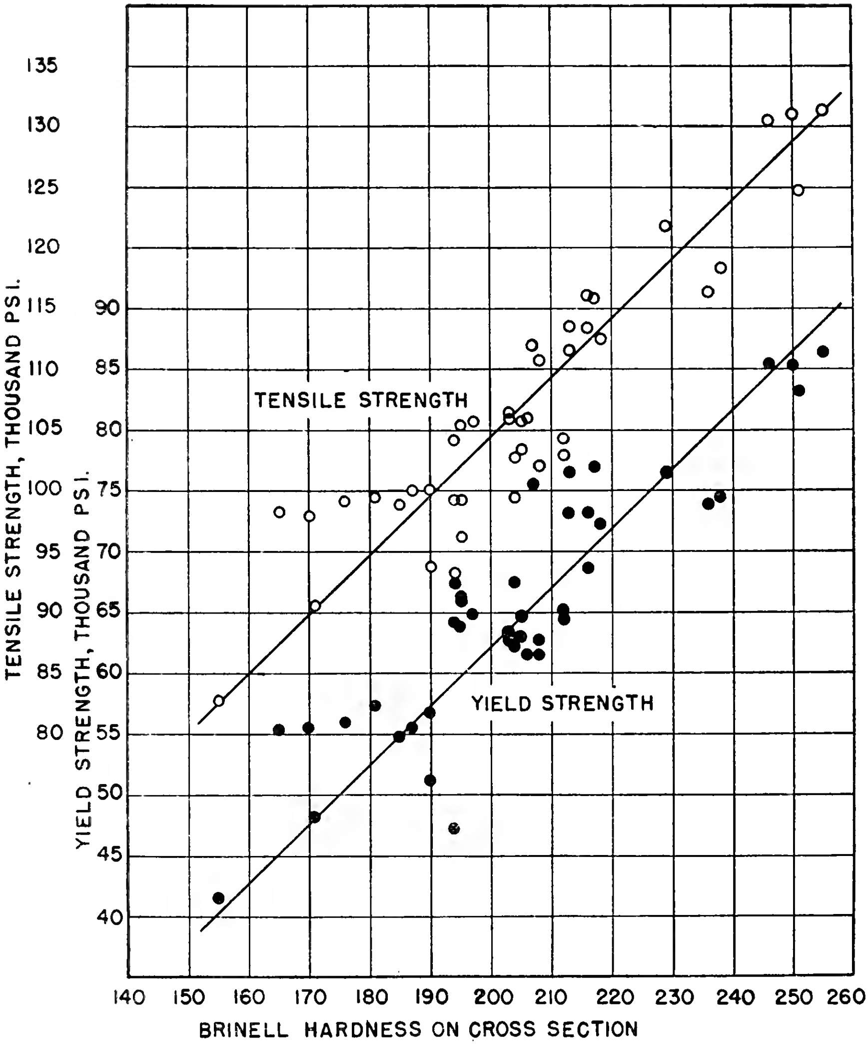


Fig. 6. Physical properties vs. Brinell of joint bars from service.

Summary

1. Twelve tests of 131 K4 headfree 39-in. long-toe bars averaged 1,279,600 cycles. Two joints ran to 2,000,000 cycles without failure; one bar failed from the base at a rail end, and nine bars failed from cracks starting in spike slots.

2. Twelve tests of 115 K22 headfree 36-in. bars averaged 648,950 cycles. All failures were from the top at a rail end.

3. The pressed easements on the 115 K22 bars reduced gouging but did not entirely eliminate it. It seems probable that gouging could be eliminated altogether either by larger easements or by locating the easements higher up on the bars.

4. Micrographs taken on all failed bars revealed decarburized bar surfaces to varying depths up to 0.030 in.

5. Brinell and tensile tests on 42 of 242 failed bars from service indicated lower hardness on the cross section at the center of the head of the bars than near the bar surface. Data from these tests indicated that bars which met both specifications of 70,000 psi. minimum yield and 100,000 psi. minimum tensile strength had Brinell hardnesses of at least 207.

Apendix 8-b

Service Tests on the Burlington Railroad near Fort Morgan, Colo., of Joint Bars of Different Metallurgies

In the Proceedings, Vol. 47, 1946, page 411, a description was given of the test installation of joint bars of various metallurgies placed in the single-track main line of the Chicago, Burlington & Quincy, near Fort Morgan, Colo., in July 1939. The joint bars were applied at the time new 112 RE rail was laid. This rail was control cooled, but not end hardened. The purpose of the test was to compare the service performance, and, in particular, the resistance to developing fatigue cracks at the top midlength, of joint bars with higher strength steel, and 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 included five test sections of 100 pairs of joint bars each in tangent track. All of the joint bars of one type were installed 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 24-in. in length, with four 1-in. dia. heat-treated bolts and triflex springs. The test bars are the Rail Joint Company's designs. A description of the chemistry and heat treatment of the test bars is given in the report referred to previously. Types 1 to 4, inclusive, are the B-34-1 head-contact section, and type 5 is the B-53 headfree section. The test observation on type 5 had to be discontinued because these bars were replaced in track by mistake in connection with a general joint bar replacement through this area.

Joint Wear

On October 11, 1950, 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.

Because the available take-up or pull-in of the new head-contact joint bars before they contact the rail web is 0.38 in., the decreases shown 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 1950, varied from 0.12 to 0.15 in. At this stage of the investigation, the harder bars show more resistance to wear, which may be a factor in increasing the life of the bar. During the 1950 inspection,

Table 1. Decrease in Out-to-Out Distance of Joint Bars (November 1939 to October 1950) Reading in Inches

Type	November 1950			October 1948
	Top	Bottom	Avg.	Avg.
1 —HC ordinary chemistry	0.170	0.147	0.158	0.105
2*—HC hardened top center	0.168	0.121	0.145	0.095
3 —HC water quenched, drawn	0.141	0.122	0.132	0.078
4 —HC rail steel, oil quenched, drawn	0.146	0.109	0.127	0.071

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* Average of 9 joints because one pair of bars was replaced.

a cracked bar was noted in the test section of type 2 joint bars. This was the first cracked bar in this group. A badly worn pair of bars was replaced in 1948. These two failures are the only failures for the entire experiment up to date. It was also noted, as in 1948, that the take-up at the east end of the bar is greater than on the west end, except for bars of type 1, which showed no difference on the end take-up. Bars of types 2, 4 and 3 had an increasing take-up on the east end in the order shown.

Joint Droop

The amount of sag or dip at the rail end is important as an indication of how well the joint bars are supporting the rail ends. Table 2 shows the average sag or dip in the rail surface 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 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 the rail ends on all four test sections were built up by welding in the summer of 1947, the value of this particular measurement was largely destroyed.

Table 2. Rail End Sag of Dip at ½ In. from Rail Ends

Type	Oct. 1940	Oct. 1941	July 1943	Nov. 1945	Nov. 1946	Nov. 1948	Nov. 1950
1	0.004	0.006	0.011	0.023	0.023	0.012	0.015
2	0.002	0.006	0.016	0.024	0.026	0.016	0.039
3	0.002	0.006	0.012	0.031	0.028	0.015	0.026
4	0.003	0.007	0.012	0.031	0.030	0.018	0.020

Joint Bar Failures

Only one cracked bar has been observed in the test to date. This occurred on type 2 bars, which were of ordinary chemistry and heat treatment, subsequently flame hardened at the top center portion.

Acknowledgement

The committee and the Association are indebted to the Burlington Railroad for making the installation and providing assistance in taking the field measurements.

Report on Assignment 9

Rail Fractures Resulting from Engine Wheel Burns, Including Effect of Repairing Such Burns

by Oxyacetylene or Electric Welding

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This is a brief report on this assignment prepared since the last report covered in AREA Proceedings, Vol. 51, 1950, page 594.

As noted in the previous report, 21 rail specimens were artificially burned in the wheel testing machine at the University of Illinois. Five specimens from this group were repaired by hand welding and five by the semi-automatic welding machine developed by the Oxweld Railroad Service Company. Since the last report, two additional welded rails have been tested in the rolling-load machines and these did not fail after two million cycles. At present, one burned specimen, three specimens repaired by hand welding, and four specimens repaired by the Oxweld machine remain to be tested in this group.

In addition to the above, 50 rail specimens were sent to the University of Illinois to be artificially burned. However, since the burns produced on the first 21 specimens were too deep to permit the wheel of the rolling-load machine to pass over the burn, it was decided to produce a burn on 11 rails of this set small enough to locate the burn in the wheel path and yet produce failure within a reasonable number of cycles.

Three of these 11 rails have been tested. One specimen failed at 625,000 cycles, but the other two did not fail after 2 million cycles. Two additional rails from this set are being run at present, but it would appear that the remainder of 39 rails will have to be burned in the same manner as the original 21 specimens and placed in the rolling-load machine with the burn located outside of the wheel path.

Sufficient data have not been accumulated at the present time to draw conclusions from these rolling-load tests.

Report on Assignment 10

Causes of Shelly Spots and Head Checks in Rail: Methods for Their Prevention

L. S. Crane (chairman, subcommittee), C. H. Blackman, T. A. Blair, B. Bristow, C. B. Bronson, E. E. Chapman, C. J. Code, W. J. Cruse, P. O. Ferris, J. L. Gressitt, G. F. Hand, C. B. Harveson, L. R. Lamport, C. C. Lathey, W. B. Leaf, E. E. Mayo, Ray McBrian, E. H. McGovern, R. J. Middleton, L. T. Nuckols, Embert Osland, W. C. Perkins, G. A. Phillips, J. G. Roney, I. H. Schram, A. A. Shillander, G. L. Smith, Barton Wheelwright, R. P. Winton, J. E. Yewell.

This is a progress report, presented as information.

This investigation is conducted by four task groups. The work of Group 1 is handled directly by the subcommittee; that of Group 2 by the research staff of the Engineering Division, AAR; of Group 3 by the University of Illinois; and of Group 4 by Battelle

Memorial Institute. The AAR provides funds for the work conducted by Group 2, and the AAR and AISI jointly provide funds to support the work of Groups 3 and 4. A small administrative committee composed of members appointed by the subcommittee and by the rail manufacturers has met regularly during the past year with the research investigators at both the University of Illinois and Battelle Memorial Institute.

The subcommittee has been unable to determine any positive solution for this problem. The installations of heat-treated rail continue to perform well. It is believed that the installations of alloy rail recently installed will also prove effective in retarding the onset of shelling. However, both alloy and heat-treated rail are expensive, and in many cases the economics of the problem may not permit of its solution by these means. The research work is being continued in an effort to ascertain the fundamental mechanics of the failure, with the hope that some simple and economical solution may be forthcoming.

Group 1

The committee has continued to follow the performance of the various installations of heat-treated rail. A summary of the performance of these test installations follows:

Chesapeake & Ohio Railway

Service Test of 132 RE Heat-Treated Rail

This test was installed near Martha, W. Va., on the Logan subdivision of the Huntington division, on a 3-deg. 6-min. curve, both high and low side. Twelve heat-treated (oil quenched) and 12 end-hardened rails from the same heat, all control cooled. were laid on May 2, 1949. The heat-treated rails were laid on the receiving end of the curve, followed by the end-hardened rails. Six rails of each grade were laid on the high and low sides.

This curve was inspected on August 9, 1950, after an accumulated tonnage of 26,500,000 tons. Visual examination of the rails revealed the following surface condition:

All low rails, both heat treated and control cooled end hardened, are in excellent shape.

On the high side, two adjacent control-cooled rails show severe flaking. The heat-treated rails on the high side do not show any flaking, although one rail has fine hair-line crasks on the gage corner throughout its entire length.

The rolling-load test results at the University of Illinois on companion samples of these rails showed the following:

Control Cooled *cycles*	*Heat Treated* *cycles*
900,000	3,232,000
1,206,000	5,022,000*
1,667,000	5,032,000*

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* Specimen did not fail. Test stopped.

Pennsylvania Railroad

Service Test of 155-lb. Heat-Treated Rail

This test was installed in No. 1 E.B. track, Middle division, near Forge, Pa., No. 11 curve, 6 deg., in the high side only. Twelve oil-quenched, heat-treated rails and 12 end-hardened rails, all control cooled from the same heat, were laid on January 19, 1949.

The test rails were laid in the following sequence, beginning at the receiving end of the curve, high side only: 2 ordinary rails, 2 end-hardened test rails, 2 heat-treated rails, 2 end-hardened, 2 heat-treated, etc.

The last inspection of this test curve was on August 25, 1950. The accumulated tonnage as of that date was 92,000,000 tons.

Visual examination of the test rails showed the following surface conditions: All the test rails on the receiving end of the curve are flaking in various degrees. Incidentally, for some unaccountable reason, one heat-treated rail appears the worst of the lot; the heat-treated rail preceding this and the control-cooled rail immediately ahead showing only moderate flaking.

The rolling-load test results at the University of Illinois on companion samples of these rails showed the following:

Control Cooled *cycles*	*Heat Treated* *cycles*
350,000	4,764,000
782,000	5,000,000*
831,000	

---

* Specimen did not fail. Test stopped.

Norfolk & Western Railway

Service Test of 132 RE Heat-Treated Rail

This test was installed in the main line, westbound track, M.P. Na 6, west of the station at Kermit, W. Va., west of tunnel exit, in a 6-deg. curve, on both high and low side. Twenty three heat-treated, oil-quenched rails and 24 end-hardened rails from the same heat, all control cooled, were laid on May 3, 1949.

Ordinary rails were laid through the tunnel and at the exit end; 6 end-hardened test rails on both high and low sides, followed by 12 and 11 heat-treated rails on high and low sides, respectively, followed by 6 end-hardened test rails on both high and low sides.

This curve was visually inspected on August 10, 1950, after an accumulated tonnage of 52,000,000 tons.

The visual examination of these test rails revealed the following surface condition: Beginning at the receiving end, *low* side, the 6 end-hardened rails are badly flowed and some head crushing is developing; the next 11 heat-treated rails are in excellent shape, and aside from some engine-slippage burns, are as good as the day they were installed; the 6 end-hardened rails on the leaving end of the curve show moderate to heavy flow.

Beginning at the receiving end of the curve, ***high*** side, the first 6 end-hardened rails show moderate flaking on the gage corner; the 12 heat-treated rails are free of flaking, but show fine hair-line cracks around the gage corner; and the last 6 end-hardened rails show moderate flaking or hair-line cracks.

The rolling-load test results at the University of Illinois on companion samples of these rails showed the following:

Control Cooled *cycles*	*Heat Treated* *cycles*
900,000	3,232,000
1,206,000	5,022,000*
1,667,000	5,032,000*

---

* Specimen did not fail. Test stopped.

Extensive research work has been conducted by the Carnegie–Illinois Steel Corporation to develop an economical alloy steel rail capable of being manufactured by standard equipment and practice. Results of over 350 experimental heats have indicated that a manganese–chromium–vanadium analysis will produce rail steel in the as-rolled condition with desirable hardness, microstructure and physical properties.

A 15-ton heat of the analysis identified as C–V rail has been rolled into seven 39-ft. and four 25-ft., 127-lb. section rails and is now installed on the New York Central at Cedar Run, Pa. A full-size heat of similar analysis has been rolled into 132 RE section and is now awaiting installation on the Norfolk & Western.

Group 2

The Engineering Division research staff has continued to assist the committee in the direction of the research work and the field studies. A rail engineer has been added to the staff of the research engineer and will be available to assist the committee in following the performance of the field tests.

Group 3

The third portion of the assignment is covered by a report prepared by Professor R. E. Cramer, which follows as Appendix 10–a.

Group 4

Progress has been made on work assigned to the Battelle Institute, but no report of this work will be made until tests, now underway, are completed.

Appendix 10–a

Ninth Progress Report of the Shelly Rail Studies at the University of Illinois

By R. E. Cramer

Special Research Associate Professor of Engineering Materials, University of Illinois

Organization and Acknowledgment

The shelly rail studies at the University of Illinois are financed equally by the Association of American Railroads and the American Iron and Steel Institute.

Acknowledgment is given of the help of Homer Smith and Robert Bond, student assistants, who designed the new cradle rolling machine, and of Marion Moore, mechanic, who has built this machine. Special credit is due the metallurgists of the rail manufacturers, who supplied the rails used in the laboratory tests.

Rolling-Load Tests on Heat-Treated Rails

Last year's report gave cradle-type rolling-load tests on Bethlehem heat-treated 155-lb. rails from the same heats which were laid in the tracks of the Pennsylvania Railroad. One heat-treated specimen ran 4,764,000 cycles before a shelling crack developed and the other specimen ran 5 million cycles without developing a failure. Companion, as-rolled rails, all failed at less than one million cycles.

This year similar rolling-load tests have been continued on Bethlehem 132-lb. heat-treated and companion, as-rolled rails, from the same heats, which were laid in the tracks of the C. & O. and N. & W. Railways. Table 1 gives the results of physical tests and rolling-load tests on six of these rails. The table shows that the average Brinell hardness of the heat-treated rails was raised to 360 compared to an average Brinell hardness of 269 for the companion as-rolled rails. The average yield strength of the heat-treated rails was 125,600 psi. compared to 76,300 psi. for the as-rolled rails. Tensile strength

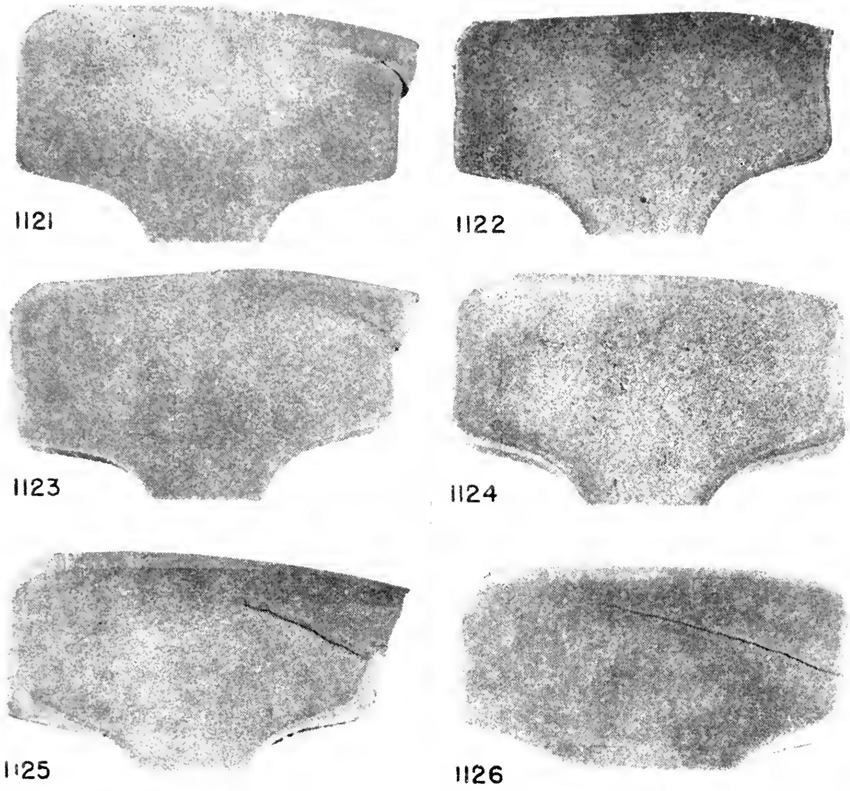

Fig. 1. Heat treated and companion rails after testing. Etched in hot 50-percent hydrochloric acid.

Rail No.	Heat treatment or as rolled	Classification of failure	Average Brinell hardness	Cycles in rolling machine
1121	As rolled	Shelling crack	273	900,000
1122	Quenched in oil and tempered	No failure	361	5,022,000
1123	As rolled	Shelling crack	267	1,206,000
1124	Quenched in oil and tempered	No failure	354	5,032,000
1125	As rolled	Shelling crack	266	1,667,000
1126	Quenched in oil and tempered	Shelling crack	366	3,232,000

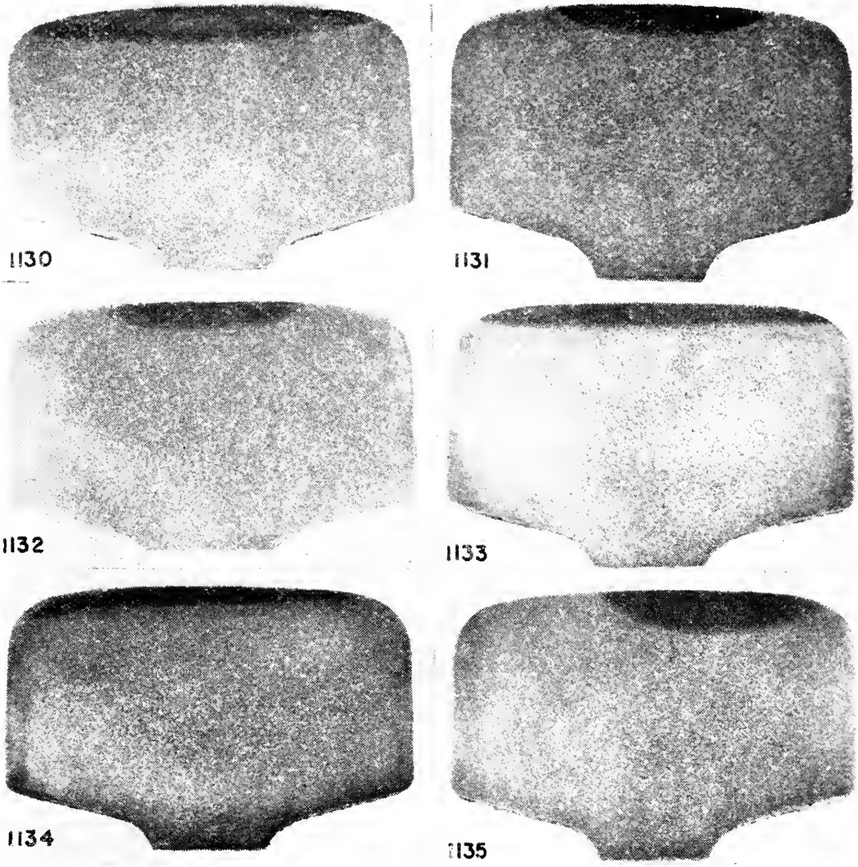

Fig. 2. Flame-hardened areas on Oxweld rails. Etched with ammonium persulfate which darkens flame hardened area.

was raised from 133,700 psi. to 175,400 psi. Both percent elongation and reduction of area were increased by the heat treatment and the Charpy value for unnotched specimens was increased from an average of 94 to 271 ft.-lb. These decided improvements in physical properties can explain the rolling-load tests where two of the heat-treated specimens ran over 5 million cycles without failure while the as-rolled specimens failed at an average of about one million cycles. Etched slices from all heat-treated and companion rails are shown in Fig. 1.

Rolling-Load Tests of Flame-Hardened Rails

The specimens 1129 to 1135 as listed in Table 1 were flame hardened on the treads by the Oxweld Railroad Service Company. The hardened areas of six rails are shown in Fig. 2. These specimens were etched in ammonium persulfate which darkens the area which was reheated during the flame hardening process. As indicated in Table 1, four of the seven specimens failed in the cradle machine by fillet cracks starting at the end of the specimens. Fig. 3a shows an end view of the fillet crack in specimen 1132 and a

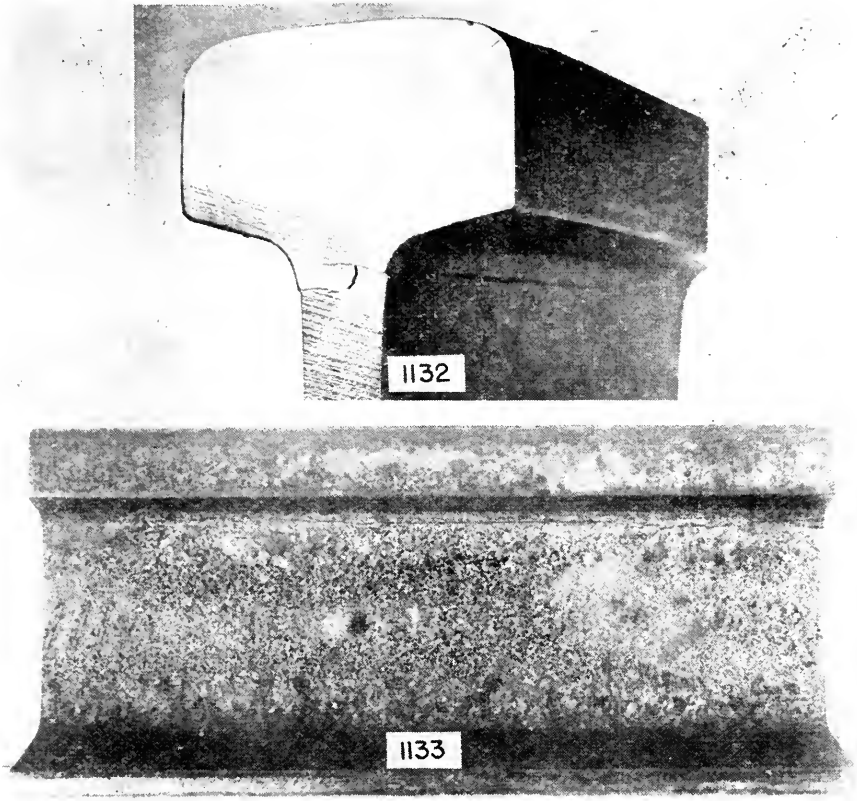

Fig. 3. Fillet cracks in flame-hardened rails. Developed in cradle rolling machine.

side view of the crack in specimen 1133. Three of the flame-hardened rails failed by shelling cracks and a small internal shelling crack was found in specimen No. 1133 after it had failed by a fillet crack. Etched cross sections of six specimens after the rolling-load tests are shown in Fig. 4. All these specimens had been prepared from one length of 112-lb. rail. This rail has since been examined at the fillet and it was found that on one side of the rail there was deep decarburization and it was noted that there were laps rolled in the fillet. These laps can explain the fillet failures and it is unfortunate that the laps were in these specimens. However, of the four specimens which developed shelling cracks only two gave rolling-load tests above one million cycles and these did not go to two million cycles. So far, laboratory tests of flame-hardened rails have not given as good results as heat-treated or alloy rails.

Rolling-Load Tests of Alloy Rails

Two specimens of alloy rails containing about 1.35 percent manganese, 0.90 percent chromium and 0.12 percent vanadium are shown in Table 1 as Nos. 1136 and 1137. Specimen 1136 is 127-lb. section and represents a small number of test rails placed in service on the New York Central Railroad. Specimen 1137 is 132-lb. section from a full heat of around 150 rails placed in service by the Norfolk and Western Railway.

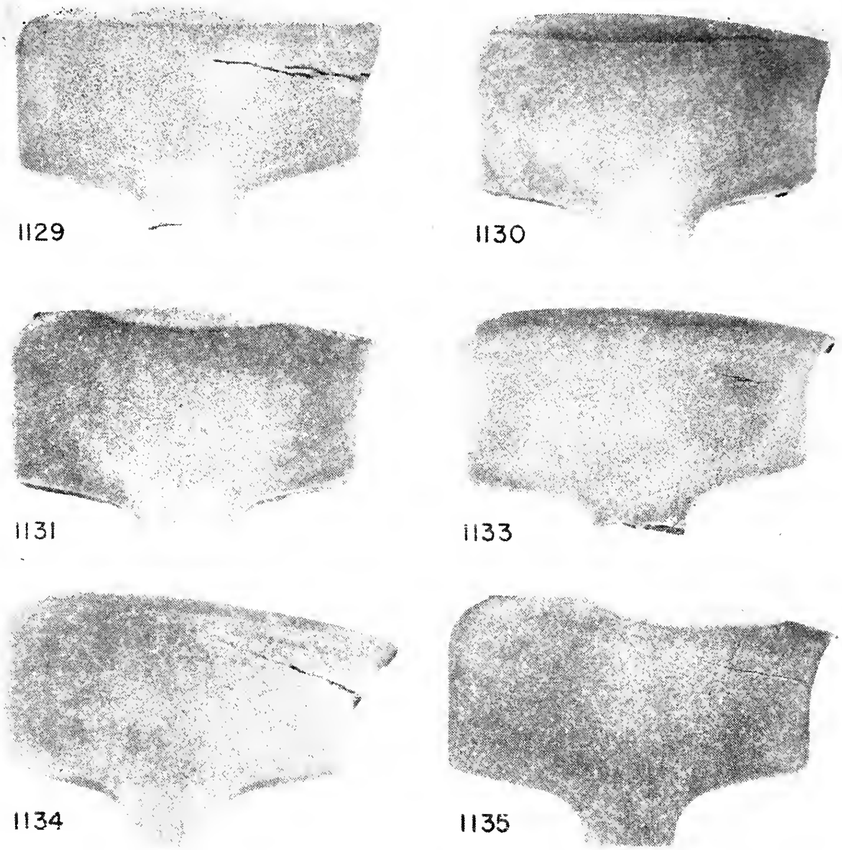

Fig. 4. Oxweld flame-hardened rails after testing. Etched in hot 50-percent hydrochloric acid.

Rail No.	Characteristics of hardened area	Classification of failure	Average Brinell hardness	Cycles in rolling machine
1129	Medium depth across head	Shelling cracks	319	1,790,000
1130	Deep area across head	Fillet crack	327	672,000
1131	1½ in. wide, middle of head	Fillet crack	327	935,000
1133	Shallow depth across head	Fillet crack	336	823,000
1134	Shallow depth across head	Shelling crack	311	660,000
1135	1½ in. wide, gage side head	Shelling crack	327	1,887,000

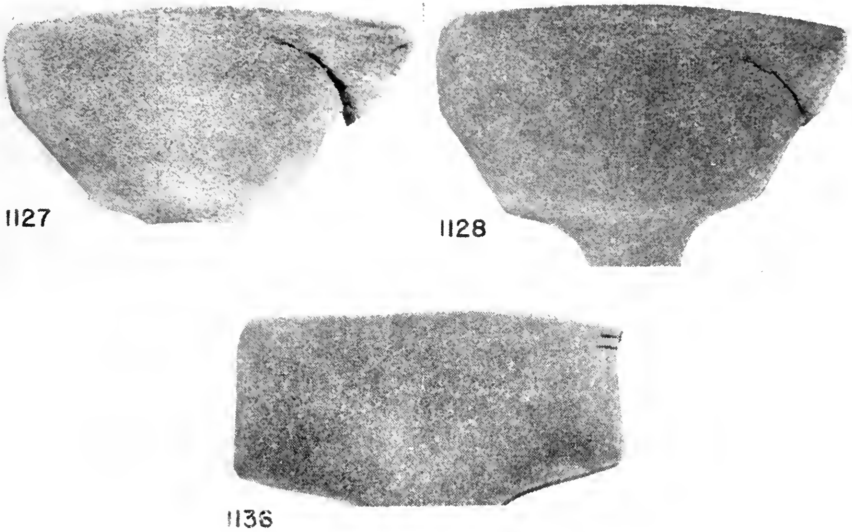

Fig. 5. Head free and alloy rails after testing. Etched in hot 50-percent hydrochloric acid.

Rail No.	Type of rail	Classification of failure	Average Brinell hardness	Cycles in rolling machine
1127	113-lb. headfree	Shelling crack	256	731,000
1128	132-lb. headfree	Shelling crack	266	901,000
1136	Mn, Cr, V, Alloy rail	Shelling crack at side of rail head	365	8,117,000

This alloy was developed by the rail manufacturers after the study of around 100 small laboratory heats covering a wide range of alloy compositions. It will be noted that these rails have a Brinell hardness around 360 as cooled in air after rolling. Both their hardness and physical properties compare closely to the heat-treated rails described earlier in this report. Both specimens ran more than 5 million cycles in the rolling-load tests, which was as long as the heat-treated rails were tested due to the limited number of cradle-type rolling machines. Specimen 1136 developed a shelling crack one inch long on the side of the rail head at 7 million cycles. This crack had only grown to two inches in length at 8 million cycles when the test was stopped. Two cracks are shown in Fig. 5, specimen 1136, which appeared to be of surface origin and had only progressed about 3/16 in. into the rail head. Specimen 1137 developed a large internal shelling crack at 5,027,000 cycles. The laboratory tests of the two alloy rails give results which indicate that these rails may give unusually good service in track.

Rolling-Load Tests of Headfree Rails

Rolling-load tests to produce shelling in the cradle-type machines were made on two headfree rails supplied by the Colorado mill. These specimens are Nos. 1127 and 1128 in Table 1 and Fig. 5. The question has been raised as to whether headfree rails resisted shelling as well as AREA designed rails. These rails developed failures in the rolling-

TABLE 1. PHYSICAL TESTS AND CRADLE ROLLING-LOAD TESTS, OCTOBER 1, 1949, TO OCTOBER 1, 1950

Speci-men No.	Chemical analysis			Heat Treatment Q=quenched D=drawing temp. deg. F. HF=headfree	Avg. Brin. hard	Yield strength 0.2% psi.	Tensile strength psi.	Elong. in 2 in. percent	Red. of area percent	Charpy Value ft.—lb.		Endur. limit psi.	Cycles for failure 50,000-lb. +did not fail
	C.	Mn.	Si. Alloys							No. notch	Key hole notch		
1121	0.78	0.79	0.17	Beth. 132-lb.; As rolled	273	78,200	136,000	10.	13.6	95	3.8	60,000	900,000
1122	0.78	0.79	0.17	Beth. 132-lb.; Oil Q:D-740	361	123,700	176,300	12.5	32.1	269	7.3	80,000	5,022,000+
1123	0.77	0.83	0.15	Beth. 132-lb.; As rolled	267	76,600	132,700	9.7	15.7	89	2.3	58,000	1,206,000
1124	0.77	0.83	0.15	Beth. 132-lb.; Oil Q:D-740	354	130,300	177,900	11.1	35.4	287	7.5	85,000	5,032,000+
1125	0.77	0.83	0.15	Beth. 132-lb.; As rolled	266	74,000	132,500	10.0	16.0	99	4.6	59,000	1,667,000
1126	0.77	0.83	0.15	Beth. 132-lb.; Oil Q:D-740	366	123,000	172,000	11.5	31.4	251	8.1	84,000	3,232,000
1127	0.72	0.79	0.16	Colo. 113-lb. HF; As rolled	256	71,500	127,500	11	18.6	114	4.6	56,000	731,000
1128	0.79	0.80	0.17	Colo. 132-lb. HF; As rolled	266	71,200	127,700	11.7	20	108	5.5	57,000	901,000
1129				Oxweld 112-lb.; flame hardened	319	Failed by shelling; fillet cracks ½ way through web							1,790,000
1130				Oxweld 122-lb.; flame hardened	327	Failed by fillet crack; no shelling crack							672,000
1131				Oxweld 112-lb.; flame hardened	327	Failed by fillet crack; no shelling crack							935,000
1132				Oxweld 122-lb.; flame hardened	336	Failed by fillet crack; no shelling crack							968,000
1133				Oxweld 112-lb.; flame hardened	336	Failed by fillet crack; found short internal shelling crack							823,000
1134				Oxweld 122-lb.; flame hardened	311	Failed by shelling; fillet crack ½ way through web							660,000
1135				Oxweld 122-lb.; flame hardened	327	Failed by shelling; fillet crack 1-in. long							1,887,000
				Cr. V.									
1136	0.79	1.40	0.25	0.95 0.15 Gary 127-lb.-Alloy Rail	365	120,000	175,300	7.2	14.6	137	2.3	84,000	8,117,000
1137	0.74	1.30	0.25	0.90 0.12 Gary 132-lb.-Alloy Rail	361	118,000	177.000	9.1	13.3	157	3.1	84,500	5,027,000

load tests at a slightly lower number of cycles than the average for standard rails, but within the range which has been previously obtained. Some significance may be indicated by the shape of the shelling cracks shown in Fig. 5. In these headfree rails the shelling cracks progress downward near the outside toward the cutaway part of the rail head.

Laboratory Examination of Detail Fractures from Shelling

Seven failed control-cooled rails were examined which had developed detail fractures from shelling. These all had short horizontal shelling cracks which appeared to have started longtitudinally in the steel and then turned into tranverse detail fractures. One example of internal shelling which had not reached the side of the rail head was reported by L. S. Crane of the Southern Railway, and is shown in Fig. 6a. This rail has a very pronounced segregation streak along the center of the shelling crack. A metallurgical examination was made of a transverse section, located directly in line with the horizontal streak and approximately ½ in. beyond one end of the shelly crack. This revealed the presence of the hot torn spot shown in Fig. 6b, which is a micrograph of the unetched metal at 90× magnification. Metallographic tests at the University laboratory have often located non-metallic inclusions near the segregation streaks found in shelly rail failures, but no previous shelling cracks have been found which developed from hot torn steel.

Design and Construction of New Cradle-Type Rolling Machine

At the 1949 meeting of the Joint Contact Committee on the shelly rail investigation, it was decided to proceed with the design and construction of a cradle-type rolling machine which may make it possible to produce detail fractures from shelling in the laboratory. The present cradles on two rolling machines are not long enough to allow the rail specimens to bend vertically. The new cradle will hold a longer specimen and by cutting a slot in the rail web it will be possible to develop high bending stresses in the rail head, accompanied by high enough direct wheel loads to produce shelling failures. It is hoped to study the conditions under which detail fractures from shelling develop.

One rolling machine with a 6-in. stroke (the first one developed to produce transverse fissures in the laboratory) has not been used for several years. It has been remodeled to have a 10-in. stroke, and the cradle is 22 in. inside length. The design of this machine has been completed and most of the machine work has been done.

Studies of Rail Steel with Electron Microscope

Electron photomicrographs have been made on rail 1123, and on its companion 1124 which was heat treated to 354 Brinell hardness, as well as on alloy rail 1137, by W. J. Craig, metallurgist for a Navy research program on the fatigue of metals, under the direction of Professor T. J. Dolan. In order to use the electron microscope on metals, it is necessary to polish and etch the specimens as is customary for use with a light microscope, but from that point on the technique is quite different.

Electron beams are not reflected by metals, so it is necessary to cast a transparent collodion film on the etched specimen and use this film in the microscope. After drying, this film is then covered with a ⅛-in. diameter disk of 200-mesh wire screen. This area is then covered with scotch tape and the whole mass is stripped from the specimen. If the collodion replica of the steel surface strips successfully, the collodion is then shadow cast with a very thin layer of metallic chromium in a vacuum. The scotch tape can then be removed and the ⅛-in. disk placed in the electron microscope. The electron beam can then penetrate the collodion image in the areas between the holes in the 200-mesh screen which holds the collodion in a flat plane.

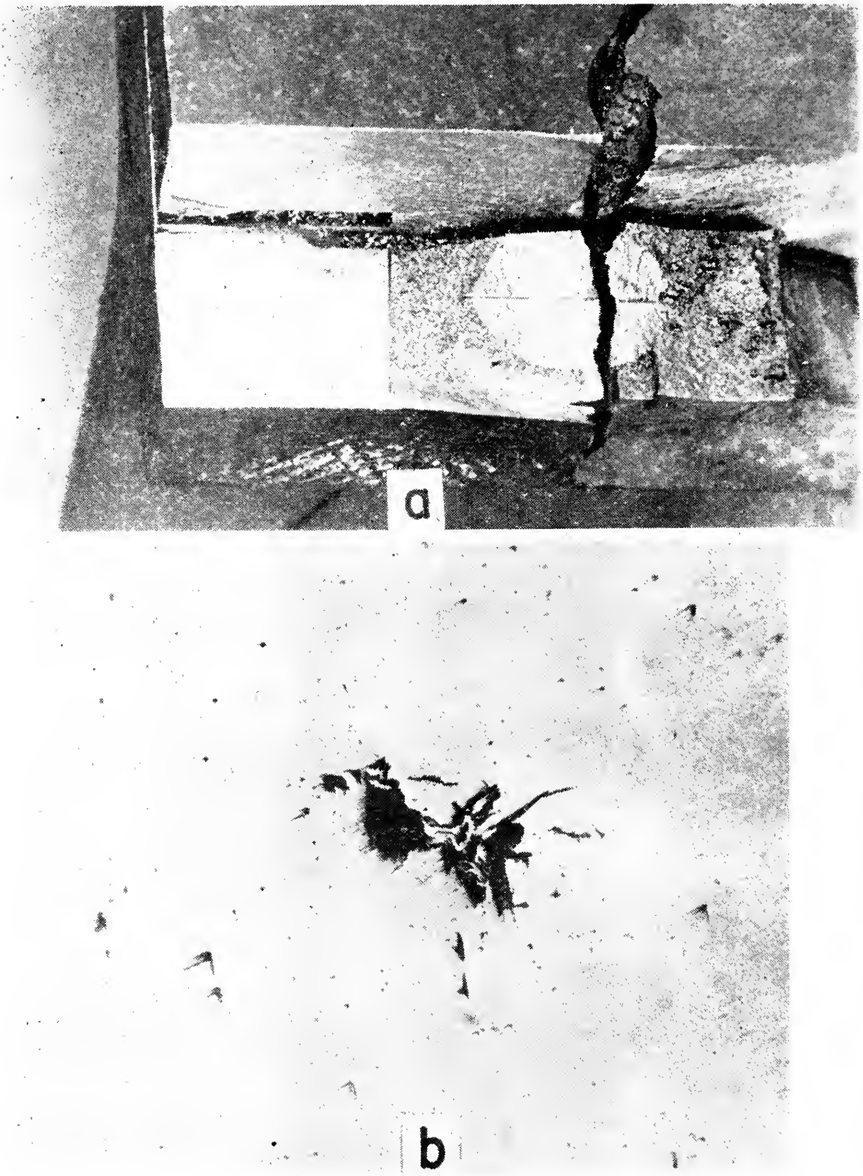

Fig. 6. Internal shelling crack along segregation streak.

(a) Shelling crack opened up.

(b) Photomicrograph of hot torn steel in line with segregation streak. Magnification 90×. Unetched.

Fig. 7 Electron photomicrograph rail 1123. Magnification 20000×, etched in 1-percent nital. Note two small inclusions.

Fig. 8. Electron photomicrograph rail 1123. Magnification 20000×, etched in 1-percent nital.

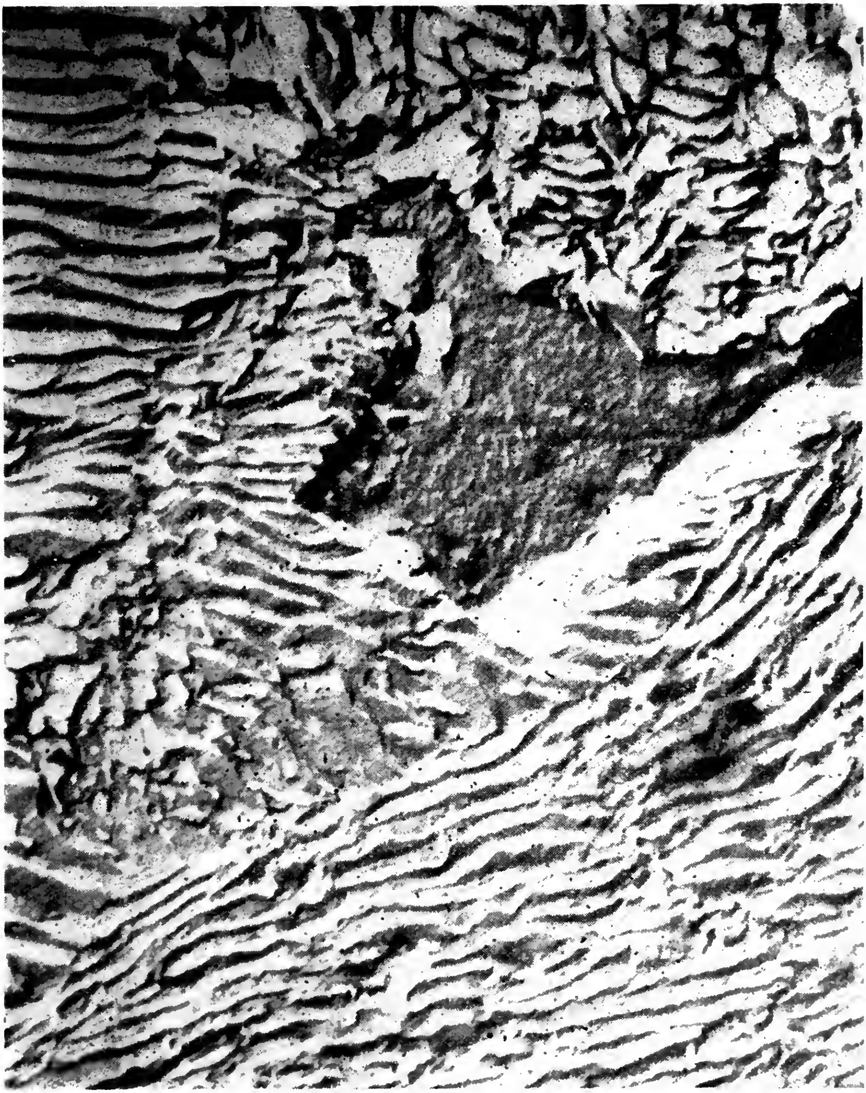

Fig. 9. Electron photomicrograph rail 1124. Magnification 20000×. etched in 1-percent nital.

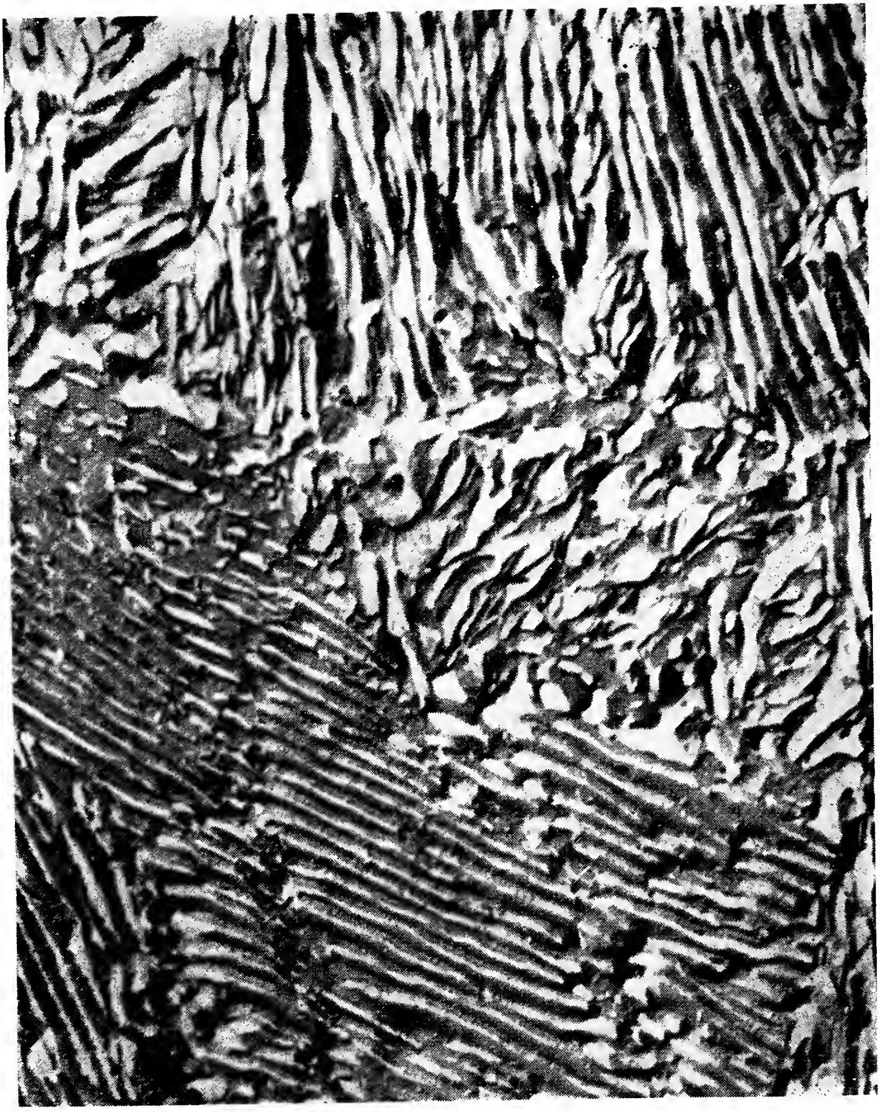

Fig. 10. Electron photomicrograph rail 1124. Magnification 20000×, etched in 1-percent nital.

Fig. 11. Electron photomicrograph rail 1137. Magnification 20000×. etched in 1-percent nital.

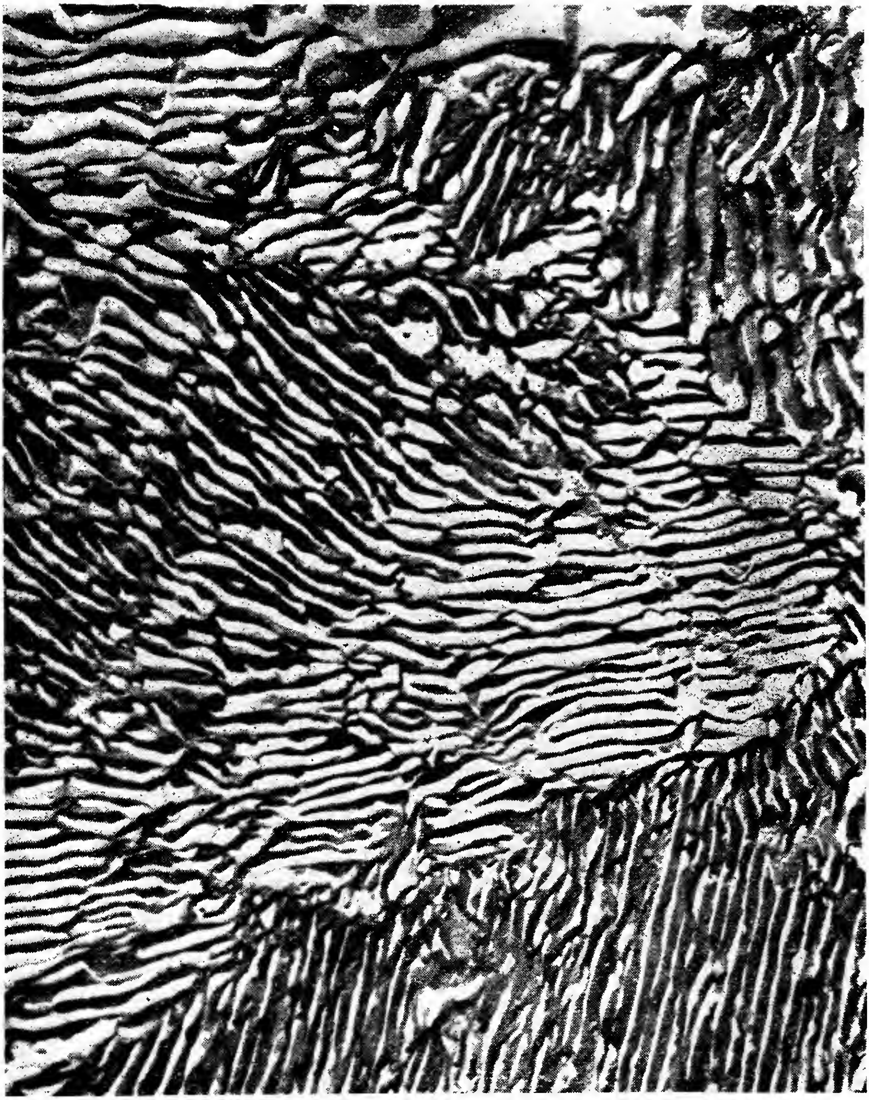

Fig. 12. Electron photomicrograph rail 1137. Magnification 20000×, etched in 1-percent nital.

Many electron micrographs were taken of these three rails at 6000× magnification, but only two of each are included in this report. After the photomicrographs are taken on a 2-in. by 2-in. glass plate they are enlarged to 35,000× magnification in 8-in. by 10-in. photographic prints (reproduced at 20,000× enlargement in this report).

Fig. 7 shows the as-rolled standard carbon rail 1123. The usual pearlitic structure of rail steel is very clearly revealed and two small inclusions of iron oxide are included in this area. This is a cross section of the inclusions, and they are found to be 0.00004 and 0.00007 in. in diameter. Many rail steel inclusions at 6000× magnification almost cover the full area of the 2-in. by 2-in. plates. The white shadows on the inclusions come from the shadow casting with metallic chromium and no detail is revealed in these areas. Fig. 8 shows another area of rail 1123 where the pearlite plates were almost parallel to the polished surface. Many details of the pearlite plates are revealed.

Figs. 9–10 are two areas of companion rail 1124, which was reheated to 1500 deg. F. in 12 hours and quenched in oil for 20 min., followed by drawing at 740 deg. F. for 6 hours. This treatment also results in a pearlitic structure not greatly different from the companion rail which was cooled in air from the rolling temperature. However, the pearlite has somewhat smaller grains in this specimen and this can account for its increased Brinell hardness and tensile strength.

Figs. 11–12 are of the manganese, chromium, vanadium, alloy rail 1137. They show small irregular pearlite grains which would not be resolved well at 2000× magnification, which is about the maximum ordinarily used with a light microscope.

Summary

1. Rolling-load and physical tests of heat-treated rails were continued on two specimens of 132-lb. rails. Brinell hardness was increased from 269 to 360 by the heat treatment. Yield strength was increased 65 percent, tensile strength 31 percent, elongation 18 percent, reduction of area 100 percent, and endurance limit 40 percent. Cycles for failure of as-rolled rails averaged 1,257,000, while the heat-treated rails averaged 4,421,000 cycles before failure.

2. Rolling-load tests were made on seven rails which were flame hardened different amounts on the rail treads. Four of these specimens failed by head and web separation cracks starting at the ends of the specimens. The three specimens which failed by shelling averaged 1,448,000 cycles, which is not a large increase over standard rails. It is thought the head and web separation failures were caused by laps in the head and web fillets.

3. Rolling-load and physical tests were made on two specimens of alloy rail steel containing about 1.35 percent Mn., 0.90 percent Cr., and 0.12 percent V, with 0.75 percent carbon. These rails have physical properties which compare closely with the heat-treated rails described above. They ran eight million and five million cycles in the rolling-load tests.

4. Seven detail fractures from shelling were examined in the laboratory. It appeared that the shelling cracks started longitudinally in the steel and then turned into transverse detailed fractures.

5. A new cradle-type rolling-load machine has been designed and construction is almost completed. This machine has a longer cradle to allow bending of the rail specimen. It is hoped to be able to study the conditions under which detail fractures from shelling develop.

6. A description of the technique used to produce electron micrographs at 35,000× magnification is given. Two such micrographs are included of a standard rail, a heat-treated rail, and an alloy rail used in recent rolling-load tests.

Report on Assignment 11

Recent Developments Affecting Rail Section

C. J. Code (chairman, subcommittee), T. A. Blair, C. B. Bronson, W. J. Burton, E. E. Chapman, H. R. Clarke, L. S. Crane, R. A. Emerson, P. O. Ferris, G. F. Hand, E. M. Hastings, S. R. Hursh, C. C. Lathey, H. S. Loeffler, B. R. Meyers, R. J. Middleton, R. A. Morrison, W. C. Perkins, G. A. Phillips, F. S. Schwinn, G. L. Smith.

This is a progress report, presented as information.

The topics being pursued under the assignment are:

(a) Continuation of study of fatigue of rail web steel.
(b) Field measurement of stresses (outside the joint) in the new rail sections.
(c) Continuation of the study of rail web stresses within joint bar limits.
(d) Redesign of 100 RE rail and joint bars.

Appendix 11-a—Professor Jensen's report presented herewith concludes the fatigue tests sponsored by the subcommittee at the University of Illinois. The fatigue properties of rail web steel have been given very thorough study, both with and without corrosion.

The report now presented shows marked reduction in endurance limit, for all types of stress cycle, when the specimen is subjected to corrosion. The most severe reductions are shown for those types of stress cycle where the predominating stress is tensile. For a stress cycle from zero to a maximum in tension the reduction in the endurance limit is 57.5 percent.

Such a stress cycle is quite likely to be encountered in the rail web within the joint when static stress due to wedging action of joint bars is added to dynamic stress due to wheel loads.

As mentioned in the previous annual report, more severe reductions in endurance limit may be encountered under more severe corrosive conditions.

The report points toward the necessity for overcoming any severe corrosive condition which affects the rail web, particularly within the joint.

Report of the Research Engineer, Appendix 11-b herewith, covers stress measurements on 115 RE rail in tangent track, both outside the joint and inside the joint. The stresses reported are all moderate.

Field work has been completed on stress measurements on sharp curves in both 115 RE and 132 RE rail, but the time required for analysis of the data will prevent a report being presented this year.

At the request of the subcommittee, the research staff is undertaking a study of the stresses developed around a bolt hole when, due to contraction of the rail, the bolt comes into contact with the margin of the hole. This work will be carried out at the Central Research Laboratory.

Appendix 11-a

Fatigue Tests of Rail Webs

By R. S. Jensen

Special Research Assistant Professor of Engineering Materials

Introduction and Acknowledgment

Fatigue tests on T-section specimens with as-rolled surfaces cut from the web of a 112 RE rail and tested as cantilever beams in flexure were reported in AREA Proceedings, Vol. 51, 1950, pages 640–647. The stress ranges included completely reversed stress,

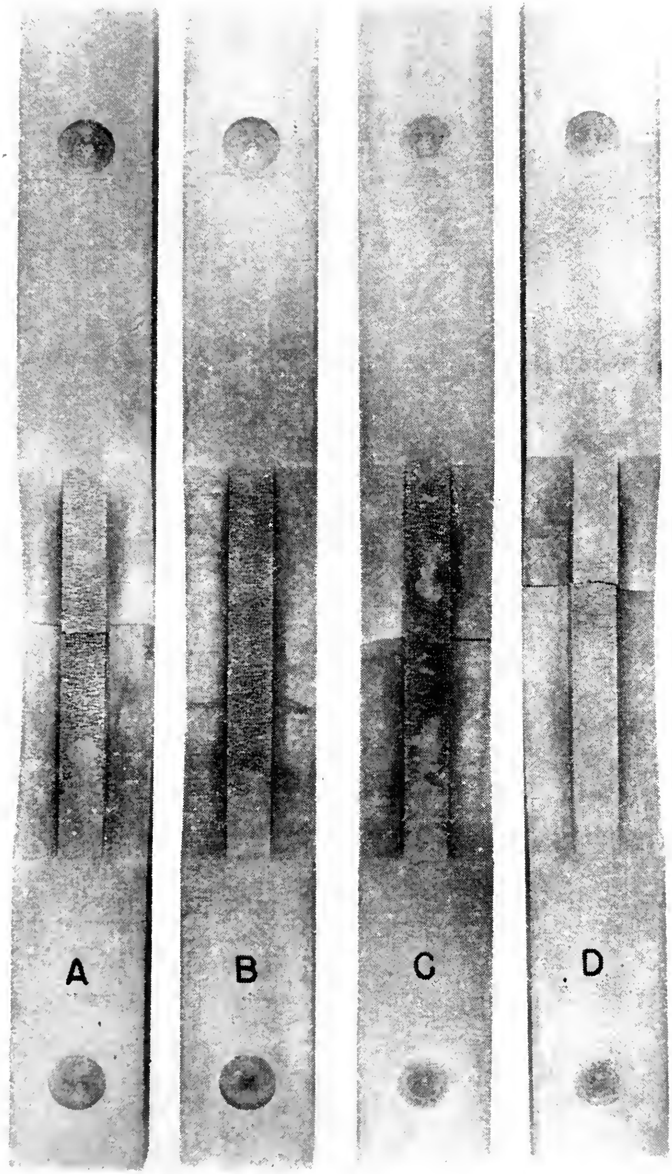

Fig. 1. T-section corrosion fatigue specimens from rail web.

(A) Specimen 827-68 amx. stress 70,000 psi.
(B) Specimen 827-67 max. stress 80,000 psi.
(C) Specimen 827-74 max. stress 42,000 psi.
(D) Specimen 827-57 max. stress 30,000 psi.

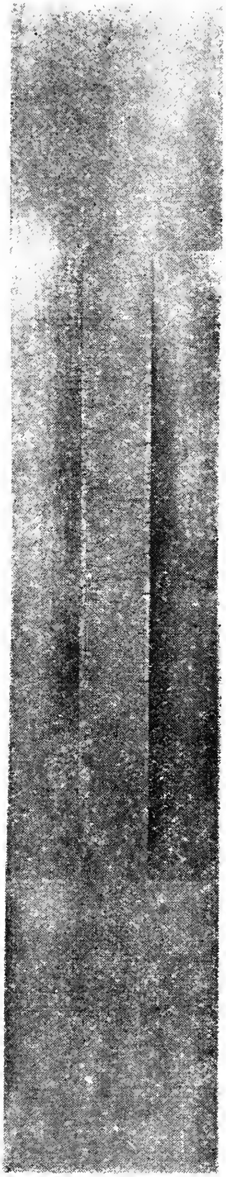

Fig. 2. T-section corrosion-fatigue specimen from rail web. (1½× magnification. Hot 50-percent HC1 etch)

Corrosion fatigue cracks on specimen 827–65 after 4,193,600 cycles of stress from zero to 26,000 psi. tension.

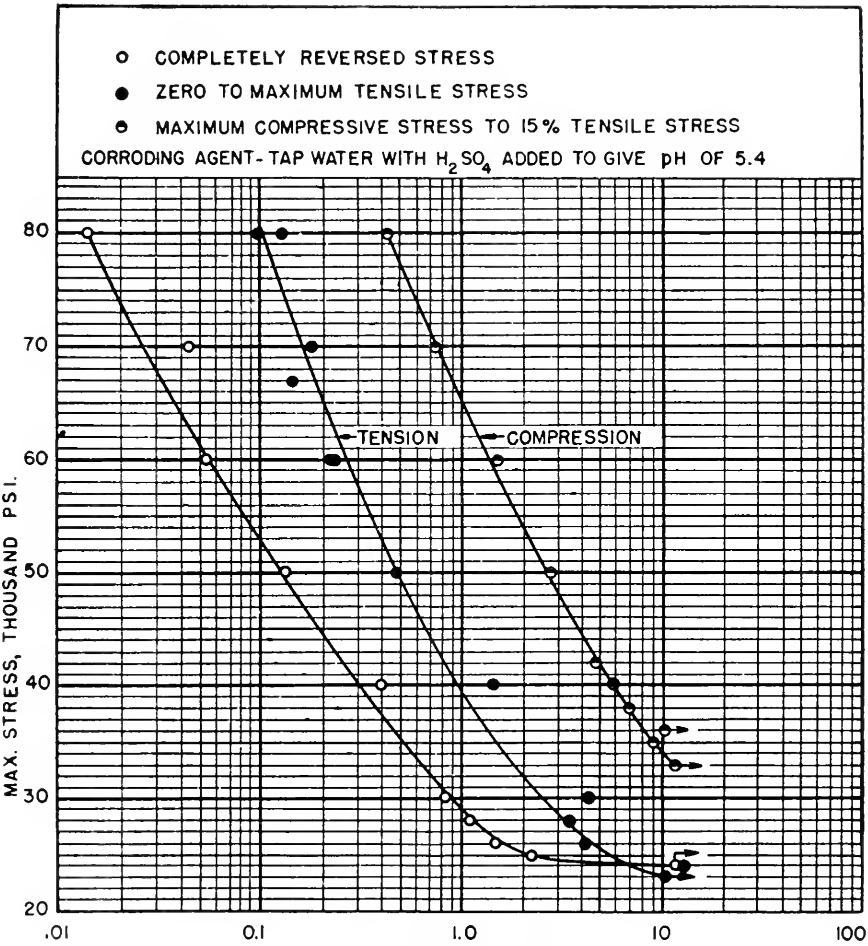

Fig. 3. S–N diagrams for corrosion-fatigue tests.

zero to maximum tensile stress, mean compressive stress of 10,000 psi., mean tensile stress of 10,000 psi., mean tensile stress of 20,000 psi., and maximum compressive stress to 20 percent tensile stress.

Because service failures in rail webs occurred at some locations in track where corrosion was quite heavy, at considerably fewer cycles than were demonstrated by laboratory fatigue tests, it was thought that the discrepancy which existed between laboratory tests and service life at these locations was due mainly to corrosion. Therefore, a series of laboratory corrosion-fatigue tests was proposed, in which modified tap water was used as a corroding agent and the speed of the fatigue machines was reduced. in order to prolong the time the specimens were subject to corrosion. Previous laboratory tests, using tap water, with the machines operating at their normal speed of 1.1 million cycles per day, failed to show substantial reductions in fatigue life.

This report covers corrosion fatigue tests under the same ranges of stress, using a corroding agent of tap water mixed with sufficient sulfuric acid (approximately 3 cc. of acid per 5 gal. of water) to reduce the pH value to 5.4. This solution was allowed to drip on the specimens at a rate of 10 drops per minute. Because of the relatively large amount of bicarbonates present in the tap water, 330 parts per million, it was aerated for several hours before mixing with the acid. Daily checking of the pH values indicated that the stability of the solution was good for about three days, but that after that length of time there was a greater tendency for the pH value to increase. Consequently, a newly mixed solution was used every third day.

Specimens were stressed at a rate of 150 cycles per minute for the first 1,000,000 cycles (5 days), or until a crack had been detected. After 1,000,000 cycles, the speed of testing was increased to 800 cycles per minute and maintained at that rate until the specimen cracked, or until 10,000,000 cycles had been reached.

Acknowledgment is made of the services of Charles Peterson and Daniel Kennedy, student assistants, who assisted in this work.

Results of Tests

Results of the tests are tabulated in Table 1 and plotted in Figs. 3 to 6.

Fig. 1 shows four of the specimens after etching in hot hydrochloric acid to reveal numerous small cracks which developed on the as-rolled surface. Specimens A, B, and C were tested under a range of stress from maximum compression to 15 percent as great tension, and specimen D was stressed from zero to maximum tensile stress.

Fig. 2 shows a specimen at 1½× magnification after 4,193,600 cycles of stress from zero to 26,000 psi. tensile stress, and was included in order to show that several cracks can develop under low stresses with corrosion. Before etching, only the two largest cracks near the center of the specimen were clearly visible.

TABLE 1. RESULTS OF CORROSION FATIGUE TESTS
Completely Reversed Stress

Specimen No.	*Max. stress, psi.*	*Cycles to start crack*
827–50	80,000	13,600
827–49	70,000	47,300
827–53	60,000	51,400
827–52	50,000	130,600
827–46	40,000	398,800
827–37	30,000	850,000
827–40	28,000	1,100,000
827–41	26,000	1,500,000
827–54	25,000	2,157,200
827–51	24,000	13,044,700—no failure
Zero to maximum tensile stress		
827–58	80,000	95,600
827–63	80,000	125,800
827–56	70,000	193,000
827–59	60,000	210,000
827–62	60,000	236,200
827–61	50,000	492,500
827–64	40,000	1,659,000
827–57	30,000	4,387,200
827–60	28,000	3,406,200
827–65	26,000	4,193,600
827–66	24,000	12,389,200
827–78	23,000	10,633,200—no failure

TABLE 1.—Continued

Maximum compressive stress to tensile stress 15 percent as great

827–67	80,000	430.000
827–68	70.000	730,500
827–69	60,000	1,500,900
827–70	50,000	2,729.200
827–74	42,000	4,974,500
827–76	40,000	5,943.000
827–75	38,000	7,132,000
827–77	36,000	10,003,000—no failure
827–72	35,000	9,157,400
827–79	33,000	12.191.800—no failure

Mean stress of 10,000 psi. compression

827–114	80,000	40.800
827–111	70,000	246,000
827–106	60,000	242.000
827–102	50,000	376,600
827–110	45,000	975,200
827–101	40,000	7,276,100
827–115	39,000	6,268,000
827–112	38,000	8,784,700
827–116	37,000	11,370,700
827–104	35,000	10.000.000—no failure

Mean stress of 10,000 psi. tension

827–91	80,000	50,500
827–81	70,000	43,800
827–86	60,000	279,200
827–88	50,000	463,600
827–82	50,000	471,100
827–84	40,000	814,500
827–80	30,000	4,222,600
827–87	27,000	8,133,100
827–92	26,000	10,000,000—no failure
827–93	25,000	10,018,400
827–85	25,000	3,308,000
827–95	23,000	10,000,000—no failure
827–83	20,000	10,000,000—no failure

Mean stress of 20,000 psi. tension

827–99	80,000	60,000
827–105	70,000	92,600
827–97	60,000	167,700
827–94	50.000	480,200
827–90	40,000	5,647.800—broken
827–96	40,000	1,163,500
827–100	37,000	3,469,000
827–98	35,000	8,964,000
827–107	34,000	10,000,000—no failure
827–103	33,000	2,467,000
827–109	33,000	2.211,000
827–113	32,000	9,508,000
827–89	30,000	10,000,000—no failure

The S–N diagrams for three series of tests are shown in Fig. 3. The curve for specimens under completely reversed stress indicates an endurance limit at 10.000.000 cycles of 24,000 psi. Because of the greater range of stress for specimens of this group. the specimens at the higher stresses failed at a lower number of cycles than specimens of any other group.

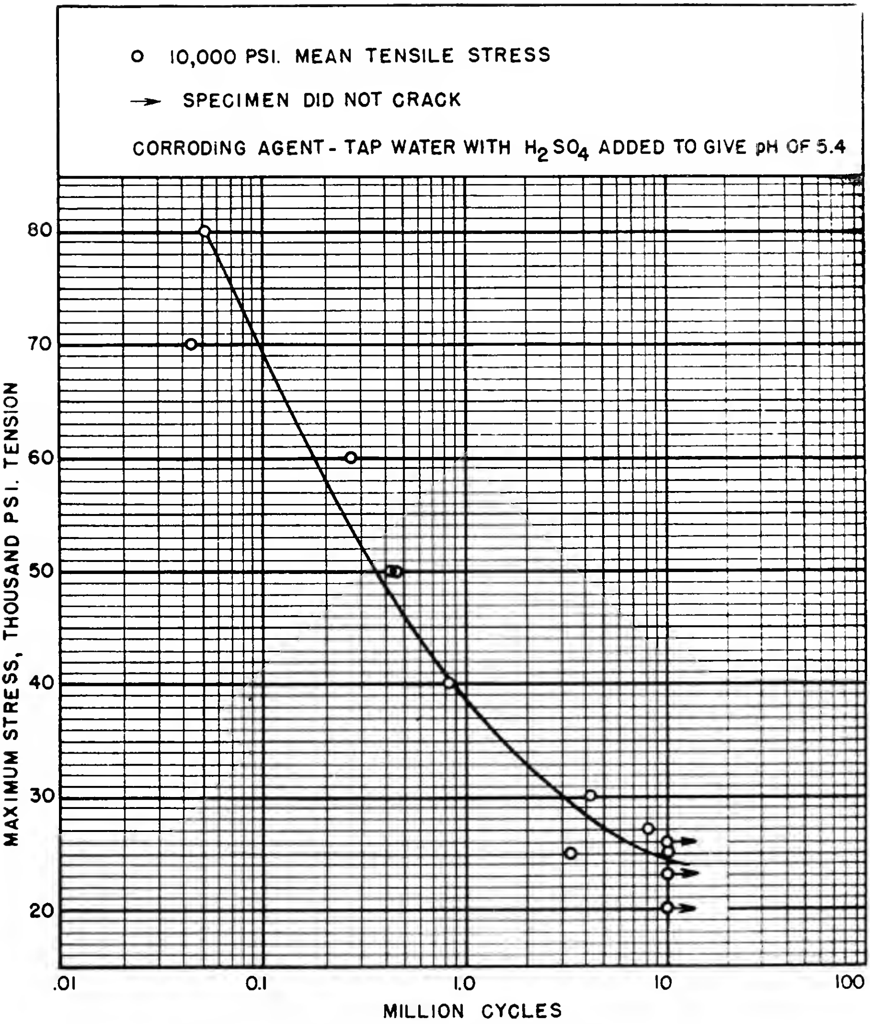

Fig. 4. S–N diagram for corrosion-fatigue tests.

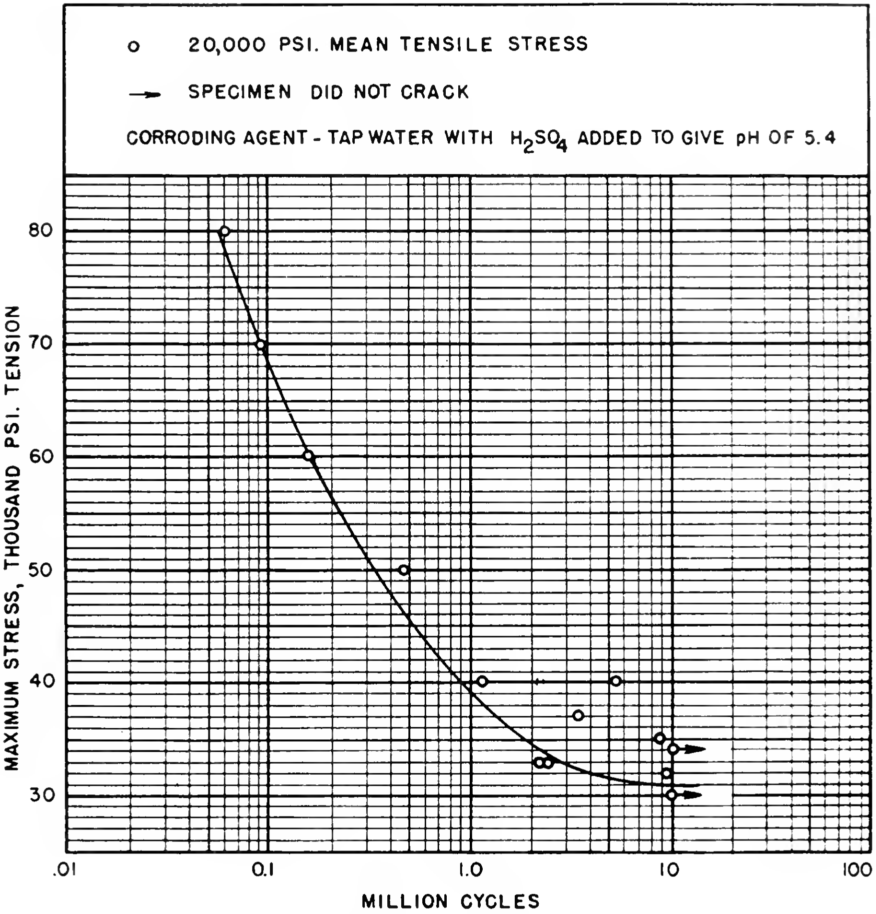

Fig. 5. S-N diagram for corrosion-fatigue tests.

The curve for specimens from zero to maximum tensile stress indicates an endurance limit of 23,000 psi., although the curve could have been drawn through the point on the 24,000 psi. stress line since that specimen had not failed at 10,000,000 cycles but did show a crack at 12,389,200 cycles. At the higher stresses, these specimens ran for several times the number of cycles of specimens under complete reversals because their range of stress was only half as great. Since both curves show approximately the same endurance limit, it appears that at the lower stresses the magnitudes of the tensile stresses have more effect in causing fatigue failure than range of stress.

The curve for specimens from maximum compressive stress to tensile stress 15 percent as great indicates an endurance limit of 33,000 psi. It appears from this curve that the compressive stresses are less destructive than tensile stresses in starting fatigue cracks.

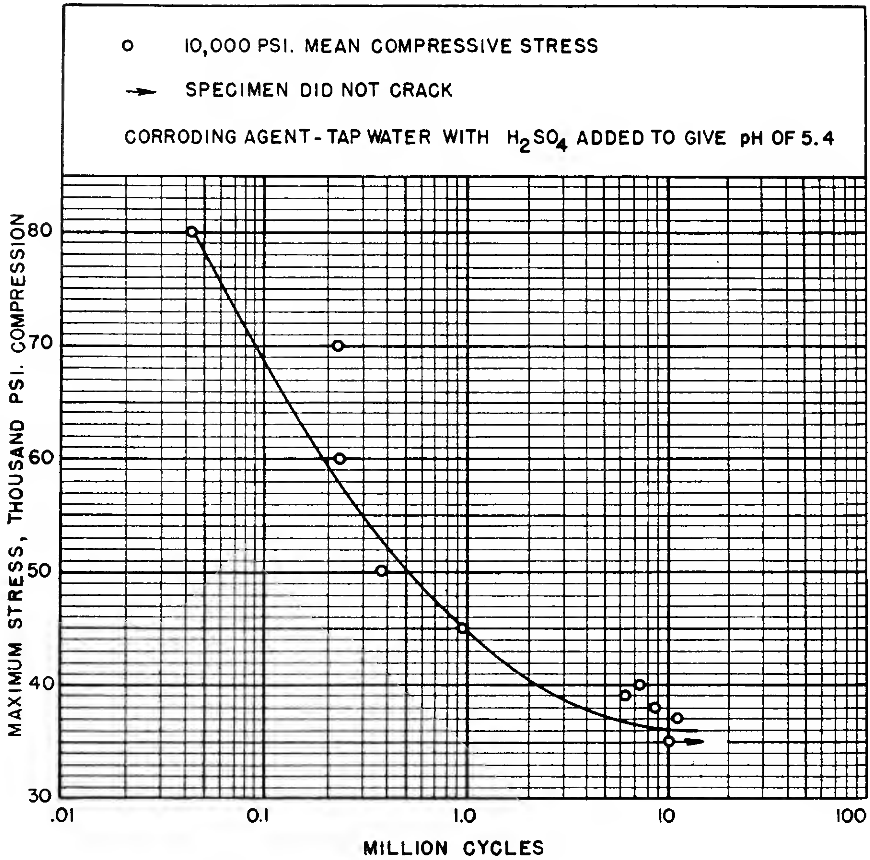

Fig. 6. S–N diagram for corrosion-fatigue tests.

The S–N diagram of Fig. 4 for specimens with a mean tensile stress of 10,000 psi. indicates an endurance limit of approximately 24,000 psi., and Fig. 5 for specimens with a mean tensile stress of 20,000 psi. shows an endurance limit of 31,000 psi.

In Fig. 6 the S–N diagram for specimens with a mean compressive stress of 10,000 psi. indicates an endurance limit of 36,000 psi.

A modified Goodman diagram for the corrosion fatigue tests is shown in Fig. 7. In the modified Goodman diagram for the specimens with no corrosion, reported last year,[1] in which ordinates to the upper line represented the maximum tensile stresses at the endurance limit, ordinates to the middle line represented mean stresses, and ordinates to the lower line represented the maximum compressive stresses at the endurance limit for the various ranges of stress tested, a good correlation of data was observed, i.e., the points representing maximum tensile stresses at the endurance limit all fell upon or very close to the upper line of the diagram. For the modified Goodman diagram of

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[1] AREA Proceedings, Vol. 51, 1950, p. 645.

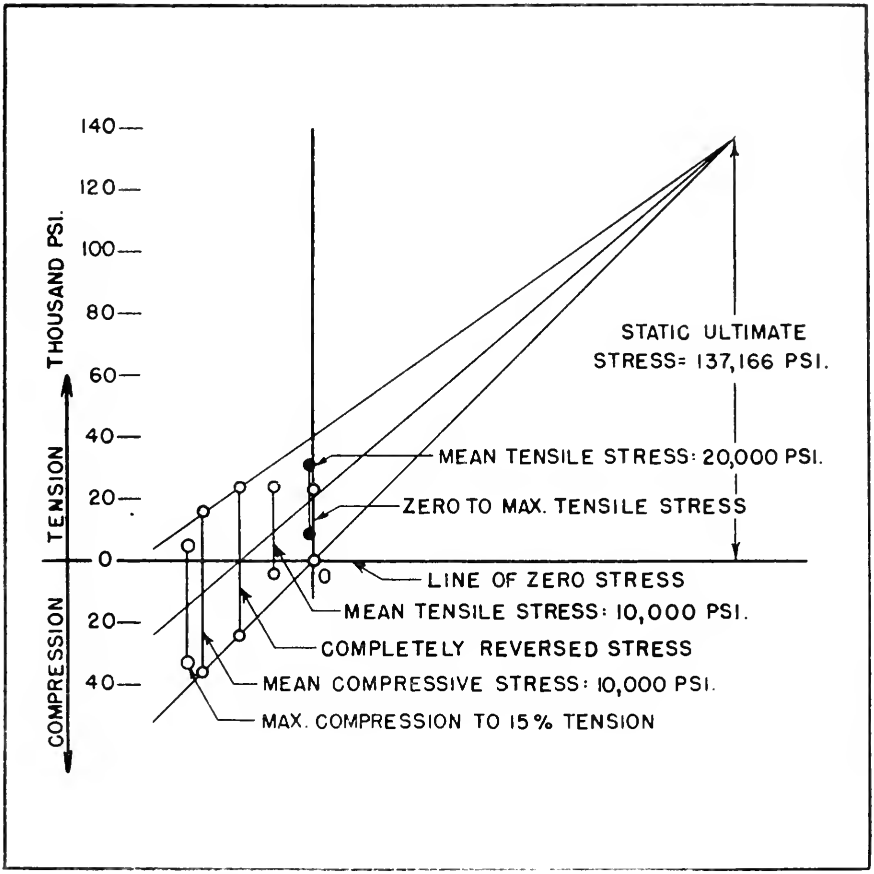


Fig. 7. Modified Goodman diagram for corrosion-fatigue tests.

Fig. 7, it appears that, with corrosion, the maximum tensile stresses, rather than range of stress, predominate in determining the endurance limit. The specimens under completely reversed stress, specimens with mean tensile stress of 10,000 psi., and specimens from zero to maximum tensile stress, all show an endurance limit of 23,000 psi. to 24,000 psi.

The foregoing data, represented by the S–N curves and modified Goodman diagram, would indicate that for the high stresses corresponding to the upper part of the S–N curves, range of stress is the important factor in causing corrosion fatigue failure, whereas for the low stresses near the endurance limits, maximum tensile stress seems more important than range of stress. The actual failure in the field may occur in any part of the S–N diagram, and it seems probable that many head and web separations which have occurred away from the joint were due to a relatively small number of cycles of fairly high stress, and failures within the joint bar limits probably occur due to a relatively large number of cycles of low stress, with tensile stress predominating.

A comparison of tests on specimens without corrosion and with corrosion is given in Table 2.

TABLE 2. COMPARATIVE FATIGUE TESTS WITH AND WITHOUT CORROSION

Type of stress cycle	*Endurance limit, psi. without corrosion*	*Endurance limit, psi with corrosion*	*Percent reduction in endurance limit*
Complete reversals	±33,000	±24,000	27.2
Zero to maximum tension	+54,000	+23,000	57.5
Mean compressive stress of 10,000 psi	—46,000	—36,000	21.8
Mean tensile stress of 10,000 psi	+42,000	+24,000	42.8
Mean tensile stress of 20,000 psi	+51,000	+31,000	39.2
Maximum compression to 20 percent tension	—59,000		
Maximum compression to 15 percent tension		—33,000	

From the above comparison it is apparent that a substantial reduction in the fatigue life of rail webs results from the action of the relatively mild corroding agent of tap water modified to give a pH value of 5.4.

Appendix 11-b

Measurement of Stresses in 115 RE Rail on Tangent Track—North Western Railway

Web Stresses in the New 115 RE Rail Section

The report on Assignment 7 describes the test sections for the new 115 RE rail which was installed on the westbound main track of the Chicago & North Western Railway near Sterling, Ill., 106 miles west of Chicago on the Omaha Line. Each test section includes 100 joints and is approximately 2000 ft. long. The test section was installed for the purpose of testing various joint bar designs. Included in these designs were two AREA design bars on the following locations:

Location AA—New AREA design, headfree 36-in. joint bar for 115 RE rail, with bolt spacing of 4½–9 in. (4 bolts in 36-in. bars).

Location BB—Same joint bar design with new AREA bolt spacing of 3½–6–6 in.

This installation offered an opportunity to obtain measurements of stresses developed under regular traffic in the new 115 RE rail section. The measurements are thought to be informative, because they determine to what extent the service stresses in the upper web and upper rail fillets had been reduced with the new rail design, and indicate the effect of the number of bolt holes and their spacing on the range of web stresses developed in service.

The measurements, analysis of data, and preparation of the report for these tests were made by the Engineering Division research staff of the Association of American Railroads, under the direction of G. M. Magee, research engineer, M. F. Smucker, assistant electrical engineer, and Olaf Froseth, assistant track engineer, assisted by other staff members. The results of a similar investigation with the 132 RE rail section were reported in the AREA Proceedings, Vol. 51, 1950, page 626, Appendix 11–a.

Previous reports of the committee have described the high stresses that were found in the old 112 RE and 131 RE rail sections in the upper portion of the rail web and in the upper rail fillets. It was pointed out that these were due to stress concentration effects from the wheel-bearing pressure, and were aggravated by the bending of the head on the web because the wheel load was frequently applied eccentrically, generally toward the gage corner. In the design of the new 115 RE and the 132 RE rail sections, the upper part of the web was thickened and longer fillet radii were used. Laboratory tests indicated that this modification would effect a stress reduction of approximately 25 percent. In addition, the top of the rail was rounded to relieve the gage corner from excessive bearing pressure and to bring the point of contact between wheel and rail more nearly to the center of the head.

The stress measurements were conducted at four different locations in the track. At track Locations 1 and 2, the stress gages were placed directly over the same tie on opposite rails, and at Locations 3 and 4 the gages were placed halfway between ties on opposite rails. The stresses were measured only near the upper web fillets on the gage and field sides of the rail (at gages 3 and 13 located 4½ in. above the rail base), because previous tests had shown these to be the areas of highest stress. Regular train operation over this track included both steam and diesel locomotives and passenger and freight trains, covering a speed range to 80 mph. Figs. 1 to 4, inclusive, show the results obtained from the measurements. These charts were prepared to show the percentage of stresses occurring within a given stress range for diesel and steam locomotives separately and for passenger and freight cars separately. From this presentation of the data anticipated stress frequencies for any traffic condition can be estimated. As the wheel loads experienced in these tests are representative of those normally encountered on almost any main line railroad, the results obtained in these tests provide a reasonably accurate picture of prevailing stress frequency for tangent track.

It will be observed that with this improved rail section on tangent track the stress range is as well balanced as can be expected on both the gage and field sides. For diesel locomotives and passenger cars the stress range lies between 5000 psi. tension and 25,000 psi. compression on the gage side of the web and between 15,000 psi. tension and 15,000 psi. compression on the field side. For steam locomotives the stresses are somewhat larger, but still balanced with a stress range of 5000 psi. tension to 35,000 psi. compression on the gage side and a stress range of 15,000 psi. tension to 25,00C psi. compression on the field side. The freight cars show the best balanced stress range, with 5000 psi. tension to 25,000 psi. compression on the gage side and 5000 psi. tension to 15,000 psi. compression on the field side. These stress ranges are larger than those of the 132 RE rail of the same design, as reported in the AREA Proceedings, Vol. 51, 1950, due to difference in weight in the two rail designs.

Rail Web Stresses within Joint Bar Limits

In AREA Proceedings, Vol. 49, 1948, page 464, a complete report was given of laboratory tests conducted at the University of Illinois by the research staff with three different bolt spacings for the new 115 RE rail section. As a result of the data obtained in these tests, the Association adopted a revised bolt hole spacing of 3½–6–6 in. in lieu of the old spacing of 2½–6½–6½ in. Laboratory tests indicated that the new spacing effected substantial reductions in the rail web stress in the upper fillet at the rail end and at the first bolt hole. It was also shown in these laboratory studies that the applied bolt tension alone is responsible for a substantial web stress, which is referred to as the static web stress. Dynamic stresses result from passing wheel loads and the flexure on the joint.

The installation on the North Western Railway afforded an opportunity to obtain measurements in the field on the new bolt spacing for the new 115 RE section, as well as 4½–9 in. spacing, for which an interest had been expressed by several railways. Accordingly, rail web stress measurements were made in 1949 at two joints with the AREA headfree design bars for each of the two above bolt spacings. These measurements included the dynamic stresses developed in the rail web under regular service trains. Measurements were made at the rail end on the rail web 4½ in. above the rail base near the upper fillets at gage lines 1g, 1f, 2g and 2f. Other measurements were made as near to the edge of the first bolt hole as the gages permitted on each rail end at the joint and on both field and gage web faces at gage lines 4g, 4f, 5g and 5f.

Discussion of Dynamic Stresses

Figs. 5 to 8, inclusive, show the maximum tension and compression stress during each test run obtained at one joint with the new spacing (3½–6–6 in.) and another joint with the two hole spacing (4½–9 in.) on the north rail. The chart shows the stresses for diesel and steam locomotives separately, and also those developed under the cars. Values are plotted with respect to the speed of the train. The diagrams show the location for each numbered gage at the rail end, providing a convenient means of identification. It will be observed from these that there is no definite trend for change in stress range or increase in stress with increase in speed. In fact, there appears no apparent relation between stress and train speed within the speed range of 10 and 80 mph. The stresses in the upper webs at the rail ends of 2-hole drillings 4½–9 in.) compared to those of the 3-hole drillings (3½–6–6 in.) are less in the case of the 2-hole drillings. Practically all of the web stresses for the 2-hole drillings fell within a stress range of 20,000 psi. tension to 25,000 psi. compression, compared to the stress range of the 3-hole drillings of 15,000 psi. tension to 35,000 psi. compression. The stress range at the edge of the first bolt hole for the 2-hole drillings is 5000 psi. tension to 15,000 psi. compression, compared to the stress range of the 3-hole drilling of 10,000 psi. tension to 25,000 psi. compression.

A better visual comparison of the dynamic stresses is afforded by Fig. 9, in which the average maximum for each run and the single maximum stress obtained are shown for the joints of the two different rail drillings. It is interesting to note that the range of stress at the receiving rail end is somewhat higher than for the leaving end. Here again a difference in the stress range at the edge of the first bolt hole for the two different drillings can be noted.

(text continued on page 704)

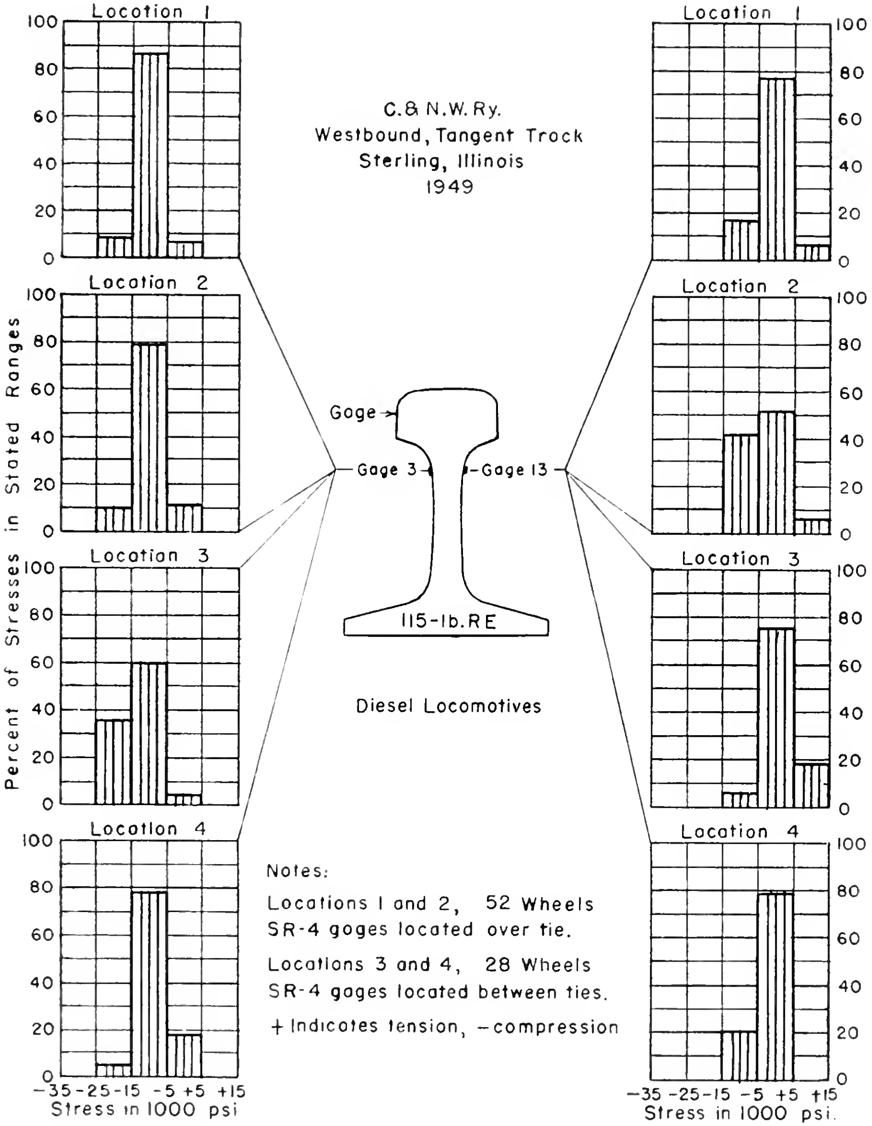
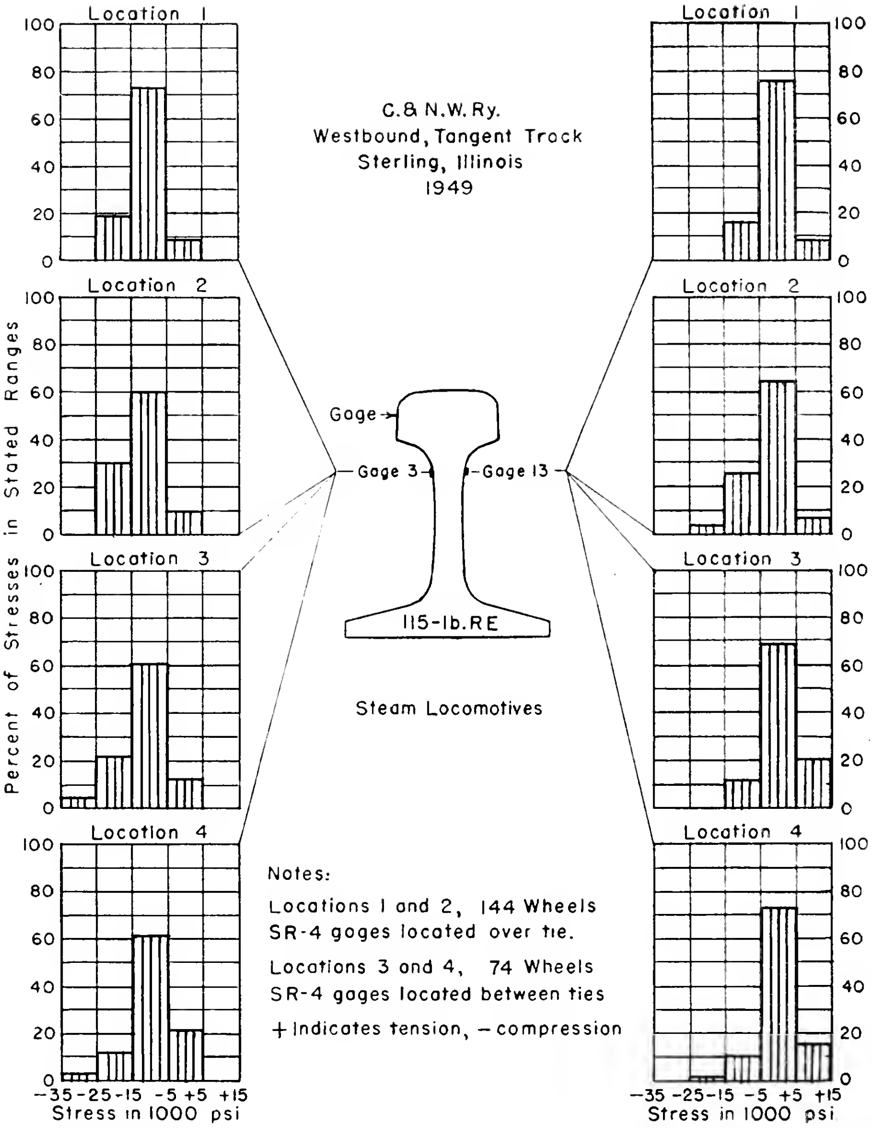


Fig. 1. Frequency of occurrence of stresses in rail web at quarter points between rail joints. Stresses produced by diesel locomotives.



Notes:

Locations 1 and 2, 144 Wheels
SR-4 gages located over tie.

Locations 3 and 4, 74 Wheels
SR-4 gages located between ties

+ Indicates tension, − compression

Fig. 2. Frequency of occurrence of stresses in rail web at quarter points between rail joints. Stresses produced by steam locomotives.

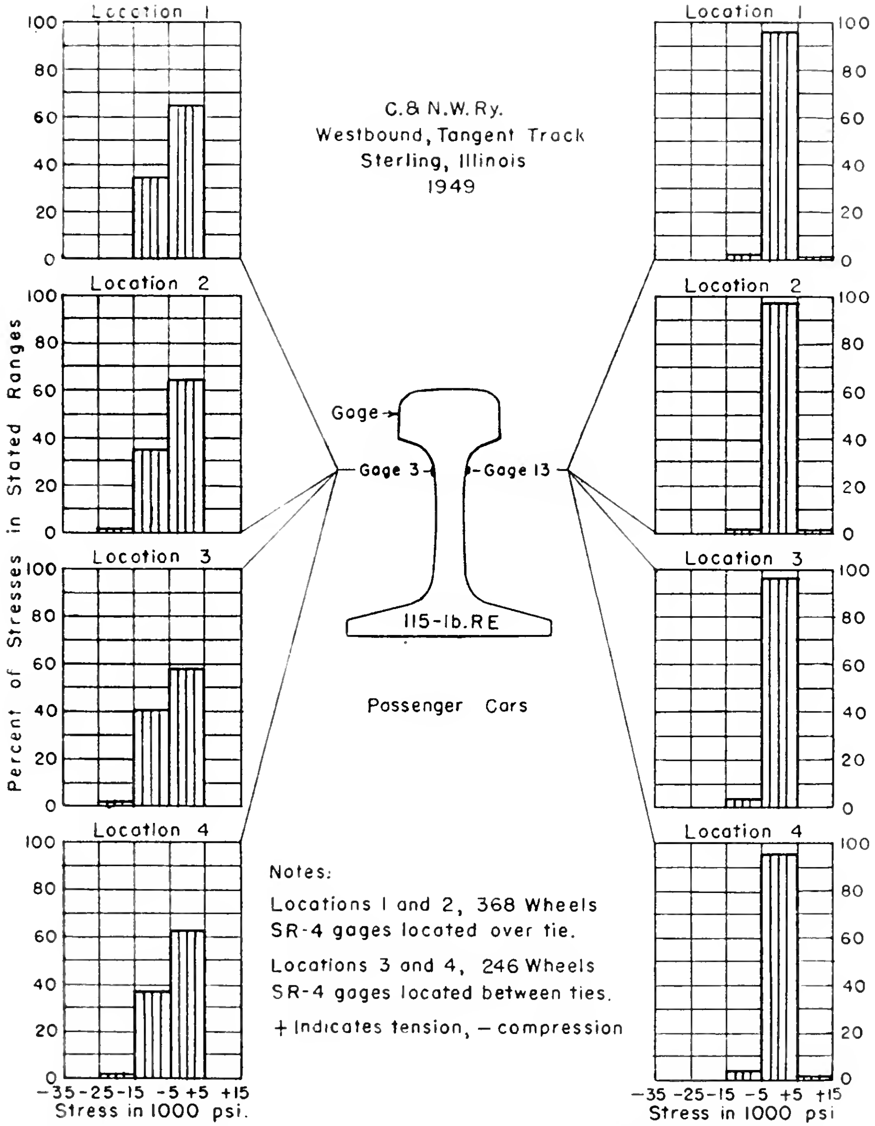


Fig. 3. Frequency of occurrence of stresses in rail web at quarter points between rail joints. Stresses produced by passenger cars.

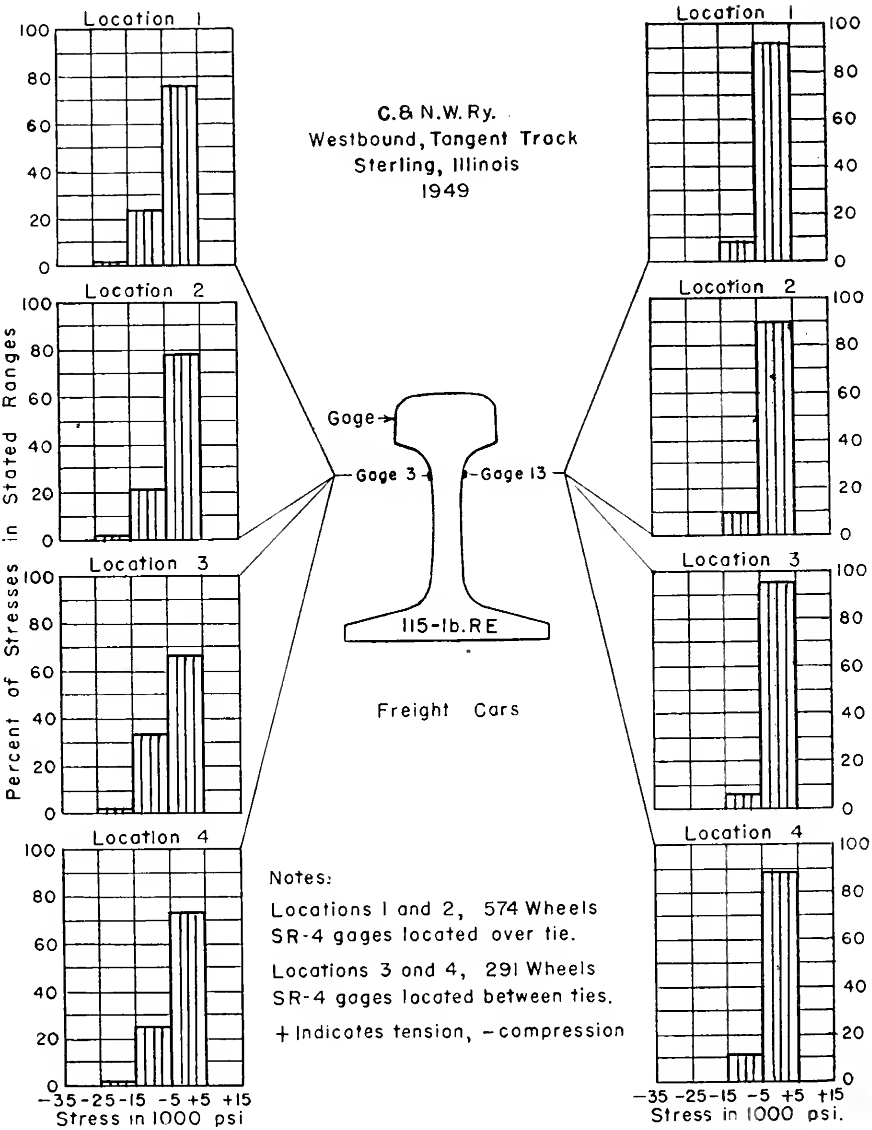


Fig. 4. Frequency of occurrence of stresses in rail web at quarter points between rail joints. Stresses produced by freight cars.

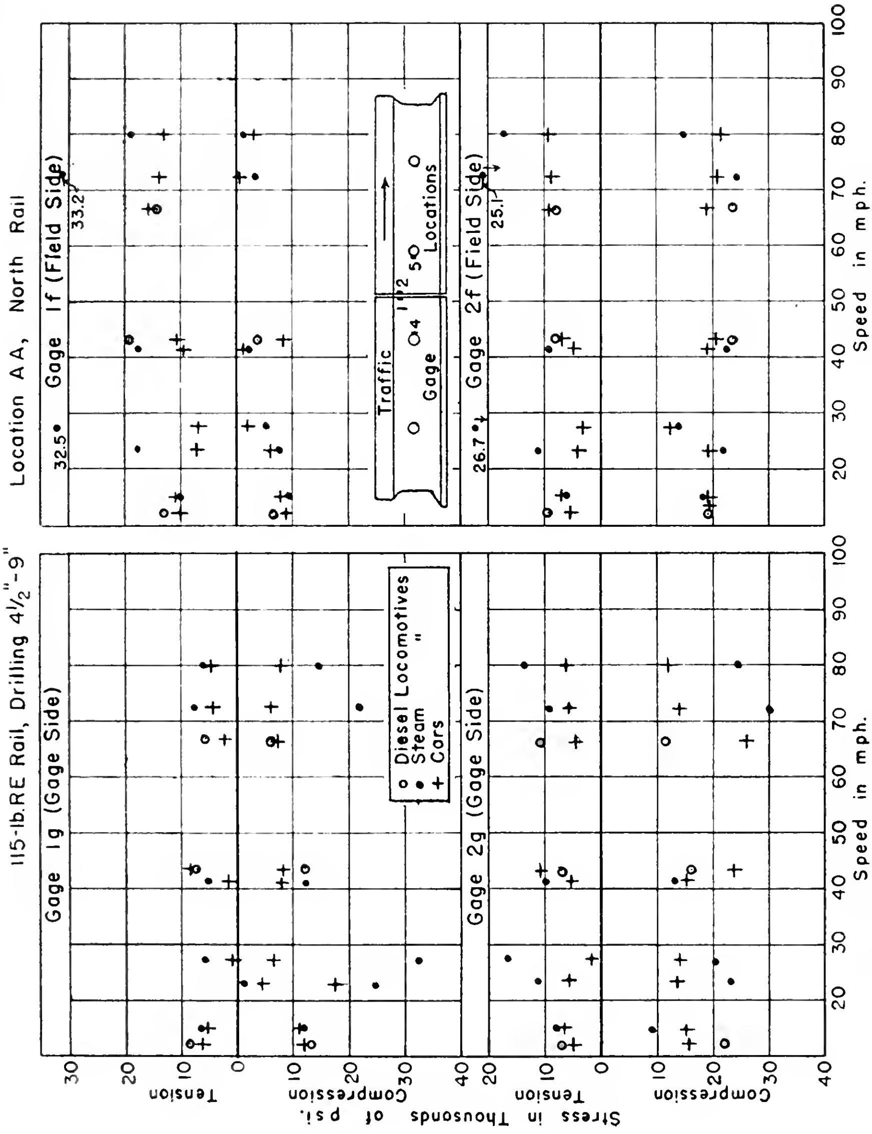


Fig. 5. Maximum dynamic rail web stresses at gages 1 and 2. Joint A-4, C. & N. W. Ry.

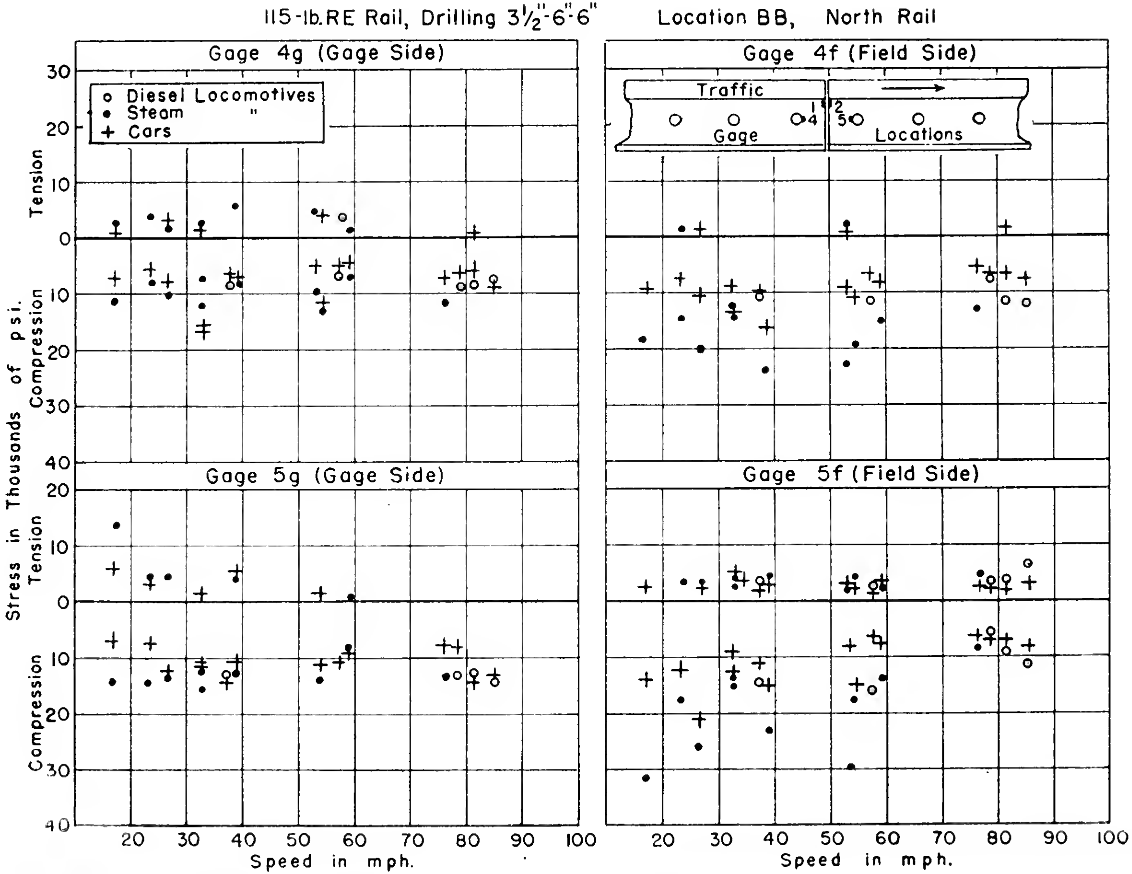


Fig. 6. Maximum dynamic rail web stresses at gages 4 and 5. Joint A–4, C. & N. W. Ry.

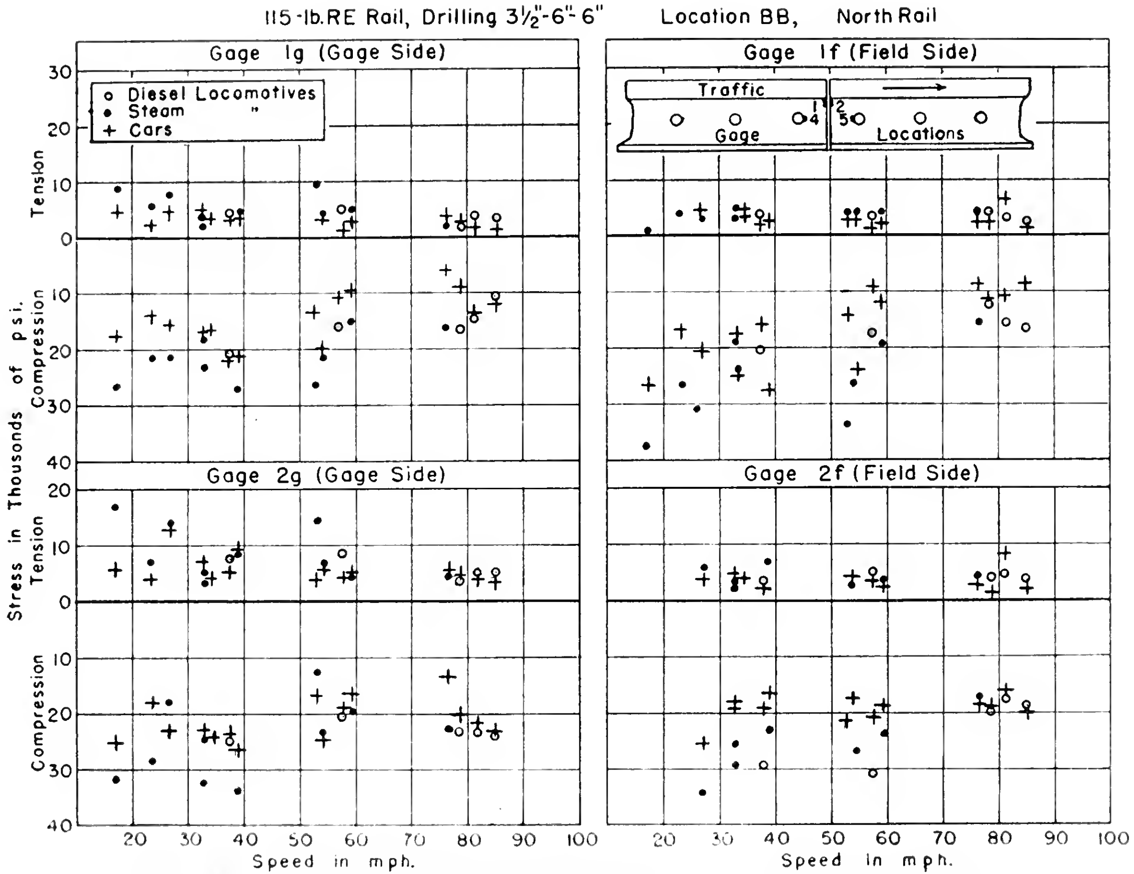


Fig. 7. Maximum dynamic rail web stresses at gages 1 and 2, Joint B 2, C. & N. W. Ry.

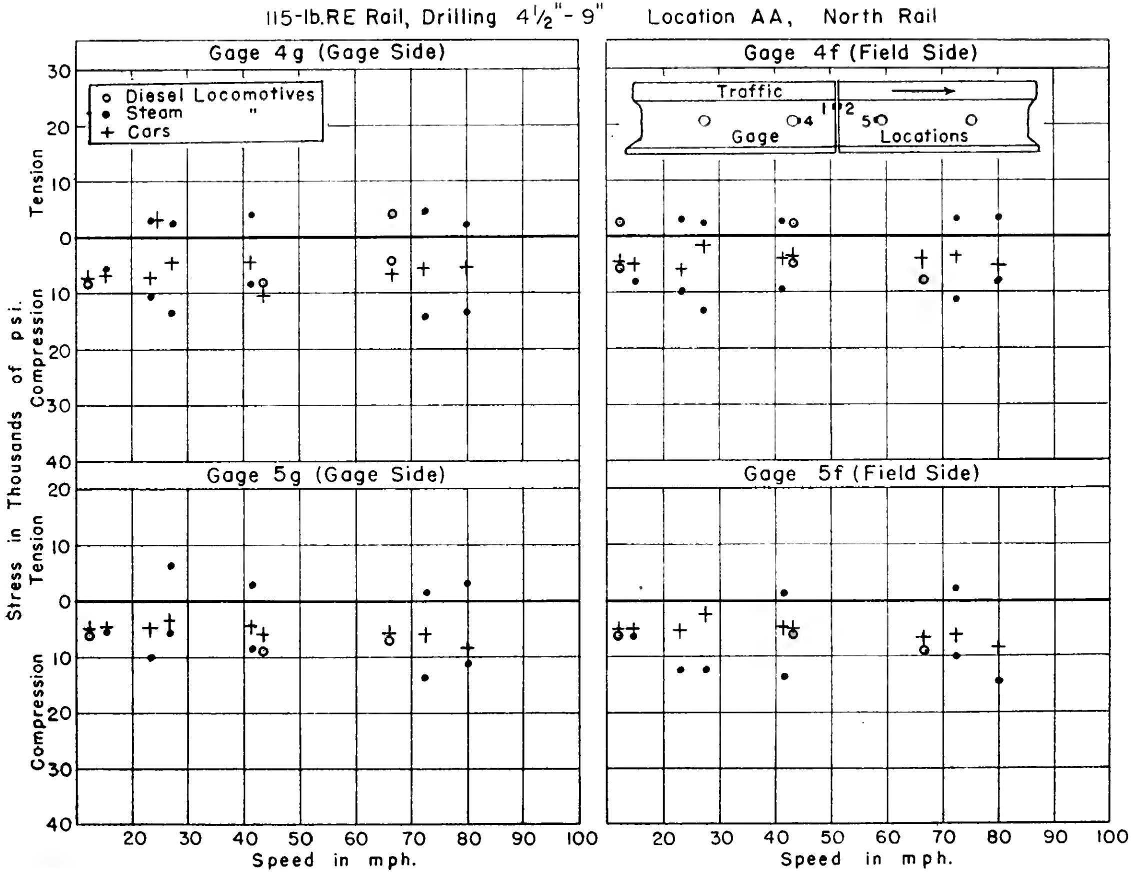
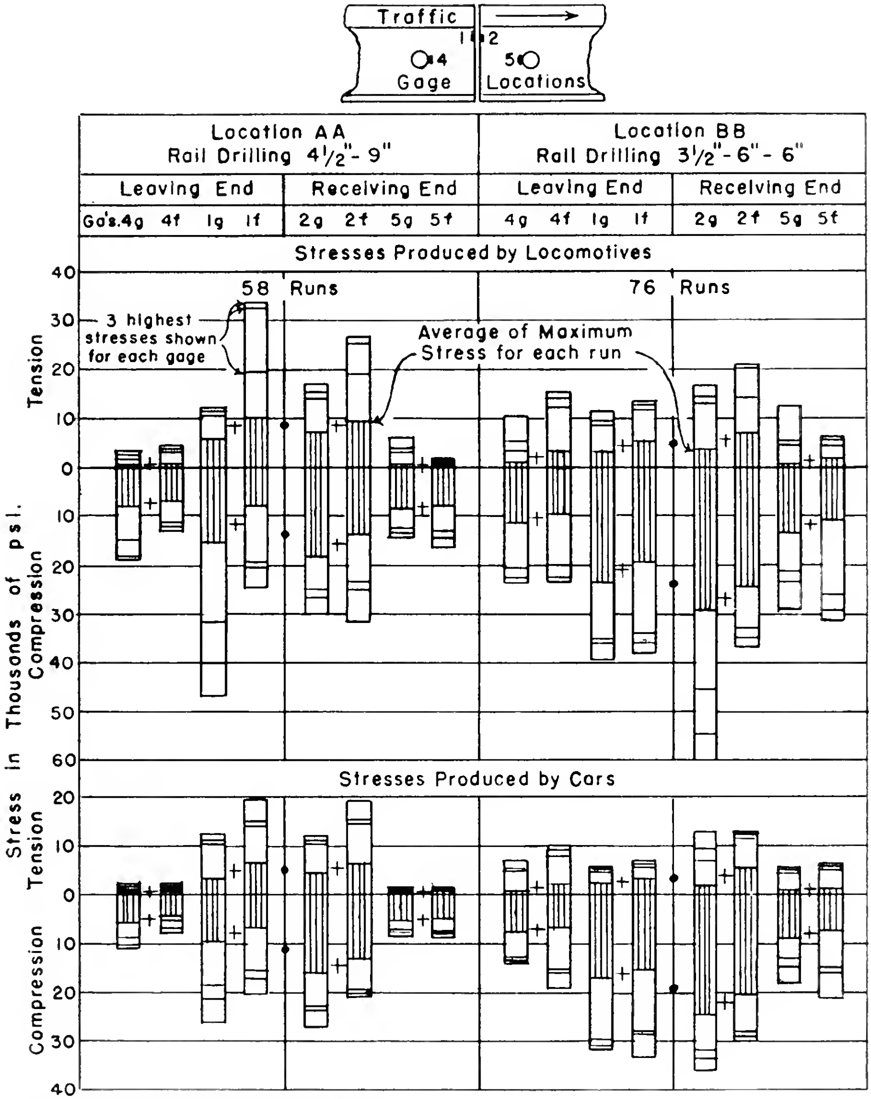
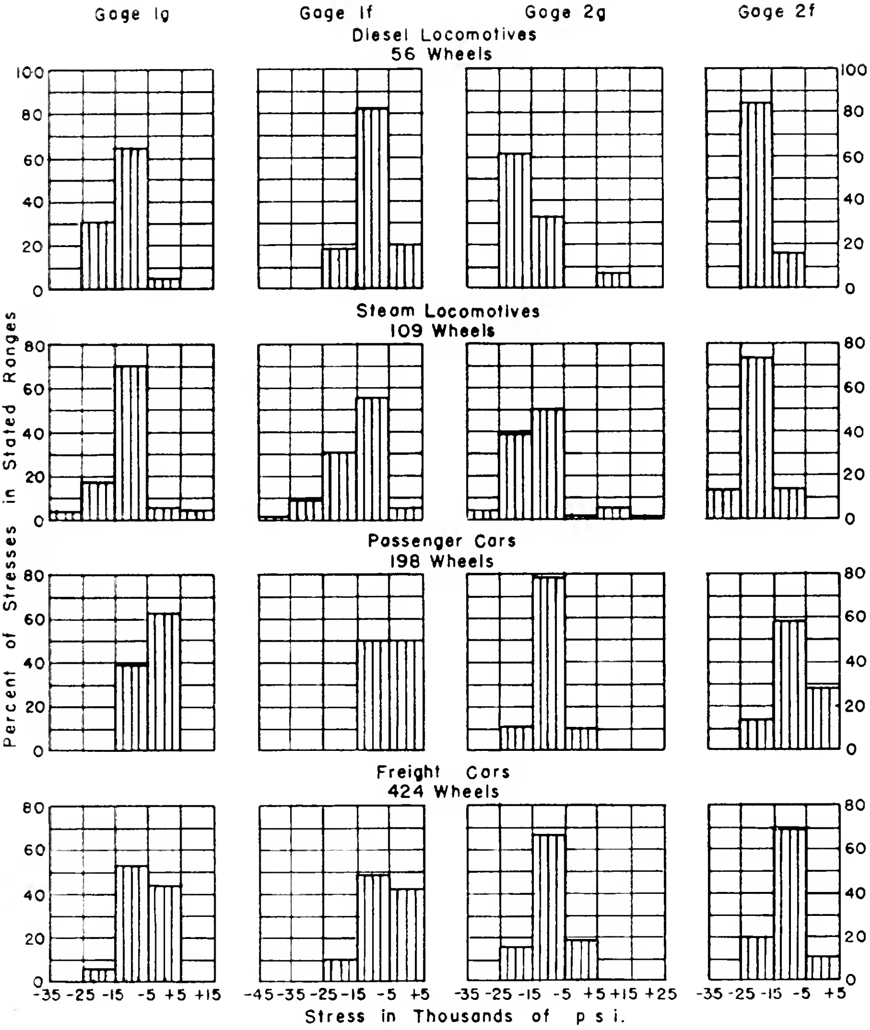


Fig. 8. Maximum dynamic rail web stresses at gages 4 and 5. Joint B–2, C. & N. W. Ry.



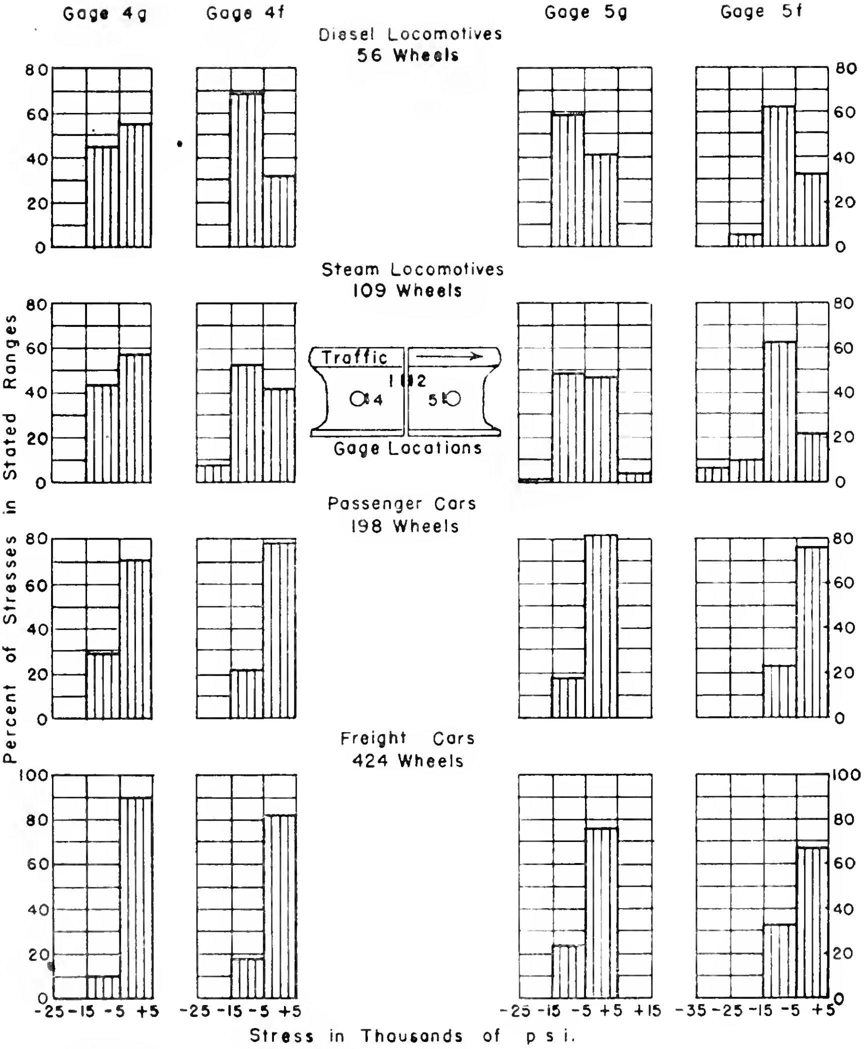
Notes: Stresses measured from records of runs over six rail joints.
+ Indicates the average of gage and field side stresses.
• " " " " leaving and receiving end stresses, gages 1 and 2.

Fig. 9. Dynamic stresses in rail web at joints of 115-lb. RE rail. C. & N. W. Ry.



Note: Position of SR-4 Strain Gages shown on Fig. 11.

Fig. 10. Frequency of occurrence of dynamic stresses in upper part of rail web at joint B-2, location BB, C. & N. W. Ry.



Note: Test joint located over center of tie.

Fig. 11. Frequency of occurrence of dynamic stresses in rail web at first bolt holes from rail ends, Joint B-2, Location BB, C. & N. W. Ry.

(text continued from page 692)

Correlation of Measured Stresses with Laboratory Fatigue Data

In the report on stresses in 132 RE rail on tangent track in the AREA Proceedings, Vol. 51, 1950, a comparison between measured stresses and laboratory fatigue data has been made. It was found in that investigation that the range of dynamic stresses is only one-third of the fatigue strength of the steel as determined from the laboratory tests. In view of the fact that Figs. 10 and 11 of the above named report, showing the frequency of occurrence of dynamic stresses, are comparable to Figs. 10 and 11 of the data pertaining to the 115 RE rail, it may be stated that the range of dynamic stresses is less than one-half of the fatigue strength of the steel. From the diagrams on Figs. 10 and 11 it can be noted that at any specific gage location the maximum stress range at which there would appear to be sufficient frequency of stress to produce fatigue failure does not exceed 30,000 psi. From this it is evident that the new 115 RE rail design on tangent track with either of the bolt hole spacings has sufficient fatigue strength to resist development of fatigue cracks, provided no unusual corrosion conditions exist.

Conclusions

From these tests conducted on tangent track under conditions typical of main line operation, it may be concluded:

(a) That the stresses in the upper rail fillets on tangent track outside of the joint bar limits have been reduced with the new 115 RE section to well within the fatigue strength of rail steel, and

(b) That the concentrated rail web stresses within joint bar limits at the rail end and at the first bolt hole with the new 115 RE rail section and new AREA bolt spacing are well within limits that can be tolerated, provided no unusual corrosion conditions exist that substantially reduce the fatigue strength of the rail steel.

PROCEEDINGS

Program

Fiftieth Annual Meeting

Palmer House, Chicago

TUESDAY, MARCH 13

Morning Session, Grand Ballroom—9:45 to 12:30

Address of President—H. S. Loeffler

Report of the Secretary, by Neal D. Howard

Report of the Treasurer, by J. D. Moffat

Greetings from the Signal Section, AAR, by D. W. Fuller, Chairman

Greetings from the Electrical Section, AAR, by H. F. Finnemore, Chairman

Address—A Wartime Economy—Will It Leave the Railroads Unscathed? by J. H. Aydelott, Vice President, AAR

Presentation of Honorary Membership to John Edwin Armstrong, Chief Engineer, Canadian Pacific Railway

Address—The AREA—From the Viewpoint of a Junior Member, by P. T. Trax, Assistant Supervisor Track, Pennsylvania Railroad

Address—Highlights in Engineering Research, by G. M. Magee, Research Engineer, Engineering Division AAR

Reports of Committees	Bulletin Numbers
9—Highways	490
Address on Highways, by General James A. Anderson, Commissioner of Highways, Virginia, and President of AASHO	
24—Cooperative Relations with Universities	492
Address on Future Needs, and the Supply of Technical Personnel for the Railroads, by Dean O. W. Eshbach, Northwestern Technological Institute	

Afternoon Session, Grand Ballroom—2:00 to 5:00

Reports of Committees	Bulletin Numbers
13—Water Service and Sanitation	490
14—Yards and Terminals	490
20—Contract Forms	490
11—Records and Accounts	492
Address on Obsolescence in the Dieselization Program, by J. B. Akers, Chief Engineer, Southern Railway System	
16—Economics of Railway Location and Operation	490
Address on Terminals and Trains, by Dr. L. K. Sillcox, Executive Vice President, New York Air Brake Company	

WEDNESDAY, MARCH 14

Morning Session, Red Lacquer Room—9:00 to 12:00

Reports of Committees	Bulletin Numbers
27—Maintenance of Way Work Equipment	491
22—Economics of Railway Labor	491
Address on Impressions of a Group of European Railway Maintenance of Way Engineers on Their Tour of U. S. Railroads, by G. M. O'Rourke, Assistant Engineer Maintenance of Way, Illinois Central Railroad	
6—Buildings	491
Address on Fire Prevention, by J. P. Gallagher, General Superintendent of Insurance and Fire Protection, New York Central System	
17—Wood Preservation	491
1—Roadway and Ballast	493
Special Committee on Continuous Welded Rail	493

Association Luncheon, Grand Ballroom—12:00 Noon

Address—American Railroads at Mid-Century, by J. M. Budd, Vice President, Operations, Great Northern Railway

Announcement of Results of Election of Officers

Afternoon Session, Red Lacquer Room—2:30 to 5:00

Reports of Committees	Bulletin Numbers
3—Ties	491
Address on Progress in Cross Tie Research, by G. M. Magee, Research Engineer, Engineering Division, AAR	
5—Track	493
4—Rail	493
Address on Rail Failure Statistics and Their Reporting, by G. M. Magee, Research Engineer, Engineering Division, AAR	
Research Attack on the Shelly Rail Problem, by L. S. Crane, Engineer of Tests, Southern Railway System	
Shelly Rail Studies at the University of Illinois, by R. E. Cramer, Special Research Associate Professor, University of Illinois	
Review of Joint Bar Research, by R. E. Jensen, Special Research Assistant Professor of Engineering Materials, University of Illinois	

THURSDAY, MARCH 15

Morning Session, Grand Ballroom—9:00 to 12:30

Reports of Committees	Bulletin Numbers
7—Wood Bridges and Trestles	492
Address on Fatigue Tests of Timber Stringers, by Professor J. L. Leggett, University of Kentucky	
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Closing Business

Installation of Officers

Adjournment

Report of the Tellers

Presented Wednesday Noon March 14, 1951

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

T. A. Blair	1586

*For Vice President**

C. G. Grove	1569

For Directors (four to be elected)

W. C. Perkins	1168
R. J. Gammie	1000
L. L. Adams	933
A. N. Laird	827
E. S. Birkenwald	758
Ray McBrian	722
F. R. Smith	535
J. E. Hoving	432

For Members Nominating Committee (five to be elected)

L. H. Powell	1129
L. H. Laffoley	975
H. E. Kirby	895
W. G. Powrie	838
E. J. Brown	801
C. J. Code	724
W. E. Cornell	723
J. F. Marsh	615
W. R. Swatosh	591
R. W. Seniff	512

Twelve other miscellaneous votes were cast for the various offices listed above.

THE COMMITTEE OF TELLERS

R. C. BARDWELL, *Chairman*
F. B. BALDWIN
C. M. BARDWELL
H. T. BRADLEY
M. A. BRYANT
W. M. DUNN
W. S. GATES
J. G. GILLEY
L. C. HARMAN
J. E. HOVING
M. J. HUBBARD
G. R. JANOSKO
L. P. KIMBALL
W. A. KRAUSKA
J. J. LAUDIG
F. R. LAYNG
C. E. McCARTY
H. L. McMULLIN
G. F. METZDORF
L. R. MORGAN
L. T. NUCKOLS
W. C. PINSCHMIDT
S. H. POORE
C. B. PORTER
J. P. RAY
E. F. SALISBURY
H. M. SCHUDLICH
W. D. SIMPSON
R. M. STIMMEL
D. C. TEAL
J. E. TEAL
K. J. WEIR
J. E. WIGGINS
A. R. WILSON

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* Under the provisions of the Constitution, C. J. Geyer advances automatically from junior vice president to senior vice president.

PROCEEDINGS

Running Report of the Annual Meeting of the American Railway Engineering Association, March 13–15, 1951, Palmer House, Chicago, Including Abstracts of All Discussion, All Formal Action on Committee Presentations, Specific Papers and Addresses Presented in Connection with Committee Reports, and Other Official Business of the Association

The opening session of the fiftieth annual meeting convened at 9:50 a.m., President H. S. Loeffler* presiding.

President Loeffler: This is the fiftieth annual meeting of the American Railway Engineering Association, and includes the concurrent session of the Construction and Maintenance Section of the Engineering Division, Association of American Railroads.

In accordance with long-established practice, I have the honor to request that all of the past presidents in attendance please come to the platform and take places at my right. The current vice presidents, directors, secretary and treasurer of the Association will please come to the platform and take places at my left.

[The past presidents and officers of the Association came to the platform and were introduced to the convention. The past presidents included F. S. Schwinn, assistant chief engineer, Missouri Pacific Lines; Armstrong Chinn, president, Terminal Railroad Association of St. Louis; C. H. Mottier, vice president and chief engineer, Illinois Central Railroad; J. B. Akers, chief engineer, Southern Railway System; F. R. Layng, formerly vice president and chief engineer, Bessemer & Lake Erie Railroad, retired; H. R. Clarke, chief engineer, Burlington Lines; A. R. Wilson, retired engineer of bridges and buildings, Pennsylvania Railroad; and E. F. Wendt, consulting engineer, Pittsburgh, Pa.]

Past President F. S. Schwinn (Missouri Pacific Lines): Mr. President, may I have the privilege of the floor? Whenever I think of the American railroads, I am reminded of their remarkable development and expansion from their beginning in 1830 to their present extent of approximately 225,000 miles. When I think of that growth and what it meant to our nation, I am reminded of the fact that our railroads typify most realistically the freedom which is the heritage of all Americans—the freedom of individualism and opportunity—the American way of life.

I wish to take but a few moments of your time to say a little bit about one of the rugged individualists who did much toward the growth and expansion of the railroads of America.

Once upon a time—all nice stories should start that way—there was a small settlement on the Mississippi known by the exalted name of Pig's Eye. To this settlement in the year 1856—95 years ago—there came a young man. The little settlement was destined to become the fine and beautiful city of St. Paul, Minn. The young man was destined to be one of those pioneering individualists who made railroad history—who made American history.

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* Assistant Chief Engineer, Great Northern Railway.

As in the case of most great men, this man was both disliked and liked. Those who did not like this barbed-wired, shaggy-headed individual accused him of wrecking Minnesota, the Dakotas and Montana. Those who like him called him "the little giant," and "the empire builder."

Now you know of whom I am speaking. Jim Hill, as he was generally known, had much to do with the development of that great area lying between the Great Lakes and Puget Sound. His name and that of the Great Northern became synonymous. As the years passed, his railroad control and interests were extended to include the Northern Pacific, the Burlington, and many smaller roads. It is quite probable that no other single American exerted quite so great an influence upon the growth and development of so large a region.

With these few words I wish to transplant our thoughts to the present, and to another Great Northern man. Due to a most unfortunate and regrettable occurrence, with which you are all familiar, our president was deprived of that highlight of personal experience to which an incoming president looks forward—induction into office. Because President Loeffler was not formally inducted before an annual meeting of this Association, the Association, in turn, was deprived of the pleasing opportunity of seeing him squirm in an effort to control his emotion and to express his appreciation.

As a consequence, his associates on the Great Northern bethought themselves of a very original and unique way in which to make amends. Their answer was found in a piece of office furniture—a walnut desk that had been used by James J. Hill. The desk had been recently retired from active service, and I hold a gavel fashioned in the Great Northern shops from a leg of that desk.

On this gavel there is a silver plate, inscribed, "H. S. Loeffler, President, AREA, 1950–1951."

There is another inscription showing that it was made from a desk used by James J. Hill, Great Northern Empire Builder.

It is most appropriate that the gavel to be used by the president of an association of individuals representing and cooperating in the interests of a highly individualistic industry should come from the property of this rugged individualist.

President Loeffler, it is my privilege and pleasure, as well as a distinct honor, to hand you this gavel as the symbol of your office, and a token of the esteem of your associates on the Great Northern and in the American Railway Engineering Association.

President Loeffler: Mr. Schwinn, it is my humble pleasure to receive this token of high regard in the same friendly spirit in which it has been presented. I appreciate this gift because it comes from my friends and associates on the Great Northern, because it sustains the memory of James J. Hill, the "Empire Builder," and because it will serve a useful purpose in carrying on the proceedings of the American Railway Engineering Association.

The first order of business is the approval of the minutes of the last annual meeting. These minutes have been printed in the 1950 AREA Proceedings, 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, I declare the minutes of the last annual meeting approved as printed.

Address by President H. S. Loeffler

Members of the American Railway Engineering Association, friends, guests and ladies:

Approximately one year ago George L. Sitton, assistant chief engineer of the Southern Railway, was elected to serve as president of this Association. Unfortunately, however, illness prevented him from attending the 1950 annual meeting. Subsequently, because of continued illness, he submitted his resignation on April 17, 1950. This resignation was accepted by the Board of Direction on April 25, 1950.

Mr. Sitton joined our Association in 1921. Subsequently, at various times he has served on five standing committees, served as a director for five years, as junior vice president during 1948, and as senior vice president during 1949. In these various positions he served the Association extremely well. On behalf of the American Railway Engineering Association, I take this opportunity to thank Mr. Sitton for the excellent service he has rendered to the benefit of the Association and the railroads. It is deeply regretted that because of his physical condition he was unable to serve the Association as its President throughout the year 1950.

Revision of Constitution

When the American Railway Engineering Association was organized on March 30, 1899, the Association's constitution, adopted at that time, defined the objective of the Association as "the advancement of knowledge pertaining to the scientific and economical location, construction, operation and .maintenance of railroads." We are greatly indebted to the pioneer railway engineers who founded our organization for bringing forth this brief and concise statement of purpose, which, throughout the years has withstood the test of time. Today, after 52 years of existence, the AREA continues to function in a most satisfactory manner in accordance with this well-conceived purpose.

It has been necessary, however, on a few occasions, to make some revisions to our constitution in order to accommodate the Association's ever-expanding activities and to meet current requirements, so that our organization could continue to function in an orderly manner without in any way altering the purpose set forth in the constitution as originally adopted. During the past year the AREA constitution has been revised so as to provide for the advancement or selection of officers to fill any position which may become vacant because of resignation, or other event whereby an officer of the Association is unable to continue in the office to which he may have been elected.

In accordance with the constitution as thus revised, Senior Vice President H. S. Loeffler, on July 5, 1950, was advanced to the office of President, to replace G. L. Sitton, who previously had resigned. Also, on the same date, Junior Vice President T. A. Blair was advanced to the office of senior vice president. Subsequently, by action taken on August 4, 1950, the AREA Board of Direction elected C. J. Geyer to serve the Association as junior vice president to fill the unexpired term of Mr. Blair.

Membership

It is of interest to know that the Association's membership continued to increase during 1950. The secretary's report, which will be presented later this forenoon (and which merits your careful reading), discloses a net gain of 39 members during the past year, making our membership 3092 as of February 1, 1951. Thirty-eight additional members were admitted to membership in February, making a total of 3130 members as of March 1, 1951. Incidentally, this is the largest membership of record.

In order to assure the continued healthy growth of our organization it is necessary that a substantial portion of the new membership shall consist of young personnel. It is of special interest, therefore, to observe that 92 Junior Members were admitted to membership during the past year, making a total of 220 Junior Members as of February 1, 1951. I take this opportunity to welcome these Juniors into the membership of our organization. To the Juniors, may I say, "your earnest cooperation in progressing the Association's objectives will be expected. I am confident your efforts in this direction will be of substantial benefit to you as well as to the American Railway Engineering Association."

Standing and Special Committees

The objectives that may be accomplished by our Association are dependent, to a large extent, on the progressive spirit of our individual members, and are definitely dependent on the cooperative efforts displayed by such individual members in serving on the Association's standing and special committees.

When the Association was organized in 1899, several standing committees were established for the purpose of investigating and reporting on various subjects distinctly related to the objective for which the Association was organized. Today, after 52 years of progress we have 21 standing committees and 1 special committee, which are engaged in studying, investigating and reporting on 170 separate subjects covering in a comprehensive way all current problems relating to the design, construction and maintenance of railway facilities. The personnel of those committees consists of carefully selected members, who, because of their ability, initiative and experience, are especially competent to serve on the various committees concerned. These committees now have a total personnel of 910 members, comprising nearly one-third of the Association's membership.

The special committee just previously mentioned was organized during the past year. It is known as the "Special Committee on Continuous Welded Rail." It has a personnel of 28 members, and its objective is to investigate and report on all phases of the manufacture, installation and maintenance of continuous welded rail, including special consideration to the subject of economics with respect to the use of this type of rail.

The fact that all of our standing and special committees have been very active during the past year will be confirmed by the presentation of many timely and informative reports during the present annual meeting. These excellent reports merit your most careful consideration. I take this opportunity to commend the chairmen, the vice chairmen, and the subcommittee chairmen of these standing and special committees for the valuable service they have rendered to the Association during the past year. Also, I wish to express appreciation to each and every individual member of the Association for any service which he may have performed in furnishing data used in the preparation of committee reports.

Emergency Committees

During 1942 a serious national emergency was brought about as a result of World War II. At that time our Association, under the able leadership of President H. R. Clarke, established several emergency committees for the purpose of investigating and reporting on emergency conditions affecting the railroad industry, particularly with respect to the necessity of restricting the use of critical materials, and with reference to the possibility of developing improved railway maintenance methods which, to some extent, would relieve the shortage in available manpower. As a result of this action several so-called Emergency Provisions and Specifications were put in effect for the duration of World War II.

During the past year world conditions again have become very unstable. It is realized that the American Railway Engineering Association should be prepared to be of maximum service to the railway industry, and to the nation, in dealing with any serious emergency that might develop. With this situation in mind your Board of Direction, during the past year, re-established five emergency committees, as follows:

Emergency Committee of the Board of Direction
Emergency Committee on Track Problems
Emergency Committee on Structural Problems
Emergency Committee on Fuel, Water and Sanitary Facilities
Emergency Committee on Ties and Wood Preservation

The personnel of these emergency committees was published in the October 1950 AREA News, and will be included in the Secretary's report as to be published in the AREA Proceedings for 1951.

These five emergency committees have a total personnel of 32 members, well distributed among the various railroads throughout the United States. These committees are in position to handle with dispatch any emergency problems of a railway engineering nature that may arise in the event of another world war, or other serious national emergency.

As a preliminary procedure, several AREA standing committees have been instructed to review, and, if necessary, recommend revisions and amendments to the AREA Emergency Provisions and Specifications previously in effect, so that emergency specifications adequate to meet current requirements will be available for adoption quickly, if and when such action becomes necessary. Furthermore, in order to bring our information on labor and materials conservation up to date, 14 standing committees have been instructed to investigate and report on the subject, "Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3-A—General Reclamation, of the Purchases and Stores Division, AAR." Also, Committee 22—Economics of Railway Labor, has been assigned the subject: "Means of conserving labor supply for the duration of the State of National Emergency, advising the secretary currently of recommendations or practices that merit emergency publication by the AREA.

The Manual

The AREA Manual of Recommended Practice continues to expand and is being kept up-to-date currently. It now has approximately 2000 pages. The Manual is in broad demand, not only by the railroads, but also by many outside agencies.

Finances

The financial condition of the Association is satisfactory; the Association's assets having increased by the amount of $7,957.93 during 1950.

Research

Research continues to occupy a front-line position in the work being done by our Association.

One year ago, during the 1950 annual meeting, special recognition was given to the completion of construction of the AAR Central Research Laboratory at a cost of about $600,000. During the past year the Association of American Railroads has equipped this laboratory with a test track and a number of modern testing machines and other essential equipment, which has increased the total investment in this facility to approximately one million dollars.

The personnel of the Engineering Division, AAR, is carrying out in this laboratory a substantial amount of the research work involved in progressing the current assignments being handled by various AREA standing committees.

It is encouraging to know that the Association of American Railroads has made available funds in the amount of $354,770 for the use of the Engineering Division in progressing its research work during 1951. This research authorization for 1951 provides an increase in research funds in the amount of $60,725, representing roughly a 20 percent increase as compared to the amount authorized for 1950. It is expected, of course, that our Association will recognize the necessity of carefully and wisely controlling the expenditure of these funds, so that maximum benefits will be derived from this authorization.

AREA News

During the past year the AREA News, which is edited under the direction of our congenial Secretary, Neal Howard, has continued to expand. This monthly news bulletin not only keeps our information up to date with respect to the activities of our standing and special committees, but also serves as a monthly reporter with respect to many other current events of special interest to our membership.

Secretary Howard and his office staff are to be highly commended for their effective efforts in processing the publication of this brief and concise AREA News bulletin.

The Outlook

Because of the availability of improved equipment and the development of new and better methods of handling railway construction, operation, and maintenance, the field of railway engineering continues to expand, and thereby creates increased opportunity for our members to serve the railway industry.

During the next three days our activities for the preceding year will be rapidly concluded, and our record of accomplishments for that brief period of solar time will be filed in the Association's "past of achievement."

Because of continually changing conditions that will affect the nation's requirements for economical transportation, the railway industry in the future will be faced with new problems, problems which may challenge our very ability to meet to the fullest extent the Association's objective, this objective being (if you will please pardon my repetition), "to advance the knowledge pertaining to the scientific and economical location, construction, operation and maintenance of railroads." We have a "past of achievement" of which we are justly proud. However, as we face the future let us be not content to rest our potential power on our past accomplishments, but rather, let us be ever alert to discover and take advantage of every possible opportunity to devise new and improved methods of meeting the Association's objective. By following that procedure, we shall successfully meet the challenge, and shall be of maximum service to the Association, to the railway industry, and to the nation.

The next order of business is the report of the secretary, followed by the report of the treasurer. Mr. Howard, will you present the report of the secretary?

Secretary's Report

Mr. President, officers and members of the American Railway Engineering Association, I am happy to make this, my first report to you—my 3130 bosses. The Constitution of our Association wisely requires that your secretary make an annual report, but it is well that it does not specify that the secretary read it in full to the annual convention.

But I do want you to know, as many of you already do, that a somewhat detailed report has been prepared and appears in the March 1951 Year Book, which was mailed to all members on March 6. In fact, this year's report is somewhat longer and more detailed than similar reports in recent years—which really gives justification for taking less than the usual amount of time to present it orally.

That I be brief, and informal, I feel is a special obligation on my part, because as our program was enlarged and strengthened by the addition of special papers and addresses, it became necessary that I ask a number of committees to cut the time normally allotted for their presentations. So to preclude any justifiable criticism on the part of committees, and to ease my own conscience, I want to take a cut also.

In summary, the secretary's report discusses:

The advancement of officers during the year as the result of the inability of our elected president, George L. Sitton, to serve as president
Membership—including the record admission of 92 as Junior Members
Finances
Work of Committees
Publications
Manual changes and additions
The creation of a new Special Committee on Continuous Welded Rail and of five Special Emergency Committees
The reassignment of wartime subjects dealing with "Labor and Materials Conservation"
Research Work
The overhauling of our Constitution, and several special Board of Direction projects

As is clearly evident in the published report, and I think you will agree, the Association has had a good year in every respect—membership, financial, and constructive work of its committees. Furthermore, it has been keenly alert to its responsibilities to the railroads and to the growing tenseness of world conditions and the mobilization effort of the country, which may at any time call for emergency measures, procedures and studies on the part of the Association. With that in mind, it has set up and put into action machinery to meet emergencies quickly.

From the standpoint of the secretary's office, I believe we can say truthfully that, during the past year, we have made an effort in your behalf. Like a new baby, however, your secretary has had to learn to creep before he could walk. He has had to lean heavily upon his small but experienced staff.

We have not accomplished all that we would. We have made mistakes. Try as we might, we will, in all probability, continue to make mistakes. Only those who have nothing to do and who are successful in doing it, don't make some mistakes—and I can assure you that we have something to do in the secretary's office, and have been trying to do more. In fact, during the past year we have endeavored to clean up several items of long-standing unfinished business.

But that's the way we like it, and it has all been a special pleasure to me—working with a capable and loyal staff, to mention only the three men thereon—assistant secretary Frank McNellis, assistant to secretary, Ed Gehrke, and assistant to all of us, Emil Fritch. And that pleasure has been greatly enhanced by the full and cordial cooperation we have received from as fine, capable and understanding a group of officers as ever headed any organization. I should like to take this opportunity to thank these officers individually and collectively on behalf of the secretary's office. I cannot tell you how much your support and encouragement have meant to us.

And I want, too, to express the appreciation of the secretary's office for the splendid cooperation received from committees and committee chairmen, and from Mr. Magee and members of his staff. I, personally, particularly appreciate the courtesies that have been extended to me by committees as I have found it possible to attend or drop in on their meetings.

Gentlemen, this is my verbal report. The written report, as I have already stated, is to be found in the 1951 Year Book—and if you can take President Loeffler's word for it, as stated in his address, you will find it worthwhile reading. Even past secretary Lacher has said that he enjoyed reading it. At any rate, if you will read it, you will know your Association better and will appreciate it more.

President Loeffler: Thank you, Mr. Howard, for this very excellent report. Before asking for approval of the secretary's report, we will have the report of the treasurer. I refer you to J. D. Moffat, chief engineer of the Western Region, Pennsylvania Railroad, Chicago, who will present the treasurer's report at this time.

J. D. Moffat (Pennsylvania Railroad): Mr. President, ladies, guests, and members of the AREA: I hope to make this the shortest speech of the day, and the shortest report ever put out by a treasurer.

I do not believe it necessary to recite here any of the figures that are in the annual statement, as it has been published in your March Bulletin. There is one comment, however, that I cannot refrain from making, and that is that in these days of increasing prices and increasing costs of trying to do anything I have found that your Finance Committee, the secretary, and his office staff, have thoroughly reviewed every expenditure before it has been made. For that reason, as you will see, we have lived within our income.

These officers have also had due respect for the budget that was made a year ago. As a result, I can simply say that the organization is solvent, and I see no reason why it should not continue to be so in the future.

President Loeffler: Thank you, Mr. Moffat.

We have heard the reports of the secretary and of the treasurer. What is your pleasure, gentlemen, with respect to these two reports? Do I hear a motion that they be approved?

(Upon a motion regularly made and seconded, the reports which appear on page 877, were adopted.)

President Loeffler: It has been mentioned previously this morning that this meeting is a concurrent session of the Construction and Maintenance Section of the Engineering Division, Association of American Railroads. I am pleased to inform you that we have with us here on the platform this morning the representatives of two closely allied Sections of the Engineering Division, namely, the Signal Section and the Electrical Section.

Our relationship with these two other Sections of the Engineering Division has been a happy one for many years—and an essential one: We have many problems of mutual interest, and, as a result, have need for much collaboration. It is our hope and expectation that this close relationship will continue for many years in the future. In this connection we assure each of these two other Sections the fullest cooperation on the part of the Construction and Maintenance Section.

The representative of the Signal Section is D. W. Fuller, chairman of that Section. Mr. Fuller is signal engineer of the Atcheson, Topeka & Santa Fe System, with headquarters at Topeka, Kans. Mr. Fuller, we welcome you, and will be glad to have a few words from you at this time.

D. W. Fuller (Santa Fe): Mr. President, members of the American Railway Engineering Association, and guests: Looking over this audience this morning, I am indeed pleased to see a number of familiar faces from the Signal Section. It is my pleasure and privilege to bring you greetings from the Signal Section of the Association of American Railroads.

Your Association and the Signal Section have to date enjoyed excellent cooperation, and I assure you that this cooperation will continue on the part of the Signal Section.

I have a few remarks to make concerning machines and materials.

During the past decade manufacturers have constantly been making machines and materials of improved design available, which have resulted in greater efficiency and economy. It is important that we make a careful study to determine what can be used to advantage in executing our engineering problems. Due to the increase in war production, it is probable that many items will not be available when needed, and it is, therefore, an added responsibility of engineering officers to see that the best use is made of those machines and materials that are available.

The 1951 annual meeting of the Signal Section will be held at the Edgewater Beach Hotel on September 10, 11 and 12, and on behalf of the Signal Section I extend a cordial invitation to each of you to attend these sessions. I thank you.

President Loeffler: Thank you, Mr. Fuller. We are pleased to have had you with us here this morning, and we are also pleased to know that members of the Signal Section Committee 1—Economics of Railway Signalling, are in our audience. We appreciate and are honored by their presence.

The representative of the Electrical Section is H. F. Finnemore, chairman of that Section. Mr. Finnemore is chief electrical engineer of the Canadian National Railways at Montreal, Que.

Mr. Finnemore, we welcome you, and would be glad to have a few words from you at this time.

H. F. Finnemore (Canadian National): Mr. President, ladies and gentlemen: It is my very good pleasure and privilege to be here this morning to extend to you the greetings of the Electrical Section of the AAR.

In these days when it becomes evident that prices are rising and materials are very difficult to secure, it is very apparent that the first impact of those conditions falls upon the shoulders of the engineer. He it is who must make the best of what he can get. He may have to substitute, and, in any event, it looks as though before long he will be trying to do with 1¾, the things that he should be doing with 2.

The best definition that I have ever heard of the engineer's work is that he takes the ordinary job, turns it into routine, and does it on time; the impossible takes a little longer. And, gentlemen, when you are performing the impossible, you may rest assured that the Electrical Section is behind you, wishing you good luck. Thank you.

President Loeffler: Thank you, Mr. Finnemore. We appreciate your being with us, and hope that both you and Mr. Fuller will participate in the deliberations of our annual meeting to the extent that your time will permit.

The Construction and Maintenance Section of the Engineering Division, AAR, forms one of the units of the Operations and Maintenance Department of the Association of American Railroads. We have present with us today J. H. Aydelott, vice president of this Operations and Maintenance Department.

Previous to assuming his present highly responsible position with the AAR, he served several years as an operating officer on the Burlington Lines. He is well qualified to discuss railway problems from a practical standpoint. Mr. Aydelott is well known to railway men throughout the nation, and needs no further introduction to this audience, He will speak to us at this time on the subject, A Wartime Economy—Will It Leave the Railroads Unscathed?

J. H. Aydelott (Vice President, AAR). President Loeffler, Officers and Directors of the AREA, fellow members, ladies and other guests: It is a very great privilege and an honor for me to be included on the program of this great Association. I want to take this opportunity to thank the officers of the AREA and the committees for their most excellent contributions to the forward movement of our American railroads, particularly as related to physical progress.

A War Economy—Will It Leave the Railroads Unscathed?

By James H. Aydelott

Vice President, Operations and Maintenance Department, AAR

My remarks today will be made for the purpose of informing you, as best I can, on what is going on in Washington to affect the industry in which all of us have a responsible interest. You, no doubt, have a special interest in knowing the extent to which the supply of material and manpower required to maintain and improve our railroad properties may be affected by the mobilization program.

As an industry which is devoted exclusively to the transportation of goods and persons, we are confronted with none of the conversion difficulties which will beset industry in general. We are seriously concerned, however, in the matter of whether or not the experiences of World War II which affected our industry adversely are to be repeated. Much effort was made in the years immediately following the close of World War II to prepare a blueprint for railroad transportation in the next emergency. Among the things pointed out in this study were the ill effects of the policies followed in World War II by our Government in dealing with the manpower and material problems of the railroad industry. Certainly the necessity of scrapping more than 150,000 freight cars in the two years immediately following the close of hostilities was not a favorable recommendation for a policy which denied the railroads materials and manpower for the construction of cars during the war in numbers sufficient to represent the normal attrition from age or worn out condition. Likewise, the presence of more than 350,000 railroad workers in the Armed Services during the last war was not an indication that our manpower needs were given the consideration that should have been afforded to an industry upon which the success of our Armed Forces so clearly depended.

Car and Locomotive Construction Programs

When the mobilization effort began to get under headway about a year ago, our industry was importuned to bring its physical properties and rolling stock into prime condition so there would be no question as to the ability of the railroads to provide transportation up to the foreseen requirements for both military and civilian purposes. Diesel locomotives for freight and switching service were continued in production throughout World War II, and in the postwar years the volume of production has steadily grown, reaching its highest proportions in 1950. During the postwar years the ownership of steam locomotives has steadily declined and replacements for the most part have been made with diesel power. Reclaimed material secured from locomotives torn down, and to a very considerable extent from freight cars retired, has made it possible to maintain much of our locomotive and freight car equipment without the necessity of going into the market for the quantities of new materials that otherwise would have been required. Since the outbreak of war in Korea last June, however, it has been considered good policy not to dismantle any more engines, such as were large enough to be brought into main-line service should the needs of traffic volume later require this to be done. Similarly, railroads have been expending greater amounts in the overhauling of their freight cars than would be justified under normal conditions, merely because of existing shortages in the freight car supply and the difficulties in securing new cars soon enough to relieve the shortages.

Construction Programs Handicapped

Steel and almost all of the basic metals have been placed under rigid controls within recent months. Top priority for these metals and for rubber and certain other commodities is held by the Government, but there is yet no determination of what quantities these priority orders will take out of the available production, and therein lies much of the difficulty which has prevailed in launching a program for new construction of cars and locomotives and for repair purposes, the latter being extremely important in view of the special effort being made to bring the number of bad-order locomotives and cars down to a proper level. A car building program calling for 10,000 new units per month, approved several months ago by virtually every interested department of Government, including the Defense Establishment, and urged by the Congress, has lately been under attack. This has not only delayed the start of the program, originally scheduled for January 1, but likely will have the effect of reducing it, even though there are continuing shortages of cars which will possibly grow as defense and farm production expand. There is shop capacity in the plants of the commercial car builders and of the railroads to permit building at least 12,000 cars per month if materials and manpower are made available. New locomotive production schedules have similarly been delayed, and apparently will be cut back approximately 25 percent from the schedule originally filed.

The estimated requirements of steel for new rail, fastenings and switch material, for materials used for maintenance and construction in the field of communications and signaling, for bridge steel and for steel and other metals required for passenger car construction and maintenance, were submitted to the production authorities of the Government some weeks ago. On February 27 approval was given to all industry items of MRO under a very high rating, and it is anticipated that a supplementary order will soon follow to deal specifically with railroad requirements.

Some time has been lost in all of these programs by reason of an attempt first being made to allocate material on a voluntary basis. Had our country been in a depression, such a plan might have worked out satisfactorily, but at this time when more than 60 million of our people are gainfully employed in industries of almost every type, using vast quantities of steel, copper, rubber, etc., and hoping to continue full-time operation, it can be appreciated why it was found necessary to abandon the voluntary plan and to reactivate such agencies as were found in World War II to be so essential in controlling the distribution and use of almost every kind of raw material essential to the war effort and to the civilian economy supporting it. The staffing of these new control agencies so that each different commodity could be handled with proper understanding of supply and demand consumed further time, with the result as stated, that most of our programs, in consideration of the lead time that must be allowed for delivery of materials, are several weeks in arrears.

Government Advised of Railroad Needs

In dealing with the agencies of the Government we have called attention to the progress which the railroads have made in the postwar years in the revamping of their physical properties, including the construction of modern yards and terminal stations, the acquisition of the most modern and efficient motive power and equipment, improvement of alinement and gradient, and by various other means. We have stressed the importance of these activities being continued through the years of mobilization.

Manpower is conserved wherever a machine replaces hand labor; consequently, with a manpower shortage in the offing, mechanization of roadway maintenance and other operations should not be interrupted. Manpower is likewise conserved when greater tonnage per train can be hauled on an improved grade line, which in some cases may require a relocation of main track.

The Military Establishment today is perhaps the greatest single user of railroad transportation. It has a direct interest, therefore, in the improved efficiency of the railroad plant, such as can be obtained through the modernization of our facilities and through any other improvements which reduce time-in-transit on the goods shipped, some of which may be urgently needed where our Armed Forces are employed. The Defense Establishment has expressed a deep interest in the elimination of loss and damage to their shipments. Improved yards and modernized freight stations we know to be a direct contribution toward the elimination of damage to freight, a goal in which the general public also will become more deeply interested as basic materials, machines and supplies become in scarce supply.

Manpower Needs of the Railroads Must Be Protected

Manpower losses to the Armed Services to date through the draft, enlistments and calls of Reservists amount to 20,000 to 25,000 men, even though as to draft calls the age of railroad men taken is under 26. The building up of Army, Navy, Air and Coast Guard forces to a total strength of 3,500,000 men has raised some question as to whether there are enough men under the age of 26 to meet those requirements. It is a matter of record that the birth rate dropped off materially during the depression years, whereas, if it had remained at a normal level the number of men available within the present draft age limits would have been increased by many thousands. While an attempt will be made to reclassify those in the 4-F category for supporting service, it is not likely that this group will prove to be the reservoir of manpower that is indicated on the surface. In building an Armed Force much depends upon the length of time that each man inducted will have to serve. We may be certain that all of the potentials of the 18–25 age group will be explored, including the probable drafting of childless married men, and that this will be done before any attempt will be made to draft out of the higher age groups.

The potential losses of manpower by the railroads, particularly of men having some degree of skill, will be greater if the draft age is raised. It will be our purpose, therefore, to keep the manpower needs of the rail carriers before the several agencies of Government which make the policies in this field. These agencies have been supplied with a list of what we considered to be critical occupations in the railroad industry. A great many railroads are already experiencing shortages of mechanics, and this has resulted in some delay to the reconditioning of both locomotives and cars. Some signal construction has likewise been affected. It shall be our policy further to hold that as to requests for deferment of skilled and technically trained railroad employees, the same consideration should be given by draft boards as is given to the requests of other defense industries involving men with special qualifications when replacements are not available; likewise, as labor is diverted from nondefense to defense industries, representations will be made that the needs of the railroads in the placement of this labor should have equal consideration to that of other defense industries. The tightening of materials will force some reduction in the activities of nondefense industries and services, and it will behoove each of you in your respective territories to keep abreast of these lay-offs in order that existing vacancies in your own ranks can be filled to the greatest possible degree.

Must Conserve Manpower and Materials

The situation outlined with respect to materials and manpower makes it extremely necessary that in progressing your maintenance and construction programs you adopt those practices and methods which will secure the utmost in the conservation of both manpower and material, a program which served the industry well during the trying days of World War II. Most of you in this room contributed in this fashion to the successful operation and maintenance of your railroad in that war when, as never before, the railroads were handicapped by manpower and material shortages.

The railroads now have the highest standards ever reached with respect to track and bridge structures on primary lines and on many lines of secondary importance. Signal systems have been modernized and improved in such a manner as will bring lower maintenance costs. The operation of trains at higher speeds has made it possible with modern signaling to lengthen the distance between sidings, and many sidings have been removed. Diesel power on many thousands of miles of railroad has permitted the dismantling of water and coaling stations, treating plants and engine-houses, with large savings in maintenance. Research is making its contribution by indicating how still further economies can be secured in roadway and bridge maintenance. The railroads must, however, be supplied with material for renewals which are made necessary by age and from increased wear and tear due to the heavy traffic load which accompanies a war emergency. Recently approved allocations of material for these purposes indicate an understanding of the situation by control agencies.

In attempting to answer, therefore, the question raised in the subject of my talk today, I would say that no single element in our economy can escape the consequences of a changeover from a peace-time to a war-time economy. Each of you will feel it in the taxes you pay and in the prices of the goods and supplies which you will purchase. These prices will include taxes which the producer, the wholesaler and the retailer will pay in support of this defense program. Likewise will the taxes of the railroads be increased with respect to their earnings, and they, as users of a vast amount of materials and supplies, will have to absorb the new taxes included in the prices paid. Wage increases granted as an off-set to increases in the cost of living will so increase the out-of-pocket expense of the rail carriers as to necessitate an upward revision of the freight rate structure, and these recurring cycles of price and wage advances may continue to plague our economy unless effective controls are established by the Federal Government.

Railroads Not in Competition with Defense Effort

The present emergency has followed the last one so closely that it is most difficult in view of all the factors which must be weighed to forecast with any degree of accuracy how our properties might be affected as the period of mobilization extends, as some seem to think it will, over a long span of years. A very considerable expansion in the production of steel and aluminum is planned to take place over the next two years. Existing shortages of some non-ferrous metals, such as copper and zinc and others which we must largely import, are due not only to the increased use of such metals in the manufacture of war materials and supplies, but because concurrently with the increased use of these metals considerable quantities are being stockpiled against the needs of a future major conflict. The capacity to produce steel is considerably higher than it was during the peak of World War II, when huge tonnages, in addition to our own needs, were supplied to our allies. Today there is a sizeable importation of both ingots and finished steel from several European nations. If a major war does not come within the foreseeable future and there is new production capacity in the steel industry as planned, it is difficult to see why the railroads in their preparedness program should not be afforded access to a sufficient tonnage of steel for their required purposes, including what is necessary to sustain a heavy car and locomotive program, adequate tonnage for repairs, and for rail and various other construction and maintenance. Eventually our military programs will level off, but until then our industry may face some shortages, or at least deliveries may be deferred.

Arming and equipping a greatly increased military and naval force is in the interest of all of us, and our industry need not, in my opinion, be placed in competition with the Defense Establishment for critical materials. We believe our needs can be supplied through the diversion of tonnage now going into uses that contribute little, if anything, to the National Defense. Our Government, I am sure, recognizes the soundness of such a policy and is proceeding accordingly, but, obviously, it is a shift that cannot be made overnight.

President Loeffler: Thank you, Mr. Aydelott, for bringing this timely message to us. We deeply appreciate it.

At this point in our program we desire to honor one of our own members by presenting to that member a certificate of Honorary Membership. The AREA Constitution stipulates that an Honorary Member shall be a person of acknowledged eminence in railway engineering or management. It also stipulates that the number of Honorary Members shall be limited to ten.

On March 16, 1950, John E. Armstrong, by unanimous vote of the entire Board of Direction, was elected and declared an Honorary Member of this Association. Unfortunately, circumstances have prevented Mr. Armstrong from being with us today; consequently, we shall honor him in absentia. I shall request one of our past presidents—H. R. Clarke, chief engineer of the Burlington Lines—to make some comments with respect to Mr. Armstrong's railway engineering achievements, and in regard to his services to this Association.

Presentation of Honorary Membership to John Edwin Armstrong

Past President H. R. Clarke: Mr. President, fellow members, ladies and gentlemen. The American Railway Engineering Association is often spoken of as a national organization. It is, but it is more than that, it is international, with members in Mexico, Central and South America, Great Britain, and most other countries of Europe, and with a number of members in Asia, Africa, and Australia. This far-flung membership is evidence of the world-wide influence this Association has had and has on railroad transportation. But next only to the United States, it is in Canada that the AREA has had its greatest strength.

Through the years many of our Canadian members have given much to this Association, but none has served with greater loyalty or more effectively than the man we honor today.

John Edwin Armstrong was born in the United States at Peoria, Ill., attended the schools of that city, continued his education at Bradley Polytechnic Institute, and completed his formal schooling at Cornell University, from which he was graduated in 1908. During his college years he combined practice with theory, as is now so popular, working during vacations on the Toledo, Peoria & Western in various capacities. Upon graduation he started his career on the Pennsylvania, and in 1912 left that road to enter the service of the Canadian Pacific Railroad as an assistant engineer. He was promoted to assistant chief engineer in 1928, and in 1939 was appointed chief engineer of the great transportation system that spans the continent from the Atlantic to the Pacific and gridirons the Dominion of Canada, our neighbor on the North, from the International Border almost to the Arctic Circle.

Mr. Armstrong became a member of the AREA in 1920, serving as a member and chairman of various committees, and in 1927 was appointed a director to complete the unexpired term of Frank Lee. He was elected to the Board of Direction in 1929, vice president in 1932, and president in 1934, after which he served on the Board of Direction as a past president until 1945—due to the untimely death of four junior past presidents—a total of 18 years, the longest record of such service in the history of the Association.

He is a member and past president of the Canadian Railway Club, and also of the Engineering Institute of Canada, which he served as president with great honor to himself and profit to the Institute in 1949–1950. He well fulfills the constitutional requirements for election as an Honorary Member mentioned by our president, "A person of acknowledged eminence in railway engineering or management."

Mr. President, it is a privilege and a great personal pleasure to present to you, in absentia, an outstanding engineer and railroad officer, distinguished Canadian, chief engineer of a great railroad, the Canadian Pacific, and a past president of this Association, John Edwin Armstrong, for Honorary Membership in the American Railway Engineering Association.

President Loeffler: It is deeply regretted that Mr. Armstrong, is unable to be with us here this morning. I understand that Mr. Armstrong's son is in the audience, John E. Armstrong, Jr., who is assistant district engineer, Canadian Pacific Railway. May I ask that Mr. Armstrong, Jr., come to the platform at this time?

The certificate of Honorary Membership reads as follows:

Honorary Membership has been conferred on John Edwin Armstrong by the American Railway Engineering Association this 16th day of March, 1950, in recognition of his outstanding service to the railway industry, the engineering profession, and to this Association.

Mr. Armstrong, Jr., you will please deliver this certificate to your father, and say to him that this certificate carries with it the highest esteem and best wishes of the entire Association.

J. E. Armstrong, Jr. (Canadian Pacific): Mr. President, ladies and gentlemen: It is a matter of keen regret to the man you are honoring this morning that he could not be present in person. I bring you his greetings.

Honorary Membership in the American Railway Engineering Association is bestowed upon very few men, and it is treasured by its recipients accordingly. My father has asked me to tell you this morning that he is fully aware of the significance of the honor you are paying him, and that he accepts it with a profound sense of pride and humility.

I feel honored in being asked to deliver this certificate to him, and will do so with your best wishes.

President Loeffler: Mr. Armstrong, we greatly appreciate your response.

I have previously referred to our Junior members, and mentioned the importance of these Juniors to our Association. We have one of these Junior members with us today. He graduated from Penn State College in 1948 with the degree of Bachelor of Science, Civil Engineering. Shortly after graduation he entered the service of the Pennsylvania Railroad as junior engineer of track. He joined our Association in 1949.

I take pleasure in introducing to you at this time P. T. Trax—spelled T-r-a-x—assistant supervisor of tracks—spelled T-r-a-c-k-s—(laughter) of the Pennsylvania Railroad, Pennsylvania Station, New York City, who will address us on the subject, The AREA—From the Viewpoint of a Junior Member.

The AREA—From the Viewpoint of a Junior Member

By P. T. Trax

Assistant Track Supervisor, Pennsylvania Railroad

To address this convention on the subject assigned is a distinct privilege and honor. What I may say to you is a summation of the thoughts of five of your Junior Members—W. S. Autrey, roadmaster, Atcheson, Topeka & Santa Fe; C. E. Dysart, assistant engineer, Southern Railway; R. J. Taylor, assistant engineer, New York Central; T. D. Wofford, Jr., assistant engineer, Illinois Central; and your speaker, assistant supervisor Trax, who works on the tracks of the Pennsylvania Railroad.

It has long been a recognized fact that the American Railway Engineering Association is the outstanding organization in the railroad engineering field. Furthermore, the AREA has an admirable object or purpose, which is stated something like this: "The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation, and maintenance of railways." Therefore, we younger men have desired to be a part of it. It enables us to hear and meet the leaders of our profession. We receive the bulletins and various publications and reports of the committees. We have an opportunity to attend the conventions where we may hear the reports and discussions. We can visit periodically exhibits of the latest devices that help us in the accomplishment of our work. All of these factors lead to constructive thinking, exchange of ideas, and keeping abreast of what is regarded as the latest and best practice in our profession. It would indeed be shortsighted if we failed to grasp these advantages offered through Junior Membership.

Many of your Junior Members have belonged for only a short period of time but have benefited in many ways. A railroad engineer is a specialist in a very broad field. His college training must be supplemented by a lot of training pertaining specifically to the railroads. This additional training or education is not obtained in the class room. It is obtained from publications, by experience, and by talking with those who know railroading. We receive the AREA publications, which are the most reliable to be found, and we may leisurely study them and add them to our libraries for future references rather than hurry through borrowed copies. One of the broadening experiences is to meet top engineers from all parts of the world and to discuss mutual problems and their solution. Thus, we feel that the AREA is tremendously valuable to us from an educational point of view, as through it the accumulated knowledge of the entire railroad profession is accessible to us. Furthermore, we feel that by merely being a member of this professional society we gain prestige and have a higher standing in railway engineering circles. It also indicates our interest in our jobs to our employers, which may aid in our betterment. As Junior Members we are permitted to gather much information and to formulate our own ideas, which we hope may enable us, when we become full members, to contribute our part to the future success of the Association. It is thus our ambition during this formative period as Junior Members, to prepare ourselves by observation of action and counsel of our leaders to become worthy successors to those who are now carrying on so acceptably and wisely. At the same time, we will be able to render a better and more acceptable service to our railroad.

What we have said thus far indicates our appreciation of the good things that come to us through our Junior Membership. There are, however, a few suggestions that we desire to present, some of which may meet with your favorable consideration. It is known that the American Railway Engineering Association is a "working organization" and the "grist of the mill" is produced by the committees. It is likewise known that, due to lack of practical experience, many Junior Members are not qualified to serve on committees. If there were some way in which we could participate more in committee work, even as visitors, it would be most encouraging to us. We read of the findings of the various committees and of the methods used in determining their findings, and are intrigued. We feel that it would promote a great deal of interest among Junior Members if we could share in the work. It would also be of great benefit in preparing us for committee work when we become Members. We would know more about what is expected of a committee member, and we would learn how a committee functions so effectively.

It is not unreasonable to expect a continuing growth in Junior Membership for several years to come. On this basis it might be well for the AREA to promote more activities among the Junior Membership. There is no doubt that many advantages would result from the younger engineers carrying on activities of their own, with proper guidance from older members. The opportunity for constructive planning, public presentations, free discussion of ideas, is much broader in groups where the ages and interests of the participants are similar.

As these general suggestions indicate, we want to be a "working part" of the organization. If something could be worked out along these lines we feel that it would stimulate a great deal of interest and bring the Junior Members "closer" to the Association.

We Junior Members wish again to express our appreciation of the privilege of association and contact with you members who have "traveled the road." We welcome the opportunity, especially, of contact and conversation with you. Our zeal to become good working members and to advance the purposes of our Association will be limited only by our opportunity.

President Loeffler: I think you all agree with me that our first attempt to secure some participation by our Juniors has met with considerable success. Mr. Trax, we certainly thank you for your suggestions, and I am sure the Board of Direction will give serious consideration to those suggestions.

As you know, the Association of American Railroads is operating a splendid new research laboratory, located on the campus of the Illinois Institute of Technology here in Chicago. This laboratory was built and equipped by the Association of American Railroads at a total cost of approximately one million dollars. When this research facility was nearing completion last March, at the time of our 1950 convention, the convention literally went to the laboratory to see this facility and to gain a better conception of its possibilities for increasing the scope and effectiveness in scientific research to be carried out for the benefit of the railroad industry. No doubt, many of you here today made the trip to the laboratory at that time.

This year we have decided, figuratively speaking, to bring the laboratory to the convention, in the person of one of our members who directs all of the engineering research of the Association, conducted by and for our various committees. This member is G. M. Magee, research engineer, Engineering Division, Association of American Railroads. I take pleasure in inviting Mr. Magee to come to the platform at this time to bring us up to date—as best he can in the limited time allowed—with respect to progress in the laboratory during the past year, and regarding plans for the immediate future.

Highlights of Engineering Research

By G. M. Magee

Research Engineer, Engineering Division, AAR

All of the research projects which we of the AAR Engineering Division research staff have underway have been initiated by committees of the American Railway Engineering Association. Our research staff works closely with the committees in planning and carrying out each project, and details of the results accomplished are published in the committee reports. It does not seem that it would be well or appropriate for me to discuss any of these individual projects at this time, because this can be done more adequately in connection with the reports of the various committees. However, it does seem that it would be appropriate and of interest to the membership to have a general description of the AREA research activities as a whole.

We were all very happy to have the new Central Research Laboratory completed on March 1, 1950, so that our engineering staff and the research staffs of the other divisions could be provided with more adequate space and facilities for carrying on our research projects. Many of you saw the laboratory during the inspection last year, and any who did not or who would like to see it again will be more than welcome. Thursday afternoon has been set aside for an inspection period and we will be pleased to have all of you come who care to do so.

The research budget that has been approved by the AAR Board of Directors for 1951 is very encouraging in many respects. The total appropriation has been increased by about 20 percent to a total of $354,770. Practically every committee request was approved. I think this is encouraging because it shows that the Board of Directors are pleased with the research accomplishments of our committees and research staff, and it also reflects an increased interest in research on the part of the Board in that they are willing to place additional funds at our disposal when business conditions are such as to make these funds available.

I would like to picture our various research activities as being grouped under three separate classes as follows:

1. Special studies made in the field, using electrical stress-measurement equipment.
2. Service test installations where field observations are made to determine performance under regular service conditions.
3. Laboratory projects which are generally undertaken under cooperative agreements with some laboratory having well qualified personnel and equipment.

Considering first the classification of special field studies, last year the research staff completed measurements to determine stresses in the upper fillets in the new 115 and 132 RE sections on sharp curves. These measurements were made on the Illinois Central and the Louisville & Nashville under both steam and diesel power, the object being to determine whether the new designs had effected the stress reduction in the fillet area that was contemplated from the development tests. Another project of interest was a preliminary test on the L. & N. to obtain information on the permissible unbalanced speed on curves. Track committee members cooperated in this test to act as observers, and their reactions of riding comfort were correlated with accelerometer measuremnts of lateral throw at each individual curve of the test run.

Stress measurements were made to show the change in tension of crossing frog bolts on a heat-treated bolted T-rail crossing on the Pennsylvania and New York Central. We believe these were the first tests of this kind that have ever been made. Measurements were also made during the year with an electrical-type pressure cell developed by the research staff to determine the horizontal and vertical pressures in the roadbed under passing trains. The results obtained were compared with theoretical pressures as calculated from the Newmark charts.

Stress measurements on bridges constituted a major part of the field work of the research staff during the year. Tests were conducted on eight bridges over highways to determine the transverse and longitudinal distribution of locomotive axle loads to the floor systems. Tests were made on five girder spans on the Milwaukee, which completes the work scheduled on girder spans. Tests were completed on two concrete pile trestles on the Missouri Pacific to determine the impact and stresses in the concrete and reinforcing bars, and the distribution of the load to the concrete piles. Stress measurements were also made on the timber stringers of a 40-year old pile trestle to determine the maximum range of service stresses, which will serve as a guide to further laboratory fatigue testing of the stringers. Tests were also made on the counterweight trusses of a bascule bridge on the Chicago & North Western. Analysis of the stress measurements obtained and the preparation of the data on the above field tests constitute almost as big an undertaking as obtaining the field data.

In the research projects classified as service tests are a number of studies of much current interest. Joint bar tests, including the new AREA designs, have been placed, and the performance is being checked by periodic measurements for the 115 RE rail section on the Chicago & North Western and for the 132 RE section on the Santa Fe. The service test of rail joint lubrication established five years ago on the Chicago, Burlington & Quincy was supplemented with an additional installation on the Illinois Central. On this new installation considerable emphasis has been placed on the use of end plugs to seal the joint. Service test installations were made several years ago on various designs of tie plate on the Southern for the 132 RE rail base width and on the Illinois Central for the 115 RE rail base width. The purpose of these tests is to obtain information on the required area and thickness of tie plates to permit the most economical tie plate design.

Of much current interest is the service installation on the Louisville & Nashville of various tie plate fastenings and tie pads to determine the most effective and economical means of controlling tie plate cutting into the ties. This installation now includes 16 types of tie plate fastenings, 15 different types of tie pads, and 15 different coatings and adhesives. Measurements are being made periodically on three service test installations to determine the effectiveness of various designs of spring washers in maintaining bolt tension in railroad crossings. These include bolted T-rail, rail-bound manganese, and solid manganese crossing types.

Of particular interest during the year were service installations of heat-treated rail produced by the Bethlehem Steel Company and installed on the Chesapeake & Ohio, Norfolk & Western and the Pennsylvania, to determine the resistance of this rail to shelling on the high side of curves and to flow on the low side. Service test installations were also made of a new low alloy rail metallurgy developed by the United States Steel Company, called C–V rail. This rail can be produced by the same rolling and manufacturing process as the present rail chemistry, and service installations were made on the New York Central and Norfolk & Western.

Another service test of particular interest to bridge engineers is the installation of high-strength bolts to replace rivets. The research staff has installed and is observing the performance of high-strength bolts on 15 bridges on 10 railroads.

The research staff has continued its observations on selected locations of roadbed stabilized by means of grouting, driven ties, and sand piles, supplemented with laboratory analysis of the types of soils involved.

Under the classification of laboratory projects a large proportion of the work continues to be conducted at the University of Illinois. Included are metallographic studies of failed control cooled rails reported as transverse fissure failures, in order to continue the check of the adequacy of the control cooling process. Accelerated rolling-load tests are being made in the cradle-type machines, of steels that give promise of being resistant to shelly-type failures. Rolling-load tests are also being made on various designs of joint bars for the 115 RE and 132 RE rail sections to be compared with the results obtained in the service test installations.

Laboratory tests were completed last year on the fatigue strength of steel in the rail web, showing the extent to which the fatigue strength may be lowered by corroding agents. Progress was also made in the rolling-load tests being conducted to determine the permissible load on wheels of different diameter to prevent rail damage from the bearing pressures and internal shearing stresses developed.

Studies of the action of soil under repeated loading are also being conducted, together with laboratory analysis of soils included in the repeated load tests and the installations of stabilized roadbed which are being observed by the research staff.

At Purdue University an investigation is being conducted to determine the cause and remedy for failures in floorbeam hangers. Fatigue tests have been started in the

Krause–Purdue hydraulic testing machine of full size timber stringers. Laboratory tests are also being conducted on waterproofing paints for concrete, with the view of developing an accelerated laboratory test that may be used as an acceptance test by member roads.

At Northwestern University tests have been completed of the distribution of bearing pressure on concrete from rocker shoe slabs of different sizes and thickness. At the Forest Products Laboratory strength and fatigue tests have been conducted on small size spans cut from the same timber stringers that are being tested at Purdue. Work has continued at the Timber Engineering Company Laboratory on the causes and possible measures for preventing checking and splitting of ties and minimizing tie plate cutting into ties. At the Southern Railway laboratory, rolling-load tests have been conducted on engine-burned rail that has been repaired by welding. At Battelle Institute study has been made by X-ray diffraction methods of internal residual stresses in rail to develop information on the causes of rail shelling.

In addition to the above cooperative laboratory projects the Association has participated in and contributed to the work of the Column Research Council and Research Council on Riveted and Bolted Structural Joints established by the Engineering Foundation.

The approved research budget for 1951 includes five new projects of special interest to railway engineers. Several railways are making experimental installations of 78-ft. rail lengths and the research staff will make measurements to develop information of the service performance of these lengths compared to 39-ft. rail. Work will also be undertaken to develop laboratory tests for comparing the effectiveness of various types of fire retardant paints. A cooperative agreement will be made with Iowa State College to study the effectiveness of various types of chemicals for the control of vegetation growth. Plans are underway for the construction of a new type of repeated-load testing machine for soils and ballast at the Central Research Laboratory. The Association will also participate and contribute to the newly formed Structural Steel Painting Council to develop improved techniques for cleaning and painting structural steel.

It is evident from the foregoing that the engineering research activities have assumed very substantial proportions. It has only been possible to carry on work of this magnitude through the interest and assistance of the AREA committee members and university laboratories. We appreciate the fine cooperation that we have had, and are certain that with its continuance we shall be able to progress the needed research activities of the AREA so that the railway industry will be well repaid by, and proud of, our accomplishments.

President Loeffler: Mr. Magee, you and your staff are carrying on outstanding research work, which is proving of substantial benefit to the railway industry. The Association's various committees are highly appreciative of your interest and efforts in their behalf. During the course of our convention we will hear more about this research work, both from you and from members of your staff.

This completes the opening features of our program. We are delighted to have had so many past presidents with us this morning. The past presidents, members of the Board of Direction and guests on the platform are excused at this time, to make room for the members of the first standing committee to present its report.

American Railroads at Mid-Century

By John M. Budd

Vice President, Operation, Great Northern Railway Company

It is particularly pleasing to be with you today and to take part in your Annual Meeting. Engineering seems to have been a part of my life for many years. My father was a civil engineer and my earliest recollections of his associates were other members of railroad engineering staffs. My college course was in civil engineering, and my first work on a railroad was in that field. Engineering work has continued to be of especial interest to me.

Great changes have taken place in the type of work performed by engineering staffs, but the importance of that work has not diminished one iota. Engineering work has established a reputation for farsightedness, and changes in the type of work have been barometers indicating future trends, rather than thermometers indicating the situation as it exists at any particular time.

The members of your organization have a great heritage, following as they do the romantic explorers and locating engineers who were responsible for the original construction of our railroads.

Before taking a look at the railroads in the middle of the 20th Century, let us see what was going on in the middle of the 19th Century, and what kind of work faced your predecessors.

At that time the citizens of this country were acutely aware of the necessity for improving communications within the United States so that the country could be bound together and strengthened. Construction in the East was proceeding at a rapid rate. The discovery of gold in California had fired the imagination of many of our citizens, and the importance of tying the area along the Pacific coast more closely to the rest of the Union brought about the first steps towards construction of a transcontinental railroad.

In 1853 Congress appropriated a modest amount of money for explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi river to the Pacific ocean. This work was carried out by Army engineers, and several forces were organized to explore and survey the different routes that were to be considered. There were five trail or wagon road routes of travel in the middle of last century, but travel was slow, tedious, strenuous and next to impossible for all but the hardiest. There was still an immense territory about which practically nothing was known; just bits of information available from the early fur traders and other adventurers.

The man to whom the work in the Northern region was assigned was named Isaac Stevens. He was a New Englander, a graduate of West Point, and in the Engineers Corps of the United States Army. His son, Hazzard Stevens, writing the story of his father's life, gives this version of the task:

> "It is difficult to realize the magnitude of the task here outlined. It was to traverse and explore a domain 2000 miles in length by 250 miles in breadth, stretching from the Mississippi river to the Pacific ocean, across 1000 miles of arid plains and two great mountain ranges; a region almost unexplored, and infested by powerful tribes of predatory and warlike savages; to determine the navigability of two great rivers, the Missouri and the Columbia, which intersect the region; to locate by reconnaissance and to survey a practicable railroad route;

> to examine the mountain passes and determine the depth of winter snows in them; to collect all possible information on the geology, climate, flora and fauna, as well as the topography, of the region traversed; and finally, to treat with the Indians on the route, cultivate their friendship, and collect information as to their languages, numbers, customs, traditions and history; and all this, including the work of preparation and organization, to be accomplished in a single season."

Those exploring other routes, of course, had a task of about the same magnitude in completing their missions. The work of these early engineers is recorded in several large volumes which are extremely interesting. Their studies were complete with maps showing the proposed routes, and profiles indicating the approximate gradients. Passengers on today's trains can use these volumes as guide books, as many of the railroad lines were actually built on the routes recommended by these engineers.

During the 100 years that have elapsed since those days of exploration America has seen some truly great engineers, who took an active part in the location and construction of the railroad system as it is known today. Actual construction came to a virtual standstill about 30 years ago, but the physical plant which we are now using bears little resemblance to the properties of 1920. Improvements have been made in alinement and grades. The track structure, roadbed and bridges have been strengthened to take heavier loads, longer trains and larger locomotives. These changes have permitted the railroads to improve the quality of the service that they perform, and to operate on a basis of safety that was not even dreamed of 30 years ago.

Your organization bears witness to the fact that we have not, by any means, reached the end of this program.

Let us take a look at the railroads today, and at some of the things they face.

One of the significant facts about our railroads is that they have developed under private ownership, resulting in better service at a lower cost than that under government ownership and operation in other countries. Cooperative associations, permitting freedom of car interchange, have given the public all of the advantages of a single, nationwide system in the movement of freight and passengers. The magnitude and significance of this accomplishment is too often lost on the general public and on most railroad employees. Shippers can arrange for the movement of any commodity in any quantity from anywhere in the country to any other point by dealing with only one agent of one railroad. Passengers can similarly purchase a ticket covering travel on many lines by dealing with one individual.

Although there has always been competition among individual railroads between major centers of population, the railroad industry had a virtual monopoly on all traffic until a few years ago. For the protection of employees and the shipping and investing public against actual or potential monopolistic abuses, Federal and State governments have been regulating railroads in one way or another for many years. Regulations have continually become tighter and operations have been more hampered and expensive. The railroads still hold such a prominent place in our overall transportation field that the public has suffered in the way of service and rates because of this regulation.

Other forms of transportation are now in lively competition with the railroads for traffic. The first and most important of these operates on our highways. This competition takes two forms—one is private automobiles, which have dried up a great deal of the passenger business formerly carried on the rails. Buses are competing to a much lesser degree. Mass production methods brought the automobile into a price range within reach of the common man in the early Twenties. A demand for roads on which to drive these vehicles was met by our governments, and a network of hard-surface highways soon developed.

These highways, constructed for the benefit of private individuals, were soon invaded by trucks operated for profit. We now find this second form of highway competition is also a serious one. Truck transportation has dealt us a double blow—first, it drained off a select type of traffic which was very profitable for the railroads. Second, it forced us to lower rates on that and other types of traffic, reducing the margin of profit on an important part of our business. We are now faced with the fact that a larger and larger portion of railroad traffic is in lower rated commodities on which the margin of profit per unit is slim.

While trucks have borne part of the construction and maintenance costs of highways through license fees and gasoline taxes, they have not paid their share in full. State highway officials are, at present, acutely aware of the destructive effect of heavily loaded trucks on roads, and are faced with a choice of limiting axle loads to what the present standards of construction will bear, or of raising standards of construction. The same problem has already been met and solved on the railroads, thanks to the ability and farsighted planning of our engineering staffs.

The railroads have protested bitterly about truck competition, branding it as unfair, and with good reason. Part of the funds for highways comes from general tax funds to which the railroads are contributing. In other words, we are helping to maintain a roadway for our competitors.

Transportation by inland waterway has blossomed under a benevolent government and offers serious competition in a limited field. The government not only maintains channels for the water carriers and provides terminal facilities, but the Federal government even operates a barge line on which they have consistently failed to make operating expenses.

Airlines have prospered principally through exceptionally high payments for hauling United States mail, but also through benefits, such as beacon lights, airports, etc., the cost of which is met by government funds. Our competition with the airlines is principally for long-haul passenger business, and to a limited extent for selected commodities in express or even freight service.

Any transportation system that is relieved of even a part of its cost of providing and maintaining its roadway has a tremendous advantage over those not so relieved. In 1950 the railroads spent some 14 percent of their gross operating revenues on maintenance of way and structures. Furthermore, they paid interest on money borrowed for construction and for taxes on the value of their fixed plant. Add these three items of expense and you will find that a large part of the operating revenue must be set aside to meet the total.

There have been some important developments of late which have added materially to the problem of the railroads in providing adequate, satisfactory service at a reasonable cost, and have made a re-examination of our facilities necessary.

One of these developments, which is of extreme importance to roads handling grain, is the change in harvesting and marketing of that commodity. So much has been said and written, so many pictures have been printed, and so many investigations have been conducted over the past few years, that the movement of grain has had more than its share of the limelight.

The "Machine Age" has come to the farm. The old harvesting method consisted of binding grain as it was cut, and then threshing out of either shocks or stacks over a period of weeks on a cooperative basis among the neighbors. Present-day farmers harvest by new machines which thresh as they cut; which are pulled by tractors and operated 24 hours a day during the harvest. Itinerant harvest units complete with combines, trucks, living quarters, etc., supplement local equipment, moving with the harvest from Texas to the Canadian border. Instead of taking weeks to deliver grain to the country elevators, time can now be counted in hours.

Country elevators and farm storage cannot cope with this sudden rush of grain, and railroad facilities are inadequate to take the overflow in such a short time. It has been proved, however, that grain can be moved to terminal elevators faster than terminal elevators can unload the cars. On more than one occasion thousands of cars have been backed up in terminals when free loading has been permitted. We cannot make warehouses out of our cars and hope to provide adequate service.

Another factor bearing upon the railroads ability to handle grain is the marketing procedure. Farmers are now able to borrow money on their grain, redeeming it or defaulting on their loans as late as April 30 of the year following harvest. On default, the grain comes into the possession of the Commodity Credit Corporation. If prices are high, grain is redeemed and sold on the open market. Railroads are called upon to haul it to market when sales are consummated. If prices are low, the grain remains in country elevators or on the farms until April 30, and then starts moving out of the country elevators and farm storages on orders of the C.C.C. Country elevators cannot be cleared soon enough for the following crop, and the railroads are frequently called upon to move a crop at harvest time while still moving the crop from the previous year. It is no longer possible to determine, with any degree of accuracy, when and in what quantities grain will move during a year.

Changes have also taken place in industry which have affected our service and facilities. The principal one is the five-day week adopted by industry a few years ago. Additional rolling stock and fixed plant were needed to permit industry to ship in five days what was loaded in six days only a few years ago. A large part of the added facilities to meet this change has been provided by increasing the efficiency of operation, faster turn of cars, etc., but the problem has not yet been completely solved.

The railroads have had a five-day week among part of their employees for a year and a half. We were well aware of the potential delays to equipment if six or seven-day service was reduced to five-day service in parts of our operations, and made a sincere effort to preclude serious delays to traffic and loss of car days. Analysis on our own road indicates that we have met with some success in this respect and have not suffered too badly because of the five-day week now standard among the non-operating employees.

The tight competitive situation in which the railroads find themselves in the middle of this Twentieth century has deprived them of important sources of revenue. Improved service at even lower costs are a must if we are to retain our proper share of the traffic. Skyrocketing wages of labor and costs of materials have complicated the problem, and even with higher rates of pay, railroads find it difficult to employ enough men to maintain and operate the properties properly. The need for keeping the industry sound and solvent cannot be over-emphasized, however. This is particularly true during these times of stress and uncertainty.

These are facts with which we are faced regardless of how little we may like them. It is not intended that these remarks should be taken as a complaint against injustices, but only as a statement of a situation in which we find ourselves.

Railroad men traditionally have a deep sense of their obligations. They have fought their way through many a storm without losing their direction, and they will do it again. It is hard work, and it will take a lot of fortitude. Every department has to roll up its sleeves and tackle the job.

There is a large share of this in store for you. It will take patience and skill and daring. To you falls the task of finding better and cheaper means of maintaining the fixed property. In your hands is a problem of developing facilities to enable those in the transportation department to serve the public better, faster, safer and cheaper.

Great strides have been made in adjusting maintenance work to conform with the new conditions that have come into being. Revolutionary methods of performing many tasks have already been developed. More are within reach. Still more are but figments of the imagination. What was soundly economical with 40-cent-per-hour labor is basically unsound with a $1.40-per-hour wage scale. A reduction in man-hours has thus become essential.

Machinery has proved to be one of the most effective labor-saving devices. Experience has shown that in most instances machines perform work not only cheaper, but better, than hand labor.

On the Great Northern we have had considerable success in finding new ideas for machines among our own employees and in developing them into a workable form. All levels of employees seem to have useable suggestions, and there are many ways of bringing them forth. Here you are not dealing with exact mathematical equations and formulas, but with human minds that follow a changeable, and sometimes unpredictable, pattern. It is a fertile field and deserves your earnest attention.

Much of your committee work has been concerned with the two-fold problem of materials used in construction and maintenance; first, to develop the most practical and best specifications possible; and second, to develop ways and means of extending the life of materials after they are put to use. The importance of this research has increased many fold with the rise in costs. While the results of your work are plainly evident around the railroads, there is an urgent need for even better standards, and for longer life of ties, rails, fastenings, bridges, buildings, and everything that makes up the fixed plant.

Defense preparations now gathering momentum may have a detrimental effect on your planning for a time. Manufacturers may not be permitted or may not be able to meet your specifications during the time that "Defense Orders" are given first preference. The railroads form such an important link in the country's defense, however, that their needs should be fulfilled in both quantity and quality. Every effort must and will be made to persuade those in charge of the distribution of essential materials of that necessity.

New types of installations in yards and on the road have changed the character of train and yard operations in many parts of the country. New tools in the form of diesel engines have come hand in hand with numerous modern retarder-equipped hump yards, centralized traffic control, longer turnouts, etc. Average speeds have been increased without greatly increasing maximum speeds, all to the end that service is faster and more reliable; locomotive and car utilization are improved, and transportation costs have declined. Statistics indicate that our goal is still distant. The average freight car travels less than 50 miles a day, and the average freight train about 17 miles per hour. At that rate, the average car spends only about 3 hours a day moving in a train. If this were doubled, the car supply would be little or no problem.

The economics of freight car handling in yards and terminals is suggested as a topic for study. It can result in more workable track arrangements for present-day operations, bringing about a reduction in the dead time, and an increase in the productive potential of these cars. Transportation men will welcome a chance to join with you in such a study, as there is great concern on their part with respect to this phase of their work.

Engineers explored the wilderness. Engineers located and constructed the railroads. Engineers pioneered the refinements which have resulted in the fine physical plant of today. I have every confidence that your organization will continue this leadership in the future to an even greater railroad system than we now have.

Closing Business

President Loeffler: I am pleased to report that the total registration for this year's convention is 1707. This compares with last year's registration of 1697.

The presentation of the report of Committee 15—Iron and Steel Structures, completes the formal presentations of our committees at this convention. I take this opportunity to again thank all of the committees for their loyal and constructive efforts in behalf of the railways, and in behalf of this Association, and I want to congratulate them on their separate and combined achievements.

Have we any other business to come before the meeting at this time?

J. B. Akers (Southern): I would like the privilege of the floor, please, Mr. President. I have a matter to present which is of interest to the membership.

President Loeffler: You may have the privilege, Mr. Akers.

Mr. Akers: Mr. President, ladies and gentlemen: Time moves on, and within the hour our president will be a past president.

Mr. Loeffler, this has been an excellent annual meeting, well attended and efficiently handled. It is the climax of a very productive year for the American Railway Engineering Association.

You have been in the forefront, and responsible in large measure for its outstanding success. In recognition of that, it gives me great pleasure, indeed, to present you this plaque as a token of appreciation and high regard from the membership. We are sure you will cherish it and will give it a conspicuous position. It reads:

> **The American Railway Engineering Association records its grateful appreciation to Henry Stanley Loeffler for his able administration of the affairs of the Association during his term as President, 1950–1951.**

I congratulate you, Mr. Loeffler, and take pleasure in presenting you this plaque.

President Loeffler: Thank you very much.

Mr. Akers, and fellow members of the American Railway Engineering Association: I accept this gift with the deepest gratitude. The presentation of this plaque marks the closing moments of my term of office. It will always remind me of the many enjoyable occasions that have been mine while serving as your president.

These moments likewise mark the end of service on the Board of Direction of two past presidents, namely, Armstrong Chinn and C. H. Mottier. The Association is deeply indebted to these past presidents for their excellent counsel and for their long and valuable services. Will those two gentlemen please stand and be recognized?

The terms of office of E. C. Vandenburgh, R. L. Groover, and C. G. Grove—who have served you well and faithfully as directors—also expire at this time. Mr. Vandenburgh and Mr. Groover are retiring from the Board; Mr. Grove, as you probably know, is remaining on the Board, and will be recognized later.

Will Mr. Vandenburgh and Mr. Groover please stand to be recognized?

B. R. Meyers and his Arrangements Committee are to be commended very highly for their untiring efforts and teamwork performance in making of this convention a most successful meeting. Mr. Meyers, the service performed by you and your committee is greatly appreciated. Will you please stand and be recognized?

I would be negligent if I did not also voice special recognition for the group of ladies who, under the direction of Mrs. Meyers and Mrs. Howard, gave so kindly of their time to serve as hostesses in the ladies' registration room. The Association is appreciative of the work done by these ladies.

In performing the closing function as your president, I have the privilege, pleasure and honor of introducing to you the new officers of the Association.

Our senior vice president for the coming year is C. J. Geyer, vice president—construction and maintenance, Chesapeake & Ohio Railway. Mr. Geyer, will you please come to that platform?

Our newly elected junior vice president is C. G. Grove, chief engineer, maintenance of way, Western Region, Pennsylvania Railroad, Chicago. Mr. Grove, will you please come to the platform and stand with Mr. Geyer?

Mr. Geyer and Mr. Grove, I congratulate you on behalf of the Association, and wish you every success in progressing the interests of our Association during the forthcoming year.

We have also elected a new president in the person of T. A. Blair, chief engineer system, Atchison, Topeka & Santa Fe Railway, with headquarters at Chicago.

I will now request that two of our past presidents, Mr. Chinn and Mr. Mottier, escort Mr. Blair to the platform.

Past President Mottier (Illinois Central): I might say—and I'm sure Armstrong agrees with me—that as our last official act as members of the Board, it is a real pleasure to bring Thomas to the platform. Do you agree with that Armstrong?

Past President Chinn (T.R.R.A. St. Louis): I certainly do.

President Loeffler: Mr. Blair, I have the honor to proclaim you the duly elected president of the American Railway Engineering Association. I wish you every success in executing the duties of this office during the coming year.

It is my privilege and pleasure to present to you this beautiful gavel as a symbol of your authority to perform the obligations of your office. This gavel will have extraordinary significance to you because it has been furnished by your friends and associates in the engineering department of the Santa Fe System. It has been made of a birch panel taken from a desk that was used in Santa Fe Track Recorder Car No. 20, which you helped to develop in 1925, and which you, as an assistant engineer, piloted over the Santa Fe lines.

The inscription on this gavel reads as follows:

> **T. A. Blair, President, American Railway Engineering Association, 1951–1952. Presented by the Santa Fe Engineering Department, from wood taken from part of Santa Fe Track Recorder Car No. 20.**

I have presented this gavel to you, Mr. Blair, on behalf of your friends and associates on the Santa Fe, and on behalf of the American Railway Engineering Association.

President-elect Blair: I am completely overwhelmed. Thank you for the highest honor that a railway engineer could possibly anticipate.

I thank my associates on the Santa Fe for this gavel, and assure them that, in my opinion, my elevation to this office is as a representative, and in recognition, of the many hard-working committeemen on the Santa Fe.

I promise you, for the officers and directors of the Association, a year of conscientious endeavor to implement the work of the committees, which, after all, is the most important part of Association work.

I have spent a lot of time up here in front during this convention to get acquainted with some of my new duties, and I couldn't help but be impressed with the interest shown by the members at these sessions. It has been an inspiration to me and to the committees. I hope we have the same interest next year.

I would now like to introduce the four newly elected directors. As I call their names, will they please stand?

W. C. Perkins, chief engineer, Union Pacific. Apparently, Bill couldn't be here.

R. J. Gammie, chief engineer, Texas and Pacific.

L. L. Adams, assistant chief engineer, Louisville and Nashville.

A. N. Laird, chief engineer, Grand Trunk Western.

I would like to announce that there will be a meeting of the Board of Direction this afternoon at 12:45, in the Crystal Room.

Is there any further business to come before this meeting? If not, the 1951 meeting will stand adjourned.

(The meeting adjourned at 12:05 o'clock.)

Presentation and Discussion of Committee Reports

Discussion on Highways

(For Report, see pp. 213–218.)

(President H. S. Loeffler presiding.)

Chairman W. H. Huffman (C. & N. W.): Since the convention program is a little behind schedule, and since the speaker whom we want to present to you is on very short time, we would like to deviate from the usual procedure and present him at this time, deferring consideration of our reports until later.

I would like to present J. W. Wheeler, a member of our committee, who will introduce our speaker.

J. W. Wheeler (C. B. & Q. R. R.): Mine is a very pleasant task, to introduce to you a speaker who is president of the American Association of State Highway Officials, and also a member of AREA. I doubt if this has happened before. His name is General James A. Anderson.

General Anderson leaves at one o'clock on the New York Central for New York, and, therefore, I shall be very short in my introduction.

General Anderson is an eminent civil engineer, who has taught at the University of Virginia and at Virginia Military Institute—he has taught railway engineering and highway engineering. He is now Highway Commissioner of the State of Virginia, and has served as such for many years. In addition, he has held many other offices, and is now President of the American Association of State Highway Officials.

From the remarks which General Anderson has made heretofore, I feel that he shares with us that opinion that the best in transportation is that which is best for the economy of the United States—let the chips fall where they may.

It is my pleasure to present General Anderson, who will perhaps necessarily shorten up what he would say to you otherwise in order that he may catch his train on the New York Central. General Anderson—a member of this Association!

Highways

By General James A. Anderson

Commissioner of Highways, Virginia, and President of American Association
of State Highway Officials

It is a privilege and a pleasure to be allowed to talk to you for a few minutes this morning. Like many another "highway man" my first love in engineering was the railroad field. They did not have a place for me at the time, so I drifted away to other work.

Twice I have been employed for short periods in railway engineering. The first time was just after World War I when I learned that I was to teach railroad surveying. A job was secured on a field party and I quickly learned that the texts could be relied on to give the whole picture to the thorough student. The second time was at the beginning of the great depression in the early thirties. I went with a railroad for a summer to find out better how to pick engineering graduates for the railroads. Again, it was soon evident that they wanted smart, personable, aggressive men who would go out and fight the battles of the railroad. What industry wouldn't want smart, personable, aggressive men to fight its battles and to develop into leaders?

I am proud to tell you that I have been a member of the AREA for many years. I am a great admirer of the work of the Association and its committees.

The railroads following World War II reached out and secured the services of several of the ablest men in the highway field. Among this select group is General Lacey V. Murrow, who has been a distinguished highway administrator. I am sure that his talents have proved to be of great value to you.

All five forms of transportation are of interest to the true engineer. If the enemies of our country and our institutions could make the following trips they might realize something of the strength and greatness of our Nation.

1. Travel by rail from Chicago to Boston through the heart of industrial America.
2. Travel by water from Duluth to Buffalo by great lake ore or grain carrier.
3. Travel by highway from Chicago to Houston.
4. Travel by air from New York to San Francisco.
5. Watch delivery of petroleum products at an eastern terminal by a pipe line, such as the Big Inch.

Those of us who can visualize what would be seen by a traveler on these five trips realize to some degree the greatness and strength of our nation.

Within the past few months I have been privileged to read the biographies of two great Americans—John Marshall's "Life of Washington," and Senator Beveridge's "Life of Marshall."

Chief Justice Marshall makes frequent reference to Washington's realization that the development of our nation depended on adequate, safe and economical transportation. Washington urged his native state, Virginia, to develop its resources by developing transportation routes. Thomas Jefferson wrote Washington urging him to lend his name and talents to this development program. Jefferson said, "Would the superintendence of this work break in too much on the sweets of retirement and repose—What a monument to your retirement it would be—it would remove the only objection."

After John Marshall had been Chief Justice for about ten years he interrupted his duties by taking charge of a field party engaged in exploring the most feasible transportation route between Lynchburg, Va., on the James river, and the Ohio river. Beveridge says, "In his fifty-seventh year Marshall set out as head of the expedition, and a thorough piece of work he did. Marshall's report is alive with far-seeing and statesmanlike suggestions." Said Marshall, "Every measure which tends to cement more closely the union of the eastern with the western states would be invaluable to the whole country." This is still true.

Except for the periods during actual wars and the paralysis that followed, Virginia and the nation have been engaged in developing an adequate transportation system ever since the Revolutionary War.

The then Commander of the Second U. S. Army, General Gerow, said at a highway conference in Virginia a few months ago:

"In considering a subject of such national importance as our overall highway net, the civilian and the soldier approach the problem presented with the same fundamental incentive. That is a desire, as responsible and good Americans, to further the well being and security of the nation . . .

"The requirements for the daily activities and a war emergency are much the same—a well integrated and properly constructed network of roads . . .

"After extensive study by the War Department in coordination with the Public Roads Administration, the overall needs of the National Defense Establishment have been determined—our highway net is an integral part of our national strength—economic and military. We of this generation have seen the results of war and invasion on once prosperous and productive nations, and are resolved that America shall not suffer the same fate. To avoid it, we must continue to improve and expand those basic facilities, such as highways, that contribute to security. There is no other choice."

Thomas A. Edison once said that the great value of the automobile was that it not only stimulated transportation but helped jar people out of the ruts of commonplace thinking. The motor car, he said, "has caused them to move, to stir themselves, to get out and away, to wake up to what was going on about them . . . It has made a great many hundred thousand Americans see themselves and their neighbors—for the first time. It has set their gray matter to work . . . The automobile has made better roads—but the best roads of progress it has made are not physical. They are those mystic paths which urge men into new worlds of imagination and incentive."

Times does not permit me to review the story of the development of highway transportation. O. Henry tells the story of the *old* veteran—a "bar-fly" in Nashville, Tenn., who when the bar opened at 11 a.m. fired the opening gun at Fort Sumpter, and at midnight when the bar was closing was telling the story of Appomattox. Rather I must emulate that great cavalry leader Nathon Bedford Forrest, who, when advised by his badly scared aide to go slow—there were more Yankees on the field than Forrest had—said, "I believe you are right. I tell you what we'll do. We'll charge and give them —— for ten minutes, and if they don't run we will."

You realize as well as I that the great strength of our nation is found largely in our transportation system. In developing our railroads, highways, waterways, airways and pipe lines we have developed tremendous capacities for making steel, rubber, fuels, aluminum and the materials needed in national defense. Not only have we developed the capacities for production, we have also developed precision tools and assembly-line methods, as well as construction equipment and construction management and methods which are such a comfort to these high officials charged with the duties and responsibilities of national defense.

Let me illustrate my point by one example. In the early spring of 1941 Secretary Patterson came to Radford, Va., to dedicate a great ordnance plant. Twenty-four thousand workmen gathered for the ceremony. Secretary Patterson thanked these thousands of workmen for giving the nation what money could not buy—time. The plant was completed two months ahead of schedule. Why was this possible? Because the workmen came in light cars 50, 75 and 100 miles to work each day and returned home each night. No housing, feeding or recreational facilities were necessary. No provision had to be made for water, sewage, fire and police protection, and the 101 facilities needed in a modern industrial city. The workmen lived at home. The motor vehicle and the passable year-round road made this possible. This, plus the "know-how" of management and workers, made this modern American miracle a daily occurrence.

During World War II entirely too many high-ranking persons assumed that our roads were expendable. Frequently excessive loads were permitted. Also, materials, equipment and manpower needed to keep our highways in condition to perform vital wartime service were denied. We have never recovered from those bad practices. Our major highways are less adequate for today's needs than they were in the early part of World War II.

A highway system can not be considered expendable, for it would not be possible to replace or repair it quickly, even if the costs in money, manpower, materials and equipment could be spared from other defense needs. Policies adopted should assure reasonable protection of our highly important highway system.

It is the policy of the Department of Defense to conform to state and local laws, regulations and ordinances as to weight and size limitations of motor vehicles. Their policies are thus stated:

a. Except in instances of overriding and urgent military necessity, no vehicular movement which exceeds any legal weight or size limitation will be undertaken over public highways by or for agencies of the Department of the Army, the Navy, or the Air Force unless prior permission is granted by the State or States concerned upon request of authorized representatives of the military departments. Permits for movement of commercial vehicles will be requested only after determination has been made that military necessity requires movement by the mode and manner selected.

b. Only authorized representatives of the military departments may request permits from the State or States concerned when size and weight limitations are involved. Under no conditions shall a carrier be authorized to contact State authorities for such permits.

c. In each instance of overriding and urgent military necessity in which an oversized or overweight commercial movement is made, report will be made to the Director of the Military Traffic Service. A full statement of the circumstances and justification will be supplied.

No highway department could ask for better cooperation. We are grateful for these wise decisions.

The greatest boon of transportation is not technical. It concerns the lowering of costs of necessities and enjoyment so that happiness may be widespread. This has an importance that carries it into the realm of economics and statemanship. It is the reply to the malcontent or communist who raises his voice against our institutions. If this nation continues to be a dominant factor in the world it must continue to develop.

Increasing Productive Capacity

One of the most powerful weapons we have is our capacity to produce. Each year higher goals are set and each year those goals are reached and surpassed. From 1900 to 1950 our population doubled, but our steel-making capacity increased eight fold. Thus, our standard of living has continued to rise.

It is our hope that we can continue to produce great quantities of durable goods for civilian use while we channel an increasing percentage of our production to the defense of our nation and our allies. If our hopes are realized the most foolhardy of our enemies will hesitate to engage us.

If our expanded productive might is realized, and we have reason to hope that it will be, there need be no irksome controls over a long period. In building our productive capacity it may well be that the luxury of a short work-week must be temporarily laid aside. This is a small offering for us to make for security and freedom.

Members of AREA in their respective fields can and will make great contributions to the program. Modern manpower-saving equipment, application of the management know-how to construction and maintenance work, and increases in productive capacity will go a long way toward offsetting necessary shortages and restrictions.

The following is taken from a talk before a Highway Conference in Virginia by President Darden of the University of Virginia. He was the Governor of Virginia during World War II.

"These are times that trouble all of us. No thoughtful person is without grave concern for the years through which we are living.

"As we ponder on our troubles today we should remember that behind us are generations of men who have had to combat problems just as grave as ours. For that reason, I think we have cause to take heart. We are a great country, technically great. No person who went through the years of World War II can doubt the industrial ability of the United States.

"We are powerful, we have great industrial capacity, but we are now in the front lines with no barrier countries. Our fabulous wealth and resources are on the side of those who want peace and freedom. Patience and courage and the will to work are necessary if we are to live.

The only thing that can solve the problem of shortages in the United States is production—unbelievable production. We must lift the production of the United States far beyond anything ever seen in the past if we are to bring into balance the resources and the needs of mankind.

What has been done in the field of transportation we can do in other fields. We can improve the productive capacity of this nation beyond anything we ever dreamed of.

Among the millions of our young people there is unbelievable genius. Take that genius, open the doors to them and they will lead our country to heights heretofore beyond human conception.

If we faithfully discharge our duty, if we succeed in traveling the road that has been charted for us, we shall hand down to our children a land unbelievably rich and unbelievably happy, with freedom and liberty unimpaired.

Let me relate a short story of World War I that might be applicable to the nation's railways and highways of today. Through wise leadership, the infantry and artillery of the famous First Division came to believe that they were essential parts of the same great team. Whenever they passed each other on the road they heartily cheered one another. It is that feeling of fraternity and teamwork that makes America so great in war and peace. To put it another way, a British soldier asked an American soldier on the decks at Le Havre, "What makes you bally Americans so proud of your Country anyhow?" To which the American replied, "Other countries".

The following announcement was made a few weeks ago:

"Creation of the Texas Institute of Transportation in the Texas A. and M. College System, for the purpose of research and advanced instruction in the various forms of transportation, has been announced by Gibb Gilchrist, Chancellor of the System.

"The Texas State Highway Department has designated Texas A. and M. as the 'state agency to do highway research for and on behalf of the state of Texas and the State Highway Department.' The Texas Engineering Experiment Station has engaged in a number of projects of transportation research. These activities now are to be directed and coordinated through the Institute.

"The Institute's research will be of broad scope within the transportation field, including the economy of transportation, physical plants and property, moving carriers of all classes and types and their tracks or medium, and any other phase or activity concerned with the movement of persons or things. Graduate instruction will be provided for those who want to work to advanced degrees and to engage in research in transportation projects and problems. The Institute is authorized to receive and expend funds donated by approved sponsors to further the objectives of the Institute.

The Institute's work will be divided into the fields of highways, railways, airways, waterways and pipelines, and dedicated to 'the over-all public interest,' Mr. Gilchrist has announced. The Institute is expected to be well developed before the end of the current school year."

In closing may I relate two short stories from the work of the Apostles Peter and Paul, as related in Acts.

"But a certain man named Ananias, with Sapphira his wife, sold a possession, and kept back part of the price, his wife also being privy to it, and brought a certain part, and laid it at the Apostles' feet.

But Peter said, "Ananias, why hath Satan filled thine heart to lie"? And Ananias—fell down and gave up the ghost—and the *young men* arose, wound him up, and carried him out and buried him.

And about the space of three hours after his wife came in and lied also—and Peter said, "Behold the feet of them which have buried thy husband are at the door, and shall carry thee out." Then fell she down and yielded up the ghost, and the *young men came* in, and found her dead, and carrying her forth, buried her by her husband.

The *young men* were the ones who came and did the work that was to be done. Let us be sure in making our plans for this year, next year, and the years to come, that we include in our plans a *full quota of young men*. For sooner or later the young men must come in and take up our work and carry it forward to new heights. This the young men are prepared to do. Let us give the young men the duties and responsibilities, and the authority that goes with them.

And finally, when the Chief Captain commanded Paul to be brought into the castle and examined by scourging, Paul said to the Centurion, "Is it lawful for you to scourge a man that is a Roman and uncondemned?" The Centurion told the Chief Captain "Take heed what thou doest, for this man is a Roman." Then the Chief Captain asked Paul, "Art thou a Roman?" He said, "Yea", and the Chief Captain answered, "With a great sum obtained I this freedom." Paul said, "But I was free born."

All of us are free born, but we must give great sums to keep this freedom. This we are prepared to do. No demands or sacrifices are too great, provided our treasures are wisely used and our priceless freedom is maintained.

In all things making for our happiness and security AREA will show the way.

President Loeffler: Thank you very much, General Anderson. We greatly appreciate your kindly and informative address.

Mr. Huffman, will you please proceed?

Chairman Huffman: The report on Committee 9, as far as its assignments are concerned, will be brief as none require action from the floor.

We have submitted reports on three of our assignments, which were published in Bulletin No. 490, dated November 1950.

Assignment 2 covers the design and specifications for full-depth plank crossings. Our present report is in the form of a proposed revision of the specifications, which are now in the Manual, and which have been expended to cover both the full-depth type and shimmed-plank type construction of wood plank crossings. The committee will consider any comments on or criticisms of the specifications presented in the report, and proposes to submit them a year hence for adoption and inclusion in the manual.

Assignment 4 covers the location of highways parallel with railways. This is a subject of increasing importance and, therefore, should be given the utmost consideration in long-range planning. Our report has been divided into three sub-divisions, namely, parallel highways in vicinity of:

1. Industrial or manufacturing areas in or near cities;
2. Urban residential or retail commercial areas; and
3. Rural areas.

Our report indicates why the highways should be certain minimum distances from the railways in all three cases, not only for adequate and feasible track layouts, but also to eliminate the necessity for additional grade crossings which could not be economically separated, thus increasing the accident hazard potential.

Assignment 6 covers the principles for determining allocation of cost of public improvement projects involving highway—railway crossings.

Last year this committee presented a progress report on this assignment as information, which was published in detail in the Proceedings, Vol. 50, 1949, and requested comments and criticisms. No adverse comments having been received, it is felt that the assignment is complete. The proposed schedule of suggested participation by the railroads should remain firm unless economic conditions, public opinion, or legislation have changed to the point where the schedule set forth requires alteration. This is a final report, which is submitted as information.

Our other two reports are progress reports, and are submitted as information.

In so presenting to you all of our reports, to save time, I have deprived our subcommittee chairmen of the privilege of coming to the rostrum. However, I think these men should stand and be recognized.

On Assignment 2 our subcommittee chairman is R. E. Nottingham of the L. & N.; subcommittee chairman of Assignment 4 is W. C. Pinschmidt of the C. & O.; the subcommittee chairman of Assignment 6 is J. A. Droege, Jr., of the N. Y. C., who was unable to be present.

Mr. President, this completes our report.

President Loeffler: These three reports have been submitted by the Highways committee as information. Are there any comments or discussion? If not, the reports will be so received as information.

Mr. Huffman, the committee which you are directing is one of the Association's most important committees, particularly from the standpoint of our relationship with the public and public agencies. Over the years your committee has made valuable reports and recommendations on behalf of the railroads and with respect to safety and the public. Your contributions continue.

The committee is excused with the thanks of the Association.

We are still behind time, and there is some question as to whether we should have the report of Committee 24 at this time, or postpone it until after lunch. What is your pleasure?

S. R. Hursh (Pennsylvania and chairman of Committee 24): Mr. President, I think that for the benefit of the Association we should defer the presentation of our report until after the noon hour.

President Loeffler: If that is your wish, the meeting will stand recessed, and we will reassemble here this afternoon at 2 o'clock.

(The meeting recessed at 12:30 p.m.)

Discussion on Cooperative Relations with Universities

(For Report, see pp. 437–443.)

(President Loeffler presiding.)

Chairman S. R. Hursh (Pennsylvania): As chairman I will not take up much of your time, because we want most of the time alloted to this committee to be given to Dean Eshbach, who has a very important message to convey to the members of the Association.

As you undoubtedly know, the function of this committee is to deal with the human element, as a material, as against the actual materials considered by most of the other committees of the Association. This includes the creation of a closer relationship between the railroad industry and our leading technical schools, to encourage young men to come into the railroad industry, so that in succeeding years we may have able officers to run our railroads.

At the end of this convention I relinquish the duties of chairman of this committee, and I want to take this opportunity to thank each member of Committee 24 for his wholehearted support. A lot of the work must, of necessity, be carried on by the subcommittee chairmen, and I especially want to thank the subcommittee chairmen for the work they have performed.

The information which is presented by the committee, which is as a progress report, will be found in Bulletin 492, starting on page 437. You may read that at your leisure. I hope you do read it, because it contains some valuable information, especially on Assignments 2 and 3.

I would like now to introduce C. G. Grove, who will take over as chairman of this committee for the next two years. Mr. Grove, will you please stand?

R. J. Stone, vice president of the St. Louis–San Francisco Railway, is vice chairman for the next two years. If Mr. Stone is present, I would like to have him stand.

Dean Eshbach has some very valuable information to present, and I hope that all the top-ranking officers of our railroad industry who are present will pay strict attention to what he has to say. I hope also that those here who are not in the top ranks will read this report, and will go home and try to sell it to their top officers.

If we are to get young men to come into the railroad industry and have them in the next 10 or 15 years, we must start to get them this year, because in 1954 the number of graduate engineers is going to be very small. We must take steps to recruit them this year. Even though we may lose them to the armed services, we will still get some of those men back later.

I now present O. W. Eshbach, Dean, Northwestern Technological Institute.

Future Needs and the Supply of Technical Personnel for the Railroads

By Ovid W. Eshbach

Dean, Northwestern Technological Institute

In accepting this assignment I was well aware that anything written yesterday would likely be out of date today. Perhaps anyone who attempts to look into the crystal ball and predict what the Congress will do should have his head examined. Nevertheless, I am here to fulfill a commitment, and I feel like an unlicensed reporter.

Committee 24 is concerned with ferreting out and studying those problems that vitally affect mutually beneficial relations between the railroads and the engineering colleges. At the end of World War II, for the first time in the ten years I have been associated with you, it seemed that you would be able to acquire a steady flow of good engineering graduates to fill the gap which prior conditions caused to be accumulated over at least 15 years. Almost all public utilities have been faced with the same problem and hope. The employment programs of your companies have been modest, and today you are faced with the situation of insufficient potential leadership in the younger age groups. The hope that this would be cared for by the large veteran enrollment of recent years has vanished, with the complete disappearance of an expected surplus of engineering graduates. Last year 50,000 graduates were placed. This year's crop of 30,000 are sold out. Mr. Hursh said if you want to get some, you'd better start getting them now. It's too late for this year. They're gone. Next year will be worse, and in 1954 we will scrape the bottom of the barrel. Had we been faced with a normal peace-time situation, the decreased birth rate of the Thirties and the popular scare that engineering was becoming overcrowded would have reduced the number of graduates in 1954 to about 17,000 whereas industry alone would need 20,000. Had the policy advocated last fall by Selective Service been put into effect, it is quite likely that not over one-tenth of the industrial needs of 1954 would have been met. It was this situation that Subcommittee 3 brought to your attention at that time.

We in industry and the engineering profession are aware of the technological and scientific demands of war, of the necessity for this nation to be the arsenal of the western powers, of the need for mobilization of all transportation facilities and for the effective use and development of engineering talent to accomplish the necessary result. We do not share the view that the threat to our security will be met by putting a half billion pounds of flesh into uniform, regardless of their potential technical need in a war economy, just to say "boo" to Uncle Joe.

Although much has happened since last summer, the present situation is of more importance. In passing to it I should like to pay tribute to the thoughtful consideration of many groups whose cooperative efforts promise to bring order out of confusion. The situation has not been as chaotic as may have appeared from reports in the newspapers. Actually, there have been serious-minded, intelligent people working on this problem all the time. In mentioning a few of them, I should like to emphasize that the National Security Resources Board, headed by the Hon. W. Stuart Symington, with Robert L. Clark, Director of the Manpower Office, was, by the Defense Act of 1947, established to concern itself with relationships between supply and requirements, in the case of manpower, resources, and production facilities in time of war. Its studies recently have been concerned with the mobilization of industry, the effective mobilization and maximum utilization of manpower, and of natural and industrial resources, including the maintenance and stabilization of our civilian economy in both a preparedness and war program.

Some of the advisory committees and their reports prepared since last summer are as follows:

1) Report of the Interdepartmental Committee on Scientific Research and Development, by Lawrence R. Hafstad, Chairman, and the report of the Subcommittee on Scientific Personnel, proposing a National Service Status for persons in critically needed skill categories . . . August 2, 1950.

2) Report of Dr. M. H. Trytten, General Chairman of six scientific advisory committees, to the Director of Selective Service . . . October 5, 1950.

3) Engineering Manpower Commission of the Engineers Joint Council, organized October 12, 1950, at the request of R. L. Clark of the National Securities Resources Board, in a letter of September 6, 1950. This Commission, cooperating with the American Chemical Society and the American Institute of Physics, is considering the most effective utilization of engineers in the national effort, and is advising with other Government agencies.

4) Manpower Report No. 3 of the U. S. Department of Labor, giving statistics on technical manpower . . . December 4, 1950.

5) Scientific Manpower Advisory Committee, appointed December 13, 1950, known as the Thomas Committee, to assist Mr. Symington with his responsibility for advising the President regarding manpower policies and programs.

6) Recommendations of the American Council on Education, the National Research Council, and other cooperating groups.

Digressing for a moment, I want to give you a picture of some of the things that happened. The Trytten Committee was appointed some time ago in connection with the Selective Service Act of 1948, to advise with General Hershey regarding the draft situation. You will recall that at the time General Marshall, the Chief of Staff, was advocating universal military training, and that the American Legion had submitted what appeared to be, at the time, about the best program for universal military training.

The country refused to accept this program, and passed the Selective Service Bill, setting definite quotas—for the Army, Navy and Air Force. For a while, of course, it looked as though there would be no need to activate this law, but when the Korean situation arose in the spring, everybody got busy. The law was twice amended up until last fall, to cover its extension for one year, and also to cover the drafting of doctors. It ceases to be in force after July of this year, so it is important that whatever revisions are made should be thought out carefully now, in time for the present Congress to act upon them.

The Trytten Committee, in this situation, made a report which would have protected a flow of talent for specially needed skills from the colleges. This was accepted in principle by the Director of Selective Service.

7) Revision of the "Selective Service Act of 1948" by Gen. George C. Marshall, Secretary of Defense, and Mrs. Anna Rosenberg, with the cooperation of the National Securities Resources Board. This bill, Senate S1 and HR 1752, was submitted to the Armed Services Committees of Congress January 10, 1951, and is cited as the "Universal Military Service and Training Act."

The first results of the efforts of the groups I have mentioned will be the enactment of legislation giving authority and flexibility to a program protecting the security of our country; the fulfillment of our commitments to our allies; and, it is hoped, the enhancement of the opportunity for world peace.

At the present time, the Senate, with slight modification, has passed the bill recommended by the Secretary of Defense. The House of Representatives is contemplating more drastic modifications which, if approved, will necessitate a joint conference between the Senate and the House Committees to reach agreement.

One of the things which would have been very controversial was voted down yesterday by the House Military Affairs Committee, and that was the separation of the universal military training provision of the act, so there will be no controversy on that point. In all probability, it will be one bill.

The other point of controversy is the question of 18 or 18½ years of age. The Senate has passed 18 as the lower limit of age, and the House 18½.

A third point of controversy has to do with the return of a selected group of 75,000 each year after basic training, to American colleges. The Senate has this in the bill; it is recommended by Gen. Marshall. The House has eliminated this from the bill, but has left it up to Selective Service.

Both bills declare that an adequate armed strength must be achieved and maintained to insure the security of the nation; that in a free society the obligations and privileges of serving in the Armed Forces and the reserve components thereof should be shared generally, and in accordance with a system which is fair and just, and which is consistant with the maintenance of an effective national economy; and that adequate provision for national security requires maximum effort in the fields of scientific research and developmnet, health, and education, and the fullest possible development and utilization of the nation's technological, scientific, and other critical manpower resources. To this end, Congress further declares that it is the duty of all citizens to engage in training for military service and to prepare for the assumption of their responsibilities as citizens of a free and democratic nation, and to provide a continuous flow of personnel, recently trained in modern techniques, to assure a vital, ready reservoir from which to fill the military and civilian needs of the nation, including civilian defense. To meet these objective, the legislation will, in all probability, provide for:

1) A military force of 4,000,000.

2) The lowering of the age of draft eligibles to either 18 or 18½ years.

3) The expanding of the ROTC training programs.

4) The establishment of universal military training of from four to six months, with a total of two years of active service, followed by a period of reserve status.

5) The return to college, following basic training, of 75,000 trainees, in order that they may pursue further education in engineering, science, and other critical fields. This is uncontested in principle, but is contested in method of operation.

6) The authority for the President to prescribe regulations for the deferment from training and service of any category or categories of students for such periods of time as are deemed appropriate. This is very important, and it is uncontested in either house, but it does put up to the President the establishment of the rules and policies under which Selective Service shall operate. It is important that this should not be surrendered to the civilian board administering the Selective Service.

7) The instruction to the President to establish a six-member civilian committee, to study and advise with him concerning the administration of basic training. This is provided for in the Senate bill but not in the House bill. Also, a five-member civilian committee to select the 75,000 students is to be appointed by the President and confirmed by the Senate. Not more than three members of any political party are to be members of this committee.

These are the critical provisions affecting the supply of engineers to industry over the next few years, which may extend as long as 10 or 20. Before commenting on their probable influence, I would like to emphasize that in the discussions of the several groups mentioned as advisors in establishing the legislation, there was unanimous agreement on three points vital to your needs:

1) Provision for a continuous flow of technical students through college, with the expectation that they would be available to industry in the war effort. The newspapers have misquoted the intent of this by saying that such students are obligated for military service after they are through. The real intent is that this group shall be available in industry, if needed, and if not needed in industry, they would be taken into the Army to serve the remainder of their service.

2) Provision for a National Scientific Personnel Board, a policymaking body, outside the Selective Service, to insure effective placement and deferment of technical talent. This is not in either of the bills, but it does fall within the category of those things which are delegated to presidential authority, and has not been lost sight of by the advisory committees, upon whom the President will, by act of Congress, rely for advice.

3) Provision for the establishment of more effective policies regarding the calling of active, inactive and involuntary reserves.

The provision for the selection of 75,000 yearly from basic training is provided in the Senate Bill. The House Bill leaves this to Selective Service. The opinion of the Engineering Manpower Commission is that this number should be the minimum, not the maximum, and should not be terminated in 1954. The reason is that to produce 30,000 engineers annually, 50,000 to 60,000 freshmen will be required for this field alone. The actual registration last fall was 34,000. It looks like it will be 30,000 or less next year. The expectation that students will return to college after their service period is somewhat of a gamble, unless they are again financed by federal funds.

The establishment of a science or engineering personnel board, with some authority, which will cooperate with the administration of Selective Service is important. The bill gives the President authority to do this, but it is questionable how much authority he may delegate without further legislation. The draft situation at present is unsatisfactory. In a sense, you have a state of affairs where the policy group, or umpire, is playing on the opposing team.

The reserve situation is serious. The Engineering Manpower Commission was asked to determine how many engineers and scientists at a professional level were doing engineering and scientific work, and the percentage of them who were in a reserve status. A sample of 10 percent of the 600,000 so engaged indicated that over 25 percent of their number were in a reserve status. In some organizations the percentage was as high as 40 percent.

In addition to those who volunteered for the active and inactive reserve, there are many thousands who, after discharging their obligations in World War II, were not given the opportunity to resign, but must await declaration of the end of the emergency before separation. It is hoped that, with the signing of a peace treaty with Germany and Japan, if it is possible, these men will be given the opportunity to resign. They should be given that opportunity now. Many of these men have taken advanced degrees in science and engineering and are occupying important posts in industry. Many companies would like to give these men greater responsibilities, but are afraid that they will be called. Not only their future (they have discharged their obligation) is jeopardized, but also the welfare of the company and the welfare of the country, by continuing these men in the armed service. Fortunately, these men are not now being called.

The responsibility for regulations calling the reserves rests with the Secretary of Defense, and at the present a committee is studying the problem in an effort to arrive at a method of classifying them in terms of their value to the defense effort. This responsibility, I think, falls largely to Mrs. Anna Rosenberg. They know what the problem is and are looking for an answer.

How industry will fare depends largely on the college situation. It is anticipated that an executive order will soon be issued dealing with students now in college.

Last week, and again yesterday, from two separate, reliable sources, I was told the situation was well in hand—that it was realized that a clarifying order had to be issued so that we would not get into a chaotic situation which would be worse than that which prevailed at last Christmastime—of students just running off, trying to get into some branch of service, or of letting their studies go, thinking, "What's the use?"

If those satisfactorily pursuing their studies are allowed to finish before entering the service, the effect on the colleges will not be too serious. On the other hand, industry may expect little in the way of critical manpower unless Selective Service recognizes their needs, or an executive order is issued dealing with the matter.

An article in the Chicago Sunday Tribune reported that the colleges may expect an enrollment of 845,000 male students in 1951–1952, and that between now and 1954 the male enrollment will not fall below 719,500. The prewar male enrollment was about 900,000. In recent years enrollments were substantially higher.

The chances are that enrollments will be considerably higher, for it will take some time to process the 18-year-old class, and at a rate of induction of about 35,000 per month, it would take a year and a half to induct them. In the meantime, the next class will be 18½ years old. This gives argument to the plan to fix the age at 18½, because they won't get around to them, anyway. Thus, any boy who plans to go to college should do so. His value to the service will be much greater, and so will his chance of being selected to return after basic training. This is something that is generally overlooked. I doubt whether the provision for returning 75,000 will disappear. I think it will stay, and if it does, any boy who is in school, who has the aptitude and ability and who goes out for basic training for four to six months, will have the chance to compete to return and finish his education, which is the way it should be. His chances will be greatly enhanced if he goes to school, as he normally planned to, now.

The outlook for engineering is not very bright, because it seems unlikely that the numbers needed, who would qualify by aptitude and interest, can be found. For example, the predicted male enrollment of about 750,000 may be considered to be composed of three equal groups: 250,000 in ROTC units (a report from Washington about a week ago put the figure authorized at 202,000, but contemplated figures as high as 268,000), 250,000 selected from basic training or returned veterans, and 250,000 in 4F classification or below 18 years. A large percentage of the best engineering prospects will be in the ROTC and unavailable to industry. In order to produce a pre-war class of civilian engineers, which is about half the industrial needs, the percentage studying engineering will have to double—that is, the percentage of students who choose to study engineering will have to double to produce only a half of what industry is going to need. We never have found engineering talent in this proportion, by which I mean talent with the ability and aptitude, and also the desire to study engineering.

Still more critical is the supply of professional scientists and engineers with advanced training. Unless there is a supply of graduates there will be no graduate students. From surveys made recently, this presents a very critical situation now, and no improvement is in prospect.

I sincerely hope that no executive order or policy will further jeopardize this supply, and that at this time there will be no order to speed up education. In the latter instance, I am particularly concerned with the cooperative courses and some of the other five-year programs. These contribute to industry, foster graduate study, and help students financially to finish their education. The speed-up in education sounds like a very deserving thing to ask, but I call your attention to the fact that many boys could not go to school if they did not work in the summer. The opportunity to speed up should be there, but it should not be forced.

Thus, for the next five to ten years the outlook for potential leadership for industry in the younger age group is rather dismal. Beyond this period is too long to prophesy, but the increased birth rate during the last war period may completely reverse the situation—about 1958. In the meantime, you may again expect to accumulate a deficit and age unbalance in your individual organizations. It would please me to be able to suggest a solution, but perhaps the role of prophet in his own profession, who is honored by the invitation to talk to you on this subject, is satisfaction enough.

Chairman Hursh: Dean Eshbach, all the members of Committee 24 are very appreciative of, and I am sure that the other members of the AREA likewise appreciate, the message which you have brought to this convention.

Chairman Hursh: In singing my swan song, I think it appropriate, Mr. President, that one thing be impressed upon those higher officers of our railroads, and that is that not enough of our Class I railroads have an honest-to-God training course that can be presented to the young men of the colleges and universities to induce them to endeavor to become future officers on our railroads. To those officers in this room who may have the slightest influence on their managements, I want to say that they should encourage the establishment of a bona fide training course on their roads.

Every railroad today is faced with the possibility of a younger retirement age, forcing you men out at 65. Unless a railroad each year takes on a sufficient number of men to fill the gap caused by retirements, in sufficient time to train them, it will not have qualified men 20 or 25 years from now to run the railroad.

We owe it to ourselves and to our respective railroads to sell our respective managements on the idea of establishing a good training course, and of then going to our leading colleges and universities with accredited courses in engineering, and picking men to take this course. I think the railroad industry is now paying salaries equal to those in other industries, so I am sure we can get the men if we really have something else to offer them. But if we are going to get men in competition with other industries, we must go after them, we must pay them a reasonable starting wage, and we must have a definite program of promotion.

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—Dean R. P. Davis (University of West Virginia), subcommittee chairman.

Dean Davis: The main activity of this subcommittee continues to be in assisting school organizations in securing speakers from the railroads, and also to assist student groups in planning visits to railroad projects. To the list of inspections noted on page 439, Bulletin 492, January 1951, we desire to note a trip made by a group of civil engineering students at Northwestern University to the Markham yards of the Illinois Central Railroad to inspect the modern freight classification facilities at that point. This group also visited the downtown sections of the Illinois Central suburban installations to inspect train control operations.

Your subcommittee is also assisting in the program of publicizing among the colleges and universities the availability for loan of the lantern slides of the historical exhibit prepared by the AREA and the NRAA in 1949. To date, letters have been sent to 58 institutions offering the loan of a set of the slides. Later we expect to contact about 50 additional institutions. The responses received to date indicate that many schools are interested in showing these slides.

Chairman Hursh: This completes the presentation of our report. I want to take this opportunity to thank all members of Committee 24 for their wholehearted support.

President Loeffler: The three very excellent reports submitted by Committee 24, as published in Bulletin 492, are received as information. I recommend them to you for your careful reading.

Mr. Hursh, we of the Association are deeply indebted to the many representatives of the colleges who serve on our committee. We are particularly indebted to Dean Eshbach for his address, dealing as it does with a matter of such vital concern to the railroads and to the country.

This report completes your term as chairman of Committee 24. Under your leadership your committee has made significant contributions to the work of our Association, for which we are deeply appreciative. The committee is dismissed with the thanks of the Association.

Tuesday Afternoon Session

Discussion on Water Service and Sanitation

(For Report, see pp. 219–256.)

(President Loeffler presiding.)

Chairman H. E. Silcox (Chesapeake & Ohio): Before proceeding with the presentation of reports of Committee 13—Water Service and Sanitation, we wish to express to the Association our loss and regret in the death of two valued former members of our committee.

James Harry Davidson died on August 23. 1950. He was elected to membership in the AREA in 1920 and served as a member of Committee 13 for 27 years, contributing much to the development of water treatment.

John Patrick Hanley died on July 26, 1950. He became a member of the AREA in 1924, and was particularly active in Committee 13, always giving serious consideration to his committee work. Brief Memoirs appear on page 220, Bulletin 490.

We also record our loss, in the following Memoir, of one of our members—Aldridge Reed Nichols.

Aldridge Reed Nichols

Died March 7, 1951

Aldridge Reed Nichols was born at Decatur, Ill., June 12, 1899, the son of Paris and Ollie Nichols. In January 1924, he married Ruth Cowgill, who survives him, along with three sons and one daughter. His education was obtained in the local grade and high school at Decatur, with two and one-half years of mechanical engineering at the University of Illinois.

He entered the service of the Wabash Railroad as blue printer in the office of the superintendent of motive power in 1924 at Decatur, became tracer in 1925, and was promoted to draftsman in 1928. In 1930 he transferred to water inspector. He entered military service as captain in 1941, leaving the service as lieutenant in 1945. He was promoted to water engineer of the Ann Arbor Railroad in 1946, and to water engineer of the Wabash in 1947.

Mr. Nichols became a member of the American Railway Engineering Association in 1947 and was very active in committee work, being chairman of one of the subcommittees of Committee 13 at the time of his death. His activity in Committee 13 made him a valuable member of that committee and a credit to the railroad he represented.

He was very active in military matters, having served as an enlisted man during World War I; joining the National Guard he worked up through the ranks to become commanding officer of the headquarters company of the 33rd Division. He was an active member of the American Legion and the Veterans of Foreign Wars.

Mr. Nichols was also active in church work, teaching an adult Sunday School class at St. Pauls Methodist Church. He was a member of the Masonic Order.

This year Committee 13—is reporting on nine assignments, which will be presented by the subcommittee chairmen. In the preparation of the respective reports, our subcommittees have endeavored to present them in such form that they will be informative to the Association as to recent developments, and will inform members with respect to sanitation requirements and governmental regulations in the field covered by this committee.

The complete report appears in Bulletin 490, pages 219 to 256, inclusive.

The first report of the committee is on Revision of Manual, Assignment 1. Guy Martin, the chairman, is going through surgery, and is unable to be here.

Assignment 1—Revision of Manual, was presented by Chairman Silcox.

Chairman Silcox: Report on Assignment 1 appears in Bulletin 490, pages 221 and 222.

Your committee recommends for adoption the following revisions in Chapter 13 of the Manual:

Page 13-38.1, SPECIFICATIONS FOR WELDED STEEL TANKS FOR RAILWAY WATER SERVICE; reword as shown in our report:

101. Scope of Specifications.
102. Weather.
On page 13-38.2:
201. Quality of Metal.
On page 13-38.3:
401. Definitions and Symbols.
On page 13-59:

STANDARD METHODS OF WATER ANALYSIS AND INTERPRETATION OF RESULTS.

On page 13-61:
Add the following to the reagents:
  Schwarzenbach Hardness Buffer Solution
  Schwarzenbach Hardness Titrating Solution
  Schwarzenbach Hardness Indicator Solution
  Sodium Hydroxide Solution
  Schwarzenbach Calcium Indicator.

On page 13-62:

Substitute the following for (b) and (c), and change present (b) and (c) to (d) and (e), respectively:

(b) Alternate Schwarzenbach Test for Total Hardness.
(c) Alternate Schwarzenbach Test for Calcium.

I believe the proposed revisions to the Manual have 89.1 percent approval of the committee by letter ballot. I move that the report on Revision of the Manual, as submitted, be adopted for inclusion in the Manual.

[The motion was regularly seconded, was put to a vote and carried.]

Chairman Silcox then introduced, in turn, the several subcommittee chairmen, who presented the committee's reports.

***Assignment 2—Intercrystalline and Other Types of Corrosion of Steam* Boilers**, was presented by M. A. Hanson (Gulf, Mobile & Ohio), in the absence of R. E. Coughlan, chairman of the subcommittee.

Mr. Hanson: This report appears in Bulletin 490, pages 223 and 224, and is a final report on the intercrystalline corrosion phase of Assignment 2.

The history of intercrystalline corrosion, or, as it was formerly called, caustic embrittlement, of locomotive boiler material, dates back to an epidemic of cracking of boiler plates in the seams, and of broken rivets, which occurred in 1912 on the Chicago & North Western. Subsequent to 1912, other railroads reported similar difficulties in more or less acute stages.

In 1927, five of the nationally known organizations interested in steam boiler operation created a Joint Research Committee on Boiler Feed Water Studies, on which committee AREA Committee 13—Water Service and Sanitation, has always been represented by a minimum of three members.

In 1928 the University of Illinois issued a bulletin compiled by Professors Parr and Straub, on the study made at the University of Illinois in regard to the embrittlement of boiler plates.

The recommendations in this bulletin were that, in order to insure safe operating conditions in a boiler in which sodium hydroxide is present, a definite sodium sulfate-hydroxide ratio should at all times be maintained in the boiler. It was claimed this would prevent intercrystalline corrosion or embrittlement. The findings listed in the University of Illinois bulletin were not in accord with the experiences of the various railroads.

At the same time, the work of the Bureau of Mines proved conclusively the findings of several of the railroads that tannin, lignins, and waste sulfate liquor had an inhibiting effect in highly alkaline waters when such organic material was used under proper supervision and control.

In the meantime, the American Society of Mechanical Engineers had issued their Suggested Rules on Care of Power Boilers, in which the railroad findings, as well as the results of the research studies at the Bureau of Mines, as published in Bulletin 443, were completely ignored. On the other hand, the results of the tests at the University of Illinois, as outlined in its Bulletin, Volume 25—No. 40, June 5, 1928, suggesting the use of sodium sulfate-hydroxide ratio under various boiler pressures, were made a boiler code standard.

Your committee, cooperating with the Bureau of Mines during the past 20 years on experimental work, has definitely determined the cause and methods of prevention of this type of boiler corrosion.

During the same period of time a satisfactory agreement has never been reached between the railroad representatives and the Mechanical Section of the American Society of Mechanical Engineers regarding the use of sodium sulfate-hydroxide ratios, which the

ASME Boiler Code Committee had adopted. For this reason it is the recommendation of your committee that the following procedure be adopted:

1. It is the opinion of your committee that the railroad should disregard the sodium sulfate-hydroxide ratio recommendations, as outlined in the American Society of Mechanical Engineers' Boiler Code of 1949, which ratios are of questionable value and which increase operating difficulties in railroad steam boilers.

2. A complete investigation of boiler feed waters should be made, with special reference to alkaline content and the presence of natural inhibitors.

3. The installation of the embrittlement detectors on boilers operating in suspected water districts on the various railroads.

4. Properly supervised and controlled use of sodium nitrate or lignin in water known to have embrittling tendencies, as outlined in previous reports of your committee.

5. Proper workmanship, resulting in tight boiler seams in all boiler construction.

President Loeffler: Thank you, Mr. Hanson. May I ask you one question? In item 4 of what you have just read, you referred to previous reports. I am wondering if it would make the report more complete if the references could be included in your report when finally printed.

Mr. Hanson: That can be arranged.

President Loeffler: Thank you. This report will be received as information.

Assignment 3—Federal and State Regulations Pertaining to Railway Sanitation, Collaborating with Joint Committee on Railway Sanitation, AAR, was presented by Subcommittee Chairman H. W. Van Hovenberg (St. Louis-Southwestern.)

Mr. Van Hovenberg: This is a report of progress, submitted as information, as found on page 224 of Bulletin 490.

Your representatives on the Joint Committee on Railway Sanitation, AAR, participated during the past year in the revision of the Federal Interstate Quarantine Regulations as affecting railway interstate carriers. Such revisions or modifications appear in the railways' interest. The Handbook on Sanitation of Railroad Servicing Areas embodies these modifications and should be ready for distribution soon. Other handbooks, on the Sanitation of Railroad Passenger Car Construction, and on Dining Cars in Operation, are in the process of final writing. These three handbooks will serve as guides for railroads and other interested parties in effecting better sanitation and compliance with Federal regulations.

The AAR Sanitation Research Project, which had as its object the subject of toilet waste disposal from railway passenger cars, has completed its more than four years of excellent research. Reports of its activities are now available. Sanitation research has been moved to the AAR Research Center in Chicago, where its activities will be directed by the Joint Committee. The Joint Committee has reviewed the final personal completion report of the consultant director, Dr. Abel Wolman, and has submitted its final report to the AAR covering its comments on the recommendations and conclusions reached by Dr. Wolman. Representatives from the Engineering Division on the Joint Committee on Railway Sanitation are R. C. Bardwell, A. B. Pierce, and H. W. Van Hovenberg.

Assignment 4—Mechanics of Foaming and Carry-Over in Locomotive Boilers.

Chairman Silcox: Due to some new experimentation on anti-foaming of locomotive boilers, we are unable to make report on this subject this year.

***Assignment 5—Methods and Materials for Protection of Underground* Pipe Lines,** was presented by Subcommittee Chairman H. E. Graham (Illinois Central).

Mr. Graham: Your committee submits as information the report as published in Bulletin 490, November 1950, page 225, with the exception of one correction. The first line of the last paragraph under the caption "Non-Metallic Coatings," which appears on page 228, has been changed to read: "Probably the coating which will give the longest underground protection is portland cement mortar, which forms a film of alkaline solution in contact with the iron pipe to inhibit corrosion."

The damage done by corrosion to underground pipe lines costs the railroads a very large sum of money each year. Besides the damage to the pipes, losses of the fluid through leaks represent a large cost. The report brings out the fact that while all corrosion damage cannot be prevented economically, it can be reduced considerably by one or more of the main techniques used for controlling the rate of corrosion.

The corrosion taking place on the interior surfaces of a pipe may be more severe than the corrosion caused by the soil on the exterior surfaces; therefore, the internal surfaces and the fluids being conveyed must be given consideration when protecting underground pipe lines.

The choice of the method of corrosion control used is dependent upon: the required service life of the pipe; the life of the unprotected pipe as compared with the increased life due to the protection; the cost of the protection; and the cost of renewing the pipe line. No one type of protection is suitable for all conditions; therefore, the factors controlling the corrosion rate must be studied carefully.

Assignment 6—New Developments in Water Conditioning for Diesel Locomotive Cooling Systems, was presented by Subcommittee Chairman M. A. Hanson (Gulf, Mobile & Ohio).

Mr. Hanson: The control of corrosion in diesel cooling systems has been accomplished successfully by the use of alkaline chromate-type inhibitors. However, the availability of alkaline chromate inhibitors has become a matter of concern, in the event of an all-out National Emergency.

Considerable research has been done, both by the railroads and the various water-treatment supply companies, to develop non-chromate inhibitors.

One proprietary non-chromate type inhibitor which has been laboratory tested appears promising, when used in dosages of approximately one and one-half times as great as those used for alkaline chromate inhibitors. This dosage would be practical and feasible.

Laboratory corrosion tests are not necessarily reliable in reproducing field conditions, but do, nevertheless, give some valid indications. The tests of this product have not progressed far enough for one to be certain that it will give protection equivalent to alkaline chromate inhibitors, but it will undoutbedly give a very substantial degree of protection. It is gratifying that this much progress has been made, even though the final answer may not have been found.

It is hoped that this research can be progressed to a successful conclusion during the coming year.

This report is submitted as information.

Assignment 7—Railway Waste Disposal, was presented by Subcommittee Chairman T. A. Tennyson (St. Louis–Southwestern).

Mr. Tennyson: This is a progress report, submitted as information, as found on page 229 of Bulletin 490.

After two years of study on federal and state regulations pertaining to waste disposal as they involve the railroads, and on the problems which appeared to be of major importance, your committee recommends that this problem be turned over to a joint or collabrating committee within the American Railway Engineering Association, or within the Association of American Railroads, to keep abreast of the trend in waste-disposal regulations and developments in methods of compliance. Such a joint committee is needed—since most all departments of the railroads are involved more or less in waste disposal problems—as a source of advice for the railroad industry; to avoid duplicated effort; and to serve the interests of the railroads in controversies which will arise with the controlling agencies in stream-pollution and related problems.

President Loeffler: Thank you, Mr. Tennyson. Your recommendations will be considered by the AREA Board of Direction, and I am quite sure the matter will be referred to the Board Committee on Outline of Work. Your report will be received as information.

Assignment 8—Sanitation Practices for Location, Construction and Maintenance of Drinking Water Wells and Pumping Equipment, was presented by Subcommittee Chairman H. M. Schudlich (Northern Pacific).

Mr. Schudlich: The report on Assignment 8 is found in its entirety on page 230 of Bulletin 490, and is submitted as information.

The assignment covers in a brief and general manner the various important types of wells, with recommendations for proper location in order to maintain the sanitary quality of the water delivered. The different types of wells are illustrated, and descriptions of the construction of the various types are outlined. After the construction has been completed, disinfection is necessary before a well is placed in service, and it is recommended that annual bacteriological analysis be made. Proper maintenance is necessary to keep a drinking water facility in sanitary condition, and some of the important basic points are covered.

The sanitary standards of approximately 20 states were referred to, and it is felt that this report will cover the basic minimum requirements for all the states, and will serve as an outline for any contemplated construction. Where specific details are required, the local Board of Health should be consulted.

Assignment 9—Design and Maintenance of Septic Tanks for Railway Purposes, was presented by Subcommittee Chairman D. C. Teal (Chesapeake & Ohio)

Mr. Teal: The published report on Assignment 9 appears in AREA Bulletin 490, on pages 241 to 252, inclusive.

The septic-tank disposal method is generally accepted as the most satisfactory way of handling small amounts of sewage in rural areas, and, as a matter of fact, can be used for flows of up to 10,000 gal. a day. Septic-tank systems may be classified as simple or complex. Essential to either is an underground settling tank where sewage solids are retained and digested by bactericidal action, and a drainage field where the more or less clear water effluent can be absorbed into the soil. A simple system would be the one-compartment gravity-flow-type tank, and a tile drain absorption field, ordinarily capable of handling up to 1000 gal. of sewage a day. For proper disposal of larger quantities, a more complex system, including multiple-compartment tanks, with dosing chamber and syphon, and with sand filter trenches with under drains or open sand filter beds, may be required.

This year's report covers the basic principles involved in the construction and operation of the simple, one-compartment septic tank sewage disposal system designed for flows of from 200 to 1000 gal. a day. Fig. 1 on page 242 illustrates such a system.

The report is subdivided into six sections, with appropriate headings. The first of these is entitled General Information on Septic Tanks, and gives data on the degree of purification that may be expected, service life, advantages of seeding, effects of grease, effects of chemicals, effects of ground garbage and recommendations on inspection and cleaning.

The factors that should be considered before starting design work are next discussed. This section covers such topics as building permits, estimates of sewage flows, location of tank and drainage field with respect to buildings and topography, permeability of soil in the drainage field, and procedure for making soil percolation tests. The average daily flows of sewage from various types of establishments are shown in Table 1, and data on the absorption qualities of common types of soil are shown in Table 2.

The section headed Design of Building Sewers gives recommendations concerning materials, sizes and slopes. The size of sewer to use under varying conditions is given in Table 3.

The section headed Design of Septic Tanks presents recommended practices as to material, shapes, capacities, bury, and other pertinent details. Fig. 2 on page 246 shows a typical, small, single-chamber septic tank, and Table 4 gives the recommended dimensions of same for flows up to 1000 gal. a day.

Design of the distribution box, and design of the absorption field, are treated in a similar manner, and are illustrated by Figs. 3, 4 and 5.

A general summary is presented on page 252 of the steps that should be taken in the planning, construction and operation of small septic-tank systems.

The original assignment is being continued, and the committee expects to make another report next year covering the design and operation of the larger, more complex types of septic-tank disposal systems.

This year's report is presented as information.

Assignment 10—Specifications for Design and Installation of Diesel Fuel Oil Facilities, Collaborating with Committee 6.

Chairman Silcox: Due to the serious illness during the past year of our committee chairman, A. R. Nichols (Wabash), no report is prepared this year, but we assure the Association that a report will be furnished on this subject in the coming year.

Assignment 11—Specifications for Design and Installation of Diesel Lubricating Oil Facilities, was presented by Subcommittee Chairman G. F. Metzdorf (New York, Chicago & St. Louis).

Mr. Metzdorf: Diesel lubricating oil facilities consist of one or more clean oil supply systems of distribution, and dirty or waste oil return systems.

In general, the clean lubricating oil distributing systems include storage tanks, strainers, pumps, air releases, meters, valves, piping, storage supply loading stations, and diesel locomotive filling stations. When various brands of oil are intended to be kept in separate storage, each brand of oil should have an entirely separate system.

The dirty or waste oil return systems generally consist of diesel locomotive drain stations, pumps, storage tanks, valves, piping, and storage tank unloading stations for shipment to reclamation plants. Some railroads install their own reclamation plants; others pump the waste oil into boiler fuel oil storage tanks and use it as fuel, together with the regular fuel oil, for stationary heating boilers.

The size or capacity of storage tanks for diesel lubricating oil is governed by operation requirements, and whether the oil is to be purchased in barrel lots or in bulk carload quantities.

Lubricating oil must be kept warm enough to pump properly in cold weather. When practical, storage tanks should be placed inside of heated buildings. Outdoor tanks exposed to cold weather must be provided with heating coils and temperature controls. In addition, the piping which leads to and from the tanks must be provided with steam tracers, traps, etc., all of which involve additional maintenance.

The balance of this report covers the general data required for the design, and for the specification for installing diesel lubricating oil facilities.

Chairman Silcox: Gentlemen, this concludes my three years as chairman of Committee 13. I had hoped that Guy Martin (Illinois Central) would be here so I could present him to you as my successor—and wish him well.

I would like to thank the members of Committee 13 for the fine cooperation they have given me, and I hope that they will continue to give Mr. Martin the same support.

With the elevation of Mr. Martin, H. L. McMullin (Texas & Pacific) will become vice chairman of Committee 13. Mr. McMullin, will you rise, please?

Mr. President, this concludes the report of Committee 13.

President Loeffler: Mr. Silcox, as for many years in the past, your committee again has presented valuable information in the interest of our members and their railways. You should have great satisfaction as you complete your three-year term as chairman of Committee 13, carrying on the leadership of your successors.

I now dismiss the committee with the appreciation of the Association.

The next report will be that of Committee 14—Yards and Terminals, of which W. H. Giles, Engineer of Design, Missouri Pacific Railroad, St. Louis, Mo., is chairman. Will Mr. Giles and members of his committee please assemble on the platform?

Pardon me! I owe Mr. Giles an apology. I introduced him under his old title. Mr. Giles was recently promoted to assistant chief engineer, construction, Missouri Pacific Lines. Congratulations, Mr. Giles!

Discussion on Yards and Terminals

(For Report, see pp. 257–282.)

(President Loeffler presiding.)

Chairman W. H. Giles (Missouri Pacific): The report of Committee 14—Yards and Terminals, will be found in Bulletin 490, beginning on page 257. The committee reports on six subjects this year.

(Subsequent to the Annual Meeting of the Association, Committee 14 was shocked to learn of the death of one of its past chairmen, M. J. J. Harrison, and requested that the following Memoir be recorded in the Proceedings):

Mark J. J. Harrison

Died March 29, 1951

Mark J. J. Harrison, supervisor of scales and weighing of the Pennsylvania Railroad, an outstanding authority in scales and weighing circles, died March 29, 1951, in the Altoona Hospital, Altoona, Pa., where he had been taken only ten days previously, because of a heart condition. He was born at Wellsboro, Pa., March 12, 1893. He attended Rensselaer Polytechnic Institute, from which he was graduated in 1913 with the degree of Civil Engineer.

His professional experience included five years with the Pennsylvania State Highway Department, six months with the Armed Service in 1918, and one and one-half years with the U. S. Bureau of Standards, where, as assistant civil engineer, he gained valuable experience in weights and measures. In 1920 he entered the service of the Pennsylvania as a scale inspector; became general scale inspector of the Western region in 1923; and was made supervisor of scales and weighing at Altoona in 1937, where he remained until his death.

Mr. Harrison joined the AREA in 1925, and from 1926 until his death, he was a member of Committee 14—Yards and Terminals. On that committee he served as chairman of the subcommittee on scales used in railway service from 1926 to 1933, and from 1938 to the date of his death. He was chairman of Committee 14 from 1934 to 1937. The present specifications for railroad track scales, motor truck, grain, hopper and other scales used in railroad service were prepared under his supervision as chairman of the AREA scale subcommittee. These specifications were prepared with the collaboration of the National Bureau of Standards, the scale industry, and various state departments of weights and measures. He also served on the Association's Committee on Arrangements, and he was a familiar figure at the convention where he handled the sale of annual luncheon tickets.

His other activities included membership on the AAR Committee on Weighing, and in the National Scale Men's Association. Of the latter group he was president 1928–1929, and served on many of its committees. He was a frequent speaker on the programs of the National Conference on Weights and Measures and was highly regarded by weights and measures officials as an authority on large capacity scales. Evidence of this was his activity in many state weights and measures associations, which included his association with the Indiana Department of Weights and Measures, where he served for 11 years as chairman of the department's Question Box Committee.

He was a pioneer in the application of electronic weighing to railroad track scales, and was actively engaged in the perfection of this method of weighing at the time of his death. He had been responsible for the installation of electronic elements in several railroad track scales under his supervision.

Mr. Harrison was a Mason and a Shriner and wore the key of Tau Beta Pi, engineering honor society. He is survived only by his widow.

Committee 14 records his passing with sorrow. His wise counsel, sound judgment and genial fellowship will be missed by his associates of many years on the committee.

(Chairman Giles then called upon the various subcommittee chairmen to present their reports.)

Assignment 2—Classification Yards, Collaborating with Committee 16, was presented by Subcommittee Chairman A. S. Krefting (Minneapolis, St. Paul & Sault Ste. Marie).

Mr. Krefting: The report on this assignment may be found on page 258 of Bulletin 490. The report covers the Effect of Assisting Gradients on Drill Tracks, Ladder Tracks and Body Tracks of a Flat Yard.

In the study made, the committee found that while, in general, some assisting gradient is usually desirable, the rate of gradient most desirable will depend on conditions existing at each yard. At locations where the climate is not too severe, where the cars handled are ordinary cars—part loads and part empties—and where good alinement and surface for the track and turnouts will be maintained, the following gradients may be considered satisfactory:

Drill Track—A 0.2 percent gradient for the 300-ft. section of track which precedes the first switch, and the remainder of the track level or with a light assisting gradient.

Ladder Track—Usually a gradient between 0.2 percent and 0.3 percent. In some yards gradients as low as 0.1 percent, and in others as high as 0.5 percent, are being used. The length of a ladder track should be taken into account if an accelerating gradient is being considered.

Body Tracks—The gradient following the turnout to be 0.2 percent or 0.25 percent for a distance of about 300 ft., and gradually decreasing with a level gradient about 400 ft. long at the end of the section of track to be switched from the ladder in question.

By providing assisting gradients for drill tracks, ladder tracks, and body tracks to best suit the operating conditions which will prevail at a yard, it is possible to keep switching time to a minimum, thereby reducing operating expenses and speeding up the handling of cars through that yard. Damage to cars and their contents through rough handling should also be reduced, and it is also probable that fewer personal injuries will occur.

This report is submitted as information.

Assignment 4—Bibliography on Subjects Pertaining to Yards and Terminals in Recent Publications, was presented by Subcommittee Chairman W. C. Sadler (University of Michigan).

Mr. Sadler: You will find this report on page 258, Bulletin 490. I would like to take a minute to review this bibliography work that has been done by the committee over the period from 1923 to the present time.

In 1923 a committee on passenger terminals made a study of the literature in the field during the period from 1899 to 1923. The bibliography resulting was arranged by the various terminals, such as the LaSalle Street Station.

At various times since then, other such reports have been made by this committee. One came out in 1930, by E. E. R. Trattman, and the next year one was prepared by Mr. Trattman and me. In the following year, 1932, gathering this material was considered of sufficient importance to establish a subcommittee, which has followed it through some 20 years, to the present time.

There is a total of almost 35 various indexes which cover railroad literature, other kinds of technical literature, government reports, and so forth, and to do a proper job on the subject we have before us, it is necessary to comb material rather carefully. Of course, the material flows rather slowly from the periodicals into those indexes, such as the Engineering Index, Industrial Arts Index, and some others with which you are familiar. There is a lag anywhere from 2 or 3 weeks to 90 days.

The material you have in front of you here covers the 12 months preceding June 17, 1950. In other words, the material in front of you includes nothing subsequent to July 1950—a lag of some eight months.

Now, if that is so, and you have a matter that you want to study, it is rather difficult to get any up-to-date material from a report that comes out the following 15th of March.

We conducted a poll to determine how much active use is made of this report, since it is probable that the interest has been decreasing due to the increased quality and detail in the indexes of the various magazines, such as Railway Age. In view of this situation, the committee decided at Kansas City in the summer of last year to consider this as a final report.

Therefore, Mr. Chairman, we submit our report this year as information, and as a final report of the committee.

President Loeffler: Thank you, Professor Sadler. The report will be received as information.

Assignment 5—Locomotive Terminal Facilities, was submitted by Subcommittee Chairman D. C. Hastings (Richmond, Fredericksburg & Potomic).

Mr. Hastings: The report of Subcommittee 5 will be found in Bulletin 490, beginning on page 261.

In 1947 your committee revised the Manual section having to do with Steam Locomotive Terminals (AREA Manual, pages 14–32 to 14–32.84, incl.). In 1948 a report was submitted as information covering Diesel Locomotive Terminal Facilities (Proceedings, Vol. 49, 1948, pages 110 to 113, inc.) In 1949 a report was submitted as information covering Electric Locomotive Terminal Facilities (Proceedings, Vol. 50, 1949, pages 200 to 203, inc.)

Mr. President, inasmuch as the report of Subcommittee 5 has been published in Bulletin 490, it is assumed that sufficient time has elapsed since publication for members to have acquainted themselves with the text. It appears on pages 261 to 272, inclusive. In the interests of brevity, I will refer to the pages, mentioning the headings only.

(Having referred to the headings in order, Mr. Hastings moved that the material submitted, Bulletin 490, pages 261 to 272, inclusive, be adopted as Manual material, in lieu of the present material appearing on pages 14–32 to 14–32.84).

(The motion was regularly seconded, was put to a vote and carried.)

Assignment 7—Design and Typical Layouts of Air Lines in Freight Yards, was presented by Subcommittee Chairman F. A. Hess (New York Central).

Mr. Hess: It is the constant goal of the operating personnel to increase the availability of their locomotives. Costly minutes are spent by locomotives charging air lines in freight yards.

Committee 14 felt that a report on Design and Typical Layouts for Air Lines in Freight Yards would be of considerable value, and a subcommittee was appointed to prepare such a report. The report resulting appears on pages 273–277, inclusive, of Bulletin 490.

The construction of air lines in freight yards permits the charging and testing of the air brake systems of trains prior to coupling on the engine. This means a saving in locomotive time, from a few minutes to an hour or more.

The lines should be designed to provide an adequate amount of air at specified pressures.

The air connections should be located to require the minimum amount of travel on the part of those inspecting the air brakes, and minimum charging time.

This is a final report, submitted as information.

Assignment 8—Design of the Track Layout and Gradients in Connection with Scales Located on the Hump of a Classification Yard, was presented by Subcommittee Chairman W. H. Goold (New York Central).

Mr. Goold: A previous report on this assignment appears in the Proceedings, Vol. 51, 1950, page 190, and refers to the assignment in its entirety. This year's report presents further information pertaining to gradients, and any restatement of what has been reported previously is limited to what falls within that scope.

Motion weighing is the only kind of weighing that would be attempted on the hump of a classification yard, and the problem resulting is related to one of the following three categories:

1. The car-rider yard.
2. Retarder yard without retarder above the scale.
3. Retarder yard with retarder above the scale.

A profile of an existing yard of each type is included in this report; also included is a list of conditions to be given consideration, and a method of investigating the gradient.

This is a final report, presented as information.

President Loeffler: Thank you, Mr. Goold. Are there any comments with respect to this report? This report will be received as information, to supplement a previous report which has been published in Proceedings, Vol. 51, 1950, page 190.

Assignment 9—Factors to be Considered in Determining the Location of a Track Scale in a Yard, was presented by Subcommittee Chairman H. T. Roebuck (Baltimore & Ohio).

Mr. Roebuck: This committee presents a final report, which is published on pages 281–282, inc., Bulletin 490, dated November 1950. The report enumerates 13 factors which should be considered in determining the location of a track scale. Eleven locations are also indicated where consideration may be given to the installation of a track scale.

The presence of a scale in a much-used track results in increased costs of maintaining the scale and makes inspection and testing difficult. The installation in such a track should be avoided, except in special cases where such location can be justified.

The scale track in the vicinity of the scale should be set above the elevation of adjacent tracks so that it will not be lower than the other tracks if these tracks are raised during ordinary maintenance operations.

Chairman Giles: You have heard the report of Committee 14. We would like to have those of you who are interested in yards and terminals read this report, if you haven't already done so—particularly those interested in yard and terminal planning.

Mr. Loeffler, that concludes the report of Committee 14.

President Loeffler: This is one of the Association's most important committees, and also one of its largest, having 53 members at the present time. Considering the fact that yards and terminals include the major portion of any railroads, with the exception of railroad properties between stations, it is evident that the work of this committee is of great significance to the railroads.

The location and arrangement of railroad yards and terminals, and the type and arrangement of all miscellaneous facilities therein, required for economic operation of such yards and terminals, constitute subjects that require most careful planning, not only with respect to accommodating existing railway traffic, but also to permit convenient expansion of these yards and terminals to accommodate future anticipated traffic.

Mr. Giles, you and your committee have this subject well under control, and have presented some very valuable and comprehensive reports, for which we are very appreciative. Your committee is excused.

Discussion on Contract Forms

(For Report, see pp. 283–284.)

(President H. S. Loeffler presiding.)

Chairman L. A. Olson (C. & O.): Your committee on Contract Forms had five subjects assigned to study, and has presented reports on two of them. These reports appear in Bulletin 490, starting on page 159.

The first report, on Assignment 1—Revision of Manual, will be presented by Mr. Swatosh of the Erie.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman W. R. Swatosh (Erie).

Mr. Swatosh: The report on Assignment 1—Revision of Manual, appears in Bulletin 490, pages 283 and 284. I will read the recommendations of the subcommittee as they are listed, and ask for a vote on each item as we go along.

(Mr. Swatosh read each recommendation of his subcommittee as printed in Bulletin 490, submitting each recommendation, in turn, to a vote of the convention. Each recommendation was regularly seconded, was put to a vote and carried.)

Chairman Olson: The next report of the committee is on Assignment 2—Form of Agreement for Division of Work, Maintenance and Operation of Flood Protection Projects. In the absence of Mr. Kirkpatrick, who was unable to attend, Mr. Patterson, assistant to the chief engineer of the Pennsylvania, will make this report.

Assignment 2—Form of Agreement for Division of Work, Maintenance and Operation of Flood Protection Projects, was presented by G. W. Patterson (Pennsylvania).

Mr. Patterson: Last year your committee presented as information a tentative draft for Form of Agreement for Division of Work, Maintenance and Operation of Flood Protection Projects (Proceedings, Vol. 51, 1950, pages 169–173), and requested comments and criticism thereon. This form of agreement, with only minor revisions, is now submitted for adoption and publication in the Manual. Mr. President, I so move.

(The motion was regularly seconded, was put to a vote and carried.)

Chairman Olson: Reports on our other assignments will not be given at this time. This concludes the report of your Committee on Contract Forms. I would, however, like to call your special attention to one of our new assignments for the coming year. This assignment will cover insurance provisions recommended for various forms of agreements. This subject is becoming more and more important, due to the tremendously large awards which are being handed out by the courts, particularly when a large corporation is the defendant. Many of you have undoubtedly been confronted on many occasions, when writing agreements, with the question of just what kind and amount of insurance coverage should be specified.

It is our intention to present a complete resumé of the various types of insurance which are available, and the particular purpose each will serve to provide the desired protection on construction contracts. The following types of insurance will be covered: Workmen's compensation, employer's liability, public liability, property damage, contractual liability, owner's protective, fire insurance, comprehensive coverage on certain of the above policies to cover acts of vandalism, windstorm, etc.; and performance bonds. There may be a few others that we will pick up as we go along.

The committee would greatly appreciate any suggestions which might be offered by members of the Association with regard to any phase of this subject which will enable us to submit a better and more enlightened report. Clarence Young, assistant engineer, Baltimore & Ohio, Baltimore, 1, Md., will be the subcommittee chairman. Any questions or suggestions you may have regarding the proposed assignment should be sent to Mr. Young, or to Mr. Olson, the chairman of Committee 20.

President Loeffler: The availability of standard forms covering various types of contracts is a matter of great importance to the railroads, not only from the standpoint of saving in time and preparation of specific contracts, but also from the standpoint of having assurance that such contracts are correctly worded and complete in every detail. Committee 20 maintains information on standard contract forms up to date currently.

Mr. Olson, your committee is excused with the appreciation of the Association.

Discussion on Records and Accounts

(For Report, see pp. 409–424.)

(President H. S. Loeffler presiding.)

Chairman Louis Wolf (Missouri Pacific): The report of Committee 11—Records and Accounts, will be found in Bulletin 492, pages 409–424, inclusive.

Assignment 1—Revision of Manual, was presented by J. N. Smeaton (Canadian National).

Mr. Smeaton: This is a progress report, submitted as information. Your committee makes no recommendations for revision of the Manual this year. It is engaged in a general review of the entire subject-matter of the committee's chapter of the Manual, and has under way a proposed rearrangement of text and form. It is also working out recommendations to bring the material up to date, supplying an index, and making the chapter more readable and useable as a reference.

Assignment 2—Bibliography on Subjects Pertaining to Records and Accounts, was presented by Subcommittee Chairman A. H. Meyers (Texas & Pacific).

Mr. Meyers: Our report is found in Bulletin 492, January 1951, pages 410–415, inclusive.

The committee presents a bibliography of subjects pertaining to railroad records and accounts for the period November 1949 to September 1950, consisting of 90 articles considered worthy of note by your committee.

This report is submitted as information.

Assignment 3—Office and Drafting Practices, was presented by Subcommittee Chairman W. M. Ludolph (Milwaukee Road).

Mr. Ludolph: This is a progress report, found on pages 415–417 of Bulletin 492, which is submitted for your information. It describes a number of machines, methods and materials which have been developed, more or less recently, to speed up or improve office and drafting room work. These are as follows:

Calculator for string lining curves.
Photo-copy machine.
Reflex printing.

Direct process print papers and films.
Machines for exposing sensitized material.
Duplicating machine.

The Photo-copy machine mentioned has undergone considerable development since the information for this report was obtained, in that its operation has been simplified, and it can also be used very efficiently for microfilming documents.

Assignment 4—Use of Statistics in Railway Engineering, was presented by Subcommittee Chairman J. L. Willcox (Atlantic Coast Line).

Mr. Willcox: The report of the subcommittee on Assignment 4 appears on page 417, Bulletin 492. It is a progress report, and is presented as information.

Your committee intends to continue this subject in the coming year under its new subcommittee chairman, W. M. Hager, of the Southern.

Assignment 5—Construction Reports and Property Records; Their Relation to Current Problems, was presented by B. H. Moore (Association of American Railroads).

Mr. Moore: During the year your subcommittee studied the question of the quality of paper used by railroads for property records.

With the advent of new laws and regulations, the question of property records assumes even greater importance than heretofore. The varied uses now being made of these records makes it imperative that the quality of paper be given greater consideration by those responsible for the preparation of property records. Most railroad property lasts a long time, and we should be conscious of the fact that we are not making records for ourselves, but for our successors.

In order to make the most of the records we inherited from our predecessors, we now have the benefit of plastic sprays that at least will preserve indefinitely valuable documents and records at their present age.

The report is submitted as information.

Assignment 6 (a)—Current Developments in Connection with Regulatory Bodies and Courts, was presented by Subcommittee Chairman H. T. Bradley (Missouri Pacific).

Mr. Bradley: The only item in the report of this subcommittee which requires any additional statement is that relating to so-called elements of value as of January 1, 1950, which were being prepared by the Bureau of Valuation, Interstate Commerce Commission, at the time the report was made. These elements of value, which relate to Class I Line-Haul Railways in the United States, have since been completed and were introducd in Ex Parte 175 as Exhibit 15. This document of 24 pages, which includes an explanation of methods used in its preparation, may be obtained from G. S. Douglass, director, Bureau of Valuation, Interstate Commerce Commission, Washington, D. C.

This report is submitted as information only.

Chairman Wolf: With respect to this assignment, I wish to add that for some years the committee has recognized and discussed the need for a history of Federal valuation, and the results and uses made of it in railroad work, for incorporation in the Manual or in a committee report. This subject was again discussed and reviewed at a meeting of the committee on June 14–15, 1950, and a motion was adopted to appoint a small subcommittee to write a History of Federal Valuation and Its Current Engineering and Accounting Uses for Carrier Purposes. The committee consists of Messrs. J. H. Roach, chairman; F. B. Baldwin, H. T. Bradley, and B. H. Moore. The subject-matter is being assembled, and the subcommittee reports progress.

Assignment 7—Revisions and Interpretations of ICC Accounting Classifications, was presented by Subcommittee Chairman H. N. Halper (Erie).

Mr. Halper: The subcommittee's report this year contains one order issued by the Interstate Commerce Commission, which is of interest to engineers. The order changes the name of Account 26 from "Telegraph and Telephone Lines" to "Communication Systems," and enlarges the account by the inclusion of various radio installations and equipment.

The commission has under consideration various other changes in the Classification of Accounts. If and when issued, it will be reported by this subcommittee.

The report is submitted for your information.

Chairman Wolf: This completes the report of Committee 11. The remainder of our convention time will be given over to an address.

As the complexities of the Internal Revenue Code are untangling themselves, those of us who make property changes, or who keep property records, find ourselves enmeshed in new and perplexing problems.

The question of obsolescence is one of these problems and, to have the expert advice of one who has delved deeply, the committee asked J. B. Akers, chief engineer of the Southern, to address the convention on the subject of Obsolescence in the Dieselization Program.

Mr. Akers is a past president of this Association, and needs no formal introduction. It is with pleasure that I present him to you.

Obsolescence in the Dieselization Program

By J. B. Akers

Chief Engineer, Southern Railway System

Dieselization of the American railroads has grown by leaps and bounds during the last ten years, and with exceptional rapidity in the last four or five years. The program has affected all departments of the railroad in some way. The effect of diesel operation on the fixed properties was discussed in a paper presented at the AREA meeting of March 1949—our fiftieth anniversary. The paper appears on pages 915 to 919, inclusive, of Volume 50 of our Proceedings.

At that time, we attempted to show the effect on the track, on bridge structures, and in the planning and construction of facilities for the servicing of diesels. Changes have occurred even in the past two years, and our various committees are continually investigating and appraising the effect on the fixed properties. It is well to call attention again to the fact that, as stated before, the relative effect of diesel and steam locomotives on track and bridges is pronounced and is clearly in our favor as long as the weight and distribution thereof are approximately as at present. In other words, we must keep in mind that the figures used are based on present designs.

A number of railroads are now completely dieselized in all train operations. Most of the railroads that are 100 percent dieselized are short-line railroads. But there are many larger railroads that are well along in their programs toward 100 percent dieselization. Dieselization will continue at a rapid rate for some years because of the improved operating conditions and the economies that result.

Changeover to Diesels Has Far-reaching Effect

The changeover from steam to diesel power is far-reaching and truly revolutionary in its effect. The railroads were fully equipped with steam locomotives and all the necessary servicing facilities, such as roundhouses, machine shops, boiler shops, blacksmith shops, and fuel and water stations. Passing tracks and yards were of a length suited to operation with steam power. Then there comes a changeover to diesel power in the course of a very few years. Suddenly the greater portion of existing shop facilities and wayside facilities become obsolete—not suited at all to diesel operation. New shop facilities suited to diesel maintenance and overhaul must be built, and we must quickly provide fueling stations to issue diesel oil and lubricating oil, and construct longer passing tracks and longer yard tracks.

Shop facilities in a location which was suited to steam operation may be found entirely unsuited to diesel operation. Shops and other facilities must be abandoned and new facilities constructed. The facilities abandoned are obsolete and altogether useless as far as shop facilities are concerned. Every railroad has an enormous investment in such facilities, which would be worthless, or nearly so. Land and buildings may be sold to some revenue-producing industry, but this will recover only a moderate percentage of the loss. Railroad-type buildings are often unsuited to other business.

The railroads have applied depreciation accruals on roadway property as a deduction from income for the past eight or nine years, but very substantial sums of invested capital still remain to be recovered when these obsolete facilities are finally and completely withdrawn from service.

The facilities thus made obsolete through the substitution of diesel power for steam on the Southern Railway System have a value approximating 50 million dollars. We will have to wipe out this investment, and at the same time make another investment of a very substantial sum to provide the needed facilities for diesels. The financial impact is tremendous. We must find a means to recoup as much as possible of the original investment by whatever means are allowed.

The Bureau of Internal Revenue has recognized these conditions. Their Bulletin F, page 3, of January 1942, provides for obsolescence in a program of abandonment. Briefly, it is a method by which properties to be abandoned can be listed for amortization. The list must describe each unit of property with historical information, arriving at a remainder which is the amount to be amortized over a term of years. The program must be approved by the Bureau of Internal Revenue. Proportionate amounts to be so amortized become a charge to operating expenses each year. The recovery is through reduction of taxes by reason of the increased charges to operating expenses on this account.

The members of Committee 11 are familiar with the studies necessary for the development of depreciation bases with their numerous classifications, and of service lives of the various elements which go to make up the depreciation base. They understand this subject well and know that the amounts so determined for annual depreciation may sometimes be inadequate to permit a complete return of the capital sum to be recovered. This subject is not so well understood by others of us.

The development of a program of obsolescence becomes a duty of the engineering department through its valuation section, and the accounting department. Lists are first prepared by line-of-road officers. Each listed item must be worked out so as to show its location, description, when built, AFE, value, salvage, depreciation already taken, and last, the value to be amortized. After its preparation, the program will be in the hands of the accounting and law departments with such advice and help as the engineering

Program No.
Sheet ______ of ______
File ______
Division ______

SOUTHERN RAILWAY SYSTEM

REPORT OF PROPERTY SUBJECT TO EXTRAORDINARY OBSOLESCENCE

CARRIER: ______________________________

	Amort. Period	Effective Year	I.C.C. Acct.	Val Sect.	Location	Struct. No.	Description	Built	A.F.E.	C.R.	Value		Allowable Engineering	Total Value	Gross Salvage		B.I.R. Depreciation		Value to be Amortized
											Fed. Inv.	V.O. 3					Past	Current	

RECOMMENDED:

____
General Manager.

APPROVED:

____

CERTIFICATION:
I. J. B. Akers, Chief Engineer of the Southern Railway System, Certify That This Statement is Based on Informed Opinion as to the Present Conditions and Future Developments, and Accurately Presents the Facts Contributing to Extraordinary Obsolescence.

____
Chief Engineer.

department may then supply. The report form used by the Southern is shown on the insert.

Extraordinary Obsolescence Explained

Bulletin F, page 3, is quite clear; under it the taxpayer (the railroad in this case) applies for permission for accelerated amortization of the unrecovered value of assets found to be subject to "Extraordinary Obsolescence."

"Extraordinary Obsolescence" is something that can be anticipated. It is applicable to assets made obsolete by the changeover from steam to diesel power. A time is reached when it can be definitely predicted that the use of assets, such as shop buildings, and coal and water facilities, will be discontinued at a certain future time. It is important that "Extraordinary Obsolescence" be detected as far in advance as possible.

In a dieselization program we know that obsolescence is coming. We must determine, and prove, the date on which it begins and estimate the date on which it is to become complete. Sometimes there is a policy adopted by management, and a statement made which will prove these dates.

It is well to recognize the two types of claims for losses due to abandonment of assets prior to the end of normal life. The normal or useful life is that term during which physical exhaustion takes place through wear and tear.

Expressed simply:

> "Extraordinary Obsolescence" is predictable and should be amortized.
> "Loss of Useful Value" is not predictable, loss on unrecovered value to be taken in year of retirement.

"Extraordinary Obsolescence" usually occurs because of an improvement in the art, change in economic conditions, or a great change in methods of operation. When diesel power is substituted for steam power, the steam power and related facilities are subject to "Extraordinary Obsolescence." A spur track or branch line of railroad may be a subject for "Extraordinary Obsolescence" if it was constructed to serve an industry of known length of operation. It follows some unusually significant change in operation, such as the change from steam to diesel power. The taxpayer is required to anticipate the retirement and to spread the unrecovered cost over the remaining years of usefulness of the asset.

The program as it relates to diesel operation will anticipate the extent to which the program is to be carried. There will be no obsolescence where both steam and diesel road power are operated, nor will full operating economy result, since facilities and labor force must be available for service and repair of both types of power. Each railroad will determine how it will proceed, but we might review the method which seems to obtain on most lines. The method of changeover will determine the extent of coverage of property for obsolescence, and it will be the purpose to make it as complete as possible.

Usual Method of Conversion to Diesels Described

In its early stage, changeover from steam to diesel is applied first to long passenger runs, and next to long freight runs. As the number of diesels increases we find that the next step is dieselization by territories or areas. The economics are not fully realized as long as both steam and diesel power are maintained in an area. It often cocurs that a comparatively few diesels replacing steam power in an area will permit the abandonment and complete removal of some existing shops, enginehouses, and fuel and water stations. Such areas are chosen, having in mind the distance from main shops, haul on coal, and whether or not the area is likely to be traversed by steam locomotives enroute to some other division which may still be steam operated.

It has been considered good practice under steam operation to have the main shops of a system at one or more central points. The road diesel is a system-wide engine, and capable of long runs requiring no coal and little water. The requirement for central shops may be entirely different than what it was for steam power. A careful study must then be made to determine where shop facilities should be located, and where to place servicing facilities. Some shops will probably be wiped out entirely. We have found that true in our dieselization program and have completely abandoned the locomotive and machine shops at several locations, and others will follow. Wayside water stations and coaling stations have been removed on a considerable mileage.

As the larger railroads approach full dieselization, there will usually be found a surplus of locomotive shop space. Indications are that the floor area required for diesel power will be much less than was required for steam. For instance, boiler shops, foundries, and tender shops do not have a place in the diesel program. Space in erecting shops will be in surplus. The machines required for diesel maintenances are different from those which are required for steam. In all of these categories, there will be large values in buildings, machinery and tracks that will find their way into the program of "Extraordinary Obsolescence."

The facilities required for fueling and servicing are entirely different. Steam power will require either coal or oil for fuel, water, sand, provision for cleaning fires and disposing of cinders. The diesel requires a different kind of oil and moderate amounts of water. If both steam and diesel power are in use we must, of course, have facilities for the servicing of both types. The economy of the changeover is not complete as long as all of these varied facilities are maintained. It will surely be the policy to remove the facilities for steam power as early as that can be done for reasons of economy. But this temporary arrangement of dual operation does not remove the obsolescence blight from the steam facilities. They will eventually go. But for reasons of economy, and problems of finance and supply, we are compelled to operate these obsolete facilities.

Problem Not Easy, But Subject to a Best Solution

The working out of a dieselization program is not a simple matter, but at the same time is subject to careful analysis and planning. Full dieselization is not realized all at once because the great cost of the equipment must be spread over several years. It is to be expected, therefore, that some lines will be maintained for several years with provision for the operation of both steam and diesel power. Progress toward full dieselization has been very much of a problem on the Southern. We have several lines now fully dieselized, and have removed the obsolete equipment and buildings, including wayside fuel and water stations. When fully dieselized, additional power must be made available should business increase on the line or in the area. This will be done by drawing diesel power from other lines which have both types of power operating. In other words, there must be a reservoir of diesel power, or what we might call an "expansion tank," from which diesel power may be drawn. On such lines steam power will be restored to service to replace diesels transferred. This will be done as requirements and business conditions dictate. On the Southern System the lines from Washington to Atlanta and from Cincinnati to Chattanooga will act as "reservoirs of diesels" in this manner. In these times of heavier business because of the prospect of war, there will be a wider use of steam power than was thought would be the case a couple of years ago. Such an arrangement must remain in effect until there is sufficient diesel power to meet any contingencies that may arise.

A workable plan to meet all contingencies can be reached only through exhaustive study and analysis of conditions, present and future. The plan finally adopted must provide for the continuance of properly located shop facilities for the repair and servicing of steam power where it will continue in service, and new facilities for diesels in the territory they will serve. With 100 percent dieselization the shops and enginehouses are fewer, and more compact. They are cleaner and usually better, and must be for precision motive power of great value. Some of the smaller railroads send the entire diesel locomotive back to the builder for general over-haul, or for heavy repairs after accidents. This is a practice which may grow if the builder has a plant not too distant.

The opportunity afforded under Bulletin F is a real one. Through it, the railways will have permission to use a substantial credit, which is of prime importance when depreciable property is being considered. When buildings are removed, their values will necessarily have to be deducted from the depreciation base, and there would be no more of what we term "Ordinary Depreciation" year by year. Bulletin F gives us an opportunity to include all such fixed property under a program, get it approved, and make claim for the remainder of its undepreciated value.

Chairman Wolf: Thank you, Mr. Akers. That was an excellent address and, no doubt, was greatly appreciated by everyone here. It was particularly interesting and informative to those of us who come in contact with the Bureau of Internal Revenue. All members of Committee 11 are very grateful to you for making this address for us.

That concludes our report, Mr. President.

Mr. Edwin F. Wendt (Consulting Engineer): Mr. President, I'd like to have three minutes—five, if you like—of your time.

President Loeffler: This is Mr. Wendt, one of our past presidents.

Mr. Wendt: We have just heard from an engineer who is chief engineer for a great railway system. He finds the work of this committee absolutely necessary.

I congratulate this committee for the work it has done in the last 50 years, and the fact that it has so many members—about 54 as I count the number—indicates the interest there is in this subject.

I say to you, Mr. President—and to the next president, as well as to the secretary—that there is an opportunity here to expand the work of this committee.

Chairman Wolf: Thank you, Mr. Wendt. We appreciate those kind words very, very much.

President Loeffler: That was Edwin Frederick Wendt, who was president during the years 1913–1914. Mr. Wendt was born May 12, 1869, at New Britain, Conn., and was educated at Geneva College, Pa. He was with the Pittsburgh & Lake Erie for 25 years, and was subsequently a member of the Engineering Bureau of Valuation, Interstate Commerce Commission.

The Committee on Records and Accounts for many years has performed an important function in keeping the Association currently informed on the subjects of accounting, valuation, depreciation and related matters. We greatly appreciate Mr. Akers' excellent talk on a special phase of depreciation problems. The matter of depreciation, particularly as affected by extraordinary or accelerated obsolescence, is very important today in its relation to taxes, and is a matter of much concern to the railroads.

With your permission, Mr. Wolf, I would like to hold your committee on the platform while I make an announcement.

(President Loeffler then read the names of those whom he had appointed as tellers to canvass the ballots cast for the officers of the Association for the ensuing year. For the names of the tellers, see the Teller's report, page 708.)

President Loeffler: Mr. Wolf, your committee is excused with the thanks of the Association.

The meeting will now stand recessed, and will reconvene tomorrow morning at 9 a.m. in the Red Lacquer Room.

(The meeting adjourned at 5:10 p.m.)

Discussion on Economics of Railway Location and Operation

(For Report, see pp. 203–212.)

(President H. S. Loeffler presiding.)

Chairman C. H. Blackman (Louisville & Nashville): Mr. President, Committee 16 lost four members by death last year.

On page 204 of Bulletin 490 appears a memoir to B. J. Schwendt, assistant signal engineer, New York Central System, Big Four District, who died on May 9, 1950.

On November 8, 1950, B. T. Anderson, transportation research director, Union Switch & Signal Company, who had been an unusually valuable member of Committees 21 and 16 since 1926, was lost to our membership.

On November 24, 1950, we lost Fred Lavis, who was an active and much loved member of Committee 16 for 41 years—1910 to 1950, inclusive.

Memoirs to Messrs. Anderson and Lavis are presented with the request that they be published in the Proceedings.

In December we also lost J. F. Swenson, who had just previously resigned from our committee because ill health prevented his taking the active part that he felt should be taken by a conscientious member. With your approval, we will also present a memoir to Mr. Swenson.

President Loeffler: Your request is approved.

B. T. Anderson

Died November 8, 1950

Burt T. Anderson, transportation research director of the Union Switch & Signal Company, Swissvale, Pa., died at Pittsburgh on November 8, 1950. He is survived by his widow, Tirzah Bradley Anderson, whom he married on July 2, 1910.

Mr. Anderson was born on October 31, 1884, at Alexis, Ill., attended the public schools of that community and of Galesburg, Ill., and graduated from the University of Illinois in 1907 with the degree of Bachelor of Science in Electrical Engineering. He immediately entered the signal apprenticeship course offered by the Union Switch & Signal Company. This three-year program was divided between the Swissvale plant and the installation of automatic signals and related work on the Lake Shore & Michigan Southern, now part of the New York Central, the Hudson & Manhattan, and the Pennsylvania Railroad's terminal extension to Manhattan Island and Long Island City.

Upon completion of this course, Mr. Anderson became associated with the Atchison, Topeka & Santa Fe on June 1, 1910, as a draftsman at Topeka, Kans., but was promoted, on October 1 of that year to signal construction foreman at Barstow, Calif. In March 1913, he was advanced to assistant signal engineer and served in that capacity until June 1914, when he resigned to accept a similar position with the Delaware, Lackawanna & Western.

After holding this post for nine years, Mr. Anderson left on June 1, 1923, to become superintendent of signals of the Chesapeake & Ohio, with headquarters at Richmond, Va., and remained there until September 1, 1927, when he returned to the Union Switch & Signal Company as assistant to the vice president. His association with this, his first employer, continued unbroken until his death, and his career with it was marked by several important promotions. The first came in 1929 when Mr. Anderson was appointed assistant to the president. From August 1934 until the end of 1937 he was director of the Bureau of Railway Signaling Economics, which jointly represented the Union and the General Railway Signal companies in this special field of research. In January 1937 he was advanced to general sales manager, and became transportation research director on July 1, 1940. He occupied this latter position until his death.

Mr. Anderson was long an active member of the Signal Section, Association of American Railroads, and its predecessor, the Railway Signal Association, having first joined it on March 28, 1911. He was continuously identified with one or more of its standing committees from 1912 until the time of his death, and frequently served as chairman or vice chairman of these important working groups.

Mr. Anderson became actively identified with the American Railway Engineering Association in 1923. His committee memberships in this organization were as follows: Committee 10—Signals and Interlocking, 1925–28, 1936–37, vice chairman in 1927; Committee 16—Economics of Railway Location and Operation (or one of its predecessor components), 1926–50; and the Special Committee on Clearances, 1928.

He was also an associate member of the AIEE; a member of the Institute of Signal Engineers, London; American Association of Railroad Superintendents; and of various railroad and social clubs.

Mr. Anderson's associates on Committee 16 held him in high esteem as an industrious fellow member, a loyal friend, a good citizen and an able railroader. His good company, wise counsel, superior work and fine qualities of mind, personality and character will be greatly missed.

Fred Lavis

Died November 24, 1950

Fred Lavis, retired consulting engineer and railroad and highway authority, was born in Torquay, Devon, England, January 8, 1871. He came to the United States in 1887, became a naturalized citizen in 1904 and, after attending St. Luke's College, began his career as a rodman in the office of a Boston surveyor. Subsequently he was employed by the Boston & Maine, the Old Dominion, the New Haven, and the Pennsylvania.

In 1909 Mr. Lavis entered private practice with office in New York City, since which time his professional career has been quite colorful. He specialized in transportation embracing railway, highway, marine investigations, reports, finance, economics, surveys and construction in the United States and in foreign lands. Over a period of 40 years the professional engagements of Mr. Lavis were about equally divided between home and abroad; some of these were:

United States.—Examination of and cost estimates for railway lines in Nevada, California, Oregon, New York, Tennessee and North Carolina; examination of physical condition of the Hudson and Manhattan, including the Hudson Terminal Building in New York City, and the Interborough Rapid Transit Company.

Studies, surveys and construction work for the New Jersey State Highway Commission in Jersey City, Newark and Elizabeth, N. J.; valuation of railway property for the city of Buffalo, and the town of Ontario, N. Y.; valuation for tax purposes of the property of the Interborough Rapid Transit Company in New York City, and investigation of alleged super-adequacy of passenger terminal stations of the New York Central and Delaware, Lackawanna & Western in Buffalo, N. Y.

Foreign Services.—Examination and proposed extension of railway lines in Gautemala, Argentina, Spain, Mexico, Central America, Republic of Santo Domingo, El Salvador, El Paraguay and Venezuela.

These projects, at home and abroad, involved 10,000 miles of railroad and other land transportation developments, and cost estimates and property values in excess of 350 million dollars.

Mr. Lavis was president of the International Railway of Central America, 1928–1931, continuing as consulting engineer for that company in 1932. In 1938–1941 he was consulting engineer for the Ministry of Public Works of Venezuela and studied general land transportation by both railways and highways for that country.

Mr. Lavis became a member of the American Society of Civil Engineers in 1906. He was a member of the Highway Research Board, the Institute of Civil Engineers of Great Britain, the American Institute of Consulting Engineers, the New York Society of Terminal Engineers, and the Association of American and Chinese Engineers.

He became a member of the American Railway Engineering Association in 1908 and a member of Committee 16—Economics of Railway Location, in 1910; he was also a member of Committee 9—Highways, from 1935 to 1944; his broad experience in the transportation field was helpful in the deliberations of the committee on railway location problems and on the economics of railway operation subsequent to the consolidation of Committee 21 with Committee 16.

Mr. Lavis was respected by AREA members and all who came in contact with him, and his sound advice will be greatly missed. Surviving are a son, Fred Lavis, Jr., of Phoenix, Ariz., and three granddaughters.

John Frithjof Swenson

Died February 4, 1951

John F. Swenson was born July 25, 1888, at Irwin, Pa., and was graduated from Pennsylvania State College in 1911 with the Degree of Bachelor of Science in Civil Engineering.

His career in the maintenance of way department of the Pennsylvania Railroad began on October 25, 1911, and continued for the remainder of his busy and useful life. Mr. Swenson first served as rodman from 1911 to 1916, then as transitman, 1916–1917, and later as assistant supervisor of track, 1917 to 1922. He was promoted to supervisor in 1922 and to division engineer on November 10, 1928. Mr. Swenson continued to serve in the latter capacity for the next 16 years, with successive transfers following to divisions of increased responsibility. He was division engineer of the New York division on December 1, 1944, when assigned to serve in that capacity in the office of the chief engineer maintenance of way at Chicago.

Illness confined Mr. Swenson to his home for more than a year prior to his death on February 4, 1951. He is survived by his widow, Mrs. Irene Spicer Swenson of Chicago.

Mr. Swenson had been a member of the Maintenance of Way Club of Chicago, and of the American Railway Engineering Association, and actively participated in the work of the latter's Committee 16—Economics of Railway Location and Operation—during the last year of his railway career.

Chairman C. H. Blackman (Louisville & Nashville): The report of Committee 16 is in Bulletin 490, the first item in the Bulletin. This year we are prepared to report on only two assignments. The first is Assignment 1, which, like the poor, is always with us—Revision of the Manual. The other subject is Assignment 4, Higher Speed.

(Chairman Blackman then called upon, in turn, the two subcommittee chairmen handling these assignments, to present their reports.)

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman E. G. Allen (Santa Fe).

Mr. Allen: In this year's progress report on Assignment 1—Revision of the Manual, Committee 16 is recommending several new revisions to supplement those previously recommended and adopted at the 1950 convention. Last year's recommendations were published in Volume 51 of the Proceedings, beginning with page 88. A full description of the new recommendations was published last November on pages 205 and 206 of AREA Bulletin 490. Credit for the completion of part of the recommendations belongs to H. D. Walker of the Illinois Central, who personally handled the work of revising the material under Train Resistance, which relates to Adjusted Tonnage Rating, on page 16–7 of the Manual.

In answer to possible inquiries from those who may be interested in further revision of other material in this committee's section of the Manual, we would advise that work is still being continued on five other proposed revisions, not yet completed, which had to be divided among five smaller subcommittees under separate chairmen because of the specialized nature of some of that material or because of the amount of time and effort required for revising it in collaboration with other standing committees. Those uncompleted assignments, in the same order in which their subjects appear in the Manual, include: first, the material on page 16–4 relating to Curve Resistance, and its effect on the cost of railway maintenance and operation; second, the chapter on power, pages 16–11 to 16–38.1; third, the tables on page 16–47, indicating the service life of different weights of rail in tangent track and on curves; fourth, paragraphs 1 to 5 on pages 16–71, regarding the effect of through routing of solid trains upon the capacities of terminals; and fifth, the chapter dealing with the Yager Formula, on pages 16–79 to 16–84, inclusive.

If there are no questions regarding the new recommendations in this year's report, as described on pages 205 and 206 of Bulletin 490, I move that they be adopted for revision of the Manual.

President Loeffler: Do we hear a second to that motion?

(The motion was regularly seconded.)

President Loeffler: You have heard the motion. Is there any discussion? As I understand it, Mr. Allen, you are recommending only the matter that is printed on pages 205 and 206 of Bulletin 490, and you are not including the information presented verbally, which is not printed under the report.

Mr. Allen: That is correct.

(The motion was put to a vote, and carried.)

Chairman Blackman: Mr. President, we have no report this year on Assignments 2 and 3. Assignment 4—Effect of Higher Speed on Railway Revenues, Operating Expenses, and Charges to Capital Account, was to be presented by our subcommittee chairman, J. A. Schoch, but he is ill and not able to be with us today. I have asked D. E. Brunn, assistant engineer of the Toledo, Peoria & Western, to present this report.

Mr. Brunn comes from the railroad where the Honorary Member we elected today—J. E. Armstrong—got his start, and also where the new chairman of Committee 16, J. W. Barriger, served for a time.

Assignment 4—Effect of Higher Speed on Railway Revenues, Operating Expenses, and Charges to Capital Account, was presented by D. E. Brunn (Toledo, Peoria & Western).

Mr. Brunn: Under the direction of our subcommittee chairman, Mr. Schoch, we have prepared a report on this subject, as published in Bulletin 490, page 206. However, since this subject requires considerable additional research in order that, when entirely completed, it will be fully authoritative, it is submitted only as information at this time.

Chairman Blackman: Subcommittee 5, of which F. C. Berghaus, operating vice president of the Monon, is chairman, has a very important assignment—Comparison of Running Time with Total Time Between Points of Receipt and Delivery of Freight Cars, and Methods of Reducing Total Time.

This subcommittee is working hard on this subject, and I look for them to come up with some very worthwhile information and advice to the Association, but they are not yet ready to report. In the meantime, one of the hard-working and valuable members of the subcommittee, Dr. Louis K. Sillcox, executive vice president of the New York Air Brake Company, will present a few observations on the subject, "Terminals and Trains." Dr. Sillcox.

Terminals and Trains

By L. K. Sillcox

Executive Vice President, The New York Air Brake Company

No single element enters into present-day freight transportation so insistently, so predominantly, and without vacillation, as time. Time is the ingredient that specifies the amount of investment in, and, therefore, fixed charges on equipment and facilities necessary to handle a given business, since if cars move faster, the size of those facilities may decrease proportionately. In other words, it acts in the sense of an inventory turnover factor.

Anything standing still, whether it be locomotives, cars, or shipments, represents dead time. Shipments standing still represent poor service to the shippers. Cars standing still represent an excessive inventory in rolling stock. Locomotives standing still can only mean excessive investment in motive power to handle a given traffic volume. Therefore, when we address ourselves to "Terminals and Trains" we must instinctively address ourselves to time rather than to tonnage.

The railways are locked in mortal combat with competitive transport agencies, primarily in the case of freight traffic with the highway haulers, and major efforts must necessarily be directed toward the elimination of any avoidable time-consuming facility or practice, however revered it has come to be by usage throughout the years. Let us then during the brief time available examine our freight terminal facilities, their plans of operation, and their execution, with that viewpoint uppermost.

Proper Yard Layout Important

It is unnecessary to dwell on the matter of proper yard layout, but in passing we are reminded that receiving tracks should be long enough to receive incoming trains without breaking up, and sufficient in number to accommodate train density; that classification tracks should be long enough to avoid the necessity of "doubling over" cars of the same classification when making up trains; that departure tracks should be of sufficient length to accommodate departing trains and numerous enough to avoid congestion in classification yards; and that complete facilities should be provided to enable the inspection and servicing of through trains without delay to them, or interference with other yard operations. The judicious locating of auxiliary yard offices can be beneficial in the reduction of unavoidable time-consuming elements, such as crews walking from cabooses to yard office, as well as the discharging of yard clerks' assignments. Relative to the latter, we can soon expect the radio, or other mediums of communication, to be a factor in reducing paper work time, since it will be possible to transmit information required by the yard clerk in his duties prior to train arrival.

Planned classification of cars in blocks at originating terminals can be of immeasurable assistance in expediting set-outs at intermediate terminals, as well as in decreasing switching time at destination. While such classification of cars picked up en route cannot group all cars in units for train destination or for the several points beyond, this intermediate classification can result in the train arriving at destination as composite of several units, each representing a complete train, as it were, for the originating terminal and for each intermediate terminal where pickups were made.

Extended Car Inspection

An intelligently planned and supervised car inspection program can be as beneficial in reducing terminal time as any one element involved in total terminal time. I refer to extended car inspection, wherein it is the practice to give the cars of a through train thorough inspection at origin (if this has not been done prior to loading), and to so card those cars for the information of the inspection forces at intermediate terminals—the card to bear the name of the car inspector, with location and date of inspection for reference should trouble develop which could be attributed to faulty inspection, thus establishing personal responsibility for performance.

This inspection practice entails an initial thorough inspection of all empty cars to assure that they are acceptable for the commodities intended for loading. Running gear, safety appliances, wheels, etc., are checked and necessary corrections made before cars are offered for loading. Irrespective of this careful inspection, reinspection is conducted as each train is being made up, at which time the inspectors check running gear, air brakes, journals, safety appliances, etc., making whatever adjustments or minor repairs are found necessary. At the same time journal boxes are completely serviced by oilers. Then, at intermediate terminals these cars are given only running inspection, while oilers check the running temperature of the journals and the condition of the boxes, adjust the packing and add free oil where necessary. This permits the inspection force to concentrate on cars picked up on line or in interchange en route. The practice ensures against mechanical trouble insofar as efficient inspection can do so, and eliminates repetitive inspection, which consumes time unnecessarily. It is unfortunate that the practice is not more extensive than it is.

I have just referred to oilers carefully inspecting and servicing journals. If done properly, this takes time—more time than required by other yard operations in clearing through trains, with the consequence that it is sometimes not adequately done. However, this is a shortsighted policy, since the inevitable result is a greater incidence of hot boxes suffered between terminals, with consequent train delays while attempting to cool over-warm journals or in setting out cars, not to mention the possibility of train accidents attributable to burnt-off journals.

Train Line Charging Time Can Be Reduced

One of the most time-consuming of yard operations is the preparation of trains for departure. This time not only involves switching operations, but embraces the necessity of charging the air system. Since the modern freight brake has a large storage capacity and a charging characteristic essential to its calibration as a remarkable device for controlling trains of 150 cars or less, it may require as much as 40 min. of continuous charging for a 100-car train, and 75 min. of continuous charging for a 150-car train, before a proper terminal brake test can be performed. There is great opportunity here for time saving through conservation of the air in the car reservoirs, since, basically, the brake cylinder air is all that needs to be dissipated for switching purposes. Fifty percent and more of the charging time can now be eliminated by a device which is undergoing thorough trial in actual service.

At present, car inspection can be performed deliberately without pressure because of the time-consuming factors, such as crew walking to yard office and the time required for paper work, but if the refinements referred to herein are obtained, as illustrated by communicating advance information to accelerate yard clerk assignments, the situation will be reversed and the pressure will then be on the car inspection forces. This will necessitate a revision of inspection practice to avoid trains being delayed while that function is being performed, thereby calling for inbound inspection, with full advantage being taken of underneath inspection facilities to reduce to the minimum time devoted to outbound inspection.

Under the current tempo of accelerated rail transport freight trains are regularly operated at top speeds compatible with equipment and track considerations, often at the expense of lading and equipment damage, with the time thus saved frittered away in terminals. Obviously, this practice is pointless. In this connection, it might be well to install shock recording devices in selected cars to determine quantitatively what these high road speeds are costing in terms of damage to lading and equipment.

Centralize Responsibility for Yard Operations

If a terminal is to be economically operated the proper official should be given full responsibility for all time expended in yard operations. He should be thoroughly impressed with this responsibility, and he should conduct the various details of those operations as if they were on a piecework basis, and then check actual performance against ideal performance. He should be required to submit periodic reports of time distribution, with full explanation of any delays which occur. This report can be the basis for active prosecution of instituted practices, as well as for corrective action when weaknesses in those practices are disclosed. He must have ingenuity to evolve novel innovations, such as has one officer whom I have in mind, who has installed vertical lights on his locomotives in order that he may observe whether they are standing still or moving; or another, who periodically equips his yards locomotives with time-recording instruments which provide a permanent record of time in motion and standing idle throughout a tour of duty. In the final analysis, proper yard administration and operation must be predicated upon a smoothly functioning organization, with proper plant facility, both as to equipment and layout, and the necessary "knowhow" which can be obtained only through experience.

L. F. Loree, in his classic work, "Railroad Freight Transportation", analyzed the various movements which comprise the complete turn-around time of the average car, and, based upon his assumptions, we find that, of the total days per turn-around, 13.1 in 1948, 4.88, or 37.3 percent, comprise the following yard movements:

Movement through intermediate yards	1.42 days
Interchanges between railways	2.17 days
Movement between terminal yard and loading and unloading tracks	1.29 days

These figures are predicated upon the actual average daily car utilization of 47.2 miles which obtained during 1948. Surely if 37.3 percent of total car time, which represents 9 hours per day, is consumed in terminal movements, a real challenge faces the railways to reduce this necessary, although non-revenue, time to the minimum. When this is accomplished, I am confident the competitive position of the railways will be greatly enhanced.

Chairman Blackman: We want to thank Dr. Sillcox for giving us this advice.

The president changed the program a little bit in order to enable Dr. Sillcox to attend a board meeting of his company tomorrow morning in New York. I understand that Dr. Sillcox came here against the advice of his board of directors, and we thank him for it.

Chairman Blackman: And now, Mr. President, I have completed my term of office as chairman of Committee 16. I want to thank you and the Association for the consideration that has been shown me, and I also want to thank the members of Committee 16 for their most loyal support and cooperation.

I want to present to you the new chairman of Committee 16, John W. Barriger, president, Chicago, Indianapolis & Louisville; and the new vice chairman, E. G. Allen, special engineer, Atchison, Topeka and Santa Fe.

President Loeffler: Mr. Blackman, we sincerely regret the loss of four members of your committee. You have made many valuable contributions to the Association since you were admitted to membership in 1913. An important part of this service has been your leadership in the work of Committee 16 for the last three years.

The highly specialized reports made by your committee have rendered valuable service to our members and to the railroads. Under your leadership the work of Committee 16 rose to new heights during the past year.

As an association, we are particularly appreciative of the thought-provoking and challenging address made by one of your members, Dr. L. K. Sillcox.

Again, I compliment your committee upon its work in the past year. You are now excused.

Wednesday Morning Session

(President Loeffler presiding.)

President Loeffler: The meeting will please come to order.

It is of considerable interest to report the registration as of yesterday afternoon. The registration yesterday, the first day of the convention, was 1363, compared with 1312 for the first day last year.

The first committee to report this morning is Committee 27—Maintenance of Way Work Equipment.

Discussion on Maintenance of Way Work Equipment

(For Report, see pp. 335–379.)

(President H. S. Loeffler presiding.)

Chairman R. K. Johnson (Chesapeake & Ohio): The report of Committee 27 is found on pages 335 to 379, inclusive, Bulletin 491. Your committee has ten assignments this year; we report on 7.

We have no report on Assignment 1 nor Assignment 2, but C. E. Morgan, chairman of that subcommittee, will say a few words as to what that committee is doing and is endeavoring to do.

Assignment 2—Motor Cars, Trailer and Push Cars, was presented by Subcommittee Chairman C. E. Morgan (Chicago, Milwaukee, St. Paul & Pacific).

Mr. Morgan: This committee has received from the manufacturers of equipment their present standards on all sizes of wheels and axles for motor cars. We have distributed copies of these standards to all members, to impress on them the need for fixed standards. The inspection car axle size has been submitted to written ballot and the majority have indicated they want the $1\frac{3}{16}$ in. dia. axles. We are preparing the final draft for written ballot on all dimensions on that axle.

Results are coming in now on the size axle desired by members for the heavy-duty motor car. When these are in all remaining dimension details will be completed on that size axle and will be submitted to Committee 27 for final approval by letter ballot.

The wheel dimensions for the AREA standard inspection car axle and for the heavy-duty axle will be developed, and we believe these will be ready for a recommended AREA standard by March 1952.

Assignment 3—Improvement and Additions to Existing Work Equipment, was presented by Subcommittee Chairman N. W. Hutchison (Chesapeake & Ohio).

Mr. Hutchison: One of the duties of Committee 27 is to strive constantly to effect improvements in the design of work equipment in order to increase its efficiency and utility The purpose of this current assignment was to determine what improvements to work equipment have been made in the period from 1945 to 1950, inclusive, and, as evidence of the committee's future intentions in this respect, it has a current assignment designated as Improvements to be Made to Existing Work Equipment.

In order to find out what improvements have been made in recent years, an inquiry was directed to 135 work equipment manufacturers, which resulted in a list of 280 changes which were specified as improvements. However, your committee was of the opinion that all of the changes which the manufacturers specified as improvements did not actually increase the efficiency of the machines, and could not be so classified. Therefore, the list was carefully screened and we included in our report only those changes which we consider to be of sufficient importance to justify inclusion as improvement. These are shown on pages 336 to 340, inclusive, of Bulletin 491.

Assignment 4—New Developments in Work Equipment, was presented by Subcommittee Chairman E. L. Anderson (St. Louis–San Francisco).

Mr. Anderson: This is a final report, presented as information. The detailed report on this assignment may be found on pages 340 to 357, inclusive, Bulletin 491. This report covers machines that have come into full development during the period approximately September 1, 1948, to September 1, 1950. The report describes in general details 24 such machines, accompanied by 24 illustrations.

It is not the intention of the report to cover any improvements or additions to machines that existed prior to September 1, 1948; neither does it cover developments that may have occurred to fence building equipment or special attachments for tractors, portable lighting outfits, etc.

To receive particular benefit from the report, the illustrations and subject-matter should be studied in detail.

President Loeffler: Thank you, Mr. Anderson, for this very excellent report.

I would like to call the attention of the audience to the two microphones that we have in the two aisles leading to the platform. These microphones are provided for your use; anyone desiring to make comments or to enter into a discussion on any of these reports is urged to use them. Give your name distinctly, and also mention the company or other organization which you represent, so the reporter can make a correct record.

Is there any discussion on this important report just submitted by Mr. Anderson? If not, the report will be received as information.

Assignment 5—New Types of Work Equipment Needed, was presented by Subcommittee Chairman H. E. Michael (Railway Engineering & Maintenance).

Mr. Michael: The report of Subcommittee 5 begins on page 357 of Bulletin 491.

To make our report as comprehensive as possible, your committee sought the advice of at least one engineering or maintenance officer on every domestic railroad having membership in the AREA. Some of these men, in turn, canvassed their supervisory officers before offering official suggestions. On this basis, your committee feels that its report represents not only complete coverage of the Association's member roads, both large and small, but also the best opinions of its interested membership.

In addition to the specific information reported to you in the body of our report, many railway officers offered the committee other suggestions of a more general nature, about which you may be interested. For instance, many of these men felt that the manufacturers, generally, have been doing such a splendid job in the development of maintenance-of-way machines that it is difficult to nominate new machines for consideration. Another group, and a large one I may add, were more concerned about improvements that could be made to existing types of equipment than about newer types that might be developed. Typical of the opinions expressed by this group of officers is that of the chief engineer who said, "There are now available some very excellent machines for handling railroad maintenance problems, and I am inclined to the belief that what the railroads need most are sufficient supervisory forces who know how to use these machines effectively and keep them working regularly. However, I would be very much interested in any improvements that can be made in available machines to make them more serviceable and less subject to breakdowns." Such improvements would relieve the pressure on inadequate supervisory forces, would add to the productivity of maintenance gangs, and would generally enhance the prestige of mechanization.

Another chief engineer took cognizance of the fact that for many years the railroads promoted, and sometimes insisted on, off-track equipment. He pointed out that in recent years several machines have been developed which "have produced large savings in maintenance, but which, unfortunately, have required the use of the track to obtain their greatest effectiveness." In view of the present density of traffic on many lines, this man suggests that the railroads need today, more than anything else, machines which can still produce economies in maintenance without requiring the use of the track.

Finally, a former president of this Association reminded us that, regardless of what it may be designed to do, any machine to be worthy of development for use in the maintenance-of-way departments of American railways should have three characteristics —usefulness, simplicity and dependability. For such machines, whether new or improved, a ready market is waiting.

President Loeffler: Thank you, Mr. Michael. This is a very excellent report.

The Association is very appreciative of letters that may be received throughout the year, giving us constructive information and suggestions for reports.

Is there any discussion of this report? You understand, of course, that all these committee reports are thoroughly discussed in committee meetings. The committees have memberships of 40 to 60 members; but we would appreciate any discussion from the floor, as well as letters, such as have been mentioned.

The report will be received as information.

Assignment 6—Equipment for Fence Building, was presented by Subcommittee Chairman F. H. McKenney (Chicago, Burlington & Quincy).

Mr. McKenney: Investigation by the committee did not indicate much demand for this type of equipment, due to the fact that most fence work is maintenance of existing fence, and is carried on by local section forces, usually on a scale that does not justify much power equipment.

This report describes the various power tools and work equipment that may be employed profitably in out-of-face construction or repair of fences.

Assignment 7—Special Cars for Handling Work Equipment, was presented by Subcommittee Chairman A. H. Whisler (Pennsylvania).

Mr. Whisler: This report will be found on page 367, Bulletin 491.

An analysis of the information furnished for use in the compilation of this report indicates few persons are familiar with the conservation of manpower and materials, or the increase in the morale or efficiency of workmen that can be effected by having railroad cars properly fitted for transporting work equipment.

One manufacturer of equipment used in the maintenance of many railroads has said, and I quote:

> "And remember—to a well organized gang with proper equipment, nothing is impossible."

It is with a similar thought that our report is submitted—as information.

President Loeffler: Thank you, Mr. Whisler. This certainly is an important report, considering the fact that the railroads have been acquiring immense quantities of maintenance-of-way work equipment over the past few years.

The report is very nicely summarized in the last paragraph, which reads, "Carefully planned and designed cars for transporting maintenance-of-way equipment will result in savings in both money and time, and also increase the safety performance of maintenance forces."

Is there any discussion on this report? If not, the report will be received as information.

Assignment 8—Special Attachments for Tractors. In the absence of Subcommittee Chairman W. G. Luebke (Denver & Rio Grande Western) the report was presented by Edgar Bennett (Southern Railway System).

Mr. Bennett: There are a great number of special attachments for tractors, the majority of which are designed for work other than that customarily performed in maintaining railroad property. Your subcommittee has, therefore, attempted to segregate the various attachments available, including in its report only those which are readily adaptable for railroad use, and has briefly described and outlined the use made of the following:

Earth boring machines.
Power-operated winches.
Crane and boom attachments.
Tie loading attachment.
Trenching attachments.
Tool bar attachments.
Tractor-mounted arc welders.
Tractor-mounted air compressors.

This committee realizes the necessity of any attachments that will promote or make more efficient the equipment used in maintenance-of-way work, and it is the purpose of this committee to keep you informed of these things as much as we possibly can.

This report is recorded, starting on page 372, and contains a number of figures outlining attachments. It is a final report, submitted as information.

President Loeffler: Thank you, Mr. Bennett.

Is there any discussion of this important report. This is a final report. However, no doubt, within a few years additional attachments will be available, and a further report on the same subject will be made.

Assignment 10—Portable Lighting Outfits. In the absence of Subcommittee Chairman W. E. Kropp (Lehigh Valley) the report was presented by F. L. Etchison (Atlantic Coast Line).

Mr. Etchison: Portable lighting outfits are designed to furnish artificial light wherever it might be needed, and consist principally of a generator to supply the current, one or more floodlights with stands, and the necessary accessories. The variety in generators, floodlights, and mountings for these outfits makes it possible to set up a combination suitable to almost any maintenance-of-way requirement.

The portable lighting outfits which are adaptable for railroad use may be divided into four classes namely: Off-track wheel-mounted; on-track wheel-mounted; highway trailer-mounted; and carryable. These outfits are described and illustrated on pages 378 and 379 of Bulletin 491.

Chairman Johnson: Mr. President, this concludes the report of Committee 27.

President Loeffler: It is well known that extraordinary savings are brought about through the use of various types of power-operated maintenance-of-way equipment. Committee 27 is ever alert to make thorough investigations to inform the Association and the railroads of the development and use of new types of suitable work equipment.

Mr. Johnson, I compliment you and your committee for the excellent quality of the reports you have just presented. Your committee is excused at this time with the thanks of the Association.

Discussion on Economics of Railway Labor

(For Report, see pp. 321–334.)

(President H. S. Loeffler presiding.)

Chairman H. E. Kirby (Chesapeake & Ohio): As most of you are aware, several American railroad properties were inspected by a group of European maintenance-of-way engineers late last year. After their return to Europe, a report covering their observations and thinking on American practices was compiled by Arthur Dean, of the British Railway Executive. This report is in the form of a letter to Mr. Howard, secretary of the AREA.

The report itself was thought to be of such general interest that it was decided that everyone should hear it, and I am quite sure that you will find many of their observations thought-provoking and of general interest.

Last year, you will recall that Committee 22 called upon its former chairman, one of its mainstays during the greater part of its existence, to describe to you something of the history of the committee and of such achievements as it may have attained to date. This year we have again called upon this man to present to you this report by Arthur Dean, and I now present him—George M. O'Rourke.

Impressions of a Group of European Railway Maintenance of Way Engineers on Their Tour of U. S. Railroads

By Arthur Dean*

Chief Officer Engineering Works, The Railway Executive, British Railways,
London, N. W. 1, England

In seeking to fulfill the promise which we gave to you in Chicago, to let you have our assessment of the maintenance of way and construction practices on the American railroads, I have thought it best that our observations should be in the form of a letter.**

I am influenced to use this form for several reasons. Firstly, we were able to see only a very limited extent of the American railroads in relation to their widespread nature. Secondly, as our assessments gradually shaped themselves we could not go back and re-discuss various aspects, and confirm our assessments. Thirdly, we prefer that what we have to say should be more in the form of a friendly communication, primarily to those railroad officers whom we were privileged to meet, and who gave so freely of their time to seek to inform us as to their standards and practices. So in addressing this to you, we are really addressing all our American railroad friends.

We were interested to read the note relating to our departure from the United States in the AREA News for November 1950, and at the outset we must make sure that there should be no misunderstanding of the reference made in that note that:

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* The author was chairman of the study group of European railway engineering and maintenance officers who visited the United States for a period of six weeks, beginning September 9, 1950. These foreign railway officers made their visit under the auspices of the Economic Cooperation Administration, with the full cooperation of the Association of American Railroads and of the individual railroads visited. The countries represented in the group were England, Denmark, Germany, Italy, The Netherlands, Norway, Sweden, Greece and Turkey. The escort-consultant of the group throughout its tour of United States railroads was C. D. Merrill, assistant to general manager, Pennsylvania Railroad.

** This letter was addressed to the secretary of the American Railway Engineering Association, and was written with the knowledge of the writer and his associates that it would be brought to the attention of members. It was read to the Annual Meeting in connection with the presentation of Committee 22—Economics of Railway Labor, by G. M. O'Rourke, assistant engineer maintenance of way of the Illinois Central Railroad, a member of that committee.

Members of the group made many significant observations of American railway engineering and maintenance practices in comparison with their own.

Conditions Differ Widely in U. S. and Europe

The main observation which we made while studying U. S. railroads was that the conditions under which American railway engineering and maintenance practices have been developed are very different from those under which such practices have been developed on most European railways.

In this connection, we cannot do better than quote observations which we have made elsewhere on this very important factor:

Maintenance-of-way practice—General considerations—In relation to the question of economy of maintenance of track, there exist certain major differences between conditions governing maintenance in the U. S. and those governing maintenance on European railways. It is appropriate that these differences should be set down.

(a) Type of rolling stock—Almost all passenger and freight cars in the United States are long-wheelbase vehicles, carried on four and six-wheeled trucks. They are coupled centrally, and this type of vehicle will ride well and safely at high speed on track having appreciable irregularity in rail top level by European railway standards.

On the represented European railways, a big proportion of the freight vehicles, and some passenger-carrying vehicles, are of comparatively short wheelbase, with two axles, having only limited freedom of movement, and with springing of the simplest form. They are provided with spring buffers and are coupled centrally.

For safe running, other than at strictly limited speed, a relatively high standard of regularity of track must be maintained. Appropriate maintenance practices have been developed in Europe to attain this relatively high standard.

(b) Train intensity—The comparatively light passenger train service in the U. S. and the high average tonnage of individual freight trains result in a train intensity over a very extensive mileage of track which is much less than that on most European railways. In consequence, despite the large tonnage hauled by the U. S. railroads on a substantial proportion of the line mileage, sufficiently long intervals are available during daylight hours on weekdays, between trains, even on the extensive mileage of single track, for the economic use of on-track mechanical equipment for maintenance-of-way work.

(c) Operating facilities—The operating facilities in relation to the present train intensity on U. S. railroads, arising from the existence of multiple tracks in certain cases, and signaling installations which have a high degree of operating flexibility as compared with those generally available on European railways, also contribute to the existing widespread facility with which intervals can be made available for the economic use of on-track mechanical equipment for maintenance-of-way work.

(d) Width of property and freedom of access—Due to the greater width of railroad property outside the tracks, and to the general absence of fencing along U. S. railroads, as compared with the restricted conditions on many European railways, direct access along an extensive mileage of track is possible in the U. S. for both mechanical equipment and highway transport vehicles, to an extent which is quite impossible on the represented European railways.

(e) Freedom to raise the level of track—On a considerable mileage of U. S. railroads there still exists complete freedom from physical restriction, such as overbridges and stations, to raise the level of tracks. As a result, it is possible to carry out the necessary periodic surfacing of tracks by the speediest and most advantageous method. Such opera-

tions are physically restricted to a much greater extent on European railways, and maintenance practices appropriate to these restricted conditions must be adopted.

(f) Special limitations in some European countries—In some countries, such as Greece, Norway and Turkey, a substantial proportion of the track mileage comprises single lines. These lines run through difficult terrain, with many curves and tunnels, and with signaling facilities or other operating control appropriate to the safe working of the train service which is operated.

Compared with the extensive mileage of single-line track in the U. S., where long, straight and level lengths exist, and where modern signaling has been installed, the existing natural and other limitations in these countries preclude entirely the use of much of the mechanical equipment for maintenance of tracks which is possible on U. S. railroads.

(They did not have an opportunity to observe some of the railroad lines located through mountainous terrain in the western part of the United States, with their many curves and tunnels.)

Standards and Practices Compared

Maintenance-of-way practice—Effect of track construction—Despite the heavier axle loads carried by U. S. track than are carried by track on the represented European railways, it is our view that the proportionately stiffer rail in general use on U. S. railroads, and the closer spacing of ties give a track which requires less day-to-day maintenance to provide satisfactory riding conditions for the type of rolling stock which is used, than is the case on European railways.

Maintenance-of-way construction and practice—Economic factors—In seeking to assess whether the provision of stronger track on European railways, and such wider mechanization of maintenance work as may be physically practicable, will in fact bring actual overall economy, certain selected economic comparisons have been made. They are approximate only, based on available data, and may still be subject to later revision, but the differences in the relative economic effects of the provision of materials, fuel, and mechanical equipment in the represented European countries to the cost of labor, compared with in the U. S., are sufficient to indicate that no clear combined recommendation on this major question is possible. Furthermore, it cannot be assumed without the most complete investigation that any overall economy would be attained by seeking materially to change existing European railway track construction and maintenance practice, while the present economic relationships continue.

On the question of train intensity, we were fortunate to obtain copies of the admirable little booklet "Railroad Facts," 1950 Edition, from which it was possible for us to derive one or two overall statistics. For example, from a close approximation of the single running line mileage of Class I American railroads, we derived that there are, on the average, 4 passenger and 6 freight trains per track per 24 hours, i.e., 10 in all. *(The main lines of many American railroads carry a substantially greater density of traffic than this average.)* The comparable number on the British railways is 30, on the German railways 20, and on the Netherlands railways 33. We gathered from responsible engineers in the U. S., that broadly speaking, mechanical equipment is an economical proposition if it is actually in use, on the average, four hours per day. We also gathered that on-track equipment is considered to be an economical proposition, provided that it can work effectively, without interruption, for periods of at least half an hour. It is, therefore, as we have indicated, by no means a foregone conclusion that, even if we could get mechanical equipment relatively as cheaply as you do in the U. S., we could use it, under our conditions, with sufficient effectiveness for it to produce economy in maintenance on such a wide scale as you do.

Country	Tons of rail per mile of track	Ratio of cost of rail to annual basic wage	Number of ties per mile of track	Ratio of cost of ties to annual basic wage	Ratio of cost of rails and ties to annual basic wage
U. S.	205	6.2	3,200	4.0	10.2
Denmark	165	10.4	2,400	7.55	17.95
Germany	157	11.0	2,500	9.6	20.6
Greece	142	26.5	2,400	37.9	63.5
Netherlands	151	20.9	2,670	18.5	39.4
Italy	157	18.3	2,400	4.4	22.7
Norway	154	10.3	2,250	6.0	16.3
Sweden	157	8.45	2,400	3.95	12.4
Turkey	145	39.6	2,320	36.3	75.5
U. K.	171	13.5	2,112	10.0	23.5

Labor and Material Costs Compared

When we compare the prices which you pay for rails and ties in dollars with the prices we pay in our countries, and relate them to the basic wage rate which you pay in dollars, and to those basic wage rates which are paid in our countries, we find the following relationships:

We recall how frequently we were told of the high level of wage payments on the U. S. railroads. I am not sure that I was always successful in impressing my quite different angle on this important aspect, i.e., that the basic factor which is governing your practices at the present time is not really the high level of wages, but rather the cheapness, relative to those high wages, of the basic materials you use—rails, ties and fittings—and of a wide range of mechanical equipment and of highway and rail transport vehicles.

Mechanization of Maintenance-of-Way Operations

We found that, generally speaking, the price of mechanical equipment in our countries is not widely different from the prices you pay in dollars, revalued in our currencies at the prevailing rates of exchange.

As we see it, you do not have much difficulty in substantiating the economic justification for the acquisition of mechanical equipment on a generous scale, and for providing a very stiff rail, and over 3,000 ties per mile of track. So far as we were able to assess the position on some of your railroads, mechanical equipment to the value of some $1,000,000 per 1000 single-line miles of fairly heavily-used track exists on some of your railroads, and may well exist on many others at any rate in the near future. And again, so far as we could assess, the annual cost of this equipment runs at about $220,000, or the annual basic wages of some 88 of your men.

This is so clearly justified under U. S. railroad conditions that it is perhaps no subject for surprise that we found difficulty in collecting broad figures of the actual total cost per annum of your mechanical equipment, and of its fuel consumption. When we considered what would be involved to us in maintaining and running a similar value of mechanical equipment, we found that the annual charges and costs would be equivalent to the annual basic wages of about 200 men in Denmark, Norway and Sweden, 270 to 340 men in Germany, Italy, the United Kingdom and the Netherlands, and 500 to 600 men in Greece and Turkey.

It will be readily appreciated from this how different are the economics of widespread mechanization of maintenance-of-way practices in the U. S. as compared with Europe.

But we cannot pass from this question of the use of mechanical equipment without some observations on its use, and of the organization of the labor force used with the equipment, as we saw it. We think that you could man these mechanized operations much tighter than was the case on some of the works we saw.

There may be good reasons which we could not know for mechanizing some of the minor operations, such as the use of a mechanical appliance to clear out the ballast from between the ties, ahead of the rotary adzers, with several men following to clear the ballast and finish the job. Our reaction was that fewer men could have done this little job better with hand tools. In fact, just now and again we wondered whether there was not a danger that the *"idea"* of mechanization could become the ruling influence.

Greater Refinement in Track Surface and Cross Level in Europe

Continuing on the question of the track, which is, after all, by far the largest single element in the whole field of maintenance of way, we must be quite candid and say that, on occasions, we saw some of your main-line tracks with a degree of vertical irregularity which prompted us to ask what was to be done about it. We should have been a little concerned to have found track with a similar degree of vertical irregularity carrying unrestricted main-line traffic in our countries. We gathered in such cases that the length of track in question was likely to be resurfaced in the not too distant future, but that there was no cause for concern at the condition as seen. It took us quite a while to believe that there was not real cause for concern, and to appreciate, as we did eventually, that your long wheelbase vehicles, with their four-wheel trucks, and your diesel-electric, straight electric, and steam locomotives are so designed as to travel at quite high speed on such track with safety.

We saw very good track, and plenty of it, and the standard of alinement which we saw was consistently high.

We noted how limited is the use of any form of recorder for checking alinement and track conditions generally, and we did not see many alinement monuments. And associated with this, we noted that the method of checking cross level of the track was by means of a cross level with an adjustable step. This may seem a trivial matter on which to comment, but taken in association with the limited use of recording equipment, it was to me, at any rate, very significant indeed.

To many of us on European railways the maintenance of track to accurate cross level, in relation to alinement, is perhaps the most important element in track maintenance. We know all too well the result of indifferent maintenance of cross level, and, in consequence, we use recording instruments and graduated cross-level gages whereby it is possible regularly to check the track much more speedily than is possible without such means.

We could only conclude that, with your short rails, heavier track, and rolling stock with a greater element of riding flexibility, the maintenance of accurate cross level of the track must call for less regular consideration on U. S. railroads than is the case with us.

As has been mentioned previously, we thought your alinement generally to a high standard, and we scarcely ever experienced rolling when riding, even at high speeds, over your lines. But we did very often assess a pronounced deficiency of cross cant, when running on curves at fairly high speed. This was clearly the deliberate setting of the tracks, but, considering the generally high speed at which your freight trains operate, we wonder if you are not sacrificing the comfort of passengers a little too much to balancing the cant to the weighted average speed of all traffic. And at times we experienced some quite pronounced bouncing, particularly when traveling in sleeping cars.

Perhaps we could sum up our appreciation of the general standard of track maintenance, so far as we saw it, by saying that we could not show you on our railways anything better than the best we saw on your railroads, but that you permit unrestricted running over less perfect track than our own experience would lead us to permit.

Labor Productivity

We were, of course, very interested in the question of labor productivity, to assess if for some reason your track maintenance men exert more effort than our men do. We saw no evidence to lead us to think that this is the case.

We are not in a position to enlarge on this subject. We generally saw men and gangs working on specific operations in our planned itinerary, and impressions gained under those conditions must be treated with caution. On the other hand, we are not inexperienced in noting the signs, and we would stick to our view of this.

When a machine was setting the pace, either in front of or behind a gang, we saw good team work and effort. When the machine is absent, or when a work is planned as a combined mechanized and manual operation, with a substantial amount of heavy work done manually, we doubt if you get the output some of us do.

When we sought manning figures to enable us to compare track maintenance manning with that on our own systems, we found that your manning varies within wide limits throughout the whole year.

We gathered figures relating to a few of your railroads which showed that the summer manning would be quite three times the winter manning. In other words, the major part of your track maintenance is done with what we would call "casual" or "seasonal" labor.

We asked, as a matter of interest, what the men dispensed with in the fall of the year did for a living until the following spring.

But we wondered if this big "casual" element in your labor strength might not account for the assessment we have indicated previously, on the "tightness" of the manning of some of your work.

Welded Rails and End Hardening

We were very interested in the various indications we received as to the variations in policy with respect to the welding of rails into longer lengths. We noted, of course, that your rails are rolled in 39-ft. lengths. When we examine the annual statistics of the bulk materials used on your railroads, we are struck by the high relationship of the tonnage of "other track fittings" used, to the rail tonnage used.

We were impressed with the rail end-hardening practice as seen at one of your more modern rolling mills. It was an admirable, tidy "set up" in the production line. We surmise that your rolling mills must be able to show you that it is cheaper to pay the extra for end hardening 39-ft. rails, and for you to provide the joints, than for them to supply you with rails twice as long, with the change in handling technique on the track which would be involved. You know best on these matters, but we think we will stick to our longer rails as rolled.

(One of the assignments of Committee 4—Rail, is Service Performance and Economics of 78-ft. rail.)

Closer Cooperation Possible Both in Europe and U. S.

One purpose of the invitation to us to come to your country, and to see your conditions and practices, was for us to return and seek closer cooperation among ourselves, with advantage to the economic condition of Europe in general.

As a matter of fact, there exists much closer technical cooperation in Europe, for example, through the U.I.C., than was perhaps fully appreciated. But from our association together, and relating our practices to yours, we have formulated recommendations for still closer cooperation on matters such as rail section and rail composition.

But if, perchance, we do not get as far with these things as quickly as might have been hoped, you will, no doubt, forgive us if we indicate that even in U. S. A., within one national boundary, with one language, and one system of measurement only, there exist circumstances which require rail sections to be used which differ from the generally accepted standard, or details of fittings whereby each railroad appears to produce its own set of standard drawings, to mention only one or two points we noticed.

Bridge and Building Practices

We made practically no study of your organization and practices for maintaining buildings and bridges, nor did we see much actual new construction work in progress. This was perhaps unavoidable. But our impression was that, arising from the different "history" of development of your railroads as compared with ours in relation to existing urban development and highway systems, and the comparatively light passenger traffic on your railroads, our requirements are quite different from yours. We exchanged views on certain aspects, such as bridge examination practice and the basis of assessment of capacity.

It was our impression that steel remains predominantly your medium of construction, even in cases where we should probably seek to adopt concrete in one form or another primarily to keep down maintenance cost in the future, or even on the strength of lower initial cost. But economic bases are quite different with you—your steelwork is comparatively cheap—and we hesitate to do more than record this impression.

Suggest Greater Interchange Between U. S. and European Railways

We realize, no less than you do, that, ultimately, long-term research and investigation work is a profitable investment, provided that it is well planned and coordinated. We assess very highly the value of the organization which exists within the AAR to this end, particularly in the field with which the railway civil engineer is concerned. And the medium through which information relating to progress of this work is disseminated gives no excuse for railway engineers of other countries being unaware of what you are doing in this field.

It is possibly more difficult for the results of research and investigation work done in Europe to be readily known among U. S. railroad engineers, but we suggest that such work is not without merit, and in some cases in relation to work being pursued by you.

But although in some fields we have not as good regular documentation as you have, through the AREA and the technical press, of practically everything of value which is being pursued, there does exist the International Railway Congress Association, through which, from time to time quite comprehensive reviews are made and published, not only of important engineering practices, but also of practices in operating and other fields of railway work. Very few of your railroads are members of this International Association, and while this is understandable in relation to the long distance from the U. S. A. to the centers at which the Congresses have hitherto been held, the limited contribution to its periodic reviews by U. S. railroads is a pity.

Just by way of example, we actually had with us during our inspections in the U. S., very recent full reports on practices throughout Europe and many other countries on "Freight classification yards," "Rail joints—plated and welded," and "Modern tendencies in construction, particularly of bridges."

Saw Much of Value—Deep Appreciation Expressed

We could no doubt continue to comment on this, that or the other, of what we saw or were told—on such matters as organization, staff training, and safety in which fields we found much to admire, but we must not be too lengthy.

There was a great deal of value in what we saw, and we have scheduled, before and since we left your country, some 70 technical items, ranging through rail profile and composition, end-hardening practice, switch and crossing assembly and manufacture, applications of mechanical plant, etc., together with a comprehensive schedule of research investigations in progress in the United States. Each of these, some or all of us thought should be thoroughly considered in our own countries, in relation to our own practices.

Our mission to the United States was initiated to be of value to us, as indeed it was, and we realize how much was done by many railroad engineers and others in fulfilling that purpose. As most of us were newcomers to your country, looking at your standards and practices for the first time, we hope that these friendly comments of ours will be received in the same spirit as they have been put together.

We cannot conclude without indicating how impressed we were with the evidence of the most cordial relationship which exists between all grades of your staff. It was indeed refreshing to note the complete absence of any artificial barrier between any two people—whatever their relative positions. And there was no doubt about the existence of pride in their own railroad.

And with this letter we send our kind remembrances to all those railroad officers whom we met, and reaffirm our sincere appreciation of all that they did for us during our visit.

President Loeffler: Thank you, Mr. O'Rourke. That was a most interesting and challenging report. I'm sure that the AREA Board Committee on Publications will give serious consideration to publishing this report so that it will be available for the membership in printed form.

Mr. Kirby, you may proceed with your report.

Chairman Kirby: I also wish to thank Mr. O'Rourke for the manner in which he presented that paper. No summary comment is indicated, except to say, possibly, that those particular remarks which might be considered to be of a critical nature were intended as constructive. I'm sure you were all impressed with the cost ratio of labor and materials as between United States and European countries. I might also suggest that it be borne in mind that this report comes from the background of the English socialistic viewpoint, which may have had some bearing upon the thoughts of our European friends as they looked over the railway properties in this country.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman C. G. Grove (Pennsylvania).

Mr. Grove: The report on revision of the Manual may be found on pages 322, 323 and 324 of Bulletin 491.

Last year your committee reviewed and revised the text relative to plans for outfit cars, while this year the revision of the drawings on pages 22–13 and 22–14 was accomplished.

There is a wide variation in the types and standards for cars used for camp equipment on the different railroads, and it is not possible to provide plans that will meet the needs of everyone. The revised plans are typical of the better class of camp equipment, and it is the thought of your committee that they may be used by everyone as a guide to what they may desire for camps to meet the standards of the various roads in this country.

It is our recommendation that the drawings, as revised, be adopted for inclusion in the Manual, and I so move.

President Loeffler: Is there a second?

(The motion was regularly seconded, put to a vote and carried.)

Chairman Kirby: One of the more important perennial subjects studied by this committee is that of Subcommittee 2, having to do with the investigation of practices on railroads on which marked economies have been effected. For the past year this study was under the direction of Charles Reeve, who, unfortunately, could not be here. In his absence, R. J. Gammie, of the Texas & Pacific, now vice chairman of this committee, will deliver Mr. Reeve's report.

Assignment 2—Analysis of Operations of Railways That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work, was presented by R. J. Gammie (Texas & Pacific).

Mr. Gammie: Subcommittee 2 is constantly on the alert to find where outstanding economics of labor have been effected in maintenance of way work. As you recall, last year a report was made on the unusual savings made by the Pennsylvania through the use of power roadway machines. In 1950 we found another example of important savings and requested an opportunity to make a study and present our findings to you. These savings were discovered on the Elgin, Joliet and Eastern. The management of the E. J. & E. graciously granted our request and put at our disposal Chief Engineer F. G. Campbell and his staff to allow us to study the economies made by these men in the work of yard cleaning.

The E. J. & E. has developed over a period of years a system of yard cleaning that each year is showing greater economies. Originally this work was done entirely by hand labor, except for the final loading of piles of debris by cranes handled by work train. The first major advance in the system was the use of hydraulic dump bodies, pulled by motor cars. This permitted the debris to be hauled readily to convenient low spots to be wasted, and eliminated the crane and work train. When it was no longer economical to waste the debris, portable elevating loaders were acquired and the yard cleanings were dumped from the hydraulic dump bodies to the elevator and loaded into gondolas for further disposal. The debris, however, was still being accumulated from the tracks and loaded into the dump bodies by hand.

Not satisfied with the cost of doing this work, Mr. Campbell and his staff built a machine to accumulate the refuse from the tracks. The development of this machine was no easy task. It took considerable study and experimenting. With this machine, it was no longer necessary to use hand labor to clean the material from the tracks, but it was still necessary to load the material into the dump bodies by hand. The next step was obvious—a portable conveyor to pick up the material accumulated by the cleaner and load it into the dump bodies. By this development the cost of yard cleaning was reduced from 10.86 man-hours per yard to 2.94 man-hours per yard.

The details of these savings have all been noted in the report, and I shall not go into them further. But I would like to call your attention to why I believe this report is valuable to members of the AREA. Here we have a group of able maintenance engineers who, inspired by outstanding leadership, solved a problem in the economics of railroad labor by the use of ingenuity and skill, even to the point of developing and building machinery. They were not only able to show the management of their railroad that savings could be made, but have aided other railroads by the machinery which they were able to design.

I believe it is fitting at this time for Committee 22 to pay tribute to one of its valued members—F. G. Campbell—who, with the help of an excellent staff, has not only made such a contribution to his own railroad, but to all of the railroads participating in the AREA.

Assignment 3—Organization of Forces for Track Maintenance Operations, was presented by Subcommittee Chairman H. C. Archibald (Boston & Maine).

Mr. Archibald: The report of Subcommittee 3 covers the organization of forces for the use of a multiple electric tamper in surfacing track. Last year's report covered the use of a power ballaster, a machine used for a similar purpose.

In the preparation of the report and in the discussion at committee meetings it became apparent that our subject was one in which all railroad maintenance men were interested, and upon which each member had a definite (and different) opinion.

Questionnaires sent to 25 railroads gave us the details of numerous types of organization, from which a more or less composite crew could be set up. It must be emphasized, however, that the conclusions presented are general in scope, and are offered as an aid in the organization and procedure to be adopted to secure good results from the use of a mechanized tool in place of hand labor. The adaptation of this tool to fit local conditions of labor, rail, ballast and traffic is properly under the sole control of the officers in the field.

The report emphasizes that quality of work is more important than quantity, and that to secure the inherent benefits of modern machinery in track work, sufficient time should be taken to secure long-lasting results.

The multiple electric tamper is a self-propelled, on-track machine. A cross-head, to which are attached 12 vibratory tamping units, is raised and lowered in each crib, tamping both sides of each tie simultaneously. The number of insertions needed to consolidate the ballast under the tie varies with conditions, and it is recommended that this be left to the officer in charge in the field.

While the machine may be readily removed from the track at a prepared set-off, it is better, from the standpoint of uniform work and steady progress, to secure possession of the track for a reasonable length of time when this can be done.

The distribution of ballast ahead of the tamping is an operation upon which proper tamping depends to a very large degree. Too much ballast, or too little, is harmful and adds greatly to the cost of the job. The education and supervision of foremen on this operation will certainly pay good dividends.

For a crew capable of tamping 1500 ft. to 2000 ft. of track a day, an organization consisting of 1 foreman, 3 assistant foremen, 1 machine operator, and 38 trackmen is suggested, the details of which are shown in the printed report.

Assignment 7—Labor Economies Which May be Effected Through Grading of Right-of-Way. In the absence of Subcommittee Chairman E. J. Brown (Chicago, Burlington & Quincy) the report was presented by A. D. Alderson (Minneapolis, St. Paul & Sault Ste. Marie).

Mr. Alderson: The report of Assignment 7 is published on page 332 of Bulletin 491.

Right-of-way grading, as outlined in this report, covers the following:

1. The widening and lowering of ditches in cuts to permit better drainage, resulting in reduced labor to maintain smooth track. The elimination of wet cuts will also reduce the amount of labor required for shimming track during winter months. This applies to northern railroads.

2. The restoration and widening of embankments and the flattening of embankment slopes to eliminate possible slides.

3. The construction of special drainage and interception ditches to lead water away from track embankments, thereby reducing possible slides and settling of embankments.

4. Leveling of the right-of-way to permit the transportation of employees and materials by trucks, thereby eliminating time wasted in moving crews by conventional on-track equipment. This applied mainly to railroads having heavy traffic.

5. Smoothing rough terrain on the right-of-way to permit the use of power mowing machines to control vegetation, thereby eliminating the hand cutting of weeds and small brush.

6. The removing of small cuts that frequently are blocked with snow, thus eliminating the necessity for the construction of snow fences. This tends to reduce the number of times the snow plow must be run.

In conclusion, the trend on the railroads toward the use of mobile earth-moving equipment for grading right-of-way was accelerated during the recent war, due to labor shortages, and received further impetus more recently when increased wage rate and the shorter work week went into effect.

Contour leveling, grading and draining of the right-of-way lessen the shock of extreme weather conditions, allowing the forces of nature to dissipate themselves in a less harmful manner.

Mr. President, this is a final report, and is presented as information.

President Loeffler: Thank you, Mr. Alderson. I think that possibly a seventh item could be added to the six items on page 333, to cover the construction of ditches which would lead natural drainage away from cuts—the construction of these ditches to be outside of the tops of the cuts.

Mr. Alderson: I believe that is a good suggestion and it will be taken into consideration.

President Loeffler: Are there any other comments on this report? If not, the report will be received as information.

Chairman Kirby: With that subcommittee report the presentation of Committee 22 is concluded. I should like to add that I am very grateful for the wholehearted support and cooperation of every member of the committee.

President Loeffler: The subject of economies in the use of labor in all phases of railway construction and maintenance has been a matter of ever-increasing importance throughout the years, and never has it been more important than at the present.

During emergencies, of course, the economics of a situation frequently take second place to the importance of getting the work done promptly to meet a vital need. However, we should never lose sight of the necessity in normal times, and the desirability in times of stress, of using labor in the most economic manner.

We have been fortunate in that Committee 22 has kept this matter constantly before us.

Mr. Kirby, we are highly appreciative of the efforts of your committee and the reports that you have presented this year. We are also appreciative of the highly interesting and enlightening letter from our fellow engineering and maintenance officers in Europe, as presented by Mr. O'Rourke. The constructive criticisms contained in that letter with respect to matters of safety and the economical use of manual labor merit our most careful consideration.

Mr. Kirby, your committee is dismissed at this time with the thanks of the Association.

Discussion on Buildings

(For Report, see pp. 285–299.)

(President H. S. Loeffler presiding.)

Chairman A. G. Dorland (Elgin, Joliet & Eastern): The report of your Committee on Buildings is found in Bulletin 491, pages 285 to 299, inclusive.

On page 286 you will see a notice of the death of Walter L. Turner. His loss is deeply regretted by the committee.

We are also very sorry to lose two faithful members of our committee who, having retired from their respective railways in 1947, are automatically dropped from the committee according to a rule adopted by the AREA. These two men, W. T. Dorrance and H. M. Church, will certainly be missed, since they have been very active in our committee work.

Mr. Dorrance, formerly of the New York, New Haven and Hartford, joined the AREA in 1908. He had been a member of Committee 6 for 42 years and was chairman from 1921 to 1927; he also served on Committee 12 Rules and Organization, and on Committee 26—Standardization. He also was a director of the Association, 1935 to 1937, inclusive. Mr. Dorrance expected to be here, and I'm certainly sorry that he is absent.

H. M. Church joined the AREA in 1909, but did not get on our committee until 1936; but he has been chairman of one or more subcommittees ever since. He was formerly with the Chesapeake & Ohio. Mr. Church has been very active on other committees. He served on the following Committees: 5—Track; 7—Wood Bridges and Trestles, having been chairman of that committee; 9—Highways, 13—Water Service and Sanitation; 18—Electricity; 22—Economics of Railway Labor; 26—Standardization; and 28—Clearances. He has had the remarkable record of a total of 73 years of committee work. He is also a past president of the American Railway Bridge and Building Association, and we are very sorry that it was impossible for him to be with us today.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman J. B. Schaub (Illinois Central).

Mr. Schaub: As our chairman has brought to your attention, this material is in Bulletin 491, December 1950, commencing on page 286. The recommended revision of the Manual starts with pages 6–7 to 6–10, inclusive. Sewers and Drainage. This specification was revised slightly back in 1949, but, as the result of several questions raised, the committee decided it would be advisable to revise the specification completely to bring it up to date. Since it is published in full in the Bulletin, I don't think we need to read it at this time.

We recommend therefore, the deletion of the entire specification on Sewers and Drainage, and the substitution of the recommended specification found on pages 286, 287, 288 and 289—and I so move.

President Loeffler: Do I hear a second to this motion?

(The motion was regularly seconded.)

President Loeffler: May I suggest a slight correction, Mr. Schaub? In paragraph 2, under Excavation and Backfilling, about the middle of the paragraph, it reads "shall be cut vertically or with only a slight slope." I believe it would be more correct to use the word, "batter" instead of "slope."

Mr. Schaub: I see no objection to that change.

President Loeffler: Are there any further comments with respect to this Manual material?

(There being no further comments the motion was put to a vote and carried.)

Mr. Schaub: The next recommendation is found on pages 6–223 and 6–224 of the Manual. The committee recommends that the next matter dated 1936, appearing under Rest Houses, be submitted for reapproval, dated 1951, without change. I so move.

(The motion was regularly seconded, was put to a vote and carried.)

Assignment 5—Lumber Specifications for Railway Buildings. In the absence of Subcommittee Chairman H. M. Church (Chesapeake & Ohio, retired) the report was presented by R. L. Fletcher (Timber Engineering Co.).

Mr. Fletcher: The material in this report was originally presented in Volume 51 of the Proceedings, on pages 240 to 241. Last year it was presented as information, with the provision that, subject to your comments and suggestions, it would be subsequently recommended for publication in the Manual.

With some corrections that have been found necessary or advisable, your committee recommends that this material be published in the Manual.

President Loeffler: Do you make that in the form of a motion, Mr. Fletcher?

Mr. Fletcher: I move that the material included in Lumber Specifications for Railway Buildings be included in the Manual.

(The motion was regularly seconded, was put to a vote and carried.)

Assignment 6—Docks and Wharves. In the absence of Subcommittee Chairman J. P. Gallagher (New York Central System) the report was presented by Chairman Dorland.

Chairman Dorland: This report is found on pages 290 to 292, inclusive, in Bulletin 491, dated December 1950. It is informative and is submitted as information only.

The committee recommends that this subject be reassigned in the near future, in order that the committee may elaborate on the descriptive text and possibly supplement it with photographs and drawings to illustrate the various types of design and construction described.

I also have a comment here from Meyer Hirschthal, consulting engineer, and formerly concrete engineer, Delaware, Lackawanna & Western, which I should like to read. This is addressed to N. D. Howard, secretary of the AREA.

"In the report of the Committee on Buildings, Bulletin 491—on the subject of docks and wharves, and specifically on substructures on page 291, I would like to call attention to the fact that the Lackawanna, in the design and construction of the Lake Freight House at Buffalo, N. Y., used the following type of design more than 20 years ago: This consisted of circular reinforced concrete columns 3 ft. in diameter, with the use of sheet piling as forms, facia girders between these columns or piers along the face of the structure, with girders at right angles resting on the in-shore end on pile caps surmounting piles driven to refusal. The deck consisted of reinforced concrete of "T"-beam design framed into the girders above referred to. The condition which made this a feasible type of construction was that rock was available at the front face within 35 ft. of the water level. This formed a fireproof design and did not require any fire stops additional to the construction.

Chairman Dorland: I think this is a very good comment, and should be included in the report of the convention.

President Loeffler: It will be so included.

Mr. Dorland, do you have in mind that this subject should be continued next year or some following year in the future.

Chairman Dorland: The idea is to drop it for a year or so, and then have it reassigned in 1952. It isn't assigned for 1951.

Assignment 8—Modernization of Station Buildings, was presented by Subcommittee Chairman J. J. Schnebelen (Missouri Pacific).

Your committee submits as information this progress report on the subject Modernization of Station Buildings. The report appears in AREA Bulletin 491, pages 293 to 299, inclusive, and consists of six parts. Part 1 reviews the present streamlined era of mass transportation that came into being late in the first half of the Twentieth century with the progressive modernization of locomotives and trains. In the early part of this period two additional modes of travel entered the field of mass transportation: First, the automobile, followed by the airplane. The intensive competition developed by the bus and air lines to date challenges the railroads' supremacy in the mass transportation field. During this period the construction, renovation and modernization of station buildings languished, for the changes in train equipment to date far surpass improvements in passenger stations, both in number and achievement.

A great number of the existing stations were constructed in the latter part of the last half of the Nineteenth century and show signs of decay; first, due to obsolescence caused by the passing of time; second, due to deterioration caused by the elements and wear and tear from use; and third, due to neglect of essential maintenance, which accentuates their present unprepossessing appearance. Part 1 of the report also contains comments and suggestions on the selection of the style of architecture.

Part 2 relates to the re-adjustment of existing floor plans and offers many comments and suggestions on waiting, toilet, powder, rest and lounge rooms, ticket offices, street entrances, train gates and baggage facilities.

Part 3 covers interior remodeling and offers many comments and suggestions on interior walls, floors, ceilings and lighting.

Part 4 offers many suggestions on heating, as well as a few remarks on the insulation of walls and ceilings as a factor to conserve fuel and the control of summer temperatures.

Part 5 deals with the selection of furniture, telephone booths, baggage lockers, directional signs, drinking fountains, etc.

Part 6, the last part of the report, covers exterior remodeling and gives many suggestions on painting, on chemically washing masonry walls, on doors, windows and their frames, and on roofs and roofing materials.

Many of the factors covered by this report also apply to new construction.

This report will probably be helpful to those who have some remodeling problems on their railroad.

President Loeffler: Thank you, Mr. Schnebelen.

This report is an important one, particularly at this time when the mounting costs of construction, especially the cost of materials, bring about a situation wherein it is very desirable in many cases to remodel or reconstruct existing buildings, rather than construct entirely new structures.

Chairman Dorland: I just wish to say that Mr. Schnebelen's subcommittee has spent a lot of time on this report, and if you haven't read it, you will find it worthwhile to do so.

J. P. Gallagher, general superintendent of insurance and fire protection, New York Central System, was to have addressed us on Fire Prevention, but he wrote to me Monday—sending the letter by one of the men from New York—advising that he is indisposed. He sent his paper, which will be read by L. H. Laffoley. Mr. Laffoley is a former chairman of this committee, and is engineer of buildings of the Canadian Pacific. Mr. Laffoley, will you read this paper?

Fire Prevention and Fire Protection, and the Fire Prevention or Fire Protection Engineer

B. J. P. Gallagher
General Superintendent Insurance and Fire Protection, New York Central System

It is a pleasure to be invited to address you on the subject of Fire Prevention and its importance to the personnel and various departments of the railroads of America. Fire prevention is one of the most important sciences, the application of which is reflecting itself in the economy and stability of our vast rail systems. I speak not only of the railroads of the United States, but also of the great Canadian systems, and of the railroads of countries to our south.

This paper will deal in a general way with the subject "Fire Prevention and Fire Protection," and with those members of the railroads who are assigned to put into effect, in the most efficient way, practices which will result in "fire safe" building construction; the reduction to the minimum, or the elimination of fire hazards in railroad structures; and the reduction of "fire waste" in physical properties and rolling equipment of our rail transportation systems; as well as the loss by fire of property and merchandise while in their respective custodies and for which they may be liable.

Statistics Emphasize Importance of Subject

It might be of interest to note that the 1949 fire loss experience on 272,514 miles of railroad in the United States and Canada records 5475 fires reported, with losses exceeding $8,700,000. This was a marked improvement over the all-time high of more than $11,000,000 for the previous year. Statistical data for 1950 are not available at this time for comparison. The losses in the Canadian provinces included in the above total of $8,700,000 amounted to 609 fires on 42,923 miles of railroad, totalling approximately $880,000. Twenty-one percent of the reported fires occurred in frame or combustible building construction, with a loss exceeding $3,100,000. The greatest number of fires developed in rolling stock, and represented 41 percent of the total, with a loss of approximately $3,000,000. These few references to the statistics should impress upon all of us the importance of fire prevention and fire protection.

Fire prevention is an important consideration in the design of railroad structures. It starts to function before the preparation of plans. It is paramount to the philosophy of "initial cost" nowadays. Who would think of designing a building of frame construction today to accommodate modern signaling equipment? Yet, it was not so long ago that the famous hand-operated signaling equipment, having considerable monetary value, was generally housed in buildings of burnable material, with the possible exception of the foundation at grade. When this type of tower was constructed, apparently no one thought of the serious loss and inconvenience which would be caused by a fire, through the temporary interruption of traffic, and other incidental operating expenses, let alone the financial loss.

Good Housekeeping and Maintenance

Fire prevention is good housekeeping and maintenance. A property which is in an orderly and clean condition from day to day is a good risk as far as fire loss is concerned. It costs considerably less to do a housecleaning job from day to day than allowing accumulations of rubbish to build up to such an extent that it is necessary to call into the picture "company forces and work train service."

Maintenance particularly refers to the correction of minor hazards created by "cure-alls" in electrical and heating deficiencies. It is generally conceded that if employees are not given adequate light, heat and power in this day and age, they are ingenious enough to work out their own problems. If a 10-ampere fuse, which is the watchdog on an average lighting circuit, does not hold up after gradually increasing the load on the circuit by substituting lamps of higher voltage and adding electrical appliances and gadgets for which the circuit was not designed, a 30-ampere fuse takes its place, or the fuses are cleverly bridged, eventually creating a cause of fire. The simple expedient of using incombustible shades on lighting fixtures, or of providing vaporproof globes or wire guards over lamps where their use is indicated, is low-cost maintenance when the possibility of fire loss due to make-shift combustible lamp shades, oversize lamps and other such deficiencies are considered.

The simple weaknesses in heating units in small buildings, such as defective ash pans and bodies, poorly maintained and supported smoke pipes, lack of proper insulation for combustible wall and floor construction under and around heating units, and failure to provide safe clearance between smoke jacks and combustible ceiling finish and roof framing, are another group of conditions which can and should be corrected. The proper selection of fuel for the type of heater in use is always important. Recently, as the result of small properties, such as local passenger stations, freight houses and section houses, being closed during the long week ends, and without attendants to take care of the heating facilities using coal, automatic oil heaters designed for burning No. 1 oil have been substituted. Only a short time ago, explosion and fire was caused by an oil heater due to the fact that a grade of oil was used for which the heater was not designed.

Fire prevention also means the elimination of fire hazards existing in railroad properties. The correction of minor deficiencies, a few of which have been enumerated above, costs little as far as out-of-pocket expense is concerned, compared with the "fire waste" experienced when corrective measures to remove the cause are ignored or are deferred for future action.

Fire protection treats of the control and extinguishment of fire, and the equipment which is necessary to accomplish this. The proper application or assignment of apparatus, whether portable or permanent, to protect properties from damage or destruction by fire should be seriously studied and explored in relation to the hazards presented or existent. Many portable devices for the control and extinguishment of fire are available on the market, but promiscuous use of such apparatus should not be adopted unless recommended by members of the personnel who are familiar with the hazards, and who are qualified to recommend extinguishing equipment which will afford the best protection insofar as an extinguishing medium is concerned. For instance, the use of water on fires involving high or low-tension electrical equipment is prohibited as far as good fire protection is concerned.

Consult Your Fire Prevention Specialists Constantly

What are the railroads doing to promote fire prevention and fire protection and to reduce the annual "fire waste?" Most of our rail systems have specialists to handle this phase of railroad economy and efficiency. These members of the respective personnel are the Fire Prevention Engineers or Fire Protection Engineers. These engineers are specialists in their particular profession. They are qualified to advise regarding new facilities as far as location, exposure and "fire safe" construction are concerned. These men are consultants in fire-fighting equipment and appliances and their application. They are equipped to make recommendations relative to building use and occupancy in their relation to the fire risk. They are interested in design only from a fire prevention and fire protection viewpoint, and leave the structural details and the functioning of the facilities in a building to the departments to which such responsibilities are delegated.

Fire prevention or fire protection engineers assign part of their routine to the inspection of the properties under their jurisdiction, to advise regarding fire hazards which may exist, and to offer recommendations for their correction. Their advice should be obtained in connection with hazards introduced into leased railroad properties, and in connection with the use of side tracks, whether general or private, where the handling of material and commodities may develop a fire hazard or expose railroad property and rolling stock to possible loss by fire or explosion and ensuing fire. Take these men into your confidence! Your respective railroads have created these positions with only one thought in mind—to reduce the "fire waste" on the railroads.

There is no question but that the railroads are benefiting from the activities of the departments to which the responsibilities of fire prevention and fire protection have been assigned. The processes under which they function are governed by rules and regulations promulgated by local, municipal, state and federal authorities; the practices recommended by the National Fire Protection Association, the Bureau of Explosives, the National Electrical Code, the Fire Protection and Insurance Section of the Association of American Railroads, and by other recognized agencies and organizations. In many instances the railroads have adopted standards applying to their particular rights-of-way, using the recommended practices of the above authorities as a basis of such standardization where they are especially applicable. Practical application of these rules and regulations, with the assistance, interpretation and cooperation of the fire prevention and fire protection departments, is the desire of your respective managements, and will help to make the slogan—"Make Fire Prevention a Habit"—a daily reality, rather than a yearly reminder.

Chairman Dorland: Before I leave the platform, I wish to thank the members of this committee for the fine support they have given me. Our committee is endeavoring to police our chapter of the Manual so there will be nothing in Chapter 6 that is more than ten years old, and during the past three years we have recommended changing 41 pages of the Manual. In addition, we have had 26 pages of progress reports. This has all been accomplished by the members of the committee, and all I have done is to encourage them in their efforts.

I would now like to introduce the new chairman of Committee 6, J. B. Schaub, assistant engineer buildings, Illinois Central. Mr. Schaub, will you please stand and take a bow?

Our new vice chairman is O. W. Stephens, assistant to chief engineer—maintenance, Delaware & Hudson.

And I also wish to introduce the secretary of our committee, D. W. Converse, bridge engineer, Akron, Canton & Youngstown. He has been a real help to me, and I want him to stand.

This concludes the report of Committee 6.

President Loeffler: Thank you very much, Mr. Dorland. Your committee continues to make significant reports yearly to the Association. Your committee has one of the largest sections of our Manual of Recommended Practice. This year your committee has made important revisions and additions to its Manual material by submitting the completely revised specifications for sewers and drainage, and also the new lumber specifications for railway buildings.

Also, the Association is greatly appreciative of the paper which was prepared by Mr. Gallagher.

Since the presentation of this report marks the completion of your three years in service as chairman of Committee 6, I take this opportunity of thanking you for your loyal and effective effort in behalf of the committee and on behalf of the Association.

Discussion on Wood Preservation

(For Report, see pp. 311–319.)

(President H. S. Loeffler presiding.)

Chairman G. B. Campbell (Missouri Pacific): Committee 17 records its deep regret upon learning of the death of L. B. Shipley about two weeks ago. Mr. Shipley was a valued member of the committee and chairman of its Subcommittee 8, and had been a member of the committee for many years.

Levi Batchelder Shipley

Died February 26, 1951

Levi Batchelder Shipley died February 26, 1951. Mr. Shipley was born on April 28, 1884 at Seattle, Wash. He was a graduate of the University of California in the class of 1910, with the degree of Bachelor of Science in College Chemistry.

During his school and university years he worked in the chemical laboratory of the Western Sugar Refinery at San Francisco, Calif., from 1898 until 1910. From 1910 to 1912, he was in charge of the chemical laboratory of the same company as assistant superintendent. From 1912 to 1919, he was employed with the Barrett Company as a chemist technical representative, specializing on tars, creosote and floatation oils. From 1919 until his death, he was a consultant chemical engineer for the Bernuth–Lembcke Company.

Mr. Shipley was a Life Member of the American Railway Engineering Association and also of the American Wood Preservers Association, and was very active in committee work of both organizations. He was a member of the New York Chemistry Club, the Newark Athletic Club, and a member and treasurer of the Bloomfield, N. J., Art League.

Mr. Shipley was a talented musician and was deeply interested in art, paintings and antiques, having to his credit several hundred outstanding paintings.

Chairman Campbell: The report of Committee 17—Wood Preservation, is found in Bulletin 491, pages 313–319, inclusive. Several of our subcommittees do not have reports, but I would like to say that a great amount of research work has been done and is being done, and it is hoped that at the next convention we will have some interesting material to present for adoption.

Assignment 2—Service Test Records of Treated Wood, was presented by the subcommittee chairman A. J. Loom (Northern Pacific).

Mr. Loom: The report of Subcommittee 2 is found on pages 314, 315 and 316 of AREA Bulletin 491, 1950. Next year your committee expects to report on the most recent inspections of several more test tracks that were established many years ago. Any service test records that you may submit will be greatly appreciated by the members of this committee.

This report is offered as information.

Assignment 5—Destruction by Wood Destroying Insects; Methods of Prevention, Collaborating with Committees 6 and 7, was presented by Subcommittee Chairman W. F. Dunn, Sr. (Southern).

Mr. Dunn: The report on Assignment 5 appears on page 317 of Bulletin 491, and is a progress report, for information only. However, in connection with the data which W. H. Fulweiler has assembled, Mr. Fulweiler has a few words to say, and a request to make.

W. H. Fulweiler (Chemical Engineer, Philadelphia, Pa.): My plea is that we should give more attention to the effects of insects on the destruction of timber as possible forerunners of decay. We are very much interested in, and are trying to make a survey of the effect of insect damage and its extent.

During the past year I wrote to ten railroads whose lines are primarily in the South, with the expectation that in the southern states we would have more insect damage than in those states in colder latitudes. Apparently, in the light of conversations with the committee, that was a mistake. Many of the insects are attacking quite seriously in our northern latitudes.

My plea, generally, is that if you gentlemen have any experience or run into any examples of what appears to be insect attack, will you be good enough to bear our committee in mind and send us some small samples of the wood, with some brief explanation as to the extent of the damage and your feeling as to its importance? We would like to determine the type of insect and the nature of the damage.

Assignment 7—Incising Forest Products, was presented by Subcommittee Chairman W. P. Arnold (Koppers Company).

Mr. Arnold: The report on Assignment 7 refers to tests for the control of checking by incising which are being conducted by the Erie Railroad. The reports on incised ties installed in track continue to show a very favorable contrast to unincised ties with respect to the number and size of checks. We will continue to report the results of these tests on ties in service by the several railroads.

The report is submitted as information.

Chairman Campbell: The next assignment is No. 8, Review the Specifications for Creosote, Particularly with Respect to Limitation of Residue Above 355 deg. C., and Other Revisions Resulting from Changes in Processes of Manufacture. Walter Buehler has agreed to present this report.

Assignment 8—Review the Specifications for Creosote, Particularly with Respect to Limitation of Residue Above 355 deg. C., and Other Revisions Resulting from Changes in Processes of Manufacture, was presented by Walter Buehler (Technologist, University of Florida).

Mr. Buehler: The report of this subcommittee will be found on pages 318 and 319. Since it is presented for information only, I will not read it, but I wish to make a few comments regarding it.

Our committee gave consideration to the revision of creosote specifications. For many years we have worked in close cooperation with the similar committee of the American Wood Preservers' Association. We were aware of the fact that the American Wood Preservers' Association, at their convention in April, 1950, adopted as a tentative standard new creosote specifications which had some changes—radical changes—from the old specifications.

The major changes had to do with the residue of the creosote above 355 deg., and the gravity of certain fractions. The AREA specifications, as well as the former AWPA specifications, had no provision for a residue limitation; neither did they have in the body of the specifications a provision regarding the gravity of certain fractions.

The new specifications put limitations on the residue, with a minimum of 15 percent and a maximum of 40 percent. It also provides that in the body of the specifications there should be this provision that certain optional purity tests may be had.

The object of the revision on residue was to give recognition to the fact that certain classes of material are more effectively treated with higher residue material than some other classification of material which might require the lower residue.

The provisions regarding the gravity of the fractions were put in the body of the specifications to protect the purity of the product. It has been recognized for some time that the old specifications permitted certain adulterations with petroleum, which were thought very undesirable. Therefore, these gravities of fractions were put in to protect the creosote from this adulteration.

Your committee, realizing that these were major changes, decided not to act on them immediately, but to give them further study.

I might say that the committee of the AWPA recommended that this standard be adopted as the permanent standard at the next convention. That will be next month in Chicago. In the meantime, your committee will give further consideration to these changes, and it is hoped we will be able to make a definite report to you next year.

Assignment 9—Treatment of Wood to Make It Fire-Resistant, was presented by Subcommittee Chairman W. H. Fulweiler (Chemical Engineer).

Mr. Fulweiler: Our report is given on page 319. This is my first year as chairman of this subcommittee, and I regret very much that we can't give you more of a report at this time. However, the subject is a difficult one, and has been complicated largely by the lack of agreement as to what is a suitable standard for fire resistance. It is also hampered by the fact that we have no recognized standard for fire-resistant wood, and, thirdly, we haven't any good acceptance tests.

These three things have been debated back and forth for a number of years. Last Monday we held a meeting of two of the committees interested in this subject—the committee of the ASTM and our committee—and I feel that I can say that the thoughts of the men interested in this work are gradually crystallizing. It looks as though there is going to be very general acceptance of the Underwriters' tests for our classification of fire-retardant, treated materials.

What we are thinking of doing now is to gather up what we can of the work of the various building codes, and attempt to relate that to the work of our Association, so that, in the end, the appropriate officers of the railroads may expect to receive a plea from me for their suggestions as to whether it would not be possible to at least define broadly three or four applications of exposure.

For example, we might say we have a light classification where the value of the material stored or the value of a property in use is not very great, and not fundamentally an essential part of the system. I think of tool sheds and things of that sort that may be exposed to flash fires like, let's say, a grass fire. Light treatment might very well be sufficient to prevent serious damage, or at least retard the rate at which flames spread, until a section gang could get there and take care of the situation.

Then we could have a more valuable material, where the building was such that, while no human life is involved, or very valuable material is stored, it would be very desirable if we could have some protection, affording an opportunity to assemble the necessary forces to take care of a fire if it did occur.

Then, on the high end, we would have structures in which very valuable material or apparatus is stored, such as roundhouses, or where people assemble, such as the stations.

Now, whether it is too early, or whether we can secure the cooperation of the various committees of the Association, we are not clear, but I'm going to make an attempt to see whether I can, and I hope that you will cooperate with me.

This report is only a progress report, and is merely furnished for information, to show how we are thinking.

Chairman Campbell: Mr. President, that concludes the report of Committee 17.

President Loeffler: Mr. Campbell, the report of your committee continues to be of the greatest interest and value to the Association and to the railroads. Your investigations, which result in farther extending the service life of timber, are especially significant at this time, because such procedure not only concerns the nation's timber supply, but also makes available additional manpower, necessary for the nation's defense.

I take this opportunity to thank you personally, and your committee, for your continuing efforts in behalf of the Association. The committee is now dismissed, with the thanks of the Association.

Discussion on Roadway and Ballast

(For Report, see pp. 479–515.)

(President H. S. Loeffler presiding.)

Chairman H. W. Legro (Boston & Maine): Mr. President, this committee wishes to record its profound sorrow in the passing of a man who had been a loyal and hardworking member for many years, a former chairman of the committee, Augustus E Botts.

Augustus Ecton Botts

Died December 10, 1950

Augustus Ecton Botts was born on July 15, 1882, at Bethel, Ky. His early education was obtained in local schools and he attended the University of Kentucky from 1900 to 1903.

He entered the service of the Cincinnati and Ohio Railroad at Cincinnati in October, 1906, as a rodman. In this service he rose steadily, becoming in turn, assistant engineer at Ashland in 1908; division engineer at Ashland in 1911; supervisor of track in 1912; division engineer at Huntington, W. V. in 1914; general supervisor of bridges and buildings system in 1929; assistant engineer maintenance of way from 1929 to 1946; assistant chief engineer in charge of maintenance from 1946 to June 30, 1949, when he retired.

Mr. Botts joined the American Railway Engineering Association in February 1922, becoming a member of Committee 1 in 1924 and served on that committee as vice chairman in 1934 and as chairman from 1938 to 1942 inclusive. He was a member of Committee 22 from 1928 to 1935 and served on Committees 2, 5 and 26 during the period 1936 to 1944. He was made a Life Member of the AREA in 1950.

Augustus Botts was a gracious gentleman who endeared himself to his associates. He was greatly respected for his deep interest in the objectives of the Association and for his accomplishments as chairman of Committee 1.

Mr. Botts is survived by his widow, Mrs. Elizabeth Botts, Richmond, Va.; one son, Ecton Botts, Richmond, Va.; two daughters, Miss Jane Botts, Richmond, Va.; and Mrs. Charles Spain, Charlotte, N. C., and two grandchildren.

Chairman Legro: The Roadway and Ballast committee is in progress of developing and putting into effect practical applications of the adage, "An ounce of prevention is worth a pound of cure." And what is equally to the point, the committee is finding out and is reporting in detail on instances in which relatively inexpensive remedies have resulted in a cure, compared with merely temporary relief afforded by far more costly treatment. I mean, more specifically, the stabilization of the roadbed by various means, which, as Mr. Magee pointed out yesterday, puts money in the savings drawer of the railroad, in the year of application, as well as for many years thereafter.

The committee believes that you will be interested not only in what some railroads are accomplishing in economies of maintenance, as is shown in our reports, but also in the possibility that you, yourselves, may discover and develop from the information given. Thus, your own railroad may obtain money-in-the-pocket benefits from the generous fund allotted by the Association of American Railroads for research sponsored by this committee. We urge you, therefore, to note particularly the progress reports prepared by the research staff.

Mr. President, Committee 1 reports on seven of its ten assignments, and they will be presented by the respective subcommittee chairmen.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman A. P. Crosley (Reading).

Mr. Crosley: Mr. President, the report of the Subcommittee on Revision of Manual appears on page 481, Bulletin 493. It consists of a review of certain sections of the Manual under Roadway and Ballast, which, under the ten-year rule, require action.

The subjects deal with the specifications for the formation of roadway, signs, and cinder ballast. If there are no objections, they are submitted as a whole, with the recommendation that they be reapproved without change, and it is so moved.

(The motion was regularly seconded, was put to a vote and carried.)

Assignment 2 (a)—Physical Properties of Earth Materials—Roadbed, Load Capacity, Relation to Ballast, Allowable Pressure, was presented by Subcommittee Chairman J. W. Demcoe (Canadian National).

Mr. Demcoe: In our report to the convention last year, it was stated that results obtained from subgrade pressures by pressure cells justified additional work, as it was believed that future research would yield information which would be of benefit.

Further study was conducted during the past year by the Engineering Division research staff of the Association of American Railroads, under the general direction of Research Engineer G. M. Magee; Dr. Peck, research professor of soil mechanics, University of Illinois; Rockwell Smith, roadway engineer, and M. F. Smucker, assistant electrical engineer, of the research staff, AAR. The preliminary results of the work done during the past year are published in Bulletin 493, pages 482 to 491, inclusive.

For vertical pressures very good correlation was obtained between recorded and theoretical pressures prior to grouting. There was no change in the relationship of load to calculated pressure intensity after grouting was performed, but the recorded data indicated a slight decrease in the measured pressure intensity. For horizontal pressures, values recorded exceeded the theoretical under the tie, but 8 ft. out from the centerline of track the reverse was obtained.

The data so far obtained are not sufficient to indicate that the reduction of pressure intensity is the result of a wide distribution of the load.

It is quite probable that the action of the cement slurry is beneficial in other ways, such as waterproofing the subgrade, with a consequent prevention of moisture absorption and reduction in strength.

Further work was done in laboratories on investigation of roadbed stabilization studying the factors that cause soft spots in roadbeds. These studies seem to indicate that the beneficial results obtained from track grouting are not physical-chemical reactions or frictional resistance of the grout, and, as stated above the benefit is mostly derived by the grout waterproofing the subgrade, although this is not certain. Benefit of the grout may be due to its injection under pressure into the upper part of the subgrade and the corresponding squeezing of water out of the pockets in the subgrade.

Various techniques of pressure injection of grout in lab tests have been tried, but as yet it has not been possible to inject in a small-scale model in a manner comparable to that in the field. Further attempts will be made to develop a technique for injecting grout into model subgrades.

The report in the Bulletin referred to above is submitted as information for study.

President Loeffler: Thank you, Mr. Demcoe.

This is the third progress report on the study of soil being conducted by the Engineering Division, Research Staff, Association of American Railroads. Are there any comments or discussion on this report? The report will be received as information.

Assignment 4 (b)—Culverts, Installation of Pipe Culverts, In the absence of Subcommittee Chairman A. W. Schroeder (Chicago & Eastern Illinois) the report was presented by W. T. Adams (Armco Drainage & Metal Products Company).

Mr. Adams: The proposed specifications published in Bulletin 493 are submitted at this time for information only.

Chairman Legro: I might add that it is the intention of the committee to receive comments from the members of the Association and to submit the specification next year as Manual material.

Assignment 6—Roadway: Formation and Protection, was presented by Subcommittee Chairman B. H. Crosland (St. Louis–San Francisco).

Mr. Crosland: The report of Subcommittee 6 will be found in Bulletin 493. This subcommittee has three assignments, and, in order to progress its studies more efficiently, the subcommittee was divided into three sections, each with its own section chairman, each of whom was charged with the responsibility of developing his own assignment.

As the chairman of our committee indicated in his opening remarks, the AAR has very generously furnished funds for research work on this important first subject, which is entitled Roadway Stabilization. In connection with this work, Mr. Magee assigned to Rockwell Smith the actual development of the research work and the field studies, and, as you know, for several years Mr. Smith has been preparing progress reports indicating the progress made in various parts of the country on roadbed stabilization.

The early reports were devoted entirely to roadbed grouting. However, in more recent reports, Mr. Smith has attempted to include in the reports other methods of roadbed stabilization as they have been developed by various railroads, with the idea of putting before all of us information that would be useful in this very important struggle in attempting to stabilize our roadbed—a struggle which, because of rising labor costs, is more important now than ever before. I think you will agree with me that, with the increase in labor costs during the last ten years, we need help. I would like to ask all of you to help us in assembling information and in distributing it throughout the industry. If any of you have tried any method that we have not reported on, we would very much like to have you tell us about it. Mr. Smith or someone else will then go and inspect it and get the information from you, and pass it on to other members.

Our report this year should have been submitted to you by F. H. Simpson of the New York Central, who is chairman of that section, but he was unable to be here today; so, at my request, Rockwell Smith has very kindly offered to present the report to you. He made the report, so he will be best able to answer any questions that you may have.

Assignment 6 (a)—Roadbed Stabilization, was presented by Rockwell Smith (Association of American Railroads).

Mr. Smith: Going further with Mr. Crosland's cost of maintenance, I dug out figures from a few years ago, and found that 36 percent of the maintenance dollar went to two labor accounts—track laying and surfacing, and roadway maintenance. Even a minor reduction of this 36 percent will, of course, create vast savings to the industry as a whole.

Further elaboration of the report appearing in Bulletin 493 is hardly necessary, but there are other investigations that have not been reported on as yet, and a very brief discussion of these investigations will be in order.

One of the advantages of the cooperative research program with the University of Illinois is the possibility of integrating the results of various investigations in a broad program, from which all interested parties may obtain greater benefit than would be possible under any one research project of moderate proportions.

We are particularly interested in the broad subject of the stability of embankments, especially with respect to changes in stability conditions with the passage of time. This subject is of great importance to railroad engineers, but it is also important to highway engineers, and to the builders of earth dams. For instance, the Illinois Division of Highways is sponsoring a research program at the University of Illinois in which some of the fundamental aspects of this problem are being investigated. Furthermore, the University is investigating the characteristics of earth dams built by the Corps of Engineers, U. S. Army, some 15 years ago, to determine what changes have taken place since construction. Finally, a close but informal relationship is maintained with the U. S. Bureau of Reclamation in connection with similar construction.

From these investigations Committee 1 is able to secure additional information, away beyond that which is included or could be included in the scope of the investigation financed by the AAR.

Great credit is due Committee 1 for stimulating these other agencies to go into this subject. I am firmly convinced—in fact, I know from almost first-hand information—that these other agencies started this work after the AREA had requested research funds from the AAR.

In many instances information concerning the characteristics of an embankment can be obtained during construction, but the behavior of embankments cannot be determined until after several years have passed. This is particularly true of railroad embankments, which are of a little different type than the average highway or dam embankment. To an undetermined degree, impact and railroad loading have considerable effect upon the action of a fill.

To get this preliminary information, a rather extensive program of tests, both in the laboratory and in the field, have been carried out on several roads. The results of these tests have not been reported, because they will not acquire significance until the behavior of the fills is known.

Much valuable information can be obtained from a study of these unstable fills. One of the most instructive examples has been that of several slides of the Little Mistongo River crossing on the Canadian National near Cochrane, Ont. Several slides occurred at this locality when the railroad was constructed in 1905, and instability has been apparent ever since. The extent of the slide is remarkable, considering the flatness of the terrain. We have found fill material in this particular slide more than 350 ft. from the center line of the track, and, as originally constructed, this particular fill took approximately 20,000 cu. yd. of material.

The record shows that 225,000 cu. yd. of material have been placed in this fill since it was constructed, and its general outline is no larger now than when it was built originally.

The instability of embankments will be understood more thoroughly as a cause of slides when the natural soil strata becomes better known. For this reason, fairly detailed investigations have been carried out in connection with several such slides, some of them of considerable extent, involving bluffs and mountains. Many locations of unstable slopes have been inspected.

The policy is to procure samples of the significant material and to forward them to the laboratory for proper description in terms of results of physical tests. In this manner, rather a large body of useable statistical information is being accumulated.

It is believed that this program will, within a few years, be highly fruitful in promoting a better understanding of the causes and treatment of instability in railroad embankments and cuts. None of this work could have been carried out without the full and complete cooperation of the roads involved, and the committee wishes to extend its thanks for the cooperation that has been received.

This report is presented as information.

Chairman Legro: Your committee is not reporting on Assignment 6 (b) this year. However, a brief preliminary progress report has been prepared on Assignment 6 (c).

Assignment 6 (c)—Chemical Eradication of Vegetation, was presented by G. B. Harris (Chesapeake & Ohio) in the absence of Subcommittee Chairman J. C. De Jarnette (Richmond, Fredericksburg & Potomac).

Mr. Harris: Your committee has prepared a progress report on this subject, which is submitted as information.

Many thousands of dollars are expended annually for weed control on the railways. However, the railroads, for lack of specific information, find it necessary to use the formulations commercially available. These formulations, while successful for many conditions, are designed primarily for agricultural purposes.

Because of this fact your committee has proposed that a research program be initiated, and an appropriation has been approved by the Association of American Railroads for this purpose, and negotiations are under way with Iowa State College to conduct such research. The program to be followed is outlined in the committee's report.

Appraisal and classification by the committee of the results of the research should lead to conclusions or specifications with respect to formulations, dosage, and use in various sections of the country, and under varying climatic conditions.

Assignment 8 (c)—Fences, Instruction for Maintenance Inspection of Fences, was presented by Subcommittee Chairman L. V. Johnson (Minneapolis, St. Paul & Sault Ste. Marie), who read the report as printed on page 505 of Bulletin 493.

Assignment 9—Signs, was presented by Subcommittee Chairman Paul McKay (New York, Chicago & St. Louis).

Mr. McKay: Our formal report, which is presented as information on page 505 of Bulletin 493, is primarily concerned with a study of the reflectorization of roadway signs, and is not concerned with the reflectorization of highway crossing signs, nor of building or station signs.

In the judgment of the committee, the reflectorization of all types of roadway signs would result in unnecessary expense, which could not be justified. Certain types may be reflectorized, where distinct warnings of special conditions are considered necessary by night as well as by day.

Assignment 10—Ballast, was presented by Subcommittee Chairman A. T. Goldbeck (National Crushed Stone Association).

Mr. Goldbeck: The report of Subcommittee 10 consists of reports by two subcommittees, one on Ballasting Practices, under the chairmanship of F. H. Simpson, New York Central, and the other, on Special Ballasts, under the chairmanship of C. D. Turley, Illinois Central.

Mr. Simpson was unable to be here, so he asked me to present his report. I have attempted to condense the report, which is already condensed, and now I am about to perform a miracle—I'm going to condense the condensation.

The report on Ballasting Practices, appearing in Bulletin 493, February 1951, was compiled from an analysis of answers to a questionnaire participated in by 35 individuals representing 22 railroads. The answers showed great variation in ballasting practices as between the different railroads. Only the highlights of the report can be mentioned at this time.

I'm going to content myself by simply mentioning the various subjects that were covered by this questionnaire.

One had to do with size of ballast. The predominant size of stone ballast and slag ballast evidently is still 2½ in. to 3¾ in.; gravel from 1¼ in. to No. 10 sieve, or 1½ in. to No. 4 sieve.

A range in quality of ballast is reported. In Los Angeles abrasion tests losses vary from 8 to 27 percent.

The amount of track lift reported varied, all the way from 3 to 8 in. for reballasting, and from 1¼ to 2½ in. for resurfacing, for stone, and 1 to 3 in. for crushed gravel. It depends upon the conditions and the kind of ballast used.

Many different kinds of tools were used—spades and tamping bars, and hand electric and hand pneumatic tampers, with machines operating up to 16 tools each.

The labor force varies widely too, apparently all the way from 7 men up to 78 men.

Production per machine also varies. I notice the figures go all the way from 440 to 4000 ft. a day. Apparently it depends upon the kind of tools you are using; the power ballaster evidently has the record of 4000 ft. a day, according to the questionnaire.

The cost also depends upon a number of different things. The number of men used has a very important bearing and also the kind of tools used. Most roads prefer machine to hand tamping. Roads using power ballasters believe this type of machine puts up better track than hand tools.

As to the cleaning of ballast, seven roads reported they do not clean ballast at all, and four only do a limited amount of this work. Of the roads which clean ballast, cleaning is confined to crushed materials only.

The frequency of cleaning varies a lot. Some roads clean yearly; others apparently clean at intervals up to 12 years, and no doubt some will have a longer period than that. The machines used consist of a variety of types, as pointed out in the report, although one road, cleaning annually, uses ballast forks and screens.

The question as to whether cribs, center ditches or shoulders were cleaned showed widely varying practices.

With regard to production per machine, I notice the mole-type ranged up to 1200 ft. a day; one road reported 100 ft. an hour; one reported 9/10 to 1¼ miles a week. With the large, on-track machines, some reported up to six miles a day. This was work done by contract, by the way.

The labor force varies greatly with different roads and different machines—with 3 foremen and 13 laborers, 4 foremen and 19 laborers, and so on. One road, using hand methods, uses a regular section gang of 8 men, or extra gangs of 30 men.

Costs also vary, naturally. I notice there are figures of $1700, $1250, $1500, and up to $3000 per mile for cleaning ballast.

On the question of adding new ballast after cleaning, two roads do not add new ballast; another felt it was unnecessary; another adds as required; all other roads add new ballast in varying amounts, so many tons per mile—50 tons, 250 to 300 tons, 1100 tons, 7 to 10 cars, etc. You see, there is a wide variation.

On the question of the relative merits of cleaning or wasting foul ballast, seven railroads consider cleaning to be more economical; two roads consider it more economical to waste the ballast. A number of conditions must be considered, and these are discussed in the published report.

It is quite evident from the answers to the questionnaires on ballasting practices that these practices vary widely between the different railroads, due, perhaps, to the extremely wide range in those factors which, of necessity, affect the behavior of ballast in the track.

Mr. President, this report is offered as information.

Assignment 10 (c)—Special Types of Ballast, was presented by Subcommittee Chairman C. D. Turley (Illinois Central).

Mr. Turley: The report is found in Bulletin 493, February 1951, pages 512 to 515, inclusive.

The extensive use of prepared stone and slag ballast on the heavy-traffic and high-speed railroads has been accomplished by the rather difficult, never-ending and expensive problem of cleaning ballast. Dirt and other fine materials foul the ballast, thereby preventing necessary quick drainage, which eventually soften the roadbed, and rough track results.

At points where adequate surface drainage is difficult to obtain, such as at station platforms and on ballast-deck bridges, track maintenance becomes especially difficult and expensive. In recent years much interest has developed in the use of bituminous asphaltic materials, either mixed with the ballast or used as a covering over the ballast, to prevent fine materials from entering and fouling the ballast and to provide quick drainage, thereby leaving the roadbed hard and dry.

The report this year describes an installation made in 1947 by the New York Central on its steel-deck arch bridge over the Niagara river at Niagara Falls, Ont. The ballast had become fouled, the drainage greatly handicapped, and maintenance conditions affecting both the track structure and the bridge deck were quite unsatisfactory.

The waterproofing on the steel deck and the old ballast on the bridge were completely removed and replaced with new and improved materials. The steel deck was covered with a 1-in. to 1¾-in. coat of asphalt mastic; a two-ply membrane ½ in. thick was then applied and the entire surface covered with a second coat of asphalt mastic 1½ in. thick. All ties were renewed and new clean ballast was applied and brought to proper contour; the track was brought to grade and thoroughly tamped; and then asphalt paving, thoroughly compacted, was placed over the entire ballast surface with a waterproof spray top coat of bitumen and a coat of sand.

Now, after approximately four years of service, the performance of this construction is considered quite satisfactory. The committee will be pleased to learn of other similar installations or tests.

Mr. President, this report is presented as information only.

Chairman Legro: Mr. President, this concludes the presentation of the report of Committee 1. Before the committee retires, however, I wish to record that it has taken note of the suggestions made by P. T. Trax in behalf of our Junior members. Those Junior members who are interested in the work of Committee 1 are cordially invited to sit in with the committee and participate in its discussions. I suggest that interested Junior members write to the chairman of the committee, and he will see to it that they are notified of the time and place of meetings.

With the close of this convention, Mr. President, I relinquish my duties as chairman of Committee 1. I have had a happy term with the hearty cooperation of the subcommittee chairmen and the members of the committee, together with the most helpful consideration on the part of the officers of the Association.

I wish to present my successor, who I know will carry forward the work of this committee with vigor and understanding—G. W. Miller, engineer maintenance of way, Eastern region, Canadian Pacific, at Toronto, Ont., and a member of the Board of Direction of this Association.

I am also glad to present the incoming vice chairman, who I am sure will be a bulwark of support and strength in the committee, and to the chairman—B. H. Crosland, assistant chief engineer of the St. Louis-San Francisco, Eastern district, at Springfield, Mo.

Mr. President, this concludes the report of the committee.

President Loeffler: Thank you, Mr. Legro, and your committee, for another very worthwhile report. We also want to thank Mr. Smith for his cooperation on behalf of the research staff in the work of your committee. We are greatly indebted to you, Mr. Legro, for your services as chairman of this committee. The committee is dismissed.

We have already passed high noon by five minutes, and luncheon is waiting for us. That being the situation, we will defer the report of our Special Committee on Continuous Rail until after lunch. The meeting is recessed at this time. We will reconvene at 2:30 p.m.

(The meeting recessed at 12:05 p.m.)

Wednesday Afternoon Session

President Loeffler: The meeting will please come to order.

We will now hear the report of the Special Committee on Continuous Welded Rail, which report was deferred until after the noon luncheon. This committee was authorized by the Board of Direction and organized during the past year to take over, tentatively, at least, the specific assignments of three of our other committees dealing with the investigations of continuous welded rail. The chairman of this new committee is H. B. Christianson, assistant chief engineer, Chicago, Milwaukee, St. Paul & Pacific, with headquarters at Chicago. I take pleasure in inviting Mr. Christianson and the members of his committee to the platform at this time.

Discussion on Continuous Welded Rail

(For Report, see pp. 589–594.)

(President H. S. Loeffler presiding.)

Chairman H. B. Christianson (Chicago, Milwaukee, St. Paul & Pacific): The Special Committee on Continuous Welded Rail was formed last October. It is made up of members of Committee 4—Rail, Committee 5—Track, and Committee 22—Economics of Railway Labor. The chairmen of these committees did considerable and excellent work to organize this new committee.

The first meeting of the whole committee was held on November 22, 1950, at Chicago. There, the assignment as prescribed by the Board was discussed in detail.

It was decided to set up five subcommittees:

1—Fabrication.
2—Laying.
3—Fastenings.
4—Maintenance.
5—Economics.

A summary of the assignments is given in the report. The subcommittees are all of about the same size, with five or six men, and no member of the general committee is on more or less than one of the subcommittees.

The Chairmen of the subcommittees are:

1—F. W. Creedle of the Chicago & North Western.
2—F. G. Campbell of the Elgin, Joliet & Eastern.
3—J. W. Hopkins of the Bessemer & Lake Erie.
4—C. E. R. Haight of the Delaware & Hudson.
5—I. H. Schram of the Erie.

Our assignment requires that we obtain information concerning costs and the performance of continuous welded rail from railroads that have installed it. The preparation of a questionnaire for this purpose is in process, which will be made as simple as possible and still serve the purpose of the committee's assignments. We are confident that the railroads will do a good job of answering the questionnaire.

The report for this year consists principally of a bibliography on continuous welded rail, which will facilitate a review of the work that has been done in the past in laboratory research and field testing, methods of welding procedure, the laying of continuous welded rail, and allied matters.

Our assignment will involve the study of a substantial number of projects. We expect to have something of value to report next year.

President Loeffler: Mr. Christianson, I congratulate you upon the extensive scope of your assignments, and upon the comprehensive bibliography which you have presented relative to subjects concerning continuous welded rail, as being the first logical step in the study to be made by your committee.

Your committee is involved in a subject of great interest to practically all the railroads and to many of our members. It is confronted with a real challenge in its obligation to run down the correct answers to the questions involved. Your leadership, combined with the strong personnel of your committee, indicate that you will meet that challenge.

The committee is excused at this time with the thanks of the Association.

Discussion on Ties

(For Report, see pp. 305–311.)

(President H. S. Loeffler presiding.)

Chairman B. D. Howe (Louisville & Nashville): It is with deep regret that we record the loss by death on December 10, 1950, of Wilbur O. Nelson (Baltimore & Ohio) a member of Committee 3. Mr. Nelson took an active interest in the work of this committee, and his loss will be keenly felt. It is understood that a more extended memoir of Mr. Nelson will be presented to the Association by Committee 7, of which he was a member for many years.

Committee 3 is reporting on six of its eight assignments. These reports may be found in Bulletins 488 and 491.

(Chairman Howe then called upon the various subcommittee chairmen to present their reports.)

Assignment 2—Extent of Adherence to Specifications, was presented by Subcommittee Chairman P. D. Brentlinger (Pennsylvania).

Mr. Brentlinger: Members of Committee 3 continue to participate in an inspection of the stocks of ties stored at various wood preserving plants throughout the country.

The most recent visits have disclosed a return to near-normalcy of the quality and sizing of cross ties. Careless inspection and intentional disregard of specifications by some railroads that developed during World War II days, were observed to be fast disappearing. Unconfirmed reports today indicate some buyers of cross ties are again up-grading ties in order to replenish stocks in the face of the current scramble for ties. This committee has repeatedly advised the Association of the false economy of paying for sub-standard and up-graded ties, and again goes on record to advise the railroads to adhere to proven specifications and to not be convinced that production will be increased by acceptance of substandard and up-graded cross ties.

Assignment 4—Tie Renewals and Costs per Mile of Maintained Track. Chairman Howe: The statistics for 1949, compiled by the Bureau of Railway Economics, were published in Bulletin 488, page 92, June–July, 1950.

Assignment 6—Bituminous Coating of Ties for Protection from the Elements. In the absence of Subcommittee Chairman R. W. Cook (C. of Ga.) the report was presented by C. D. Turley (Illinois Central).

Mr. Turley: Maintenance engineers have observed over the years that a very large percentage of the causes leading to the removal of ties from track start from the top surface of the tie. The top face, which is exposed to the sun, checks open and provides ready entrance for surface moisture into the tie which, in turn softens and weakens the wood. If the checks continue far enough into the tie to expose the untreated heartwood, decay will be set up since, where oxygen, moisture, mild temperatures and food for the fungi are present in wood decay results.

It seems logical that if a bituminous seal coating or covering is placed over the tops of ties, the top exposed face would be protected from the elements, existing checks would be sealed, and further checking greatly reduced. As a result, the service life of ties would be very materially improved and lengthened.

Service tests are being conducted with different materials by several individual railroads, and by the Timber Engineering Company laboratory at Washington, D. C., in connection with the joint research project of the National Lumber Manufacturers Association and the Association of American Railroads to improve the service life of cross ties. The results to date are encouraging. The tests will be continued and progress reports on them and on new developments will be made to the Association by this committee.

Assignment 7—Causes Leading to the Removal of Ties, was presented by Subcommittee Chairman B. S. Converse (Chicago & North Western).

Mr. Converse: The purpose of this assignment is to determine and study the basic causes for the removal of cross ties from track and to classify these causes for removal as to their order of frequency and importance. From this information your committee hopes to be able to arrive at definite conclusions which should be of considerable value in pointing the direction in which measures to prolong tie life should be undertaken.

It is important to note that in speaking of basic cause we do not necessarily refer to the physical appearance of a tie when removed from track, but rather the initial cause. For example, a track foreman may replace a tie because of severe decay under the tie plate. In all probability this decay was of a secondary nature, resulting from mechanical wear, and in this case the basic cause would be shown under one of the mechanical wear classifications.

Also, this study is not confined to failures alone, it being recognized that ties are removed from track for other reasons.

Some progress has been made on the assignment. The records of 302,621 cross ties removed from track have been received and tabulated, and a report on this limited progress may be found in Bulletin 491, page 309.

It is obvious that the members of this committee do not have an opportunity to examine a sufficient number of ties to progress this assignment properly. Conclusive deductions cannot be made until records of a large number of cross ties removed from well diversified territories have been accumulated, so it is the immediate problem of the committee to find additional sources of tie removal data.

We have made one solicitation of the already over-solicited chief engineers, which resulted in a very encouraging response. We are in hopes that this year other engineering officers might be persuaded to designate roadmasters, track supervisors or other qualified personnel to inspect ties removed during the season's work in the interest of this study, and to tabulate the causes leading to removal on the established form.

President Loeffler: Thank you very much, Mr. Converse, for this preliminary report, which will be received as information. We will be looking forward with great interest to the presentation of the final report on this subject, which we expect will be presented either next year or the following year.

Assignment 8—Prebored Ties: Benefits and Factors Affecting Economy.

Chairman Howe: W. J. Burton, Missouri Pacific, chairman of the subcommittee, could not be present. This is a final report, and is presented as information. It may be found on pages 310 and 311 of Bulletin 491.

President Loeffler: The report will be received as information.

Assignment 5—Methods of Retarding the Splitting and Mechanical Wear of Ties, Including Stabilization of Wood, Collaborating with the NLMA:

Chairman Howe: T. H. Friedlin of the New York Central is chairman of this subcommittee, the report of which may be found on pages 307 and 308, Bulletin 491.

It is felt that no study now being made by Committee 3 has greater general interest than the work being done by the Timber Engineering Company under the direction of G. M. Magee, research engineer, AAR. We are again fortunate in having Mr. Magee with us today, and he has consented to bring us up to date on this important work.

G. M. Magee (Association of American Railroads): As Mr. Howe has told you, he asked me if I would meet with you today and bring you up to date on what I told you last year about the research work under way at the Timber Engineering Company laboratory in Washington. You remember that three years ago we entered into a cooperative agreement with the National Lumber Manufacturers Association, whereby we would share equally in the costs of conducting a program of research for the purpose of reducing the checking and splitting of ties and otherwise prolong tie life. I think the best way to go about that will be to discuss the various phases that are being investigated.

Progress in Cross Tie Research

By G. M. Magee

Research Engineer, Engineering Division, AAR

I mentioned last year that a number of damaged ties removed from track from various locations in the United States had been sent to the TECO Laboratory for study by their wood technicians. In practically no case was there found to be evidence of decay, most of the damage being due to tie abrasion or to splitting and checking.

I also indicated that some evidence had been found of a chemical deterioration of the tie fibers under the tie plate from corrosion of the bottom of the plate and the spikes. It was considered that the moisture, and perhaps some of the acids in the ties, had attacked the bottom of the tie plate, causing iron to be taken in the solution, and that this iron in solution had, in turn, attacked the cellulose structure of the wood fibers, causing some deterioration. Further study has indicated that this condition actually exists to some extent, although it is not yet certain as to how important a factor this chemical deterioration may be in producing tie wear to the extent that necessitates tie renewal.

Laboratory tests were also made with outdoor exposure of steel plates on samples of wood which had been treated with lime water, and on other specimens which had not been so treated—both being subjected to atmospheric corrosion conditions. It was found that the neutralizing of the wood fibers adjacent to the steel surface with lime water preserved the wood in much better condition.

The work on the prevention of splitting and checking of cross ties has several different phases. As reported last year, it was found that most of the splitting and checking originated during the seasoning period of the ties in the tie yard. Accordingly, one of the most important projects has been experimental work looking to the development of a treating process which will eliminate this seasoning period, and permit the treating of the ties as soon after they are cut as possible. Following up the results in the small treating cylinder experiments reported last year, laboratory equipment was provided of sufficient capacity to treat a 7-in. by 9-in. timber, 4 ft. long, or approximately one-half the size of an ordinary crosstie. The results obtained in tests with this equipment indicate that glycol, in combination with the regular creosote-coal-tar treating solution, gives promising results with respect to the prevention of splitting and checking, and also gives good penetration of the preservative. However, the amount of glycol retained in the tie was so much that the cost of treatment with this chemical would, unquestionably, be uneconomical.

Accordingly, laboratory studies were continued in search of some other less expensive chemical that could be added to the treating solution for the purpose of attracting the water from the wood cells and permit them to be filled with the treating solution. After considerable work it was found that a glycol-borate mixture appeared to be quite effective, and that the cost of the chemical retained appeared to be within economic possibilities. Tie sections have been treated by this method and are now undergoing exposure tests in the laboratory yard. This treatment requires that the temperature of the ties be brought up to approximately 325 deg. F., and there is some concern as to whether temperatures this high may have a damaging effect of consequence on the strength of the wood fibers. This question will, of course, have to be thoroughly explored. Arrangements are also being made to have full size ties treated by this process and installed in track as quickly as possible so that their service performance can be observed.

Another phase of the research work which appears promising is the coating of the tops and end of ties in track, to protect the wood against the moisture and temperature changes to which it is normally subjected. An outside exposure yard has been established near the laboratory, in which short sections of treated oak ties have been placed in stone ballast and coated with various types of protective materials. The development of seasoning splits and checks is periodically observed and recorded. Some of the coatings used have indicated very good protection after one year exposure, both in preventing the development of additional checks, and in filling in to some measure and preventing the continued growth of splits and checks already formed.

Consideration is also being given to the possible development of a laminated tie. The AAR research staff, in cooperation with the TECO engineers, conducted stress measurements last year on wood ties in railway track of sharp curvature. Tests were made on a tie in both end-bound and center-bound condition to obtain information on the bending stresses developed under most severe service conditions, and to learn what strength would have to be provided in a laminated tie to give satisfactory service. With this information now obtained, consideration will be given to possibilities in tie design. It will also be necessary to give further study to means of making the laminations, as the present cost of laminated construction would have to be reduced materially to make this construction a practical and economical procedure for crossties.

An advisory committee consisting of six representatives from the AAR and six representatives from the manufacturers are working closely with the TECO engineers in this research work. This administrative committee is cognizant of the needs for making substantial reductions in the large annual expenditures of the railways for crossties, and is giving the TECO technicians all the assistance and benefit of their advice and experience they can to progress this work to a successful conclusion.

Chairman Howe: Mr. President, this concludes the report of Committee 3.

President Loeffler: Mr. Howe, it is evident from your reports that your committee is continuously alert to discover and recommend new ways and means of extending the service life of track ties. Your efforts in that direction throughout the years have resulted in substantial savings to the railroads.

The committe is excused with the thanks of the Association.

Discussion on Track

(For Report, see pp. 517–588.)

(President H. S. Loeffler presiding.)

Chairman F. J. Bishop (Akron, Canton & Youngstown): The report of Committee 5—Track, will be found in Bulletin 493, which Bulletin is divided into two parts—Parts 1 and 2.

Your committee has lost the services, through death, of two of its very valued members during the year—A. E. Botts of the Chesapeake & Ohio, and G. J. Slibeck of the Pettibone-Mulliken Company.

Mr. Slibeck served on this committee for many years. In his memory, a memoir has been prepared by a committee headed by Carl Johnson, and it appears on the following page.

Since Mr. Botts had been chairman of Committee 1—Roadway, for many years, that committee has prepared a memoir for him, which is included with its report.

Your committee was assigned ten subjects, and we are reporting on all but two of them.

Gustave J. Slibeck

Died January 9, 1951

Gustave J. Slibeck, engineer and sales representative of the Pettibone, Mulliken Company, Chicago, died on January 9, 1951, at Chicago, Ill.

He was born in Chicago, November 22, 1880, and received his higher education at the Lewis Technical Institute. He married Gertrude Rockwell on June 19, 1907. He entered the railway service with the Cleveland, Cincinnati, Chicago & St. Louis Railroad (Big Four) as a rodman on location and construction work in 1904, at Greencastle, Ind. In 1905 he went with the Southern Pacific Lines as a rodman, and subsequently held the positions of levelman, transitman, and assistant engineer on location and construction at points in both the United States and Mexico. Two years after going west he returned to Chicago as office engineer, in the maintenance-of-way department of the Chicago, Rock Island and Pacific Railroad. In 1911 he went with the Missouri Pacific Lines, where he successively held the positions of assistant engineer, roadmaster and division engineer in the maintenance of way department. His first connection with the railway supply industry was with The Buda Company, as salesman. He went with the Pettibone, Mulliken Company as chief engineer in 1915, and in a few years entered the railroad sales department of that company.

Mr. Slibeck became a member of the American Railway Engineering Association in 1918, and was active on Committee 5—Track, from 1920 until the time of his death.

He was a member of the Bunker Hill Country Club, the Hamilton Club, the Maintenance of Way Club of Chicago; the Roadmasters' and Maintenance of Way Association of America, and the Chicago Engineers' Club.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman C. R. Strattman (New York Central).

Mr. Strattman: The report of Subcommittee 1 is found on page 518, Bulletin 493, and since it is short I will read it.

(Mr. Strattman then read the report on Revision of Manual.)

Mr. Strattman: I move the adoption of this report.

(The motion was regularly seconded, was put to a vote and carried.)

Assignment 3—Track Tools, was presented by Subcommittee Chairman Troy West (Union Railroad).

Mr. West: Your committee presents the following recommended practice for adoption and publication in the Manual:

On page 5–54.1 of the Manual in II Plans for Track Tools, under Recommended Limits of Wear for Tools To Be Reclaimed, add the following clause: "For reclaiming alloy track tools, company forces should be limited to grinding methods; where it is advisable to reclaim them by heating methods, due to the numerous and continuous changes in alloy, they should be returned to the manufacturer who is familiar with their precise metallurgical content."

This recommendation by Subcommittee 3 came about through a study of the use of carbon and alloy steels in making spike mauls, to guard against the spauling of the metal of striking tools, with possible injury to men.

This action was endorsed by the members of Committee 5 in a letter ballot, in which 79.5 percent of the members approved.

Therefore, I have been directed by the committee to move that the recommended practice as stated be adopted and published in the Manual.

(The motion was regularly seconded, was put to a vote and carried.)

We show in the Bulletin revised AREA Claw Bar, Plan 11–51, to show the location of hardness points. Plan 11–50 in the Manual on page 5–59 does not show hardness points, which we consider was an oversight.

Subjects offered as information by the subcommittee appear on page 520 of the Bulletin.

President Loeffler: Is it your thought, Mr. West, that the addition to the drawing covering the claw bar should be approved for Manual material?

Mr. West: Mr. President, we didn't consider it was necessary that it be approved, since it was felt it was a correction only.

President Loeffler: Thank you. The latter material referred to will be received as information.

Assignment 4—Plans for Switches, Frogs, Crossings, Spring and Slip Switches, was presented by Subcommittee Chairman M. J. Zeeman (Atchison, Topeka & Santa Fe).

Mr. Zeeman: The report on Assignment 4 will be found in Bulletin 493, beginning on page 520 and ending on page 553. The drawings are contained in the Supplement to Bulletin 493, Part 2.

As stated in the opening paragraph of this report, on page 520, your committee has found it desirable to recommend the revision of a rather large number of trackwork plans. A short outline of the reasons for the revisions in the frog and switch plans under consideration is given on page 520, items 1 to 6, inclusive, covering curved switches, tie layouts for all switches, switch point planing, location of holes in switches, hook twin tie plates, and railbound manganese steel insert frogs.

Your particular attention is directed to the revision of the curved switch plans, item 1. Of the present four lengths of curved points, we desire to retain two lengths, the 19-ft. 6-in. and 39-ft. 0-in. lengths, and recommend to change the 11-ft. 0-in. and 30-ft. 0-in. lengths to 13-ft. 0-in. and 26-ft. 0-in. lengths, respectively. As stated in item 1, improvement has been made in all curved switches by providing a better balance between the switch curvature and lead curvature, resulting in a shorter lead for several turnouts.

The plan numbers of the switches, both straight and curved, and details for same, which your committee offers for adoption as recommended practice to replace the present issue of each plan, are shown on the upper half of page 521; also the third item from the top on page 522.

Mr. President, I move the adoption as recommended practice, for publication in the Portfolio of Trackwork Plans, the following plans, to wit:

Plans 111 to 118, inclusive, 121 to 128, inclusive, 181, 209, 221, 222 and 920, all with suffix–51, and that the present issue of each plan be withdrawn from the Portfolio.

President Loeffler: Do we hear a second to that motion?

(The motion was regularly seconded.)

President Loeffler: This is important Manual material which is offered for publication, and involves the withdrawing of present Manual material. Is there any discussion on this subject? Does anyone know of any reason why these new plans shouldn't be adopted?

(The motion was put to a vote and carried.)

Mr. Zeeman: Plan 241 covers twin tie plates. On new plan 241–51, the hook design of twin tie plate is substituted for the plain flat plates to provide a shoulder against the rail base. This affects plans for graduated riser switches as well as all of the frog plans.

As explained in the footnote following the asterisk at the bottom of page 521, your adoption of new plan 241–51 would authorize us to revise the individual plans affected for issue in the 1951 supplement to the Trackwork Plans. For ready reference, this information is shown at present on a single sheet, plan 241–A, which is included with the other plans in Part 2 of Bulletin 493. Therefore, plan 241–A will be dropped when the information on this plan has been transferred to the individual plans.

Since we are now dealing mainly with frog plans, we wish to consider also the revision of plan 600–51, Rail Bound Manganese Steel Insert Frogs, which plan has been revised as outlined in item 6 on page 520.

Mr. President, I move the adoption, as recommended practice, for publication in the Portfolio of Trackwork Plans, of plans 241–51 and 600–51, with the understanding that adoption of plan 241–51 authorizes the revision of the 16 plans on page 521 and the 2 plans at top of page 522, identified with an asterisk before the plan number; also that the present issue of each plan be withdrawn from the Portfolio.

President Loeffler: Do I hear a second to that motion?

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Zeeman: As stated near top of page 522, lack of time prevented your committee from revising some details on plan 912–41, Bills of Timber for Turnouts and Crossovers, and plan 921–41, Location of Joints for Turnouts with Curved Split Switches. Your approval of the new plans for curved switches necessitates revision of Table B, Bill of Timber for Turnouts with Curved Switches, and Table D, Bill of Timber for Crossovers with Curved Switches, on plan 912–41, and a complete revision of plan 921–41.

With reference to plan 768–50, as mentioned on page 522, it has been found that in the title of this plan the weight of rail limitation "for rails less than 6 in. in height" was omitted, and we desire to republish this plan with the correct title.

Therefore, Mr. President, I move to withdraw table B and table D on plan 912–41, and to withdraw plan 921–41, with the understanding that the committee intends to revise these two plans during the year and submit them to the convention next year; also that plan 768–50 be republished as plan 768–51 entitled Manganese Steel Insert Crossings, Angles 14 deg. 15 min. to 8 deg. 10 min., for Rails Less Than 6 in. Height.

President Loeffler: Do I hear a second to that motion?

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Zeeman: As mentioned on page 522, your committee has completely and carefully reviewed the AREA specifications for Special Trackwork, Appendix A, in the Portfolio of Trackwork Plans. Since these specifications have not been reviewed since 1942, all references to specifications sponsored by other associations have been brought up to date and the intent of the requirements has been clarified. The result of this review and your committee's recommendations for revision of certain paragraphs are shown on pages 522 to 528.

Mr. President, I move that the paragraphs of Appendix A, shown under Appendix A, beginning on page 522 and ending with paragraph 1304 on page 528, be approved for insertion, and that the present corresponding paragraphs be withdrawn from Appendix A–42; no change to be made in any paragraphs not mentioned.

President Loeffler: Do I hear a second to this motion?

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Zeeman: Your committee wishes to acknowledge the hearty cooperation of the Standardization committee of the Manganese Track Society and of the manufacturers in the drafting of these plans and in reviewing the specifications of Appendix A presented in this report.

Your committee also wishes to present three progress reports. The first, Service Tests of Designs of Manganese Castings in Crossings at McCook, Ill., is shown on page 528 as Appendix 4–a.

The second report, covering Service Test of Solid and Manganese Insert Crossings Supported by Steel T-Beams and Longitudinal Timbers, is shown on page 529 as Appendix 4–b.

The third report, covering Crossing Frog Bolt Tension Tests, is shown as Appendix 4–c on page 532. These three subjects are handled by the research staff of the AAR, and these reports have been prepared under the general direction of Mr. Magee. No definite conclusions can be reported at this time, and the study of each of these subjects will be continued. Therefore, Mr. President, these three reports are presented as information.

This concludes the report on Assignment 4.

Assignment 6—Design of Tie Plates, was presented by Subcommittee Chairman J. de N. Macomb (Inland Steel Company, retired).

Mr. Macomb: The report on this assignment is on pages 553 to 563, inclusive, of Bulletin 493, February, 1951.

Figs. 1 and 2 on pages 554 and 555, respectively, are 15-in. and 16-in. tie plates, with eccentricity of 1¼ in., for use on curves where needed: Fig. 1 for 5½-in. rail base width; and figure 2 for 6-in. rail base width.

Punching arrangements are the same as those of plans 7 and 12, respectively, in the Manual.

These tie plates are for use on either or both rails of curves, including portions of the spirals, where observation of tie plate cutting or past experience indicates that one or both rails cant outward sufficiently to require too frequent re-adzing and re-gaging.

Figs. 1 and 2 are offered for adoption as recommended practice and publication in the Manual, and I so move.

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Macomb: Pages 556 to 563, inclusive, contain a progress report covering the service performance of seven designs of tie plates on the Illinois Central, near Curve and Henning, Tenn., these studies having been made by the research department. This report is offered as information.

President Loeffler: It will be so received.

Mr. Macomb: That completes the report on Design of Tie Plates.

Assignment 7—Hold-Down Fastenings for Tie Plates, Including Pads Under Plates; Their Effect on Tie Wear, was presented by Subcommittee Chairman Blair Blowers (Erie).

Mr. Blowers: This is a progress report, submitted as information.

The chief objective of this assignment is to determine the most effective and economical methods for extending the service life of ties by minimizing plate cutting and the amount of regaging on curves.

The major service test installation for this investigation is located in the northward main track of the Louisville & Nashville, near London, Ky., and is about 1¼ miles long. Included in this test are 45 different sections, many of which are further subdivided and duplicated on tangent track as well as on curves. Sixteen designs of fastenings, 15 kinds of tie pads, and 15 different coatings and adhesives are being tested.

The major portion of the test installation was built in 1947, and has had only 55 million gross tons of traffic over it since the base readings were taken. During the three-year period (and less for subsequent additions) the plate cutting has been quite small. In general, the special hold-down fastenings showed less tie wear than in the cut-spike construction. All of the tie pads, except one, have eliminated tie abrasion. Only the coated tie pads and two of the coatings applied to the bottoms of the tie plates held the moisture content of the wood under the tie plate to an amount below the fiber saturation point of 26 percent.

A considerably longer test period will be necessary to determine the serviceability of the hold-down fastenings and tie pads.

The Association is greatly indebted to the L. & N. for its contribution in installing these tests, and also for the assistance rendered by the manufacturers.

Assignment 8—Effect of Lubrication in Preventing Frozen Rail Joints, was presented by Subcommittee Chairman C. W. Breed (Chicago, Burlington & Quincy, retired).

Mr. Breed: At the time the joint lubrication test was installed, July 1945, it was decided, in addition to studying the life and effects of lubricating materials, to observe their effect on bolt tension, joint gaps and joint-bar pull-in.

This year's report is a progress report and contains certain definite information as follows:

As to Joint Gap—No condition tested was effective in bringing about a superior uniformity of rail gap width, particularly in cold weather.

As to Joint-Bar Pull-in—There was no indication that any of the lubricants reduced joint wear. A final conclusion will be arrived at in 1951.

As to Bolt Tension—The test indicates little difference in loss of bolt tension as between headfree and head-contact bars, as between lubricants used, or in joints where no lubricant was used. This test early indicated the positive need for end plugs to protect the joints, as well as the lubricants, particularly on the receiving end of joints.

The new tests on the Illinois Central were installed in June 1950 for the purpose of investigating the service performance of new types of rust preventives or lubricants, different methods of application, lubricants with end plugs, and end plugs on joints without lubricants, and the investigation of any related matter which may develop.

The work under this asssignment, including the preparation of the report, was done by Mr. Magee and his assistants.

Assignment 10—Critical Review of the Subject of Speed on Curves as Affected by Present-Day Equipment, was presented by Subcommittee Chairman J. W. Fulmer, (Southern).

Mr. Fulmer: In 1914 a special subcommittee made a report on the proper elevation of curves for comfortable riding at various speeds. It was the opinion of the committee that passengers would experience no discomfort if trains were operated on curves at a speed that would require 3 in. additional elevation to give equal pressure on the inner and outer rails. This conclusion was based upon the personal observation and experience of committee members. The present AREA recommended practice for elevating curves is based upon the findings of this special subcommittee.

Another subcommittee published a report in 1929 giving the practice followed by various railroads in elevating curves. This report contained information from 47 roads. Some of them followed AREA recommended practice, while others followed it with modifications.

Several minor reports have been made on the elevation of curves, but none of them has been as comprehensive as those published in 1914 and 1929.

In casting about to determine the best way to carry out the present assignment: Critical Review of the Subject of Trains on Curves as Affected By Present-Day Equipment, the subcommittee learned that the AAR research staff has scientific instruments that can be used to measure the riding comfort of cars operated on curves at various speeds. After consulting with Mr. Magee, research engineer, the committee decided to use these instruments to determine the proper elevation of curves, rather than to depend upon personal opinions or to make a recommendation based upon the present practices of the various railroads.

A preliminary test run was made on the L. & N. between Cincinnati, Ohio, and Bowling Green, Ky., last May. This was made possible by L. L. Adams, assistant chief engineer of the road. The Research Staff instruments were installed on the C. & O. track inspection car being operated over the L. & N. Twelve members of the Track committee and representatives of interested manufacturers accompanied the research staff on the inspection trip, and acted as observers to correlate their impressions of riding comfort with the readings of the test instruments.

February Bulletin 493 contains the report of the research staff on this preliminary test run. Much valuable information was obtained, which will serve as a guide for future work on the assignment.

President Loeffler: Mr. Fulmer, I would like to know whether the matter of the length of easement curves is a part of this assignment.

Mr. Fulmer: Yes, sir; I think that is to be taken into consideration. It is really in Mr. Magee's hands.

President Loeffler: That is really very important in the rating of curves. I am glad to know that it is included in the assignment.

Chairman Bishop: Mr. President, that completes the report of the Track committee.

President Loeffler: Mr. Bishop, it is quite evident from the examination of the reports just presented that your committee has been very active during the past year, and has presented material of considerable interest to our members and the railroads. Your efforts are greatly appreciated by the Association.

The committee is excused with the thanks of the Association.

Discussion on Rail

(For Report, see pp. 595–704.)

(President H. S. Loeffler presiding.)

Chairman Ray McBrian (Denver & Rio Grande Western): The full report of the committee has been sent you in published form, in Bulletin 493, February 1951. The 11 assignments of the Rail committee have been covered in progress or information reports. However, it is the desire of the committee to acquaint you again with the problems under study. Therefore, we wish to present a series of four short addresses covering the important topics assigned to us.

First, however, we must have action on our Assignment 1—Revision of Manual. Mr. Code, chairman of that subcommittee, will present this to you.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman C. J. Code (Pennsylvania).

Mr. Code: My chairman told me he had allowed me 12 min. for my presentation and that I was to make the recitation of specifications glamorous. I studied that directive quite a while, and still don't know how to do it.

Not long ago at a technical meeting I heard the following new definition of a specification: A specification is a description of the worst piece of material that the manufacturer can expect the purchaser to accept." (Laughter)

Since that is a somewhat cynical viewpoint, I tried to dig up another one of my own, and have come up with this: "A specification is a description of what we want, adjusted to fit what we think we can get." (Laughter)

We have one specification to recommend for reapproval in its present form. That is the specification for beveling or slotting of rail ends, and I move its reapproval. It is found on pages 4–21 to 4–23, inclusive, in the Manual.

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Code: We have revision of three specifications to recommend. A specification, like a railroad, has to be maintained. As new things turn up, it has to be adjusted.

The first one is the rail specification. The proposed revisions are the result of several years of conferences between representatives of the Rail committee and of the Technical committee of the American Iron and Steel Institute. The specifications are on pages 4–1 to 4–6, inclusive, of the Manual.

I neglected to state that these revisions are shown in Bulletin 493, on pages 596 to 605, inclusive. The changed portions of the specification, only, are shown.

The change in article 201 separates chemical analysis of rails 70 to 90 lb. per yd. into two groups—70 to 80 lb. and 81 to 90 lb., assigning a lower carbon range to the rails 70 to 80 lb. This was done at the request of the manufacturers, inasmuch as they stated that they had difficulty meeting the drop test requirements for the higher carbon in the 70 to 80-lb. range.

The change in Art. 203 authorizes the use of average analysis from three ingots, conforming with present mill practice. The change in Art. 405 places the entire 1/16-in. tolerance in bolt size on the plus side, eliminating bolt holes less than standard size.

Paragraph (d) is added to Art. 207 to permit stamping "CC" instead of branding on rails 100-lb. per yard and lighter, except 100 R.E. The reason for this is that rails of the lighter weights are frequently rolled for export without control cooling, and the present specification would require grinding off the letters "CC" on the brand side.

The change in Art. 408 fixes more exactly the position of the thermocouple at the end of a rail in the middle tie for control cooling.

I move that the proposed revisions of Specifications for Open-Hearth Steel Rails be adopted.

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Code: As a result of conference with the steel manufacturers, and thorough consideration and recommendation by Subcommittee 8, Revision of Specifications for Quenched Carbon–Steel Joint Bars, Manual pages 4–21 to 4–23, inclusive, is recommended for adoption. The changes in the specifications in their proposed form are given in the Bulletin.

Except for Art. 5 and 12, the changes are of an editorial nature. Art. 5 permits a higher manganese content in order to give the manufacturers greater leeway, while Art. 11, formerly Art. 12, calls for a greater number of tests, which it is believed will give improved control over the quality of the finished product. The increase in manganese content was given thorough study, and it is the opinion of the members of the committee that the greater leeway provided in the manganese content will not be in any way harmful, while the greater number of tests will be of material advantage in controlling the quality of the finished bars.

The editorial changes made bring the specifications in line with the corresponding specifications of the American Society for Testing Materials. That society is considering changes in manganese content and number of tests, the same as we are now proposing, so that when the two specifications are revised, they will be practically identical.

I move that the proposed revision of Specifications for Quenched Carbon-Steel Joint Bars be adopted.

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Code: As a result of tests conducted by R. P. Winton, and of studies by him and C. B. Bronson, incidental to the work of a committee of the American Standards Association, revision of the Specifications for Heat-Treated Carbon-Steel and Alloy-Steel Track Bolts is recommended for adoption. The specifications in their proposed form are given in the Bulletin. Editorial changes have been made throughout the specifications. The ASTM is also considering editorial changes in their specification, and when the two proposed specifications are adopted, they will be practically identical.

The term "medium carbon nuts" has been substituted for the term "high strength nuts," the new term being more accurately descriptive.

In Art. 6, the two grades of carbon steel have been combined into one, having the superior physical properties generally of the grade two, except that the ductility requirements of grade one are retained. These are sufficient and give the manufacturers somewhat greater latitude.

Art. 9 has been radically revised, and gives more specific and more rigid strip test requirements, which have been agreed to by the manufacturers.

Art. 13 has been revised to add a maximum tightness requirement for the bolts with free fit, and to emphasize the free fit as the prevailing type, with a wrench-turn fit as an alternative.

The following additional editorial changes, not shown in the draft present in the Bulletin, are necessary:

In Art. 1, add the words, "also carbon-steel nuts."

In Art. 8, paragraph (a), omit the words, "grade one and grade two."

In Art. 8, further, under "Bend Test," place the phrase, "without cracking on the outside of the bent portion," after the word "degrees" in the third line, so that this sentence will then read: "8 (a) Full size carbon-steel track bolts shall stand being bent cold through 45 deg., without cracking on the outside of the bent portion, around a pin. the diameter of which is equal to the diameter of the bolt."

The same change is to be made in the location of the phrase in Art. 8 (b). This change in paragraphs 8 (a) and 8 (b) will make the language similar to that used in the specifications for joint bars.

In Art. 9, in the headnig over the table, use the words "minimum load pounds" instead of the words "nominal strength pounds."

In Art. 9, under the table, add a note: "The above is predicated on minimum thickness of nut being equal to the nominal bolt diameter."

I move the adoption of the proposed revisions of Specifications for Heat-Treated Carbon-Steel and Alloy-Steel Track Bolts, including the editorial changes previously mentioned.

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Code: As a result of several years of painstaking study by a committee of the American Standards Association, in which Messrs. Bronson and Winton of the Rail committee took an active part, there have been presented revised tables of dimensions of track bolts, Manual pages 4–33 to 4–35, inclusive. These appear currently as Figs. 414 and 415, and Tables 401 and 402 of the Manual.

A revision of Fig. 416 and Table 403 had also been prepared; however, this revision failed to obtain the required two-thirds affirmative vote of the Rail committee when submitted to letter ballot, and is. therefore, not included in the recommendations for adoption.

I move the adoption of Figs. 1 and 2, as well as Tables 1 and 2, as presented in the Bulletin, replacing the tables and figures currently appearing on Manual pages 4–33 to 4–35, inclusive, excepting Fig. 416, Track Bolt Nuts, on page 4–35, which will be given further study.

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Code: That concludes the report of Subcommittee 1.

President Loeffler: Thank you very much, Mr. Code.

Mr. McBrian, you may proceed.

Chairman McBrian: Mr. Code, for a very dry subject, I think you did a glamorous job. Most members don't realize what revision of the Manual means, and the amount of work involved. Mr. Code has certainly done a marvelous job with it, and I am very happy with his presentation.

The next item on the program will be an address on Rail Failure Statistics and Their Reporting, by G. M. Magee, research engineer of the Engineering Division, AAR.

Might I call your attention to the vital fact that many roads are making improper classification of rail failures? We deem this a very serious matter.

Rail Failure Statistics and Their Reporting

By G. M. Magee

Research Engineer, Engineering Division, AAR

We are sometimes prone to fail to appreciate fully the good things which we have day after day, and I believe this may be the case with our rail failure statistics. I think we may not fully realize and appreciate the improvement in rail performance and the reduction in rail failures over the period of years as reflected in these statistics, and that we may not have fully realized the use and value that the statistics, in themselves, have to us in assuring that the quality of rail purchased is as good as present art makes possible, and in the guidance that they afford us in the design and maintenance of rail. Much importance is attached by many people to having a proving ground, and considerable credit is given to certain industries which maintain such a proving ground for testing their products. I believe that the railway industry, in its system of rail failure statistics, has the largest and most satisfactory proving ground in the world.

Let us consider, for example, that each rail of the some 1½ million tons that will be rolled and laid this year, will have its own separate indentity when it goes into track. The brand will show its cross section design, the company and mill that manufactured it, the month and year it was rolled, and that it is open-hearth process and control cooled. In addition, the rail will be stamped to show the number of the heat and the specific furnace that it came from, its ingot number, and its position in the ingot. From now on that rail is in the proving ground. It is tested periodically by rail detector cars, and if a failure is detected or developed in service it is reported on a comprehensive form by the sections foreman. If the type of failure is thought to be a transverse fissure, a specimen of the rail is sent to the University of Illinois for metallographic test to determine whether the rail was properly control cooled to eliminate shatter cracks. At the end of the year the chief engineers of the railways send to our research office a report of the failures that have occurred in each year's rolling of rail, with respect to the mill and the type of failure. The annual report of the Rail committee to the Association gives the current results as we learn them from this vast proving ground of rail performance.

I would like to refer to a few of the charts that are shown in this year's report and point out to you their particular significance. Figure 1 on page 612 gives the number of service and detected rail failures reported by 61 roads, comprising practically all of the main-line mileage of the United States. This chart is particularly interesting to us because it shows the extent to which we are reducing our annual service failures by the use of detector cars, and by the replacement of rail not control cooled with control-cooled rail. It is gratifying to note that the total number of service transverse fissures marked line "A" in the figure has steadily declined since 1943, indicating the effectiveness of these two measures.

The line marked "B" shows the number of detected transverse defects. This line showed a decrease from 1943 to 1946, and then an increase in 1947, and an even more sharp increase in 1948. This does not actually mean, however, that the number of detected transverse fissures increased in those years. Many railways do not break their detected transverse defects to permit classification with respect to transverse fissures, compound fissures, detail fractures, and engine-burn fractures. Beginning in 1947, these railways discontinued the practice of trying to separate detected transverse fissures from other detected transverse defects. From 1947 on, line "B" has reported all detected transverse defects, which accounts for the increase in number. This is evident from line "D", which shows detected transverse fissures for 24 roads that do break and classify the transverse defects. It will be noted from line "D" that the number of detected transverse failures has also steadily decreased since 1943. It is evident, therefore, that the installation of control-cooled rails in rail renewals is producing a gratifying reduction in the number of transverse fissures.

These statistics are also of value in comparing the performance of rails from the various mills. I would like to direct your attention particularly to Figure 3 on page 619, which shows the control-cooled rail failures per 100 track mile years for each mill for the rollings from 1939 to 1948, inclusive. It will be noted that the rate of failures is reasonably uniform for all mills except one. Study of Table 7, which shows the failures as reported by individual railways, discloses that the reason for the relatively large number of failures for this one mill is the number of web failures reported by one large railway. This, as will be discussed later, can hardly be assigned as a fault in manufacture and, in general, as far as mill performance is concerned, the statistics indicate a very satisfactory showing. However, of course, we must strive to do even better, because every rail failure in track is a risk to safety.

Table 6 is of particular value in indicating the more prevalent types of failures. It will be noted that the compound fissure and detail fracture classification, together with the web failures, comprise about 75 percent of all failures reported, and that the web failures within the limits of the joint bar represent 38 percent of all failures reported. It seems probable that the detail fractures, to a large extent, have developed from shelly spots. The Rail committee is concentrating its research efforts on means of determining the causes of shelling and of finding a satisfactory and economical remedy for it. If this solution can be found, the statistics indicate that it will eliminate a substantial proportion of rail failures.

Web failures within joint bar limits are becoming a serious problem, especially on several railroads. Steps that have been taken within recent years by the Rail committee should be helpful. The redesign of the 115 and 132 RE rail section was primarily for the purpose of reducing fillet stresses in the rail, and the rail, and the new recommended spacing of bolt holes one inch farther from the rail end was for the purpose of lowering stresses around the first bolt hole and in the upper fillets at the rail end. It seems certain that these changes will be beneficial. However, laboratory studies conducted at the University of Illinois for the Rail committee to determine the fatigue strength of steel in the rail web has demonstrated the very important influence that corrosion can have in reducing the fatigue strength of the steel. It is evident from this laboratory work that control of corrosion conditions within the joint bar must be effected if we are to make substantial headway in lowering the large number of web failures that are now being reflected to an increasing extent in our rail failures statistics.

President Loeffler: Are there any questions with respect to this report on rail failure statistics?

Thank you very much, Mr. Magee, for this very interesting, informative report.

Chairman McBrian: Next, we would like to present an address by L. S. Crane, engineer of tests, Southern Railway, on Research Attack on the Shelly Rail Problem. Incidentally, Mr. Crane is chairman of the Subcommittee on Shelly Rail.

Research Attack on the Shelly Rail Problem

By L. S. Crane

Engineer of Tests, Southern Railway System

The long and arduous program of research work leading to the elimination of transverse fissures in rail steel was finished by 1938; railway maintenance men were comforted by the thought that at last a steel free from defects had been developed, and that as increasing quantities of rail made from this steel were laid in track, premature failure of rail would become a thing of the past.

The Committee on Rail provided for a check on the quality of rail steel produced by requesting member roads to submit to the University of Illinois all samples of control-cooled rail which developed service failures classified as transverse fissures. The results of this continued examination, together with the yearly compilation of rail failure statistics, began to indicate that the control cooling of rail would not prove a panacea for all the ills affecting rail steel. The statistics and the laboratory examinations revealed that failures in CC rail were occurring with increasing frequency within the joint bar area as the results of high web stress. Also, these failures were developing from the progression of engine burns and from the flaking and spalling on the gage corner of the rail head.

Defects of the last type were termed "shelly spots," and a new subcommittee of the Rail committee was formed in 1941 to investigate this type of failure—define it and develop measures for its prevention.

Under the direction of the late F. S. Hewes of the Santa Fe, field inspection trips were made by the committee to familiarize all members with the problem. It was observed that the shelly spots were generally located on the top gage corner of high rails on curves, but sometimes occurred on tangents. The defects first appeared as dark spots on the running surface, which developed into multiple cracks running longitudinally. Eventually pieces of the metal, varying in length from 1 to 6 in, ¼ in. to 1½ in. wide, and ⅛ in. to ½ in. deep, would fall out of the gage side of the head. At times the cracks, instead of continuing in a longitudinal direction, would turn transversely and cause the rail to break in two.

Metallurgical examination of the failed rails revealed the rail steel to be severely cold worked from the kneading action of the tread and flange of the car wheel. This cold work occurred to such an extent that the ductility of the rail steel had apparently been exhausted and cracks developed. These cracks progressed under service loads, causing the longitudinal and transverse failures observed.

To investigate the problem systematically the committee organized its research work along three lines:

The first consisted of studies which could be handled directly by the committee; the second covered studies to be handled by the Engineering Division Research Staff, and the third concerned studies to be handled at the University of Illinois.

The committee's research studies established the fact that the tendency of rail to shell bore no relationship to its chemistry, except as the chemistry affected the hardness of the running surface. A tabulation of curvature, elevations, speeds and grades for curves developing these defects failed to show any significant pattern. Although the onset of shelling could be retarded by slow cold working, thereby hardening the running surface, or by transposing rails from the high to low sides on curves, both methods failed to offer a permanent solution to the problem.

The University of Illinois in the meanwhile, had continued the metallurgical examination of shelly rail specimens and had confirmed their original conclusion that the failures were caused by severe cold working of the gage corner of the rail. In an effort to reproduce this type of failure in the laboratory, the rolling-load machines, which had served the transverse fissure investigation so well, were modified to permit concentration of the wheel load along the gage corner of the test specimen. The machines were successful in reproducing gage corner flaking and shelling on laboratory rail specimens, and demonstrated that the resistance of a given rail specimen to shelling was enhanced by an increase in hardness, tensile strength and ductility. This observation suggested to the committee that a solution to the problem might be achieved by (A)—Reducing the stress per unit area imposed on the rail steel by the wheel load, or (B)—Increasing the strength of the rail steel by heat treatment or by the addition of alloy elements.

In order to explore the potentialities of the first suggestion, the Engineering Division Research Staff initiated a program to determine the relationship between the contour of the wheel tread and the rail head. Worn rail contours were obtained on curved and on tangent track and were compared with worn wheel contours obtained from 50-ton and 70-ton cars on several member roads. These studies indicated that improvement in the design of the gage corner fillet might assist in reducing the tendency of the rail to shell by reducing the load imposed on the gage corner. This work has resulted in the improved gage corner design incorporated in the new 115-lb. through 155-lb. RE sections, and test installations have demonstrated the desirability of this change.

Throughout the investigation the Rail Manufacturers' Technical Committee of the American Iron & Steel Institute has contributed the time, services, and facilities of their organization and has paid a part of the financial cost of the investigation.

In 1947 it was decided to employ the services of the Battelle Memorial Institute, a research organization of outstanding reputation in the metals field, to make a critical metallurgical survey of the shelly rail problem as a supplement to a part of the work conducted at the University of Illinois. This work at Battelle was carried forward under the direction of G. M. Manning and L. R. Jackson.

The work at Battelle confirmed the results of the work conducted at the University of Illinois, but amplified certain phases. In the course of Battelle's investigation they have examined several hundred rails, both control cooled, and non-control cooled, collected from various member roads. The results of this investigation have established the fact that two distinct types of failures are occurring.

The first of these is defined as "gage corner shelling and flaking." This type of failure is characterized by components which lie in a horizontal plane and develop into horizontal fractures. The second type is defined as "detail fractures from shelling." These failures are characterized by having components which lie in both horizontal and vertical planes.

The metallurgical examination has indicated that "gage corner shelling and flaking" failures are predominantly of surface origin, resulting from abnormal shearing stresses imposed on the gage corner of the rail by the wheel loads. Battelle's investigators confirmed the previous suggestion that if the wheel loads could not be reduced, the strength of the rail steel to resist these loads must be increased.

Two methods gave promise of achieving the desired increase in strength; one was to heat treat normal rail steel, the second to develop an alloy steel with the desired physical properties. It was here that the AISI representative provided invaluable assistance. One company had already developed and constructed heat-treating equipment for use in manufacturing heat-treated track work. This company arranged to produce some quantities of heat-treated rail with physical properties superior to normal rail steel. Preliminary rolling-load tests indicated that these rails could be expected to offer superior resistance to shelling. Test installations of these heat-treated rails have been installed in the tracks of several member roads where to date, they are fulfilling the performance expected of them. Another rail manufacturer undertook to develop an alloy steel rail. It was recognized that such a rail would have to be produced economically, thereby precluding the use of excessive or expensive alloy additions. Furthermore, the analysis would have to be adaptable to production under conditions of normal open-hearth, and rail mill practice. This poised a difficult problem and over 350 experimental heats were produced before an analysis meeting these requirements was developed.

Again, rolling-load tests of the proposed alloy rail were run and the results were promising. Since that time small quantities of these rails have been installed in tracks of member roads for field service test.

It is not believed, however, that heat-treated or alloy steel rail will provide a complete and satisfactory answer to the shelly rail problem since their use is barred by economic considerations in many cases. Your committee has, therefore, pressed its investigations into the fundamental aspects causing the mechanism of this type of failure with the hope of finding some simple and economical solution.

President Loeffler: Thank you very much, Mr. Crane, for this very interesting report. Mr. McBrian, you will proceed.

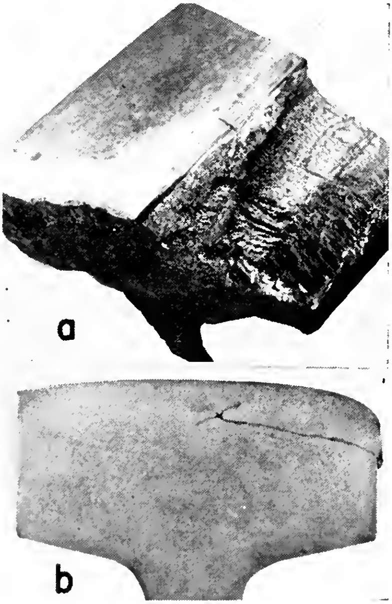
Chairman McBrian: Next, we would like to present an address on Shelly Rail Studies at the University of Illinois, by Professor R. E. Cramer, special research associate professor, University of Illinois.

Shelly Rail Studies at the University of Illinois

By R. E. Cramer

Research Associate Professor of Engineering Materials

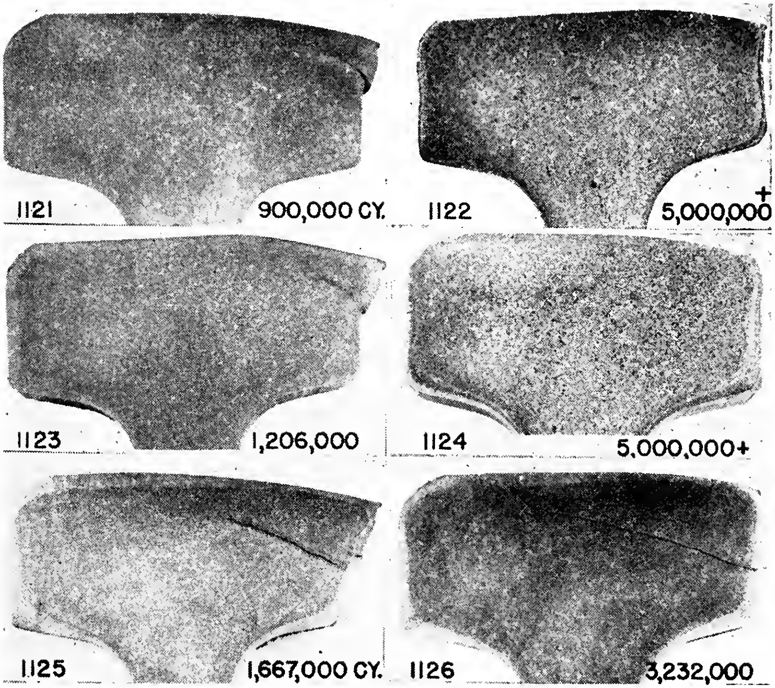
My comments will relate to the ninth of the Progress Reports on Shelly Rail Studies, which have been printed yearly in the AREA Proceedings; this year's report being on page 664. The work is financed equally by the Association of American Railroads and the American Iron and Steel Institute. These annual reports are also available as Reprints from the Engineering Experiment Station of the University of Illinois.



Slide 1

Slide 1

In order to review what we mean by a shelly rail, this slide shows a shelly rail from service which has been opened up in the top picture, while the bottom picture is a transverse slice through this same rail just back of the section shown in the top picture. These failures first appear as black spots on the gage corner of rails. They appear to be the most common type of failure occurring in control-cooled rails. This opened section shows a longitudinal streak about ¾ in. from the gage side of the rail, with growth rings indicating that the horizontal shelling crack started along this streak. The remainder of my slides will show cross sections only of the shelling cracks we have developed in our laboratory cradle-type rolling-load machines on standard carbon steel rails, heat-treated rails, and alloy rails tested during the past year. By heat treatment we mean an oil quenching of the full rail section from a temperature of 1500 deg. F., holding in the oil for 20 min., followed by tempering in another furnace at 740 deg. F. for 6 hours.



Slide 2

Slide 2

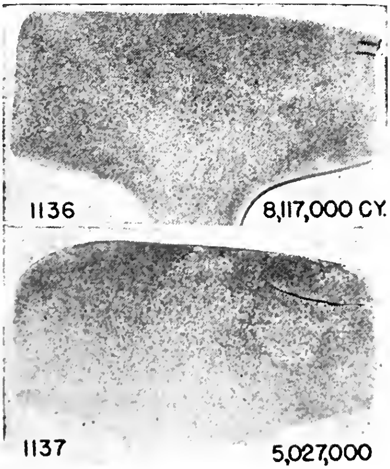
This slide shows three standard rails on the left, with the number of cycles they ran in our rolling-load machines. These rails ran 900,000, 1,200,000 and 1,667,000 cycles, or an average of a little over a million cycles. The heat-treated rails from the same melt of steel are shown on the right side of the slide. You will note that no shelly cracks developed in the top two rails at 5,000,000 cycles when the tests were stopped. It takes about 2½ months steady running of the rolling machine to obtain 5,000,000 cycles, so the machine was stopped in order to test other rails. The bottom heat-treated rail developed a large crack at 3,200,000 cycles. These were 132-lb. rails from the same heats placed in the tracks of the Chesapeake & Ohio and Norfolk & Western.

PHYSICAL TESTS OF THREE RAILS

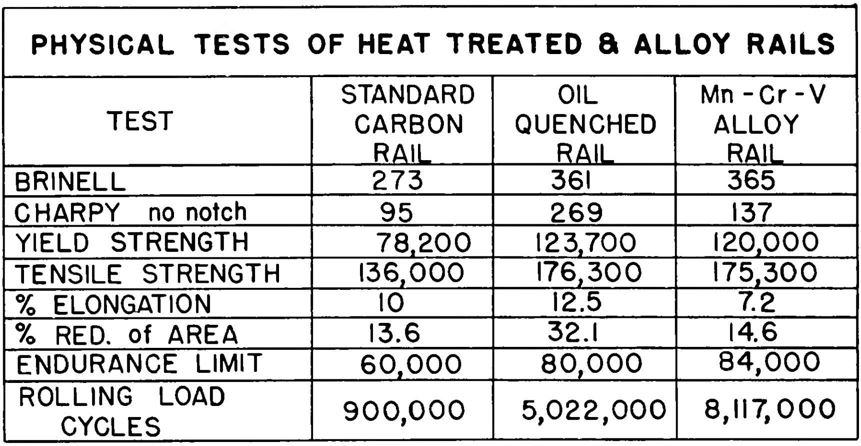
Test	Standard carbon rail	Oil quenched rail	Mn-Cr-Va alloy rail
Brinell hardness	273	361	365
Charpy-no notch-ft. lb.	95	269	137
Yield strength psi.	78,200	123,700	120,000
Tensile strength psi.	136,000	176,300	175,300
Percent elongation	10.	12.5	7.2
Percent red. of area	13.6	32.1	14.6
Endurance limit	60,000	80,000	84,000
Rolling-load cycles	900,000	5,000,000+	8,117,000

Slide 3

This slide shows two alloy rails Nos. 1136 and 1137. The chemical analysis averaged 0.76 percent carbon, 1.35 percent manganese, 0.92 percent chromium, and 0.13 percent vanadium, which is the analysis developed by the Carnegie–Illinois Steel Corporation after making 350 experimental melts. These rails are from the same heats placed in the tracks of the New York Central and Norfolk & Western Railroads. You will note that after 8 million cycles the top rail had developed two very shallow cracks, which appeared to have started at the gage side of the rail head and had not grown into the rail more than ¼ in. One of these cracks was noticed on the surface at 7 million cycles, so it did not grow much in the last million cycles. Rail 1137 developed a large internal shelling crack at 5 million cycles.



Slide 3



PHYSICAL TESTS OF HEAT TREATED & ALLOY RAILS

TEST	STANDARD CARBON RAIL	OIL QUENCHED RAIL	Mn - Cr - V ALLOY RAIL
BRINELL	273	361	365
CHARPY no notch	95	269	137
YIELD STRENGTH	78,200	123,700	120,000
TENSILE STRENGTH	136,000	176,300	175,300
% ELONGATION	10	12.5	7.2
% RED. of AREA	13.6	32.1	14.6
ENDURANCE LIMIT	60,000	80,000	84,000
ROLLING LOAD CYCLES	900,000	5,022,000	8,117,000

Slide 4

Slide 4

This slide shows the physical properties of a standard carbon rail, its companion heat-treated rail, and one alloy rail, shown in the previous two slides.

We consider that it is the high strength of the steel which makes these rails show up so well in the rolling-load tests. If the rails stand up as well in service as our rolling-load tests indicate, either kind may prove an economical rail to buy for heavy-duty track. There are other tests described in our printed report, but most of these tests gave negative results or will be repeated and reported on next year.

The remaining four slides are a metallographic study of these rails using the electron microscope. The electron micrographs of these three rails were made by Wm. Craig. The procedure for taking the micrographs is quite complicated, and I will not have time to describe it, but will show you the results.

Slide 5

Slide 5 shows the carbon rail steel at about 20000X magnification (see Fig. 7, page 673). This micrograph shows two small oxide inclusions and resolves the structure of the rail steel much better than ordinary light micrographs. The smallest carbide particles shown in this picture are only about 1 millionth of an inch in diameter.

Slide 6 (see Fig. 8, page 674)

All of these electron micrographs, as actually taken, are about 35000X magnification. The two pictures in slides 5 and 6 won honorable mention for Mr. Craig at last year's ASM convention in their photomicrograph contest. This area shows some pearlite where the carbide plates were almost parallel with the polished surface of the specimen.

Slide 7 (see Fig. 10, page 676)

This slide shows the structure of a heat-treated rail, or quenched rail. The structure is much finer pearlite, which accounts for the better physical properties of the heat-treated rail steel.

Slide 8 (see Fig. 11, page 677)

This slide shows the structure of the manganese, chrome, vanadium alloy steel. It also has a fine structure and high physical properties.

In closing, we can say that all laboratory tests indicate that either the heat-treated carbon steel rail or the manganese, chrome, vanadium alloy rail will give good service in track. We will await with much interest the results of the actual service tests of these same rails.

President Loeffler: Thank you, Mr. Cramer.

Mr. McBrian, will you proceed with the presentation?

Chairman McBrian: Last, we would like to present A Review of Joint Bar Research, by R. S. Jensen, special research assistant professor of Engineering Materials, University of Illinois.

Review of Joint Bar Research*

By R. S. Jensen
Research Assistant Professor of Engineering Materials, University of Illinois

For the past ten years the Association of American Railroads has sponsored and financed a cooperative investigation on joint bar research at the University of Illinois. The program has consisted mainly of a series of rolling-load tests to obtain comparative fatigue data on various types of joint bars with the consideration of improving the design or otherwise increasing or extending the useful life of the bars. Actually, we have learned that there are several factors, in addition to design differences, which influence the test results; and I would like to comment on a few of these, such as variations in hardness, gouging by hot-sawed rail ends, and decarburization, together with some of the improvements which have been made to increase joint bar life in service.

Slide 1. Machine

The first slide shows one of the three machines in use at the University for making tests on joint bars. Bars are bolted to short lengths of rail, and the assembled joint is installed on the machine carriage with supports at 18 in. to each side of the joint gap. The joint is loaded by a 33-in. steel wheel. The upper beam carrying the wheel has a fulcrum pin at the left end, and a calibrated spring at the right end through which the load is applied. The spring constant is about 3000 lb. per in. of deflection, and the lever action of the beam is 5 to 1. The stroke of the machine is 33 in.

Maximum bending moment and highest bar stresses are obtained with the wheel at the joint gap. For bars for the 112 and 115-lb. rail section the wheel load used is 44,400 lb., giving a bending moment of 400,000 in. lb. For joints of heavier rail, such as the 131, 132 and 133-lb. sections, which have about 25 percent greater section modulus, the wheel load is increased 25 percent to 55,500 lb., which gives a bending moment of 500,000 in. lb. With the wheel load in the joint gap the bar stresses for all size bars are about 40,000 psi., tension on the lower surface and compression on the top surface. The

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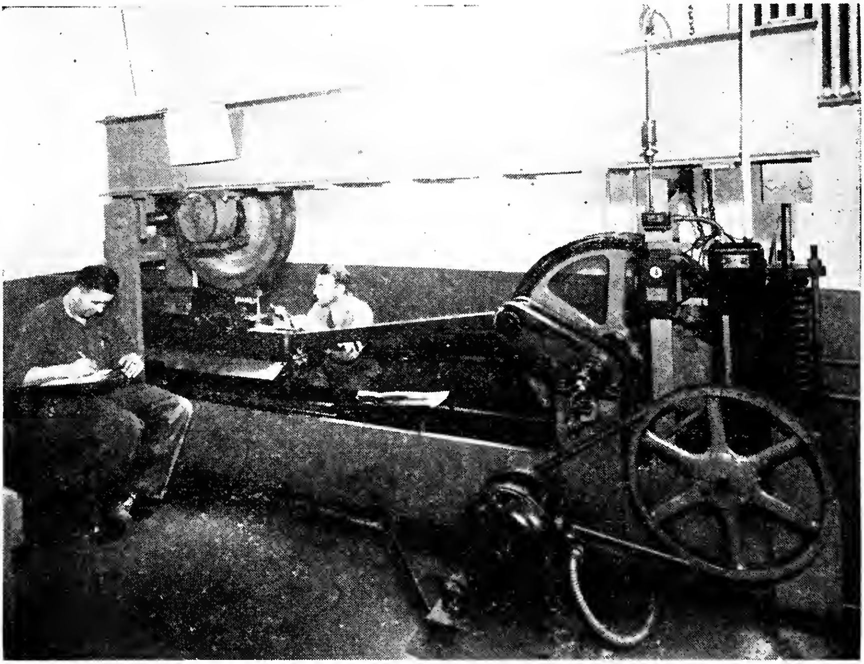
* An illustrated lecture.

support blocks between rail and carriage are so spaced that the bending stresses are 50 percent in value and reversed in sign when the wheel is at the cantilever end of the stroke. The load is accurately measured by the calibrated spring and the cycles are recorded by a revolution counter on the crankshaft.

Bolt tension is maintained at 15,000 lb. in the heat-treated pre-stressed bolts, and periodic checks are made and measurements taken at regular intervals. The criterion for bar failure is taken to be the number of cycles of loading to propagate a fatigue crack to ½ the bar height.

Nearly all bars tested have been between 0.42 and 0.49 percent carbon, and are oil quenched. AREA specifications allow the carbon content to range from 0.35 to 0.60 percent; however, by agreement, the range 0.42 to 0.50 is usually maintained.

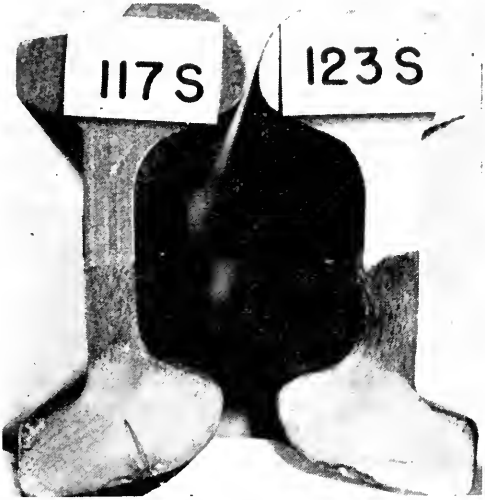


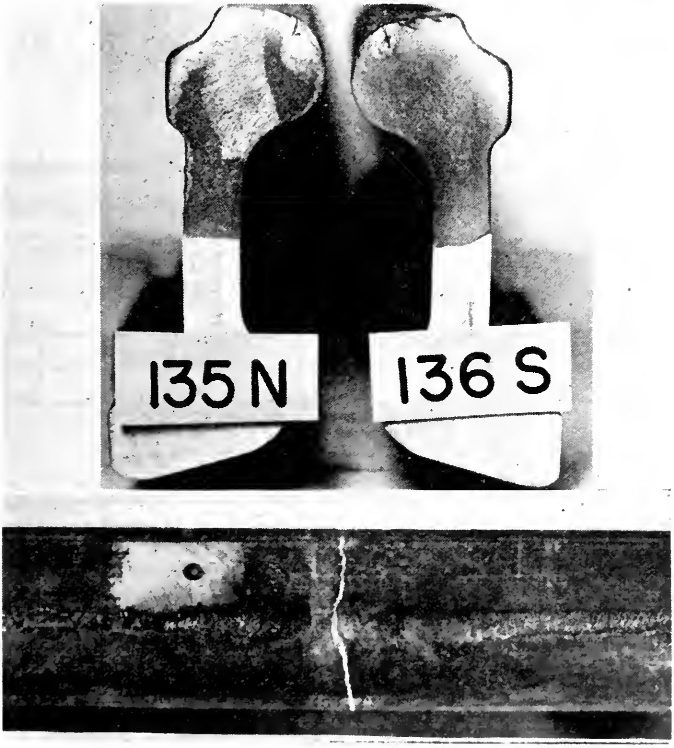
Slide 1. One of three machines at University of Illinois for making joint bar tests.

Slide 2. Fractures From Base of Bars

Since the *tensile* bending stresses are a maximum on the lower surface, we would normally expect fatigue failures starting on the bottom side, and approximately 50 percent of all bars tested have failed from the lower surface. This slide shows the fatigue failures of two 115-lb. headfree bars which started near the rail end in areas of heavy bearing pressure.

Slide 2. Fatigue failures from lower surfaces of 115-lb. headfree bars.





Slide 3. Fatigue failures from top fishing surfaces of 132-lb. AREA bars.

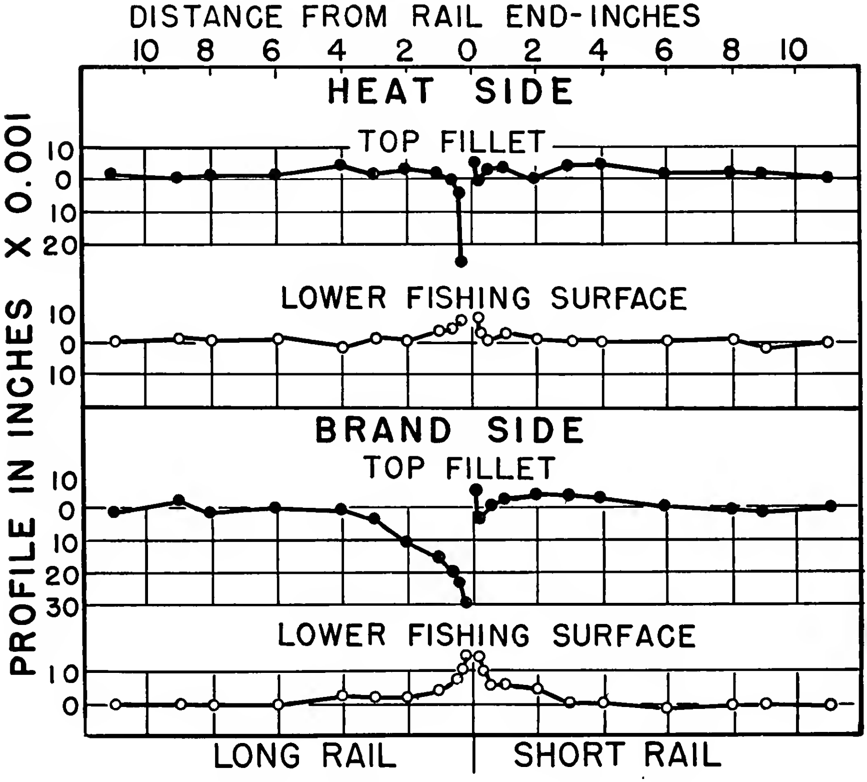
Slide 3. Fractures From Top of Bars

The remaining 50 percent of the bars fail from the upper surface, where, although the tensile bending stresses are lower, gouging of the bars by the rail ends is severe enough to start a crack. This slide shows two of the 132-lb. AREA bars in which the crack started on the top fishing surface in gouges caused by hot-sawed rail ends. The lower portion of the slide shows the crack outlined by Magnaflux in the gouge on the top fishing surface of one of the bars.

One improvement in bar design is the formation of pressed easements on some bars 1/64 to 1/32 in. in depth over the central 1¼ in. of the top surface, which have materially reduced the amount of gouging.

Slide 4. Rail Fishing Surface Profiles

This gouging of bar surfaces by hot-sawed rail ends is one of the factors which has affected the rolling-load tests to a varying degree. All rails are cut to length at the mill in the hot condition by high-speed rotary friction saws. Subsequently, by a hand grinding operation, fins and burrs are removed, but specifications call for no rail-end



Slide 4. Rail fishing surface profiles—hot-sawed ends.

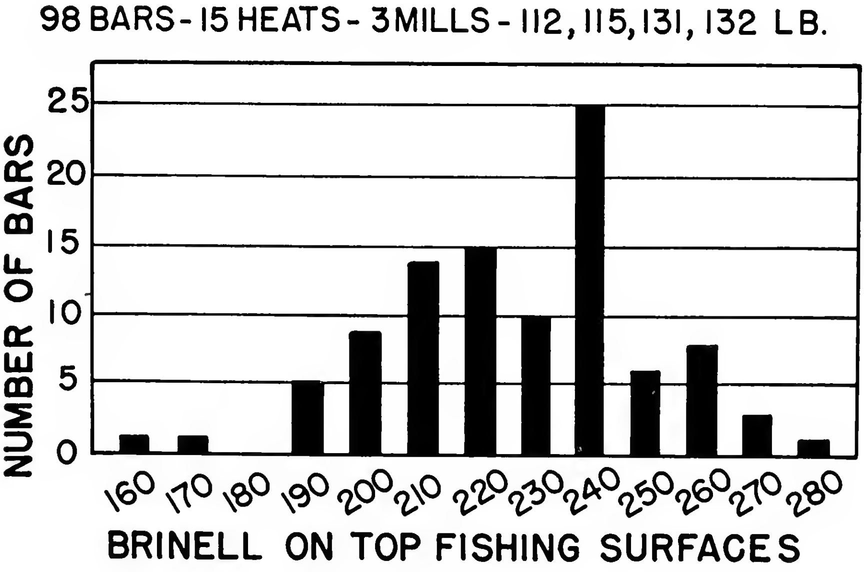
beveling on the fishing surfaces. This slide shows a rail end condition occasionally met. The projections downward of about 1/32 in., which is an extreme case, cause the rails to gouge the bars, starting fatigue cracks and causing early bar failure. Fishing surface profiles, which are taken on all hot-sawed rails used in our tests, show reductions in fishing height ranging, as a rule, from 2 to 30 thousandths of an inch.

An improvement in this condition has resulted from milling the ends after hot sawing, which is standard practice at some mills, and a more careful grinding operation at other mills which has greatly reduced the rail end distortion.

Slide 5. Bar Hardness

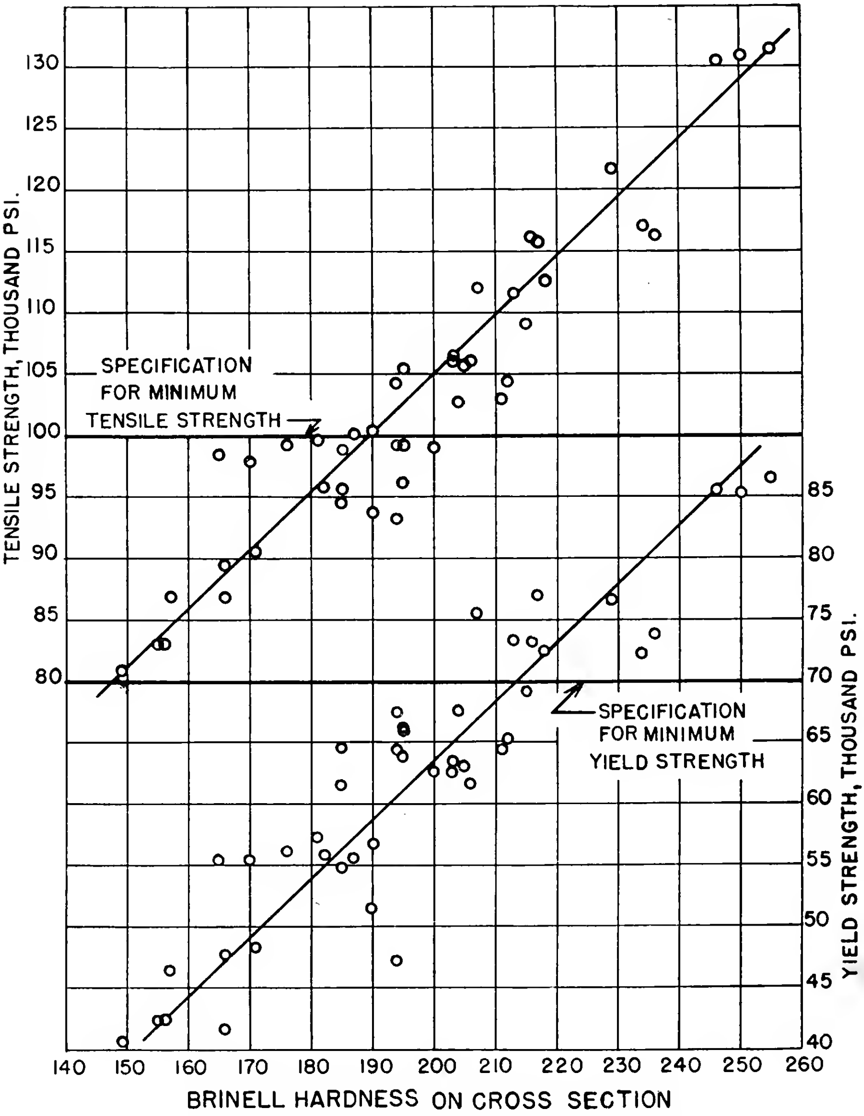
Another factor, aside from design, influencing the test results, is the variation in Brinell hardness which is reflected in variation in strength of the bars. Brinell hardness measurements are taken on both the top and bottom surfaces of all bars when received and, insofar as possible, pairs of bars of similar hardness are selected for each joint. This slide shows the range of hardness on 98 bars, representing 15 heats from 3 mills. While the hardness ranges from 160 to 280 Brinell, the majority, or 85 percent of the bars, fall in the range 190 to 260 Brinell.

It is believed that the extreme variations in hardness encountered in bars from the same lot are due, in part, to the quenching temperature. Bars sheared to the proper length are heated in a gas or oil-fired furnace and, emerging from the furnace, go to a punching press and then to a straightening press, and are subsequently discharged into an oil bath. The operation is carefully timed and the furnace temperature adjusted so the bars are quenched at from 1475 to 1550 deg. F.; however, delays in the operations



Slide 5. Joint bar hardness.

between furnace and quench may result in the quenching of individual bars from below the critical temperature of 1405 to 1450 deg. F. Some tests were made at the University a few years ago in which pieces of joint bar were quenched at various temperatures below the critical (from 1400 to 1175 deg. F.) and the resulting Brinell hardnesses dropped from 250 Brinell at 1400 deg. to 172 Brinell at 1175 deg. quench.



Slide 6. Physical properties vs. Brinell of failed bars from service.

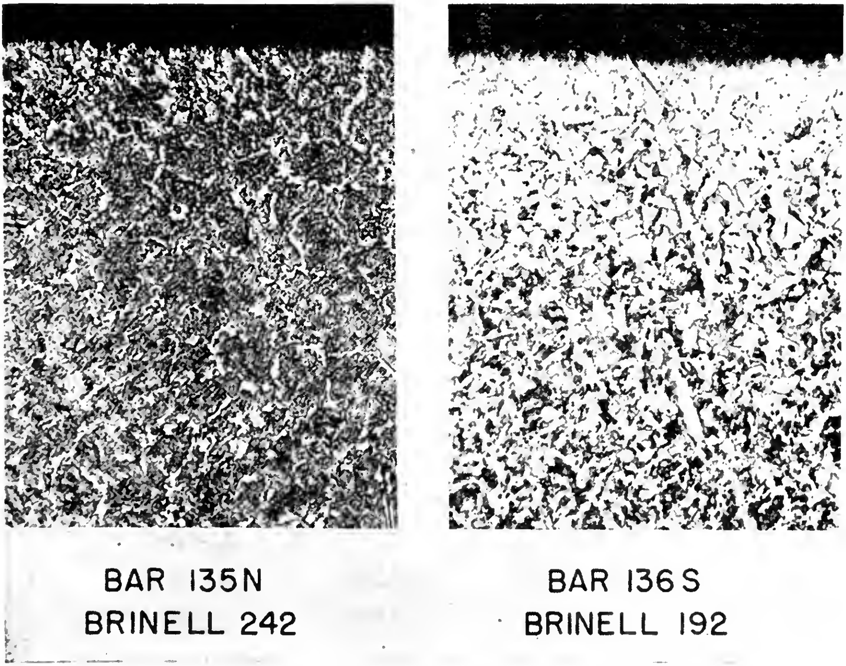
This range of hardness indicates a rather large variation in strength of bars as shown by slide 6.

Slide 6. Physical Properties vs. Brinell

Tensile specimens were selected from bars ranging in hardness from about 150 to 255 Brinell, and for that range of hardness the tensile strength ranged from 81,000 psi. to 131,000 psi., and the yield strength from 40,000 to 87,000 psi. The AREA specifications call for a minimum yield point of 70,000 psi. and a minimum tensile strength of 100,000 psi. Bars of this group below 187 Brinell did not meet the tensile strength requirement, and bars below 207 Brinell did not meet the yield strength requirement. These tests on failed bars from service correlate well with laboratory-tested bars, and bars tested in the rolling-load machines show a definite decrease in fatigue life when they are under 200 Brinell.

Slide 7. Decarburization

Another factor, or variable, closely allied to bar hardness is decarburization. This slide shows micrographs of sections of two bars from the same heat, the one on the left with a Brinell hardness of 242 showing very little decarburization, and the other, with a Brinell of 192, showing a decarburized layer about 24 thousandths of an inch in depth. The upper part on the slide corresponds to the upper fishing surfaces of the bars, and the light colored area extending downward from the top on the right indicates the decar-



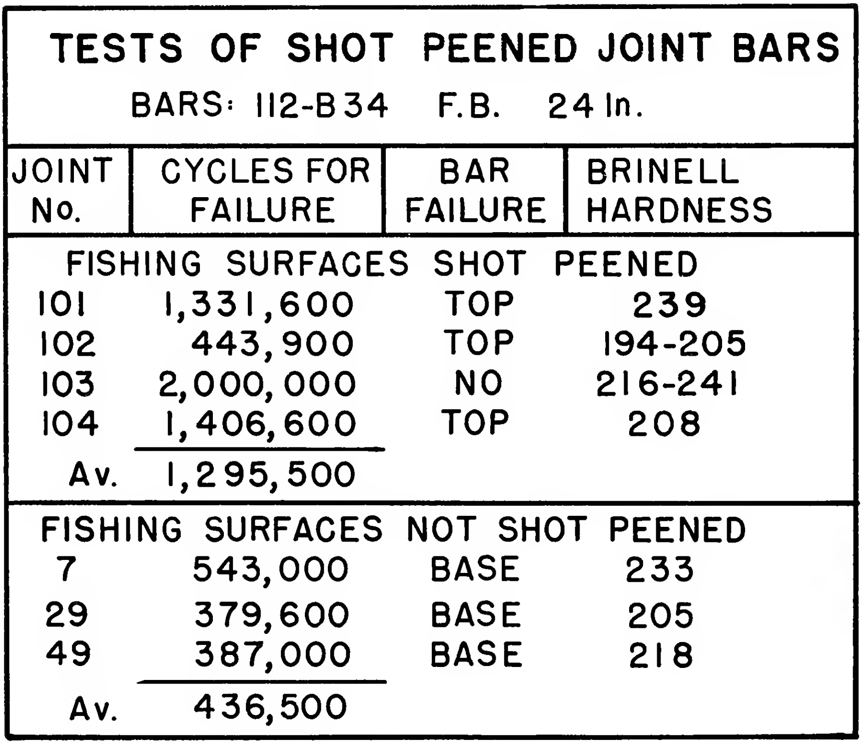
Slide 7. Sections of bars at upper fishing surfaces, showing decarburization—70X magnification.

burized area. Both of these bars failed from the top surfaces and the bar showing no decarburization ran from 3½ times as many cycles as the one with the decarburized surface. Micrographs, taken on about 100 bars, show depths of decarburization from less than 1 thousandth to 24 thousandths of an inch. No clearly defined correlation between decarburization and cycles for failure has been established for all bars, although several bars with a large amount of decarburization have failed at fairly low numbers of cycles.

These last three variables mentioned, Brinell hardness, physical properties, and decarburization, are all dependent on the heat treatment the bars receive, and improvements along this line will have to come from the mills which furnish the bars. An improvement should result from the adoption of the new specifications which provide for an increased number of physical tests: "One test from each lot of 1000 bars or fraction thereof, but not less than one test per heat per day."

Slide 8. Shot Peening

This slide shows another factor which has possibilities in extending the life of joint bars, namely, shot peening. Using 4-hole, 24-in. 112 B34 head-contact bars, shot peening approximately tripled the fatigue life of these bars in the laboratory rolling machine tests. There is, of course, a question as to whether it would triple their life in track, because of corrosion, wear, etc., but the results of the laboratory tests appear promising.



TESTS OF SHOT PEENED JOINT BARS

BARS: 112-B34 F.B. 24 In.

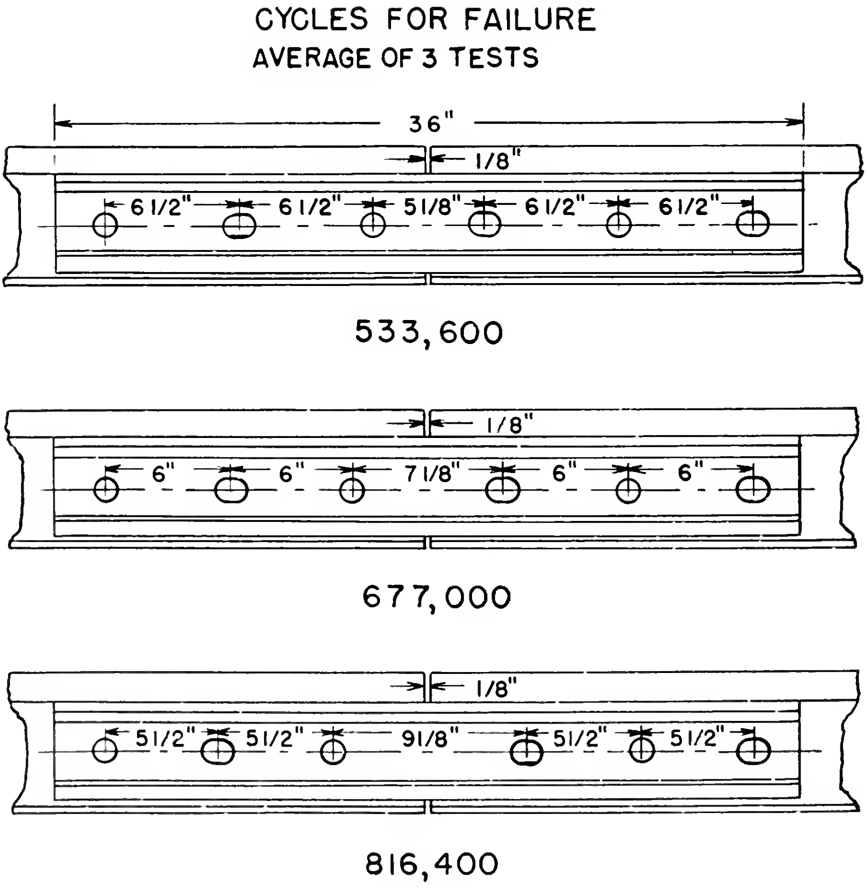
JOINT No.	CYCLES FOR FAILURE	BAR FAILURE	BRINELL HARDNESS
FISHING SURFACES SHOT PEENED			
101	1,331,600	TOP	239
102	443,900	TOP	194-205
103	2,000,000	NO	216-241
104	1,406,600	TOP	208
Av.	1,295,500		
FISHING SURFACES NOT SHOT PEENED			
7	543,000	BASE	233
29	379,600	BASE	205
49	387,000	BASE	218
Av.	436,500		

Slide 8. Tests of shot-peened joint bars.

Slide 9. Effect of Bolt Hole Spacing

One of the improvements in design of bars occurred about three years ago when the newer 115 and 132-lb. rail sections were adopted. At that time a great many stress measurements were made by the AAR research group around the vicinity of the end bolt hole in the rail in order to reduce the number of bolt hole breaks in rail. The standard drilling had been 2½ in. from the rail end for the first hole, but stress measurements indicated that a considerable reduction in stress could be effected by moving the hole one or two inches further back from the rail end. Joint bars, allowing ⅛ in. for the rail gap, had central hole spacing of 5⅛ in.

To determine what effect a change in bolt hole spacing would have on joint bars, 3 sets of 6 bars each for the 115-lb. rail section were sent to our laboratory for testing with central bolt holes spaced 5⅛, 7⅛, and 9⅛ in. apart. Based on average cycles for failure, the tests indicated that increased fatigue life resulted from greater spacing of the



Slide 9. Effect of bolt hole spacing on fatigue life of joint bars.

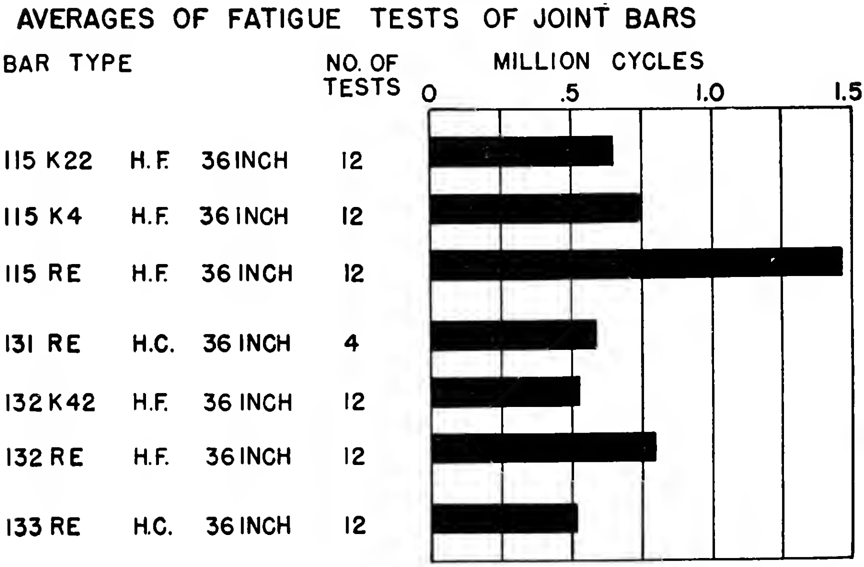
central holes. The bars with 5⅛-in. spacing averaged 533,000 cycles, bars with 7⅛-in. spacing averaged 677,000 cycles, and bars with 9⅛-in. spacing averaged 816,000 cycles. The 7⅛-in. central hole spacing has since been adopted as standard drilling for bars by the AREA.

Slide 10. Bar Graph of Cycles for Failure

Undoubtedly an improvement resulted in headfree bars with the increase in the upper radius necessitated by the adoption of the 115-lb. and 132-lb. rail sections, both with upper fillet radii of ¾ in., which give larger bearing areas of bar on rail than the ⅜-in. fillet radius on the 112-lb. rail or the ½-in. radius on the 131-lb. rail section.

This slide shows the results of tests on some of the various types of bars tested in the past few years. In all of the joints shown here, hot-sawed rail ends have been used and, with the exception of the 131 RE bars, 12 tests of each design were made in order to minimize as much as possible such variables as Brinell hardness, decarburization, etc., which I have previously mentioned. In the upper part of the slide are shown the results of tests on three designs of headfree bars for the 115-lb. rail section; the K22 bars averaged 648,950 cycles, the K4 bars 748,500 cycles, and the RE bars averaged, 1,462,450 cycles. These RE bars for 115-lb. rail, which show an outstanding increase in fatigue life, also represent a saving in weight of about 19 lb. per pair of bars over the older RE head-contact bars for the 112-lb. rail section.

The 132 RE bars showed an average of 794,000 cycles, which is also a substantial increase over the average of 580,000 cycles for the older type 131 RE bars. These newer bars also represent a saving in weight of about 16.8 lb. per pair of bars.



Slide 10. Bar graph of cycles for failure of various types and weights of joint bars.

The results of rolling-load tests on the new RE bars for both the 115-lb. and 132-lb. rail which show a substantial increase in fatigue life over the older bars, together with a reduction in weight, indicate that considerable improvement has been made in the design of joint bars and should afford the railroads quite a saving both in lower cost and longer life.

President Loeffler: Thank you very much, Mr. Jensen.

Mr. McBrian, proceed with your report.

Chairman McBrian: Mr. President, this concludes the presentation of Committee 4, unless there are any further comments or questions.

President Loeffler: The development of proper sections for track rails and angle bars adequate to meet, in an economic manner, all of the requirements of present-day railway traffic, is a subject of extensive importance to the railroads. The investigations and studies being made under the supervision of Committee 4—covering the metallurgy of rail, and with respect to various kinds of rail defects, as determined from statistics and tests—have been of great assistance in progressing this subject during the last few years.

The work of this committee is distinctly related to the matter of safety and, consequently, is of benefit to the public as well as to the railway industry.

Mr. McBrian, your committee is excused with the thanks of the Association.

This completes our program for today. We will now recess, to reconvene tomorrow morning at 9 a.m. in the Grand Ballroom. Please assemble on time, as we have six committees to report, in addition to the closing business session.

(The meeting adjourned at 5:00 o'clock.)

Thursday Morning Session

(President Loeffler presiding.)

President Loeffler: The meeting will please come to order.

As we open our session this morning, the first committee to report is Committee 7—Wood Bridges and Trestles. The work of this committee has been under the leadership of C. V. Lund, assistant engineer, Chicago, Milwaukee, St. Paul & Pacific, with headquarters at Chicago.

Discussion on Wood Bridges and Trestles

(For Report, see pp. 425–436.)

(President H. S. Loeffler presiding.)

Chairman C. V. Lund (Chicago, Milwaukee, St. Paul & Pacific): It is with regret that your committee records the loss during the past year of one of its highly respected members, in the death of Wilbur O. Nelson of the Baltimore & Ohio, a member of this committee since 1939. A memoir on Mr. Nelson will be printed with the report of this committee in the 1951 Proceedings.

Wilbur O. Nelson

Died December 10, 1950

Wilbur O. Nelson, assistant maintenance engineer, Baltimore & Ohio Railroad, at the time of his death on December 10, 1950, became a member of the American Railway Engineering Association in May, 1938. He was appointed to Committee 7—Wood Bridges and Trestles, in April of the following year, and served continuously on this committee until his death. He also served on Committee 3—Ties, from April 1949.

Mr. Nelson was born on January 21, 1887, at Baltimore, Md. He entered railroad service with the Baltimore & Ohio in August 1912 as assistant engineer in the engineering department. He transferred to the maintenance of way department in January 1914, as district bridge inspector, with headquarters at Wheeling, W. Va., and later became assistant engineer in charge at that location. He was appointed assistant division engineer of the former Ohio River division in September 1915, and later held similar positions on the Monongah division and the Pittsburgh division. In October 1920 he became assistant engineer in charge of the engineering corps of the Pennsylvania district, at Pittsburgh, Pa.

Mr. Nelson was attached to the staff of the chief engineer maintenance from April 1924, serving successively as maintenance inspector, district bridge inspector, and assistant maintenance engineer. He was holding the last named position at the time of his death, which terminated 38 years' service on the Baltimore & Ohio.

Mr. Nelson was an active member of Committee 7. His contributions, characterized by a practical approach to all problems, his pleasant fellowship, and his keen sense of humor, will be missed by his many friends and associates on the committee.

Your committee is reporting progress on five of its eight assignments, and is offering final reports on two other assignments. The report of the committee appears in Bulletin 492, January 1951, beginning on page 425.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman Nelson Handsaker (Northern Pacific).

Mr. Handsaker: Your committee recommends action on three items in the Manual, which have passed the ten-year limit for revision or readoption:

1. Pile Record Form, on Manual page 7-53. This form, adopted in 1911, is offered for readoption with no change except in the manner of numbering the bents. We propose to add a note to accompany the form in the Manual, in recognition of the fact that variations are often found desirable. You will find the proposed note in Bulletin 492, page 426.

Mr. President, I move the readoption of the Pile Record Form with the above minor change and added note.

(The motion was regularly seconded, was put to a vote and carried.)

2. Relative Merits of Open and Ballasted-Deck Wood Trestles, on Manual page 7-63. We believe that this section, adopted in 1925, is still a correct and useful statement.

Mr. President, I move the readoption of the section entitled Relative Merits of Open and Ballasted-Deck Wood Trestles, without change.

(The motion was regularly seconded, was put to a vote, and carried.)

3. Use of Guard Rails and Guard Timbers for Wood Bridges and Trestles, on Manual page 7–65.

The proposed revision of this subject is printed in Bulletin 492, pages 426 and 427.

In rewording this section, which was adopted in 1920, we have had collaboration by Committee 5—Track, and Committee 15—Iron and Steel Structures. The principal change proposed is in permitting a maximum difference in height, below running rails, of two inches instead of one, in guard rails five inches or more in height. We also propose a change in the title, to "Use of Guard Rails and Guard Timbers for Railway Bridges", in acknowledgment of the collaboration of Committees 5 and 15 to make the subject matter applicable to bridges other than those of wood.

Mr. President, I move the withdrawal of the matter now in the Manual under the heading Use of Guard Rails and Guard Timbers for Wood Bridges and Trestles, and the adoption of the revised section under the revised title just mentioned.

(The motion was regularly seconded, was put to a vote and carried.)

Assignment 2—Grading Rules and Classifications of Lumber for Railway Uses; Specifications for Structural Timber, was presented by Subcommittee Chairman C. H. Newlin (Southern).

Mr. Newlin: The existing text, now appearing in the Manual under the title Classification of the Uses of Lumber and Timber Under American Railway Engineering Association Specifications, on pages 7–101 to 7–107, inclusive, presents recommendations for grades of lumber to be used in both railway bridge and building construction. Committee 6—Buildings, has presented new recommendations for yard grades of lumber for use in building work, and yesterday the convention voted to adopt these recommendations. To avoid conflicting and superseded material in the Manual, your committee recommends deletion of the entire present text in Chapter 7 under the above title, and proposes to prepare new and revised recommendations for stress grades of lumber for bridge construction and other structural uses to be based on the new specifications for structural timbers now being prepared.

Mr. President: I move that the material now appearing in the Manual under the title Classification of the Uses of Lumber and Timber under American Railway Engineering Association Specifications, on pages 7–101 to 7–107, inclusive, be deleted.

(The motion was regularly seconded, was put to a vote and carried.)

President Loeffler: Thank you, Mr. Newlin. We will be looking forward to a final report on this matter next year, with recommended Manual material.

Assignment 3—Specification for Design of Wood Bridges and Trestles. In the absence of Subcommittee Chairman J. P. Dunnagan (Southern Pacific) the report was presented by Chairman Lund.

Chairman Lund: At the annual meeting in 1950 your committee presented as information the table printed in the Proceedings, Vol. 51, page 433, showing the allowable loads in pounds on one common bolt loaded at both ends, to supplement basic design data given in the specifications. The table presents, in convenient form allowable loads on bolts for the more usual condition of exposure of timber—occasionally wet but quickly dried. Adjustments for bolts loaded on one end are given in footnotes to the table.

Your committee now recommends that this table be adopted and published in the Manual, and that a paragraph be added to Section 307, page 7–124, of the specifications, making reference thereto, as printed in Bulletin 492, page 428.

Chairman Lund: Mr. President, I move the adoption of the table of allowable loads for bolts, and the proposed revisions to the specifications.

(The motion was regularly seconded, was put to a vote and carried.)

Assignment 4—Improved Design of Timber Trestles. In the absence of Subcommittee Chairman F. W. Madison (Chicago, Rock Island & Pacific) the report was presented by Chairman Lund.

Chairman Lund: At the 1947 convention your committee presented as information a paper by W. H. O'Brien of the Southern Pine Association, which described in detail the method used in sawing, fabricating, gluing and treating glued, laminated timbers which were later installed as a test in bridges on the Southern Railway and the Chesapeake and Ohio.

This year your committee is reporting on additional installations of glued, laminated timbers made on the Texas & Pacific and Southern Pacific, as well as the results of the latest available inspections made of all of these installations. On the whole, it can be reported that the performance of all glued, laminated timbers in the test installations has been satisfactory and that there is no evidence to date of failures in service due to delamination.

The report is presented as information.

President Loeffler: May I inquire, Mr. Lund, how long such tests have been under observation?

Chairman Lund: The original test installations were made in 1944, I believe, Mr. President.

President Loeffler: Are there any other questions in regard to this report?

The report will be received as information.

Assignment 5—Instructions for Inspection of Timber Trestle Railway Bridges, was presented by Subcommittee Chairman J. R. Showalter (Missouri Pacific)

Mr. Showalter: Last year your committee presented as information a tentative draft of Instructions for Inspections of Timber Trestle Railway Bridges (Proceedings, Vol. 51. No. 485, pages 433 to 436) and requested comments and criticisms thereon. These instructions, with minor revisions, are now submitted with the recommendation that they be adopted and published in the Manual.

It is the purpose of these instructions to describe the manner of inspecting a timber bridge; no attempt is made to set up the organization nor to fix the responsibility or the functioning of the various members of the organization.

The instructions embodied in this report offer no new innovations, shortcuts, or labor-saving methods that the inspector may use to reduce the laborious detail incident to bridge inspection. However, these instructions do outline in logical, systematic order the detail necessary to make a thorough and conclusive inspection of a timber trestle railroad bridge.

Your committee feels that a competent inspector, using these instructions as his guide, will cover every detail necessary to evaluate properly the physical condition of the structure and note and record all defects which should be corrected.

The concluding part of these instructions lists some general recommended practices as a guide for the inspector in detailing repairs which may be necessary to maintain the structure properly in good physical condition.

Mr. Showalter: Mr. President, it is moved that these instructions be adopted by this convention and published as Manual material.

(The motion was regularly seconded, was put to a vote and carried.)

Chairman Lund: On Assignment 7—Statistics Relating to Wood Bridges and Trestles, your committee is presenting a final report of current statistics, with a view to recommending reassignment of the subject some years hence to develop the changes and trends in the use and design of timber bridges.

Assignment 7—Statistics Relating to Wood Bridges and Trestles, was presented by Subcommittee Chairman A. L. Leach (Illinois Central).

Mr. Leach: Under this assignment questionnaires were sent to all Class I member railroads, requesting information regarding their practices and standards pertaining to timber trestles. Last year a progress report was made summarizing the replies from 52 railroads.

This year questionnaires were again sent to those railroads which had not reported, and 36 additional replies were received.

A complete summary of the replies from 88 railroads in the United States, Canada and Mexico appears on pages 433 to 436, inclusive, of Bulletin 492, Volume 52. The total Class I railroads reporting operate 86 percent of the total mileage in the United States, 95 percent in Canada, and 89 percent in Mexico.

This is a final report, submitted as information.

Chairman Lund: With regard to Mr. Leach's report, I might add that statistical data on all types of bridges is lacking, but it is estimated that more than 40 percent of all railroad bridges in the United States are of timber construction. This lends emphasis to the importance of timber bridges, and in itself suggests that greatly increased research into the behavior and design of timber structures is warranted.

President Loeffler: Mr. Lund, with respect to those treated bridges, can you tell us what percentage is of treated timber, creosote or otherwise?

Chairman Lund: The statistical data presented in Bulletin 492 give such a separation, Mr. President.

President Loeffler: Thank you.

Assignment 8—Specifications for Design of Wood Culverts, was presented by Subcommittee Chairman F. E. Schneider (Atchison, Topeka & Santa Fe).

Mr. Schneider: The report on this assignment, which is found between pages 428 and 429 in Bulletin 492, consists of a plan showing recommended practice for design of wood culverts.

Your committee prepared this plan from timber culvert design plans submitted by a number of railroads. It shows typical details, accompanied by notes, design assumptions, and a table of typical size boxes and unit stresses for the usual range of box sizes and fills used.

The committee has several additions and corrections which it thinks advisable but additional comment and criticism of the plan are invited.

This is a progress report, submitted as information, with the view of offering the plan, as may be revised, for inclusion in the Manual next year.

President Loeffler: Thank you, Mr. Schneider.

My only suggestion on this matter is that if and when the final report is made, some reference might be made in the report to the effect that anyone using this information should very carefully check into the relative economics of timber and other types of culverts.

Of course, it is necessary for us to have a definite plan for use in the event timber culverts are required for construction in emergencies, and even in other places where it is more economical to use that type of construction than culverts of more permanent materials.

I think it would be a safeguard if a paragraph could be put into the final report bringing out the necessity for proper consideration of the matter of economy.

Chairman Lund: Thank you, Mr. President. The committee will take that under advisement and make such provision in the final report.

President Loeffler: Are there any other questions, or is there any discussion with respect to this matter? The report will be received as information.

Chairman Lund: One of the current research projects being conducted by the AAR under direction of the research engineer is that of fatigue testing of full-size timber stringers. This work is being conducted at Purdue University. Other tests on clear specifications from large timbers are being made at the Forest Products Laboratory at Madison, Wis.

Initial tests at Purdue were started during the past year, and while only a few timbers have been tested to date, your committee believes the ultimate results will be of such interest that it has invited Professor J. L. Leggett. Jr., graduate research fellow, who is performing the tests at Purdue under direction of Professor L. T. Wyly, to talk to us briefly on the conduct of the tests to date.

It is my pleasure to introduce Professor Leggett.

Fatigue of Timber Stringers

By James L. Leggett, Jr.
Graduate Research Fellow, Purdue University

It is a pleasure and a privilege to present this brief discussion on the fatigue tests of timber stringers. Since railroads first started operating, timber stringers have been used extensively in trestles and other structures. Many of these timbers have been in service for 40 years or more. From time to time, stringers have been replaced as apparent weakness or decay became evident. In many cases, the cause of the structural weakness was not definitely known. The trouble may have been defects in the timber, overloading, or even fatigue. Furthermore, the determination of allowable unit working stresses for timber in the design of railway bridges should take into consideration, and possibly be based on, the behavior and strength of timber under repeated loading. At the present time data are lacking with respect to timbers of such large dimensions as those used in railway bridges. These considerations led to the present investigations into this new field.

Acknowledgment

Tests on full size stringers are being conducted at the Purdue University Engineering Experiment Station by the speaker under the direction of Professor L. T. Wyly. The project is sponsored by the Association of American Railroads upon the recommendation of Committee 7—Wood Bridges and Trestles, of the American Railway Engineering Association, and is carried on under the guidance of the AAR research office. The Forest Products Laboratory is cooperating in this investigation by conducting tests on small clear specimens taken from the stringers, and by acting as a consultant and advisor.

Test Program—First Phase

The committee decided that the project should include tests of unseasoned and seasoned new stringers, stringers which had been in service many years, and also treated stringers. The present laboratory investigation consists of testing 12 unseasoned, untreated stringers—6 southern pine, and 6 Douglas fir. These timbers are being tested at a theoretical extreme fiber stress based upon the modulus of rupture. The modulus of rupture and modulus of elasticity have been estimated for each timber by the Forest Products Laboratory.

Test Program and Procedure

Slide 1 shows a typical set-up of a stringer in the Krouse-Purdue Universal Fatigue Machine, which is the first hydraulic machine of its kind. The timber beam is simply supported on 13-ft. centers, with the left end flush on its support and the right end overhanging its support by 15 in. The total load, which is in the order of 40,000 lb., is applied at the third points by means of the delta frame shown in the top center. Ram loading is measured by means of the oscilloscope, right-lower center, connected to SR–4 strain gages.

Strains on the tension and compression faces of the timber are measured by two separate instruments:

Slide 1

1. (1) Oscilloscope, lower left, connected to two SR–4 strain gages on the tension face, and one on the compression face.
2. (2) Two-channel Brush oscillograph, not shown, connected to one SR–4 strain gage on the tension face, and one on the compression face. Slide 2 shows the type of permanent record obtained with this instrument.

Deflections at midspan are measured by means of a taut piano wire suspended over pulleys mounted on uprights fastened to the end supports.

Horizontal strain and slip between the compression and tension faces at the end reactions are being investigated. The frames for these gages are shown at the end supports (see slide 3).

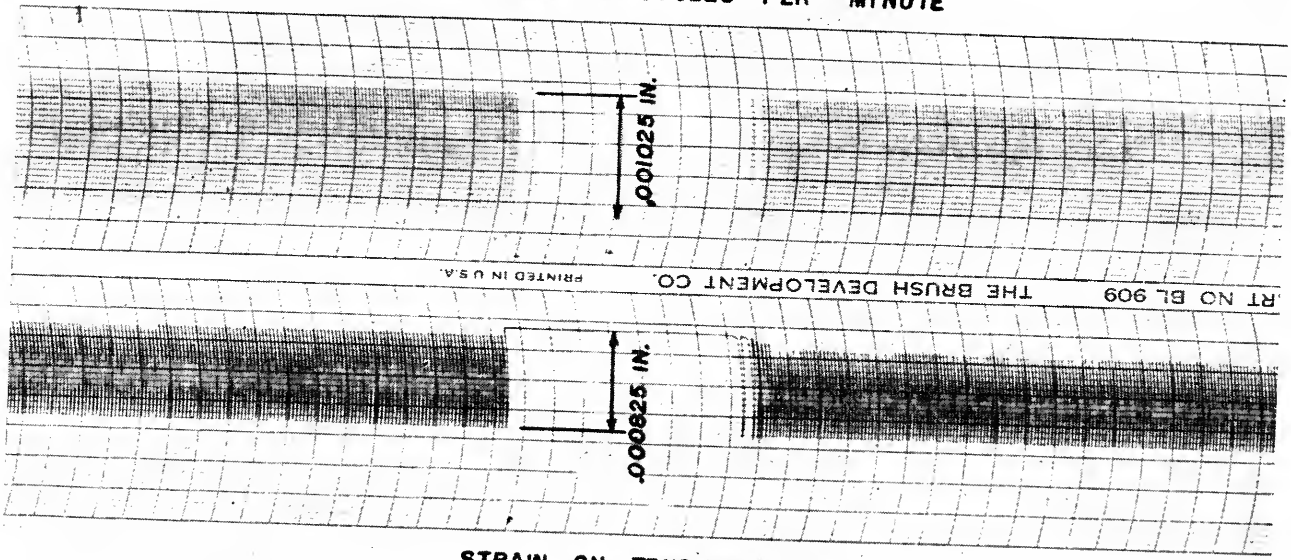
Four additional dial gages are used to measure the longitudinal slip at the checks that existed in the beam before testing (see slide 3). These dials are arbitrarily mounted across the checks which appear most severe.

Four beams—two firs and two pines—have been tested to date at 50 percent of the modulus of rupture. These data have not yet been fully analyzed. However, it was observed that initial failures were in horizontal shear, as shown in slide 4. This slide shows the stringer in a static testing machine, used to determine the residual strength after failure and removal from the fatigue machine.

STRAIN ON COMPRESSION FACE

SR-4 GAGE A-1

FREQUENCY 35 CYCLES PER MINUTE



STRAIN ON TENSION FACE

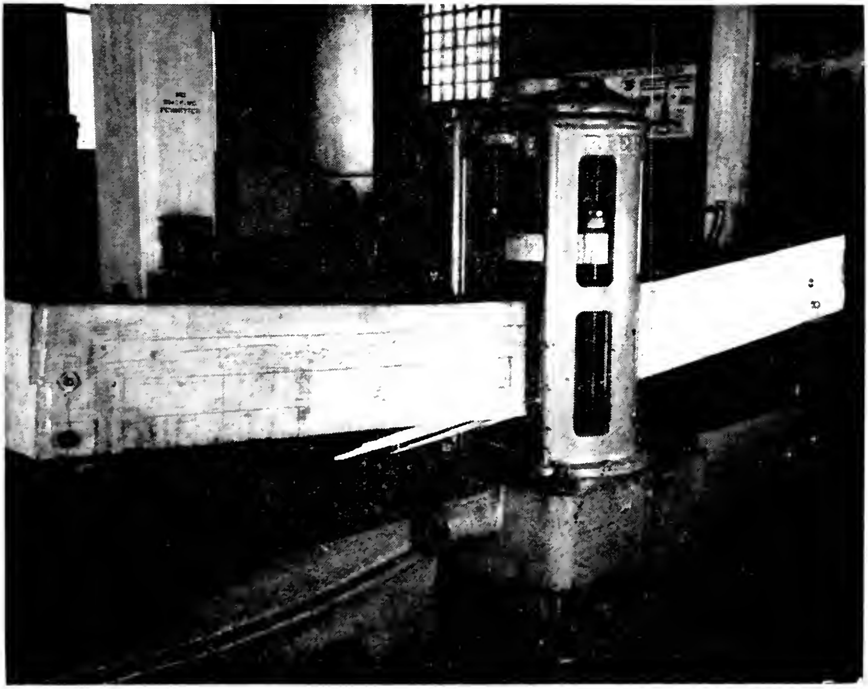
BEAM F-1

LOAD ON RAM = 26,500 LBS.

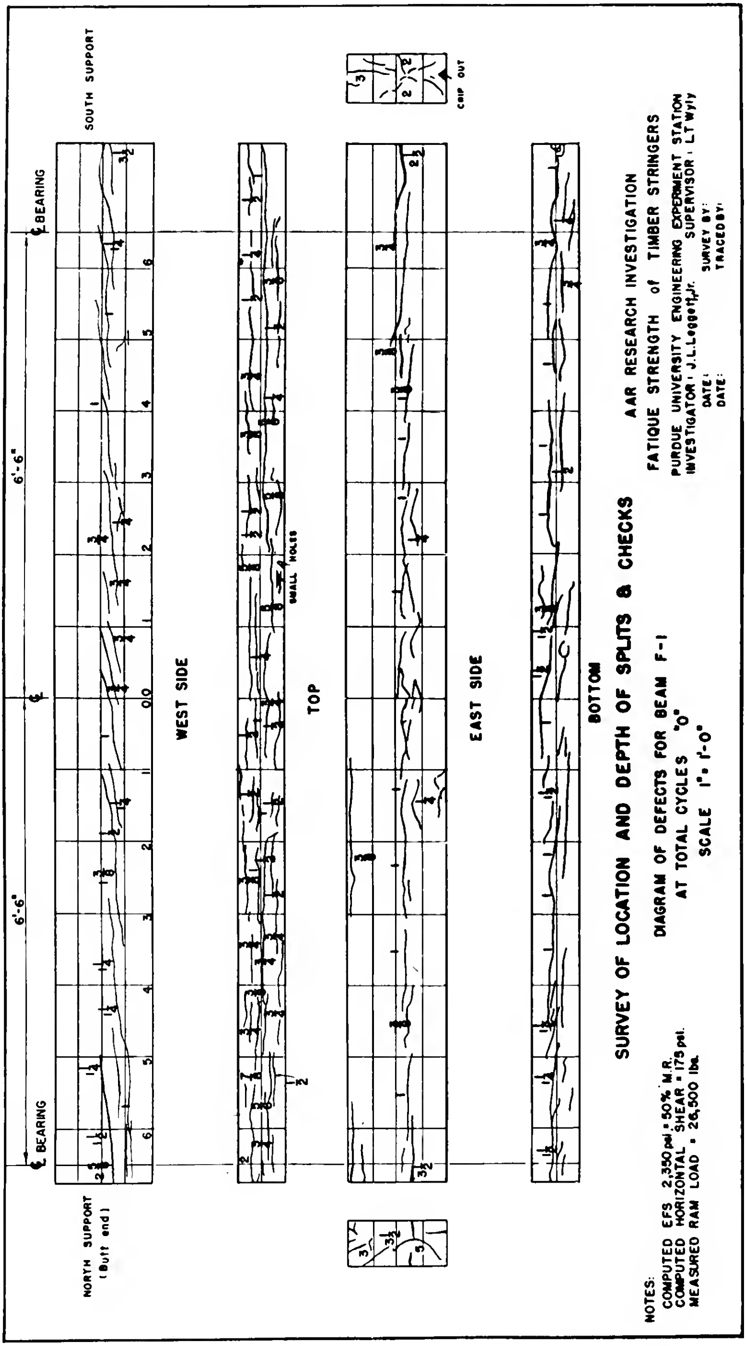
COMPUTED EFS = 2350 PSI = 50% MODULUS OF RUPTURE

Slide 2

Slide 3



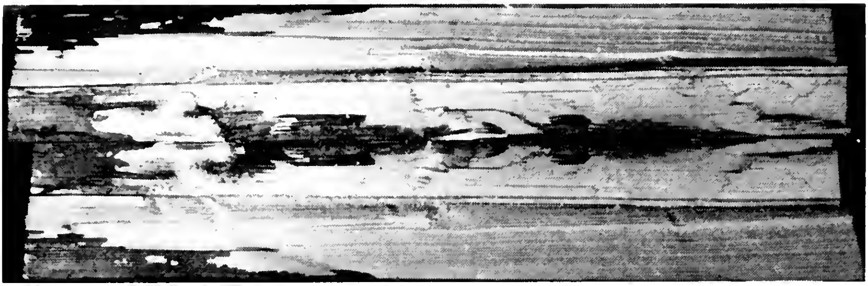
Slide 4


SOUTH SUPPORT
℄ BEARING
6'-6"
℄
6'-6"
℄ BEARING
NORTH SUPPORT (Butt end)
6 5 4 3 2 1 0,0 1 2 3 4 5 6
WEST SIDE
TOP
SMALL HOLES
EAST SIDE
BOTTOM
CHIP OUT
SURVEY OF LOCATION AND DEPTH OF SPLITS & CHECKS
DIAGRAM OF DEFECTS FOR BEAM F-1
AT TOTAL CYCLES "O"
SCALE 1" = 1'-0"
AAR RESEARCH INVESTIGATION
FATIGUE STRENGTH of TIMBER STRINGERS
PURDUE UNIVERSITY ENGINEERING EXPERIMENT STATION
INVESTIGATOR: J.L.Leggett,Jr. SUPERVISOR: L.T.Wyly
SURVEY BY: DATE:
TRACED BY: DATE:
NOTES:
COMPUTED EFS 2,350 psi = 50% M.R.
COMPUTED HORIZONTAL SHEAR = 175 psi.
MEASURED RAM LOAD = 26,500 lbs.

Slide 5

After the first stringer was tested, a program of surveying and mapping the checks in each beam, before and after testing, was instituted as illustrated by slide 5. This survey was carried out by using a standard probe.

In addition to the probe survey, a water solution of Nigrosine Blue dye was forced into the original checks. It was felt that the probe alone did not always measure the depth of check completely. Slide 6 shows the end of a stringer split open after testing. The dye indicates that the maximum depth of the check was more than two-thirds the width of the stringer.



Slide 6

Dye application to the surface of the stringer and into the checks serves an additional valuable purpose; one is able to spot new checks, extensions of old checks, and other indication of distress much more easily than was the case if no dye were used.

Summary

In summarizing the tests to date, the outstanding feature observed has been that all four stringers failed initially in horizontal shear. The first three failed between the loading point and that end of the stringer which was flush with the support. The fourth failed at the end with the 15-in. overhang.

These first tests may be considered as being exploratory in nature. The technique of testing full-size timbers in fatigue is new and, consequently, many problems have arisen and will continue to arise. As time goes on, it is hoped that some of the fatigue problems will be solved. However, fatigue testing is a slow process, and many tests must be conducted before all the answers are known.

President Loeffler: Thank you very much, Mr. Leggett.

Mr. Lund, will you proceed with the remainder of your report?

Chairman Lund: With the close of this convention I am completing my term as your chairman.

At this time it is my privilege and pleasure to introduce to you the new chairman of this committee—J. R. Showalter, bridge engineer of the Missouri Pacific. Under his able leadership your committee looks forward to active and enthusiastic committee work in the years ahead.

Mr. Showalter, will you please rise?

It is also my privilege to introduce to you the new vice chairman, C. H. Newlin, assistant engineer, Southern Railway, who succeeds Mr. Showalter. Mr. Newlin.

Mr. President, this concludes the report of Committee 7.

President Loeffler: Wood bridges and trestles continue to be important and economical types of railway structures for use under various conditions and at many locations. Mr. Lund, the Association is greatly indebted to you and your committee for your efforts in keeping us informed currently with respect to the proper and economic use of such bridge structures.

The address by Professor Leggett contained information of considerable interest to many of our members.

Mr. Lund, your services as chairman of this committee for the past three years are greatly appreciated. Your committee is excused at this time with the thanks of the Association.

Discussion on Clearances

(For Report, see pp. 403–408.)

(President H. S. Loeffler presiding.)

Chairman A. R. Harris (Chicago & North Western): The report of Committee 28, Clearances, will be found on page 403 of Bulletin 492.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman J. E. Fanning (Illinois Central).

Mr. Fanning: In order that the clearances shown on the equipment diagram may be maintained irrespective of operating conditions, and also for the sake of consistency, your committee recommends the following revision, page 28–9, Fig. 9 in the Manual. Add the following note: The 4 in. above top of rail is the absolute minimum under any and all conditions of lading, operation and maintenance (wear of axles, wheels and settlement of parts). Allowance must be made for the service conditions in the design of new cars.

I move that this minor revision be made.

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Fanning: Mr. President, this concludes the report on Assignment 1.

Assignment 5—Clearance Allowance to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear and Spring Deflection, Collaborating with the Mechanical Division, AAR, was presented by the Subcommittee Chairman, S. M. Dahl (Chicago, Milwaukee, St. Paul & Pacific).

Mr. Dahl: The report by this subcommittee is presented for information only.

I wish to call your attention to an error which unfortunately is to be found in the report of this subcommittee. In the definitions of the symbols appearing in the formula $T = CV^2D$, T is defined as the "throw in feet, measured from the perpendicular to the plane of the rails", whereas, this should have read "throw in feet of equipment measured from an 'at rest' position."

Your committee is satisfied that the formula for measuring throw is mathematically correct. Field tests have been made by one railroad which verify the results obtained from this formula; however, it is hoped that an opportunity will be afforded to carry out tests to substantiate these results further.

Your committee recognizes that there are many other factors entering into the problem which are not covered by the formula, such as equipment irregularities, variations in gage, superelevation, curvature, track surface, etc. These factors are subjects for future study and report by your committee.

Assignment 6—Methods for Measuring Railway Clearances, was presented by Subcommittee Chairman A. M. Weston (Baltimore & Ohio).

Mr. Weston: This is a progress report, submitted as information.

Under this assignment, efforts were directed toward assembling information pertaining to present practices of the railroads in measuring clearances as outlined in the report on pages 405 to 408, Volume 52, Bulletin 492, dated January 1951. Five different methods of measuring clearances were described.

Illustrations of two clearance measuring cars, together with descriptions of their use, bring out clearly the advantages of this method of measuring railway clearances.

At this time your committee offers no recommendation for a uniform method of measuring clearances.

Chairman Harris: Mr. President, this concludes the report of Committee 28—Clearances.

President Loeffler: The work of this committee is closely related to the subject ot safety, with respect to railway property, railway personnel and the public.

In the first instance, standard clearance diagrams must be available to guide the structural engineers who are responsible for the design of new structures to be built over or adjacent to railway tracks, and to guide the designers of the locomotives, cars, and work equipment that are to be operated over such tracks.

Secondly, the accurate determination of clearances as applied to existing railway structures is a matter that cannot be overlooked.

Committee 28 has both of these matters well in hand. The committee is excused with the thanks of the Association.

Discussion on Waterproofing

(For Report, see pp. 303–304.)

(President H. S. Loeffler, presiding.)

Chairman R. L. Mays (New York, Chicago & St. Louis): The report of Committee 29 will be found in Bulletin 491, pages 303 and 304.

On Assignments 1 and 2 there is no report.

On Assignment 3, Waterproofing Protection to Prevent Concrete Deterioration, Collaborating with Committee 8, there is a progress report, beginning on page 303, which I will present. It will be presented for information only.

At present, and for the past few years, many of our railroad maintenance officers have been disturbed by the increasing rate of deterioration of concrete in certain classes or age groups of concrete structures. Repairs to these structures require work of tremendous proportions, and at great cost.

Along with this problem, much thought has been given to methods of repairs and preservation of concrete. To make concrete durable, it must either be manufactured so that it is waterproof within itself and will resist weathering, or be given some effective surface treatment.

It is the latter, or surface treatment, with which your committee is concerned. In view of the demand for a product that will give adequate results, it becomes more and more apparent that tests and investigations should be made on waterproofing coatings to determine their ability to waterproof concrete. Accordingly, last year your committee presented as information the progress in making tests on commercial waterproofing paints and coatings for surface treatments. These tests, recommended by your committee, were made at Purdue University, under contract with the Association of American Railroads.

These tests were made to determine the waterproofing ability and durability of 72 different commercial waterproofing coatings, and were performed on an accelerated laboratory basis. Concrete test specimens 1 in. by 3 in. by 8 in. coated with the waterproofing paints were subjected to a 72-hour immersion test in water, and gain in weight because of moisture absorbed was compared to an unpainted specimen subjected to the same test to determine the waterproofing ability of the paints.

Further tests were made subjecting the specimens to a weatherometer test of 150 hours, and to determine the amount of absorbed moisture in the coated specimens as compared with the uncoated specimens after 72 hours immersion in water. These tests were followed by a test of 50 cycles of freezing and thawing and determination of the moisture absorbed, same as before. Finally, all specimens were placed outside for an out-of-doors weathering test of 90 days, and then subjected to the 72 hours of immersion in water to determine the effects of weathering on their waterproofing effectiveness and durability.

The results of the studies indicate that the commercial waterproofing paints tested are not capable of preventing the passage of water through them in an immersion test. There was, however, a wide range in performance between the most waterproof and the least waterproof, both as to waterproofing ability and to durability in the weathering test. Some of the painted specimens absorbed as much water during the immersion tests as the unpainted control specimens, but four paints were fairly waterproof throughout the testing period.

The range of durability in the weathering tests was just as great as that for waterproofing ability when all the paints were considered. It was not the intention to completely destroy the paint films in the weathering test, and only three complete failures occurred.

These tests and results appear in Progress Report No. 1, which has been sent to the chief engineers of member roads, but have not as yet been published.

Additional tests are in progress using 16 paints, and will be reported in the next progress report. These tests are intended to be destructive to the various paint coatings so that a relative index of impermeability and durability can be determined. The paints chosen for the new series of tests were those which showed good to fair waterproofing ability before the weathering tests, regardless of the effects of the subsequent weathering tests on the paint coatings. The tests, utilizing different specimens in each, are as follows:

1. Coated specimens exposed to the carbon-arc light of the weatherometer until failure occurs.
2. Coated specimens subjected to freeze-thaw cycles until the coatings have failed.
3. Coated specimens half-buried in the ground, in an upright position, for field exposure durability tests.
4. Coated specimens, containing a coarse aggregate with known poor laboratory and field performance records in concrete, subjected to freezing and thawing cycles to determine the additional life the specimens will have as compared to unpainted specimens

because of the ability of the paint coating to prevent water from being absorbed by the specimens.

5. Field exposure tests, on a vertical concrete surface with southerly exposure, in which 3 ft. by 3 ft. concrete panels are coated with each of the paints to obtain information on durability.

These tests will be reported on at a later date. When all tests are completed, your committee expects to draft a set of specifications for performance requirements and acceptability tests for surface waterproofing paints.

Mr. Mays: When that is done, it is expected that this will become a part of our Manual material.

I have just received a very interesting comment from Meyer Hirschthal, retired concrete engineer of the Lackawanna, and more recently a consulting engineer in the city of New York. I would like to read this comment. It opens up a little different field.

> In connection with the report of Committee 29—Waterproofing, Bulletin 491, and its Assignment 3, which calls for waterproofing protection to prevent concrete deterioration, I would like to call to the attention of the committee the fact that last year I wrote Professor Woods at Purdue, suggesting a parallel series of tests on coatings to test their ability to withstand the effect of stray currents of electricity on concrete structures.
>
> This resulted from an experience we had on the Lackawanna, where direct current is used in electrification, where the stray current caused deterioration of several reinforced concrete station platforms and bridges, with the result that these structures required treatment.
>
> We found at that time that materials such as asphalt emulsions served as protective treatment, similar to treatment against water action, and the writer's opinion was and is that, since the same material acted as protection against both water and deterioration due to stray electric currents, it might be feasible to make a parallel set of tests on the same protective coatings to see how effectively they are able to protect against such action.

This opens up another angle of the tests which have been carried on at Purdue, and is a matter which will be referred to your committee for proper action.

I would just like to mention that the tests which have been going on at Purdue have been under the very able direction of Professor K. B. Woods and J. B. Blackman, and have been carried out very meticulously. It has been a great pleasure for this committee to work with Purdue and with Professors Blackman and Woods.

Both Professor Blackman and Professor Woods are in the audience, and if there are any questions regarding these tests and how they were conducted, I'm sure that they would be glad to answer them.

President Loeffler: Are there any questions with respect to this report?

The Association appreciates letters such as have been written by Mr. Hirschthal on this subject. Such procedure quite frequently results in adding important information to our committee reports. I would urge that other members write such letters.

Mr. Mays: Mr. President, this completes the report, which is presented for information.

President Loeffler: Thank you, Mr. Mays; the report will be so received.

Mr. Mays: Mr. President, this also concludes the presentation of Committee 29.

President Loeffler: The type and quality of waterproofing materials and methods of applying those materials for the purpose of protecting railway structures from deterioration by the elements have an important bearing on the permanence of such structures.

Mr. Mays, the progress report on Assignment 3 just presented by your committee was of considerable interest. I am sure the final report on this subject will be of substantial benefit to all of the railroads. Your efforts are appreciated, and your committee is excused at this time.

Discussion on Impact and Bridge Stresses

(For Report, see pp. 300–302.)

(President H. S. Loeffler presiding.)

Chairman J. P. Walton (Pennsylvania): Committee 30—Impact and Bridge Stresses has 10 assignments and reports progress on all of them except Assignments 4 and 6.

A report on an investigation of impacts and stresses in three deck girder spans 70 ft. to 78 ft. long on the Chicago & North Western was presented in Bulletin 488, June–July 1950. This gives additional data on Assignments 1, 2, 3 and 10.

Tests have been made during 1950 on Assignments 5, 8 and 9, and progress is being made in the analysis of the accumulated data. Reports on these assignments will be presented as soon as possible.

On Assignment 2, the AAR research staff now has complete data on 27 girder spans varying from 40 ft. to 140 ft. in length. Data will be secured on two more spans next year. A final report on this assignment will then be presented.

On Assignment 7—Stresses and Impacts in Timber Stringer Bridges, Collaborating with Committee 7, tests in the field are planned. A serious difficulty in analyzing the results is encountered due to variation of the modulus of elasticity of the timber. The modulus varies with moisture content and from stick to stick.

Timber stringers are placed under the track so that two or more pieces carry one rail load. The load is distributed among the stringers according to the average stiffness of each stick. Field tests measure strains and not stresses. A larger strain indicates either a lower modulus of elasticity and a lower load in that stringer, or it means a larger load if the modulus of elasticity of all stringers is the same.

In planning these tests it is proposed first to make the field tests and then remove some stringers and test them in the laboratory and correlate the data.

President Loeffler: Any questions with respect to this report?

C. V. Lund (Chicago, Milwaukee, St. Paul & Pacific): Mr. Walton's remarks with respect to the testing of timber bridge stringers in the field leave the impression that results are unreliable. As I understand it, it was felt that stresses cannot be determined because the modulus of elasticity of timber is too variable, or too elusive of determination.

This is misleading. The modulus of elasticity, like other strength properties of wood, is, of course, variable, but no more so than certain other strength properties which you use in the design of bridges—in fact, it is less so. The modulus of elasticity varies principally with the specific gravity of the species and their moisture content. The specific gravity of any timber can be determined from samples of the wood, and moisture content can be determined in the field.

The variation of modulus of elasticity in any species is much less in large timbers, such as bridge stringers, than in small specimens, and the range is not outside reasonable limits of the average values established for the species.

In Professor Leggett's address this morning, he pointed out the data being recorded at Purdue on the laboratory tests being made there.

I am sure that the subcommittee is not too concerned about the variation in the modulus of elasticity.

President Loeffler: Thank you very much, Mr. Lund.

Mr. Walton, do you or any other member of the committee wish to comment on Mr. Lund's remarks at this time, or would you prefer that a copy of Mr. Lund's remarks be submitted to the committee for consideration?

Chairman Walton: I can make one short remark.

When they make the field tests, and then take the tests in the laboratory and check the modulus of elasticity, we can analyze those results very readily. When you make the tests and don't know what the modulus of elasticity is, you might be misled. I think we should watch the modulus of elasticity carefully on all timber work.

President Loeffler: Is there any further discussion from the floor on this subject? The report will be received as information.

The Association of American Railroads' research staff, with the collaboration of several other standing committees and outside interested agencies, has been carrying on an extensive program covering investigation of impact and stresses on railway bridges under various conditions of loading. Mr. Walton, your report indicates that considerable progress has been made by your committee during the past year. The efforts made by you and your committee are greatly appreciated. Your committee is excused with the thanks of the Association.

Discussion on Masonry

(For Report, see pp. 381–402.)

(President H. S. Loeffler presiding.)

Chairman C. B. Porter (Chesapeake & Ohio): The report of the Committee on Masonry is printed in Bulletin 492, pages 381 to 402, inclusive.

Your committee currently has eight assignments. While progress is being made on all eight assignments, we will report on only three at this convention.

Assignment 3—Foundations for Masonry Structures. In the absence of Subcommittee Chairman Max Nearing (New York Central) the report was presented by G. H. Dayett (Baltimore & Ohio).

Mr. Dayett: The Masonry committee recommends for adoption and publication in the Manual the revision of Art. A—General and B—Design of Specifications for Pile Foundations as they appear on pages 382 and 383 of Bulletin 492, January 1951, these articles to replace existing material under the same articles on pages 8–87 and 8–88 of the Manual.

Mr. President, I so move.

(The motion was regularly seconded, was put to a vote and carried.)

Chairman Porter: Through the efforts of the Subcommittee on Foundations, and particularly Roscoe Owen, construction engineer, Missouri Pacific Lines, and E. J. Ruble, structural engineer, research staff, Association of American Railroads, there was published in Bulletin 489, pages 149 to 202, inclusive, as an advance report of the Committee on Masonry, the results of recent tests on steel and timber piles driven in the swamps of Louisiana. This project was made possible through the sponsorship and financing of the Corps of Engineers, U. S. Army, who, in appreciation for the cooperation they received, generously gave permission for this report to make its first public appearance in an AREA Bulletin. These tests will be referred to very briefly in the report to follow.

Assignment 4—Earth Pressure as Related to Masonry Structures, was presented by the Subcommittee Chairman R. B. Peck (University of Illinois.)

Mr. Peck: At the request of the committee, this report is divided into two parts. The first deals with proposed specifications for design of retaining walls and abutments, and the second with the results of various full-scale tests on groups of piles recently reported in engineering literature.

The specifications proposed for retaining walls and abutments are to be found in Bulletin 492, pages 384–393, inclusive. These specifications differ to a considerable extent from those now appearing in the Manual, which are concerned primarily with the details of computing earth pressures and with certain details of structural design. They do not comprise a well-rounded or complete summary of the procedures that should govern the design of retaining structures. The proposed specifications begin with a statement of the information required prior to design. There follows a brief discussion of the methods of determining the earth pressure. Considerable attention is given to the conditions for the stability of the structure as a whole, especially in connection with the adequacy of the foundation materials. This emphasis has been prompted by the subcommittee's belief that most failures of retaining walls and abutments have been the result of errors in judgment concerning the supporting capacity of the materials beneath the base level of the foundation. Finally, considerable attention is given to appropriate methods of placing backfill and for carrying out the details of design and construction.

Part of the information in the proposed specifications deals with the same load that may be placed upon the foundation. This, in turn, requires some discussion of the properties of subsurface materials. It is anticipated that data now being prepared by Committee 1 concerning soil properties and by Committee 8 concerning footing foundations will ultimately permit the elimination of part of this material from the retaining wall specifications.

These specifications are presented as information, and with the hope that criticisms and suggestions will be freely offered during the coming year.

The request for comments concerning pile loading tests is the result of several very instructive full-scale experiments in which entire groups of piles have been loaded, and in which, in some instances, the manner of distribution of the pile load to the soil has been experimentally determined.

Three principal series of tests have now been performed, all in materials where very little of the capacity of the pile could be attributed to bearing at the point. The first series was made in connection with the Morganza Floodway in 1940, and was reported in a paper (1943) by Mr. Masters in the Transactions of the American Society of Civil Engineers. The second series was made in connection with the Atchafalaya Floodway, and the results were reported in AREA Bulletin 489, September 1950. The third group of tests was made at Omaha by the bridge department of the State of Nebraska in 1950.

The principal object of all the tests was to determine the behavior of groups of piles in contrast to that of single piles. It was known in a general way that the settlement of a group of piles exceeded that of individual piles at the same load per pile. It was also realized that under certain conditions the capacity of a group of friction piles could be appreciably smaller than the sum of the ultimate capacity of each pile in the group. Various expressions, such as the Converse–LaBarre efficiency formula, have been proposed to take these factors into account. The validity of the procedures appeared somewhat questionable from a theoretical point of view and required field verification. All the tests demonstrated that if the piles in a group are spaced too closely, the capacity of the group is appreciably smaller than the sum of the ultimate capacity of each pile in the group. However, taken as a whole, there is no convincing evidence that elaborate efficiency formulas are justifiable as design tools. Much more evidence will be required before such formulas can be considered acceptable, and it seems more than likely that the evidence will indicate their inadequacy rather than their suitability.

The tests provide some evidence that the distribution of load to individual piles in a group of friction piles may be considered uniform. There is no definite trend, for example, to indicate that the corner piles may be more heavily loaded than the interior piles.

In the last two series of pile tests, strain measurements were made to determine the distribution of the shear between piles and soil. Both sets of experiments indicated relatively high shearing stresses near the upper parts of the piles. However, all the tests were of comparatively short duration. As a matter of fact, devices capable of measuring stress under field conditions for long periods of time have not yet been developed. Hence, the tests have indicated only the distribution of soil reactions within the first few days or weeks after loading. Under the weight of a structure or under continued repetition of load, this distribution may change radically with time. We are not yet in a position to predict what the ultimate state of stress in and around a pile group would be.

Because of this factor, the tests should be regarded as pioneer research projects, useful in the design of the particular foundations for which they were intended, but by no means conclusive concerning our knowledge of the behavior of pile foundations. Too much generalization on the results at the present time could easily be dangerous.

President Loeffler: Thank you very much, Mr. Peck.

I would like to take a moment to call your attention to one apparent error on page 386 of Bulletin 492. In the last paragraph before the heading, "C. Computation of Applied Forces," the paragraph reads, "Other procedures for investigating the relative density of sands or the consistency of clays may be used in places"—I believe it should be "in place"—"of those recommended in the preceding paragraphs, provided such procedures lead to quantitative results." That last should be "qualitative results," I believe.

Mr. Peck: I believe "quantitative" is correct. "Place" should be singular. The meaning is that you should be able to get numerical results for the physical properties in which we are interested.

President Loeffler: Do you think the word, "numerical," would be better understood than "quantitative?"

Mr. Peck: Maybe.

President Loeffler: The committee might consider that in the final draft of the report.

I would like to make another suggestion. At the bottom of page 385, under "5. Character of Foundation," the next to the last paragraph outlines a method of determining the relative density of the material, the relative density of soils. It shows a method of determining the density by determining the distance—the penetration, so to speak—a prescribed spoon is driven, as a result of a driving weight.

It reads, "The relative density is measured by the number of blows N required to obtain a penetration of 1 ft." Following that is another short paragraph that describes the method of determining the unconfined compressive strength of clay soil.

Following that paragraph on the next page is a very excellent table describing the relative consistency of the clay soil, as determined by these various tests.

I wonder if it would also be advisable to have a similar table following the first paragraph that I referred to on page 385? In other words, if a person makes a test according to the information contained in the paragraph as written, and obtains the number of blows required to penetrate the spoon so many feet, it still leaves him without any indication as to what the relative density of this material is.

On the other hand, if you had a table set up something like the table at the top of page 386, anyone could count the number of blows required to penetrate the spoon 1 ft. in the soil, and then, by referring to the table, would have some kind of a guide to the relative density of the material concerned.

Mr. Peck: I think, Mr. President, that the chart on page 389, which relates the values of N to the angles of internal friction (which is the quantity in which you are most interested—that you would use in computation) serves that purpose.

President Loeffler: That being the situation, should there be some reference at the end of that paragraph to the table shown on page 389?

Mr. Peck: Yes, that would be desirable.

President Loeffler: That is a very excellent report, and it is received as information.

Assignment 7—Methods for Improving the Quality of Concrete and Mortars, Collaborating with Committee 6, Buildings, was presented by Subcommittee Chairman M. S. Norris (Baltimore & Ohio).

Mr. Norris: The report on Assignment 7—Methods for Improving the Quality of Concrete and Mortars, will be found on page 394 of Bulletin 492, published January 1951.

In recent years many railroads have found it economical to use ready-mixed concrete. The information given in the report will supplement the specifications found in the Manual.

The ready-mixed concrete industry, during its 30 years of existence, has to a great extent overcome the difficulties of segregation which resulted from hauling plastic concrete. The use of entrained air in concrete helped to solve the segregation problem, but, at the same time, it presented new problems in controlling the air content. The development of improved trucks and batching equipment has been an important factor in the production of better ready-mixed concrete.

Ready-mixed concrete has several distinct advantages. The principal one is the convenience of having plastic concrete, ready to be placed in the structure, delivered to the site of the work. Its use eliminates the need for transporting mixing equipment, handling and storing materials, and locating a suitable water supply. The chief disadvantage of using ready-mixed concrete on the railroad is the difficulty in reaching some structures along the right-of-way.

Ready-mixed concrete is generally produced by one of two methods. The materials are either proportioned at a central plant and mixed enroute to the job, or the concrete is mixed at the central plant and hauled to the job in trucks.

The report describes the equipment used in the measurement and control of materials and the various types of trucks necessary for the transportation of the concrete. In recent years many improvements have been made in batching equipment. Weighing batchers of the semi-automatic type and full-automatic type, with operations interlocked, have been developed. These machines, if properly operated and maintained, will provide accurate control of aggregates.

A careful inspection of the plant and personnel of a ready-mixed concrete producer should be made when making arrangements for service. The plant equipment and material storage should show evidence of good housekeeping. A plant that is carelessly operated and maintained will not be able to furnish dependable service and will cause costly delays. The capacity of the plant and trucks should be sufficient to meet the maximum demand for the delivery of concrete.

A ready-mixed concrete plant, adequately equipped and properly supervised, affords excellent opportunities for the control of concrete quality. The best material, combined with scientific proportioning and the most modern equipment, will not produce good concrete unless it is handled by capable and conscientious personnel. Competent supervision of the production of ready-mixed concrete must include every operation from the material stockpile to the delivery of the concrete.

The time element assumes more importance in the ready-mixed concrete business than in any other branch of the building materials industry, for the reason that freshly mixed concrete is an extremely perishable commodity. The operations of the producer and the purchaser must be closely coordinated to keep to the minimum the time between the addition of mixing water to the cement and the final consolidation of the concrete in the structure.

It is the responsibility of the ready-mixed concrete manufacturer to interpret the specifications intelligently. Many of the control problems peculiar to the ready-mixed concrete industry are caused by the varied specifications which the producer must meet. The plant organization must be flexible as well as competent, for it is not uncommon for the same plant during one day's operation to furnish concrete to several jobs having different specifications. The producer's aim is to furnish concrete of high quality in an economical manner. The purchaser with little or no knowledge of the principles of mix design can obtain specification concrete from the ready-mixed plant. Only through a meeting of the minds of the purchaser and the producer, and an understanding of each others problems, can the full benefits of the use of ready-mixed concrete be realized.

Mr. President, we would like to recommend that this report be accepted as information.

President Loeffler: Is there any discussion of this report? The report will be received as information.

Chairman Porter: In recent months many of us have heard reference to prestressed concrete. Some of us are not too well acquainted with just what is meant by this relatively new term. In order that we may have a better general idea of what prestressed concrete is, I take pleasure in presenting George Paris, of the Structural and Railway Bureau, Portland Cement Association, a member of this committee, who will speak briefly on the subject, Prestressed Concrete for Railroad Construction.

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Prestressed Concrete for Railroad Construction

By G. H. Paris

Railroad Representative, Structural and Railway Bureau, Portland Cement Association

The development of prestressed concrete has created a new structural material which is making possible some remarkable advances in structural engineering. Basically, it is a new application of old ideas, which has produced a highly efficient material with many different uses.

Prestressed concrete brings to the construction field a material which combines the important qualities of concrete with the physical advantages of a homogeneous material. It is made with the same cement, aggregate and concrete equipment as before, and yet prestressed concrete performs entirely different under load. It is, in effect, a lighter and stronger material than conventional reinforced concrete and can be used to build longer spans to carry heavier loads. Prestressed concrete is an elastic material, for which the stresses and deformations can be accurately computed. Probably no other development in the structural field in recent years has created so much interest among engineers and builders as the introduction of prestressed concrete. This is apparent from the fact that not more than three years ago it was practically unknown in this country, while today it is one of the most talked about and highly publicized subjects in the construction field.

The basic purpose in prestressing concrete is simply to eliminate tensile stresses by superimposing compressive stresses. This is done by stretching the reinforcement and transferring the force to the concrete. This much was known 63 years ago, but it was almost 40 years later before the principle was applied successfully. Mild steel was used in the early attempts to prestress concrete, and although the neutralizing compressive stresses could be induced they could not be maintained indefinitely. When Eugene Freyssinet, a French engineer, used high-tensile-strength steel in place of mild steel, the main obstacle was overcome and prestressed concrete became a reality.

The design of this new engnieering material is relatively simple and involves nothing new in design principles. It is designed essentially as any other homogeneous material subject to direct load and bending. Actually, prestressed concrete is more of a construction technique than it is a design problem. Prestressing is a simple procedure in which simple equipment is used. The whole process of casting and prestressing is equally adaptable to casting yard or job site production, although it lends itself particularly well to precasting with all of its inherent advantages and economies. The reinforcement may be single wires, or cables or strands composed of many wires. If the reinforcement is tensioned before the concrete is placed, the prestressing process is known as pre-tensioning, and if the reinforcement is tensioned after the concrete is placed and hardened, the process is known as post-tensioning.

Prestressed concrete has been used successfully in many European countries for several years. It has been used for highway and railroad bridges, industrial buildings, hangars, tanks, and reservoirs, and for precast structural units, such as pipes, poles and joists. It has been used for many other purposes also, but we are more interested in its use and possible uses in this country. Already it has been used here in water tanks, pressure pipes, piles, floors, roofs and highway bridges. The Walnut Lane bridge in Philadelphia, Pa., is an outstanding example of the use of prestressed concrete in long-span bridges. The 160-ft. center span is comparable with the longest span of this type found in Europe. The depth of the girders is only 6 ft. 7 in., a depth to span ratio of 1:23.

In Tennessee a three-span highway bridge has been designed and built using concrete blocks. The blocks were cast in an ordinary block machine and strung on high-tensile-strength airplane strands. The blocks were assembled at the casting yard in single-block-wide beams, which were later prestressed laterally in the field to tie them together in a unit. This same procedure, or prestressing precast units to form beams, has been used in Europe to construct bridges with span as long as 240 ft. In California, the state highway department has been making a study of prestressed concrete highway bridges and has found that they can increase the length of their solid-deck spans from 60 ft. to about 80 ft. by prestressing. They found that this length could be further increased to about 120 ft. by casting cores in the slab.

The application of prestressed concrete to the railroad bridge field is equally possible. To demonstrate the performance of this material under railroad loads a prestressed concrete trestle slab was designed and built in the Portland Cement Association's laboratories. With the cooperation of the Association of American Railroads the slab was tested to failure before members of the AREA Masonry committee, the American Railway Bridge and Building Association, and representatives of several state highway departments and the Bureau of Public Roads.

The slab was full size, 25 ft. long, 7 ft. wide, and 18 in. deep, or approximately one-half the depth of a conventional reinforced concrete slab of the same length. It was designed for an E72 live load and full impact. Concrete strength was 6000 psi., and the slab was prestressed with fifteen 1⅜-in. diameter galvanized bridge strands. Each strand consisted of thirty-seven 5-mm. diameter wires, with a total cross-sectional area of 1.12 sq. in. The strands were post-tensioned to 120,000 psi. Each strand was encased in a plastic tube to prevent bond.

The slab remained perfectly elastic up to its ultimate load, which was 2.5 times the total design load or 2.8 times live load and impact. Many of the advantages of prestressed concrete were apparent from the results of the test. These were a reduction in dead load, savings in steel and concrete, greater span to depth ratio, and increased resistance to flexure.

Prestressed concrete offers many advantages and economies of construction to the railroad engineer as well as to the practicing engineer elsewhere. The ultimate use of prestressed concrete will be determined by its economic advantages over other methods and materials of construction. It is not expected to compete with conventional reinforced concrete, but rather to extend the use of concrete into other fields formerly limited by span length or load. Undoubtedly, there will be improvements in end anchorages and fittings, and in construction methods as experience is gained.

The prestressed trestle slab was built and tested to help railroad engineers familiarize themselves with the merits of prestressed concrete. A colored motion picture was taken during the construction and testing of the slab to show the details of construction and the performance of the slab under load. By means of this film, I would like to take you to the laboratory now to see that work. [*This address was followed by a showing of the motion picture referred to.*]

Chairman Porter: Thank you, Mr. Paris.

Mr. President, I feel it would be appropriate at this time to advise the members of the Association that during the past year the AREA has been given well deserved recognition in the field of masonry in two specific instances.

Gentlemen, your Association has received and accepted an invitation to join with other outstanding engineering organizations and government agencies to form the Reinforced Concrete Research Council. The purpose of this Council is primarily to sponsor and coordinate worthwhile research in the field of reinforced concrete, and to act in an advisory capacity to the Engineering Foundation in regard to the allocation and administration of funds for that purpose.

In the other case your Association received and accepted an invitation to join five other selected national engineering organizations as co-sponsor of the First United States Conference on Prestressed Concrete, to be held at Massachusetts Institute of Technology during the month of August 1951. Your Association's representatives took an active part in a preliminary meeting concerning this very important conference, which was held in New York City last February 9.

Your committee feels that substantial benefit will accrue to the railroad industry, as well as to the Association, as a result of our active participation in these two very worthwhile projects.

President Loeffler: Thank you very much, Mr. Porter.

Chairman Porter: As chairman of the Committee on Masonry, I want to express to all our members my sincere appreciation of their fine work, attendance at meetings, and wholehearted cooperation during the past year.

Mr. President, this concludes the report of the Committee on Masonry.

President Loeffler: Mr. Porter, the subject of masonry construction—including, in particular, plain and reinforced concrete—is one of vital interest to the railroads. Your committee continues to improve its standard specifications for the design and construction of masonry structures, and has developed new rules and better methods of mixing and placing concrete, with the result that the permanence of concrete and the life of masonry structures have been substantially increased.

Your committee is to be specially commended for taking up this relatively new subject of prestressed concrete. You are excused with the thanks of the Association.

Discussion on Iron and Steel Structures

(For Report, see pp. 445–478.)

(President H. S. Loeffler presiding.)

Chairman J. L. Beckel (New York Central): The report of Committee 15 is printed in Bulletin 492, starting on page 445. Of the ten assignments of the committee, we are reporting on three this morning. I would like to say that very good progress is being made on the other seven assignments.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman E. S. Birkenwald (Southern).

Mr. Birkenwald: Starting on page 446 of Bulletin 492, you will note that Assignment 1—Revision of Manual, includes three items, namely: Rules for Rating Existing Iron and Steel Bridges, Blast and Fume Protection, and Specifications for Movable Railway Bridges.

When the Association adopted the current Rules for Rating Existing Iron and Steel Bridges in 1950, retention of Art. 106a was not included, nor was it expected that Art. 112 would state "Same as Art. 114 of the current rating rules." What was intended, of course, was that Art. 114 of the rules just prior to adoption in 1950 should be used as the current Art. 112.

The Committee feels that the Association should adopt and publish the corrections to the Rating Rules as indicated on page 446, and I so move.

President Loeffler: Do we hear a second to that motion?

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Birkenwald: Heretofore, blast and fume protection have been considered by the Association in connection with steel highway bridges. At the 1923 annual meeting of the Association, a specification for steel highway bridges was presented as information, in which provision was made for cast iron blast plates at least 4 ft. wide, located over the center line of each track where members of bridges spanned steam railroad tracks and had a clearance over the tracks of less than 20 ft.

At the 1924 annual meeting a revised specification for steel highway bridges, with the same provision, was presented as information, since it developed that the American Society of Civil Engineers and the American Association of State Highway Officials were also working on a like specification, and it was thought desirable that there should be joint effort on the part of the three organizations.

Subsequently, at the 1929 annual meeting, specifications for steel highway bridges, compiled by a conference committee composed of representatives from the AASHO and

AREA, were adopted for publication in the Manual. The adopted specifications provided for blast protection in which cast iron plates not less than 3 ft. wide and not less than ¾ in. thick were to be used in the same locations as specified in the earlier specifications presented as information.

With the adoption of a new AASHO Specifications for Steel Highway Bridges in 1935, the Association decided at the 1936 annual meeting to withdraw its specifications for steel highway bridges, and to recommend the use of the AASHO specifications of 1935. Later, in 1942, the Association omitted reference to the AASHO specifications in the Manual, since it was pointed out that each state highway department insisted on the use of its own specifications for the construction of highway bridges.

Several years ago it was suggested that the committee develop a recommended practice for blast and fume protection, inasmuch as many of the railroads had underpass or overhead crossings with other railroads, besides other overhead structures which were railroad maintained. This recommended practice is given on pages 446 and 447 of Bulletin 492. It differs from the current AASHO specifications in the following respects:

1. The proposed AREA practice indicates that overhead structures 24 ft. or less above top of rail should be protected, as against the AASHO less than 20 ft.

2. The AREA practice, if adopted, will rule out the use of asbestos board shields, and will permit the use of stainless steel and corrosion-resisting low alloys of thinner dimensions than the blast-resisting alloy provided in the AASHO specifications.

In this connection, Meyer Hirschthal recently wrote to the Association, calling attention to the use of transite shields used by the Delaware, Lackawanna & Western, which have been installed now for at least 15 years, and which do not appear to be deteriorated.

Your committee considered the use of asbestos board or transite shields, and it was determined that some installations of this material had failed in a relatively short time. In view of this, the committee decided against including this material as protection from blast and fumes.

3. The AREA version provides for the use of larger bolts and rivets than the AASHO, and is more specific as to protection of the fastenings.

4. It provides for projection beyond the structure, and calls attention to the fact that blast plates should be so detailed and placed as not to deflect the blast against other parts of the structure.

It is felt that this new material on blast and fume protection should be included as a part of Chapter 15, and I therefore move its adoption and publication in the Manual.

(The motion was regularly seconded, was put to a vote and carried.)

Mr. Birkenwald: At the last annual meeting the committee submitted a partial draft of Specifications for Movable Railway Bridges. Comments and criticisms were solicited. At the present meeting the committee is submitting revisions of the draft submitted last year, which can be found on pages 447 to 450, inclusive, and pages 465, 466 and 467, covering sections I, II, III and V of the Specifications. Section IV, covering details of design in this year's draft, is now complete, and includes those articles in Section IV of last year's draft. Sections VI through IX are new, and complete the specifications.

It is noted that the introduction to these specifications on page 447 is not sufficiently delineated from the material on Blast and Fume Protection, so that the reader might momentarily be confused. It is hoped that this can be corrected when the Proceedings is printed.

The committee is indebted to Messrs. Hardesty and Tammen for their untiring work in preparing modern specifications for movable railway bridges. These specifications have been subjected to rigorous review by the committee, and, if no further comments or criticisms are received, will be submitted next year for adoption and publication. The specifications, contained on pages 447 to 477, inclusive, are presented this year as information.

President Loeffler: Thank you, Mr. Birkenwald.

Are there any comments or suggestions with respect to these specifications at this time?

Chairman Beckel: I have a written comment from Meyer Hirschthal, concrete engineer, retired, of the D. L. & W., in which he states that the specifications for movable bridges—page 451 of Bulletin 492, under "403. Counterweights"—contains the provision that "Pockets shall be provided in the counterweights to house the balance blocks necessary to care for not less than 3½ percent underrun and 5 percent overrun in the weight of the span. Each completed counterweight shall contain not less than 1 percent of its weight in balance blocks," while the following sentence calls for a provision of additional blocks of only ½ of 1 percent weight. He says, "It seems to me that this is not consistent."

Then to continue, with paragraph 404 on Concrete: "The type of cement is Type 2 only, whereas it might be advisable to include Type 3, which is a high early-strength cement which might be used where it is found necessary to expedite the work."

Mr. President, inasmuch as this specification is being presented as information, we welcome such comments as Meyer Hirschthal's, and we would be very pleased to receive any additional comments from members during this coming year, in which time the subcommittee will review all the comments and make their recommendations when we propose this specification for adoption at the next convention.

President Loeffler: Thank you very much, Mr. Beckel. The report will be received as information.

Assignment 5—Design of Steel Bridge Details, was presented by Subcommittee Chairman G. L. Staley (Missouri-Kansas-Texas).

Mr. Staley: The report of this subcommittee is submitted as information. It is published in Bulletin 489, pages 111 to 129, inclusive, and is a report of the effects of fatigue of metals as adapted from the University of Illinois bulletins 377 and 382, entitled Flexure Fatigue Strengths of Steel Beams and Fatigue Strength of Various Details Used for the Repair of Bridge Members.

Both bulletins were prepared under the direction of Professor W. N. Wilson, research professor of structural engineering, who is well known to most of us here. Mr. Wilson has done a great deal of work over the past 30 years or more on fatigue, and has greatly advanced the knowledge of this important matter.

In the consideration of fatigue in metals as a practical matter, it must be kept in mind that failures occur only after a great many applications of force, producing unit stresses well over the design stresses, and perhaps approaching the yield strength of the metal, and over a wide range of stress and tensity.

The information developed by these tests is valuable, in that it permits us to design and detail new bridges better, and to know where to expect trouble in, and how better to arrange details of repairs to old bridges.

E. J. Ruble, construction engineer, AAR, who does a great deal of the committee's work, prepared a report on this matter and presented it to the committee at one of our meetings during the past year. He will now present a similar report here.

President Loeffler: Thank you, Mr. Staley.

E. J. Ruble (Association of American Railroads): The report on the fatigue tests of beams in flexure appearing in Bulletin 489 covers essentially the results obtained when various types of beams were subjected to repeated loads. The load cycle on the beam was repeated until failure developed at some location in the beam, and the fatigue strengths at 100,000 cycles and 2,000,000 cycles were determined from the results.

Fatigue data were obtained on 27 different types of beams such as: plain rolled beams, rolled beam with partial-length cover plates attached by either welding or riveting, rolled beams with full-length cover plates attached by either welding or riveting, and fabricated beams consisting of flange plates welded to a web plate. Data were also secured on the various methods of welding the ends of the partial-length cover plates to the beams, either welding or riveting various attachments to the beam flanges and splicing beams by riveting or welding.

The most significant features pointed out in this report are:

1. Any plain rolled beam will have a greater fatigue life than any cover-plated beam or any fabricated beam of the same section modulus. It is evident that the permissible stresses in fabricated or cover-plated beams should be lower than those in rolled beams when the members are subjected to repeated cycles of load.

2. The carrying capacity of a beam with partial-length cover plates is decreased tremendously over that of a beam with full-length cover plates. If lack of depth dictates cover-plating of beams in new work, or if existing beams are cover-plated for reinforcement, the cover plates should preferably be of full length and in any case long enough so that the stress in the main material at the end of the plate is greatly reduced.

3. The various tests conducted on specimens with partial-length cover plates fastened to the beams with welds, but with different plate and weld end conditions, indicate that there is no practical method to increase their fatigue strength.

4. The carrying capacity of a beam with partial-length welded cover plates is not reduced by welding across the ends of the plates, as the stress-raising effect of this weld is about the same as that of the longitudinal welds.

5. The customary working stresses and methods of design of reinforcement are adequate for flexural members, such as girder spans, designed to withstand not over 100,000 cycles of maximum stress range, but precautions are recommended in the report in designing reinforcements for flexural members, such as stringers and beam spans, where the members are subjected to more than 100,000 cycles of stress.

President Loeffler: Thank you very much, Mr. Ruble.

Chairman Beckel: I might say in connection with the reports of Mr. Staley and Mr. Ruble that three of our subcommittees are now working on this subject, and from the valuable information obtained from Professor Wilson's work, I am sure that in the near future we will have certain recommendations with respect to changing our design specifications.

Assignment 8—Specifications for Design of Corrugated Metal Culverts, Including Corrugated Metal Arches, was presented by Subcommittee Chairman J. F. Marsh (Chicago, Rock Island & Pacific), who read the report as printed on page 478 of Bulletin 492.

Chairman Beckel: Mr. President, I wish at this time to express my deep appreciation and many thanks for the wholehearted cooperation of each and every member of Committee 15. It is only through their earnest efforts that Committee 15 can accomplish the work it is doing.

That concludes our report, Mr. President.

President Loeffler: Inasmuch as steel may possibly become one of the nation's most highly critical construction materials, it is especially desirable that Committee 15 should continue to formulate and maintain up-to-date specifications that will bring about the most economical use of steel for structural purposes, keeping in mind, however, that an adequate factor of safety must be maintained.

The reports just presented by Committee 15 assure us that Mr. Beckel and his committee have this subject well under control.

Mr. Beckel, you and your committee are excused at this time, with the thanks of the Association.

MEMOIRS

MEMOIR

Frederick E. Morrow

Died April 29, 1950

Fred Morrow, retired chief engineer of the Chicago and Western Indiana Railroad Company and The Belt Railway Company of Chicago, was born October 27, 1880 at Kokomo, Ind., and died on April 29, 1950 at his home in Oak Park, Ill. He received his engineering education at Purdue University, being awarded the degree of B.S. in 1904 and C.E. in 1908.

Mr. Morrow began his railroad career with the Chicago and North Western Railway in 1904. In 1907 he left the Chicago and North Western Railway and served as field engineer for the Board of Supervising Engineers, Chicago Traction, from 1907 until 1910. He entered the service of the Chicago and Western Indiana Railroad and The Belt Railway Company of Chicago as office engineer in 1910, serving those roads continuously until his retirement October 1, 1948. He was advanced successively to positions of principal assistant engineer, assistant chief engineer and chief engineer, which latter position he held at the time of his retirement.

Frederick E. Morrow

Mr. Morrow was a member of the American Society of Civil Engineers and the Western Society of Engineers. He was active in the work of the Western Society of Engineers and served as chairman of the Railroad Section in 1918, second vice-president in 1924, first vice president in 1925 and as president in 1926. He contributed greatly to the Society and was largely instrumental, through his initiative and foresight, in bringing about the removal of the Society from its inadequate quarters in the Monadnock Building in Chicago to new offices, with the use of the large auditorium, in the Engineers

Building on Wacker Drive, which was occupied by the Society until the recent removal to its present location.

Mr. Morrow joined the American Railway Engineering Association in 1918 and was one of its most valued and progressive members. He served as chairman of the important Shops and Locomotive Terminals committee from 1920 to 1927, as director from 1928 to 1931, chairman of the Waterways and Harbors committee in 1936, vice president 1936 to 1938, and president of the Association 1938 to 1939.

Not only was he an engineer by education and occupation but he was a born engineer with a keen, analytical mind and vision, but thoroughly practical.

As official of two terminal railroads in Chicago, he encountered many problems incident to the development of the city, such as track elevation, study of passenger terminals, waterways, etc., and was an active member of committees formed relating to these matters. Because of his good judgment and practical vision his counsel and advice in these matters was sought and valued.

Mr. Morrow was particularly active in waterway matters, and his services were enlisted to oppose such waterway development as would have been to the disadvantage of the railroads, and to the city of Chicago in general. About 1915, he organized and was made chairman of the Calumet Sag Canal Engineering Committee, representing 25 railroads involved in this Chicago waterway project.

Through his constructive work and cooperative efforts, he succeeded in getting the U. S. Engineers to agree to a limited overhead clearance which would permit barge operation, but not the operation of masted vessels. This eliminated the need for movable bridges over most of the area involved, thereby saving the railroads and taxpayers from very large expenditures required to build, maintain and operate movable-type railroad and highway bridges. This contribution not only made possible a saving on the local project but established a precedent for like savings on similar projects throughout the country. Through the efforts of this committee, formed by Mr. Morrow, large proposed expenditures for the Sag Canal project which were not economically justified have been deferred.

In the death of Mr. Morrow the American Railway Engineering Association, other engineering societies with which he was associated and in which he was keenly interested, and a host of friends have suffered a great loss. All who were associated with him recognized his professional ability and valued highly his sound and seasoned judgment.

H. R. CLARKE, *Chairman,*
A. R. WILSON
D. J. BRUMLEY
G. P. PALMER
V. R. WALLING
Committee on Memoir.

MEMOIR

A. A. Miller

Died March 25, 1951

Albert Arthur Miller, son of Peter and Bertha (Timroth) Miller was born September 28, 1879, at Zanesville, Ohio.

He attended high school at Zanesville, and was graduated in 1902, with the degree of civil engineer, from Ohio State University. During vacations at Ohio State he worked for coal mines in Ohio and West Virginia and for the Ohio and Little Kanawha Railroad.

Upon graduation Mr. Miller entered the service of the Baltimore and Ohio Railroad as rodman at Wheeling, W. Va. After only four months as rodman he was promoted to assistant engineer, being located first at Cleveland, Ohio, and then at Baltimore, Md. In January 1907, he was appointed division engineer of the Philadelphia Division, where he served until September.

Albert A. Miller

An exceptional offer to engage in silver mining in Old Mexico tempted Mr. Miller to leave railroading. He became chief engineer of the West Coast Mining Company, and for about two years he endured the hardships and rough life of a mining camp. But the price of silver dropped and the project failed. This experience taught Mr. Miller that railroad engineering in the good old United States had its advantages, even though the chances for early great wealth might not be so promising.

Just at this time, May 1909, the Missouri Pacific's engineering department was being strengthened and, because of his Baltimore & Ohio experience, Mr. Miller had no difficulty in finding work. A car was being designed and built to record automatically defective gage, surface and line of track, and as Mr. Miller had had a part in designing and building a similar car on the B. & O., he was immediately assigned to this project.

After a year and a half as assistant engineer working out of the general office, Mr. Miller was made division engineer of the Kansas City Terminal Division, and then of the Missouri Division with headquarters at Poplar Bluff, Mo. While division engineer Mr. Miller married Margaret Kathryn Tietjen on October 8, 1913. Mrs. Miller passed away on Christmas Eve, 1950, only three months before Mr. Miller's death.

On January 1, 1917, Mr. Miller was promoted to engineer maintenance of way of the Southern District at Little Rock, Ark., and a year and a half later was moved to Kansas City in charge of maintenance on the Western District.

In 1921 Mr. Miller was made superintendent, and served as such for four years at Poplar Bluff, Mo., and Wynne, Ark. Then, on February 4, 1925, after 16 years with Missouri Pacific, he was appointed engineer maintenance of way of the entire railroad and (with a change in title to chief engineer maintenance of way, in 1938) served as such until his retirement on October 31, 1949.

Mr. Miller became a member of the American Railway Engineering Association in 1920. He served on the Contract Forms and Rail committees, and was elected director in 1940, vice president in 1943, and president in 1945. He also served on the Committee on Cooperative Relations with Universities from 1946 until his death.

As a member of the Railroad Committee for the Study of Transportation, headed by Judge Fletcher of the Association of American Railroads, Mr. Miller rendered very valuable assistance.

His other memberships included the American Society of Civil Engineers (1919), the Engineer's Club of St. Louis (1925), the Ancient and Accepted Scottish Rite, the Delta Upsilon Fraternity, and the Fourth Church of Christ, Scientist, St. Louis, Missouri. He was also a member of The Mother Church, The First Church of Christ, Scientist, Boston, Mass.

Although Mr. Miller was an authority on track and roadbed maintenance, his accomplishments along those lines were overshadowed by his stimulating and extreme optimism. Every one with whom he came in contact felt the force of his personality. Because of this, it became the custom to call on Mr. Miller to address the monthly meetings of Missouri Pacific staff officers, and these good-will sermons are a most prized memory.

Mr. Miller passed away on a visit to his only child, his son Albert A., Junior, on Easter Sunday, March 25, 1951.

R. P. HART, *Chairman*
A. R. WILSON
H. R. CLARKE
F. R. LAYNG
Committee on Memoir

Report of the Secretary

March 1, 1951.

To the Members:

The past year for the Association opened on a sad note as our newly elected president, George L. Sitton, assistant chief engineer of the Southern Railway System, became ill just at the time of our 1950 convention, could not be in attendance at that meeting, and was forced subsequently, for reasons of health, to resign his office, effective April 25. However, the Association was fortunate in its able senior vice president, H. S. Loeffler, assistant chief engineer, Great Northern Railway, who immediately stepped into the breach and assumed the duties of president, and who subsequently—on July 5—became president, as the result of the adoption by the membership of an emergency amendment to the constitution. This amendment provides for the immediate and automatic advancement of vice presidents in the event of a vacancy in the office of president. At the same time, T. A. Blair, chief engineer, Atchison, Topeka & Santa Fe, system, and junior vice president, was advanced automatically to senior vice president. Subsequently, C. J. Geyer, vice president—construction and maintenance, Chesapeake & Ohio Railway, was elected junior vice president by the Board of Direction, to fill the vacancy created by the advancement of Mr. Blair.

Thus, while the office of president was unsettled for the first few months of the year, there was no faltering or hesitancy in any phase of Association activity, which has progressed steadily, first under Mr. Loeffler as acting president, and later as president.

Likewise, any concern for the welfare of the Association as a result of a change in its secretary, which, admittedly, was fully justified, apparently lessened as the year progressed, as your new secretary, with the loyal help of his staff, began to grasp the multiplicity of details attendant to the secretary's office. Your new secretary had to lean heavily upon the experienced members of the office staff for information and guidance in conducting routine procedure, but, favored with the necessary advice and help, for which he is deeply appreciative, the work of the secretary's office has kept pace. In fact, all publications were issued on or ahead of schedule, and the office put forth efforts which saw the progression or final disposition of several long-standing items of "unfinished business."

So, in spite of any uncertainties as the 1950 Association year got under way, the year as a whole passed without set back or failures. In fact, thanks to the wise guidance of your officers and the loyal effort and cooperation of your committee chairmen, and the membership generally, the Association has had a highly successful year from every standpoint—financial, membership, and productive work of committees. Furthermore, it has been fully alert to the growing tenseness of international relations, with their probable repercussions on the railway industry, and the work of railway engineering and maintenance officers in particular. In this regard, as is referred to in more detail later in this report, it took steps to assure that the recommended practices of the Association, and its investigations and studies, will keep in close step with current requirements, whatever they may be.

Membership

The membership of the Association for the year February 1, 1950, to February 1, 1951, which showed a net gain of 39, was as follows:

Members on the rolls February 1, 1950		3053
New members		211
Reinstatements		30
		3294
Deceased	39	
Resigned	39	
Dropped	94	
Juniors transferred and dropped	30	202
Net gain	39	
Membership February 1, 1951		3092

While the number of members who resigned and who were dropped was somewhat larger than during 1949, this was more than offset by the number of new members added, the greater number of reinstatements, and fewer number of deaths.

The classification of membership for the last five years is shown in one of the accompanying tables. The most significant fact herein disclosed is the large net increase in the number of Junior Members, which was brought about by the enrollment of 92 such members during the year. This compares with the enrollment of 49 Juniors in 1949, and represents by far the largest number of Juniors taken in in any one year since the class of Junior Member was established in 1940.

Many member railway officers played an important part in this greater interest in AREA among younger railway engineering and maintenance department employees. However, by far the greater share of the credit for this increased interest must go to the Board Committee on Membership because of its special efforts to apprise this group of employees of the value of membership in the Association, and for its stimulus to higher engineering and maintenance officers to encourage Junior membership among their more alert and promising junior engineers. Possibly, its most effective effort in this latter regard was the article which it presented in the September 1950 issue of the AREA News, headed "Is Your Road Adequately Represented in the AREA—Especially Among Your Younger Engineers?" This article, subsequently reprinted and further distributed to the chief engineering and maintenance officers of the railroads with personal letters from the secretary's office, received exceptionally favorable comment and attention, with the result that, even as the membership year closed on February 1, an unusual number of applications for Junior membership continued to be received.

	1947	*1948*	*1949*	*1950*	*1951*
Life	277	294	325	339	355
Member	1618	1686	2263	2276	2243
Associate	287	317	275	280	274
Junior	34	37	145	158	220
	2216	2334	3008	3053	3092

Although the Association is now completing its 52nd year, the membership roll still includes eight charter members. They are:

T. L. Condron
L. C. Fritch, past president and past secretary
E. C. Macy
William Michel
F. L. Nicholson, past director
W. B. Poland
A. D. Schindler
E. F. Wendt, past president

It is a pleasure to record too that, supplementing the 1949 list of seven living Honorary Members, John Edwin Armstrong, chief engineer of the Canadian Pacific Railway, was added during the year, having been elected to Honorary Membership on March 16, 1950.

A special development during the year with respect to membership was the increasing number of members entering the military service of the country, repeating what took place during the early years of World War II. Altogether, 26 members are now in such service. In view of this development, the Board of Direction reactivated its World War II rules with respect to members in military service, under which such members are relieved of all dues payments for the period of their service, while at the same time are assured of receiving all of the publications of the Association, either currently at a given address, or upon their return to civilian status.

Deaths during the year totaled 39, as recorded in the roster of deceased members appearing at the end of this report. Among those who died during the year were F. E. Morrow, who was chairman of Committee 23—Shops and Locomotive Terminals, from 1920 to 1927, chairman of Comittee 25—Waterways and Harbors, during 1936, and president of the Association, 1938–1939; Frank Lee, who was a director during 1926 and 1927; A. E. Botts, who was chairman of Committee 1—Roadway and Ballast, 1938–1940; C. A. Knowles, who was chairman of Committee 11—Records and Accounts, 1939–1943; and R. C. Young, who was chairman of Comittee 19—Conservation of Natural Resources, 1917–1920.

Work of Committees

As during the two previous years, the number of members serving on committees continued at a high level during the past year, and committee work continued unabated, although, as the result of strict adherence to rules as to service on committees, there were 35 fewer members actively assigned to committee work. According to the records, on February 1, 1951, 910 members were serving on committees, occupying a total of 1035 places on these committees, since a number of members serve on two or more committees. This compares with the 945 members who occupied 1036 places on committees on the same date in 1950, and with the 911 members who served in 1003 places two years ago. In addition, however, it should be pointed out that many committees carried "guests" on their rosters, who were members awaiting definite assignment to the committees with their reorganization last fall, and the publication of the 1951 Outline of Work Pamphlet. Also, several committees invited "visitors" to their meetings, including interested outsiders, retired members, and members who, for quota reasons, could not be assigned to the committees. In fact, there is beginning a move to increase the number of "visitors" at meetings, especially among Junior Members, by encouraging non-committee members to ask permission to attend meetings of those committees in which they are most interested, especially when such meetings are held within or convenient to their headquarters cities.

Under a rule which seeks to effect a change of approximately 10 percent in the personnel of committees each year, primarily to pass membership around, instill new blood in committee work, and purge rosters of inactive members, there were many changes in committee personnel with the formation of the new committee rosters last fall—and this

Classification of Material in the Committee Reports

	1945	*1946*	*1947*	*1948*	*1949*	*1950*	*1951*
Revisions of the Manual—minor	6	10	13	36	21	16	6
Revisions of the Manual—major	..	7	11	22	16	8	14
Reapproval of Manual material	..	..	..	23	7	5	5
New Manual material—minor	1	..	2	1	2	2	..
New Manual material—major	2	3	3	4	2	4	5
New Manual material—tentative	2	1	5	7	2	4	2
Information	33	32	33	29	35	49	57
Reports on research work	12	14	15	16	19	18	23
Reports on service tests	4	5	6	3	7	7	1
Statistical data	3	2	2	3	4	2	3
Analytical studies	2	2	2	8	14	7	2
Bibliographies	2	2	2	2	2	3	3
Brief reports of progress	7	7	13	16	20	13	8
War emergency provisions	4	1	..	..	..	..	..
	78	86	107	170	151	138	129

reshuffling is certain to continue as the various committee chairmen, together with the Board Committee on Personnel, seek wide railroad and territorial representation on their committees, and are becoming less lenient with members who, for one reason or another, find it impossible to attend committee meetings or who fail to participate in committee work through correspondence.

Committee Meetings

Measured by number of meetings, committee activity in 1950 was closely comparable to that of the previous year. Altogether, there were 49 meetings of full committees, compared with 51 the year earlier. One committee held five meetings, 9 held three meetings each, 7 held two meetings each, and 3 held only one each. Of the 49 meetings, 27 were held in Chicago, 2 each were held in St. Louis, Mo., Kansas City, Mo., Lafayette, Ind., and Washington, D. C., while 14 were held in as many different places, including one in Montreal, Que., and one in El Paso, Tex. Supplementing these general meetings, of course, many subcommittee meetings were held under a growing recognition of the desirability of expediting and consummating subcommittee work, across the table, prior to, and with the least loss of time at, general committee meetings.

As in past years, the Board of Direction and the secretary's office have endeavored to cooperate with committees in bringing about a clearer understanding of their assignments and of the rules governing committee procedure, especially in the preparation of reports. To this end, continuing a procedure started in 1947, the president, the chairmen of all Board Committees, and the secretary and assistant secretary, met with all committee chairmen in Chicago on April 25. Following this meeting, the secretary's office, with the cooperation of the Board of Direction, carefully reviewed and revised the "Information for the Guidance of Committees," first published in the 1950 Committee Roster and Assignments Pamphlet, and reprinted this material in the 1951 Outline of Work Pamphlet.

New Special Committee

Other significant developments in connection with committees during the year were the organization of a new Special Committee on Continuous Welded Rail, the appointment of five Emergency Committees to review the Emergency Provisions and Specifications adopted by the Association during World War II, in the light of the new mobilization effort of the country, and the reassignment to committees of the "Labor and Materials Conservation" assignments which they carried during the last war.

The new Committee on Continuous Welded Rail was authorized as a result of Board action as its meeting on August 4, 1950, and takes over, at least temporarily, the assignments relative to this type of construction formerly held by the Committees on Track, Rail, and Economics of Railway Labor. Under the new committee the subject of Continuous Welded Rail will be studied and investigated in the broadest and most comprehensive manner possible, from the processing of the rail and welds in fabrication to final disposition of the rail as scrap. It is expected that this cradle-to-grave treatment, so far as is practicable, will reflect the most desirable processes and practices of welding, and best methods of transportation, laying and relaying; that it will develop information on failures, repairs, auxiliary or supplemental operations and practices necessary or desirable with this type of track construction; and that it will include a comprehensive study of its economic worth. The committee will make its first report at the 1951 annual meeting.

Emergency Committees Established

Determined that the Association will be prepared in the event of another war emergency to throw its full weight behind the load which will be thrust upon the railroads of the country, the Board of Direction, at its meeting on August 4, also set up an Emergency Committee within itself to review in detail the organizations and procedures which were followed so successfully by the Association during World War II, and to blueprint plans for similar organizations and procedures to meet any future emergency. Subsequently, following the pattern set up during the last war, this committee appointed four Technical Emergency Committees to consider and advise on any emergency matters affecting AREA standards or specifications that might arise as the result of the large-scale rearmament program of the country. These committees are the Emergency Committee on Track Problems; Emergency Committee on Structural Problems; Emergency Committee on Fuel, Water and Sanitary Facilities; and Emergency Committee on Ties and Wood Preservation. Late in 1950 these four committees, in turn, referred to the interested Standing committees, for critical review and recommendations, all of the Emergency Provisions and Specifications adopted by the Association during the last war, and this review was well under way as the Association year closed.

Reassign Wartime Subjects

Supplementing this action, in the light of the "State of National Emergency" proclaimed by President Truman on December 16, 1950, and the anticipated scarcity of labor and materials resulting, the Board Emergency Committee, on January 11, recommended to the Board Committee on Outline of Work that it give consideration to the immediate reassigning to the various Standing committees the "Labor and Materials Conservation" subjects which they carried during the war years 1943, 1944, and 1945. This recommendation was adopted by the Board Committee on February 16, 1951, and immediately all of the committees concerned with labor and materials, except Committee 22, were given the following assignment—Means of Conserving Labor and Materials, Including the Adaptation of Substitute Non-critical Materials, and Specifications for the Reclamation of Released Materials, Tools and Equipment, Collaborating with Committee 3-A—General Reclamation of the Purchases and Stores Division, AAR. Committee 22—Economics of Railway Labor, was assigned the subject—Means of Increasing or Conserving Labor Supply for the Duration of the Emergency, Advising the Secretary

Currently of Recommendations or Practices That Merit Emergency Publication by the AREA.

Thus, it is evident that the officers of your Association have been keenly aware of the responsibility of the Association in the face of the new defense mobilization effort of the country, and are determined that the Association will be prepared to do its part to help meet the needs of the country, and the essential requirements of the railroads as a vital element in the national defense.

Publications

The seven Bulletins, ending with the February 1951 issue, contained 962 pages of text matter, exclusive of advertising, compared with 1176 pages for the seven preceding Bulletins, and 890 pages two years ago. The high total for the year ending with the February 1950 Bulletin is accounted for largely by the unusual size of the Golden Jubilee Year Book (Bulletin 480 for March 1949), which contained a special section of 120 pages devoted to the history of the Association. Vol. 51, 1950, of the Proceedings contained 944 pages, compared with 963 pages in Vol. 50, and with 854 pages in Vol. 49.

The committee reports published for presentation at the March 1951 convention occupy 502 pages in Bulletins 490 to 493, inclusive, to which should be added the 199 pages of reports on research projects sponsored by AREA committees or groups in which AREA committees are interested, which appeared in Bulletins 488 and 489.

Contents of Bulletin 488, June–July 1950

Tests of Steel Girder Spans on the Chicago & North Western Railway
Preliminary Report of Committee 3—Ties
Lateral Forces Exerted by Locomotives on Curved Tack
Memoir—Frederick E. Morrow

Contents of Bulletin 489, September–October 1950

Fatigue Tests of Beams in Flexure
Effect of Wheel Unbalance, Eccentricity, Tread Contour and Track Gage on Riding Quality of Railway Passenger Cars
Steel and Timber Pile Tests—West Atchafalaya Floodway—New Orleans, Texas and Mexico Railway

Of special significance in connection with the publications of the Association during the year was the publication, in reprint form, of the 1950 report of Subcommittee 8 of Committee 8—Masonry, entitled "Instructions for Mixing and Placing Concrete," of which a total of 3014 copies had been sold to individuals and the railroads by February 1, 1951.

The Manual

The Supplement embracing the revisions authorized at the annual meeting in March 1950 contained 105 new sheets for insertion in the loose-leaf Manual, and was accompanied by instructions for the removal of the same number of old sheets. The Manual has now been in loose-leaf form for almost 15 years, and in that time 1902 new sheets have been issued and 1717 have been withdrawn, resulting in a net increase of 185 pages in the book.

As has been pointed out in the secretary's report for the last two years, extensive work in rearranging and reprinting the Manual is due in the next two or three years.

For example, it has not always been possible to introduce new material into the chapters in locations that would insure a logical sequence of the subject-matter, and two chapters have already been reprinted to permit of a complete rearrangement. The recasting of other chapters is in process, as well as a general revision of much of the text matter by the respective committees responsible.

These changes, together with a need of resetting substantially all of the type, which has become worn from repeated reprintings, point to the desirability of changes in style (modern practice with respect to abbreviations, use of numerals, etc.), so that, with this resetting, it will be necessary to replace all of the sheets in the Manuals issued to date. This program calls for an enormous amount of work following some very careful planning, together with the scheduling of major revisions by committees of their respective chapters well in advance of the actual reprinting. The exact timing has not yet been determined, since it is contingent on the estimated date of depletion of the present stock of Manuals. However, it is certain the work will have to be completed not later than some time in 1953.

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
1949	151	144	7
1950	105	105	0
Total	1902	1717	185

Finances

The financial statement for the calendar year 1950, which appears on following pages, contains a number of features of special significance, one of the most important of which is that, in spite of the fact that receipts were smaller than in 1949, the excess of receipts over disbursements was greater than in 1949. This is indicated in the following:

	1949	*1950*
Receipts	$62,081.61	$59,752.98
Disbursements	57,075.63	51,795.05
Excess of receipts over disbursements	$ 5,005.98	$ 7,957.93

The larger receipts in 1949 are explained principally in the special membership drive during the Golden Anniversary year, with the attendant increase in entrance fees and dues payments, and in the special drive for advertising to appear in the 1949 Golden Anniversary Year Book. The larger disbursements in that year are likewise explained by the inordinately heavy expenditures made during the Golden Anniversary year, especially in connection with the annual meeting. In other words, it was to be expected that both receipts and disbursements in 1950 would be considerably smaller than in 1949, but it is significant that receipts held up so well, on the one hand, and that disbursements were so effectively controlled, on the other hand, in spite of generally rising costs.

That the Association should show net earnings in any one or more years is as it must be because the normal operations of the Association are such as to bring about a rather marked variation in both income and outgo from year to year, with actual deficits in some years. For example, the Association faces a possible deficit in 1953 or 1954 when it must absorb the extremely high costs that will be involved in completely reprinting its Manual. The excess of receipts over disbursements of the past three years will thus be a welcome cushion for the anticipated deficit year ahead.

COMPARISON OF RECEIPTS AND DISBURSEMENTS FOR A 16-YEAR PERIOD

	Receipts	*Disbursements*	*Net Gain*
1935	$29,001.00	$30,110.00	$1,109.00*
1936	28,643.00	34,662.00	6,019.00*
1937	36,523.00	32,200.00	4,323.00
1938	28,422.00	23,394.00	5,028.00
1939	28,189.00	23,847.00	4,342.00
1940	28,272.00	26,451.00	1,821.00
1941	32,433.00	29,384.00	3,049.00
1942	31,500.00	26,692.00	4.808.00
1943	28,736.00	23,809.00	4,927.00
1944	30,492.00	26,534.00	3,958.00
1945	32,305.00	29,305.00	3,000.00
1946	28,836.00	34,583.00	5,747.00*
1947	46,993.00	46,989.00	4.00
1948	57,741.00	53,062.00	4,679.00
1949	62,081.00	57,075.00	5,005.00
1950	59,752.00	51,795.00	7,951.00

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* Deficit.

Research Work

In cooperation with the research staff of the Engineering Division, AAR, working through its facilities at the new AAR Central Research Laboratory at Chicago, and the facilities of several colleges and research institutions, the research work of the Association's committees progressed favorably during 1950, although, dollarwise, it was somewhat restricted compared with 1949, for reasons pointed out in last year's report. However, a total of $294,045 was allotted for this work, which was greater than in any previous year, except 1949.

TOTAL ALLOTMENTS FOR RESEARCH WORK, ENGINEERING DIVISION, 1938–1951

1938	$ 78,158	1945	$138,110
1939	77,650	1946	159,510
1940	69,250	1947	234,428
1941	95,150	1948	291,840
1942	87,932	1949	372,457
1943	98,445	1950	294,045
1944	109,050	1951	354,770

Reflecting further the growing interest of the railways in engineering research—and in anticipation of more favorable earnings in the year ahead—the AAR has appropriated $354,770 for the research work of its Engineering Division in 1951. This represents an increase of $60,725, or 20.6 percent, compared with the allotment for 1950, and includes 10 new or revived projects.

A summary of the 1951 program, compared with the 1949 and 1950 programs, with the new projects indicated by asterisks, is presented as a part of this report.

AAR to Pay for Publishing Research Reports

One of the significant new items in the 1951 research appropriation, especially from the standpoint of the AREA, is that for $7200 to cover the publication of research reports in the AREA Bulletins and Proceedings. Heretofore, all engineering research reports prepared by the research staff of the Engineering Division, in collaboration with AREA committees, were published at AREA expense, which threw an increasingly heavy burden on the Association as the volume of research reports increased and printing costs continued to rise. Upon a request of the Board of Direction to the Research Committee, AAR, the item of $7200 for publishing research reports in AREA publications was included in the research budget.

In proposing that the cost of publishing these reports be included in the budget, the Board pointed out that, until more recent years, most of the material presented in AREA publications was the product of its own committees and meetings. But, it said, this situation had changed completely during the last 10 or more years, during which time there has been an increasing volume of valuable material offered for publication as the result of the increased activities of the research staff, cooperating with AREA committees. In fact, it said, that rising AREA publishing costs in more recent years had become so large that the Association necessarily was giving consideration to putting definite limitations upon the amount of material which it could afford to publish (both its own material and research reports) or was faced with the necessity of finding a source of financial assistance.

AREA publishing costs for its Bulletins and Proceedings, excluding its Year Book (which is largely a roster of members), increased from $7051 in 1939 to $9758 in 1946, to an average of $15,480 for the years 1948 to 1950, inclusive. The cost for 1950 was approximately $18,000. The cost of publishing the Bulletins and Proceedings in 1951 is estimated at approximately $19,000—if all research material likely to be offered for publication is printed in full.

An indication of how the volume of research material offered for publication has increased during the past 11 years is seen in the fact that, whereas such material amounted to only about 13.5 percent of all material published by the AREA in 1939, it had grown to an average of approximately 40 percent during the last three years, and is estimated to be about the same in 1951.

Under the arrangement whereby the AAR, from its 1951 research funds, will pay that proportion of AREA printing costs arising solely and entirely from the printing of engineering research reports and related material, the AREA will publish all engineering research reports in full; will distribute them to the chief engineering officers of AAR member roads; and will make available up to 200 copies of the printed reports to the Engineering Division research staff for its files and special purposes, without cost—thus relieving the AAR of any printing or distribution costs on its own account.

As was pointed out in submitting the proposal to the AAR, it is expected that the financial savings to the AAR resulting from the new arrangement will approach the sum budgeted to help defray AREA printing costs; that all research reports will receive much wider distribution; and that the AAR will receive far greater recognition of its research work.

Engineering Division Allotments for Research

Committee on Rail	*1949 Budget*	*1950 Budget*	*1951 Budget*
Transverse Fissure Investigation	$ 5,500	$ 5,500	$ 5,500
Investigation of Shelly Spots	13,500	15,500	18,500
Rail Investigation Committee	9,808	9,100	8,970
Service Tests of Joint Bars	9,076	4,500	4,500
Rolling-Load Tests of Joint Bars	9,000	9,000	9,000
Investigation of Driver Burns	3,000	4,000	4,000
Rail Design Investigation	18,545	14,800	11,800
Tests with 78-ft. Rail	0	0	5,000*
Total	$ 68,429	$ 62,400	$ 67,270
Committee on Track			
Stresses in Tie Plates	$ 11,028	$ 8,000	$ 8,000
Bolt Tension and Joint Lubrication	5,000	5,000	5,000
Corrosion from Brine Drippings	10,000	2,500	12,000
Stresses in Manganese Frogs	5,245	5,245	5,000
Tests of Rail Anchorage	5,000	0	5,000*
Tie Plate Fastenings	10,688	9,000	9,000
Total	$ 46,961	$ 29,745	$ 44,000
Relation Between Track and Equipment			
Rail and Wheel Gage and Contour	$ 8,000	$ 6,500	$ 0
Relation Wheel Load to Wheel Diameter	5,500	5,500	5,500
Lateral Forces from Locomotives	2,000	0	0
Relation of Wheel Pressures to Track Curvature	15,000	0	7,500*
Total	$ 30,500	$ 12,000	$ 13,000
Structural Projects			
Bridge Impact Investigation	$ 97,792	$ 80,000	$ 80,000
Riveted and Bolted Structural Joints	10,000	10,000	10,000
Stress in Bridge Frames	10,000	10,000	10,000
Rocker Shoe Assemblies	4,000	2,000	0
Column Research Council	4,000	6,000	6,000
Tests of Waterproofing Paints	15,343	6,000	5,000
Finishing Structural Plate Edges	0	0	3,000*
Steel Structures Paintnig Council	0	0	2,000*
Timber Stringer Tests	0	0	7,500*
Performance for Fire Retardants	0	0	5,000*
Concrete Deterioration	0	0	9,000*
Total	$141,135	$114,000	$137,500
Roadway and Ballast			
Roadbed Stabilization	$ 26,496	$ 24,900	$ 24,900
Ballast Tests	6,700	0	5,000*
Vegetation Control by Chemicals	0	0	5,000*
Total	$ 33,196	$ 24,900	$ 34,900
Miscellaneous			
Research Office	$ 31,236	$ 31,000	$ 30,900
Electrolytic Corrosion of Steel in Concrete	1,000	0	0
Wear and Splitting of Ties	20,000	20,000	20,000
Research Publications Cost	0	0	7,200
Total	$ 52,236	$ 51,000	$ 58,100
GRAND TOTAL	$372,457	$294,045	$354,770

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* New or revived projects.

Constitution Modernized

During the year the constitution of the Association was completely overhauled. Following emergency changes submitted to letter ballot on May 5, 1950, to provide for the orderly succession of officers in the event of a vacancy in office, and to give more leeway in the selection of a convention city in the event of an emergency, or for other compelling reasons, the constitution, under the direction of the Board Committee on Special AREA Services, was completely overhauled to bring its provisions into line with present practice, clarify intent and purpose, and incorporate desirable editorial changes. Amendments to this end were submitted to letter ballot of the membership on August 30, 1950. Both the emergency changes and subsequent amendments were adopted by overwhelming votes.

Other Board Action

Still other special Board activities included a genuine effort toward effecting closer relations and collaboration with the Signal and Electrical Sections of the AAR, sister sections with the AREA as the C. & M. Section, in the Engineering Division, AAR, and detailed consideration to the development and adoption of a supplemental pension plan for its employees, to put them on a comparable basis, pensionwise, with railroad personnel and AAR employees.

Respectfully submitted,

Neal D. Howard,
Secretary

Emergency Committees

Emergency Committee of the Board of Direction

H. S. Loeffler, Chairman (G. N.)
T. A. Blair, Vice Chairman (A. T. & S. F.)
C. J. Geyer (C. & O.)
Armstrong Chinn (T. R. R. A. of St. L.)
F. S. Schwinn (M. P. Lines)
C. H. Mottier (I. C.)

Emergency Committee on Track Problems

H. R. Clarke, Chairman (Burlington)
L. L. Adams (L. & N.)
J. B. Akers (Sou.)
Bernard Blum (N. P.)
C. B. Bronson (N. Y. C.)
J. L. Gressitt (Penna.)
W. C. Perkins (U. P.)

Emergency Committee on Structural Problems

E. S. Birkenwald, Chairman (Sou.)
F. N. Cramer (C. B. & Q.)
R. P. Hart (M. P.)
A. N. Laird (G. T. W.)
B. J. Ornburn (C. M. St. P. & P.)
G. E. Robinson (N. Y. C.)
R. A. Van Ness (A. T. & S. F.)

Emergency Committee on Fuel, Water, and Sanitary Facilities

G. E. Martin, Chairman (I. C.)
R. C. Bardwell (C. & O.)
R. E. Coughlan (C. & N. W.)
B. W. DeGeer (G. N.)
A. W. Johnson (A. T. & S. F.)
A. B. Pierce (Sou.)

Emergency Committee on Ties and Wood Preservation

W. J. Burton, Chairman (M. P.)
P. D. Brentlinger (Penna.)
L. P. Drew (U. P.)
H. R. Duncan (C. B. & Q.)
E. F. Salisbury (K. C. S.)
C. D. Turley (I. C.)

Deceased Members

B. T. Anderson
Transportation Research Director, Union Switch & Signal Company, Pittsburgh, 18, Pa.

M. B. Atkinson
Retired Assistant Superintendent Engineer, Department of Railways and Canals, Welland Ship Canal, St. Catherines, Ont.

F. A. Barnes
Emeritus Professor of Railroad Engineering, Cornell University, Pleasant Valley, Conn.

A. E. Botts
Retired Assistant Chief Engineer—Maintenance, Chesapeake & Ohio Railway, Richmond, 22, Va.

C. E. Brown
Retired Vice President and General Manager, San Francisco & Napa Valley Railroad, Napa, Calif.

C. M. Burgess
Chief Draftsman, Erie Railroad, Cleveland, 15, Ohio

F. T. Darrow
Retired Chief Engineer, Chicago, Burlington & Quincy Railroad, Riverside, Ill.

J. H. Davidson
Retired Water Engineer, Missouri–Kansas–Texas Lines, Parsons, Kans.

S. A. Erickson
Retired Division Engineer, Northern Pacific Railway, Missoula, Mont.

S. M. Golden
Vice President—Operating, Chicago Great Western Railway, Chicago, 6, Ill.

E. L. Haley
Division Engineer, Chicago, Burlington & Quincy Railroad, Casper, Wyo.

J. P. Hanley
Retired Assistant Superintendent Water Service, Illinois Central Railroad, Miami, 35, Fla.

F. A. Hartman
Vice President, Protexol Corporation, New York, 17, N. Y.

J. C. Holden
Retired District Engineer, Canadian Pacific Railway, Winnipeg, Man.

H. B. Holmes
Retired Chief Engineer, Georgia & Florida Railroad, Evans, Ga.

C. A. Knowles
Retired Assistant Comptroller, Chesapeake & Ohio Railway, Richmond, 10, Va.

Fred Lavis
300 East Monte Vista, Phoenix, Ariz.

Frank Lee
Retired District Engineer, Canadian Pacific Railway, Parksville, B. C.

Paul Lillard
Structural Designer, Bridge Division Cook County Highway Department, Chicago, 11, Ill.

J. A. MacLeod
Chief Engineer, Savannah & Atlanta Railway, Savannah, Ga.

B. J. Many
B. J. Many Company, Inc., 30 North LaSalle Street, Chicago, 2, Ill.

L. C. Marshall
Assistant Engineer, Missouri Pacific Railroad, St. Louis, 3, Mo.

W. B. Marshall
Division Engineer, Southern Railway System, Selma, Ala.

A. L. Morgan
Retired Chief Engineer. Des Moines Union Railway, Des Moines, 11, Iowa

F. E. Morrow
Retired Chief Engineer, Chicago & Western Indiana Railroad; Belt Railway of Chicago, Oak Park, Ill

W. T. Neale
Assistant Division Engineer, Baltimore & Ohio Railroad, Wheeling, W. Va.

W. O. Nelson
Assistant Maintenance Engineer, Baltimore & Ohio Railroad, Baltimore, 1, Md.

A. W. Newton
Retired Chief Engineer, Chicago. Burlington & Quincy Railroad, Chicago, 13, Ill.

M. S. Ortega
Civil Engineer, Ferrocarriles Unidos de la Habana, Mantanzas, Cuba

J. H. Rickie
Retired Officer, Burma Railways, La Maison de Le 'oville, St. Owen, Jersey, Channel Island

G. M. Rowe
Assistant Division Engineer, Southern Pacific Company, Oakland. Calif.

B. J. Schwendt
Assistant Signal Engineer, New York Central System, Cincinnati, 2, Ohio

G. J. Slibeck
Engineering and Sales, Pettibone Mulliken Corporation, Chicago, 4, Ill.

L. E. Thornton
Superintendent, Baltimore & Ohio Chicago Terminal Railroad. Chicago, 7, Ill.

W. L. Turner, Jr.
Eastern Engineering Editor, Railway Age, New York, N. Y.

F. G. Vent
Consulting Engineer, Chicago, 15, Ill.

R. W. Willis
Retired Assistant Chief Engineer, Chicago, Burlington & Quincy Railroad, Hinsdale, Ill.

M. J. Wise
President, Central of Georgia Railway and Ocean Steamship Company of Savannah, Savannah, Ga.

R. C. Young
Retired Consulting Engineer, Lake Superior & Ishpeming Railroad, Marquette, Mich.

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1950

Balance on hand January 1, 1950			$111,211.51
RECEIPTS			
Membership Account			
Entrance fees	$ 1,300.00		
Dues	40,174.43		
Binding proceedings	229.00	$41,703.43	
Sales of Publications			
Proceedings	$ 1,401.09		
Bulletins	2,180.74		
Manuals	3,656.72		
Specifications	2,210.08		
Track plans	1,789.81		
Hand books	246.70		
Concrete mix	750.40	$12,235.54	
Advertising			
Publications		$ 3,125.88	
Interest Account			
Interest on investments		$ 2,468.10	
Miscellaneous		$ 220.03	
Total		$59,752.98	
DISBURSEMENTS			
Salaries	$16,472.09		
Proceedings	9,277.22		
Bulletins	8,841.88		
Stationery and printing	3,703.66		
Rent, light, etc.	1,140.00		
Supplies	190.45		
Postage	1,187.10		
Refund of dues	116.87		
Audit	400.00		
Pension	1,200.00		
Social security and unemployment taxes	645.48		
Manual	1,349.22		
Track plans	1,537.11		
Committee and officers expense	298.77		
Annual meeting expenses	1,584.83		
News letter	2,459.34		
Miscellaneous	1,241.66		
Total		$51,645.68	
Excess of Receipts over Disbursements		$ 8,107.30	
Loss on sale of bonds		149.37	$ 7,957.93
Balance on hand December 31, 1950			$119,169.44

REPORT OF THE TREASURER

To the Members:

Balance on hand January 1, 1950		$111,211.51
Receipts during 1950	$ 59,752.98	
Paid out on audited vouchers	51,645.68	
Excess of Receipts over Disbursements	$ 8,107.30	
Loss from sale of bonds	149.37	7,957.93
Balance on hand December 31, 1950		$119,169.44
Consisting o		
Bonds at cost	$102,034.00	
Cash in Northern Trust Company Bank	17,110.44	
Petty cash	25.00	
		$119,169.44

We have made an examination of the accounts of the American Railway Engineering Association for the year ending December 31, 1950, and find them to be in accordance with the foregoing statement.

C. A. Bick,
P. D. Mitchell,
Auditors.

GENERAL BALANCE SHEET

Assets	*1950*	*1949*
Due from members	$ 86.50	$ 123.00
Due from sale of publications	102.40	145.40
Due from sale of advertising	125.00	317.00
Furniture and fixtures	1,550.00	966.85
Inventory of publications (estimated)	500.00	500.00
Inventory of manuals	5,073.00	6,732.00
Inventory of track plans	1,571.50	2,159.00
Inventory of paper stocks	671.80	1,001.80
Investments (cost)	102,031.50	98,385.50
Interest accrued on investments	542.84	567.41
Cash in Northern Trust Company Bank	17,110.44	12,801.01
Petty cash	25.00	25.00
Total	$129,389.98	$123,723.97
Liabilities		
Members dues paid in advance	$ 360.50	$ 336.50
Surplus	129,029.48	123,387.47
Total	$129,389.98	$123,723.97

American Railway Engineering Association

CONSTITUTION

Revised to October 30, 1950

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) Meeting for the presentation and discussion of papers, and for action on the recommendations of committees.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions adopted by the Association shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Ill.

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 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.

(e) In determining the eligibility for Member under Section B (a) of this Article, each year of practical experience in engineering, or in science related thereto, prior to employment on a railway, if such experience were of the same specialized character as the current work of the applicant, shall be considered as equivalent to one year of railway service.

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 dean, professor, assistant professor, or equivalent in engineering in a university or college of recognized standing, or an instructor or equivalent in such university or college, who, with an engineering degree, has had at least two years' experience in teaching engineering.

(c) An engineer or member of a public board, commission or other official agency 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 or in the employ of a consulting engineering organization, who has had the equivalent of five years' engineering experience.

C. Life Member

A Life Member shall be a Member or an Associate who has paid dues for 35 years, or who has been retired under a recognized retirement plan and has paid dues for not less than 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.

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 cooperate 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 21 years of age and shall be an engineering employee of a railway corporation who has had not less than three years of experience in the location, construction, operation or maintenance of railways.

(b) His membership in this classification in the Association shall terminate at the end of the calendar year in which he becomes 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 who were formerly Members, shall have all the rights and privileges of the Association. Life Members who were formerly Associates shall continue to have all the rights and privileges of Associates.

(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 15, 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 applicant shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of these 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 qualifications for membership.

(c) If an applicant is not personally known to as many as three Members of this Association, the names of well-known persons engaged in railway or allied professional work to whom he is personally known shall be substituted, as necessary, to provide a total of at least three references. Each of these 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 qualifications 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 the required information, 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 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

An applicant for any class of membership in this Association shall declare his willingness to abide by the Constitution of the Association in his application for membership.

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 fulfilled.

7. Expulsion

Charges of misconduct on the part of anyone holding membership in this Association, if in writing and signed by ten or more Members, may be submitted to the Board of Direction for examination and action. If, in the opinion of the Board action is warranted, 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 $10 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 required for Junior Membership, except that a Junior Member, in transferring to another class of membership, shall pay the entrance fee prescribed for other classes of Membership.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be $15.

(b) The annual dues for each Junior Member shall be $7.50.

(c) Life Members and Honorary Members shall be exempt from the payment of dues. Life Members desiring to continue to receive the Bulletins and Proceedings of the Association may do so by paying a subscription fee prescribed by the Board of Direction.

3. Arrears

A person whose dues are not paid before April 1 of the current year shall be notified by the Secretary. If the dues are still unpaid on July 1, further notice shall be given, informing the person that he is not in good standing in the Association. If the dues remain unpaid by October 1, the person shall be notified that he will no longer receive the publications of the Association. If the dues are not paid by December 31, 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.

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 at the pleasure of the Board of Direction.

3. Officers Elected Annully

(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, except as provided for in Section 5 (e) of this Article. Vice Presidents and Directors shall be ineligible for re-election to the same office, except as provided for in Section 5 (e) of this Article, until, at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) If a vacancy should occur in the office of President, as set forth in Section 6 of this Article, the senior Vice President shall immediately and automatically become President for the unexpired term.

(b) If a vacancy should occur in the office of the senior Vice President, due to advancement under Section 5 (a) of this Article, or for reasons set forth in Section 6 of this Article, the junior Vice President shall automatically become senior Vice President for the unexpired term.

(c) If a vacancy should occur in the office of the junior Vice President, due to advancement under Section 5 (b) of this Article, or for reasons set forth in Section 6 of this Article, the Board of Direction shall by the affirmative vote of two-thirds of its entire membership, select a junior Vice President from the members or past members of the Board of Direction.

(d) A vacancy in the office of Director, due to advancement of a Director to junior Vice President under Section 5 (c) of this Article, or for reasons set forth in Section 6 of this Article, shall be filled by the Board of Direction by the affirmative vote of two-thirds of its entire membership.

(e) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided, however, that anyone selected to fill a vacancy as Director shall be eligible for election to that office, excepting that such appointee filling out an unexpired term of two years or more shall be considered as coming within the provisions of Section 4 of this Article.

6. Vacation of Office

(a) In the event of the death of an elected officer, or his resignation from office, or if he should cease to be a Member of the Association as provided in Section 2 (B), Article II; Section 6 or 7, Article III; or Section 3, Article IV, the office shall be considered as vacated.

(b) In the event of the disability of an officer or neglect in the performance of duty by an officer, the Board of Direction, by the affirmative vote of two-thirds of its entire membership 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 1 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	2	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 15 of the same year, and the Secretary shall report the names of these nominees to the members of the Association not later than January 1 following.

(c) At any time between January 1 and February 1 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, his 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 who has paid his dues to or beyond December 31 of the previous year, 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 remove 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 his ballot, and cast another, at any time before the polls close.

(c) Ballots received in unendorsed envelopes, 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 12 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, by virtue of his office, shall be 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.

3. Treasurer

The Treasurer shall pay all bills of the Association when properly certified by the Secretary and approved by the Finance Committee. He shall make an annual report as to the financial condition of the Association and such other reports as may be called for by the Board of Direction.

4. Secretary

The Secretary, under the direction of the President and Board of Direction, shall be 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 record the proceedings thereof. The Secretary shall see that all money due the Association is collected, is credited to the proper accounts, and is deposited in the designated depository of the Association, with receipt to the Treasurer therefor. He shall personally certify to the accuracy of all bills and vouchers on which money is to be paid. He shall invest all funds of the Association not needed for current disbursements, as shall be recommended by the Finance Committee and approved by the Board of Direction, with notification to the Treasurer of such investments. The Secretary shall conduct the correspondence of the Association, make an annual report to the Association, and perform such other duties as the Board of Direction may prescribe.

5. Auditing of Accounts

The financial accounts of the Association shall be audited annually by an accountant or accountants approved by and under the direction of the Finance Committee.

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 for 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
Publications
Outline of Work of Committees
Personnel of Committees
Membership
Manual

Other special committees may be appointed by the President at his discretion.

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 funds 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 over 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 review and pass upon the recommendations of standing and special committees for subjects to be investigated, considered and reported on by these committees during the ensuing year, and shall report thereon to the Board of Direction for its approval.

(d) Committee on Personnel of Committees

The Committee on Personnel of Committees shall review and pass upon applications of members for appointment to standing and special committees. It also shall appoint the chairman and vice chairman of such committees and make a report thereon to the Board of Direction for its approval.

(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, with the assistance of the Publications Committee, shall have general supervision over the Manual.

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, Ill., or in such other city as may be determined by the affirmative vote of two-thirds of the entire membership of the Board of Direction. The convention shall open on the second Tuesday in the month of March, or on the third Tuesday if the month of March has five Tuesdays, excepting that some other opening day in March may be designated by the affirmative vote of two-thirds of the entire membership of the Board of Direction.

(b) The Secretary shall notify all members of the Association of the time and place of the annual convention at least 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 Associations may be called by the Board of Directions on its own initiative, and may be so called by the Board of Direction upon written request of 100 Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten days in advance of the proposed date of such meeting and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five 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.

Sixty days after the date of issue of the letter ballot, the Board of Direction shall canvass the ballots which have been received, and if two-thirds of such ballots are in the affirmative the amendment shall be declared adopted and shall become effective immediately. The result of the letter ballot shall be announced to members of the Association..

Information and Rules for the Guidance of Committees

The following information and rules for the guidance of committees are designed to obtain the maximum benefits from the efforts of the members who make up the personnel of such committees. They are designed to effect a continuity of effort in committee work throughout the entire year, under a plan whereby the personnel of the committees and their respective outlines of work are set up and made public on or before the beginning of the calendar year, thus enabling the work to be continued without interruption, although the new personnel and subject assignments do not become officially effective until the beginning of the "Association Year," which starts with the close of the annual convention.

The rules also take into account the fact that the publication of the committee reports must be spread out over a period of four months (November through February), to facilitate printing and to give members of the Association a reasonable length of time in which to study such reports in advance of the convention.

Subjects Re-assigned Annually

The outline of work of each committee shall be reviewed annually. To this end, each committee shall review suggestions for new subjects submitted by the members thereof, or by others, and such suggestions as receive the approval of the committee shall be submitted by the committee chairman to the secretary of the Association not later than October 1, together with the committee's recommendations covering the withdrawal or continuation of current assignments.

The recommendations received from the various committees shall be assembled and forwarded to the Board Committee on Outline of Work which shall have the responsibility of authorizing the subject assignments to the various committees. Deviation from assignments thus authorized may be made during the course of the year only upon the authority of the Board Committee on Outline of Work.

Committee Personnel Reorganized Annually

The personnel of each committee shall be reorganized annually. It is desirable that 10 percent of the membership be changed each year. Members who do not attend meetings of the committee, who do not render service by correspondence, or who do not return letter ballots will be dropped. To this end the chairman of the committee shall submit to the secretary of the Association not later than October 1 the names of members who have been delinquent in service to the committee, as well as a list of the names of members of the Association who have been recommended for appointment to the committee.

The recommendations received from the various committees shall be assembled and forwarded to the Board Committee on Personnel, which has the duty of appointing the committee personnel.

No additions to the personnel of committees will be made during the year following the publication of the roster, except as provided for in the rules applying to "Guests."

Three-Year Terms for Chairmen

The terms of chairmen and vice-chairmen shall be three years in each position. Chairmen completing their three-year term shall recommend to the Board Committee on

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(Revised November 10, 1950)

Personnel nominees for the chairmanship and vice chairmanship, with assurance of acceptance from such nominees if appointed by the Board Committee.

Size of Committees

The total membership of any committee shall be limited to 60. In determining the membership of a committee, railroads having no more than 50 Association members may have not more than two members on any committee; railroads having 51 to 100 members may have not more than 3 members on any committee; railroads having more than 100 members may have not more than 4 members on any committee.

Retired Members

No member who has retired from active service shall serve on a committee more than 3 years following retirement. However, such member may continue to attend meetings as a "visitor," subject to the approval of the committee chairman.

Associate Members

No company will be permitted to have more than one Associate member on any committee, and company representation shall not necessarily be continuing. However, in the event that a railroad member on a committee becomes associated with a manufacturer or supply company after retirement from railroad service on pension, and thus automatically becomes an Associate member, he shall not be deprived of membership on the committee during the period of three years following his retirement from railroad service.

The membership of Associates on a committee shall be limited to 10 percent of the total membership of the committee. Committees with Associates in excess of 10 percent of their total membership 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 of Associates exceeds 10 percent, except as may be occasioned by the exception provided in the preceding paragraph.

"Guests" and "Visitors"

The previously stated rule that "no additions to the personnel of committees will be made during the year following the publication of the roster, except as provided for under the rules applying to "Guests," does not preclude the attendance at committee meetings of other members of the Association, with the approval of committee chairmen.

If there are vacancies on a committee roster (i.e., less than 60), or if vacancies occur during the year, Association members (including Junior members), with the approval of committee chairmen and the Board Committee on Personnel, can be appointed as "guests" of that committee. As such, they may attend committee meetings and participate in the committee's activities, unofficially, looking to becoming regularly assigned members at the beginning of the next Association year.

"Guests" must always be designated as such on the rosters maintained by the committees and the secretary's office. Creation of this class of committee affiliation is not intended to increase the size of any committee beyond the 60 maximum set by the Board, but rather to make it possible to add to "short" rosters between official roster changes.

Furthermore, one need not be either a "regular member" or a "guest" of a committee to attend its meetings from time to time. With the approval of the committee chairman, who must be consulted as regards any specific meeting, an AREA member (including Junior members), may sit in on the meeting as a "visitor," listen to all deliberations and participate in discussions.

Service on More Than One Committee

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—Contract Forms; Committee 24—Cooperative Relations with Universities; Committee 28—Clearances; Committee 29—Waterproofing; Committee 30—Impact and Bridge Stresses; and the Special Committee on Continuous Welded Rail.

Organizing the Committees

The new outline of work and personnel of committees shall become effective with the close of the convention in March. However the pamphlet containing this information is issued not later than January 1, in order that committees may be reorganized promptly for the new year's work, if reorganization has not already been effected. Usually this information will be available to the chairmen in tentative form at least 30 days in advance of publication.

It is the duty of the committee chairman to notify new members promptly of their appointment and to notify old members of their reappointment or release. It is also his duty to reorganize the subcommittees without delay. However, in the Association year in which his term as chairman expires, he should call on his successor for advice and assistance in this regard.

Organization Charts

The chairman shall furnish the secretary of the Association two copies of the organization chart (schedule of subcommittee assignments and personnel) of his committee, and shall advise him currently of any subsequent revisions thereof. This chart may be in the form regularly used by committees, but should not be in the form of a blueprint, on which it is difficult to make corrections. White prints are acceptable. These charts should be in the hands of the secretary by February 1, and should be prepared with the greatest care to insure the accuracy of initials and names.

The names of "guest" members on committees, if any, (not "visitors") should appear on the charts, clearly designated, however, as "guests"—these names to be arranged either alphabetically among the members or grouped at the bottom of the chart as desired by the various committees.

Notices and Minutes of Meetings

The committee chairman also shall send to the secretary of the Association copies of all notices of committee meetings, as well as minutes thereof.

Subcommittees

In general, the committees are organized to conduct their work by the appointment of one subcommittee for each subject assignment. If deemed advisable, any subject may be subdivided into several parts and a separate subcommittee assigned to each part. Committees may find it of advantage to create a subcommittee on personnel as well as a subcommittee on new subjects.

Collaboration

Subjects, the nature of which clearly indicates the possibility of overlapping interest of two or more committees, carry an appended clause reading: "collaborating with Committee ...." It is the duty of the chairmen of the committees having an assignment carrying this instruction to take the initiative in effecting such collaboration;—first, by requesting the appointment of representatives of the other interested committee or committees, and second, by submitting copies of the report to them for comment. Regardless of whether the assignment specifically mentions collaboration, committees shall be on the alert to obtain the advice and assistance of other committees in dealing with any subject that imposes any questions of possible overlapping interest or responsibility.

A committee undertaking revision of its Manual chapter should request collaboration of any committee that participated in the original development and adoption of the material under revision. The secretary of the Association will provide information concerning such previous collaboration.

Work of the Committees

Objectives

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.

Planning the Work

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

Committees are privileged to obtain data or information in any proper way. If desired, the secretary will issue circulars of inquiry, or questionnaires, which should be brief and concise. The questions contained in such circulars should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. The circulars should specify to whom answers are to be sent, and should be furnished in duplicate so that a copy can be retained by persons replying.

Research

Requests for appropriations for the conduct of research work should be sent to the secretary of the Association 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. All requests for research appropriations, with supporting data, must be in the secretary's office by July 1.

Maintaining Manual Up to Date

Each committee shall critically review the material in its chapter of the Manual at such intervals as to insure that it is kept up to date. It shall resubmit all Manual material for revision or reapproval at intervals of not more than 10 years. It is especially important that all Manual material be brought up to date during 1951 and 1952, looking to the necessity for reprinting the entire Manual in 1953.

Nature and Preparation of Reports

Form of Report

Committee reports shall be prepared in accordance with the Style Standards for committee reports, as detailed on following pages in this pamphlet.

Nature of Report

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, it may be advisable to submit as information material 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 material for adoption at a later date.

Reports on All Assignments Not Necessary

Committees should pursue their investigations on all assignments but are expected to present progress or final reports for publication only on assignments with respect to which pertinent information has been developed.

Avoid Repetition of Report Material

Reports of information, supplementing previous reports of progress, may include a brief review of material previously presented, but should avoid extended repetition of such material.

Nature of Manual Material

The material 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.

Printing of Manual Material

Material offered for adoption and publication in the Manual should be submitted in full, regardless of its publication in previous years unless the material being offered appeared in substantially identical form not more than one year before being submitted for adoption. Such material shall appear in the report of the committee that is published not less than 30 days before the annual meeting at which it is to be presented. Any recommendation for the revision of or removal from the Manual of material appearing therein shall appear likewise in full in the report of the committee as printed.

Letter Ballot Required of Committee

Any action recommended by a committee with respect to the adoption, revision, reaffirmation or withdrawal of Manual material must have received prior endorsement by the committee in the form of an affirmative vote of two-thirds of the entire membership of the committee, such vote to be taken by letter ballot. Associate members of the committee are not entitled to vote.

Publication of Reports

Dates for Filing Reports

To insure the orderly publication of the reports in accordance with a predetermined schedule, it is necessary that chairmen file complete reports with the secretary of the Association on or before the dates specified in the Outline of Work pamphlet. The manuscript of the report must be furnished in duplicate. Piecemeal filing of reports by subcommittee chairmen is permissible only under special arrangement (in writing) with the secretary of the Association.

Presentation of Reports at Annual Meetings

Presentation of Reports

Reports offered as information will be presented by title or by a brief highlight outline of the contents. Manual material submitted for adoption and publication in the Manual shall be presented by reading the title and subtitles, but the presiding officer may, upon request, authorize the reading of specific portions of the material being offered.

Oral Discussions

Comments on or criticisms of any report may be offered from the floor. 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.

Written Discussions

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.

Action on Reports

No formal action is to be taken by the convention on material submitted as information, whether in the form of a progress or final report.

Action on material 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 material presented, followed by adoption as a whole as amended.

(c) Adoption of a part, complete in itself, and referring the remainder back to the committee for further consideration.

(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.

Letter Ballot of Membership

When and as required between annual meetings, recommendations for the adoption, deletion 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.

The Board of Direction, acting under the provisions of paragraphs 6 (a) and 11 of Article VII of the AREA constitution, has the authority to amend, delete or revise Manual material at any time, subject to later confirmation or rejection by the membership, submission to the membership to be effected either by means of a letter ballot immediately following such Board action, or by a motion presented at the annual meeting.

Review by Association of American Railroads

All material adopted for publication in the Manual and all recommendations for the revision or withdrawal of Manual material shall be reviewed by the Association of American Railroads before distribution is made thereof to holders or purchasers of the Manual, or parts thereof.

Publication of Annual Supplement

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.

Publication of Abstracts by Technical Journals

The following rules will govern the releasing of material for publication in technical journals:

Committee reports to be presented at an annual convention, will not be released for publication 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 in technical journals only after issuance in a bulletin; provided, application therefor is made in writing and proper credit is given the Association, authors or committees presenting such material.

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