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Principles and Criteria for the Design of a Railroad Track Test Facility*

By Arnold D. Kerr[1]

SUMMARY

The paper contains a discussion of principles and criteria for the design of a railroad track test facility. One such facility is to be built and operated by the Federal Railroad Administration (FRA). The purpose of the tests to be conducted is to support the various track research programs which aim to improve the design as well as the maintenance procedures and safety of railroad tracks.

INTRODUCTION

As part of its effort to provide the technology necessary for improving the performance and safety of the railroad tracks in the United States, the Federal Railroad Administration (FRA) is planning to build and operate a track research laboratory in Pueblo, Colorado. The purpose of the tests to be conducted at this laboratory is to gain information for improving the design, as well as the maintenance procedures, for railroad tracks. The planned program may include tests for: (1) the determination of stresses in the rails, ties and fasteners due to static and dynamic loads and various conditions of the ballast; (2) the determination of safe temperature increases to prevent buckling of an unloaded track; and (3) a study of the effect of a moving train on the stability of a thermally compressed track. In these tests special attention should be given to the effect of tamping and traffic compaction of the ballast on the stability of the welded track, a problem of great importance for stipulating efficient track maintenance procedures.

The purpose of the following presentation is to establish a number of general principles and criteria for the design of such a track test facility.

DISCUSSION OF DESIGN PRINCIPLES AND CRITERIA

When planning a test stand for the study of the track response caused by a variety of forces, it is essential to know the approximate displacement and force distributions anticipated during the various tests. This is necessary for the stipulation of the minimum length of the test track and for estimating the largest anticipated forces. This in turn affects the choice of the loading mechanisms and the accuracy of the measuring devices.

The first task in the planning of such a test stand is the *determination of the minimum length of the test track*, L_{min}. From the literature on railroad track tests, it appears that from the multitude of tests to be conducted, the buckling and dynamic experiments require the longest track section.

Consider the straight track shown in Fig. 1-(I). A uniform temperature increase induces in the welded rails, due to constrained thermal expansions, an axial compression force N_t which does not vary along the track, as shown in Fig.

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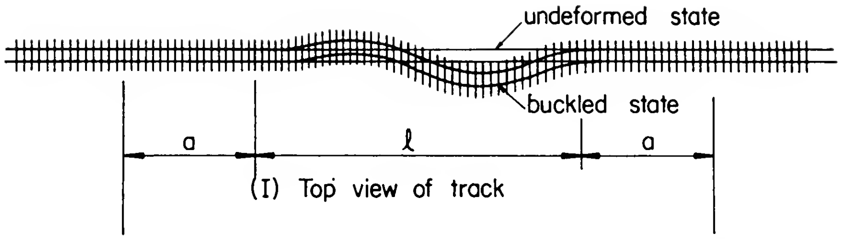
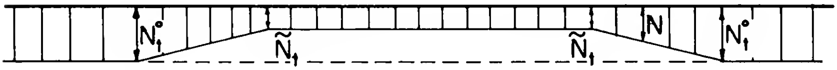


(I) Top view of track

(II) Axial compression force before buckling



(III) Axial compression force after buckling

Fig. 1

1-(II). For a large value of N_t, say N_t^o, the track may buckle out. The resulting force distribution is shown, schematically, in Fig. 1-(III). In the buckled region of length l, because of the associated deformations, part of the thermal expansions is released. This results in a reduction of the axial force N_t^o to $\tilde{N}_t$. In the adjoining regions, each of length a, due to ballast resistance to axial displacement of the track, the constrained thermal expansions vary; so does the axial force $\tilde{N}_t < N < N_t^o$, as shown in Fig. 1-(III). According to the above description, track buckling is *a local phenomenon* and except for the length $(l + 2a)$ the track is not affected by it. Thus

$$L_{min} = l + 2a \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

To realize the possible effect of the adjoining regions of length $2a$, the reader is referred to Ref. (1) and to Ref. (2). The case $n = o$ in Ref. (1) corresponds to the elimination of the effect of the adjoining regions.[*]

The test tract at the Technical University of Karlsruhe, used for the DB track research program, consisted of a 46.50-m (153-ft) track confined between two reinforced concrete piers weighing 624 tons each. For details the reader is referred to Ref. (3) (4)

The test track of the Civil Engineering Laboratory of the Western Region of British Railways consisted of a 36.6-m (120-ft) track anchored at both ends to concrete blocks sunk to ground level. For details the reader is referred to Ref. (5).

The test track of the Central Railroad Research Institute of the Soviet Union (CNII MPS) consists of a 100-m (328-ft) long straight track, mounted between two concrete piers. The length of a curved test track was fixed to 200 m (656 ft). For details the reader is referred to Ref. (6).

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[*] For buckling in the horizontal plane, the load q in (1) and (2) is to be interpreted as a resistance against lateral deformations.

According to the results of many buckling tests conducted on the 100-m test track by CNII (6), the track buckled in the horizontal plane and the buckled length (which usually consisted of more than one wave) varied for different tracks. The largest observed l for a straight track was 42 m. For many tests, l was about 30 m. The values for curved tracks were about the same. These results suggest that the test tracks of the DB and BR may have been too short. This conjecture is also confirmed by the buckling mode shown in Fig. 31 of Ref. (5).

If a test track is too short, it will usually yield higher buckling temperatures than a corresponding track encountered in the field. In view of the larger rigidities of the rails currently in use in the U.S.A. (and to be tested in the future), it is proposed that for the planned test track l_{min} should be about 60 m. Taking into consideration the additional lengths $2a$, it appears that a reasonable minimum total length of the new test track should be (for an analysis see footnote below):

$$L_{min} = 490 \text{ m (about 1,600 ft)}^{*} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

The next task is to decide on *the type of end restraints.* This may be achieved in several ways:

(1) The track may continue on both ends as in an actual railroad track. The minimum length, b, of these adjoining regions to L is determined from the largest anticipated track compression force, say $N_t^{max} = 500$ tons**, and the resistance of the unloaded track to axial displacements $r(x)$ per unit length of track. Considering the equilibrium of forces in the horizontal plane on the free body diagram shown in Fig. 2, it follows that:

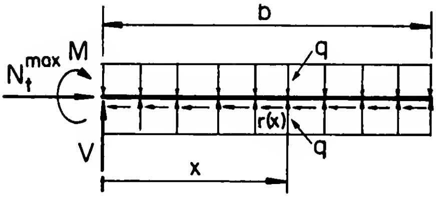

Fig. 2

$$N_t^{max} = \int_0^b r(x)\,dx \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

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* The value of $L_{min} = 490$ m in equation (2) was determined by assuming that $N_t^0 - \tilde{N}_t = 150$ tons, hence $a = (N_t^0 - \tilde{N}_t)/r_o = 215$ m and $L_{min} = l_{min} + 2a = 490$ m. The r_o value has to be determined experimentally, after the track to be tested is chosen.

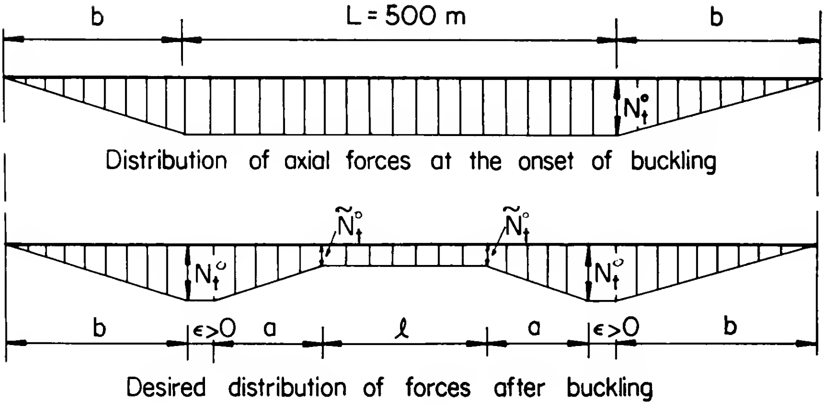
** At the Karlsruhe test stand ([4], p. 332) a buckling load of as high as 375 tons was observed. At the BR tests ([5], Table 5) the highest load encountered was about 275 tons. At the CNII ([6], p. 23) in one test no buckling was observed even at 425 tons.

When $r(x)$ is known, the above integral can be evaluated and then equation (3) solved for b, its only unknown. In the railroad literature it is often assumed that r does not vary with x. Hence $r(x) = r_o =$ constant. In this case equation (3) reduces to $N_t^{max} = r_o \cdot b$ and hence

$$b = \frac{N_t^{max}}{r_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

For example, according to equation (4), if $N_t^{max} = 500$ tons and the resistance $r_o = 7$ kg/cm (467 lb/ft), then the required b equals 715 m (2,350 ft).

In order to simulate the actual conditions in the field, the desired distribution of axial forces in the buckled track has to be as shown schematically in Fig. 3.



Distribution of axial forces at the onset of buckling

Desired distribution of forces after buckling

Fig. 3

(2) The necessary length b may be shortened considerably by placing loaded railroad cars or locomotives outside the L region. Once the weight and geometry of the available loaded cars or locomotives are known, their position on the track should be determined to insure the desired conditions in the L region.

(3) The b regions may be eliminated (almost) entirely by using heavy piers on both track ends. However, because the anticipated axial track loads may be as high as 500 tons, small displacements of the piers at the ends of the test track are usually unavoidable. The magnitude of these displacements will depend, for a fixed temperature increase, upon the weight and/or foundation of the piers. The desired distribution of axial forces in the track after buckling, is shown schematically in Fig. 4. The drop of the axial forces in the outer track regions of length b', is due to the anticipated yielding of the piers.

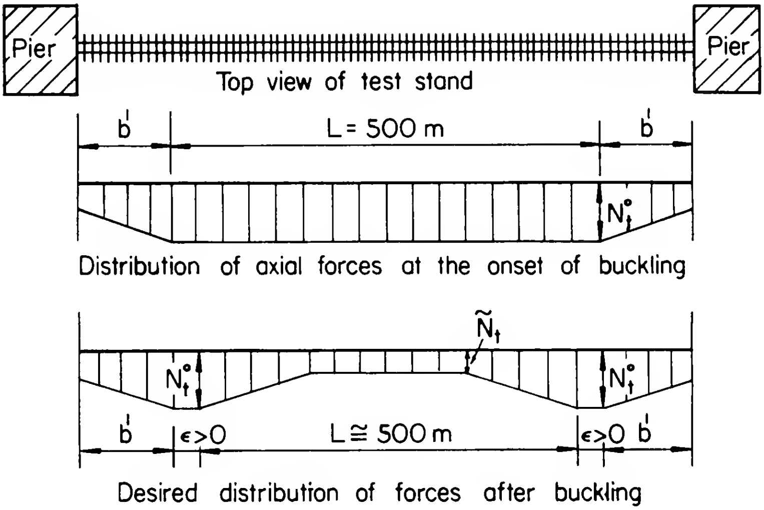


Fig. 4

The test tracks in Karlsruhe, at the BR Western Region Laboratory, and at the CNII MPS used end piers, as described above in option (3). The SNCF (7) and JNR (8) used locomotives, as described in option (2). The choice of either of the three alternatives described above should depend upon the availability of space, locomotives or cars, and other economic factors. Also the versatility of a particular arrangement with regard to various test programs to be conducted, should be taken into consideration.

For example, one possible aim to be achieved using the planned facility is to determine the effect of traffic compaction of the ballast on the stability of the track. Namely, how many passes (say, in tons) are needed after tamping to reach the desired stability of a planned track. This problem is related to the removal of imposed speed restrictions after track renovation. Such a compaction could be achieved in a test stand by moving locomotives and loaded cars back and forth on the test track (or in one direction if both ends of the test track are connected to a track loop) before it is subjected to axial compression forces. For such tests, option (1) or (2) is preferable. In option (2), after completing the compaction runs, the locomotives and cars can be used to achieve the desired end conditions. Another advantage of options (1) and (2) is that the length of the test track, L, can be easily increased, if this should become necessary. If buckling tests of a heated track subjected to a moving train are contemplated, or a study of axial rail forces induced by a moving train are planned, then option (1) is necessary. The length $L_{min} \cong 500$ m should be sufficient also for these purposes.

Tests involving compaction due to traffic also require that *proper clearance should be secured over the test track* in order not to hinder the planned movement of the locomotive or cars.

The use of locomotives or loaded railroad cars for compaction purposes requires that the test facility be connected to an existing railroad track in order to facilitate their delivery and movement. This point should be considered when deciding on *the location of the track test facility.* In order to enable a study of buckling phenomena caused by a temperature increase and a moving train, or a study of axial rail forces induced by a moving train, the possibility of *tying the test tract to an existing track loop* should be considered when deciding on the location of the test track.

For various track studies, there is a need to *exert on the track a lateral load of several tons.* The lateral load may be produced by means of hydraulic or screw jacks that press against a structure located near the track, as shown in Fig. 5. Such a structure may be a concrete pier built along the test track. A more versatile alternative is to use a heavy tractor instead of the pier. The advantages of using a tractor are that it can be placed in any desired location along the 500-m-long track, and that it can be used directly for push or pull purposes. In order to increase its resistance against displacements, when necessary, the tractor may be partially dug in.

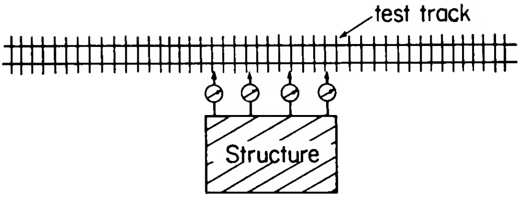


Fig. 5

For some tests it may be necessary to *exert a lateral force on the moving train* (7). This may be achieved, economically, by placing the test track near and parallel to an existing track.

The *axial compression force* in an actual welded track is often induced by raising the rail temperatures. To simulate such a situation the test track has to be heated. The use of mechanical jacks built into the rails to induce axial compression forces, as described in Ref. (9), is not admissible, as shown in Ref. (1) (10). In the test stands in Karlsruhe (3) (4) and at the CNII (6) the rails were heated utilizing electric currents. In the tests at the BR Western Region Laboratory (5) heating of the rails was achieved by placing, along each rail, parabolic reflectors fitted with electric heating elements. For the JNR tests (8) the rails were heated using steam.

The heating method which uses electric currents is to be preferred. In order to be able to heat each rail to a different temperature level, each of the two rails should have its own electric circuit. This arrangement is necessary for those tests whose purpose will be the determination of the effect of different rail temperatures (i.e. eccentricity of the axial force in the track) on track stability.

SUMMARY OF RECOMMENDATIONS

The guiding principle in designing the track test facility should be that the test track and its mechanical environment should simulate as closely as possible, for each test, the situation the actual track will encounter in the field.

It is proposed that for the planned test track, the length of the test section, *L*, be about 1,600 ft. To secure versatility, the end constraints should be achieved as discussed in option (1); namely, the test track should be sufficiently long. Both ends of the test track should be connected to a track loop, as shown in Fig. 6.

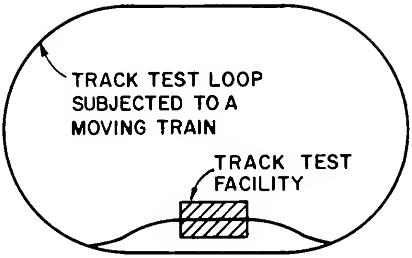


Fig. 6

This arrangement is needed for tests which require moving trains over the test section. Proper clearance over the test track should be secured to allow unhindered movement of the locomotives and cars over the entire test track. The planned test track should be connected to an existing track, to facilitate the delivery of rolling stock. If possible, the test track should be located near and parallel to an existing track. To exert vertical forces on the track, use can be made of available locomotives or cars and in special situations by utilizing cranes. Lateral forces on the track can be exerted by mechanical jacks. The necessary supporting structure should be mobile. To simulate thermal stresses in the field, the axial compression forces in the track should be induced using electric currents. Each rail should have its own circuit.

In conclusion it should be noted that because of the large variety of tests to be conducted, which will include the determination of stresses in the rails due to vertical and horizontal loads, the study of axial rail forces induced by moving trains, and track buckling caused by temperature stresses and the moving train, it is suggested that the track test facility be as versatile as possible. Thus, the construction of permanent structures, such as heavy concrete piers, should be avoided whenever mechanically possible and economically feasible.

REFERENCES

1. Kerr, A. D. "A Model Study for Vertical Track Buckling", High Speed Ground Transportation Journal, Vol. 7, No. 3, 1973, (DOT Report, 1971).
2. Kerr, A. D., "On the stability of the railroad track in the vertical plane", Rail International, Nr. 2, 1974, (DOT Report, 1972).
3. Raab, F. "Tests on the jointless track" ("Versuche am lückenlosen Gleis", in German), Eisenbahntechnische Rundschau, H. 10, 1956.
4. Birmann, F. and F. Raab, "To the development of the continuously welded track—Test results of the Karlsruhe test facility; Their analysis and interpretation" ("Zur Entwicklung durchgehend verschweisster Gleise—Ergebnisse bei Versuchen auf dem Karlsruher Prüfstand; Ihre Auswertung und Deutung", in German) Eisenbahntechnische Rundschau, H. 8, 1960.

5. Bartlett, D. L., J. Tuora, and G. R. Smith, "Experiments on the Stability of the Long-welded Rails", British Transport Commission, London, 1961.

6. Bromberg, E. M. "The Stability of the Jointless Track" ("Ustoichivost Besstykogo Puti", in Russian), Transport, Moscow, 1966.

7. Private communication to author by M. Janin of the SNCF, (Dec., 1973).

8. "The test on buckling of curved track", The Permanent Way Society of Japan, Nr. 1, 1958.

9. Ammann, O. and C. V. Gruenewaldt, "Tests on the effect of axial forces in the track" ("Versuche über die Wirkung von Längskräften im Gleis," in German), Organ für die Fortschritte des Eisenbahnwesens, 1932.

10. Kerr, A. D., "The lateral buckling of railroad tracks due to constrained thermal expansions", Proc. Symposium on Railroad Track Mechanics, Princeton University, 1975.

Advance Report of Committee 27—Maintenance of Way Work Equipment

F. H. Smith, *Chairman*

Work Equipment Repair Organizations of North American Railroads

Your committee presents, as information, the results of a survey of equipment repair organizations. The response to our questionnaire was excellent and we wish to thank all those who contributed data.

ROADS WITH 5,000 TO 24,000 MILES OF LINE

Sixteen roads in this category responded. Of these, only one repairs both automotive and maintenance-of-way (M/W) equipment. This probably reflects the travel and shipping time losses attributable to central vehicle repair as opposed to outside local shop repair. One road has 90 percent of both automotive and M/W equipment repair done in outside shops and another has all automotive and 75 percent of M/W overhauls farmed out. As might be expected, the one road that repairs both automotive and M/W equipment in company shops also has one of the closest shop spacings.

Of the 14 roads which repair all M/W equipment in company shops, three have only a single central shop. The others have from five to 20 shops of various sizes. The following table equates repair facilities and manpower with length of line:

	Number of Miles of Road per:				
	Central Shop	*All Shops*	*Field Supervisor*	*Field Mechanic*	*Total Field*
Maximum	19,459	12,521	5,118	736	736
Minimum	3,789	446	600	78	72
Average	8,509	3,909	1,689	296	255

ROADS WITH 1000 TO 5000 MILES OF LINE

Six roads responded. All except one repair M/W equipment only and have only one central shop. One repairs both automotive and M/W equipment and operates a central shop and eight smaller shops. The entire length of these roads is less than the average miles per shop for the longer roads. Thus, one shop provides better coverage.

	Number of Miles of Road per:				
	Central Shop	*All Shops*	*Field Supervisor*	*Field Mechanic*	*Total Field*
Maximum	2932	2278	Infinite	759	759
Minimum	1128	564	928	87	83
Average	1826	1247	—	237	223

ROADS WITH 500 TO 1000 MILES OF LINE

Six roads responded. Two of these roads repair both automotive and M/W equipment in company shops and three do only M/W equipment. One has all major work done on the outside.

	Number of Miles of Road per:				
	Central Shop	*All Shops*	*Field Supervisor*	*Field Mechanic*	*Total Field*
Maximum	988	946	Infinite	692	692
Minimum	542	144	247	60	54
Average	821	541	—	284	258

ROADS WITH 200 TO 500 MILES OF LINE

Twelve roads responded. As line miles become shorter, more roads repair both automotive and M/W equipment in company shops. Five roads repair both automotive and M/W equipment, the remaining seven repair M/W only. All have a single central shop except one road which has four shops.

	Number of Miles of Road per:		
	Field Supervisor	*Field Mechanic*	*Total Field*
Maximum	Infinite	393	393
Minimum	67	16	16
Average	292	161	148

ROADS WITH LESS THAN 200 MILES OF LINE

Twenty-three roads responded. Thirteen repair both automotive and M/W equipment, eight repair only M/W equipment and two have all work done in outside shops. Twenty-one roads maintaining a field repair force employ a total of 69 repairmen for 1843 miles of road, an average of 27 miles per man. Obviously, urban miles are more difficult than rural miles, and miles of track may be several times the miles of line for these roads.

CONCLUSIONS

In looking at the statistics provided by the responding roads, certain points of agreement, near agreement and disagreement are obvious:

1. Few of the longer roads repair both automotive and M/W equipment in company shops; many of the roads under 500 miles in length repair both. This is probably a matter of geography and logistics. In some cases, the extra automotive work probably helps to justify the existence of shops and shop equipment.

2. Few of the longer roads rely exclusively on one central shop, again probably a matter of logistics. Almost all of the roads under 500 miles in length have only a single central shop. However, in both classes of road, there are outstanding exceptions to the rule

3. One might think that the various roads had made a decision to balance their repair forces by choosing between frequent shop facilities and frequent field people to insure prompt and adequate handling of machine problems. Such does not appear to be the case. Roads with most closely spaced shops also tend to have most closely spaced field repairmen. Obviously, the enormity of some central shops makes up for some lack of closely spaced facilities while increasing logistic problems. The accompanying table illustrates the wide variation in repair organization spacings:

Road	*Miles per Shop*	*Miles per Field Man*
Low frequency of shops and field men:		
A	4,077	453
B	2,187	437
C	7,361	736
D	12,521	224
Balanced frequency:		
E	931	320
F	10,200	176
G	676	287
Frequent shops and field men:		
H	517	73
I	868	111
J	446	76
K	1,145	72
L	1,450	89

The most capable facility is the large, completely equipped shop. In its ultimate state of perfection, it would be able to build an entire fleet of maintenance machinery from scratch. Where complete machine rebuilding or major component rebuilding on the property is required, a major shop is a necessity. Contracting with outside shops or scrap-early-and-buy-new would be reasonable alternatives.

The key factor in any M/W repair organization is the field repairman, his equipment and the size of his territory. If his territory is too large, he will spend more time travelling than in doing repair work. If his territory is small and if he is well equipped, he will be able to do work that would otherwise go to a shop. In the foregoing mileage tabulations, average miles of road per field mechanic are 296, 237, 284, 161 and 28, in order from the longest roads to the shortest. Similarly, average miles of road per field person (supervisors and mechanics) are 255, 223, 258, 148 and 27. If heavy reliance is to be placed on field repair, it seems certain that the average mileage figures should not be exceeded. Indeed, they should be reduced, perhaps nearing minimum figures shown.

It is true that good, properly trained operators can substitute for or minimize the need for repairmen. Similarly, well equipped and competent field repairmen can substitute for and minimize the need for shop facilities. With some limitations, the reverse is also true. Thus, a repair organization can be flexible .

Our survey of field repair vehicles shows a preference for ¾-ton utility trucks. In view of the rough terrain and substantial payloads these trucks must handle, this is the minimum rating that can be recommended and in many cases may be too light for tire and suspension economy and safety; particularly when equipped at the low end of the 6000 to 9000 gross-vehicle-weight (GVW) range. Sample trucks in the repair fleet should be check weighed. A few roads use very sizeable vans: 12,000 to 30,000 GVW with miniature shops built in. Choice between the utility truck and the shop-van is one of money and organization. Where major work is done in the field and a heavy premium is placed on field ability to return machines to service quickly, extra cost of the van can be easy to justify. A tabulation of trucks and equipment is shown on page 12.

In developing or altering a repair organization, certain general considerations apply. Both shop and field work have some unique advantages to which the final scheme should adapt.

SHOP:

Shelter and working environmental control.
Parts inventory and procurement potential.
Specialized personnel.
Specialized and expensive tools and equipment.
Stenographic, communications and other office facilities.
Central control of fleet.

FIELD:

Elimination of shipping effort and time.
Knowledge of recent machine history.
Access to operator diagnosis and assistance.
Communication with local users for best time and effort management.

Since repair facilities always seem to lag behind the growth of the M/W fleet, roads with better than average organizations are certainly nearer an optimum condition. Also, the fact that few or none of the roads may follow some certain course, does not mean that the course is wrong. That course may have been unexplored or its time may have only just arrived.

VEHICLES FURNISHED TO MAINTENANCE OF WAY EQUIPMENT REPAIR PERSONNEL

ROAD SIZE MILES OF LINE	UTILITY			VAN				PICKUPS			
	OVER ONE TON	ONE TON	¾ TON	TWO TON UP	1½ TON	ONE TON	¾ TON	¾ TON	½ TON	OTHER	TOTAL
OVER 5000	2½	5	6	1½	½	½					16
1000 - 5000	1	1	2½				½			1	6
500 - 1000		1	2	¼				2½	¼		6
200 - 500			7	1			2				10
UNDER 200			6				2	2	4	5	19
	3½	7	23½	2¾	½	½	4½	4½	4¼	6	57

EQUIPMENT FURNISHED ON MAINTENANCE OF WAY REPAIR VEHICLES

ROAD SIZE MILES OF LINE	HOIST OR CRANE	ELECTRIC WELDER	GAS WELD	AIR COMPRESSOR	HYDRAULIC SYSTEM ANALYZER	NO REPLY	TOTAL ROADS
OVER 5000	6½	16	16	3	5¾	0	16
1000 - 5000	2	5	5	1	3	1	6
500 - 1000	0	3	5	0	3	0	6
200 - 500	0	5	7	2	2	1	10*
UNDER 200	1	9	11	8	4	0	19*
TOTALS	9½	38	44	14	17¾	2	57

* Additional roads do not furnish a vehicle.
NOTE: Fractions denote equipment furnished to only part of fleet.

Advance Report of Committee 3—Ties and Wood Preservation

Report on Assignment 5

Service Records

K. C. Edscorn *(chairman, subcommittee)*, L. C. Collister, M. J. Crespo, E. M. Cummings, J. K. Gloster, H. E. Richardson, R. H. Savage, G. D. Summers.

TIE RENEWALS AND COSTS

Statistics providing information on cross tie renewals and average tie costs for the year 1974, as compiled by the Economics and Finance Department, Association of American Railroads, are presented on following pages in Tables A and B.

The 1974 statistics on new tie renewals by Class I U.S. Railroads compared with 1973 are as follows:

Year	*Total New Tie Renewals*	*Renewals Per Mile*
1973	17,856,780*	61
1974	18,819,355**	65

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* Includes 28,635 concrete ties, excludes 819,324 secondhand ties.

** Includes 28,690 concrete ties, excludes 669,787 secondhand ties.

By geographical districts, the Eastern Roads inserted in replacement 53 ties per mile, the Southern Roads 97 ties per mile and the Western Roads 65 ties per mile.

"Indicated" wooden tie life determined by dividing the total number of ties in track (1967 figures) by the number of new ties inserted in 1974 is as follows: Eastern Roads 57 years, Southern Roads 32 years, Western Roads 50 years, all U. S. Class I Roads 47 years.

The most significant change to be noted in the 1974 tables is the average cost of cross ties in comparison to last year. The inflationary spiral contributed to increases in stumpage prices for timber, labor and fuel. The shortage of fuel oil resulted in substantial increases in the cost of preservatives. The combination of all factors provided a dramatic increase in the average cost of 43% over 1973.

Obviously, maintenance budgets were strained under this cost burden which perhaps accounts for the rather meager 5% increase in tie renewals. Considering the indicated service life above, it is apparent that more ties should be replaced and likely would be if costs were more in line with revenues.

The Western District replacements increased by 17% while the Eastern District and Southern District showed decreases of 6% and 2%, respectively.

The number of concrete ties inserted was almost exactly the same as in 1973, but the average cost of these ties was up almost 44%.

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, 1974

District and Road	Wooden cross ties laid in replacement			Track maintained by reporting railroad			Equated gross ton-miles (thousands) a		New cross tie replacement averages			
	New ties		Second hand ties	Miles occupied by cross ties c	Total cross ties	Cross ties per mile (1967)	Total	Per mile of track	Percent renewal to all ties	Number laid per mile	Renewal cost per mile	Renewal cost per 1,000 GTM
	Number	Average cost b										
	1	2	3	4	5	6	7	8	9	10	11	12
EASTERN DISTRICT:												
Akron, Canton & Youngstown	8 867	$8.40	-	217	640 419	2 950	561 089	2 586	1.38	41	$341	13.19¢
Ann Arbor	31 112	11.83	-	395	1 201 438	3 042	1 022 053	2 587	2.59	79	932	36.01
Baltimore & Ohio	458 415	8.28	-	9 167	26 583 780	2 900	73 537 717	8 022	1.72	50	414	5.16
Bangor & Aroostook	45 618	7.10	-	756	2 173 910	2 874	1 341 561	1 775	2.10	60	429	24.15
Bessemer & Lake Erie	66 186	13.21	1 303	396	1 187 190	3 000	3 767 134	9 513	5.58	167	2 210	23.23
Boston & Maine	134 028	10.27	765	1 901	5 608 668	2 950	7 568 606	3 981	2.39	71	724	18.19
Canadian Pacific (Lines in Me)	22 069	7.80	-	287	841 660	2 935	1 617 991	5 638	2.62	77	599	10.63
Central RR of New Jersey	15 233	12.40	-	627	1 755 154	2 798	2 103 126	3 354	.87	24	301	8.99
Central Vermont	28 730	9.26	-	463	1 335 025	2 882	1 072 216	2 316	2.15	62	575	24.81
Chesapeake & Ohio	189 242	7.67	-	7 868	23 603 940	3 000	62 694 918	7 968	.80	24	184	2.31
Chicago & Eastern Illinois	13 424	11.92	-	722	2 198 172	3 043	8 399 963	11 634	.61	19	222	1.90
Delaware & Hudson	32 749	10.99	1 322	1 019	3 157 656	3 100	6 672 730	6 548	1.04	32	353	5.40
Detroit & Toledo Shore Line	7 196	15.50	2	137	396 739	2 896	533 764	3 896	1.81	53	818	20.98
Detroit, Toledo & Ironton	25 534	10.03	4	602	1 734 998	2 880	3 476 442	5 775	1.47	42	425	7.36
Elgin, Joliet & Eastern	76 549	8.91	-	802	2 453 163	3 058	2 386 661	2 976	3.12	95	850	28.58
Erie Lackawanna	173 548	9.94	26 838	5 209	15 417 880	2 960	39 700 315	7 621	1.13	33	331	4.35
Grand Trunk Western	105 978	8.38	-	1 849	5 828 872	3 152	9 533 788	5 156	1.82	57	480	9.31
Illinois Terminal	16 414	8.65	-	290	898 018	3 094	1 168 405	4 029	1.83	57	490	12.15
Lehigh Valley	36 009	11.18	-	1 744	5 506 422	3 158	7 617 439	4 368	.65	21	231	5.29
Long Island	52 541	11.06	-	636	1 800 502	2 829	4 146 520	6 520	2.92	83	914	14.01

Maine Central	80 547	7.46	-	969	2 898 879	2 992	2 490 251	2 570	2.78	83	620	24.13
Missouri-Illinois	14 076	7.03	-	163	505 272	3 092	693 808	4 256	2.79	86	607	14.27
Monongahela	14 982	13.42	107	250	753 434	3 017	683 717	2 735	1.99	60	804	29.40
Norfolk & Western e	1 069 789	9.52	-	12 179	37 888 115	3 111	126 308 188	10 371	2.82	88	836	8.06
Penn Central	1 650 038	10.97	17 963	34 061	102 524 667	3 010	245 080 156	7 195	1.61	48	531	7.39
Penna-Reading Seashore Lines	21 791	11.82	199	332	899 490	2 709	348 688	1 050	2.42	66	777	73.99
Pittsburgh & Lake Erie	38 362	12.83	544	566	1 730 618	3 059	2 951 254	5 214	2.22	68	869	16.67
Reading	79 312	9.37	-	2 132	5 871 616	2 754	9 245 720	4 337	1.35	37	348	8.04
Richmond, Fred'burg & Potomac	56 096	8.78	1 185	429	1 382 653	3 223	3 360 072	7 832	4.06	131	1 149	14.67
Western Maryland	31 239	9.54	-	1 120	3 250 318	2 902	7 839 160	6 999	.96	28	266	3.80
Total Eastern District	4 595 674	9.94	50 232	87 288	262 028 668	3 002	637 923 452	7 308	1.75	53	523	7.16
SOUTHERN DISTRICT:.												
Atlanta & West Point	7 994	6.63	-	125	331 278	2 656	1 109 389	8 875	2.41	64	424	4.78
Clinchfield	39 658	7.86	200	432	1 399 153	3 240	7 600 533	17 594	2.83	92	722	4.10
Florida East Coast e	180 089	8.03	-	931	2 806 280	3 015	5 034 786	5 408	6.42	193	1 485	27.47
Georgia	32 013	8.12	200	423	1 288 537	3 046	1 911 673	4 519	2.48	76	615	13.60
Illinois Central Gulf	1 061 139	8.66	-	12 802	40 621 241	3 173	74 878 052	5 849	2.61	83	718	12.28
Louisville & Nashville	581 089	7.91	8 621	9 523	27 465 399	2 884	89 511 694	9 400	2.12	61	482	5.13
Seaboard Coast Line e	796 031	8.83	7 796	12 776	39 772 869	3 113	94 817 725	7 422	2.00	62	550	7.41
Southern System d	2 229 410	9.62	-	13 912	43 294 368	3 112	121 937 065	8 765	5.15	160	1 542	17.60
Western Ry of Alabama	23 227	6.72	-	171	510 437	2 988	1 200 444	7 020	4.55	136	912	13.00
Total Southern District	4 950 650	8.98	16 817	51 095	157 489 562	3 082	398 001 361	7 789	3.14	97	870	11.17

Table A (Continued)

District and Road	Wooden cross ties laid in replacement			Track maintained by reporting railroad			Equated gross ton-miles (thousands) a		New cross tie replacement averages			
	New ties		Second hand ties	Miles occupied by cross ties c	Total cross ties	Cross ties per mile (1967)	Total	Per mile of track	Percent renewal to all ties	Number laid per mile	Renewal cost per mile	Renewal cost per 1,000 GTM
	Number	Average cost b										
	1	2	3	4	5	6	7	8	9	10	11	12
WESTERN DISTRICT:												
Atchison, Topeka & Santa Fe e	1 196 309	$8.73	232 375	18 678	59 640 000	3 193	182 701 250	9 782	2.01	64	$559	5.72¢
Burlington Northern	1 892 808	7.17	35 339	30 252	91 936 719	3 039	209 800 034	6 935	2.06	63	449	6.47
Chicago & North Western	690 734	11.25	123 503	13 236	39 457 617	2 981	64 344 520	4 861	1.75	52	587	12.08
Chicago, Milw., St. Paul & Pac	548 045	7.07	77 867	12 288	37 268 537	3 033	50 283 832	4 092	1.47	45	315	7.71
Chicago, Rock Island & Pacific	473 550	7.94	24 973	8 818	26 278 970	2 980	52 011 974	5 898	1.80	54	427	7.23
Colorado & Southern	21 789	6.28	123	742	2 271 465	3 060	5 467 292	7 368	.96	29	185	2.51
Denver & Rio Grande Western	157 679	9.40	2 446	2 687	8 295 894	3 087	23 306 091	8 674	1.90	59	552	6.36
Duluth, Missabe & Iron Range	33 827	9.40	1 075	781	2 327 090	2 979	5 456 090	6 986	1.45	43	407	5.83
Duluth, Winnipeg & Pacific	62 484	8.55	-	206	595 616	2 890	2 244 540	10 896	10.49	303	2 592	23.79
Fort Worth & Denver	107 305	8.05	4	1 404	4 213 132	3 001	5 314 103	3 785	2.55	76	615	16.26
Green Bay & Western	3 152	11.70	25 146	303	871 257	2 880	815 533	2 692	.36	10	122	4.54
Kansas City Southern (incl. L&A) e	424 862	8.89	-	2 263	7 240 372	3 199	16 803 888	7 425	5.87	188	1 669	22.47
Lake Superior & Ishpeming	4 747	10.11	693	168	504 750	3 000	67 058	399	.94	28	286	71.58
Minneapolis, Northfield & Southern	2 906	6.04	281	115	277 531	2 417	218 841	1 903	1.05	25	157	8.23
Missouri-Kansas-Texas	121 488	10.66	10 598	2 525	8 090 887	3 204	14 391 446	5 700	1.50	48	513	9.00
Missouri Pacific	884 580	7.86	-	9 901	30 574 043	3 088	92 078 967	9 300	2.89	89	702	7.55
Northwestern Pacific	33 696	8.59	-	382	1 098 720	2 880	1 479 229	3 872	3.07	88	757	19.54
Oregon Electric	1 415	6.61	-	182	563 856	3 093	506 084	2 781	.25	8	49	1.78
St. Louis-San Francisco	346 299	7.46	1 305	6 547	20 550 246	3 139	43 184 771	6 596	1.69	53	395	5.98
St. Louis Southwestern	249 456	11.28	-	1 698	5 201 495	3 063	31 641 623	18 635	4.80	147	1 657	8.89
Soo Line	217 728	7.84	14 187	5 230	15 733 184	3 008	21 875 546	4 183	1.38	42	326	7.80
Southern Pacific	819 698	10.91	-	16 382	48 326 276	2 950	206 673 632	12 616	1.70	50	546	4.33
Spokane International	81 046	11.52	-	152	446 700	2 935	666 766	4 387	18.14	533	6 145	140.08
Texas & Pacific	108 885	7.70	-	2 386	7 265 090	3 045	23 403 117	9 809	1.50	46	351	3.58
Texas Mexican	25 724	12.05	-	239	755 843	3 168	625 126	2 616	3.40	108	1 297	49.59
Toledo, Peoria & Western	8 340	7.57	-	295	933 388	3 168	1 307 743	4 433	.89	28	214	4.82
Union Pacific	663 681	9.77	52 823	13 156	37 190 947	2 827	172 248 471	13 093	1.78	50	493	3.76
Western Pacific	90 798	11.96	-	1 785	5 328 281	2 985	17 340 861	9 715	1.70	51	608	6.26
Total Western District	9 273 031	8.73	602 738	152 801	463 237 906	3 032	1 246 258 428	8 156	2.00	61	530	6.50
Total United States	18 819 355	9.09	669 787	291 184	882 756 136	3 032	2 282 183 241	7 838	2.13	65	587	7.50
CANADIAN ROADS:												
Canadian National	959 517	7.96	-	30 320	89 100 000	2 938	-	-	1.07	32	252	-
Canadian Pacific	1 306 483	9.32	-	20 619	61 195 313	2 968	129 721 272	6 291	2.13	63	590	9.38
Ontario Northland	22 563	8.88	-	724	2 175 800	3 007	3 057 037	4 225	1.04	31	277	6.55

a - Gross ton-miles of cars and contents, plus two times gross ton-miles of locomotives in freight service, plus three times gross ton-miles of locomotives in passenger service.

b - "Average cost" represents storekeepers' average cost of all kinds, sizes and grades of ties charged out and used rather than the average price of ties purchased during the year.

c - Column 4 based on cross ties per mile of track in 1967, the last year for which reported.

d - Includes all Southern System Class I Railroads.

e - Comprised of both wooden and other than wooden ties as follows:

District and Road	Other than wooden ties		Wooden ties	
	Number	Average Cost	Number	Average Cost
Road:				
Norfolk & Western	800	$36.25	1 068 989	$9.50
Florida East Coast	15 117	25.47	164 972	6.05
Seaboard Coast Line	205	14.63	795 826	8.83
Atchison, Topeka & Santa Fe	400	27.50	1 195 909	8.72
Kansas City Southern (incl. L&A)	12 168	14.71	412 694	8.72
District:				
Eastern District	800	36.25	4 594 874	9.93
Southern District	15 322	25.32	4 935 328	8.93
Western District	12 568	15.12	9 259 463	8.72
United States	28 690	21.16	18 789 665	9.07

Association of American Railroads, Economics and Finance Department, Washington, D. C. 20036
from Annual Reports of Class I Railroads to the Interstate Commerce Commission.

July 1975

Table B

NUMBER AND AGGREGATE COST OF NEW CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW 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 five years 1970 to 1974 inclusive

Note: All figures are exclusive of switch and bridge ties

District and Road	Number of new cross tie renewals per mile of maintained track						Aggregate cost of new cross tie renewals per mile of maintained track						Percent new cross tie renewals to all ties in track					
	1970	1971	1972	1973	1974	5 year average	1970	1971	1972	1973	1974	5 year average	1970	1971	1972	1973	1974	5 year average
EASTERN DISTRICT:																		
Akron, Canton, & Youngstown	72	169	51	26	41	72	$425	$802	$313	$180	$341	$412	2.44	5.72	1.74	.90	1.38	2.44
Ann Arbor	17	42	33	36	79	41	94	255	205	233	932	344	.56	1.39	1.09	1.20	2.59	1.37
Baltimore & Ohio	52	66	52	44	50	53	277	394	307	260	414	330	1.78	2.27	1.81	1.51	1.72	1.82
Bangor & Aroostook	103	74	73	51	60	72	496	374	400	395	429	419	3.57	2.56	2.55	1.79	2.10	2.51
Bessemer & Lake Erie	44	50	114	102	167	95	306	368	835	927	2210	929	1.46	1.68	3.81	3.39	5.58	3.18
Boston & Maine	28	39	66	79	71	57	158	297	439	555	724	435	.95	1.34	2.22	2.68	2.39	1.92
Canadian Pacific (Lines in Me.)	7	96	46	37	77	53	30	554	251	254	599	338	.24	3.28	1.57	1.26	2.62	1.79
Central RR of New Jersey	78	51	65	150	24	74	510	344	429	108	301	338	2.80	1.82	2.32	.58	.87	1.68
Central Vermont	81	20	80	85	62	66	381	86	385	532	575	392	2.82	.69	2.77	2.96	2.15	2.28
Chesapeake & Ohio	51	63	38	37	24	43	269	369	219	216	184	251	1.70	2.10	1.26	1.22	.80	1.42
Chicago & Eastern Illinois	255	72	230	59	19	127	1206	363	1328	328	222	689	8.38	2.38	7.55	1.94	.61	4.17
Delaware & Hudson	50	49	6	63	32	40	340	346	46	473	353	312	1.62	1.57	.20	2.04	1.04	1.29
Detroit & Toledo Shore Line	-	45	52	4	53	31	-	359	269	29	818	295	-	1.57	1.80	.13	1.81	1.06
Detroit, Toledo & Ironton	28	37	46	53	42	41	161	216	307	355	425	293	.98	1.29	1.60	1.85	1.47	1.44
Elgin, Joliet & Eastern	96	42	96	105	95	87	516	245	611	721	850	589	3.12	1.39	3.14	3.44	3.12	2.84
Erie Lackawanna	56	46	30	64	33	46	335	280	207	464	331	323	1.90	1.55	1.01	2.15	1.13	1.55
Grand Trunk Western	47	62	54	59	57	56	297	387	346	415	480	385	1.50	1.96	1.71	1.88	1.82	1.77
Illinois Terminal	37	73	74	110	57	70	166	358	357	585	490	391	.21	2.37	2.39	3.55	1.83	2.07
Lehigh Valley	3	11	4	11	21	10	13	47	33	103	231	85	.09	.36	.14	.33	.65	.31
Long Island	49	86	62	62	83	68	230	656	506	499	914	561	1.75	3.02	2.19	2.19	2.92	2.41

Maine Central	64	74	64	66	83	70	338	424	419	444	620	449	2.15	2.46	2.16	2.19	2.78	2.35
Missouri-Illinois	97	75	61	75	86	79	456	369	291	382	607	421	3.13	2.41	1.96	2.43	2.79	2.54
Monongahela	10	45	23	78	60	43	70	324	180	602	804	396	.38	1.50	.78	2.57	1.99	1.44
Norfolk & Western	89	66	75	77	88	79	562	388	448	541	836	555	2.86	2.11	2.40	2.46	2.82	2.53
Penn Central	37	49	53	52	48	48	212	284	342	365	531	347	1.24	1.63	1.75	1.74	1.61	1.59
Penna-Reading Seashore Lines	29	37	65	78	66	55	159	238	412	541	777	425	1.06	1.37	2.40	2.89	2.42	2.03
Pittsburgh & Lake Erie	52	54	58	66	68	60	363	383	436	541	869	518	1.72	1.76	1.89	2.16	2.22	1.95
Reading	41	59	68	60	37	53	245	333	378	371	348	335	1.49	2.13	2.47	2.19	1.35	1.93
Richmond Fred'burg & Potomac	226	175	126	98	131	151	1688	1224	886	702	1149	1130	7.03	5.43	3.90	3.05	4.06	4.69
Western Maryland	55	62	47	45	28	47	337	389	307	347	266	329	1.88	2.14	1.62	1.56	.96	1.63
Total Eastern District	51	55	55	56	53	54	291	329	345	382	523	374	1.69	1.85	1.83	1.85	1.75	1.79
SOUTHERN DISTRICT:																		
Atlanta & West Point	d	d	d	d	64	64	d	d	d	d	424	424	d	d	d	d	2.41	2.41
Clinchfield	47	79	88	92	92	80	299	539	612	631	722	561	1.46	2.45	2.73	2.83	2.83	2.46
Florida East Coast	102	311	30	152	193	158	761	3238	286	1147	1485	1383	3.38	10.30	.99	5.06	6.42	5.23
Georgia	60	69	71	34	76	62	354	432	461	223	615	417	1.98	2.27	2.32	1.11	2.48	2.03
Illinois Central Gulf a	90	95	112	91	83	94	436	503	607	545	718	562	2.83	2.98	3.54	2.85	2.61	2.96
Louisville & Nashville b	83	98	51	61	61	71	588	485	259	349	482	433	2.87	3.39	1.75	2.11	2.12	2.45
Seaboard Coast Line	101	116	117	93	62	98	524	651	675	580	550	596	3.23	3.72	3.74	3.00	2.00	3.14
Southern System	134	181	175	140	160	158	782	1118	1100	967	1542	1102	4.29	5.78	5.60	4.49	5.15	5.06
Western Ry of Alabama	d	d	d	d	136	136	d	d	d	d	912	912	d	d	d	d	4.55	4.55
Total Southern District	103	126	115	100	97	108	545	746	675	637	870	695	3.34	4.10	3.74	3.23	3.14	3.51

Table B (Continued)

District and Road	Number of new cross tie renewals per mile of maintained track						Aggregate cost of new cross tie renewals per mile of maintained track						Percent new cross tie renewals to all ties in track					
	1970	1971	1972	1973	1974	5 year average	1970	1971	1972	1973	1974	5 year average	1970	1971	1972	1973	1974	5 year average
WESTERN DISTRICT:																		
Atchison, Topeka & Santa Fe	77	86	83	72	64	76	$344	$419	$434	$390	$559	$429	2.40	2.69	2.59	2.26	2.01	2.39
Burlington Northern c	37	40	46	50	63	47	195	227	285	309	449	293	1.20	1.31	1.51	1.65	2.06	1.55
Chicago & North Western	27	29	13	14	52	27	157	171	83	92	587	218	.90	.96	.44	.46	1.75	.90
Chicago, Milwaukee, St. Paul & Pac.	44	48	55	45	45	47	245	274	324	278	315	287	1.45	1.60	1.81	1.49	1.47	1.56
Chicago, Rock Island & Pacific	66	72	71	35	54	60	308	341	340	194	427	322	2.22	2.42	2.37	1.19	1.80	2.00
Colorado & Southern	32	40	21	66	29	38	137	185	118	369	185	199	1.03	1.31	.70	2.15	.96	1.23
Denver & Rio Grande Western	22	32	41	37	59	38	138	185	270	277	552	284	.71	1.04	1.33	1.21	1.90	1.24
Duluth, Missabe & Iron Range	42	29	39	53	43	41	265	186	261	382	407	300	1.41	.99	1.30	1.79	1.45	1.39
Duluth, Winnipeg & Pacific	80	23	155	113	303	135	433	133	1018	741	2592	983	2.78	.80	5.34	3.90	10.49	4.66
Fort Worth & Denver	39	48	48	71	76	56	217	263	327	516	615	388	1.30	1.59	1.60	2.36	2.55	1.88
Green Bay & Western	5	22	26	5	10	14	24	109	141	33	122	86	.18	.77	.91	.19	.36	.48
Kansas City Southern	82	101	172	142	188	137	506	583	1005	938	1669	940	2.58	3.15	5.37	4.44	5.87	4.28
Lake Superior & Ishpeming	8	1	1	5	28	9	37	7	7	34	286	74	.26	.05	.05	.16	.94	.29
Minneapolis, Northfield & Southern	d	d	d	d	25	25	d	d	d	d	157	157	d	d	d	d	1.05	1.05
Missouri-Kansas-Texas	69	75	80	80	48	70	369	414	446	586	513	466	2.15	2.33	2.51	2.49	1.50	2.20
Missouri Pacific	97	118	121	79	89	101	446	551	580	404	702	537	3.15	3.83	3.92	2.56	2.89	3.27
Northwestern Pacific	64	92	91	64	88	80	349	392	467	297	757	452	2.23	3.20	3.15	2.22	3.07	2.77
Oregon Electric	24	19	7	8	8	13	134	105	45	49	49	76	.77	.60	.23	.25	.25	.42
St. Louis-San Francisco	69	75	96	83	53	75	288	351	454	417	395	381	2.20	2.40	3.07	2.63	1.69	2.40
St. Louis Southwestern	127	125	144	113	147	131	715	773	919	825	1657	978	4.14	4.09	4.71	3.68	4.80	4.28
Soo Line	39	47	37	34	42	40	164	220	180	180	326	214	1.29	1.57	1.24	1.11	1.38	1.32
Southern Pacific	45	96	65	49	50	61	227	523	358	329	546	397	1.52	3.24	2.20	1.67	1.70	2.07
Spokane International	d	d	d	d	533	533	d	d	d	d	6145	6145	d	d	d	d	18.14	18.14
Texas & Pacific e	120	97	82	55	46	80	574	447	393	284	351	410	3.94	3.19	2.71	1.82	1.50	2.63
Texas Mexican	d	d	d	126	108	117	d	d	d	920	1297	1109	d	d	d	3.98	3.40	3.69
Toledo, Peoria & Western	71	75	109	25	28	62	395	453	673	146	214	376	2.24	2.38	3.45	3.79	.89	2.55
Union Pacific	29	47	49	31	50	41	183	295	299	199	493	294	1.04	1.66	1.75	1.09	1.78	1.46
Western Pacific	57	57	46	46	51	51	470	492	417	449	608	487	1.92	1.92	1.55	1.54	1.70	1.73
Total Western District	52	64	59	52	61	58	264	339	326	313	530	354	1.72	2.10	1.94	1.71	2.00	1.89
Total United States	60	72	67	61	65	65	320	405	389	390	587	418	1.99	2.37	2.21	2.02	2.13	2.14
CANADIAN ROADS:																		
Canadian National	44	35	29	38	32	35	186	161	141	229	252	194	1.5	1.2	1.01	1.28	1.07	1.2
Canadian Pacific	57	57	58	47	63	56	300	357	333	354	590	387	1.94	1.94	1.95	1.57	2.13	1.91
Ontario Northland	33	33	53	45	31	39	188	192	288	344	277	258	2,02	1.19	1.92	1.49	1.04	1.53

a - Includes separate operations of Gulf, Mobile & Ohio merged August 10, 1972.

b - Includes separate operations of Monon merged July 31, 1971.

c - Formed by merger of Chicago, Burlington & Quincy, Great Northern, Northern Pacific and (by lease) Spokane, Portland & Seattle railroads effective March 3, 1970. Data shown for BN include separate operations of those roads for the periods prior to merger, (Merger did not include Oregon Electric and Oregon Trunk railroads which were included in SP&S report for the two months but which began separate reporting as Class I and Class II roads, respectively, effective March 1, 1970.)

d - Reported as a Class II railroad.

e - Includes separate operations of Kansas, Oklahoma & Gulf merged April 1, 1970.

Table C

OTHER THAN WOODEN CROSS TIES LAID IN 1974 AND NUMBER OF OTHER THAN WOODEN CROSS TIES IN MAINTAINED TRACK OCCUPIED BY CROSS TIES AS OF DECEMBER 31, 1974

District and Road	Other than wooden cross ties laid in replacement		Other than wooden cross ties laid in additional tracks, new lines and extensions		Number of other than wooden cross ties in maintained track occupied by cross ties (12/31/74)
	Number	Average Cost	Number	Average Cost	
EASTERN DISTRICT:					
Central R. R. of N. J.	-	-	-	-	840
Delaware & Hudson	-	-	-	-	57 809
Norfolk & Western	800	$36.25	-	-	800
Total Eastern District	800	36.25	-	-	59 449
SOUTHERN DISTRICT:					
Florida East Coast	15 117	25.47	24 365	16.96	353 232
Louisville & Nashville	-	-	-	-	808
Seaboard Coast Line	205	14.63	26 095	25.01	292 136
Southern System	-	-	-	-	68 579
Total Southern District	15 322	25.32	50 460	17.08	714 755
WESTERN DISTRICT:					
Atchison, Topeka & Santa Fe	400	27.50	-	-	6 000
Burlington Northern	-	-	-	-	303
Duluth, Missabe & Iron Range	-	-	-	-	530
Kansas City Southern (Incl. L&A)	12 168	14.71	5 254	12.46	191 379
St. Louis-San Francisco	-	-	-	-	74 480
Western Pacific	-	-	-	-	735
Total Western District	12 568	15.12	5 254	12.46	273 427
Total United States	28 690	21.16	55 714	16.64	1 047 631

Association of American Railroads
Economics and Finance Department
Washington, D. C. 20036

July 7, 1975

Table D

TYPICAL CROSS TIE PRICES
As of January 1

10 Selected Class I Railroads

District/description of cross tie	1969	1970	1971	1972	1973	1974	1975
EAST:							
7"x9"x8'6" oak treated	$5.33	$5.83	$5.83	$6.41	$6.67	$9.02	$12.94
Grades (4&5 Latest A.R.E.A. Spec.) 60/40 Cr/Coal	6.50	6.90	7.45	7.45	7.68	8.23	10.72
Grades 4&5 treated (latest A.R.E.A. spec. 60/40 Creosoted	6.35	6.90	7.45	7.45	7.68	8.23	10.72
SOUTH:							
6"x7', 7"x8" and 7"x9" by 8"6" treated oak & mixed hardwood	3.62	4.63	5.22	5.09	5.67	6.08	9.09
7"x9"x8'6 treated	5.09	5.13	5.29	5.64	5.71	6.48	10.77
7"x9"x8'6 oak, creosoted	5.60	6.50	6.00	6.71	6.89	8.63	11.20
WEST:							
7"9"x8'6" red oak, Gr. 5	4.77	5.07	5.24	5.24	5.59	6.53	8.95
7"x9"x9'	5.01	5.63	5.63	5.63	6.40	8.95	13.55
7"9"x8' Doug. fir rough - No. 1 & better	5.00	6.01	6.99	5.77	6.06	7.50	10.90
7"x8"x9' Hardwood treated	4.67	5.09	5.12	5.33	5.05	8.10	10.37

Association of American Railroads
Economics and Finance Department
Washington, D. C. 20036

February 20, 1975

Advance Report of the Special Committee on Scales

Report on Assignment 3

Statistical Data for Coupled-in-Motion Weighing and Testing

N. A. Wilson *(chairman, subcommittee)*, O. T. Almarode, B. F. Banks, R. O. Bradley, Robert Brumbaugh, E. W. Buckles, J. L. Dahlrot, R. H. Damon, Jr., T. A. DeAlba, O. C. Denz, G. F. Graham, I. M. Hawver, S. Levinson, L. L. Lowery, B. H. Price, Jr., W. H. Rankin, S. H. Raskins, R. D. Roberts, A. E. Robinson, K. D. Tidwell, J. L. Finnell.

Your committee submits as information the following interim report on the performance of track scales designed for coupled-in-motion weighing of freight cars. The committee reviewed tests for tolerance on 18 scales and 27 modes over the scales, utilizing 2707 weights. Many railroads participated in the testing program, along with representatives of the AREA, weighing bureaus, cities, states and the National Bureau of Standards.

Test equipment has now been assembled at Martinsburg, West Virginia, to be calibrated by the National Bureau of Standards to gather further information for the study of weighing over coupled-in-motion track scales.

There are presented below and on the next page summaries of the test results, followed by the complete computer printout for each weight.

Summary of Coupled-in-Motion Track Scale Tests

Number of tests	18 Scales (27 Modes)
Number of cars weighed	2,707

Average Percent Deviation of Individual Cars

0.00% to 0.20%	0.21% to 0.50%	0.51% to 1.00%
81.42	17.58	1.00

Total weight test trains	Reference	416,770,950 lb
Total weight deviation	Trains (Gross)	127,835 lb
Weight deviation per car	(Net)	8 lb
Total weight deviation	Cars (Gross)	504,745 lb
Weight deviation per car	(Gross)	186 lb

COUPLED-IN-MOTION TRACK SCALE TEST RESULTS

			Percent Deviation Individual Cars			UNIT TRAIN DATA		
TEST #	MODE #	CARS	0.00% To 0.20%	0.21% To 0.50%	0.51% To 1.00%	Test Train Weight	Test Train Weight Deviation	Percent Deviation Test Train
1	1	100	84	11	5	13,703,000	-4,300	.031
	2	100	80	15	5	13,703,000	+7,600	.055
2	1	100	88	12		15,445,400	-1,360	.008
3	1	100	76	24		10,952,800	-5,590	.051
	2	100	71	29		10,952,800	-6,000	.054
4	1	100	92	8		19,617,000	+13,200	.067
5	1	100	94	6		19,511,800	+1,110	.005
6	1	100	77	20	3	11,797,400	-1,260	.010
7	1	100	90	10		20,252,000	-5,200	.025
8	1	100	81	18	1	12,785,800	+3,190	.024
	2	100	73	24	3	12,785,800	+3,590	.028
	3	100	82	18		12,710,900	+3,050	.023
9	1	100	79	21		18,944,100	+ 580	.003
10*	1	99	80	16	4	12,852,000	+ 1,800	.014
11	1	100	77	22	1	12,928,800	-1,100	.008
	2	100	71	28	1	12,928,800	+400	.003
	3	100	65	35		12,928,800	+ 20,900	.161
	4	100	82	18		12,928,800	+1,200	.009
12	1	100	85	15		15,084,400	+2,030	.013
	2	100	83	15	2	15,084,400	-1,095	.007
13	1	100	80	20		18,557,800	- 11,130	.059
14	1	100	95	5		15,172,400	+4,020	.026
	2	100	86	14		15,172,400	- 190	.001
15	1	100	80	19	1	20,645,520	-9,700	.046
16	1	108	75	24	1	22,209,750	+4,150	.018
17	1	100	80	20		18,557,800	-5,760	.032
18	1	100	93	7		18,557,800	+8,130	.043
Test #17&18 were made on scales at different locations.								
						GROSS TOTAL	127,835	

*Missed 1 car

```
DIRECTION-  PW    CODE=  P(PULL),S(SHOVE)-N,E,S,W                              DATE  MAY 20, 1975      TEST NO. 1, MODE 1

    CAR NO. REF WGT      RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
===================================================================================================================================
 1  036618   218700.   218900.   218400.   218400.   218400.   218200.   218100.   218400.   218300.   218400.   218600.  2184100.
    ERROR                 200.     -300.     -300.     -300.     -500.     -600.     -300.     -400.     -300.     -100.    -2900.
    PER CENT            0.091    -0.137    -0.137    -0.137    -0.228    -0.274    -0.137    -0.182    -0.137    -0.045    -0.132
                                                                 *         *
 2  366468    64000.    63900.    63600.    63700.    63700.    63600.    63700.    63700.    63600.    63500.    63500.   636500.
    ERROR                -100.     -400.     -300.     -300.     -400.     -300.     -300.     -400.     -500.     -500.    -3500.
    PER CENT           -0.156    -0.625    -0.468    -0.468    -0.625    -0.468    -0.468    -0.625    -0.781    -0.781    -0.549
                                   *         *         *         *         *         *         *         *         *
 3  003046    58100.    58200.    58100.    58200.    58000.    58100.    58100.    58100.    58100.    58100.    58100.   581100.
    ERROR                 100.        0.      100.     -100.        0.        0.        0.        0.        0.        0.      100.
    PER CENT            0.172     0.000     0.172    -0.172     0.000     0.000     0.000     0.000     0.000     0.000     0.017

 4  010389   117080.   117400.   117200.   117200.   117100.   117100.   117100.   116900.   116900.   117000.   117000.  1170900.
    ERROR                 320.      120.      120.       20.       20.       20.     -180.     -180.      -80.      -80.      100.
    PER CENT            0.273     0.102     0.102     0.017     0.017     0.017    -0.153    -0.153    -0.068    -0.068     0.008
                         *
 5  010310   175920.   176000.   176100.   176000.   176000.   176000.   176100.   175800.   175700.   175800.   175700.  1759200.
    ERROR                  80.      180.       80.       80.       80.      180.     -120.     -220.     -120.     -220.        0.
    PER CENT            0.045     0.102     0.045     0.045     0.045     0.102    -0.068    -0.125    -0.068    -0.125     0.000

 6  010305   176100.   176200.   176100.   176000.   176000.   176100.   176000.   175900.   176000.   175900.   176000.  1760200.
    ERROR                 100.        0.     -100.     -100.        0.     -100.     -200.     -100.     -200.     -100.     -800.
    PER CENT            0.056     0.000    -0.056    -0.056     0.000    -0.056    -0.113    -0.056    -0.113    -0.056    -0.045

 7  010417   176040.   176300.   176300.   176500.   176400.   176300.   176400.   176300.   176200.   176300.   176300.  1763300.
    ERROR                 260.      260.      460.      360.      260.      360.      260.      160.      260.      260.     2900.
    PER CENT            0.147     0.147     0.261     0.204     0.147     0.204     0.147     0.090     0.147     0.147     0.164
                                             *         *                   *
 8  771818   100000.   100000.    99900.    99800.    99900.    99800.    99900.   100000.    99900.   100000.    99900.   999100.
    ERROR                   0.     -100.     -200.     -100.     -200.     -100.        0.     -100.        0.     -100.     -900.
    PER CENT            0.000    -0.100    -0.200    -0.100    -0.200    -0.100     0.000    -0.100     0.000    -0.100    -0.090

 9  010466   175680.   175900.   175800.   175800.   175600.   175700.   175600.   175600.   175400.   175700.   175700.  1756800.
    ERROR                 220.      120.      120.      -80.       20.      -80.      -80.     -280.       20.       20.        0.
    PER CENT            0.125     0.068     0.068    -0.045     0.011    -0.045    -0.045    -0.159     0.011     0.011     0.000

10  010479   108680.   108900.   108800.   108700.   108700.   108800.   108800.   108700.   108600.   108700.   108800.  1087500.
    ERROR                 220.      120.       20.       20.      120.      120.       20.      -80.       20.      120.      700.
    PER CENT            0.202     0.110     0.018     0.018     0.110     0.110     0.018    -0.073     0.018     0.110     0.064
                         *
TOT WGT     1370300.  1371700.  1370300.  1370300.  1369800.  1369700.  1369800.  1369400.  1368700.  1369400.  1369600.
ALG ERR                  1400.        0.        0.     -500.     -600.     -500.     -900.    -1600.     -900.     -700.
PER CNT                 0.102     0.000     0.000    -0.036    -0.043    -0.036    -0.065    -0.116    -0.065    -0.051

          TOT REF WGT   13703000.               DEVIATION IN --- 100  WGTS    PCNT          ALLOW  ACTUAL  PCNT OF TOT WGTS
          TOT MOT WGT   13698700.                                             OVER 0.200     30     16           16.0
          TOT ERR          -4300.                                             OVER 0.500      5      5            5.0
          PCNT             -0.031                                             OVER 1.000   NONE      0            0.0
          MAX ALLOW         0.200               GROSS ERR      16300.
```

```
DIRECTION-  SE     CODE=  P(PULL),S(SHOVE)-N,E,S,W                                DATE   MAY 20, 1975    TEST NO. 1, MODE 2

    CAR NO. REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=================================================================================================================================
 1  036618  218700.   218900.   219000.   219000.   218900.   218900.   218800.   218800.   218800.   218900.   218800.  2188800.
    ERROR                200.      300.      300.      200.      200.      100.      100.      100.      200.      100.     1800.
    PER CENT            0.091     0.137     0.137     0.091     0.091     0.045     0.045     0.045     0.091     0.045     0.082

 2  366468   64000.    63900.    63900.    64000.    64100.    64000.    64000.    64100.    64100.    64000.    64100.   640200.
    ERROR               -100.     -100.        0.      100.        0.        0.      100.      100.        0.      100.      200.
    PER CENT           -0.156    -0.156     0.000     0.156     0.000     0.000     0.156     0.156     0.000     0.156     0.031

 3  003046   58100.    58000.    58000.    57900.    57900.    57900.    57900.    57900.    57800.    57900.    57800.   579000.
    ERROR               -100.     -100.     -200.     -200.     -200.     -200.     -200.     -300.     -200.     -300.    -2000.
    PER CENT           -0.172    -0.172    -0.344    -0.344    -0.344    -0.344    -0.344    -0.516    -0.344    -0.516    -0.345
                                              *         *         *         *         *         *         *         *
 4  010389  117080.   117600.   117700.   117700.   117800.   117500.   117600.   117600.   117500.   117400.   117300.  1175700.
    ERROR                520.      620.      620.      720.      420.      520.      520.      420.      320.      220.     4900.
    PER CENT            0.444     0.529     0.529     0.614     0.358     0.444     0.444     0.358     0.273     0.187     0.416
                          *         *         *         *         *         *         *         *         *
 5  010310  175920.   176000.   175700.   175900.   175800.   175900.   175800.   175900.   175600.   175900.   175800.  1758300.
    ERROR                 80.     -220.      -20.     -120.      -20.     -120.      -20.     -320.      -20.     -120.     -900.
    PER CENT            0.045    -0.125    -0.011    -0.068    -0.011    -0.068    -0.011    -0.181    -0.011    -0.068    -0.051

 6  010305  176100.   175900.   176200.   176200.   176100.   176200.   176200.   176200.   176100.   176400.   176200.  1761700.
    ERROR               -200.      100.      100.        0.      100.      100.      100.        0.      300.      100.      700.
    PER CENT           -0.113     0.056     0.056     0.000     0.056     0.056     0.056     0.000     0.170     0.056     0.039

 7  010417  176040.   176200.   176200.   176200.   176200.   176200.   176000.   176200.   176100.   176400.   176400.  1762100.
    ERROR                160.      160.      160.      160.      160.      -40.      160.       60.      360.      360.     1700.
    PER CENT            0.090     0.090     0.090     0.090     0.090    -0.022     0.090     0.034     0.204     0.204     0.096
                                                                                                      *         *
 8  771818  100000.   100100.   100200.   100100.   100100.   100000.   100100.   100100.   100200.   100000.   100000.  1000900.
    ERROR                100.      200.      100.      100.        0.      100.      100.      200.        0.        0.      900.
    PER CENT            0.100     0.200     0.100     0.100     0.000     0.100     0.100     0.200     0.000     0.000     0.089

 9  010466  175680.   175700.   175600.   175600.   175700.   175700.   175700.   175600.   175500.   175600.   175700.  1756400.
    ERROR                 20.      -80.      -80.       20.       20.       20.      -80.     -180.      -80.       20.     -400.
    PER CENT            0.011    -0.045    -0.045     0.011     0.011     0.011    -0.045    -0.102    -0.045     0.011    -0.022

10  010479  108680.   108900.   108700.   108700.   108600.   108800.   108700.   108700.   108800.   108800.   108800.  1087500.
    ERROR                220.       20.       20.      -80.      120.       20.       20.      120.      120.      120.      700.
    PER CENT            0.202     0.018     0.018    -0.073     0.110     0.018     0.018     0.110     0.110     0.110     0.064
                          *
TOT WGT    1370300.  1371200.  1371200.  1371300.  1371200.  1371100.  1370800.  1371100.  1370500.  1371300.  1370900.
ALG ERR                  900.      900.     1000.      900.      800.      500.      800.      200.     1000.      600.
PER CNT                 0.065     0.065     0.072     0.065     0.058     0.036     0.058     0.014     0.072     0.043

          TOT REF WGT  13703000.             DEVIATION IN --- 100   WGTS   PCNT         ALLOW   ACTUAL   PCNT OF TOT WGTS
          TOT MOT WGT  13710600.                                           OVER 0.200     30      20             20.0
          TOT ERR          7600.                                           OVER 0.500      5       5              5.0
          PCNT             0.055                                           OVER 1.000   NONE       0              0.0
          MAX ALLOW        0.200             GROSS ERR     15600.
```

```
DIRECTION-     CODE=  P(PULL),S(SHOVE)-N,E,S,W                             DATE  MAY 20, 1975    TEST NO. 2

   CAR NO. REF WGT      RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=================================================================================================================================
 1 000101    41480.    41360.    41490.    41450.    41440.    41410.    41520.    41450.    41480.    41520.    41470.   414590.
   ERROR                -120.       10.      -30.      -40.      -70.       40.      -30.        0.       40.      -10.     -210.
   PER CENT            -0.289     0.024    -0.072    -0.096    -0.168     0.096    -0.072     0.000     0.096    -0.024    -0.050
                        *
 2 000102   106220.   106260.   106290.   106340.   106280.   106270.   106300.   106270.   106450.   106420.   106350.  1063230.
   ERROR                  40.       70.      120.       60.       50.       80.       50.      230.      200.      130.     1030.
   PER CENT             0.037     0.065     0.112     0.056     0.047     0.075     0.047     0.216     0.188     0.122     0.096
                                                                                              *
 3 000103   176260.   176440.   176430.   176370.   176400.   176330.   176360.   176380.   176440.   176510.   176430.  1764090.
   ERROR                 180.      170.      110.      140.       70.      100.      120.      180.      250.      170.     1490.
   PER CENT             0.102     0.096     0.062     0.079     0.039     0.056     0.068     0.102     0.141     0.096     0.084

 4 030581   251640.   251940.   252000.   251740.   251930.   251750.   251790.   251630.   251550.   251350.   251760.  2517440.
   ERROR                 300.      360.      100.      290.      110.      150.      -10.      -90.     -290.      120.     1040.
   PER CENT             0.119     0.143     0.039     0.115     0.043     0.059    -0.003    -0.035    -0.115     0.047     0.041

 5 030541   252540.   251970.   252060.   252010.   252110.   251620.   251630.   252130.   251690.   251670.   251990.  2518880.
   ERROR                -570.     -480.     -530.     -430.     -920.     -910.     -410.     -850.     -870.     -550.    -6520.
   PER CENT            -0.225    -0.190    -0.209    -0.170    -0.364    -0.360    -0.162    -0.336    -0.344    -0.217    -0.258
                        *                   *                   *         *                   *         *         *
 6 008499   136870.   136880.   136770.   136840.   136850.   136940.   136810.   137010.   136830.   136920.   136830.  1368680.
   ERROR                  10.     -100.      -30.      -20.       70.      -60.      140.      -40.       50.      -40.      -20.
   PER CENT             0.007    -0.073    -0.021    -0.014     0.051    -0.043     0.102    -0.029     0.036    -0.029    -0.001

 7 023645   138110.   137890.   138120.   138020.   137940.   137880.   138000.   138110.   138010.   138040.   138190.  1380200.
   ERROR                -220.       10.      -90.     -170.     -230.     -110.        0.     -100.      -70.       80.     -900.
   PER CENT            -0.159     0.007    -0.065    -0.123    -0.166    -0.079     0.000    -0.072    -0.050     0.057    -0.065

 8 006372   139610.   139540.   139340.   139520.   139540.   139370.   139500.   139380.   139390.   139480.   139570.  1394630.
   ERROR                 -70.     -270.      -90.      -70.     -240.     -110.     -230.     -220.     -130.      -40.    -1470.
   PER CENT            -0.050    -0.193    -0.064    -0.050    -0.171    -0.078    -0.164    -0.157    -0.093    -0.028    -0.105

 9 054326   134310.   134480.   134480.   134430.   134340.   134380.   134430.   134440.   134430.   134320.   134440.  1344170.
   ERROR                 170.      170.      120.       30.       70.      120.      130.      120.       10.      130.     1070.
   PER CENT             0.126     0.126     0.089     0.022     0.052     0.089     0.096     0.089     0.007     0.096     0.079

10 142268   167500.   167670.   167790.   167750.   167800.   167740.   167830.   167920.   167910.   167890.   167830.  1678130.
   ERROR                 170.      290.      250.      300.      240.      330.      420.      410.      390.      330.     3130.
   PER CENT             0.101     0.173     0.149     0.179     0.143     0.197     0.250     0.244     0.232     0.197     0.186
                                                                                    *         *         *
TOT WGT    1544540.  1544430.  1544770.  1544470.  1544630.  1543690.  1544170.  1544720.  1544180.  1544120.  1544860.
ALG ERR                 -110.      230.      -70.       90.     -850.     -370.      180.     -360.     -420.      320.
PER CNT                -0.007     0.014    -0.004     0.005    -0.055    -0.023     0.011    -0.023    -0.027     0.020

      TOT REF WGT   15445400.        DEVIATION IN --- 100  WGTS   PCNT        ALLOW  ACTUAL   PCNT OF TOT WGTS
      TOT MOT WGT   15444040.                                     OVER 0.200   30     12            12.0
      TOT ERR          -1360.                                     OVER 0.500    5      0             0.0
      PCNT             -0.008                                     OVER 1.000 NONE      0             0.0
      MAX ALLOW         0.200        GROSS ERR     18560.
```

```
DIRECTION-  PE    CODE=  P(PULL),S(SHOVE)-N,E,S,W                                   DATE  MAY 20, 1975    TEST NO. 3, MODE 1

    CAR NO. REF WGT      RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10        TOT
===================================================================================================================================
 1 090027  113980.     113890.   113880.   114070.   114070.   114040.   114130.   113940.   113910.   114040.   114070.   1140040.
    ERROR                 -90.     -100.       90.       90.       60.      150.      -40.      -70.       60.       90.       240.
    PER CENT            -0.078    -0.087     0.078     0.078     0.052     0.131    -0.035    -0.061     0.052     0.078      0.021

 2 292129  127980.     128010.   128190.   128050.   128230.   128170.   128130.   128130.   127920.   128080.   128190.   1281100.
    ERROR                  30.      210.       70.      250.      190.      150.      150.      -60.      100.      210.      1300.
    PER CENT             0.023     0.164     0.054     0.195     0.148     0.117     0.117    -0.046     0.078     0.164      0.101

 3 006671  128200.     127890.   128130.   127820.   128080.   127830.   127880.   128010.   127970.   128150.   128330.   1280090.
    ERROR                -310.      -70.     -380.     -120.     -370.     -320.     -190.     -230.      -50.      130.     -1910.
    PER CENT            -0.241    -0.054    -0.296    -0.093    -0.288    -0.249    -0.148    -0.179    -0.039     0.101     -0.149
                         *                   *                   *         *
 4 091100  107020.     106860.   106970.   106860.   107010.   106940.   107080.   106960.   106960.   106980.   107180.   1069800.
    ERROR                -160.      -50.     -160.      -10.      -80.       60.      -60.      -60.      -40.      160.      -400.
    PER CENT            -0.149    -0.046    -0.149    -0.009    -0.074     0.056    -0.056    -0.056    -0.037     0.149     -0.037

 5 065338   74160.      74160.    74170.    74280.    74230.    74170.    74120.    74210.    74290.    74210.    74310.    742150.
    ERROR                   0.       10.      120.       70.       10.      -40.       50.      130.       50.      150.       550.
    PER CENT             0.000     0.013     0.161     0.094     0.013    -0.053     0.067     0.175     0.067     0.202      0.074
                                                                                                                 *
 6 130059  119380.     119090.   119140.   118980.   119130.   119130.   119140.   119260.   119350.   119490.   119420.   1192130.
    ERROR                -290.     -240.     -400.     -250.     -250.     -240.     -120.      -30.      110.       40.     -1670.
    PER CENT            -0.242    -0.201    -0.335    -0.209    -0.209    -0.201    -0.100    -0.025     0.092     0.033     -0.140
                         *         *         *         *         *         *
 7 006919  125000.     124650.   124890.   124700.   124840.   124640.   124760.   124730.   124870.   125040.   125040.   1248160.
    ERROR                -350.     -110.     -300.     -160.     -360.     -240.     -270.     -130.       40.       40.     -1840.
    PER CENT            -0.280    -0.088    -0.240    -0.128    -0.288    -0.192    -0.216    -0.104     0.032     0.032     -0.147
                         *                   *                   *                   *
 8 063006   60420.      60190.    60470.    60360.    60450.    60300.    60380.    60290.    60390.    60500.    60520.    603850.
    ERROR                -230.       50.      -60.       30.     -120.      -40.     -130.      -30.       80.      100.      -350.
    PER CENT            -0.380     0.082    -0.099     0.049    -0.198    -0.066    -0.215    -0.049     0.132     0.165     -0.057
                         *                                                           *
 9 006916  139140.     138860.   139100.   138830.   138820.   138770.   138880.   138810.   138990.   139090.   139190.   1389340.
    ERROR                -280.      -40.     -310.     -320.     -370.     -260.     -330.     -150.      -50.       50.     -2060.
    PER CENT            -0.201    -0.028    -0.222    -0.229    -0.265    -0.186    -0.237    -0.107    -0.035     0.035     -0.148
                         *                   *         *         *                   *
10 771818  100000.      99810.   100040.   100050.   100030.    99840.    99960.    99910.   100120.   100380.   100410.   1000550.
    ERROR                -190.       40.       50.       30.     -160.      -40.      -90.      120.      380.      410.       550.
    PER CENT            -0.190     0.040     0.050     0.030    -0.160    -0.040    -0.090     0.120     0.380     0.410      0.054
                                                                                                       *         *
TOT WGT   1095280.    1093410.  1094980.  1094000.  1094890.  1093830.  1094460.  1094250.  1094770.  1095960.  1096660.
ALG ERR                 -1870.     -300.    -1280.     -390.    -1450.     -820.    -1030.     -510.      680.     1380.
PER CNT                 -0.170    -0.027    -0.116    -0.035    -0.132    -0.074    -0.094    -0.046     0.062     0.125

          TOT REF WGT   10952800.               DEVIATION IN --- 100  WGTS   PCNT        ALLOW  ACTUAL   PCNT OF TOT WGTS
          TOT MOT WGT   10947210.                                            OVER 0.200   30      24            24.0
          TOT ERR          -5590.                                            OVER 0.500    5       0             0.0
          PCNT             -0.051                                            OVER 1.000 NONE       0             0.0
          MAX ALLOW         0.200               GROSS ERR     14410.
```

```
DIRECTION-  SW    CODE=  P(PULL),S(SHOVE)-N,E,S,W                  DATE  MAY 20, 1975   TEST NO. 3, MODE 2

    CAR NO. REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=================================================================================================================================
 1  090027  113980.   113970.   113760.   114090.   114140.   114230.   114250.   113890.   113520.   114020.   113960.  1139740.
    ERROR                -10.     -220.       20.      160.      250.      270.      -90.     -460.       40.      -20.      -60.
    PER CENT          -0.008    -0.193     0.017     0.140     0.219     0.236    -0.078    -0.403     0.035    -0.017    -0.005
                                                                *         *                   *
 2  292129  127980.   128220.   128210.   128390.   128280.   128510.   128250.   128270.   128060.   128230.   128080.  1282500.
    ERROR                240.      230.      410.      300.      530.      270.      290.       80.      250.      100.     2700.
    PER CENT           0.187     0.179     0.320     0.234     0.414     0.210     0.226     0.062     0.195     0.078     0.210
                                            *         *         *         *         *
 3  006671  128200.   128010.   127900.   127910.   127980.   128040.   127980.   127930.   127970.   128000.   127600.  1279320.
    ERROR               -190.     -300.     -290.     -220.     -160.     -220.     -270.     -230.     -200.     -600.    -2680.
    PER CENT          -0.148    -0.234    -0.226    -0.171    -0.124    -0.171    -0.210    -0.179    -0.156    -0.468    -0.209
                                  *         *                                       *                             *
 4  091100  107020.   107290.   106670.   106850.   107140.   107160.   106850.   107070.   106600.   106690.   106790.  1069110.
    ERROR                270.     -350.     -170.      120.      140.     -170.       50.     -420.     -330.     -230.    -1090.
    PER CENT           0.252    -0.327    -0.158     0.112     0.130    -0.158     0.046    -0.392    -0.308    -0.214    -0.101
                        *         *                                                           *         *         *
 5  065338   74160.    74200.    74110.    74200.    74320.    74260.    74170.    74200.    73990.    74080.    73990.   741520.
    ERROR                 40.      -50.       40.      160.      100.       10.       40.     -170.      -80.     -170.      -80.
    PER CENT           0.053    -0.067     0.053     0.215     0.134     0.013     0.053    -0.229    -0.107    -0.229    -0.010
                                                      *                                       *                   *
 6  130059  119380.   119210.   119090.   119210.   119380.   119580.   119510.   119430.   119280.   119450.   119380.  1193520.
    ERROR               -170.     -290.     -170.        0.      200.      130.       50.     -100.       70.        0.     -260.
    PER CENT          -0.142    -0.242    -0.142     0.000     0.167     0.108     0.041    -0.083     0.058     0.000    -0.023
                                  *
 7  006919  125000.   124770.   124710.   124950.   124880.   124810.   124800.   124590.   124790.   124730.   124740.  1247770.
    ERROR               -230.     -290.      -50.     -120.     -190.     -200.     -410.     -210.     -270.     -260.    -2230.
    PER CENT          -0.184    -0.232    -0.040    -0.096    -0.152    -0.160    -0.328    -0.168    -0.216    -0.208    -0.178
                                  *                                                 *                   *         *
 8  063006   60420.    60410.    60440.    60480.    60420.    60340.    60460.    60230.    60380.    60260.    60280.   603700.
    ERROR                -10.       20.       60.        0.      -80.       40.     -190.      -40.     -160.     -140.     -500.
    PER CENT          -0.016     0.033     0.099     0.000    -0.132     0.066    -0.314    -0.066    -0.264    -0.231    -0.082
                                                                                    *                   *         *
 9  006916  139140.   139100.   139000.   138890.   139050.   139110.   139030.   138930.   138960.   138970.   138950.  1389990.
    ERROR                -40.     -140.     -250.      -90.      -30.     -110.     -210.     -180.     -170.     -190.    -1410.
    PER CENT          -0.028    -0.100    -0.179    -0.064    -0.021    -0.079    -0.150    -0.129    -0.122    -0.136    -0.101

10  771818  100000.   100090.    99870.    99870.    99960.   100020.   100070.    99980.    99720.   100030.   100020.   999630.
    ERROR                 90.     -130.     -130.      -40.       20.       70.      -20.     -280.       30.       20.     -370.
    PER CENT           0.090    -0.130    -0.130    -0.040     0.020     0.070    -0.020    -0.280     0.030     0.020    -0.037
                                                                                              *
TOT WGT    1095280.  1095270.  1093760.  1094750.  1095550.  1096060.  1095370.  1094520.  1093270.  1094460.  1093790.
ALG ERR                  -10.    -1520.     -530.      270.      780.       90.     -760.    -2010.     -820.    -1490.
PER CNT               -0.000    -0.138    -0.048     0.024     0.071     0.008    -0.069    -0.183    -0.074    -0.136

         TOT REF WGT   10952800.           DEVIATION IN --- 100  WGTS   PCNT          ALLOW  ACTUAL  PCNT OF TOT WGTS
         TOT MOT WGT   10946800.                                        OVER 0.200     30     29              29.0
         TOT ERR          -6000.                                        OVER 0.500      5      0               0.0
         PCNT             -0.054                                        OVER 1.000   NONE      0               0.0
         MAX ALLOW         0.200           GROSS ERR     16420.
```

```
DIRECTION-        CODE=  P(PULL),S(SHOVE)-N,E,S,W                                       DATE   MAY 20, 1975    TEST NO. 4

    CAR NO. REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=================================================================================================================================
 1  234793  153800.  153900.   154000.   153700.   153600.   153900.   154100.   153800.   153700.   154100.   153900.  1538700.
    ERROR               100.      200.     -100.     -200.      100.      300.        0.     -100.      300.      100.      700.
    PER CENT           0.065     0.130    -0.065    -0.130     0.065     0.195     0.000    -0.065     0.195     0.065     0.045

 2  078931  242400.  242800.   242600.   242600.   242600.   242600.   242900.   242800.   242700.   242600.   242700.  2426900.
    ERROR               400.      200.      200.      200.      200.      500.      400.      300.      200.      300.     2900.
    PER CENT           0.165     0.082     0.082     0.082     0.082     0.206     0.165     0.123     0.082     0.123     0.119
                                                                            *
 3  071192  186200.  185700.   186100.   186200.   186200.   186100.   186100.   185900.   186200.   186000.   185900.  1860400.
    ERROR              -500.     -100.        0.        0.     -100.     -100.     -300.        0.     -200.     -300.    -1600.
    PER CENT          -0.268    -0.053     0.000     0.000    -0.053    -0.053    -0.161     0.000    -0.107    -0.161    -0.086
                        *
 4  347827  154300.  155000.   154500.   154200.   154800.   154600.   154800.   154200.   154000.   154300.   154100.  1544500.
    ERROR               700.      200.     -100.      500.      300.      500.     -100.     -300.        0.     -200.     1500.
    PER CENT           0.453     0.129    -0.064     0.324     0.194     0.324    -0.064    -0.194     0.000    -0.129     0.097
                        *                           *                   *
 5  005814  151900.  152000.   152000.   151800.   151800.   152000.   151900.   152000.   151800.   151800.   151800.  1518900.
    ERROR               100.      100.     -100.     -100.      100.        0.      100.     -100.     -100.     -100.     -100.
    PER CENT           0.065     0.065    -0.065    -0.065     0.065     0.000     0.065    -0.065    -0.065    -0.065    -0.006

 6  152484  202200.  202400.   202400.   202500.   202400.   202300.   202300.   202400.   202500.   202500.   202300.  2024000.
    ERROR               200.      200.      300.      200.      100.      100.      200.      300.      300.      100.     2000.
    PER CENT           0.098     0.098     0.148     0.098     0.049     0.049     0.098     0.148     0.148     0.049     0.098

 7  061809  242600.  242900.   243000.   242900.   242800.   242800.   242800.   242900.   242800.   242800.   242800.  2428500.
    ERROR               300.      400.      300.      200.      200.      200.      300.      200.      200.      200.     2500.
    PER CENT           0.123     0.164     0.123     0.082     0.082     0.082     0.123     0.082     0.082     0.082     0.102

 8  068472  240800.  241200.   241300.   241000.   241000.   241100.   241100.   241100.   240900.   241100.   241100.  2410900.
    ERROR               400.      500.      200.      200.      300.      300.      300.      100.      300.      300.     2900.
    PER CENT           0.166     0.207     0.083     0.083     0.124     0.124     0.124     0.041     0.124     0.124     0.120
                                  *
 9  151655  189900.  190200.   190200.   190200.   190300.   190100.   190200.   190100.   190200.   190100.   190200.  1901800.
    ERROR               300.      300.      300.      400.      200.      300.      200.      300.      200.      300.     2800.
    PER CENT           0.157     0.157     0.157     0.210     0.105     0.157     0.105     0.157     0.105     0.157     0.147
                                                    *
10  144901  197600.  197400.   196900.   197700.   197900.   197700.   197500.   197600.   197500.   197800.   197600.  1975600.
    ERROR              -200.     -700.      100.      300.      100.     -100.        0.     -100.      200.        0.     -400.
    PER CENT          -0.101    -0.354     0.050     0.151     0.050    -0.050     0.000    -0.050     0.101     0.000    -0.020
                                  *
TOT WGT     1961700. 1963500.  1963000.  1962800.  1963400.  1963200.  1963700.  1962800.  1962300.  1963100.  1962400.
ALG ERR                1800.     1300.     1100.     1700.     1500.     2000.     1100.      600.     1400.      700.
PER CNT               0.091     0.066     0.056     0.086     0.076     0.101     0.056     0.030     0.071     0.035

          TOT REF WGT    19617000.              DEVIATION IN --- 100   WGTS    PCNT        ALLOW   ACTUAL   PCNT OF TOT WGTS
          TOT MOT WGT    19630200.                                             OVER 0.200    30       8               8.0
          TOT ERR           13200.                                             OVER 0.500     5       0               0.0
          PCNT              0.067                                              OVER 1.000  NONE       0               0.0
          MAX ALLOW         0.200               GROSS ERR     21800.
```

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DIRECTION-        CODE=  P(PULL),S(SHOVE)-N,E,S,W                                    DATE  MAY 20, 1975     TEST NO. 5

    CAR NO. REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=================================================================================================================================
 1  276869  211870.   211840.   211800.   211660.   211670.   211690.   211610.   211660.   211840.   211740.   211720.  2117230.
    ERROR                -30.      -70.     -210.     -200.     -180.     -260.     -210.      -30.     -130.     -150.    -1470.
    PER CENT           -0.014    -0.033    -0.099    -0.094    -0.084    -0.122    -0.099    -0.014    -0.061    -0.070    -0.069

 2  828457  172800.   172920.   172720.   173140.   172620.   172740.   172940.   172740.   172660.   172670.   172840.  1727990.
    ERROR                120.      -80.      340.     -180.      -60.      140.      -60.     -140.     -130.       40.      -10.
    PER CENT            0.069    -0.046     0.196    -0.104    -0.034     0.081    -0.034    -0.081    -0.075     0.023    -0.000

 3  830785  177350.   177520.   177300.   177420.   177290.   177280.   177230.   177480.   177620.   177210.   177440.  1773790.
    ERROR                170.      -50.       70.      -60.      -70.     -120.      130.      270.     -140.       90.      290.
    PER CENT            0.095    -0.028     0.039    -0.033    -0.039    -0.067     0.073     0.152    -0.078     0.050     0.016

 4  279430  216300.   216130.   216500.   216060.   216190.   216330.   216420.   216370.   216220.   216440.   216000.  2162660.
    ERROR               -170.      200.     -240.     -110.       30.      120.       70.      -80.      140.     -300.     -340.
    PER CENT           -0.078     0.092    -0.110    -0.050     0.013     0.055     0.032    -0.036     0.064    -0.138    -0.015

 5  900119  214020.   214030.   213940.   214010.   214050.   214170.   214230.   213970.   214030.   214070.   214370.  2140870.
    ERROR                 10.      -80.      -10.       30.      150.      210.      -50.       10.       50.      350.      670.
    PER CENT            0.004    -0.037    -0.004     0.014     0.070     0.098    -0.023     0.004     0.023     0.163     0.031

 6  832061  182230.   182170.   182480.   182020.   182490.   182230.   182310.   182300.   182160.   182050.   182140.  1822350.
    ERROR                -60.      250.     -210.      260.        0.       80.       70.      -70.     -180.      -90.       50.
    PER CENT           -0.032     0.137    -0.115     0.142     0.000     0.043     0.038    -0.038    -0.098    -0.049     0.002

 7  459800  217080.   217250.   217570.   217610.   217520.   217470.   217420.   217470.   217220.   217310.   217320.  2174160.
    ERROR                170.      490.      530.      440.      390.      340.      390.      140.      230.      240.     3360.
    PER CENT            0.078     0.225     0.244     0.202     0.179     0.156     0.179     0.064     0.105     0.110     0.154
                                   *         *         *
 8  900596  214740.   214570.   214620.   214520.   214600.   214680.   214600.   214370.   214650.   214570.   214650.  2145830.
    ERROR               -170.     -120.     -220.     -140.      -60.     -140.     -370.      -90.     -170.      -90.    -1570.
    PER CENT           -0.079    -0.055    -0.102    -0.065    -0.027    -0.065    -0.172    -0.041    -0.079    -0.041    -0.073

 9  000516  176590.   176420.   176220.   176550.   176260.   176400.   176390.   176440.   176530.   176290.   176410.  1763910.
    ERROR               -170.     -370.      -40.     -330.     -190.     -200.     -150.      -60.     -300.     -180.    -1990.
    PER CENT           -0.096    -0.209    -0.022    -0.186    -0.107    -0.113    -0.084    -0.033    -0.169    -0.101    -0.112
                                   *
10  000171  168200.   168430.   168740.   168350.   168480.   168310.   168580.   168450.   168260.   168180.   168340.  1684120.
    ERROR                230.      540.      150.      280.      110.      380.      250.       60.      -20.      140.     2120.
    PER CENT            0.136     0.321     0.069     0.166     0.065     0.225     0.148     0.035    -0.011     0.083     0.125
                                   *                                       *
TOT WGT    1951180.  1951280.  1951890.  1951340.  1951170.  1951300.  1951730.  1951250.  1951190.  1950530.  1951230.
ALG ERR                  100.      710.      160.      -10.      120.      550.       70.       10.     -650.       50.
PER CNT                 0.005     0.036     0.008    -0.000     0.006     0.028     0.003     0.000    -0.033     0.002

       TOT REF WGT   19511800.           DEVIATION IN --- 100  WGTS   PCNT          ALLOW  ACTUAL  PCNT OF TOT WGTS
       TOT MOT WGT   19512910.                                        OVER 0.200       30       6             6.0
       TOT ERR           1110.                                        OVER 0.500        5       0             0.0
       PCNT              0.005                                        OVER 1.000     NONE       0             0.0
       MAX ALLOW         0.200           GROSS ERR      16690.
```

```
DIRECTION-  SS    CODE=  P(PULL),S(SHOVE)-N,E,S,W                                DATE  MAY 20, 1975      TEST NO. 6

    CAR NO.  REF WGT      RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
===================================================================================================================================
  1 771817  100000.      99980.   100120.   100160.   100060.   100060.   100120.   100120.   100040.    99960.   100100.  1000720.
    ERROR                  -20.      120.      160.       60.       60.      120.      120.       40.      -40.      100.      720.
    PER CENT            -0.020     0.120     0.160     0.060     0.060     0.120     0.120     0.040    -0.040     0.100     0.071

  2 023614  201880.     201720.   201640.   201700.   201700.   201640.   201760.   201380.   201500.   201500.   201600.  2016140.
    ERROR                 -160.     -240.     -180.     -180.     -240.     -120.     -500.     -380.     -380.     -280.    -2660.
    PER CENT            -0.079    -0.118    -0.089    -0.089    -0.118    -0.059    -0.247    -0.188    -0.188    -0.138    -0.131
                                                                                      *
  3 001605  110880.     110860.   111100.   111180.   111100.   110920.   111060.   111020.   110840.   110980.   111380.  1110440.
    ERROR                  -20.      220.      300.      220.       40.      180.      140.      -40.      100.      500.     1640.
    PER CENT            -0.018     0.198     0.270     0.198     0.036     0.162     0.126    -0.036     0.090     0.450     0.147
                                              *                                                                     *
  4 001627  114560.     114480.   114700.   114520.   114720.   114620.   114420.   114500.   114480.   114440.   114560.  1145440.
    ERROR                  -80.      140.      -40.      160.       60.     -140.      -60.      -80.     -120.        0.     -160.
    PER CENT            -0.069     0.122    -0.034     0.139     0.052    -0.122    -0.052    -0.069    -0.104     0.000    -0.013

  5 525612   66120.      66200.    66160.    66300.    66240.    66040.    66200.    66080.    65940.    66060.    66360.   661580.
    ERROR                   80.       40.      180.      120.      -80.       80.      -40.     -180.      -60.      240.      380.
    PER CENT             0.120     0.060     0.272     0.181    -0.120     0.120    -0.060    -0.272    -0.090     0.362     0.057
                                              *                                                 *                   *
  6 053124   93980.      94060.    93960.    93960.    94140.    94000.    93880.    93920.    93920.    93900.    93880.   939620.
    ERROR                   80.      -20.      -20.      160.       20.     -100.      -60.      -60.      -80.     -100.     -180.
    PER CENT             0.085    -0.021    -0.021     0.170     0.021    -0.106    -0.063    -0.063    -0.085    -0.106    -0.019

  7 525622   66260.      66180.    66540.    66500.    66440.    66380.    66380.    66540.    66560.    66500.    66400.   664420.
    ERROR                  -80.      280.      240.      180.      120.      120.      280.      300.      240.      140.     1820.
    PER CENT            -0.120     0.422     0.362     0.271     0.181     0.181     0.422     0.452     0.362     0.211     0.273
                                    *         *         *                             *         *         *         *
  8 052273   97480.      97320.    97340.    97380.    97380.    97180.    97400.    97240.    97280.    97660.    97160.   973340.
    ERROR                 -160.     -140.     -100.     -100.     -300.      -80.     -240.     -200.      180.     -320.    -1460.
    PER CENT            -0.164    -0.143    -0.102    -0.102    -0.307    -0.082    -0.246    -0.205     0.184    -0.328    -0.149
                                                                  *                   *         *                   *
  9 044711  234020.     234020.   233940.   234000.   233880.   234320.   234240.   234260.   234240.   233980.   234400.  2341280.
    ERROR                    0.      -80.      -20.     -140.      300.      220.      240.      220.      -40.      380.     1080.
    PER CENT             0.000    -0.034    -0.008    -0.059     0.128     0.094     0.102     0.094    -0.017     0.162     0.046

 10 053310   94560.      94360.    94520.    94760.    94500.    94100.    94400.    94500.    93920.    94020.    94080.   943160.
    ERROR                 -200.      -40.      200.      -60.     -460.     -160.      -60.     -640.     -540.     -480.    -2440.
    PER CENT            -0.211    -0.042     0.211    -0.063    -0.486    -0.169    -0.063    -0.676    -0.571    -0.507    -0.258
                          *                   *                   *                             *         *         *
TOT WGT     1179740.   1179180.  1180020.  1180460.  1180160.  1179260.  1179860.  1179560.  1178720.  1179000.  1179920.
ALG ERR                   -560.      280.      720.      420.     -480.      120.     -180.    -1020.     -740.      180.
PER CNT                 -0.047     0.023     0.061     0.035    -0.040     0.010    -0.015    -0.086    -0.062     0.015

          TOT REF WGT  11797400.            DEVIATION IN --- 100  WGTS  PCNT          ALLOW  ACTUAL  PCNT OF TOT WGTS
          TOT MOT WGT  11796140.                                        OVER 0.200     30     23          23.0
          TOT ERR         -1260.                                        OVER 0.500      5      3           3.0
          PCNT            -0.010                                        OVER 1.000   NONE      0           0.0
          MAX ALLOW        0.200            GROSS ERR     16220.
```

```
DIRECTION-        CODE=  P(PULL),S(SHOVE)-N,E,S,W                                          DATE  MAY 20, 1975     TEST NO. 7

    CAR NO. REF WGT       RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
===================================================================================================================================
  1  007544  184520.    184260.   184150.   184410.   184220.   184220.   183900.   184260.   184490.   184270.   184280.  1842460.
     ERROR                -260.     -370.     -110.     -300.     -300.     -620.     -260.      -30.     -250.     -240.    -2740.
     PER CENT            -0.140    -0.200    -0.059    -0.162    -0.162    -0.336    -0.140    -0.016    -0.135    -0.130    -0.148
                                     *                                       *
  2  007298  206140.    206010.   205970.   206080.   206260.   206280.   206430.   205970.   206020.   206240.   206130.  2061390.
     ERROR                -130.     -170.      -60.      120.      140.      290.     -170.     -120.      100.      -10.      -10.
     PER CENT            -0.063    -0.082    -0.029     0.058     0.067     0.140    -0.082    -0.058     0.048    -0.004    -0.000

  3  088161  219960.    220100.   219790.   219600.   219740.   220010.   219610.   219700.   219660.   219520.   219620.  2197350.
     ERROR                 140.     -170.     -360.     -220.       50.     -350.     -260.     -300.     -440.     -340.    -2250.
     PER CENT             0.063    -0.077    -0.163    -0.100     0.022    -0.159    -0.118    -0.136    -0.200    -0.154    -0.102

  4  089770  184160.    183960.   183920.   183700.   183640.   183830.   184060.   184400.   184000.   184060.   183850.  1839420.
     ERROR                -200.     -240.     -460.     -520.     -330.     -100.      240.     -160.     -100.     -310.    -2180.
     PER CENT            -0.108    -0.130    -0.249    -0.282    -0.179    -0.054     0.130    -0.086    -0.054    -0.168    -0.118
                                               *         *
  5  007900  184840.    184910.   185110.   184710.   184600.   184700.   184850.   185040.   185060.   184780.   184930.  1848690.
     ERROR                  70.      270.     -130.     -240.     -140.       10.      200.      220.      -60.       90.      290.
     PER CENT             0.037     0.146    -0.070    -0.129    -0.075     0.005     0.108     0.119    -0.032     0.048     0.015

  6  121912  230880.    230880.   230930.   230590.   230420.   230760.   231060.   230890.   231030.   230990.   231000.  2308550.
     ERROR                   0.       50.     -290.     -460.     -120.      180.       10.      150.      110.      120.     -250.
     PER CENT             0.000     0.021    -0.125    -0.199    -0.051     0.077     0.004     0.064     0.047     0.051    -0.010

  7  007241  196040.    196160.   195810.   195720.   195590.   195580.   195800.   195890.   195660.   195910.   195870.  1957990.
     ERROR                 120.     -230.     -320.     -450.     -460.     -240.     -150.     -380.     -130.     -170.    -2410.
     PER CENT             0.061    -0.117    -0.163    -0.229    -0.234    -0.122    -0.076    -0.193    -0.066    -0.086    -0.123
                                                         *         *
  8  087624  205840.    205860.   205960.   205830.   205570.   205990.   205950.   205740.   205650.   205630.   205740.  2057920.
     ERROR                  20.      120.      -10.     -270.      150.      110.     -100.     -190.     -210.     -100.     -480.
     PER CENT             0.009     0.058    -0.004    -0.131     0.072     0.053    -0.048    -0.092    -0.102    -0.048    -0.023

  9  032198  216480.    216880.   217140.   216760.   216600.   216890.   216870.   216550.   216910.   216860.   216920.  2168380.
     ERROR                 400.      660.      280.      120.      410.      390.       70.      430.      380.      440.     3580.
     PER CENT             0.184     0.304     0.129     0.055     0.189     0.180     0.032     0.198     0.175     0.203     0.165
                                     *                                                                               *
 10  032146  196340.    196830.   196820.   196470.   196460.   196280.   196300.   196060.   196430.   196400.   196600.  1964650.
     ERROR                 490.      480.      130.      120.      -60.      -40.     -280.       90.       60.      260.     1250.
     PER CENT             0.249     0.244     0.066     0.061    -0.030    -0.020    -0.142     0.045     0.030     0.132     0.063
                           *         *
TOT WGT     2025200.   2025850.  2025600.  2023870.  2023100.  2024540.  2024830.  2024500.  2024910.  2024660.  2024940.
ALG ERR                    650.      400.    -1330.    -2100.     -660.     -370.     -700.     -290.     -540.     -260.
PER CNT                   0.032     0.019    -0.065    -0.103    -0.032    -0.018    -0.034    -0.014    -0.026    -0.012

          TOT REF WGT   20252000.          DEVIATION IN --- 100   WGTS    PCNT          ALLOW  ACTUAL   PCNT OF TOT WGTS
          TOT MOT WGT   20246800.                                         OVER 0.200      30      10          10.0
          TOT ERR          -5200.                                         OVER 0.500       5       0           0.0
          PCNT            -0.025                                          OVER 1.000    NONE       0           0.0
          MAX ALLOW        0.200           GROSS ERR     21780.
```

```
DIRECTION-       CODE=  P(PULL),S(SHOVE)-N,E,S,W                                  DATE  MAY 20, 1975    TEST NO. 8, MODE 1

    CAR NO. REF WGT       RUN 1      RUN 2      RUN 3      RUN 4      RUN 5      RUN 6      RUN 7      RUN 8      RUN 9     RUN 10        TOT
=============================================================================================================================================
1   001305    63640.     63670.     63700.     63660.     63560.     63440.     63660.     63530.     63620.     63660.     63600.    636100.
    ERROR                   30.        60.        20.       -80.      -200.        20.      -110.       -20.        20.       -40.      -300.
    PER CENT              0.047      0.094      0.031     -0.125     -0.314      0.031     -0.172     -0.031      0.031     -0.062     -0.047
                                                                       *
2   012895    63840.     63850.     63860.     63730.     63800.     63720.     63860.     63720.     63790.     63860.     64000.    638190.
    ERROR                   10.        20.      -110.       -40.      -120.        20.      -120.       -50.        20.       160.      -210.
    PER CENT              0.015      0.031     -0.172     -0.062     -0.187      0.031     -0.187     -0.078      0.031      0.250     -0.032
                                                                                                                              *
3   004048   167040.    167220.    167180.    167180.    167070.    166980.    167240.    167240.    167150.    167190.    167180.   1671630.
    ERROR                  180.       140.       140.        30.       -60.       200.       200.       110.       150.       140.      1230.
    PER CENT              0.107      0.083      0.083      0.017     -0.035      0.119      0.119      0.065      0.089      0.083      0.073

4   002254   163680.    163600.    163440.    163230.    163400.    163420.    163480.    163300.    163440.    163290.    163380.   1633980.
    ERROR                  -80.      -240.      -450.      -280.      -260.      -200.      -380.      -240.      -390.      -300.     -2820.
    PER CENT             -0.048     -0.146     -0.274     -0.171     -0.158     -0.122     -0.232     -0.146     -0.238     -0.183     -0.172
                                                 *                                           *                     *
5   073866   122640.    122880.    122920.    122590.    122720.    122700.    122980.    122660.    122880.    122980.    122760.   1228070.
    ERROR                  240.       280.       -50.        80.        60.       340.        20.       240.       340.       120.      1670.
    PER CENT              0.195      0.228     -0.040      0.065      0.048      0.277      0.016      0.195      0.277      0.097      0.135
                                      *                                           *                                *
6   073866   176980.    176700.    176980.    176620.    176820.    177040.    177200.    176760.    177080.    177080.    176920.   1769200.
    ERROR                 -280.         0.      -360.      -160.        60.       220.      -220.       100.       100.       -60.      -600.
    PER CENT             -0.158      0.000     -0.203     -0.090      0.033      0.124     -0.124      0.056      0.056     -0.033     -0.033
                                                 *
7   144571   129120.    129500.    129300.    129060.    129280.    129380.    129470.    129280.    129320.    129440.    129320.   1293350.
    ERROR                  380.       180.       -60.       160.       260.       350.       160.       200.       320.       200.      2150.
    PER CENT              0.294      0.139     -0.046      0.123      0.201      0.271      0.123      0.154      0.247      0.154      0.166
                           *                                           *          *                                *
8   107871   126500.    127140.    126600.    126400.    126010.    126610.    126430.    126500.    126560.    126420.    126500.   1265170.
    ERROR                  640.       100.      -100.      -490.       110.       -70.         0.        60.       -80.         0.       170.
    PER CENT              0.505      0.079     -0.079     -0.387      0.086     -0.055      0.000      0.047     -0.063      0.000      0.013
                           *                                *
9   743380   139400.    139600.    139460.    139280.    139420.    139260.    139580.    139240.    139300.    139320.    139500.   1393960.
    ERROR                  200.        60.      -120.        20.      -140.       180.      -160.      -100.       -80.       100.       -40.
    PER CENT              0.143      0.043     -0.086      0.014     -0.100      0.129     -0.114     -0.071     -0.057      0.071     -0.002

10  075649   125740.    126010.    125970.    125720.    126000.    125900.    126100.    125960.    126020.    125880.    125780.   1259340.
    ERROR                  270.       230.       -20.       260.       160.       360.       220.       280.       140.        40.      1940.
    PER CENT              0.214      0.182     -0.015      0.206      0.127      0.286      0.174      0.222      0.111      0.031      0.154
                           *                                *                     *                     *
TOT WGT     1278580.   1280170.   1279410.   1277470.   1278080.   1278450.   1280000.   1278190.   1279160.   1279120.   1278940.
ALG ERR                   1590.       830.     -1110.      -500.      -130.      1420.      -390.       580.       540.       360.
PER CNT                   0.124      0.064     -0.086     -0.039     -0.010      0.111     -0.030      0.045      0.042      0.028

          TOT REF WGT    12785800.          DEVIATION IN --- 100  WGTS   PCNT          ALLOW  ACTUAL  PCNT OF TOT WGTS
          TOT MOT WGT    12788990.                                       OVER 0.200     30     19             19.0
          TOT ERR            3190.                                       OVER 0.500      5      1              1.0
          PCNT               0.024                                       OVER 1.000   NONE      0              0.0
          MAX ALLOW          0.200          GROSS ERR     15830.
```

```
DIRECTION-        CODE=  P(PULL),S(SHOVE)-N,E,S,W                          DATE  MAY 20, 1975    TEST NO. 8, MODE 2

    CAR NO. REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
==================================================================================================================================
1  001305     63640.    63770.    63750.    63800.    63760.    63820.    63740.    63700.    63720.    63600.    63690.   637350.
   ERROR                  130.      110.      160.      120.      180.      100.       60.       80.      -40.       50.      950.
   PER CENT              0.204     0.172     0.251     0.188     0.282     0.157     0.094     0.125    -0.062     0.078     0.149
                          *                   *                   *
2  012895     63840.    63800.    63840.    63930.    63920.    63920.    63930.    63860.    63800.    63780.    63880.   638660.
   ERROR                  -40.        0.       90.       80.       80.       90.       20.      -40.      -60.       40.      260.
   PER CENT             -0.062     0.000     0.140     0.125     0.125     0.140     0.031    -0.062    -0.093     0.062     0.040

3  004048    167040.   167060.   167100.   167130.   167200.   167140.   167100.   167040.   167160.   167110.   167180.  1671220.
   ERROR                   20.       60.       90.      160.      100.       60.        0.      120.       70.      140.      820.
   PER CENT              0.011     0.035     0.053     0.095     0.059     0.035     0.000     0.071     0.041     0.083     0.049

4  002254    163680.   163910.   163750.   163820.   163820.   164040.   163830.   163740.   163620.   163560.   163690.  1637780.
   ERROR                  230.       70.      140.      140.      360.      150.       60.      -60.     -120.       10.      980.
   PER CENT              0.140     0.042     0.085     0.085     0.219     0.091     0.036    -0.036    -0.073     0.006     0.059
                                                                  *
5  073866    122640.   122620.   123000.   122780.   122860.   122720.   122830.   122660.   122930.   122800.   122540.  1227740.
   ERROR                  -20.      360.      140.      220.       80.      190.       20.      290.      160.     -100.     1340.
   PER CENT             -0.016     0.293     0.114     0.179     0.065     0.154     0.016     0.236     0.130    -0.081     0.109
                                    *                                                           *
6  550465    176980.   176990.   176670.   176950.   176660.   176820.   176600.   176680.   176490.   176650.   176840.  1767350.
   ERROR                   10.     -310.      -30.     -320.     -160.     -380.     -300.     -490.     -330.     -140.    -2450.
   PER CENT              0.005    -0.175    -0.016    -0.180    -0.090    -0.214    -0.169    -0.276    -0.186    -0.079    -0.138
                                                                            *                   *
7  144571    129120.   129260.   129160.   128590.   129320.   129500.   129420.   129380.   129320.   129240.   129460.  1292650.
   ERROR                  140.       40.     -530.      200.      380.      300.      260.      200.      120.      340.     1450.
   PER CENT              0.108     0.030    -0.410     0.154     0.294     0.232     0.201     0.154     0.092     0.263     0.112
                                              *                   *         *         *                             *
8  107671    126500.   125770.   125980.   126800.   126240.   126480.   126550.   126210.   126400.   126290.   126670.  1263390.
   ERROR                 -730.     -520.      300.     -260.      -20.       50.     -290.     -100.     -210.      170.    -1610.
   PER CENT             -0.577    -0.411     0.237    -0.205    -0.015     0.039    -0.229    -0.079    -0.166     0.134    -0.127
                          *         *         *         *                             *
9  743380    139400.   139140.   139380.   139560.   139490.   139320.   139270.   139500.   139260.   139450.   139340.  1393710.
   ERROR                 -260.      -20.      160.       90.      -80.     -130.      100.     -140.       50.      -60.     -290.
   PER CENT             -0.186    -0.014     0.114     0.064    -0.057    -0.093     0.071    -0.100     0.035    -0.043    -0.020

10 075649    125740.   126720.   126140.   126500.   126000.   126100.   125370.   126170.   125400.   125300.   125840.  1259540.
   ERROR                  980.      400.      760.      260.      360.     -370.      430.     -340.     -440.      100.     2140.
   PER CENT              0.779     0.318     0.604     0.206     0.286    -0.294     0.341    -0.270    -0.349     0.079     0.169
                          *         *         *         *         *         *         *         *         *
TOT WGT     1278580.  1279040.  1278770.  1279860.  1279270.  1279860.  1278640.  1278940.  1278100.  1277780.  1279130.
ALG ERR                   460.      190.     1280.      690.     1280.       60.      360.     -480.     -800.      550.
PER CNT                  0.035     0.014     0.100     0.053     0.100     0.004     0.028    -0.037    -0.062     0.043

          TOT REF WGT  12785800.        DEVIATION IN --- 100  WGTS    PCNT         ALLOW  ACTUAL   PCNT OF TOT WGTS
          TOT MOT WGT  12789390.                                      OVER 0.200    30     27                27.0
          TOT ERR          3590.                                      OVER 0.500     5      3                 3.0
          PCNT             0.028                                      OVER 1.000  NONE      0                 0.0
          MAX ALLOW        0.200        GROSS ERR      18470.
```

```
DIRECTION-       CODE=  P(PULL),S(SHOVE)-N,E,S,W                              DATE  MAY 20, 1975   TEST NO. 8, MODE 3

   CAR NO.  REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=================================================================================================================================
 1 004048   166760.   166850.   166860.   166930.   166840.   166740.   166940.   167140.   166620.   166860.   166830.  1668610.
   ERROR                  90.      100.      170.       80.      -20.      180.      380.     -140.      100.       70.     1010.
   PER CENT             0.053     0.059     0.101     0.047    -0.011     0.107     0.227    -0.083     0.059     0.041     0.060
                                                                                    *
 2 002254   163140.   163040.   163150.   163240.   163160.   163230.   163300.   163460.   162800.   163220.   163040.  1631640.
   ERROR                -100.       10.      100.       20.       90.      160.      320.     -340.       80.     -100.      240.
   PER CENT            -0.061     0.006     0.061     0.012     0.055     0.098     0.196    -0.208     0.049    -0.061     0.014
                                                                                              *
 3 073866   121720.   121850.   122040.   121940.   121820.   121780.   122060.   122020.   121610.   121860.   121770.  1218750.
   ERROR                 130.      320.      220.      100.       60.      340.      300.     -110.      140.       50.     1550.
   PER CENT             0.106     0.262     0.180     0.082     0.049     0.279     0.246    -0.090     0.115     0.041     0.127
                                  *                                       *         *
 4 550465   176560.   176660.   176560.   176670.   176660.   176680.   176660.   176640.   176060.   176540.   176300.  1765430.
   ERROR                 100.        0.      110.      100.      120.      100.       80.     -500.      -20.     -260.     -170.
   PER CENT             0.056     0.000     0.062     0.056     0.067     0.056     0.045    -0.283    -0.011    -0.147    -0.009
                                                                                              *
 5 144571   127860.   128160.   127960.   128250.   127880.   128060.   128200.   127980.   127920.   128160.   127850.  1280420.
   ERROR                 300.      100.      390.       20.      200.      340.      120.       60.      300.      -10.     1820.
   PER CENT             0.234     0.078     0.305     0.015     0.156     0.265     0.093     0.046     0.234    -0.007     0.142
                        *                   *                             *                             *
 6 074338   138380.   138540.   138360.   138240.   138430.   138130.   138360.   138440.   138120.   138540.   138280.  1383440.
   ERROR                 160.      -20.     -140.       50.     -250.      -20.       60.     -260.      160.     -100.     -360.
   PER CENT             0.115    -0.014    -0.101     0.036    -0.180    -0.014     0.043    -0.187     0.115    -0.072    -0.026

 7 075649   124430.   124390.   124300.   124250.   124400.   124180.   124660.   124280.   124060.   124650.   124300.  1243470.
   ERROR                 -40.     -130.     -180.      -30.     -250.      230.     -150.     -370.      220.     -130.     -830.
   PER CENT            -0.032    -0.104    -0.144    -0.024    -0.200     0.184    -0.120    -0.297     0.176    -0.104    -0.066
                                                                *                             *
 8 107871   125140.   124980.   124990.   124940.   125020.   124800.   125140.   124920.   124800.   125100.   125050.  1249740.
   ERROR                -160.     -150.     -200.     -120.     -340.        0.     -220.     -340.      -40.      -90.    -1660.
   PER CENT            -0.127    -0.119    -0.159    -0.095    -0.271     0.000    -0.176    -0.271    -0.031    -0.071    -0.132
                                                                *                             *
 9 013705    63400.    63460.    63460.    63460.    63420.    63440.    63560.    63440.    63340.    63540.    63620.   634740.
   ERROR                  60.       60.       60.       20.       40.      160.       40.      -60.      140.      220.      740.
   PER CENT             0.094     0.094     0.094     0.031     0.063     0.252     0.063    -0.094     0.220     0.347     0.116
                                                                          *                             *         *
10 012895    63700.    63800.    63740.    63820.    63730.    63780.    63900.    63740.    63720.    63780.    63700.   637710.
   ERROR                 100.       40.      120.       30.       80.      200.       40.       20.       80.        0.      710.
   PER CENT             0.156     0.062     0.188     0.047     0.125     0.313     0.062     0.031     0.125     0.000     0.111
                                                                          *
TOT WGT    1271090.  1271730.  1271420.  1271740.  1271360.  1270820.  1272780.  1272060.  1269050.  1272250.  1270740.
ALG ERR                  640.      330.      650.      270.     -270.     1690.      970.    -2040.     1160.     -350.
PER CNT                 0.050     0.025     0.051     0.021    -0.021     0.132     0.076    -0.160     0.091    -0.027

        TOT REF WGT   12710900.         DEVIATION IN --- 100  WGTS   PCNT        ALLOW  ACTUAL  PCNT OF TOT WGTS
        TOT MOT WGT   12713950.                                      OVER 0.200   30     18           18.0
        TOT ERR           3050.                                      OVER 0.500    5      0            0.0
        PCNT             0.023                                       OVER 1.000 NONE      0            0.0
        MAX ALLOW        0.200          GROSS ERR     13830.
```

```
DIRECTION-         CODE=  P(PULL),S(SHOVE)-N,E,S,W                          DATE  MAY 20, 1975     TEST NO. 9

    CAR NO. REF WGT         RUN 1      RUN 2      RUN 3      RUN 4      RUN 5      RUN 6      RUN 7      RUN 8      RUN 9     RUN 10        TOT
===============================================================================================================================================
 1  001923     189850.    189930.    189920.    189940.    189900.    189810.    189960.    190080.    189790.    190070.    190030.   1899430.
    ERROR                     80.        70.        90.        50.       -40.       110.       230.       -60.       220.       180.       930.
    PER CENT                0.042      0.036      0.047      0.026     -0.021      0.057      0.121     -0.031      0.115      0.094      0.048

 2  039137     177450.    177170.    177390.    177330.    177610.    177590.    177440.    177380.    177570.    177820.    177500.   1774800.
    ERROR                   -280.       -60.      -120.       160.       140.       -10.       -70.       120.       370.        50.       300.
    PER CENT               -0.157     -0.033     -0.067      0.090      0.078     -0.005     -0.039      0.067      0.208      0.028      0.016
                                                                                                                     *
 3  052709      96530.     96710.     96920.     96960.     96580.     96730.     96880.     96530.     96660.     96540.     96640.    967150.
    ERROR                    180.       390.       430.        50.       200.       350.         0.       130.        10.       110.      1850.
    PER CENT                0.186      0.404      0.445      0.051      0.207      0.362      0.000      0.134      0.010      0.113      0.191
                                         *          *                     *          *
 4  101729     260120.    259770.    259940.    259970.    260600.    260610.    260310.    260020.    260220.    260280.    261010.   2602730.
    ERROR                   -350.      -180.      -150.       480.       490.       190.      -100.       100.       160.       890.      1530.
    PER CENT               -0.134     -0.069     -0.057      0.184      0.188      0.073     -0.038      0.038      0.061      0.342      0.058
                                                                                                                                *
 5  100524     268590.    268350.    268160.    268440.    268320.    268360.    268520.    268500.    268130.    268420.    268660.   2683860.
    ERROR                   -240.      -430.      -150.      -270.      -230.       -70.       -90.      -460.      -170.        70.     -2040.
    PER CENT               -0.089     -0.160     -0.055     -0.100     -0.085     -0.026     -0.033     -0.171     -0.063      0.026     -0.076

 6  100635     264490.    264470.    264160.    263950.    264300.    264130.    264340.    264710.    264130.    265100.    264490.   2643780.
    ERROR                    -20.      -330.      -540.      -190.      -360.      -150.       220.      -360.       610.         0.     -1120.
    PER CENT               -0.007     -0.124     -0.204     -0.071     -0.136     -0.056      0.083     -0.136      0.230      0.000     -0.042
                                                    *                                                                *
 7  028683     159310.    159250.    159000.    159440.    159390.    159060.    159260.    159340.    159250.    159390.    159540.   1592920.
    ERROR                    -60.      -310.       130.        80.      -250.       -50.        30.       -60.        80.       230.      -180.
    PER CENT               -0.037     -0.194      0.081      0.050     -0.156     -0.031      0.018     -0.037      0.050      0.144     -0.011

 8  371304     168140.    168000.    168050.    168280.    168140.    168280.    168620.    168480.    168460.    168560.    168570.   1683440.
    ERROR                   -140.       -90.       140.         0.       140.       480.       340.       320.       420.       430.      2040.
    PER CENT               -0.083     -0.053      0.083      0.000      0.083      0.285      0.202      0.190      0.249      0.255      0.121
                                                                                     *          *                     *          *
 9  366668     179530.    179500.    179270.    179550.    179650.    179730.    179820.    179570.    179920.    179700.    179810.   1796520.
    ERROR                    -30.      -260.        20.       120.       200.       290.        40.       390.       170.       280.      1220.
    PER CENT               -0.016     -0.144      0.011      0.066      0.111      0.161      0.022      0.217      0.094      0.155      0.067
                                                                                                          *
10  001697     130400.    130320.    130200.    129810.    130080.    129770.    129960.    130070.    129840.    130030.    129970.   1300050.
    ERROR                    -80.      -200.      -590.      -320.      -630.      -440.      -330.      -560.      -370.      -430.     -3950.
    PER CENT               -0.061     -0.153     -0.452     -0.245     -0.483     -0.337     -0.253     -0.429     -0.283     -0.329     -0.303
                                                    *          *          *          *          *          *          *          *
TOT WGT        1894410.   1893470.   1893010.   1893670.   1894570.   1894070.   1895110.   1894680.   1893970.   1895910.   1896220.
ALG ERR                     -940.     -1400.      -740.       160.      -340.       700.       270.      -440.      1500.      1810.
PER CNT                    -0.049     -0.073     -0.039      0.008     -0.017      0.036      0.014     -0.023      0.079      0.095

          TOT REF WGT   18944100.             DEVIATION IN --- 100  WGTS   PCNT          ALLOW   ACTUAL   PCNT OF TOT WGTS
          TOT MOT WGT   18944680.                                          OVER 0.200     30      21              21.0
          TOT ERR            580.                                          OVER 0.500      5       0               0.0
          PCNT              0.003                                          OVER 1.000   NONE       0               0.0
          MAX ALLOW         0.200             GROSS ERR     21940.
```

```
DIRECTION-       CODE=  P(PULL);S(SHOVE)-N,E,S,W                                  DATE  MAY 20, 1975    TEST NO. 10

   CAR NO.  REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
==================================================================================================================================
 1 992511    80000.    80100.    80000.    80100.    79800.    79900.    80000.    80100.    79800.        0.    79900.   719700.
   ERROR                 100.        0.      100.     -200.     -100.        0.      100.     -200.        0.     -100.     -300.
   PER CENT             0.124     0.000     0.124    -0.249    -0.124     0.000     0.124    -0.249     0.000    -0.124    -0.041
                                                       *                                       *
 2 095397    60700.    60700.    60700.    60700.    60800.    60600.    60600.    60600.    60800.    61000.    60900.   607400.
   ERROR                   0.        0.        0.      100.     -100.     -100.     -100.      100.      300.      200.      400.
   PER CENT             0.000     0.000     0.000     0.164    -0.164    -0.164    -0.164     0.164     0.494     0.329     0.065
                                                                                                         *         *
 3 095940   156800.   156500.   157100.   156700.   156800.   157000.   156800.   157100.   156800.   156600.   156500.  1567900.
   ERROR                -300.      300.     -100.        0.      200.        0.      300.        0.     -200.     -300.     -100.
   PER CENT            -0.191     0.191    -0.063     0.000     0.127     0.000     0.191     0.000    -0.127    -0.191    -0.006

 4 304005   201900.   202000.   202100.   201800.   201800.   201900.   201900.   201700.   201900.   202000.   201600.  2018700.
   ERROR                 100.      200.     -100.     -100.        0.        0.     -200.        0.      100.     -300.     -300.
   PER CENT             0.049     0.099    -0.049    -0.049     0.000     0.000    -0.099     0.000     0.049    -0.148    -0.014

 5 095334   209600.   209100.   209400.   209800.   209800.   209500.   209500.   209900.   209800.   209500.   209500.  2095800.
   ERROR                -500.     -200.      200.      200.     -100.     -100.      300.      200.     -100.     -100.     -200.
   PER CENT            -0.238    -0.095     0.095     0.095    -0.047    -0.047     0.143     0.095    -0.047    -0.047    -0.009
                         *
 6 095335   209100.   208900.   208800.   209100.   209100.   209200.   209400.   209500.   209800.   209100.   209700.  2092600.
   ERROR                -200.     -300.        0.        0.      100.      300.      400.      700.        0.      600.     1600.
   PER CENT            -0.095    -0.143     0.000     0.000     0.047     0.143     0.191     0.334     0.000     0.286     0.076
                                                                                               *                   *
 7 279051   210100.   210100.   210200.   209800.   210000.   210400.   210100.   210900.   210200.   209900.   210500.  2102100.
   ERROR                   0.      100.     -300.     -100.      300.        0.      800.      100.     -200.      400.     1100.
   PER CENT             0.000     0.047    -0.142    -0.047     0.142     0.000     0.380     0.047    -0.095     0.190     0.052
                                                                                     *
 8 072895    54800.    54600.    54600.    54600.    54700.    55000.    54900.    54400.    54900.    54900.    54900.   547500.
   ERROR                -200.     -200.     -200.     -100.      200.      100.     -400.      100.      100.      100.     -500.
   PER CENT            -0.364    -0.364    -0.364    -0.182     0.364     0.182    -0.729     0.182     0.182     0.182    -0.091
                         *         *         *                   *                   *
 9 073525    54400.    54500.    54500.    54600.    54400.    54500.    54500.    54500.    54400.    54600.    54500.   545000.
   ERROR                 100.      100.      200.        0.      100.      100.      100.        0.      200.      100.     1000.
   PER CENT             0.183     0.183     0.367     0.000     0.183     0.183     0.183     0.000     0.367     0.183     0.183
                                             *                                                           *
10 304003    55800.    55700.    56000.    55700.    55800.    55400.    55500.    55400.    55700.    56000.    55900.   557100.
   ERROR                -100.      200.     -100.        0.     -400.     -300.     -400.     -100.      200.      100.     -900.
   PER CENT            -0.179     0.358    -0.179     0.000    -0.716    -0.537    -0.716    -0.179     0.358     0.179    -0.161
                                   *                             *         *         *                   *
TOT WGT    1293200.  1292200.  1293400.  1292900.  1293000.  1293400.  1293200.  1294100.  1294100.  1213600.  1293900.
ALG ERR                -1000.      200.     -300.     -200.      200.        0.      900.      900.      400.      700.
PER CNT                -0.077     0.015    -0.023    -0.015     0.015     0.000     0.069     0.069     0.030     0.054

         TOT REF WGT   12852000.        DEVIATION IN ---   99   WGTS    PCNT         ALLOW  ACTUAL   PCNT OF TOT WGTS
         TOT MOT WGT   12853800.                                        OVER 0.200     29     20              20.2
         TOT ERR           1800.                                        OVER 0.500      4      4               4.0
         PCNT              0.014                                        OVER 1.000   NONE      0               0.0
         MAX ALLOW         0.200        GROSS ERR       16200.
```

```
DIRECTION-  PS    CODE=  P(PULL),S(SHOVE)-N,E,S,W                                     DATE  MAY 20, 1975   TEST NO. 11, MODE 1

    CAR NO. REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=================================================================================================================================
 1  010415  141100.   140900.   141200.   140900.   140700.   141300.   140600.   141000.   140700.   140800.   141100.  1409200.
    ERROR                -200.      100.     -200.     -400.      200.     -500.     -100.     -400.     -300.        0.    -1800.
    PER CENT            -0.141     0.070    -0.141    -0.283     0.141    -0.354    -0.070    -0.283    -0.212     0.000    -0.127
                                                        *                   *                   *         *
 2  526047  198360.   198400.   198600.   199300.   198700.   198800.   198400.   198700.   198500.   198500.   198700.  1986600.
    ERROR                  40.      240.      940.      340.      440.       40.      340.      140.      140.      340.     3000.
    PER CENT             0.020     0.120     0.473     0.171     0.221     0.020     0.171     0.070     0.070     0.171     0.151
                                              *                   *
 3  010389  117140.   117900.   117600.   116800.   117500.   117100.   117700.   117300.   117500.   117500.   117600.  1174500.
    ERROR                 760.      460.     -340.      360.      -40.      560.      160.      360.      360.      460.     3100.
    PER CENT             0.648     0.392    -0.290     0.307    -0.034     0.478     0.136     0.307     0.307     0.392     0.263
                          *         *         *         *                   *                   *         *         *
 4  019090  180840.   180800.   180500.   180500.   180300.   180400.   180200.   180000.   180100.   180000.   180400.  1803200.
    ERROR                 -40.     -340.     -340.     -540.     -440.     -640.     -840.     -740.     -840.     -440.    -5200.
    PER CENT            -0.022    -0.188    -0.188    -0.298    -0.243    -0.353    -0.464    -0.409    -0.464    -0.243    -0.288
                                                        *         *         *         *         *         *         *
 5  040729  194460.   194500.   194700.   194800.   194300.   194700.   194700.   194600.   194700.   194800.   194800.  1946600.
    ERROR                  40.      240.      340.     -160.      240.      240.      140.      240.      340.      340.     2000.
    PER CENT             0.020     0.123     0.174    -0.082     0.123     0.123     0.071     0.123     0.174     0.174     0.102

 6  010416  141060.   141000.   141000.   140800.   140900.   140900.   140800.   140900.   140800.   140800.   140900.  1408800.
    ERROR                 -60.      -60.     -260.     -160.     -160.     -260.     -160.     -260.     -260.     -160.    -1800.
    PER CENT            -0.042    -0.042    -0.184    -0.113    -0.113    -0.184    -0.113    -0.184    -0.184    -0.113    -0.127

 7  010446   55340.    55400.    55300.    55300.    55300.    55400.    55300.    55300.    55400.    55400.    55400.   553500.
    ERROR                  60.      -40.      -40.      -40.       60.      -40.      -40.       60.       60.       60.      100.
    PER CENT             0.108    -0.072    -0.072    -0.072     0.108    -0.072    -0.072     0.108     0.108     0.108     0.018

 8  010479  108700.   108800.   108700.   108800.   108700.   108700.   108700.   108700.   108600.   108600.   108600.  1086900.
    ERROR                 100.        0.      100.        0.        0.        0.        0.     -100.     -100.     -100.     -100.
    PER CENT             0.091     0.000     0.091     0.000     0.000     0.000     0.000    -0.091    -0.091    -0.091    -0.009

 9  010380   55880.    55900.    55900.    55900.    55800.    55900.    55700.    55600.    55800.    55700.    55800.   558200.
    ERROR                  20.       20.       20.      -80.       20.     -180.      -80.      -80.     -180.      -80.     -600.
    PER CENT             0.035     0.035     0.035    -0.143     0.035    -0.322    -0.143    -0.143    -0.322    -0.143    -0.107
                                                                            *                             *
10  771818  100000.   100100.   100100.   100000.   100000.   100000.   100000.   100000.   100000.   100000.   100000.  1000200.
    ERROR                 100.      100.        0.        0.        0.        0.        0.        0.        0.        0.      200.
    PER CENT             0.100     0.100     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.019

TOT WGT    1292880.  1293700.  1293600.  1293100.  1292200.  1293200.  1292100.  1292300.  1292100.  1292100.  1293300.
ALG ERR                   820.      720.      220.     -680.      320.     -780.     -580.     -780.     -780.      420.
PER CNT                  0.063     0.055     0.017    -0.052     0.024    -0.060    -0.044    -0.060    -0.060     0.032

           TOT REF WGT   12928800.          DEVIATION IN --- 100  WGTS    PCNT        ALLOW  ACTUAL   PCNT OF TOT WGTS
           TOT MOT WGT   12927700.                                        OVER 0.200   30     23           23.0
           TOT ERR          -1100.                                        OVER 0.500    5      1            1.0
           PCNT             -0.008                                        OVER 1.000 NONE      0            0.0
           MAX ALLOW         0.200          GROSS ERR     20540.
```

```
DIRECTION-  SN    CODE=  P(PULL),S(SHOVE)-N,E,S,W                                        DATE  MAY 20, 1975  TEST NO. 11, MODE 2

    CAR NO. REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=================================================================================================================================
 1  010415  141100.   141400.   141400.   141400.   141500.   141300.   141200.   141400.   140800.   141200.   140800.  1412400.
    ERROR                300.      300.      300.      400.      200.      100.      300.     -300.      100.     -300.     1400.
    PER CENT           0.212     0.212     0.212     0.283     0.141     0.070     0.212    -0.212     0.070    -0.212     0.099
                        *         *         *         *                             *         *                   *
 2  526047  198360.   198700.   198700.   198900.   198800.   198700.   198600.   198700.   198700.   198700.   198400.  1986900.
    ERROR                340.      340.      540.      440.      340.      240.      340.      340.      340.       40.     3300.
    PER CENT           0.171     0.171     0.272     0.221     0.171     0.120     0.171     0.171     0.171     0.020     0.166
                                            *         *
 3  010389  117140.   117200.   117200.   117100.   117000.   117000.   117200.   117200.   117200.   117200.   117100.  1171400.
    ERROR                 60.       60.      -40.     -140.     -140.       60.       60.       60.       60.      -40.        0.
    PER CENT           0.051     0.051    -0.034    -0.119    -0.119     0.051     0.051     0.051     0.051    -0.034     0.000

 4  019090  180840.   181000.   181000.   180600.   180900.   180700.   180900.   180900.   180800.   180800.   181000.  1808600.
    ERROR                160.      160.     -240.       60.     -140.       60.       60.      -40.      -40.      160.      200.
    PER CENT           0.088     0.088    -0.132     0.033    -0.077     0.033     0.033    -0.022    -0.022     0.088     0.011

 5  040729  194460.   194000.   194100.   194200.   194000.   194000.   194000.   193900.   193900.   193800.   194000.  1939900.
    ERROR               -460.     -360.     -260.     -460.     -460.     -460.     -560.     -560.     -660.     -460.    -4700.
    PER CENT          -0.236    -0.185    -0.133    -0.236    -0.236    -0.236    -0.287    -0.287    -0.339    -0.236    -0.242
                        *                             *         *         *         *         *         *         *
 6  010416  141060.   141100.   141100.   141000.   140800.   140900.   141100.   140900.   141100.   141000.   141100.  1410100.
    ERROR                 40.       40.      -60.     -260.     -160.       40.     -160.       40.      -60.       40.     -500.
    PER CENT           0.028     0.028    -0.042    -0.184    -0.113     0.028    -0.113     0.028    -0.042     0.028    -0.035

 7  010446   55340.    55600.    55700.    55500.    55600.    55400.    55600.    55500.    55500.    55600.    55500.   555500.
    ERROR                260.      360.      160.      260.       60.      260.      160.      160.      260.      160.     2100.
    PER CENT           0.469     0.650     0.289     0.469     0.108     0.469     0.289     0.289     0.469     0.289     0.378
                        *         *         *         *                   *         *         *         *         *
 8  010479  108700.   108700.   108600.   108900.   108800.   108700.   108800.   108700.   108600.   108800.   108600.  1087200.
    ERROR                  0.     -100.      200.      100.        0.      100.        0.     -100.      100.     -100.      200.
    PER CENT           0.000    -0.091     0.183     0.091     0.000     0.091     0.000    -0.091     0.091    -0.091     0.018

 9  010380   55880.    55700.    55800.    55800.    55800.    55700.    55800.    55700.    55800.    55800.    55800.   557700.
    ERROR               -180.      -80.      -80.      -80.     -180.      -80.     -180.      -80.      -80.      -80.    -1100.
    PER CENT          -0.322    -0.143    -0.143    -0.143    -0.322    -0.143    -0.322    -0.143    -0.143    -0.143    -0.197
                        *                                       *                   *
10  771818  100000.   100000.   100000.    99900.    99900.    99900.    99900.    99900.   100000.   100000.   100000.   999500.
    ERROR                  0.        0.     -100.     -100.     -100.     -100.     -100.        0.        0.        0.     -500.
    PER CENT           0.000     0.000    -0.100    -0.100    -0.100    -0.100    -0.100     0.000     0.000     0.000    -0.050

TOT WGT    1292880.  1293400.  1293600.  1293300.  1293100.  1292300.  1293100.  1292800.  1292400.  1292900.  1292300.
ALG ERR                  520.      720.      420.      220.     -580.      220.      -80.     -480.       20.     -580.
PER CNT                0.040     0.055     0.032     0.017    -0.044     0.017    -0.006    -0.037     0.001    -0.044

          TOT REF WGT  12928800.           DEVIATION IN --- 100  WGTS   PCNT        ALLOW  ACTUAL  PCNT OF TOT WGTS
          TOT MOT WGT  12929200.                                        OVER 0.200    30      29           29.0
          TOT ERR           400.                                        OVER 0.500     5       1            1.0
          PCNT             0.003                                        OVER 1.000  NONE       0            0.0
          MAX ALLOW        0.200           GROSS ERR    17840.
```

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DIRECTION-  PN    CODE=  P(PULL),S(SHOVE)-N,E,S,W                               DATE  MAY 20, 1975   TEST NO. 11, MODE 3

   CAR NO.  REF WGT       RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
===================================================================================================================================
1  771818   100000.     100200.   100200.   100100.   100200.   100100.   100200.   100200.   100100.   100200.   100100.  1001600.
   ERROR                   200.      200.      100.      200.      100.      200.      200.      100.      200.      100.     1600.
   PER CENT               0.200     0.200     0.100     0.200     0.100     0.200     0.200     0.100     0.200     0.100     0.159

2  526047   198360.     198800.   199100.   198700.   199100.   199000.   199100.   198800.   199100.   199000.   198900.  1989600.
   ERROR                   440.      740.      340.      740.      640.      740.      440.      740.      640.      540.     6000.
   PER CENT               0.221     0.373     0.171     0.373     0.322     0.373     0.221     0.373     0.322     0.272     0.301
                           *         *                   *         *         *         *         *         *         *
3  010389   117140.     117300.   117300.   117200.   117500.   117500.   117200.   117300.   117200.   117400.   117100.  1173000.
   ERROR                   160.      160.       60.      360.      360.       60.      160.       60.      260.      -40.     1600.
   PER CENT               0.136     0.136     0.051     0.307     0.307     0.051     0.136     0.051     0.221    -0.034     0.136
                                                         *         *                                       *
4  019090   180840.     181000.   181100.   181400.   181400.   181300.   181400.   180900.   181400.   181200.   181200.  1812300.
   ERROR                   160.      260.      560.      560.      460.      560.       60.      560.      360.      360.     3900.
   PER CENT               0.088     0.143     0.309     0.309     0.254     0.309     0.033     0.309     0.199     0.199     0.215
                                               *         *         *         *                   *
5  040729   194460.     194200.   194400.   194300.   194700.   194600.   194900.   194500.   194700.   194800.   194400.  1945500.
   ERROR                  -260.      -60.     -160.      240.      140.      440.       40.      240.      340.      -60.      900.
   PER CENT              -0.133    -0.030    -0.082     0.123     0.071     0.226     0.020     0.123     0.174    -0.030     0.046
                                                                             *
6  010416   141060.     141100.   141200.   141300.   141000.   141200.   141100.   141100.   140900.   140900.   141200.  1411000.
   ERROR                    40.      140.      240.      -60.      140.       40.       40.     -160.     -160.      140.      400.
   PER CENT               0.028     0.099     0.170    -0.042     0.099     0.028     0.028    -0.113    -0.113     0.099     0.028

7  010446    55340.      55500.    55500.    55400.    55300.    55300.    55500.    55400.    55500.    55500.    55400.   554300.
   ERROR                   160.      160.       60.      -40.      -40.      160.       60.      160.      160.       60.      900.
   PER CENT               0.289     0.289     0.108    -0.072    -0.072     0.289     0.108     0.289     0.289     0.108     0.162
                           *         *                                       *                   *         *
8  010479   108700.     108600.   108800.   108600.   108500.   108600.   108800.   108700.   108800.   108800.   108700.  1086900.
   ERROR                  -100.      100.     -100.     -200.     -100.      100.        0.      100.      100.        0.     -100.
   PER CENT              -0.091     0.091    -0.091    -0.183    -0.091     0.091     0.000     0.091     0.091     0.000    -0.009

9  010380    55880.      56000.    55900.    55800.    56100.    55800.    55900.    55800.    55800.    55800.    55800.   558700.
   ERROR                   120.       20.      -80.      220.      -80.       20.      -80.      -80.      -80.      -80.     -100.
   PER CENT               0.214     0.035    -0.143     0.393    -0.143     0.035    -0.143    -0.143    -0.143    -0.143    -0.017
                           *                             *
10 010415   141100.     141700.   141800.   141600.   141700.   141800.   141600.   141800.   141500.   141600.   141700.  1416800.
   ERROR                   600.      700.      500.      600.      700.      500.      700.      400.      500.      600.     5800.
   PER CENT               0.425     0.496     0.354     0.425     0.496     0.354     0.496     0.283     0.354     0.425     0.409
                           *         *         *         *         *         *         *         *         *         *
TOT WGT     1292880.    1294400.  1295300.  1294400.  1295500.  1295200.  1295700.  1294500.  1295000.  1295200.  1294500.
ALG ERR                   1520.     2420.     1520.     2620.     2320.     2820.     1620.     2120.     2320.     1620.
PER CNT                   0.117     0.187     0.117     0.202     0.179     0.218     0.125     0.163     0.179     0.125

         TOT REF WGT  12928800.              DEVIATION IN --- 100  WGTS   PCNT           ALLOW  ACTUAL  PCNT OF TOT WGTS
         TOT MOT WGT  12949700.                                           OVER 0.200     30     35            35.0
         TOT ERR         20900.                                           OVER 0.500      5      0             0.0
         PCNT             0.161                                           OVER 1.000   NONE      0             0.0
         MAX ALLOW        0.200              GROSS ERR      24940.
```

```
DIRECTION-  SS    CODE=  P(PULL),S(SHOVE)-N,E,S,W                         DATE   MAY 20, 1975   TEST NO. 11, MODE 4

    CAR NO. REF WGT      RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
==================================================================================================================================
 1  771818  100000.    100100.   100100.   100100.   100000.   100200.   100200.   100300.   100300.   100200.   100300.  1001800.
    ERROR                 100.      100.      100.        0.      200.      200.      300.      300.      200.      300.     1800.
    PER CENT            0.100     0.100     0.100     0.000     0.200     0.200     0.300     0.300     0.200     0.300     0.179
                                                                                     *         *                   *
 2  526047  198360.    198600.   198600.   198100.   198300.   198500.   198300.   198500.   198400.   198300.   198200.  1983800.
    ERROR                 240.      240.     -260.      -60.      140.      -60.      140.       40.      -60.     -160.      200.
    PER CENT            0.120     0.120    -0.131    -0.030     0.070    -0.030     0.070     0.020    -0.030    -0.080     0.010

 3  010389  117140.    117000.   116900.   117000.   116800.   117000.   117000.   117400.   117400.   117200.   117300.  1171000.
    ERROR                -140.     -240.     -140.     -340.     -140.     -140.      260.      260.       60.      160.     -400.
    PER CENT           -0.119    -0.204    -0.119    -0.290    -0.119    -0.119     0.221     0.221     0.051     0.136    -0.034
                                   *                   *                             *         *
 4  019090  180840.    180900.   180800.   180900.   180200.   180800.   180700.   180900.   180700.   180900.   180600.  1807400.
    ERROR                  60.      -40.       60.     -640.      -40.     -140.       60.     -140.       60.     -240.    -1000.
    PER CENT            0.033    -0.022     0.033    -0.353    -0.022    -0.077     0.033    -0.077     0.033    -0.132    -0.055
                                                       *
 5  040729  194460.    194800.   194900.   195000.   194400.   194900.   194800.   194700.   194800.   194800.   194500.  1947600.
    ERROR                 340.      440.      540.      -60.      440.      340.      240.      340.      340.       40.     3000.
    PER CENT            0.174     0.226     0.277    -0.030     0.226     0.174     0.123     0.174     0.174     0.020     0.154
                                   *         *                   *
 6  010416  141060.    140700.   141000.   140900.   141000.   140900.   140900.   140900.   140900.   141000.   140800.  1409000.
    ERROR                -360.      -60.     -160.      -60.     -160.     -160.     -160.     -160.      -60.     -260.    -1600.
    PER CENT           -0.255    -0.042    -0.113    -0.042    -0.113    -0.113    -0.113    -0.113    -0.042    -0.184    -0.113
                         *
 7  010446   55340.     55300.    55300.    55300.    55500.    55300.    55300.    55500.    55300.    55500.    55500.   553800.
    ERROR                 -40.      -40.      -40.      160.      -40.      -40.      160.      -40.      160.      160.      400.
    PER CENT           -0.072    -0.072    -0.072     0.289    -0.072    -0.072     0.289    -0.072     0.289     0.289     0.072
                                                       *                             *                   *         *
 8  010479  108700.    108700.   108600.   108600.   108700.   108700.   108700.   108700.   108500.   108600.   108500.  1086300.
    ERROR                   0.     -100.     -100.        0.        0.        0.        0.     -200.     -100.     -200.     -700.
    PER CENT            0.000    -0.091    -0.091     0.000     0.000     0.000     0.000    -0.183    -0.091    -0.183    -0.064

 9  010380   55880.     55800.    55800.    56000.    56000.    55800.    55800.    55900.    55800.    55900.    55800.   558600.
    ERROR                 -80.      -80.      120.      120.      -80.      -80.       20.      -80.       20.      -80.     -200.
    PER CENT           -0.143    -0.143     0.214     0.214    -0.143    -0.143     0.035    -0.143     0.035    -0.143    -0.035
                                             *         *
10  010415  141100.    141200.   141100.   141100.   141100.   141100.   141000.   141100.   141100.   141000.   140900.  1410700.
    ERROR                 100.        0.        0.        0.        0.     -100.        0.        0.     -100.     -200.     -300.
    PER CENT            0.070     0.000     0.000     0.000     0.000    -0.070     0.000     0.000    -0.070    -0.141    -0.021

TOT WGT    1292880.   1293100.  1293100.  1293000.  1292000.  1293200.  1292700.  1293900.  1293200.  1293400.  1292400.
ALG ERR                   220.      220.      120.     -880.      320.     -180.     1020.      320.      520.     -480.
PER CNT                 0.017     0.017     0.009    -0.068     0.024    -0.013     0.078     0.024     0.040    -0.037

        TOT REF WGT   12928800.          DEVIATION IN --- 100  WGTS    PCNT         ALLOW   ACTUAL   PCNT OF TOT WGTS
        TOT MOT WGT   12930000.                                        OVER 0.200    30      18           18.0
        TOT ERR           1200.                                        OVER 0.500     5       0            0.0
        PCNT             0.009                                         OVER 1.000  NONE       0            0.0
        MAX ALLOW        0.200           GROSS ERR      14120.
```

```
DIRECTION-        CODE=  P(PULL),S(SHOVE)-N,E,S,W                          DATE  MAY 20, 1975   TEST NO. 12, MODE 1

    CAR NO. REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=================================================================================================================================
 1  000100  192000.   192100.   191295.   192570.   191935.   191970.   192185.   191720.   192200.   192340.   191775.  1920090.
    ERROR                100.     -705.      570.      -65.      -30.      185.     -280.      200.      340.     -225.       90.
    PER CENT            0.052    -0.367     0.296    -0.033    -0.015     0.096    -0.145     0.104     0.177    -0.117     0.004
                                   *         *

 2  232477  169520.   169925.   169900.   169660.   170125.   169735.   169590.   169750.   169670.   169420.   169455.  1697230.
    ERROR                405.      380.      140.      605.      215.       70.      230.      150.     -100.      -65.     2030.
    PER CENT            0.238     0.224     0.082     0.356     0.126     0.041     0.135     0.088    -0.058    -0.038     0.119
                         *         *                   *

 3  230248  152080.   152325.   152070.   152065.   152355.   152170.   152185.   152235.   152125.   152205.   152105.  1521840.
    ERROR                245.      -10.      -15.      275.       90.      105.      155.       45.      125.       25.     1040.
    PER CENT            0.161    -0.006    -0.009     0.180     0.059     0.069     0.101     0.029     0.082     0.016     0.068

 4  040680  205460.   205455.   205640.   205490.   205465.   205445.   205825.   205645.   205645.   205170.   205370.  2055150.
    ERROR                 -5.      180.       30.        5.      -15.      365.      185.      185.     -290.      -90.      550.
    PER CENT           -0.002     0.087     0.014     0.002    -0.007     0.177     0.090     0.090    -0.141    -0.043     0.026

 5  008855   48660.    48695.    48670.    48710.    48725.    48720.    48525.    48660.    48590.    48735.    48735.   486765.
    ERROR                 35.       10.       50.       65.       60.     -135.        0.      -70.       75.       75.      165.
    PER CENT            0.071     0.020     0.102     0.133     0.123    -0.277     0.000    -0.143     0.154     0.154     0.033
                                                                           *

 6  230281  136120.   136045.   135745.   135935.   136195.   136050.   136145.   136200.   136160.   135980.   136190.  1360645.
    ERROR                -75.     -375.     -185.       75.      -70.       25.       80.       40.     -140.       70.     -555.
    PER CENT           -0.055    -0.275    -0.135     0.055    -0.051     0.018     0.058     0.029    -0.102     0.051    -0.040
                                   *

 7  000101   70000.    70145.    70040.    70160.    70050.    70110.    70325.    70165.    70040.    70055.    69815.   700905.
    ERROR                145.       40.      160.       50.      110.      325.      165.       40.       55.     -185.      905.
    PER CENT            0.207     0.057     0.228     0.071     0.157     0.464     0.235     0.057     0.078    -0.264     0.129
                         *                   *                             *         *                             *

 8  049210  161300.   161075.   161120.   161205.   161025.   161085.   161165.   161080.   160955.   160900.   160970.  1610580.
    ERROR               -225.     -180.      -95.     -275.     -215.     -135.     -220.     -345.     -400.     -330.    -2420.
    PER CENT           -0.139    -0.111    -0.058    -0.170    -0.133    -0.083    -0.136    -0.213    -0.247    -0.204    -0.150
                                                                                               *         *         *

 9  698721  122780.   122830.   122830.   122770.   122905.   122940.   122985.   122865.   122885.   122900.   122910.  1228820.
    ERROR                 50.       50.      -10.      125.      160.      205.       85.      105.      120.      130.     1020.
    PER CENT            0.040     0.040    -0.008     0.101     0.130     0.166     0.069     0.085     0.097     0.105     0.083

10  035830  250520.   250480.   250435.   250465.   250245.   250635.   250570.   250515.   250415.   250350.   250295.  2504405.
    ERROR                -40.      -85.      -55.     -275.      115.       50.       -5.     -105.     -170.     -225.     -795.
    PER CENT           -0.015    -0.033    -0.021    -0.109     0.045     0.019    -0.001    -0.041    -0.067    -0.089    -0.031

TOT WGT    1508440.  1509075.  1507745.  1509030.  1509025.  1508860.  1509500.  1508835.  1508685.  1508055.  1507620.
ALG ERR                  635.     -695.      590.      585.      420.     1060.      395.      245.     -385.     -820.
PER CNT                 0.042    -0.046     0.039     0.038     0.027     0.070     0.026     0.016    -0.025    -0.054

         TOT REF WGT   15084400.       DEVIATION IN --- 100  WGTS    PCNT         ALLOW  ACTUAL   PCNT OF TOT WGTS
         TOT MOT WGT   15086430.                                     OVER 0.200    30      15           15.0
         TOT ERR           2030.                                     OVER 0.500     5       0            0.0
         PCNT             0.013                                      OVER 1.000  NONE       0            0.0
         MAX ALLOW        0.200        GROSS ERR      15070.
```

```
DIRECTION-        CODE=  P(PULL),S(SHOVE)-N,E,S,W                                     DATE  MAY 20, 1975  TEST NO. 12, MODE 2

    CAR NO. REF WGT       RUN 1      RUN 2      RUN 3      RUN 4      RUN 5      RUN 6      RUN 7      RUN 8      RUN 9     RUN 10        TOT
=============================================================================================================================================
 1  000100   192000.    192020.    191840.    192045.    192040.    192110.    192105.    192070.    191970.    192065.    192240.   1920505.
    ERROR                   20.      -160.        45.        40.       110.       105.        70.       -30.        65.       240.       505.
    PER CENT             0.010     -0.083      0.023      0.020      0.057      0.054      0.036     -0.015      0.033      0.124      0.026

 2  232477   169520.    169410.    169525.    169565.    169575.    169390.    169485.    169545.    169415.    169505.    169610.   1695025.
    ERROR                 -110.         5.        45.        55.      -130.       -35.        25.      -105.       -15.        90.      -175.
    PER CENT            -0.064      0.002      0.026      0.032     -0.076     -0.020      0.014     -0.061     -0.008      0.053     -0.010

 3  230248   152080.    152110.    151915.    152050.    152140.    152105.    152000.    151950.    151955.    152080.    151980.   1520285.
    ERROR                   30.      -165.       -30.        60.        25.       -80.      -130.      -125.         0.      -100.      -515.
    PER CENT             0.019     -0.108     -0.019      0.039      0.016     -0.052     -0.085     -0.082      0.000     -0.065     -0.033

 4  040680   205460.    205545.    205565.    205570.    205520.    205470.    205480.    205545.    205580.    205655.    205565.   2055495.
    ERROR                   85.       105.       110.        60.        10.        20.        85.       120.       195.       105.       895.
    PER CENT             0.041      0.051      0.053      0.029      0.004      0.009      0.041      0.058      0.094      0.051      0.043

 5  008855    48660.     48600.     48405.     48640.     48390.     48510.     48570.     48495.     48620.     48560.     48520.    485310.
    ERROR                  -60.      -255.       -20.      -270.      -150.       -90.      -165.       -40.      -100.      -140.     -1290.
    PER CENT            -0.123     -0.524     -0.041     -0.554     -0.308     -0.184     -0.339     -0.082     -0.205     -0.287     -0.265
                                      *                     *          *                     *                     *          *
 6  230261   136120.    136090.    136090.    136290.    136270.    136440.    135725.    136475.    135830.    136050.    136335.   1361595.
    ERROR                  -30.       -30.       170.       150.       320.      -395.       355.      -290.       -70.       215.       395.
    PER CENT            -0.022     -0.022      0.124      0.110      0.235     -0.290      0.260     -0.213     -0.051      0.157      0.029
                                                                       *          *          *          *
 7  000101    70000.     69900.     70275.     69900.     70065.     69850.     70145.     69715.     70075.     70145.     70070.    700140.
    ERROR                 -100.       275.      -100.        65.      -150.       145.      -285.        75.       145.        70.       140.
    PER CENT            -0.142      0.392     -0.142      0.092     -0.214      0.207     -0.407      0.107      0.207      0.100      0.019
                                      *                                *          *          *                     *
 8  049210   161300.    161015.    160865.    160910.    161065.    160995.    161125.    161135.    161050.    160990.    161155.   1610305.
    ERROR                 -285.      -435.      -390.      -235.      -305.      -175.      -165.      -250.      -310.      -145.     -2695.
    PER CENT            -0.176     -0.269     -0.241     -0.145     -0.189     -0.108     -0.102     -0.154     -0.192     -0.089     -0.167
                                      *          *
 9  698721   122780.    122790.    122815.    122580.    122835.    122775.    122685.    122710.    122640.    122770.    122895.   1227495.
    ERROR                   10.        35.      -200.        55.        -5.       -95.       -70.      -140.       -10.       115.      -305.
    PER CENT             0.008      0.028     -0.162      0.044     -0.004     -0.077     -0.057     -0.114     -0.008      0.093     -0.024

10  035830   250520.    250730.    250655.    250675.    250775.    250860.    250615.    250775.    250660.    250860.    250545.   2507150.
    ERROR                  210.       135.       155.       255.       340.        95.       255.       140.       340.        25.      1950.
    PER CENT             0.083      0.053      0.061      0.101      0.135      0.037      0.101      0.055      0.135      0.009      0.077

TOT WGT     1508440.   1508210.   1507950.   1508225.   1508675.   1508505.   1507935.   1508415.   1507795.   1508680.   1508915.
ALG ERR                   -230.      -490.      -215.       235.        65.      -505.       -25.      -645.       240.       475.
PER CNT                 -0.015     -0.032     -0.014      0.015      0.004     -0.033     -0.001     -0.042      0.015      0.031

        TOT REF WGT   15084400.                 DEVIATION IN --- 100  WGTS    PCNT          ALLOW  ACTUAL   PCNT OF TOT WGTS
        TOT MOT WGT   15083305.                                               OVER 0.200     30     17               17.0
        TOT ERR          -1095.                                               OVER 0.500      5      2                2.0
        PCNT             -0.007                                               OVER 1.000   NONE      0                0.0
        MAX ALLOW         0.200                 GROSS ERR     13245.
```

```
DIRECTION-        CODE=  P(PULL),S(SHOVE)-N,E,S,W                          DATE  MAY 20, 1975     TEST NO. 13

   CAR NO. REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10      TOT
===============================================================================================================================
 1 180170  189480.   139520.   189610.   189340.   189480.   189600.   189440.   189520.   189540.   189740.   189750. 1895540.
   ERROR                 40.      130.     -140.        0.      120.      -40.       40.       60.      260.      270.     740.
   PER CENT           0.021     0.068    -0.073     0.000     0.063    -0.021     0.021     0.031     0.137     0.142    0.039

 2 075313  191200.   190940.   191030.   190910.   190880.   190950.   190960.   190640.   190960.   190830.   190860. 1909160.
   ERROR               -260.     -170.     -290.     -320.     -250.     -240.     -360.     -240.     -370.     -340.   -2840.
   PER CENT          -0.135    -0.088    -0.151    -0.167    -0.130    -0.125    -0.188    -0.125    -0.193    -0.177   -0.148

 3 133550  165400.   165150.   165260.   164910.   165080.   165060.   165090.   165140.   164750.   165010.   165060. 1650510.
   ERROR               -250.     -140.     -490.     -320.     -340.     -310.     -260.     -650.     -390.     -340.   -3490.
   PER CENT          -0.151    -0.084    -0.296    -0.193    -0.205    -0.187    -0.157    -0.392    -0.235    -0.205   -0.211
                                           *                   *                             *         *         *
 4 133138  173820.   174200.   174240.   174090.   173410.   173510.   173660.   173670.   173590.   173620.   173960. 1737950.
   ERROR                380.      420.      270.     -410.     -310.     -160.     -150.     -230.     -200.      140.    -250.
   PER CENT           0.218     0.241     0.155    -0.235    -0.178    -0.092    -0.086    -0.132    -0.115     0.080   -0.014
                       *         *                   *
 5 155954  194980.   195470.   195270.   195060.   195110.   195060.   195260.   195370.   195270.   195020.   195120. 1952010.
   ERROR                490.      290.       80.      130.       80.      280.      390.      290.       40.      140.    2210.
   PER CENT           0.251     0.148     0.041     0.066     0.041     0.143     0.200     0.148     0.020     0.071    0.113
                       *
 6 137574  168900.   168440.   169000.   168890.   168540.   168540.   168600.   168810.   168630.   168560.   168720. 1686730.
   ERROR               -460.      100.      -10.     -360.     -360.     -300.      -90.     -270.     -340.     -180.   -2270.
   PER CENT          -0.272     0.059    -0.005    -0.213    -0.213    -0.177    -0.053    -0.159    -0.201    -0.106   -0.134
                       *                             *         *                                       *
 7 136335  169560.   169400.   169560.   169310.   169010.   169240.   169480.   169200.   169950.   169760.   169510. 1694420.
   ERROR               -160.        0.     -250.     -550.     -320.      -80.     -360.      390.      200.      -50.   -1180.
   PER CENT          -0.094     0.000    -0.147    -0.324    -0.188    -0.047    -0.212     0.230     0.117    -0.029   -0.069
                                                     *                             *         *
 8 155198  196240.   196130.   195940.   195830.   195660.   196000.   195990.   196070.   196120.   195750.   195910. 1959400.
   ERROR               -110.     -300.     -410.     -580.     -240.     -250.     -170.     -120.     -490.     -330.   -3000.
   PER CENT          -0.056    -0.152    -0.208    -0.295    -0.122    -0.127    -0.086    -0.061    -0.249    -0.168   -0.153
                                           *         *                                                 *
 9 184166  207660.   208000.   207630.   207760.   207360.   207570.   207920.   207860.   207770.   207720.   207970. 2077560.
   ERROR                340.      -30.      100.     -300.      -90.      260.      200.      110.       60.      310.     960.
   PER CENT           0.163    -0.014     0.048    -0.144    -0.043     0.125     0.096     0.052     0.028     0.149    0.046

10 185504  198540.   198350.   198340.   198050.   198300.   198330.   198300.   198420.   198550.   198220.   198530. 1983390.
   ERROR               -190.     -200.     -490.     -240.     -210.     -240.     -120.       10.     -320.      -10.   -2010.
   PER CENT          -0.095    -0.100    -0.246    -0.120    -0.105    -0.120    -0.060     0.005    -0.161    -0.005   -0.101
                                           *
TOT WGT   1855780.  1855600.  1855880.  1854150.  1852830.  1853860.  1854700.  1854900.  1855130.  1854230.  1855390.
ALG ERR                -160.      100.    -1630.    -2950.    -1920.    -1080.     -880.     -650.    -1550.     -390.
PLR CNT              -0.009     0.005    -0.087    -0.158    -0.103    -0.058    -0.047    -0.035    -0.083    -0.021

          TOT REF WGT.  18557800.        DEVIATION IN --- 100  WGTS    PCNT         ALLOW  ACTUAL  PCNT OF TOT WGTS
          TOT MOT WGT   18546670.                                      OVER 0.200     30     20          20.0
          TOT ERR         -11130.                                      OVER 0.500      5      0           0.0
          PCNT             -0.059                                      OVER 1.000   NONE      0           0.0
          MAX ALLOW         0.200        GROSS ERR      23970.
```

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DIRECTION-  PW    CODE=  P(PULL),S(SHOVE)-N,E,S,W                                  DATE  MAY 20, 1975   TEST NO. 14, MODE 1

    CAR NO. REF WGT    RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10     TOT
=======================================================================================================================================
1   091125  252500.  252620.   252630.   252700.   252780.   253440.   252980.   252240.   252880.   252820.   252670.  2527760.
    ERROR               120.      130.      200.      280.      940.      480.     -260.      380.      320.      170.     2760.
    PER CENT          0.047     0.051     0.079     0.110     0.372     0.190    -0.102     0.150     0.126     0.067    0.109
                                                                *
2   098155  257860.  257840.   257890.   257470.   257800.   257500.   257760.   257760.   257360.   257620.   257840.  2576840.
    ERROR               -20.       30.     -390.      -60.     -360.     -100.     -100.     -500.     -240.      -20.    -1760.
    PER CENT         -0.007     0.011    -0.151    -0.023    -0.139    -0.038    -0.038    -0.193    -0.093    -0.007   -0.068

3   037814  145380.  145380.   145150.   145430.   145210.   145360.   145410.   145480.   145560.   145510.   145350.  1453840.
    ERROR                0.     -230.       50.     -170.      -20.       30.      100.      180.      130.      -30.       40.
    PER CENT          0.000    -0.158     0.034    -0.116    -0.013     0.020     0.068     0.123     0.089    -0.020    0.002

4   520559  138100.  138100.   138130.   138070.   138060.   138160.   138100.   138000.   138100.   138150.   138160.  1381030.
    ERROR                0.       30.      -30.      -40.       60.        0.     -100.        0.       50.       60.       30.
    PER CENT          0.000     0.021    -0.021    -0.028     0.043     0.000    -0.072     0.000     0.036     0.043    0.002

5   500381  104080.  104130.   104240.   104230.   104380.   104170.   104390.   104070.   104070.   104260.   104420.  1042360.
    ERROR                50.      160.      150.      300.       90.      310.      -10.      -10.      180.      340.     1560.
    PER CENT          0.048     0.153     0.144     0.288     0.086     0.297    -0.009    -0.009     0.172     0.326    0.149
                                                      *                   *                                       *
6   098152  180460.  180610.   180230.   180300.   180160.   180420.   180290.   180110.   180290.   180290.   180360.  1803060.
    ERROR               150.     -230.     -160.     -300.      -40.     -170.     -350.     -170.     -170.     -100.    -1540.
    PER CENT          0.083    -0.127    -0.088    -0.166    -0.022    -0.094    -0.193    -0.094    -0.094    -0.055   -0.085

7   097293  188760.  188720.   188860.   188820.   188790.   188960.   188800.   188820.   188880.   188890.   188930.  1888470.
    ERROR               -40.      100.       60.       30.      200.       40.       60.      120.      130.      170.      870.
    PER CENT         -0.021     0.052     0.031     0.015     0.105     0.021     0.031     0.063     0.068     0.090    0.046

8   097355  150140.  150440.   150280.   150260.   150390.   150300.   150390.   150260.   150390.   150310.   150290.  1503310.
    ERROR               300.      140.      120.      250.      160.      250.      120.      250.      170.      150.     1910.
    PER CENT          0.199     0.093     0.079     0.166     0.106     0.166     0.079     0.166     0.113     0.099    0.127

9   056613   55680.   55760.    55740.    55800.    55710.    55660.    55720.    55710.    55720.    55640.    55680.   557140.
    ERROR                80.       60.      120.       30.      -20.       40.       30.       40.      -40.        0.      340.
    PER CENT          0.143     0.107     0.215     0.053    -0.035     0.071     0.053     0.071    -0.071     0.000    0.061
                                            *
10  057005   44280.   44230.    44280.    44280.    44240.    44250.    44300.    44250.    44300.    44230.    44250.   442610.
    ERROR               -50.        0.        0.      -40.      -30.       20.      -30.       20.      -50.      -30.     -190.
    PER CENT         -0.112     0.000     0.000    -0.090    -0.067     0.045    -0.067     0.045    -0.112    -0.067   -0.042

TOT WGT     1517240. 1517830.  1517430.  1517360.  1517520.  1518220.  1518140.  1516700.  1517550.  1517720.  1517950.
ALG ERR                 590.      190.      120.      280.      980.      900.     -540.      310.      480.      710.
PER CNT               0.038     0.012     0.007     0.018     0.064     0.059    -0.035     0.020     0.031     0.046

          TOT REF WGT   15172400.          DEVIATION IN --- 100  WGTS   PCNT        ALLOW  ACTUAL  PCNT OF TOT WGTS
          TOT MOT WGT   15176420.                                       OVER  .200   30      5            5.0
          TOT ERR           4020.                                       OVER  .500    5      0            0.0
          PCNT             0.026                                        OVER 1.000 NONE      0            0.0
          MAX ALLOW        0.200          GROSS ERR       13440.
```

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DIRECTION-  SE    CODE=  P(PULL),S(SHOVE)-N,E,S,W                              DATE  MAY 20, 1975  TEST NO. 14, MODE 2

   CAR NO. REF WGT       RUN 1      RUN 2      RUN 3      RUN 4      RUN 5      RUN 6      RUN 7      RUN 8      RUN 9     RUN 10        TOT
============================================================================================================================================
 1 057005    44280.     44400.     44300.     44290.     44300.     44330.     44350.     44240.     44400.     44380.     44330.    443320.
   ERROR                  120.        20.        10.        20.        50.        70.       -40.       120.       100.        50.       520.
   PER CENT              0.271      0.045      0.022      0.045      0.112      0.158     -0.090      0.271      0.225      0.112      0.117
                          *                                                                            *          *
 2 056613    55680.     55540.     55670.     55770.     55690.     55770.     55710.     55770.     55760.     55790.     55730.    557200.
   ERROR                 -140.       -10.        90.        10.        90.        30.        90.        80.       110.        50.       400.
   PER CENT             -0.251     -0.017      0.161      0.017      0.161      0.053      0.161      0.143      0.197      0.089      0.071
                          *
 3 097355   150140.    150110.    149900.    150160.    150350.    150300.    150070.    150300.    150090.    150180.    150090.   1501550.
   ERROR                  -30.      -240.        20.       210.       160.       -70.       160.       -50.        40.       -50.       150.
   PER CENT             -0.019     -0.159      0.013      0.139      0.106     -0.046      0.106     -0.033      0.026     -0.033      0.009

 4 097293   188760.    188730.    188560.    188780.    189000.    188940.    188690.    189070.    188960.    188850.    188740.   1888320.
   ERROR                  -30.      -200.        20.       240.       180.       -70.       310.       200.        90.       -20.       720.
   PER CENT             -0.015     -0.105      0.010      0.127      0.095     -0.037      0.164      0.105      0.047     -0.010      0.038

 5 098152   180460.    180580.    180490.    180230.    180300.    180340.    180710.    180290.    180630.    180330.    180500.   1804400.
   ERROR                  120.        30.      -230.      -160.      -120.       250.      -170.       170.      -130.        40.      -200.
   PER CENT              0.066      0.016     -0.127     -0.088     -0.066      0.138     -0.094      0.094     -0.072      0.022     -0.011

 6 500381   104080.    104190.    103920.    104040.    104010.    103880.    104110.    103790.    104270.    104250.    104060.   1040520.
   ERROR                  110.      -160.       -40.       -70.      -200.        30.      -290.       190.       170.       -20.      -280.
   PER CENT              0.105     -0.153     -0.038     -0.067     -0.192      0.028     -0.278      0.182      0.163     -0.019     -0.026
                                                                                            *
 7 520559   138100.    138090.    138140.    138130.    137980.    138130.    138310.    137890.    137920.    138060.    138230.   1380880.
   ERROR                  -10.        40.        30.      -120.        30.       210.      -210.      -180.       -40.       130.      -120.
   PER CENT             -0.007      0.028      0.021     -0.086      0.021      0.152     -0.152     -0.130     -0.028      0.094     -0.008

 8 037814   145380.    144990.    144950.    145530.    144890.    144820.    144860.    144930.    144950.    145000.    144960.   1449880.
   ERROR                 -390.      -430.       150.      -490.      -560.      -520.      -450.      -430.      -380.      -420.     -3920.
   PER CENT             -0.268     -0.295      0.103     -0.337     -0.385     -0.357     -0.309     -0.295     -0.261     -0.288     -0.270
                          *          *                     *          *          *          *          *          *          *
 9 098155   257660.    258240.    257850.    258050.    257780.    257920.    258030.    258070.    257860.    257600.    257710.   2579110.
   ERROR                  380.       -10.       130.       -80.        60.       170.       210.         0.      -260.      -150.       510.
   PER CENT              0.147     -0.003      0.073     -0.031      0.023      0.065      0.081      0.000     -0.100     -0.058      0.019

10 091125   252500.    252620.    252700.    252830.    252910.    252750.    252150.    252670.    252840.    252890.    252670.   2527030.
   ERROR                  120.       200.       330.       410.       250.      -350.       170.       340.       390.       170.      2030.
   PER CENT              0.047      0.079      0.130      0.162      0.099     -0.138      0.067      0.134      0.154      0.067      0.080

TOT WGT    1517240.   1517490.   1516480.   1517810.   1517210.   1517180.   1516990.   1517020.   1517680.   1517330.   1517020.
ALG ERR                   250.      -760.       570.       -30.       -60.      -250.      -220.       440.        90.      -220.
PER CNT                  0.016     -0.050      0.037     -0.001     -0.003     -0.016     -0.014      0.029      0.005     -0.014

          TOT REF WGT   15172400.              DEVIATION IN --- 100  WGTS   PCNT          ALLOW  ACTUAL  PCNT OF TOT WGTS
          TOT MOT WGT   15172210.                                           OVER 0.200     30     14           14.0
          TOT ERR           -190.                                           OVER 0.500      5      0            0.0
          PCNT            -0.001                                            OVER 1.000   NONE      0            0.0
          MAX ALLOW        0.200               GROSS ERR     15850.
```

```
DIRECTION-  P      CODE=  P(PULL),S(SHOVE)-N,E,S,W                               DATE  MAY 20, 1975     TEST NO. 15

   CAR NO. REF WGT       RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=====================================================================================================================================
1  089439   237920.    237300.   237400.   237300.   237300.   237400.   237600.   237100.   237400.   237700.   236500.  2373000.
   ERROR                 -620.     -520.     -620.     -620.     -520.     -320.     -820.     -520.     -220.    -1420.    -6200.
   PER CENT            -0.260    -0.218    -0.260    -0.260    -0.218    -0.134    -0.344    -0.218    -0.092    -0.596    -0.261
                         *         *         *         *         *                   *         *                   *
2  044504   234900.    234900.   234300.   234600.   234800.   234800.   234200.   234600.   234500.   234700.   234600.  2346000.
   ERROR                   0.     -600.     -300.     -100.     -100.     -700.     -300.     -400.     -200.     -300.    -3000.
   PER CENT             0.000    -0.255    -0.127    -0.042    -0.042    -0.297    -0.127    -0.170    -0.085    -0.127    -0.127
                                   *                                       *
3  048690   215680.    216000.   216200.   215200.   215100.   215600.   215900.   216100.   216300.   216400.   215900.  2158700.
   ERROR                  320.      520.     -480.     -580.      -80.      220.      420.      620.      720.      220.     1900.
   PER CENT             0.148     0.241    -0.222    -0.268    -0.037     0.102     0.194     0.287     0.333     0.102     0.088
                                   *         *         *                                       *         *
4  048613   240320.    240100.   240200.   240200.   240200.   240100.   240600.   239800.   240000.   239900.   239500.  2400600.
   ERROR                 -220.     -120.     -120.     -120.     -220.      280.     -520.     -320.     -420.     -820.    -2600.
   PER CENT            -0.091    -0.049    -0.049    -0.049    -0.091     0.116    -0.216    -0.133    -0.174    -0.341    -0.108
                                                                                     *                             *
5  030691   191040.    191400.   191300.   191100.   191000.   191200.   191200.   191300.   191300.   191300.   191000.  1912100.
   ERROR                  360.      260.       60.      -40.      160.      160.      260.      260.      260.      -40.     1700.
   PER CENT             0.188     0.136     0.031    -0.020     0.083     0.083     0.136     0.136     0.136    -0.020     0.088

6  088107   206560.    206700.   206500.   206500.   206400.   206500.   206500.   206700.   206800.   206500.   206500.  2065600.
   ERROR                  140.      -60.      -60.     -160.      -60.      -60.      140.      240.      -60.      -60.        0.
   PER CENT             0.067    -0.029    -0.029    -0.077    -0.029    -0.029     0.067     0.116    -0.029    -0.029     0.000

7  088364   213500.    213600.   213500.   213400.   213700.   213400.   213500.   213400.   213500.   213500.   213500.  2135000.
   ERROR                  100.        0.     -100.      200.     -100.        0.     -100.        0.        0.        0.        0.
   PER CENT             0.046     0.000    -0.046     0.093    -0.046     0.000    -0.046     0.000     0.000     0.000     0.000

8  087710   188020.    187800.   187900.   187700.   187700.   187600.   187700.   187700.   187700.   187800.   187600.  1877200.
   ERROR                 -220.     -120.     -320.     -320.     -420.     -320.     -320.     -320.     -220.     -420.    -3000.
   PER CENT            -0.117    -0.063    -0.170    -0.170    -0.223    -0.170    -0.170    -0.170    -0.117    -0.223    -0.159
                                                               *                                                   *
9  121511   236580.    236800.   236700.   236700.   236800.   236700.   236600.   236800.   236700.   236900.   236800.  2367500.
   ERROR                  220.      120.      120.      220.      120.       20.      220.      120.      320.      220.     1700.
   PER CENT             0.092     0.050     0.050     0.092     0.050     0.008     0.092     0.050     0.135     0.092     0.071

10 771815   100000.     99700.   100100.    99900.   100200.   100100.   100000.    99900.   100000.   100000.    99900.   999800.
   ERROR                 -300.      100.     -100.      200.      100.        0.     -100.        0.        0.     -100.     -200.
   PER CENT            -0.300     0.100    -0.100     0.200     0.100     0.000    -0.100     0.000     0.000    -0.100    -0.020
                         *
TOT WGT    2064520.   2064300.  2064100.  2062600.  2063200.  2063400.  2063800.  2063400.  2064200.  2064700.  2061800.
ALG ERR                  -220.     -420.    -1920.    -1320.    -1120.     -720.    -1120.     -320.      180.    -2720.
PER CNT                -0.010    -0.020    -0.092    -0.063    -0.054    -0.034    -0.054    -0.015     0.008    -0.131

         TOT REF WGT   20645200.          DEVIATION IN --- 100  WGTS   PCNT        ALLOW  ACTUAL  PCNT OF TOT WGTS
         TOT MOT WGT   20635500.                                      OVER 0.200    30     20              20.0
         TOT ERR          -9700.                                      OVER 0.500     5      1               1.0
         PCNT             -0.046                                      OVER 1.000  NONE     0               0.0
         MAX ALLOW         0.200          GROSS ERR     25740.
```

```
DIRECTION-        CODE=  P(PULL),S(SHOVE)-N,E,S,W                        DATE  MAY 20, 1975     TEST NO. 16

    CAR NO. REF WGT      RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=====================================================================================================================================
 1  069620  186800.    186800.   187100.   187100.   187000.   186900.   187100.   187100.   186900.   186900.        0.  1682900.
    ERROR                   0.      300.      300.      200.      100.      300.      300.      100.      100.        0.     1700.
    PER CENT            0.000     0.160     0.160     0.107     0.053     0.160     0.160     0.053     0.053     0.000     0.101

 2  225516  248950.    249400.   248600.   248100.   249000.   249100.   248900.   248300.   248900.   248700.        0.  2239000.
    ERROR                 450.     -350.     -850.       50.      150.      -50.     -650.      -50.     -250.        0.    -1550.
    PER CENT            0.180    -0.140    -0.341     0.020     0.060    -0.020    -0.261    -0.020    -0.100     0.000    -0.069
                                             *                                       *
 3  130583  253400.    253300.   253000.   253600.   253200.   253300.   253600.   253900.   253400.   253300.        0.  2280600.
    ERROR                -100.     -400.      200.     -200.     -100.      200.      500.        0.     -100.        0.        0.
    PER CENT           -0.039    -0.157     0.078    -0.078    -0.039     0.078     0.197     0.000    -0.039     0.000     0.000

 4  230291  256450.    256700.   256000.   256000.   256200.   256500.   256300.   256700.   256200.   256200.        0.  2306800.
    ERROR                 250.     -450.     -450.     -250.       50.     -150.      250.     -250.     -250.        0.    -1250.
    PER CENT            0.097    -0.175    -0.175    -0.097     0.019    -0.058     0.097    -0.097    -0.097     0.000    -0.054

 5  276578  206200.    207400.   207200.   206700.   207000.   206700.   206900.   206200.   206500.   207000.        0.  1861600.
    ERROR                1200.     1000.      500.      800.      500.      700.        0.      300.      800.        0.     5800.
    PER CENT            0.581     0.484     0.242     0.387     0.242     0.339     0.000     0.145     0.387     0.000     0.311
                         *         *         *         *         *         *                             *
 6  629870  168050.    168100.   168100.   168200.   168100.   168200.   168300.   168100.   168300.   168400.        0.  1513800.
    ERROR                  50.       50.      150.       50.      150.      250.       50.      250.      350.        0.     1350.
    PER CENT            0.029     0.029     0.089     0.029     0.089     0.148     0.029     0.148     0.208     0.000     0.089
                                                                                                         *
 7  228687  260450.    260900.   260700.   261700.   260500.   260800.   261700.   261700.   261300.   260800.        0.  2350100.
    ERROR                 450.      250.     1250.       50.      350.     1250.     1250.      850.      350.        0.     6050.
    PER CENT            0.172     0.095     0.479     0.019     0.134     0.479     0.479     0.326     0.134     0.000     0.257
                                             *                             *         *         *
 8  060019  260000.    260000.   260500.   260300.   260300.   260400.   260600.   260500.   260500.   260400.        0.  2343500.
    ERROR                   0.      500.      300.      300.      400.      600.      500.      500.      400.        0.     3500.
    PER CENT            0.000     0.192     0.115     0.115     0.153     0.230     0.192     0.192     0.153     0.000     0.149
                                                                           *
 9  674685  203600.    202900.   202900.   203200.   202800.   203100.   203200.   203300.   202900.   203000.        0.  1827300.
    ERROR                -700.     -700.     -400.     -800.     -500.     -400.     -300.     -700.     -600.        0.    -5100.
    PER CENT           -0.343    -0.343    -0.196    -0.392    -0.245    -0.196    -0.147    -0.343    -0.294     0.000    -0.279
                         *         *                   *         *                             *         *
10  632443  163150.    163100.   162800.   163000.   162900.   163000.   163000.   162900.   162800.   163100.        0.  1466600.
    ERROR                 -50.     -350.     -150.     -250.     -150.     -150.     -250.     -350.      -50.        0.    -1750.
    PER CENT           -0.030    -0.214    -0.091    -0.153    -0.091    -0.091    -0.153    -0.214    -0.030     0.000    -0.119
                                   *                                                           *
11  278100  200700.    200400.   200300.   200300.   200200.   200200.   200400.   200400.   200300.   200300.        0.  1802800.
    ERROR                -300.     -400.     -400.     -500.     -500.     -300.     -300.     -400.     -400.        0.    -3500.
    PER CENT           -0.149    -0.199    -0.199    -0.249    -0.249    -0.149    -0.149    -0.199    -0.199     0.000    -0.194
                                                       *         *
12  060020   60000.     59900.    59800.    59900.    59900.    59900.    59900.    59900.    59800.    59900.        0.   538900.
    ERROR                -100.     -200.     -100.     -100.     -100.     -100.     -100.     -200.     -100.        0.    -1100.
    PER CENT           -0.166    -0.333    -0.166    -0.166    -0.166    -0.166    -0.166    -0.333    -0.166     0.000    -0.204
                                   *                                                           *
TOT WGT    2467750.   2468900.  2467000.  2468100.  2467100.  2468100.  2469900.  2469000.  2467800.  2468000.        0.
AVG ERR                  1150.     -750.      350.     -650.      350.     2150.     1250.       50.      250.        0.
PER CNT                 0.046    -0.030     0.014    -0.026     0.014     0.087     0.050     0.002     0.010     0.000

          TOT REF WGT  22209750.           DEVIATION IN --- 108  WGTS   PCNT         ALLOW  ACTUAL  PCNT OF TOT WGTS
          TOT MOT WGT  22213900.                                        OVER 0.200   32     27            25.0
          TOT ERR          4150.                                        OVER 0.500    5      1             0.9
          PCNT             0.018                                        OVER 1.000 NONE      0             0.0
          MAX ALLOW        0.200           GROSS ERR     36850.
```

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DIRECTION-      CODE=  P(PULL),S(SHOVE)-N,E,S,W                                         DATE   MAY 20, 1975     TEST NO. 17

    CAR NO. REF WGT     RUN 1     RUN 2     RUN 3     RUN 4     RUN 5     RUN 6     RUN 7     RUN 8     RUN 9    RUN 10       TOT
=====================================================================================================================================
 1  018170  189480.   189560.   188940.   189040.   189660.   189840.   189470.   189460.   189400.   188680.   189620.  1893670.
    ERROR                 80.     -540.     -440.      180.      360.      -10.      -20.      -80.     -800.      140.    -1130.
    PER CENT           0.042    -0.284    -0.232     0.094     0.189    -0.005    -0.010    -0.042    -0.422     0.073    -0.059
                                  *         *                                                             *
 2  075313  191200.   191580.   191560.   191430.   192080.   190850.   191540.   191500.   191420.   191300.   191300.  1914560.
    ERROR                380.      360.      230.      880.     -350.      340.      300.      220.      100.      100.     2560.
    PER CENT           0.198     0.188     0.120     0.460    -0.183     0.177     0.156     0.115     0.052     0.052     0.133
                                                      *
 3  133550  165400.   165610.   165320.   165380.   165580.   165340.   165440.   165440.   165320.   165220.   165420.  1654070.
    ERROR                210.      -80.      -20.      180.      -60.       40.       40.      -80.     -180.       20.       70.
    PER CENT           0.126    -0.048    -0.012     0.108    -0.036     0.024     0.024    -0.048    -0.108     0.012     0.004

 4  133138  173820.   174200.   173860.   174040.   173580.   174060.   174060.   173980.   174000.   173980.   173820.  1739580.
    ERROR                380.       40.      220.     -240.      240.      240.      160.      180.      160.        0.     1360.
    PER CENT           0.218     0.023     0.126    -0.138     0.138     0.138     0.092     0.103     0.092     0.000     0.079
                        *
 5  155954  194980.   194780.   195060.   194920.   194940.   194660.   194940.   195000.   195130.   194960.   195000.  1949390.
    ERROR               -200.       80.      -60.      -40.     -320.      -40.       20.      150.      -20.       20.     -410.
    PER CENT          -0.102     0.041    -0.030    -0.020    -0.164    -0.020     0.010     0.076    -0.010     0.010    -0.021

 6  155198  196240.   196450.   196580.   196300.   196600.   196460.   196200.   196640.   196220.   196240.   196540.  1964230.
    ERROR                210.      340.       60.      360.      220.      -40.      400.      -20.        0.      300.     1830.
    PER CENT           0.107     0.173     0.030     0.183     0.112    -0.020     0.203    -0.010     0.000     0.152     0.093
                                                                                  *
 7  184166  207660.   207440.   207300.   207020.   207360.   207100.   207140.   207180.   207200.   207120.   207020.  2071880.
    ERROR               -220.     -360.     -640.     -300.     -560.     -520.     -480.     -460.     -540.     -640.    -4720.
    PER CENT          -0.105    -0.173    -0.308    -0.144    -0.269    -0.250    -0.231    -0.221    -0.260    -0.308    -0.227
                                            *                   *         *         *         *         *         *
 8  185504  198540.   198060.   198020.   197990.   198180.   198000.   198140.   198100.   198180.   198320.   198140.  1981130.
    ERROR               -480.     -520.     -550.     -360.     -540.     -400.     -440.     -360.     -220.     -400.    -4270.
    PER CENT          -0.241    -0.261    -0.277    -0.181    -0.271    -0.201    -0.221    -0.181    -0.110    -0.201    -0.215
                        *         *         *                   *         *         *                             *
 9  137574  168900.   168640.   169140.   168940.   169160.   168900.   168800.   168880.   168980.   169100.   168980.  1689520.
    ERROR               -260.      240.       40.      260.        0.     -100.      -20.       80.      200.       80.      520.
    PER CENT          -0.153     0.142     0.023     0.153     0.000    -0.059    -0.011     0.047     0.118     0.047     0.030

10  136335  169560.   169620.   169490.   169500.   169360.   169260.   169240.   169300.   169460.   169340.   169240.  1693810.
    ERROR                 60.      -70.      -60.     -200.     -300.     -320.     -260.     -100.     -220.     -320.    -1790.
    PER CENT           0.035    -0.041    -0.035    -0.117    -0.176    -0.188    -0.153    -0.058    -0.129    -0.188    -0.105

TOT WGT    1855780.  1855940.  1855270.  1854560.  1856500.  1854470.  1854970.  1855480.  1855310.  1854260.  1855080.
ALG ERR                  160.     -510.    -1220.      720.    -1310.     -810.     -300.     -470.    -1520.     -700.
PER CNT                0.008    -0.027    -0.065     0.038    -0.070    -0.043    -0.016    -0.025    -0.081    -0.037

        TOT REF WGT   18557800.        DEVIATION IN --- 100  WGTS    PCNT           ALLOW   ACTUAL   PCNT OF TOT WGTS
        TOT MOT WGT   18551840.                                      OVER 0.200        30       20            20.0
        TOT ERR          -5960.                                      OVER 0.500         5        0             0.0
        PCNT            -0.032                                       OVER 1.000      NONE        0             0.0
        MAX ALLOW        0.200         GROSS ERR      23760.
```

```
  TESTS---           27.  WGTS----          2707.  0.200---        503.
  0.500---           27.  1.00----             0.  REF WGT-   416770950.
  ERROR---        22065.  PER CAR-             8.  GROSS ERR     504745.
  MOT WGT     416793015.  GROSS ERR CAR      186.

 TST WGTS   PCNT OVER 0.2  OVER 0.5  OVER 1.0     REF   WGT       NET ERR  PCNT ERR   GROSS ERR

  11.   100         16.00      5.00      0.00    13703000.       -4300.    -0.031     16300.
  12.   100         20.00      5.00      0.00    13703000.        7600.     0.055     15600.
  20.   100         12.00      0.00      0.00    15445400.       -1360.    -0.008     18560.
  31.   100         24.00      0.00      0.00    10952800.       -5590.    -0.051     14410.
  32.   100         29.00      0.00      0.00    10952800.       -6000.    -0.054     16420.
  40.   100          8.00      0.00      0.00    19617000.       13200.     0.067     21800.
  50.   100          6.00      0.00      0.00    19511800.        1110.     0.005     16690.
  60.   100         23.00      3.00      0.00    11797400.       -1260.    -0.010     16220.
  70.   100         10.00      0.00      0.00    20252000.       -5200.    -0.025     21780.
  81.   100         19.00      1.00      0.00    12785800.        3190.     0.024     15830.
  82.   100         27.00      3.00      0.00    12785800.        3590.     0.028     18470.
  83.   100         18.00      0.00      0.00    12710900.        3050.     0.023     13830.
  90.   100         21.00      0.00      0.00    18944100.         580.     0.003     21940.
 100.    99         20.20      4.04      0.00    12852000.        1800.     0.014     16200.
 111.   100         23.00      1.00      0.00    12928800.       -1100.    -0.008     20540.
 112.   100         29.00      1.00      0.00    12928800.         400.     0.003     17840.
 113.   100         35.00      0.00      0.00    12928800.       20900.     0.161     24940.
 114.   100         18.00      0.00      0.00    12928800.        1200.     0.009     14120.
 121.   100         15.00      0.00      0.00    15084400.        2030.     0.013     15070.
 122.   100         17.00      2.00      0.00    15084400.       -1095.    -0.007     13245.
 130.   100         20.00      0.00      0.00    18557800.      -11130.    -0.059     23970.
 141.   100          5.00      0.00      0.00    15172400.        4020.     0.026     13440.
 142.   100         14.00      0.00      0.00    15172400.        -190.    -0.001     15850.
 150.   100         20.00      1.00      0.00    20645200.       -9700.    -0.046     25740.
 160.   108         25.00      0.92      0.00    22209750.        4150.     0.018     36850.
 170.   100         20.00      0.00      0.00    18557800.       -5960.    -0.032     23760.
 180.   100          7.00      0.00      0.00    18557800.        8130.     0.043     15330.

                                                                127835.
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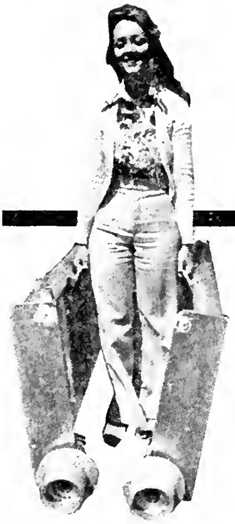

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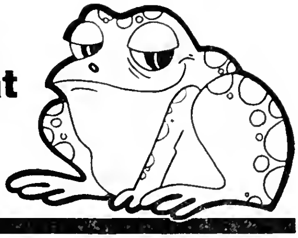

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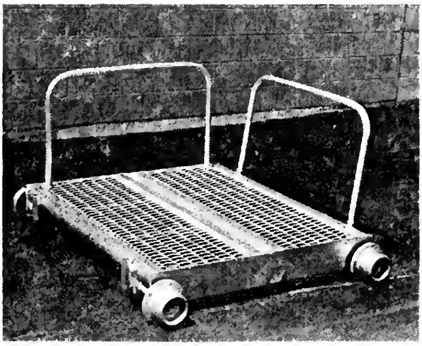

Safetran M-5000 Specifications

Weight Capacity	5000 lbs.
Frame Construction	Heavy duty aluminum plate
Deck	Heavy, expandable aluminum
Wheels	Cast aluminum – fully insulated
Bearing	Ball, pre-greased and sealed
Deck Size	52½" x 47"
Total Weight	156 lbs. (78 lbs. per section)
Height	7½" (above rail)
Handles	2 preshaped aluminum – inter-changeable
Construction	All welded

Ordering Reference: Model-5000 Track Car
Part No. 140230-X

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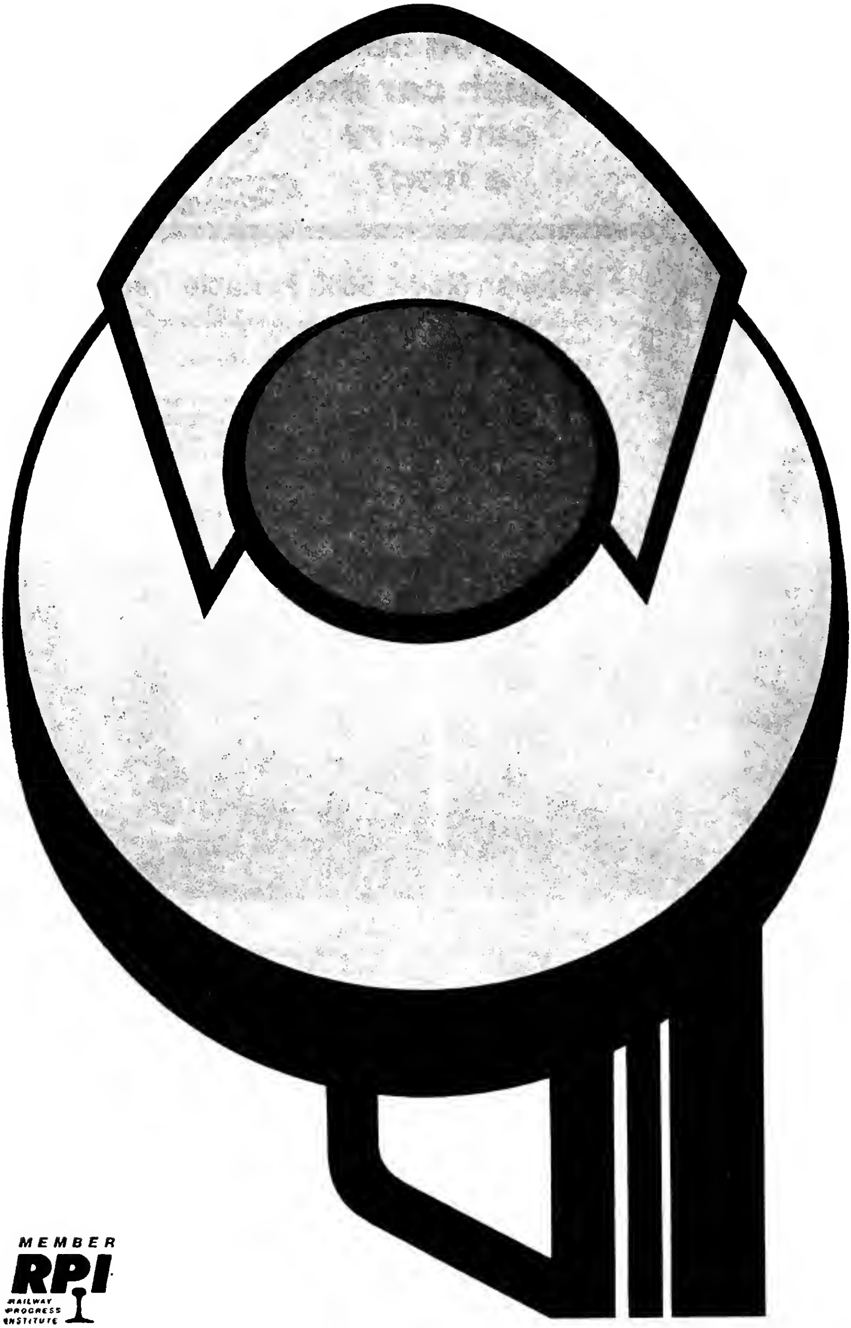

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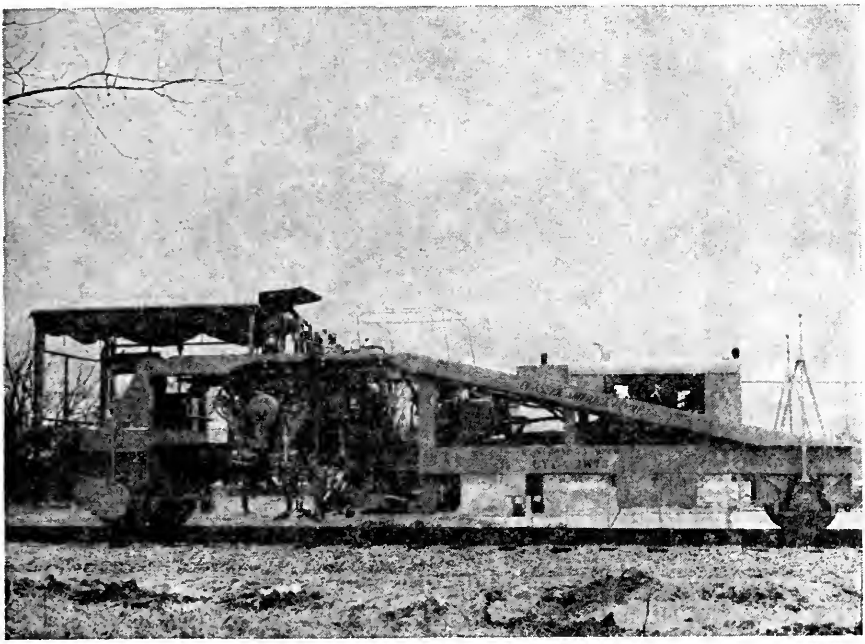


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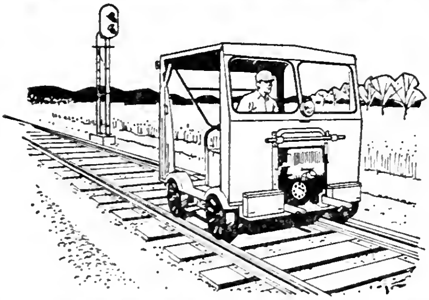

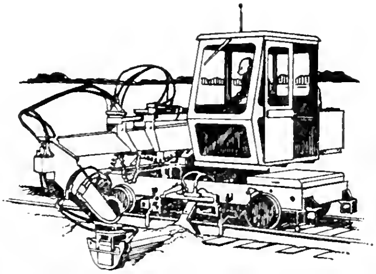

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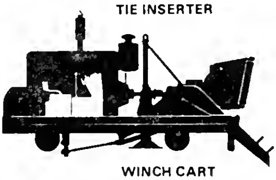

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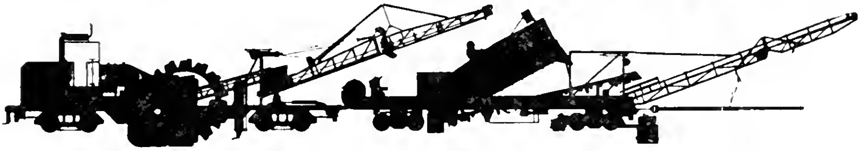

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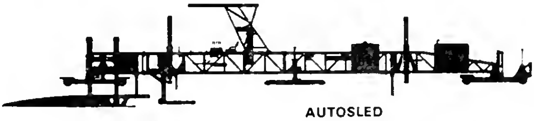

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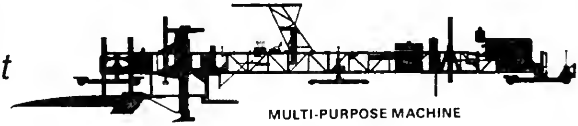

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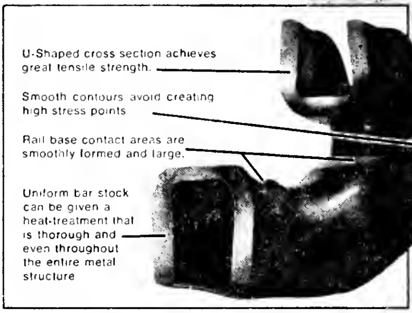
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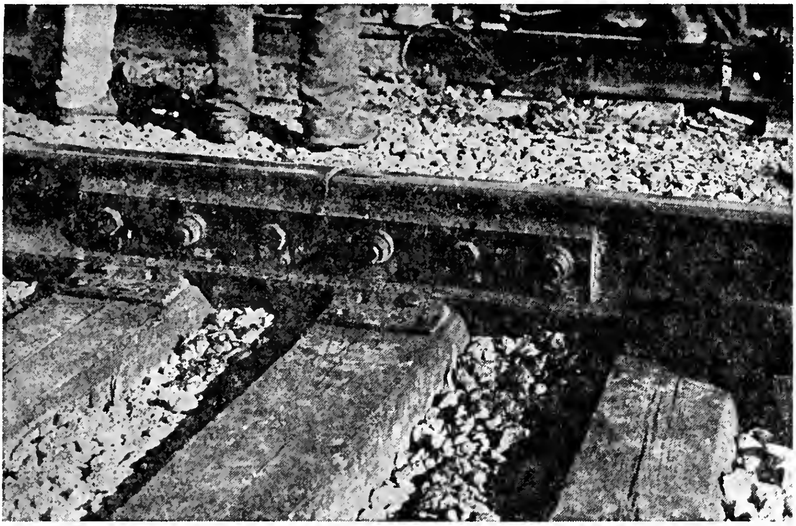
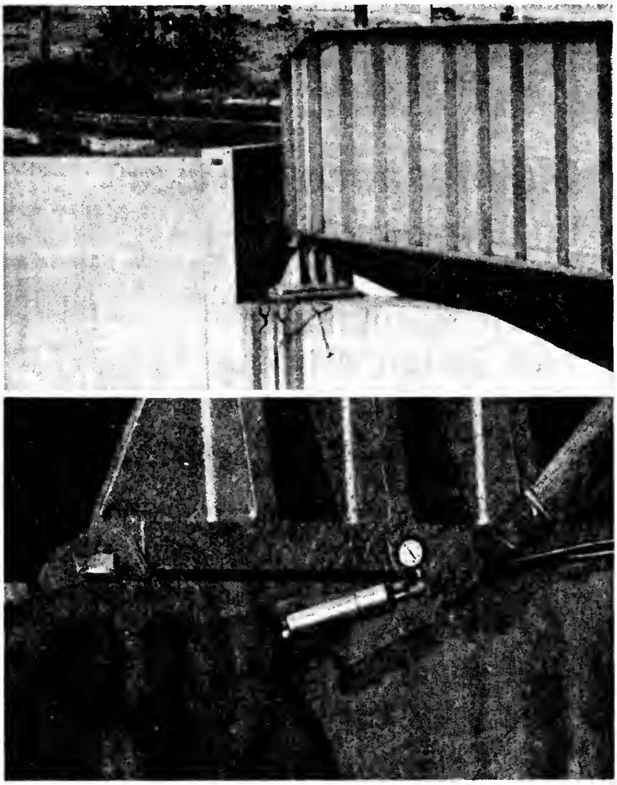
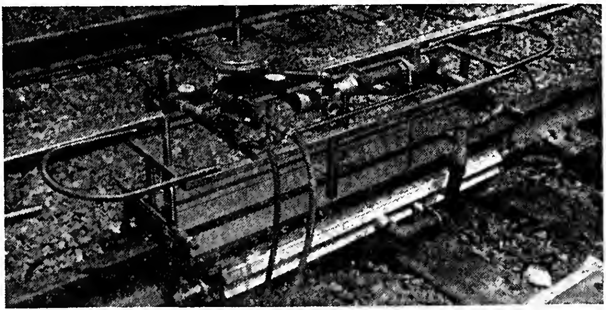






Advance Report of Committee 4—Rail

Report on Assignment 5

Rail Research and Development

W. J. CRUSE *(chairman, subcommittee)*, B. G. ANDERSON, R. M. BROWN, E. T. FRANZEN, R. E. GORSUCH, R. E. HAACKE, V. E. HALL, W. H. HUFFMAN, T. B. HUTCHESON, K. H. KANNOWSKI, W. S. LOVELACE, A. B. MERRITT, JR., J. L. MERRITT, C. O. PENNEY, I. A. REINER, W. A. SMITH.

Your committee presents, as information, the following report on the second annual inspection of a service test installation of fully heat-treated, induction head-hardened, intermediate-manganese and standard control-cooled rail on the Chessie System. The author of the report is K. W. Schoeneberg, senior research engineer, Research and Test Department, Association of American Railroads.

SUMMARY OF PERFORMANCE OF STANDARD-CARBON AND VARIOUS WEAR-RESISTANT RAILS IN TEST CURVES ON THE CHESSIE SYSTEM SECOND REPORT

By K. W. Schoeneberg

I—ABSTRACT

This report summarizes the second annual inspection of a service test installation of fully heat-treated, induction head-hardened, intermediate-manganese and standard control-cooled rail on the Chessie System.

The field inspection is part of the cooperative effort on rail research of the American Railway Engineering Association (AREA), the American Iron and Steel Institute (AISI) and the Association of American Railroads (AAR) to observe and analyze those rails in curved track that display some potential for improvement in wear-resistance and retarding the onset of shelling.

Measurements were made and recorded of curvature, superelevation and gage of four service test curves located near Oakland, Maryland. General track conditions were observed also. Rail head cross-section contours were taken and recorded of the 80 test rails contained in these curves. Rail wear has been calculated for the second year of service for the various types of rail in test.

II—ACKNOWLEDGEMENT

Appreciation is hereby acknowledged of the original invitation of J. T. Collinson, then general manager–chief engineer, now vice president–operations and maintenance, Chessie System; and the continued invitation of J. W. Brent, chief engineer, and A. L. Maynard, formerly engineer maintenance of way, now director–engineering administration, Chessie System, for the AAR, AISI and AREA to participate with Chessie on the inspection and evaluation of their rail service test installation. Sincere appreciation is expressed by those of AAR, AISI and AREA for the time and efforts rendered by Chessie personnel listed below in the preparation and conduct of this inspection.

Inspection of the rail in the four service test curves near Oakland, Maryland was made on July 30, 1974. The following individuals were in the inspection party:

A. L. Maynard —Chessie System
A. J. Kozak —Chessie System
M. Hawtof —Chessie System
D. S. Young —Chessie System
I. A. Reiner —Chessie System
W. H. Chidley —American Iron and Steel Institute
G. G. Knupp —Bethlehem Steel Corporation
J. H. Martens —Bethlehem Steel Corporation
J. L. Giove —U. S. Steel Corporation
D. L. Saxon —U. S. Steel Corporation
G. H. Way —Association of American Railroads
K. W. Schoeneberg—Association of American Railroads

III—INTRODUCTION

As part of the programs on rail research, the AAR Research and Test Department is continuing the field study and analysis of those rails that continue in service which show some potential for improvement in curve wear resistance and ability to retard the onset of shelling. Rails that are heat-treated, have a variance in chemical composition from that of standard rail or which are unconventionally produced are part of this study.

The field inspections are carried out as a cooperative effort of the Rail Research and Development Subcommittee of AREA Committee 4–Rail, the AISI Technical Subcommittee on Rail and Accessories, the AAR Research and Test Department and the railroad on whose property the test rails are installed.

Through this and several other field service tests presently being progressed by these organizations, rail wear data as well as tonnage, track component, roadbed and environment data are being generated. The correlation of these data will result in the development of rail wear rates for various combinations of track and service conditions. A further correlation of these rail wear rates with other rail metallurgical and economic studies data can set forth, as an end product, criteria or recommendations establishing the appropriate selection of rail by section (weight) and kind (standard, alloy or heat-treated) to be used by the railroads at locations of high wear or short calendar rail life.

IV—DESCRIPTION OF TEST RAILS

The Chessie System established the service test of heat-treated, alloy and standard rail on July 7, 10 and 11, 1972, when the rails were installed in four curves on its No. 2 or eastbound main track west of Oakland, Maryland. A total of 80 rails consisting of 16 each of the five following types were used:

(1) 140 R E fully heat-treated
(2) 140 R E head-hardened
(3) 140 R E intermediate-manganese
(4) 140 R E standard-carbon control-cooled—A
(5) 140 R E standard-carbon control-cooled—B

Four rails of each type were laid out for each of the four different curves, two on the high side and two on the low side of each curve. The rails were randomly welded together in 10 rail strings by the electric-flash butt method. These continuously welded strings were then installed in the curves, one on the high side and one opposite on the low side of each of the four curves. The four test curves chosen for this test are of varying nominal curvature and superelevation as follows:

Curve No. 1, 5°—50′ (299.5 m radius)—4½ in (114.3 mm) superelevation
Curve No. 2, 8°—28′ (206.5 m radius)—5 in (127.0 mm) superelevation
Curve No. 3, 4°—00′ (436.6 m radius)—2½ in (63.0 mm) superelevation
Curve No. 4, 8°—08′ (214.9 m radius)—5 in (127.0 mm) superelevation

Figures 1 through 4 show detailed information of location, curve layout and placement of the various types of rails in each of the four test curves.

V—CONDUCT OF THE INSPECTION

The inspection party examined all test rails in each of the four test curves, noting the condition of each rail as well as noting line and level of the track and conditions of the other track components. Rail head cross-section contours were taken at approximately the midpoint of each of the 80 test rails. The wear pattern of each is shown in Figures 5 through 24. The gage of the track was measured and recorded at the locations where the rail head contours were taken. These are also shown in Figures 5 through 24.

Stringlining measurements were made to check the degree of curvature of each curve, particularly in the body of the curves where the test rails were located, as a means of verifying the original degree of curvature and a check for any gross misalignment. The curvature measurement taken at each of the test rail locations is shown in Figures 5 through 24.

Superelevation measurements were also made throughout each curve and these measurements are also shown for each test rail location in Figures 5 through 24.

VI—RESULTS OF THE INSPECTION

The four curves and the track through this location appear, as was the case at the first inspection, to be well maintained and in good condition. Drainage of the roadbed and ballast section was generally good with the exception of one location on curve No. 2 where a muddy pumping ballast condition existed on the low or inside of the curve.

The rail lubricators, noted as distributing generally heavy to moderate amounts of lubricant as of the 1973 inspection, appeared to be inoperative at the time of this inspection because of the lack of lubricant on the rails of all four test curves.

Specific observations of rail conditions of each curve were noted as follows:

Curve No. 1

Head checks were noted on high side rails 94L143 D20, CT08943 C21 and CT08943 B10.

Curve No. 2

Rail 81L707 E38 had head checks and light flaking spots. Rail 59R647 C26 showed light flaking and rail CT08943 C22 had some head checks. Rail 85R812

E21 had one light flaking spot on the receiving end. Rail IM19010 D6 had continuous light flaking 6 ft of leaving (east) end.

Heavy wear was noted in rail IM19010 B9 and irregular wear pattern in rails CT07952 D17 and IM19010 D6 from apparent truck hunting, probably induced by low-side soft, muddy, pumping areas.

High-side rail 181332 G16 was not seated into tie plates.

Curve No. 3

Head checks were noted in rails CT07952 B17 and 94L143 B20. Head checks and light flaking spots were noted in rails IM19010 D1 and 63M022 E16.

Slightly abnormal batter was noted at welded joints at each end of fully heat-treated rail CT08943 B16 where it joined standard rails.

There were slight indications of corrugations on high-side rail 181332 D4.

Heavy flow at end, and fin on field side appeared on rail 71R078 C27 in low side of curve, opposite above-mentioned corrugated rail.

Sliver spots in rail 94L143 D9 and several heavy slivers near middle of rail 94L143 C24 were noted.

Curve No. 4

The "raspy" early feeling of head checks was noted on most rails in high side of curve.

Intermittent very light flaking spots were noted on rail 59R647 C23 in high side of curve.

Initial indication of high-side corrugations was noted in oblique light in rails 85R812 D20 and 181332 H18.

There was a small sliver on field side of head at middle of rail 94L143 D14, and a sliver depression 3 ft from west end of rail 94L143 D17.

From visual observation at the time of the inspection and then by study of the rail head contour tracings of all four curves, more metal flow was noted on almost all inside or low rails, and more curve wear was noted on the high rails than there was at the time of the 1973 inspection. In like manner, more metal flow and curve wear were noted in the intermediate-manganese and standard rails than in the head-hardened or fully heat-treated rails.

VII—DISCUSSION

The track containing the test rails carries predominantly eastbound manifest mixed freight and unit coal trains. During the first year the test rails were in service, August 1972 through July 1973, tonnage over this territory was 14.6 million gross tons. During the second year of test service, from August, 1973 through July 1974, the tonnage was 16.3 million gross tons. Thus a total of 30.9 million gross tons of traffic has been over these rails since they were laid in track in July 1972.

Based on a comparison of the rail head contours taken in July 1973 (after one year of service) and those taken in July 1974 (after the second year of service) the change or increase in rail wear, during this second year, was plotted and calculated by planimeter readings. From these, calculations were made of the amount (square inches) of rail wear and percent of rail wear. These values representing rail head metal worn away during the second year of service are thus shown for each rail head cross-section in Figures 5 through 24.

As noted previously, each of the four test curves contained four rails of the same type, two in the low side and two in the high side. From the calculations made of the amount of rail head metal worn away of each rail, the average of each type of rail on each curve on the high side and the low side was calculated.

In general, most of the test rails of the five types of rail on the low side of each of the curves displayed a marked increase of metal flow between the 1973 and the 1974 inspections. They showed increases of from light to medium and from medium to heavy metal flow to the field side during this second year of service. It can be noted that in some cases a lip formed, indicating metal flow to the gage side also. In only three head-hardened rails and two fully heat-treated rails a stable or non-increase in metal flow was noted.

Because, in this rail study, we are particularly interested in the wear characteristics of the high rail, the average amount of wear in square inches as well as the corresponding percent of wear of the two rails of each type in the high rail of each of the curves is shown in Table I. The average amount (square inches) of head wear versus the average curvature of these two representative rails of each type are shown graphically in Figure 25.

It can be noted that, with the exception of the intermediate-manganese rail, the standard, head-hardened and fully heat-treated rails displayed a trend of even or very slightly increasing amounts of wear for the nominal 4-, 6- and 8-degree curves, respectively. The intermediate-manganese rail showed an increase of wear on the nominal 6-degree curve versus the nominal 4-degree curve with a slight decrease in wear on the nominal 8-degree curve. All rails display a sharp increase in wear between the nominal 8 and the nominal 8½-degree curve with the exception of one of the standard type rails.

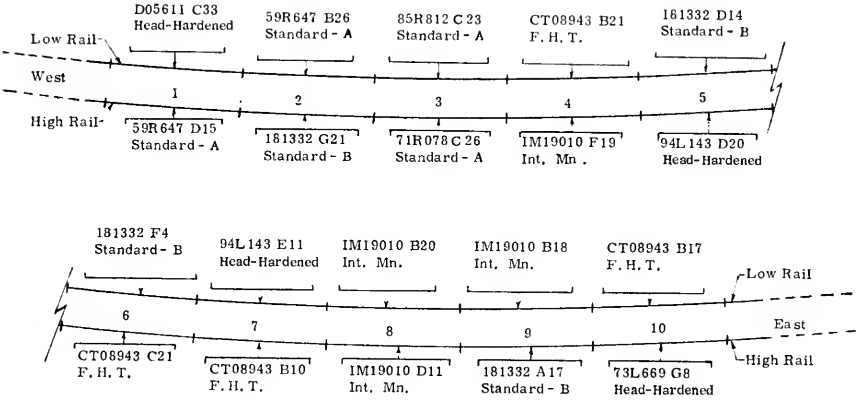
VIII—CONCLUSIONS

In general, low-rail wear and metal flow and high-rail curve wear has conformed to a pattern of more wear and flow in the standard and intermediate-manganese type rails and less wear and flow in the treated products such as head-hardened and fully heat-treated rails.

The amounts of wear recorded particularly in the high rails did not conform to a consistent pattern, but were erratic even with an averaging approach. Again, in general, the treated type rails did perform better than the others with the exception of the one standard type rail showing slightly less wear on the nominally 8½-degree curve than the head-hardened and the fully heat-treated rails.

The rather erratic wear pattern was evident also when comparison was made between the nominal degrees of curvature of the four test curves and the average wear of each of the five types of rail in test. The rather constant or slightly increasing average amount of wear calculated for the nominal 4-, 6- and 8-degree curves in contrast with the sharp increase for the nominal 8½-degree curve could possibly have been caused by or resulted from train speeds and the variations of curvature and superelevation as noted and recorded at the individual test rails in each of the curves.

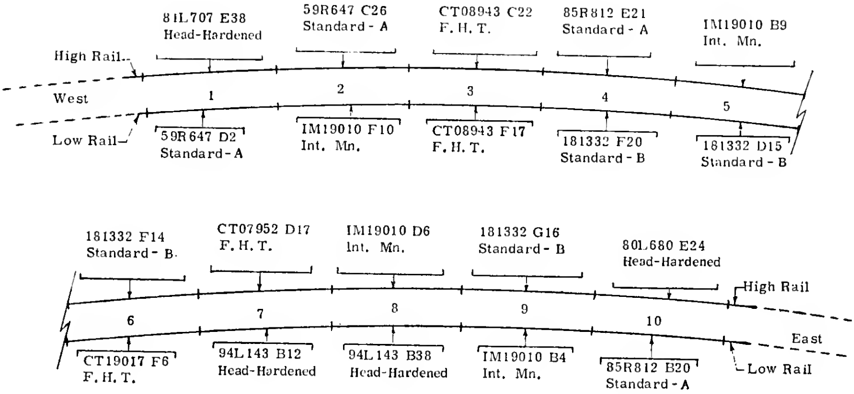
CHESSIE SYSTEM RAIL TEST
NEAR OAKLAND, MARYLAND



LAYOUT OF 140 LB. RE TEST RAILS - CURVE NO. 1
NOMINAL 5°-50' CURVE (299. 5 m RADIUS)— 4-1/2 IN. SUPERELEVATION (114. 3 mm) NOMINAL
MILE POST 233. 1

FIGURE 1

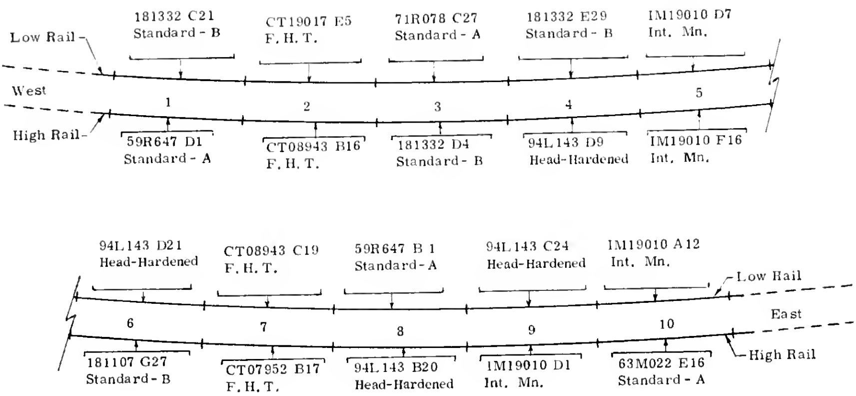
CHESSIE SYSTEM RAIL TEST
NEAR OAKLAND, MARYLAND



LAYOUT OF 140 LB. RE TEST RAILS - CURVE NO. 2
NOMINAL 8°-28' CURVE (206.5 m RADIUS) — 5 IN. SUPERELEVATION (127. 0 mm) NOMINAL
MILE POST 233. 2

FIGURE 2

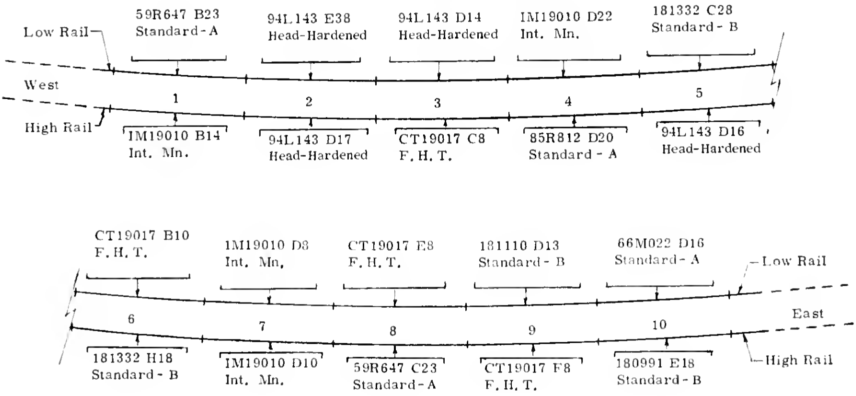
CHESSIE SYSTEM RAIL TEST
NEAR OAKLAND, MARYLAND



LAYOUT OF 140 LB. RE TEST RAILS - CURVE NO. 3
NOMINAL 4°-00' CURVE (436.6 m RADIUS) — 2-1/2 IN. SUPERELEVATION (63.5 mm) NOMINAL
MILE POST 234.0

FIGURE 3

CHESSIE SYSTEM RAIL TEST
NEAR OAKLAND, MARYLAND



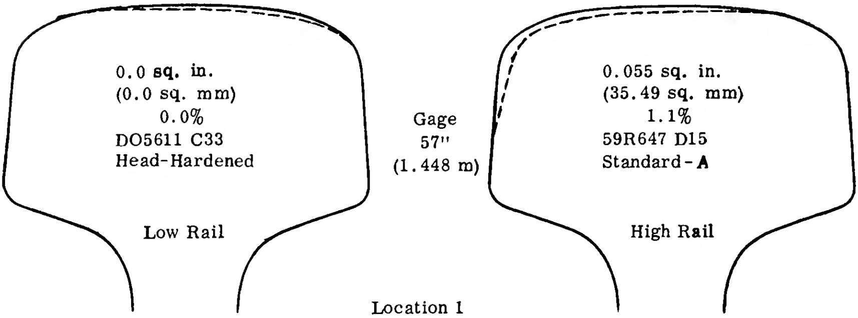
LAYOUT OF 140 LB. RE TEST RAILS - CURVE NO. 4
NOMINAL 8°-08' CURVE (214.9 m RADIUS)— 5 IN. SUPERELEVATION (127.0 mm) NOMINAL
MILE POST 235.0

FIGURE 4

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 1 - MILE POST 233.1

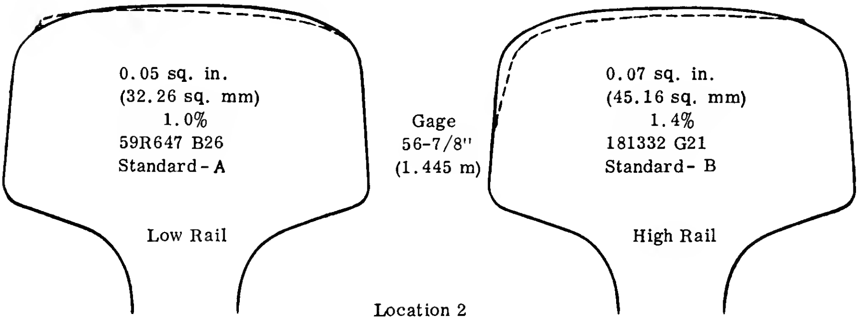
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 1

Curvature 6° - 08' (284.9 m radius) - Superelevation 4 5/8 in. (117.5 mm)



Location 2

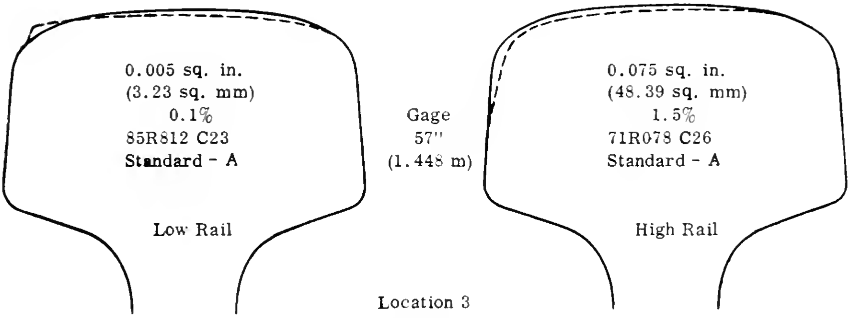
Curvature 6° - 08' (284.9 m radius) - Superelevation 4 7/8 in. (123.8 mm)

FIGURE 5

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 1 - MILE POST 233.1

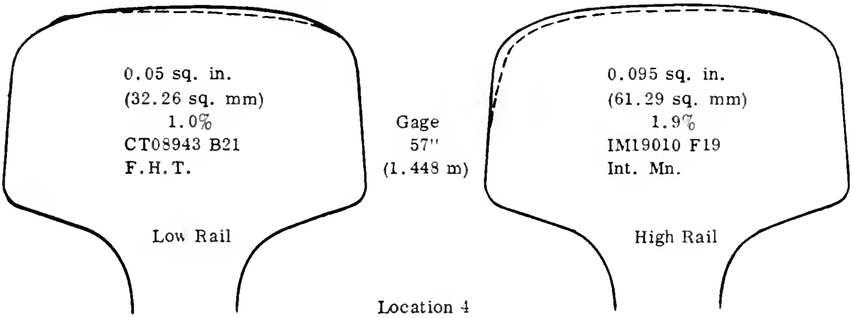
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 3

Curvature 6^{o} - 22' (274.4 m radius) - Superelevation 4/78 in. (123.8 mm)



Location 4

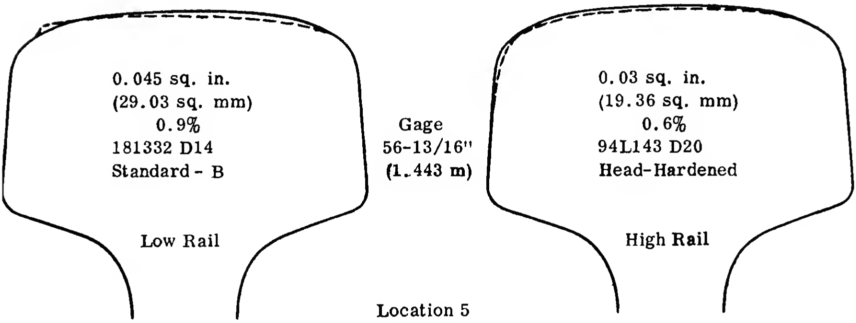
Curvature 6^{o} - 15' (279.6 m radius) - Superelevation 4 7/8 in. (124.8 mm)

FIGURE 6

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 1 - MILE POST 233.1

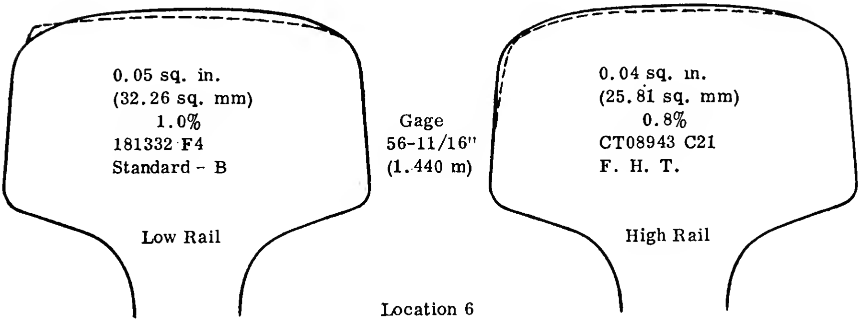
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 5

Curvature 6° - 15' (279.6 m radius) - Superelevation 5 1/4 in. (133.4 mm)



Location 6

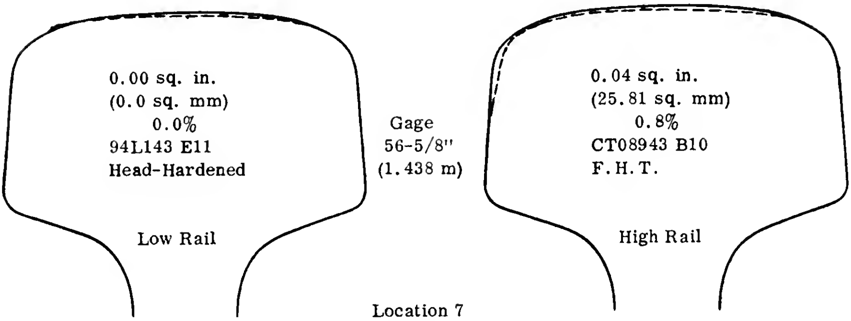
Curvature 6° - 00' (291.2 m radius) - Superelevation 4 3/4 in. (120.7 mm)

FIGURE 7

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 1 - MILE POST 233.1

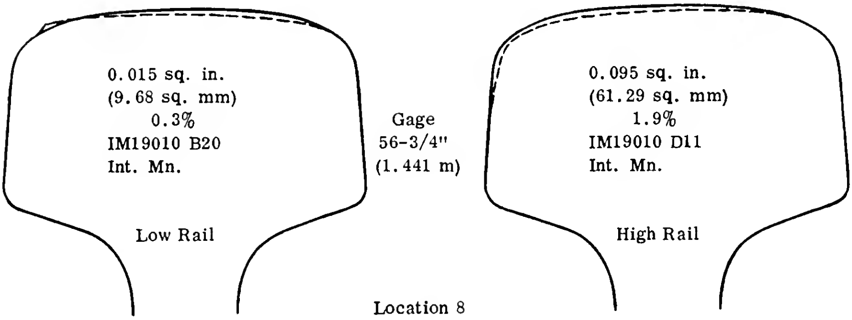
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 7

Curvature 6° - 15' (279.6 m radius) - Superelevation 4 15/16 in. (125.4 mm)



Location 8

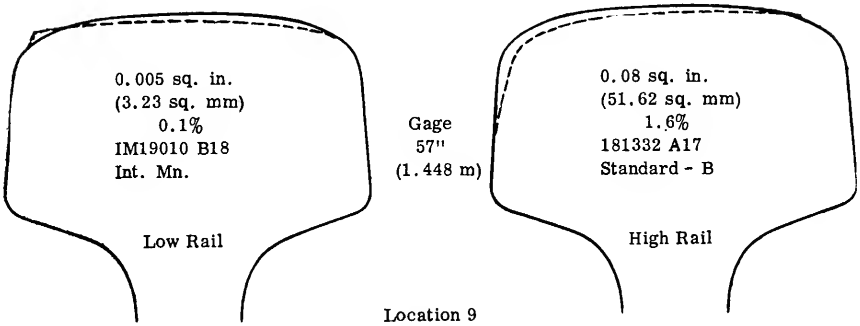
Curvature 6° - 00' (291.2 m radius) - Superelevation 4 5/8 in. (117.5 mm)

FIGURE 8

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 1 - MILE POST 233.1

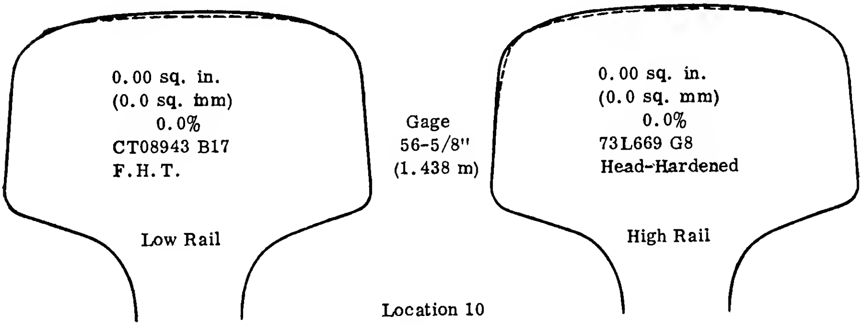
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 9

Curvature 6° - 00' (291.2 m radius) - Superelevation 4 5/8 in. (117.5 mm)



Location 10

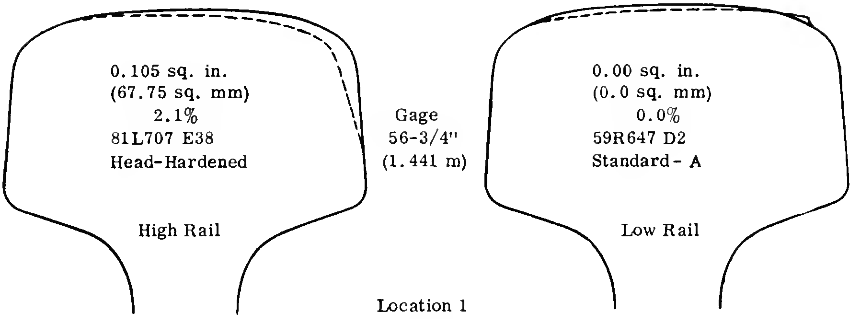
Curvature 5° - 45' (303.8 m radius) - Superelevation 4 5/8 in (117.5 mm)

FIGURE 9

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 2 - MILE POST 233.2

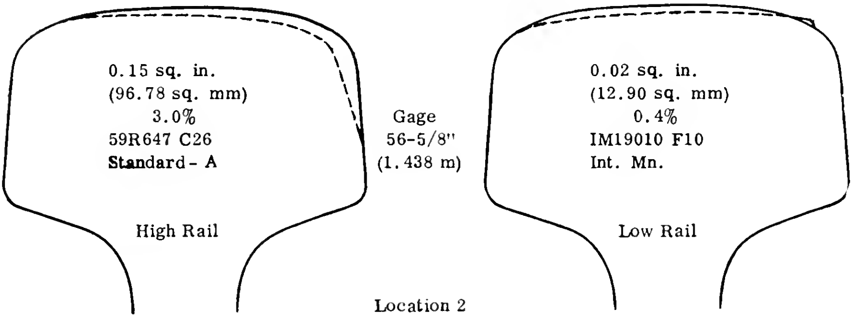
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 1

Curvature 9° - 15' (189.0 m radius) - Superelevation 4 7/8 in. (123.8 mm)



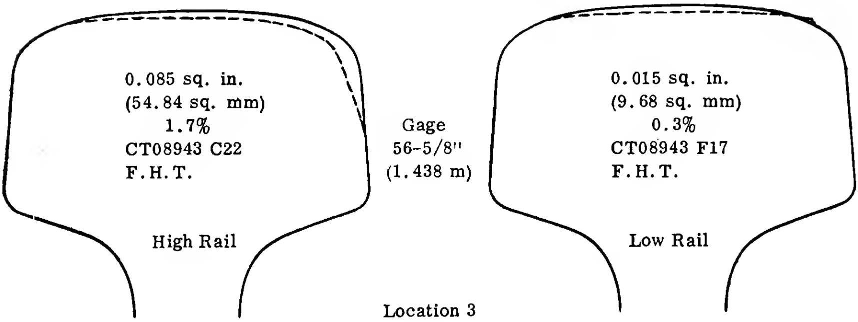
Location 2

Curvature 8° - 45' (199.8 m radius) - Superelevation 4 7/8 in. (123.8 mm)

FIGURE 10

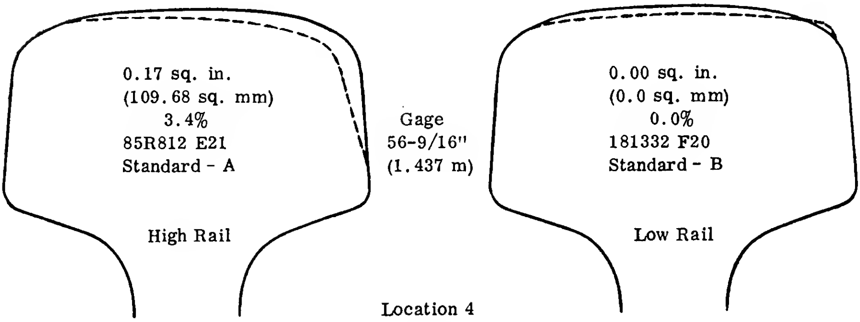
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 2 - MILE POST 233.2

INSTALLED: July 1972 INSPECTED: July 30, 1974



Location 3

Curvature 8° - 45' (199.8 m radius) - Superelevation 4 3/4" in. (120.7 mm)



Location 4

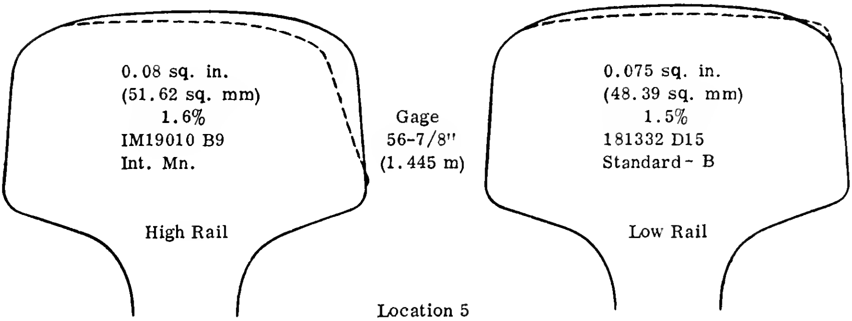
Curvature 8° - 30' (205.6 m radius) - Superelevation 4 5/8 in. (117.5 mm)

FIGURE 11

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 2 - MILE POST 233.2

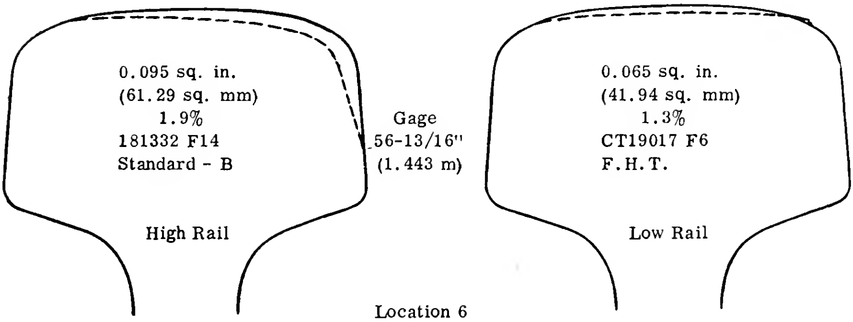
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 5

Curvature 8° - 30' (205.6 m radius) - Superelevation 4 3/4 in. (120.7 mm)



Location 6

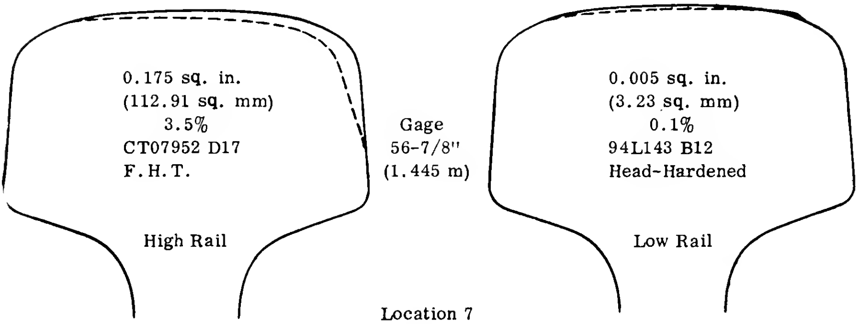
Curvature 8° - 45' (199.8 m radius) - Superelevation 4 5/8 in. (117.5 mm)

FIGURE 12

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 2 - MILE POST 233.2

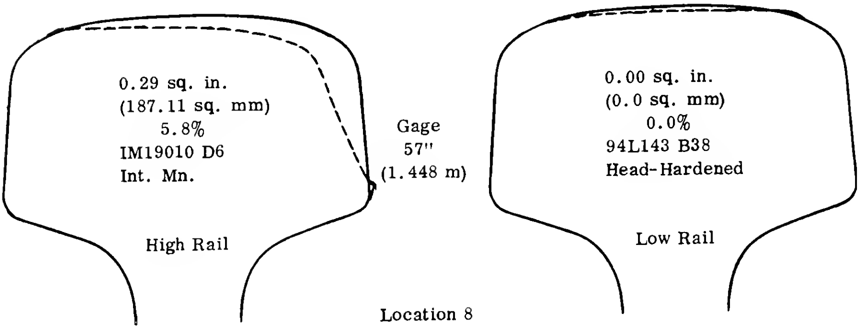
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 7

Curvature 8^{o} - 45' (199.8 m radius) - Superelevation 4 7/8 in. (123.8 mm)



Location 8

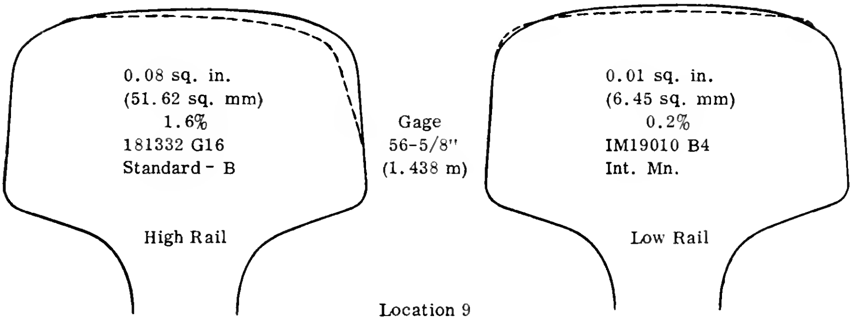
Curvature 8^{o} - 30' (205.6 m radius) - Superelevation 4 7/8 in. (123.8 mm)

FIGURE 13

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 2 - MILE POST 233.2

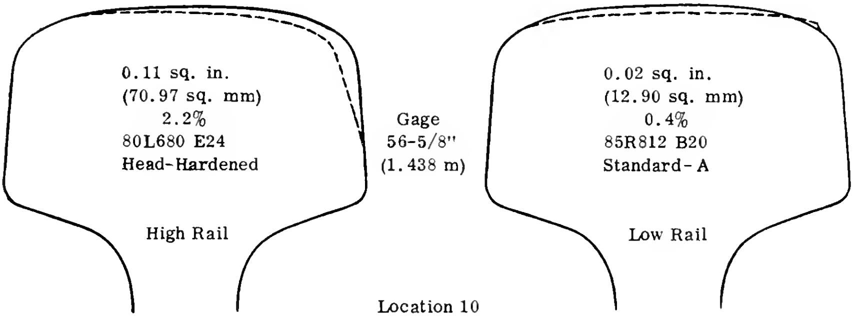
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 9

Curvature 8° - 45' (199.8 m radius) - Superelevation 5 1/4 in. (133.4 mm)



Location 10

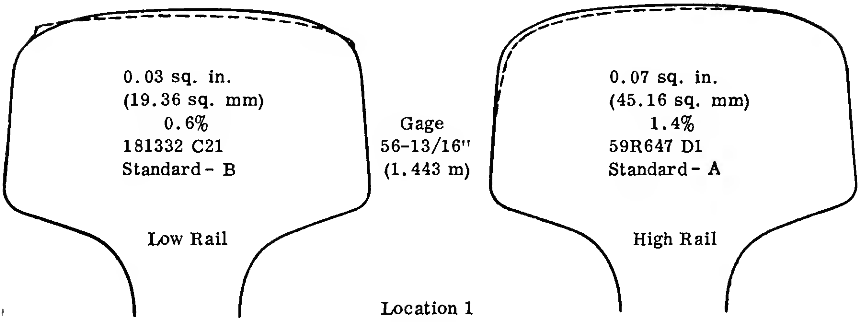
Curvature 8° - 22' (208.9 m radius) - Superelevation 5 1/16 in. (128.6 mm)

FIGURE 14

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 3 - MILE POST 234.0

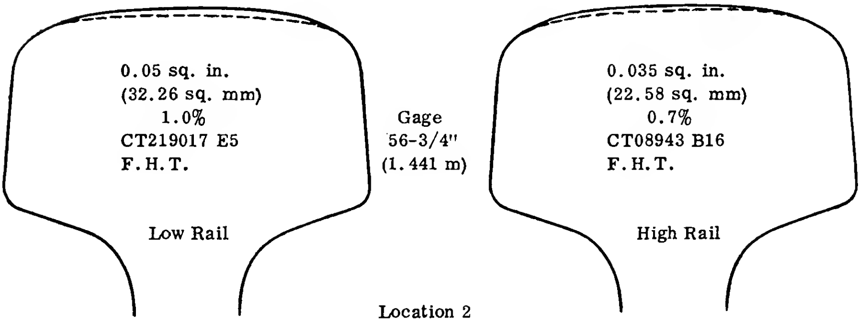
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 1

Curvature 4° - 15' (411.0 m radius) - Superelevation 2 5/8 in. (66.7 mm)



Location 2

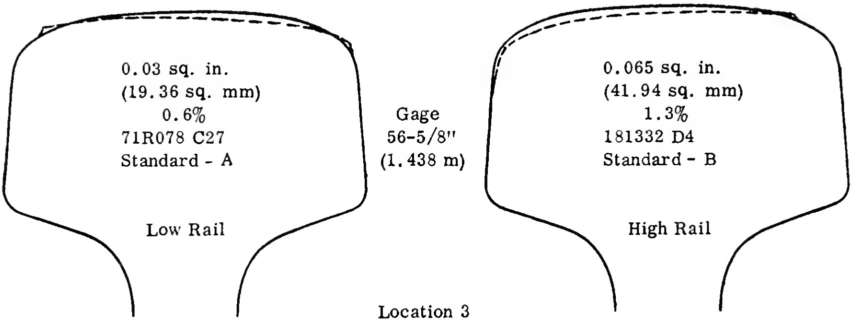
Curvature 4° - 15' (411.0 m radius) - Superelevation 2 7/8 in. (73.0 mm)

FIGURE 15

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 3 - MILE POST 234.0

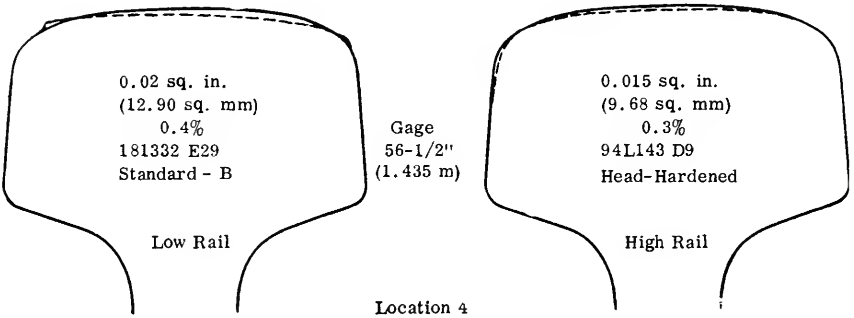
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 3

Curvature 4° - 15' (411.0 m radius) - Superelevation 2 5/8 in. (66.7 mm)



Location 4

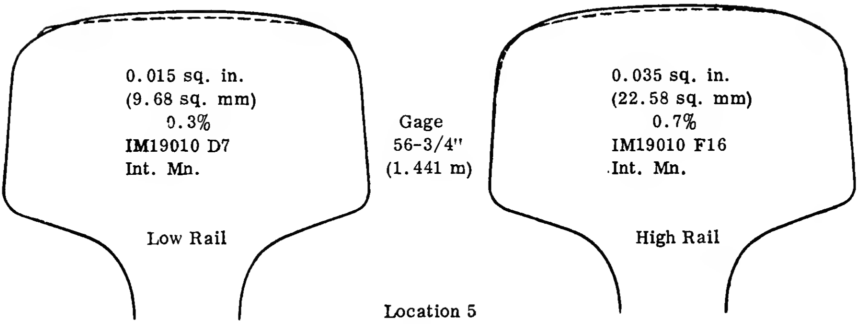
Curvature 4° - 22' (400.0 m radius) - Superelevation 2 5/8 in. (66.7 mm)

FIGURE 16

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 3 - MILE POST 234.0

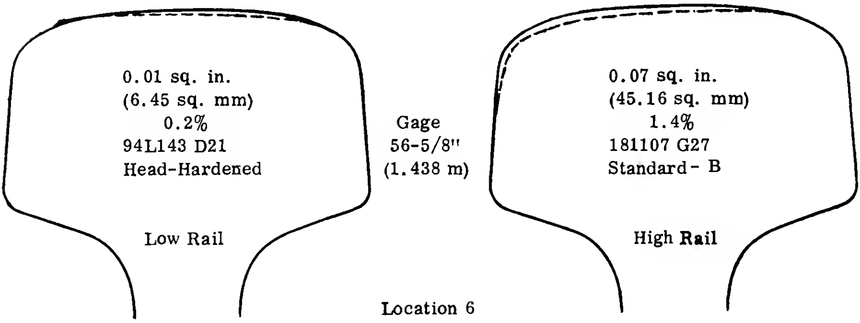
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 5

Curvature 4° - 22' (400.0 m radius) - Superelevation 2 3/8 in. (60.3 mm)



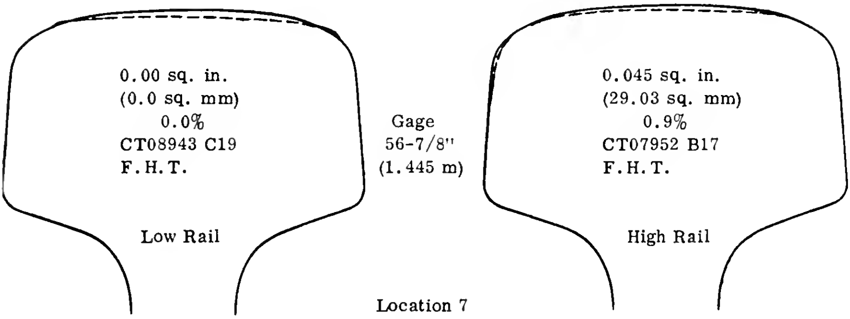
Location 6

Curvature 4° - 15' (411.0 m radius) - Superelevation 2 5/8 in. (66.7 mm)

FIGURE 17

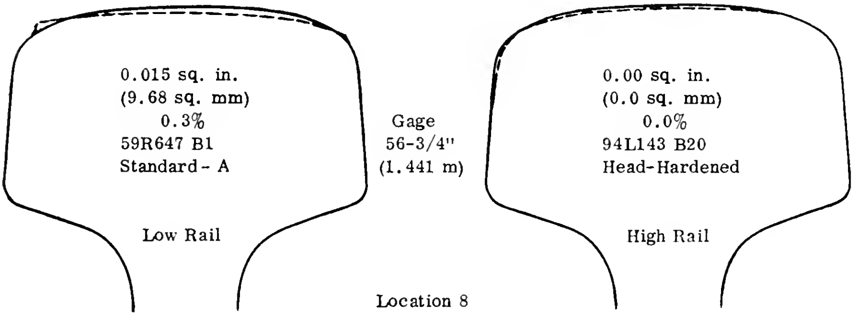
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 3 - MILE POST 234.0

INSTALLED: July 1972 INSPECTED: July 30, 1974



Location 7

Curvature 4° - 15' (411.0 m radius) - Superelevation 2 5/8 in. (66.7 mm)



Location 8

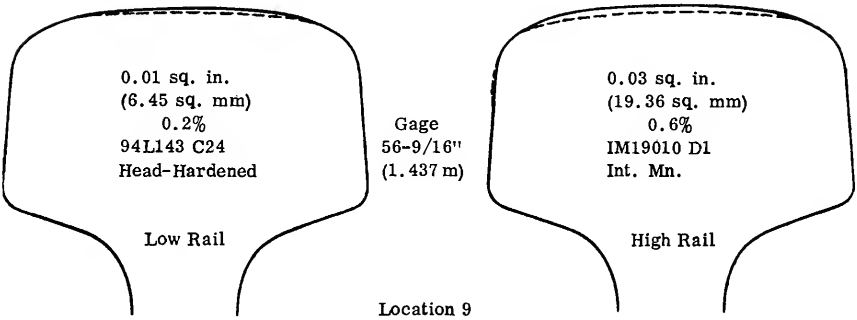
Curvature 4° - 22' (400.0 m radius) - Superelevation 2 3/8 in. (60.3 mm)

FIGURE 18

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 3 - MILE POSE 234.0

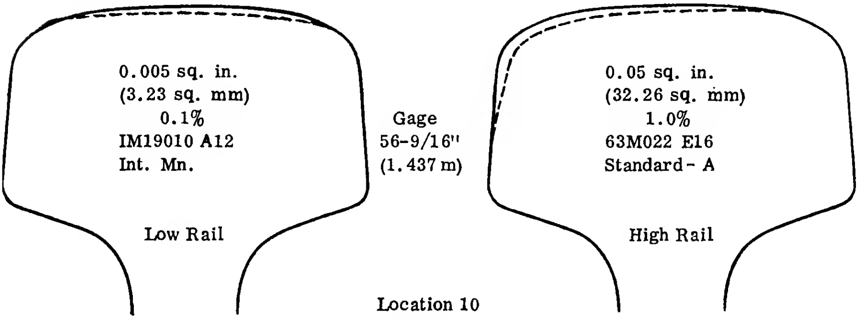
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 9

Curvature 4° - 15' (411.0 m radius) - Superelevation 2 1/2 in. (63.5 mm)



Location 10

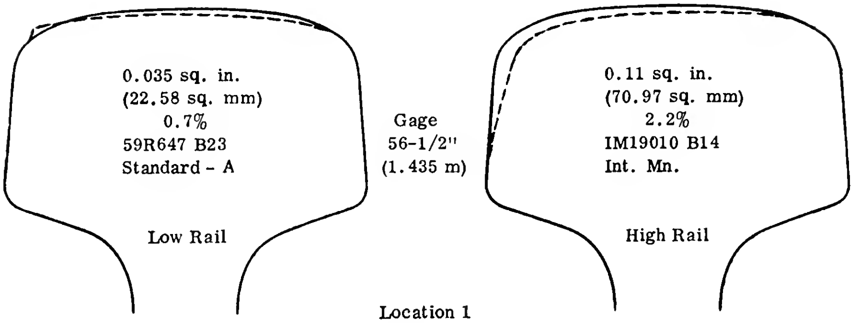
Curvature 4° - 15' (411.0 m radius) - Superelevation 2 1/2 in. (63.5 mm)

FIGURE 19

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 4 - MILE POST 235.0

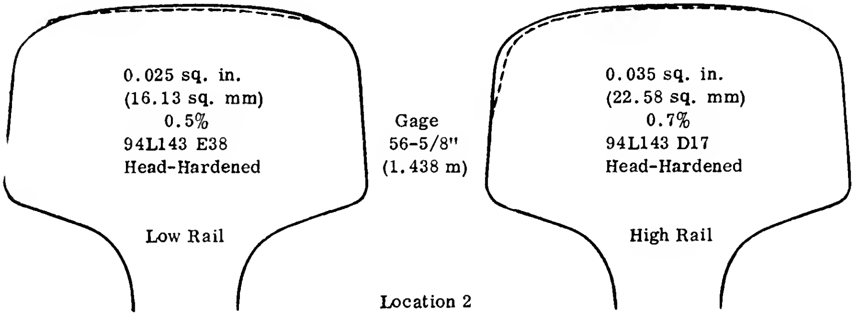
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 1

Curvature 8° - 08' (214.9 m radius) - Superelevation 5 in. (127.0 mm)



Location 2

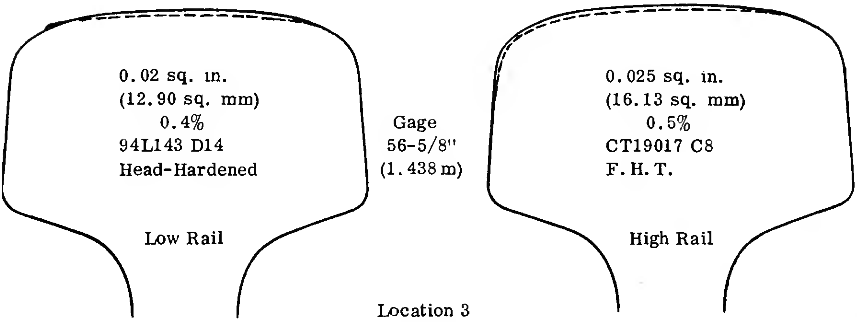
Curvature 7° - 52' (222.2 m radius) - Superelevation 4 3/4" (120 .7 mm)

FIGURE 20

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 4 - MILE POST 235.0

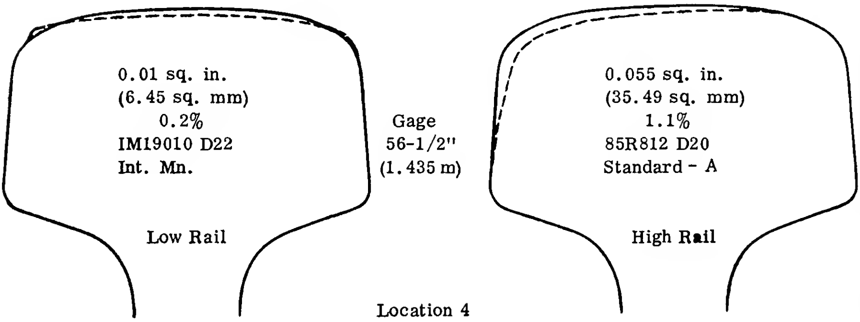
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 3

Curvature 8° - 00' (218.5 m radius) - Superelevation 4 3/4 in. (120.7 mm)



Location 4

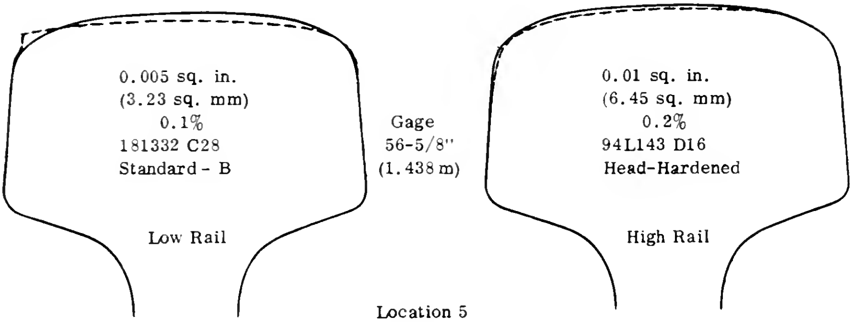
Curvature 8° - 30' (205.6 m radius - Superelevation 5 in. (127.0 mm)

FIGURE 21

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 4 - MILE POST 235.0

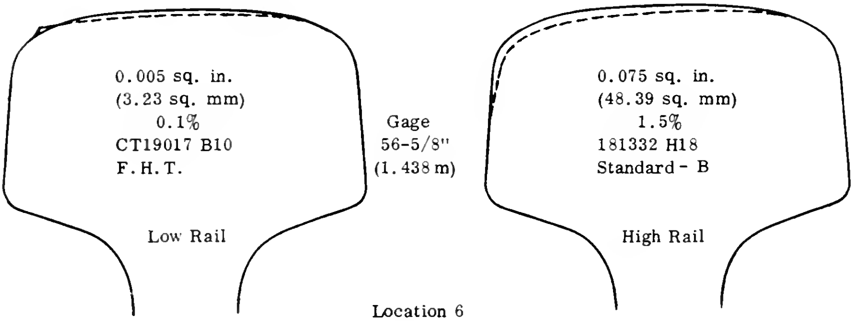
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 5

Curvature 7° - 34' (231.0 m radius) - Superelevation 4 7/8 in. (123.8 mm)



Location 6

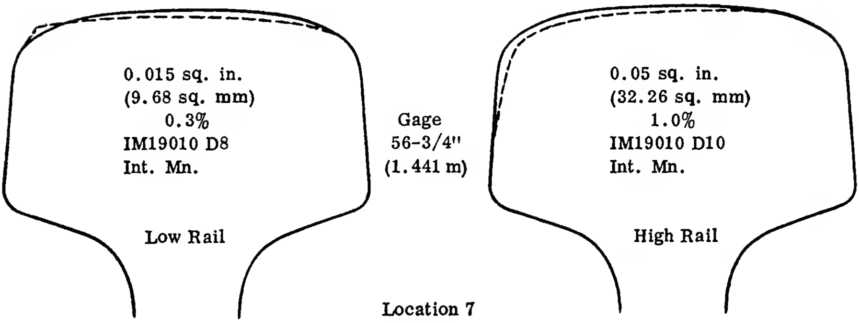
Curvature 8° - 22' (208.9 m radius) - Superelevation 4 7/8 in. (123.8 mm)

FIGURE 22

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 4 - MILE POST 235.0

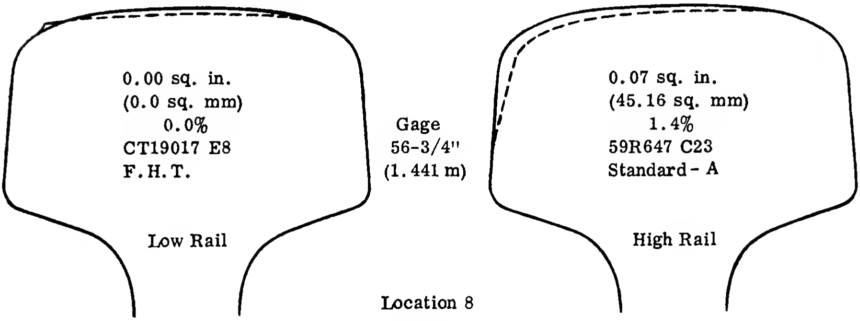
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 7

Curvature 8° - 00' (218.5 m radius) - Superelevation 4 7/8 in. (123.8 mm)



Location 8

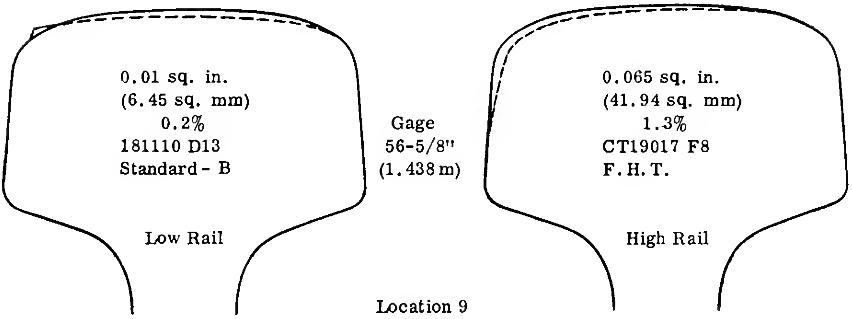
Curvature 8° - 00' (218.5 m radius) - Superelevation 5 1/8 in. (130.2 mm)

FIGURE 23

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 4 - MILE POST 235.0

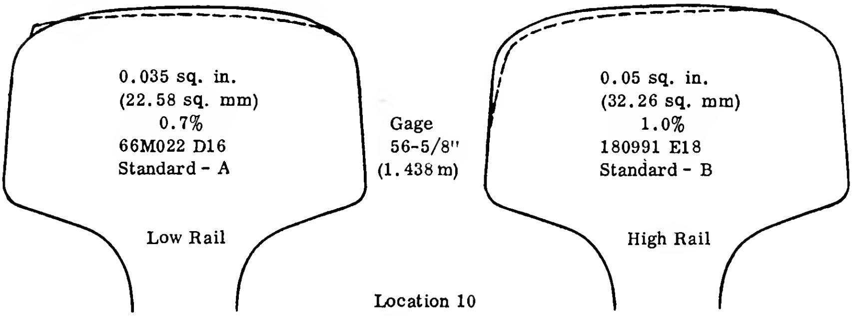
INSTALLED: July 1972

INSPECTED: July 30, 1974



Location 9

Curvature 8°-00' (218.5 m radius) - Superelevation 4 3/4 in. (120.7 mm)



Location 10

Curvature 6°-45' (258.9 m radius) - Superelevation 4 3/8 in. (111.1 mm)

FIGURE 24

AVERAGE AMOUNT OF HIGH RAIL HEAD WEAR VERSUS AVERAGE CURVATURE

IN ONE YEAR 1973 - 1974

16.3 MILLION GROSS TONS

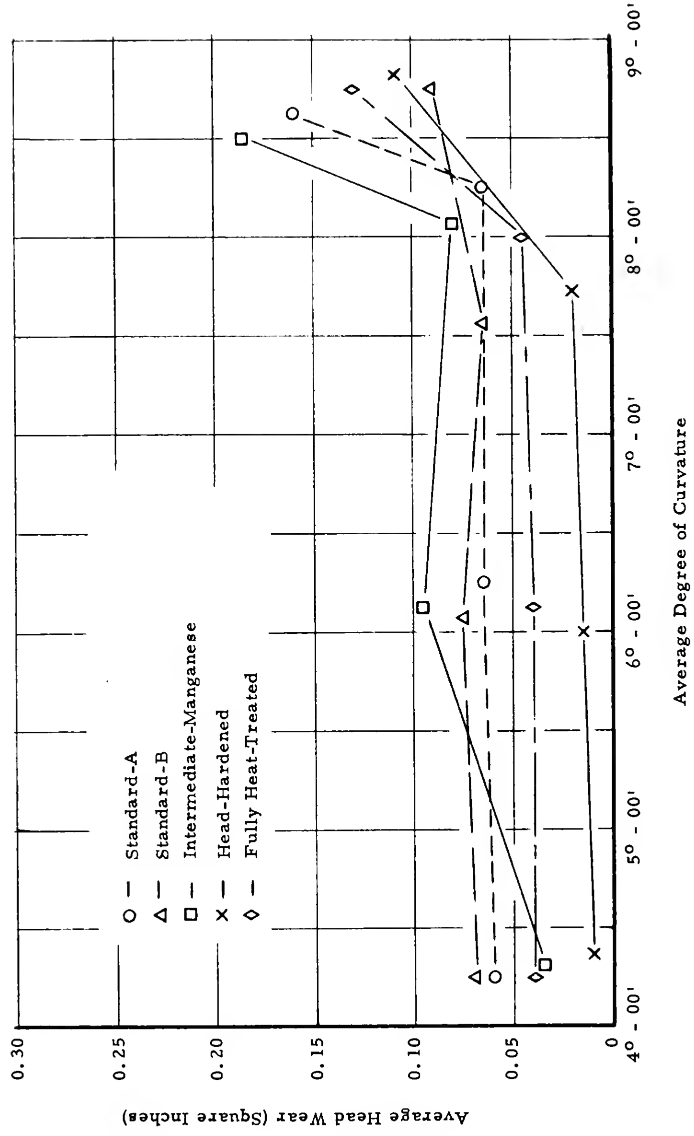


FIGURE 25

AVERAGE AMOUNT AND PERCENT OF HIGH RAIL HEAD WEAR

IN ONE YEAR 1973 - 1974

16.3 MILLION GROSS TONS

Rail Type	Curve No. 3 Nominal 4° - 00'			Curve No. 1 Nominal 6° - 00'			Curve No. 4 Nominal 8° - 00'			Curve No. 2 Nominal 8° - 30'		
	Sq. in.	Sq. mm	%	Sq. in.	Sq. mm	%	Sq. in.	Sq. mm	%	Sq. in.	Sq. mm	%
Standard-A	0.06	38.71	1.2	0.065	41.94	1.3	0.065	41.94	1.3	0.16	103.23	3.2
Standard-B	0.07	45.16	1.4	0.075	48.39	1.5	0.06	38.71	1.2	0.09	58.07	1.8
Intermediate-Manganese	0.035	22.58	0.7	0.095	61.29	1.9	0.08	51.62	1.6	0.185	119.36	3.7
Head-Hardened	0.01	6.45	0.2	0.015	9.68	0.3	0.02	12.90	0.4	0.11	70.97	2.2
Fully Heat-Treated	0.04	25.81	0.8	0.04	25.81	0.8	0.045	29.03	0.9	0.13	83.88	2.6

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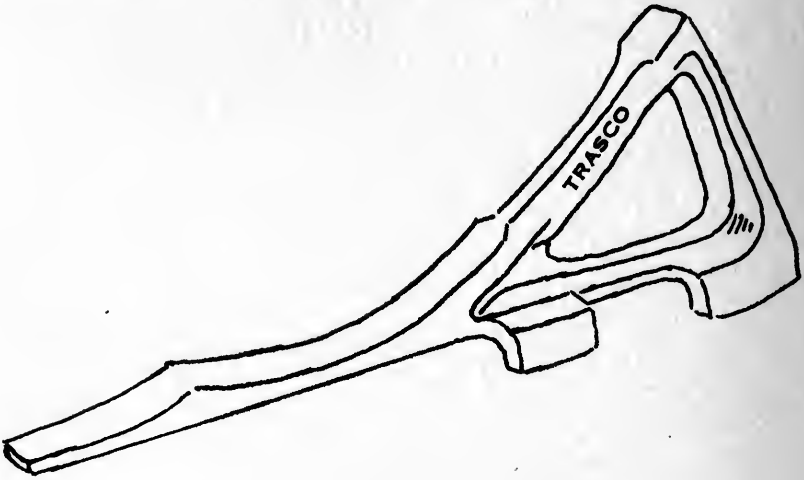
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American Railway Engineering Association—Bulletin

Bulletin 655
Proceedings Volume 77*
November–December 1975

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* Proceedings Volume 77 (1976) will consist of AREA Bulletins 654, September–October 1975; 655, November–December 1975; 656, January–February 1976; and 658, June–July 1976 (Technical Conference Report issue). Blue-covered Bulletin 657, April–May 1976 (the Directory issue), is not a part of the Annual Proceedings of the Association.

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PART 1

MANUAL RECOMMENDATIONS

All the recommendations submitted by committees for adoption and publication in the 1976 Supplement to the AREA Manual for Railway Engineering are printed in this issue of the Bulletin. These recommendations will be formally submitted for review and approval to the Board Committee on Publications and the AREA Board of Direction. Comments or objections by Members regarding any of these recommendations should be submitted to the Executive Manager not later than FEBRUARY 16, 1976.

Manual Recommendations

Committee 14—Yards and Terminals

Report on Assignment B

Revision of Manual

G. H. Chabot *(chairman, subcommittee)*, all members of Committee 14.

Your committee submits for adoption the following recommendations with respect to Chapter 14 of the Manual:

Delete present Part 1—Terminals, Part 2—Passenger Terminals, Part 3—Freight Terminals, and Part 4—Locomotive Terminals, substituting therefor the following completely revised and reorganized material.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

MANUAL FOR RAILWAY ENGINEERING

CHAPTER 14

YARDS AND TERMINALS

FOREWORD

This chapter deals with the engineering and economic problems of location, design, construction and operation of yards and terminals used in railway service. Such problems are substantially the same whether railway's ownership and use is to be individual or joint. The location and arrangement of the yard or terminal as a whole should permit the most convenient and economical access to it of the tributary lines of railway, and the location, design and capacity of the several facilities or components within said yard or terminal should be such as to handle the tributary traffic expeditiously and economically and to serve the public and customer conveniently.

In the design of new yards and terminals, the retention of existing railway routes and facilities may seem desirable from the standpoint of initial expenditure or first cost, but may prove to be extravagant from the standpoint of operating costs and efficiency. A true economic balance should be achieved, keeping in mind possible future trends and changes in traffic criteria, as to volume, intensity, direction and character.

Although this chapter contemplates the establishment of entirely new facilities, the recommendations therein will apply equally in the rearrangement, modernization, enlargement or consolidation of existing yards and terminals and related facilities. Parts 1 through 4 incl. formulate specific and detailed recommendations relative to the handling of freight, regardless of the type of commodity or merchandise, at the originating, intermediate and destination points. Parts 5 and 6 relate to locomotive and passenger facilities, respectively, and Part 7 covers miscellaneous items and facilities which may be found in yards and terminals, necessary for the general operation and function of railways. Part S—Scales, describes the various weighing systems used in railway service and is included as a part of this chapter since the majority of scales are located at yards and terminals.

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Part 2 Freight Yards and Freight Terminals

Part 3 Freight Delivery and Transfer

Part 4 Specialized Freight Terminals

Part 5 Locomotive Facilities

Part 6 Passenger Facilities

Part 7 Other Yard and Terminal Facilities

Part 1

Generalities

FOREWORD

This part deals with the general conditions, factors, features and requirements which may be basically common to or directly related with the planning, design, construction and function of yards and terminals and their associated facilities.

CONTENTS

1.1 JOINT YARDS AND TERMINALS

1.1.1 Economy

(a) It is not axiomatic that a joint yard or terminal under one management can be operated more economically and satisfactorily than two or more separately operated yards or terminals of the same aggregate capacity.

(b) In a joint yard or terminal, a single organization should control all construction, operation, maintenance and other activities within the terminal zone. All employees, including those of the participating railways, while functioning within the yard or terminal zone should be subject to the control of the appropriate officers.

1.1.2 Analyses

(a) A joint yard or terminal should not be undertaken without exhaustive comparable analyses of what may be attained in expedition, economy and convenience, under the arrangements to be surrendered and under those proposed.

(b) A joint yard or terminal may be undertaken where analyses justify anticipation of its economy as compared with other available alternatives, or where governmental authority or popular demand has substantially the force of mandate.

1.1.3 Agreement

A joint terminal agreement should anticipate and definitely cover all relationships between and among the owners, the users and the management of the joint facilities. With a view to discovering weaknesses and omissions which may be overcome in a new agreement, it will be found helpful, before drafting it, to examine existing agreements and consult those charged with their administration.

1.2 AIR RIGHTS

At yards and terminals centrally located in the larger cities, space over the facilities can often be made available, with advantage and profit, for commercial purposes such as post offices, office buildings with store frontage on the streets, hotels, certain manufacturing enterprises, and the like. These will help materially in carrying the charges on capital investments and tax assessments for the real estate occupied.

1.3 AUTOMATIC CAR IDENTIFICATION (ACI) SYSTEM

Improved yard and terminal efficiencies and performance, including total terminal control, can be achieved with an automatic car identification (ACI) system. One report on the subject and its application has been published in the Proceedings, Vol. 72, 1973, pages 230 and 231.

1.4 ENVIRONMENTAL PROVISIONS

Any yard and terminal design must consider the environmental factors and provide for the minimum controls established and required by federal, state and local laws, directives and ordinances applicable to land, water, air and noise pollution. Chapter 13—Environmental Engineering—deals with these features and requirements.

1.5 SECURITY REQUIREMENTS

1.5.1 Fire Protection

(a) Hydrants with hose houses and equipment should be located at various points within the yard or terminal so as to permit the use of at least two streams of water on any structure. Such facilities should comply to applicable codes and regulations.

(b) Water mains and hydrants should be located with due regard to future yard or terminal expansion.

(c) Water mains should be built in loops, if practicable.

(d) Chemical extinguishers should be conveniently placed to afford protection, especially against oil and electric fires.

(e) Fire lanes should be provided for access to all buildings by fire fighting equipment.

1.5.2 Theft and Vandalism

Protective measures must be carefully considered in the design of each individual situation. A report on the subject of theft and vandalism is contained in the Proceedings, Vol. 75, 1974, pages 609 to 611, incl. Information on this subject may be obtained from the Transportation Research Board, National Academy of Sciences, Washington, D.C., report No. 487, Crime and Vandalism in Public Transportation—5 Reports (1974), ISBN 0–309–02273–8, 64 pp.

Part 2

Freight Yards & Freight Terminals

FOREWORD

This part deals with the engineering and economic problems of location, design, construction and operation of all the facilities provided by a railway company, or by railway companies in common, or acting jointly, as the case may be, to handle freight to or from or through and within a given district on behalf of such railway company or companies.

Conditions of demand and feasibility vary widely, and generally each case of constructing an altogether new layout on a large scale, or of remodeling or consolidating an extensive existing layout, constitutes an essentially basic problem.

Each of these features and its appurtenances, with a full knowledge of the average and maximum demands to be made upon it, must be carefully designed to fulfill its particular functions expeditiously and economically.

The designation "freight yard" (sometimes called marshaling yard) and "freight terminal" as used herein are only relative to their location within a railway system, have similarity in meaning and may perform like functions. The use of the term "yard" as opposed to "terminal" may be used in a certain interpretation or within a certain geographical area to designate an essential unit, a supplementary adjunct or a tributary to a terminal.

CONTENTS

2.1 GENERAL

To meet traffic requirements a yard or terminal should be able, even in peak periods, to receive trains promptly upon arrival, perform any auxiliary service (such as weighing, icing, feeding and watering stock, making running repairs, etc.), switch cars into their proper classification without appreciable delay, and dispatch these cars in their proper position in outgoing trains in minimum time.

The number of yards should be as small as is consistent with the efficient handling of traffic.

An additional yard is warranted only when it will result in greater economy than the enlargement or reconstruction of, or substitution of a new yard for, an existing yard or yards.

Yard or terminal layouts should provide for future expansion so that the number and length of the tracks in them may be increased as required with minimum interference with operation or minimum relocation of existing trackage.

An existing yard or terminal which is inadequate to handle the current or immediately prospective traffic should be enlarged, or redesigned and rebuilt, or abandoned in favor of a yard or terminal in a different location, according to which of these alternatives will result in the greatest economy.

Generally in computing car capacity use a minimum of 50 ft per car for all freight car tracks other than repair tracks and tracks for special equipment.

Yard lighting is desirable. The economical distribution of light over the area involved, so as to provide proper intensity of illumination, requires careful design. Recommendations of the AAR Engineering Division Committee on Electrical Facilities—Fixed Property, should be consulted.

An adequate drainage system is essential.

Communication facilities such as teletype, pneumatic tube systems, loud speakers, ACI, talkback, paging systems, television, telephones and radios should all be considered to expedite operations.

The AREA Proceedings should be consulted for detailed information.

2.2 TRACK ARRANGEMENT

(a) Main tracks should not pass through a yard.

(b) Connections to the main track from the receiving, classification or departure tracks should be as direct as practicable.

(c) Crossovers should be provided as required to facilitate all normal and regular movements in the yard or between the yard and the main track, and their location should be such as to cause minimum interference between different movements which it may be desirable to make simultaneously.

(d) In order to keep the distance to clearance to a minimum, the angle between a ladder track and the body tracks should be as large as possible.

(e) Ladder tracks should be spaced not less than 15 ft center to center from any parallel track, and when such parallel track is another ladder track, they should be spaced not less than 18 ft center to center. The requirements of governing bodies must be observed.

(f) Body tracks should be spaced not less than 14 ft center to center, and when parallel to a main track or important running track, the first body track should be spaced not less than 20 ft center to center from such track, subject to state regulations on clearances.

2.3 YARD COMPONENTS

2.3.1 Receiving Yard

(a) The number of receiving tracks should be such that there will be one available whenever an arriving train offers to enter the yard.

(b) The length of receiving tracks should be such that each will accommodate a complete train, including assisting locomotive where used. It is desirable in some yards to have a few short receiving tracks located on the side of the yard near the running track.

(c) It is desirable that the gradient of the receiving tracks be such that band brakes will not have to be set to keep the cars from moving.

(d) Consideration may be given to track indicators and remotely controlled switches at the entrances to the receiving yard.

2.3.2 Classification Yard

(a) The type of yard which should be adopted in any given case depends upon the volume and character of traffic to be handled through it, and the train schedules. The decision should be based on a thorough traffic analysis and economic study.

(1) A single flat yard is adapted for handling traffic where the total number of cars is small and the number of switching cuts per train is also small.
(2) A double flat yard is adapted for handling traffic where the total number of cars is large but the number of switching cuts per train is small.
(3) A gravity yard or a hump yard is adapted for handling traffic where the total number of cars is large and the number of switching cuts per train is also large—also in special cases where the total number of cars is relatively small but normally received in a short period of time, and the number of switching cuts per train is large.
(4) In special cases, due to the location of the yard, the character of traffic, or the arrangement of schedules, it may be necessary to provide a double flat yard or a hump yard, because of limited time for handling.

(b) The number of classification tracks should be such that there will be at least one available for each important classification.

(c) The length of classification tracks should be such that each will normally hold all accumulated cars of the assigned classification until they are to be moved off the classification track under normal operation.

(d) Where cars of single classification accumulate rapidly enough to permit forwarding them in whole trains, it is desirable to make up and dispatch trains from the classification tracks.

2.3.3 Departure Yard

(a) Departure tracks may be located as part of the classification yard or in a separate yard, depending upon the type of trains dispatched.

(b) The number of departure tracks should be such that there will be one available for assembling a departing train whenever necessary.

(c) The length of departure tracks should be such that each will accommodate a complete train, including assisting locomotives where used.

(d) The gradient of departure tracks should be level, if possible. If adverse to the forward movement of a train, it should be at least 20 percent less than the ruling gradient to be encountered by that train during its road trip.

(e) Compressed air at suitable pressure should be piped along the departure tracks, and sufficient outlets should be provided to permit the testing of the air brake equipment on the cars of departing trains.

(f) Consideration should be given to the installation of shove indicators located at clearance point of each departure track.

2.3.4 Repair Yard

(a) The location of the car repair yard should be such that the movement of bad-order cars will be as direct as practicable, that switching the repair yard will not interfere with other work, and that repaired cars may be returned readily to the classification or departure yard, as required.

(b) The capacity of the repair yard depends on the number of cars to be repaired daily. Tracks should be as short as possible. In computing capacities, 55 ft should be allowed for each uncoupled car.

(c) Repair tracks should be connected at both ends where feasible. The tracks may be alternately spaced on narrow and wide centers, the narrow spacing to be not less than 18 ft and the wide spacing to be such as to accommodate mechanical equipment.

(d) A paved driveway should be placed between the repair tracks with wide centers, and paving is also desirable between the tracks with the narrow centers. The elevation of the driveway is usually the same as the top of rail. Crossings should be spaced at approximately 8-car intervals.

(e) Consideration should be given to the "one-spot" repair yard, where cars are moved by mechanical means to the repair building, one at a time, repaired and moved. This system is adaptable to one or more tracks. In computing the capacity of the track holding the cars, a minimum of 50 ft should be allowed for each car.

2.3.5 Local Yard

(Material being developed).

2.3.6 Miscellaneous Yard Tracks and Facilities

2.3.6.1 General

All miscellaneous tracks should be located so that the use of them will cause minimum interference with other operations in the yard, particularly road trains entering and leaving the yard.

2.3.6.2 Switching leads

Switching leads should be designed to give the enginemen working on them a clear view of switchmen passing signals along the ladder track. This may not be necessary where yard crews are equipped with engine-to-ground radio communication. Multiple parallel leads with well placed crossovers should be provided where traffic is heavy.

2.3.6.3 Caboose tracks

Caboose tracks should be double-ended and located so as to permit easy access to departure tracks. In hump yards they should be adjacent to the pull-out lead tracks or classification tracks.

2.3.6.4 Wrecker equipment track

A double-ended track for the storage of the wreck train should be provided.

2.3.6.5 Other tracks

(a) Advance tracks somewhat longer than the maximum train length, or freight main tracks extending to or beyond the outside of the yard, in either or both directions, should be provided as required.

(b) Thoroughfare tracks should provide access to all parts of the yard and between the locomotive terminal and the yard.

(c) Scale tracks should be so located that weigh cars can be weighed with minimum delay to yard operation.

(d) Storage tracks may be required, particularly in hump yards where a large number of empty cars are held for supplying local industry and on-line requirements which may restrict operation of yard.

(e) Tracks may be provided in hump yards for by-passing the hump with certain cars, or to provide an "escape" route from the retarder area to the receiving yard for hump engines.

(f) Hold tracks may be required.

2.3.6.6 Allied facilities

Icing, stock pens, LCL transfer, rail-truck handling and other allied facilities should be located so that cars may be placed with minimum delay after arrival and be readily accessible for switching or placement in outbound trains.

2.4 HUMP CLASSIFICATION YARD DESIGN

2.4.1 General

A hump classification yard should be designed for the volume and character of traffic to be handled and should provide for continuous movement while humping with minimum loss of time between successive humping operations; also for the movement of cars by gravity from the crest to their proper tracks in the classification yard without damaging impacts.

Tracks at the outbound end of the classification yard should be connected to ladders so that classifications normally assembled in one train may be assigned to permit gathering from one ladder, thus providing for minimum movement of pull-down engines. A sufficient number of ladders, with lead connections to departure tracks, should be provided to permit working at least two pull-down engines with minimum interference.

The hump end of the receiving yard should be located at sufficient distance from the crest of the hump to provide, if required, hot oil pit, under-car inspection pit, connection to set-out track for explosives, and for a connection to release road engines. A second track leading from the receiving yard to the hump will permit the use of a second hump locomotive for continuous bumping operations. If trains from two or more directions are to be humped in one direction over the hump, provision should be made so that cars can be moved into the end of the receiving yard next to the hump with minimum interference with humping operations.

It is desirable to make up and dispatch trains from the classification tracks if local conditions permit, and such a method of operation usually expedites movements through the yard and reduces the expense. This requires that a sufficient number of classification tracks be long enough for each to accommodate a full-length outgoing train, or that lead tracks be provided at the outgoing end such that the combined length of a classification track and a lead track be sufficient for a full-length train, thus avoiding unnecessary doubling over or interference with hump operation. This may involve a temporary reassignment of classification during the inspection and preparatory time of a departing train.

Departure tracks may be required for making up and dispatching trains, depending on local conditions.

Considerable reclassification of cars in a hump yard is an indication of an insufficient number of classification tracks.

The hump office, hump signal control, and other communication faciilities should be located at the crest of the hump on the right hand side. (It is desirable that cars be uncoupled from the right hand side so that the forward knuckle will be open, as the impact of normal coupling will often close the rear knuckle.)

The average gradient of the track leading to the crest of the hump should be such as to permit shoving the longest and heaviest train at humping speeds consistent with available power.

Other desirable appurtenant facilities include intercommunication and paging systems throughout the classification yard area; telephone, teletype and pneumatic tube systems between strategic points, including the general yard office, the hump office and retarder operator towers, to facilitate handling of waybills, inspection lists, switch lists, etc. In addition, a multiple-channel radio-telephone communication system connecting the various offices with hump engines is commonplace. Adequate yard lighting is particularly necessary in the retarder area, supplemented as required with spotlighting for freight car identification. Journal oiling facilities and inspection pits, when installed, should be located on the approach side of the hump, sufficiently in advance of the crest, to be in the clear of the pin-pulling operation.

2.4.2 Retarder

Many factors local to each situation affect efficient operation of a retarder yard, so that each terminal must be studied individually to produce a proper design.

The classification tracks at the hump end generally should be connected in groups, with minimum distance from the first switch of the group to the farthest clearance point. The leads to these groups should be connected to the hump lead by sub-leads in the shortest possible distance. Space should be provided for retarders to be located ahead of each group, on the hump lead, and in some cases on the subleads. Lap switches, short turnouts, curved switch points, and a relatively high degree of curvature, are of desirable assistance in obtaining the minimum distances.

The number and location of retarders depend upon the number of groups of tracks and the type of layout. The length of each retarder depends upon the height of hump and the speed of operation needed. The height of hump depends upon the climate, direction of prevailing wind, character of traffic (empty or loaded cars), and to meet definite elevation.

A retarder tower or towers should be located so that each operator will have a clear view of cars under his control. The towers should have sufficient height so that the operator can observe whether tracks are filled or have room for more cars.

Individual switches and retarders may be operated by remote control requiring one or more tower locations. Where more than on tower is provided the work should be evenly apportioned among the operators so far as practicable. Push buttons or programmed switching may be used to select route codes from which switches are operated automatically. Likewise, retarders may be operated by push-button selection of speeds or through automatic control from computers.

For a completely automatic retarder classification yard, certain measuring sections with uniform grades are required in order to determine car-rolling characteristics on both tangent and curved track.

2.4.3 Gradients

2.4.3.1 Objective

The ideal objective is the design of a series of gradients so that each car will roll to and stop at the far end of the classification yard, or will roll to coupling at an acceptable speed. The following objectives are the minimum to be expected:

(a) Deliver cars having a practical maximum rolling resistance to the clearance point under adverse weather conditions.

(b) Deliver cars of most frequently occurring rolling resistance to the far end of the yard.

(c) Permit maximum humping rate and acceptable coupling speeds.

The clearance point of a classification track is the point on that track closest to the hump which will meet clearance requirements as set by the appropriate state law or by management. Far end of the yard is the point on any classification track most distant from the hump which it is desired that cars should reach.

2.4.3.2 Rolling resistance

In designing grades for moving railroad cars under gravity, it is necessary to understand what is meant by rolling resistance. It is caused by many external opposing factors, such as car construction, track irregularities, turnouts, curves, speed, air friction, wind, temperature, rain, snow, dirt, etc. The measured rolling resistance for the same car will show a wide variation depending on whether the car is accelerating or decelerating because of storing kinetic energy in the rotating wheels and axles or in using it up. In general, rolling resistance can be defined as the summation of all these factors opposing the free rolling of the car. Quite obviously the rolling resistance for any given car will vary depending upon the factors that are working to oppose free rolling.

For gradient design purposes, rolling resistance is expressed in percent of grade necessary to just overcome the opposing factors. For example, a car is said to be a 0.4 percent resistance car if, when placed on a 0.4 percent uniform tangent grade and given a small initial velocity, it keeps rolling without accelerating or decelerating.

Recent tests indicate that the maximum rolling resistance of hard-rolling, brake-free cars is 1.4 percent while the minimum rolling resistance of easy-rolling cars is 0.08 percent. Strong head winds may increase minimum rolling resistance of empty cars to 2.0 percent. The most frequent rolling resistance is about 0.20 percent for loaded cars and about 0.35 percent for empty cars. For predicting the behavior of cars in any yard, relevant brake-free data should be used.

2.4.3.3 Theory

The speed of a car rolling on a grade can be found at any point by means of the expression $h = 0.0334V^2$ or $h = 0.0155v^2$, where V is the speed of the car in miles per hour, v is the speed of the car in feet per second and h is the velocity head of the car in feet at the point under consideration and is the vertical distance shown in Fig. 1.

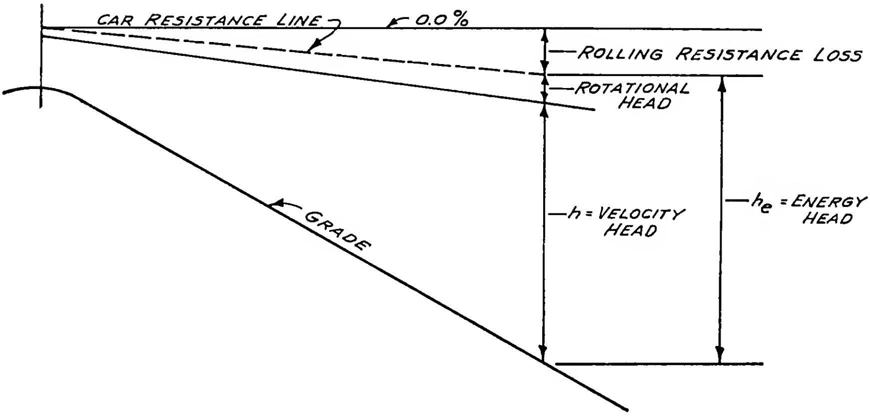


Fig. 1

The velocity head h can be found from the expression

$$h = \frac{1}{1 + \frac{4w\bar{r}^2}{D^2}\frac{1}{W}} h_e = k\, h_e$$

where,

h = Velocity head (translational head), in feet.

h_e = Energy head, in feet. This quantity is the sum of the car's translational and rotational energy head as shown in Fig. 1.

w = Weight of car's wheels and axles, in pounds.

W = Gross weight of car, in pounds.

$\bar{r}$ = Radius of gyration of the car's wheels and axles with respect to their axis of rotation, in inches.

D = Car wheel diameter at tread, in inches.

$$k = \frac{1}{1 + \frac{4w\bar{r}^2}{D^2}\frac{1}{W}}$$

Table 1 gives the value of the constant $\frac{4w\bar{r}^2}{D^2}$ for eight 33-in-nominal-diameter car wheels and four axles and for eight 36-in-nominal-diameter car wheels and four axles. The recommended values of k for various design assumptions are as follows:

Mixed empty cars	$k = 0.92$
Mixed loaded cars	$k = 0.98$
Effect of rotating wheels and axles neglected	$k = 1.00$

Table 1

Nominal Wheel Diameter	Axle Size	CONSTANT $\frac{4w\bar{r}^2}{D^2}$ IN POUNDS			
		Multiple Wear Wheels		One - Wear Wheels	
		New	Condemned for Tread Wear	New	Condemned for Tread Wear
33"	5-1/2 x 10	4,120	2,410	3,270	2,380
	6 x 11	4,140	2,430	3,300	2,400
	6-1/2 x 12	4,170	2,460	3,330	2,440
36"	7 x 14	4,750	2,580	Less Common	

When the cars for which a gradient is designed are predominantly empty or predominantly loaded, are of the same general type and their rolling characteristics are reliably known, the appropriate value of *k* can be obtained from Fig. 2a.

Safe throwing of switches, retarding and weighing of cars make it necessary for the designer to predetermine the spacing of cars as they roll from crest to clearance. This can be done by computing the time a car takes to roll between given points using one of the following two methods:

(a) The distance studied is divided into a number of increments depending on the accuracy desired. The velocity head at the midpoint of each increment is computed or scaled from a scale profile, and by means of the velocity head expressions or the graph of Fig. 2, the velocity at the midpoint of each increment is ob-

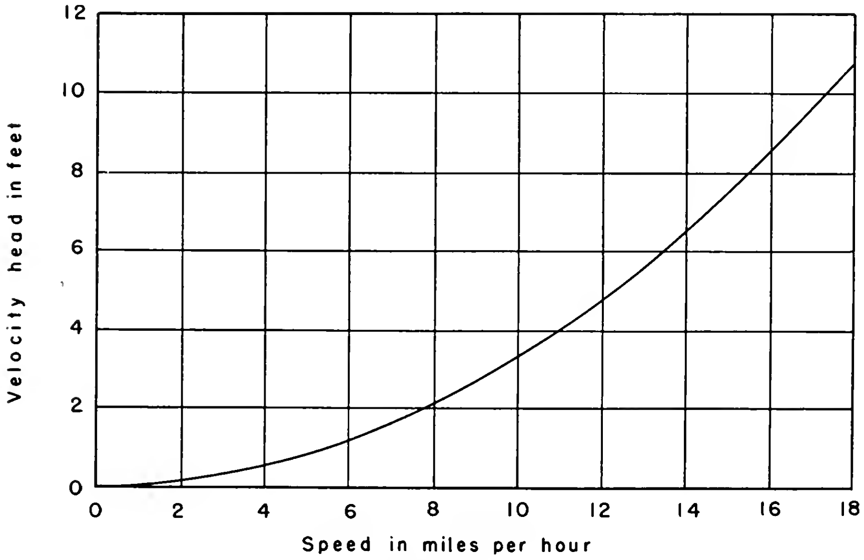


Fig. 2.

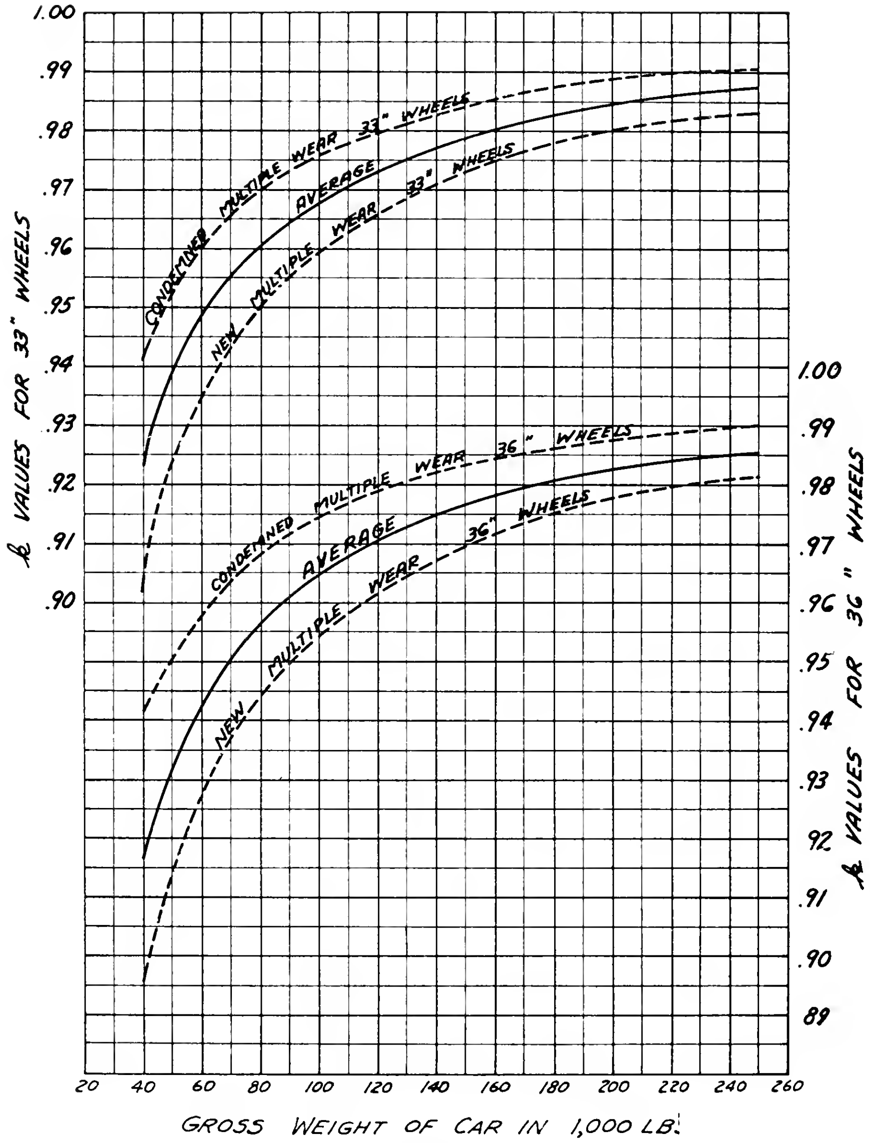

1.00
.99
.98
.97
.96
.95
.94
.93
.92
.91
.90
k VALUES FOR 33" WHEELS
CONDEMNED MULTIPLE WEAR 33" WHEELS
AVERAGE
NEW MULTIPLE WEAR 33" WHEELS
CONDEMNED MULTIPLE WEAR 36" WHEELS
AVERAGE
NEW MULTIPLE WEAR 36" WHEELS
1.00
.99
.98
.97
.96
.95
.94
.93
92
.91
.90
89
k VALUES FOR 36" WHEELS
20
40
60
80
100
120
140
160
180
200
220
240
260
GROSS WEIGHT OF CAR IN 1,000 LB.

Fig. 2a

tained. The length of the increment is then divided by the velocity corresponding to its midpoint to give the time the car takes to roll through that particular increment. When these increment times are added cumulatively, the time a car takes to roll between the given points is known.

(b) The time the center of gravity of a car takes to travel between two points "A" and "B" connected by a constant gradient can be found from the expression

$$T = 0.249 \frac{L}{h_B} \left[\sqrt{h_A + h_B} - \sqrt{h_A} \right] \text{(provided } h_A \text{ is not equal } to\ h_B\text{)}$$

where,

T = Time to travel from point "A" to point "B", in seconds.

L = Distance from point "A" to point "B', in feet.

h_A = Velocity head at point "A", in feet.

h_B = Velocity head at point "B", in feet.

When points "A" and "B" are connected by a series of gradients, the time T is computed for each gradient. If the car is retarded between points "A" and "B", the time T is computed for each retardation. If $h_A = h_B$, the speed of the car, v, is constant and T can be found from $T = \frac{L}{v}$.

2.4.3.4 Design factors

(a) Hump height for a classification track is the difference in elevation between the crest of the hump and its defined clearance point.

(b) The track on the approach side of hump crest should have adequate plus grade of sufficient length to assure easy separation of single or multiple cuts. The vertical curve at the hump should be of minimum length; care should be taken to make certain that the middle-ordinate for the chord equal in length to the distance between truck centers will provide clearance for the lowest equipment that is expected to be humped and prevent binding of car knuckles.

(c) For proper operation of a switch the clear space between the rear end of one car and the front end of the succeeding car should be not less than the length of the track circuit protecting that switch. Track circuits are usually 55 to 58 ft long. Cars with inner axle centers greater than the length of the track circuit will require special handling.

(d) A track scale of proper length and location when installed on the hump requires a gradient from the crest and over the scale which will provide sufficient time on the scale alone for weighing of cars of maximum length, minimum length, or a mixture of both, with due consideration of variations in rolling resistance.

(e) The trend toward full automation in hump yards necessitates the provision of tangent and curve rolling resistance measuring sections to be located between the crest of the hump and the group retarder. Recent yard installations have used an accelerating grade not to exceed 6.0 percent for a distance of 70 ft, more or less, at the crest of the hump to assist in providing the proper separation of cars. The resistance measuring section then is provided on an accelerating grade of 2.0 percent, more or less, to the master retarder, which may also be placed on a grade not to exceed 6.0 percent. Retarders may be constructed with a vertical curve at the lower end which facilitates placing the first switch beyond the leaving end of both master and group retarders as close to the retarders as possible.

(f) The gradient from the group (last) retarder through the classification tracks should not produce unacceptable acceleration of easy-rolling cars after leaving the group retarder. This gradient may result in deceleration of other cars, requiring the release of such cars from the group retarder at higher speeds. The gradient within the switching area for a group may be made decelerating for all cars to permit release at a higher speed for the purpose of clearing ladders quicker and to provide more space beween cars for operating switches and sending cars to adjacent tracks. The design of this part of the hump profile is important to obtain maximum humping capacity with minimum damage to cars and contents.

(g) The gradient through the group retarder should be sufficient to start most cars should they be stopped in the retarder and should preferably be at least 0.8 percent.

(h) The gradients between the crest and the track group are regulated by the hump height, the length and location of retarders, the gradient selected through the group retarder, the gradient required for the track scale and the desired speed of cars leaving each of the retarders, as follows:

(1) There should be a sufficient length of retarder in each route to stop a 0.15 percent resistance car of maximum gross weight in the group retarder when released from the crest at the design humping speed. If a pin-puller retarder is used, its retarding effect should not be included in computing the amount of retardation required between crest and clearance.

Note: The majority of existing retarder yards handling mixed traffic have been designed for cars having a maximum gross weight of 100 tons on 4 axles with 33-in-diameter wheels. Cars of heavier gross weights and having wheels of larger diameter should be taken into consideration in providing adequate retardation if they are likely to appear in large numbers at any yard.

(2) The group retarder length should be sufficient to control heavy cars having normal rolling resistance variation over the length of track on which cars are classified. For example, a group retarder having a velocity head rating of 5.5 ft would be sufficient to control heavy cars having a rolling resistance from 0.12 percent to 0.34 percent over a distance of 2500 ft from the leaving end of the group retarder.

(3) The master retarder should be of sufficient length to insure that a car of maximum gross weight having a 0.15 percent resistance will move through it, closed to maximum retardation, and leave it at a speed which will permit stopping in the group retarder when the car is uncoupled at the design humping speed. The elevation at the lower end of the retarder should be such that the exit speed (usually 8 to 14 mph) will permit adequate separation of cars between the master and group retarders.

(i) Compensation for curve resistance may be made by compensating gradients, by additional speed, or by a combination of both. This factor is of major importance in the design of gradients between the group retarder and clearance. Curvature through turnouts should be included with other curvature when calculating curve resistance.

2.4.3.5 Formulas

(a) Hump gradients

The following formulas may be used in designing hump yard gradients from the crest of the hump to the clearance point of a classification track.

H = Hump height $= S_1 R_{1h} + S_2 R_{2h} + \Delta C_h + Sw_2 - (VH)_o$

$H_1 = H - H_2$

H_2 = Drop from leaving end of group retarder to clearance $= S_2 R_{2e} + \Delta_2 C_e + Sw_2 + a$

Where,

Subscript "1" refers to the section between crest and leaving end of group retarder.

Subscript "2" refers to the section between leaving end of group retarder and clearance.

Subscript "h" refers to hard-rolling cars.

Subscript "e" refers to easy-rolling cars.

Quantities with no subscript refer to the area between crest and clearance.

S = Distance in feet.

Δ = Curvature in degrees of central angle.

$(VH)_o$ = Humping velocity head in feet.

R = Car rolling resistance expressed decimally.

C = Curve resistance in feet of drop per degree of central angle.

Sw_2 = Switch resistance in feet for switches beyond the group retarder. (Resistance of switches in Section "1" is not included as a separate item since R_{1h} is made higher than R_{2h} to include switch resistance.)

a = Difference in feet between velocity head at clearance and velocity head at leaving end of group retarder for easy-rolling cars. This will be a positive quantity if car is accelerating and a negative quantity if car is decelerating.

The quantities to be substituted for the various symbols may be determined from tests at yards now in operation.

Having determined the required vertical drops H and H_2, these drops should be distributed in their respective areas best to meet the operating requirements. There is no necessity for the curve compensation included in H_2 to be applied entirely to the curve itself and part or all of it may be put in advance of the curve.

If it is desired to deliver hard-rolling cars under adverse conditions to a point farther down in the classification yard than just to the clearance point as defined herein, these same formulas will apply by using such new point for all calculations instead of the clearance point.

It will be noted that the expression for H provides a total drop which may be different for each track, with the sides of the yard lower than the center because of the greater curvature in the outside tracks. The following are practical methods of application.

(1) Grade the classification tracks so that each track has its proper amount of curve compensation. This is done by determining the drop H_2 for each track, which will yield a yard cross section made up of a series of steps. This is not objectionable, provided the difference in elevation between adjacent tracks is not prohibitive. This method provides the most uniform rolling conditions beyond the last retarder.

(2) Grade all tracks of the same group in one plane using the H corresponding to the track having most curvature and H_2 corresponding to the track having the least curvature. This method requires higher releasing speeds at the group retarder for the tracks having more curvature.

(b) Body track gradients

In yards handling both loads and empties, gradients below the group retarder must be provided on the basis of the easy-rolling cars unless such cars are so few that the operation of the yard will not be slowed up appreciably by the necessity for bringing them practically to a stop in the last retarder. The acceleration of easy-rolling cars after leaving the group retarder should not be excessive so as to permit higher releasing speeds at the group retarder.

The gradient of the body tracks should be about 0.08 percent adjusted to meet local conditions, and any curves that there may be in the body tracks should be compensated at the rate of 0.025 ft per deg of central angle unless such curves are so located that there would be no objection to the cars decelerating.

It is advisable to have an adverse grade in the body tracks just in advance of where they join the ladders at the far end of the yard, with a rise of not less than the equivalent of 4 mph.

(c) Retardation

Retardation is obtained from the equation:

$$(VH)_{H+G} = H_1 + (VH)_0 - S_1R_{1e} - \Delta_1 C_e$$

Where,

$(VH)_{H+G}$ = Total retardation for hump and group retarder.

2.4.3.6 Example

To illustrate the aforementioned principles, the following example for northern climates is worked out analytically and the results shown graphically in Fig. 3.

LAYOUT DATA

$S_1 = 815$ ft, $S_2 = 519$ ft
$\Delta_1 = 22.65°$, $\Delta_2 = 22.65°$
$Sw_2 = 0.24$ ft (0.06 ft per turnout)

DESIGN DATA

$R_{1h} = 1.4\%$, $R_{2h} = 0.9\%$
$R_{1e} = 0.15\%$, $(VH)_o = 0.21$ ft — 2.5 mph
$R_{2e} = 0.08\%$
$C_h = 0.045$, $C_e = 0.025$
$K = 1.0$

94 ft scale 35 ft from crest.
$a = -0.67$ ft corresponding to a velocity of 6.0 mph at leaving end of group retarder, and a velocity of 4.0 mph at clearance.

SOLUTION

$H = S_1R_{1h} + S_2R_{2h} + \Delta C_h + SW_2 - (VH)_e = (815)\ (0.014) + (519)\ (0.009) + (45.3)\ (0.045) + (0.24) - (0.21) = 18.15$ ft, locating point "A" on the profile

$H_2 = S_2R_{2e} + \Delta_2 C_e + Sw_2 + a = (519)\ (0.0008) + (22.65)\ (0.025) + (0.24) - (0.67) = 0.55$ ft.

$H_1 = H - H_2 = 18.15 - 0.55 = 17.60$ ft, locating point "B" on the profile.

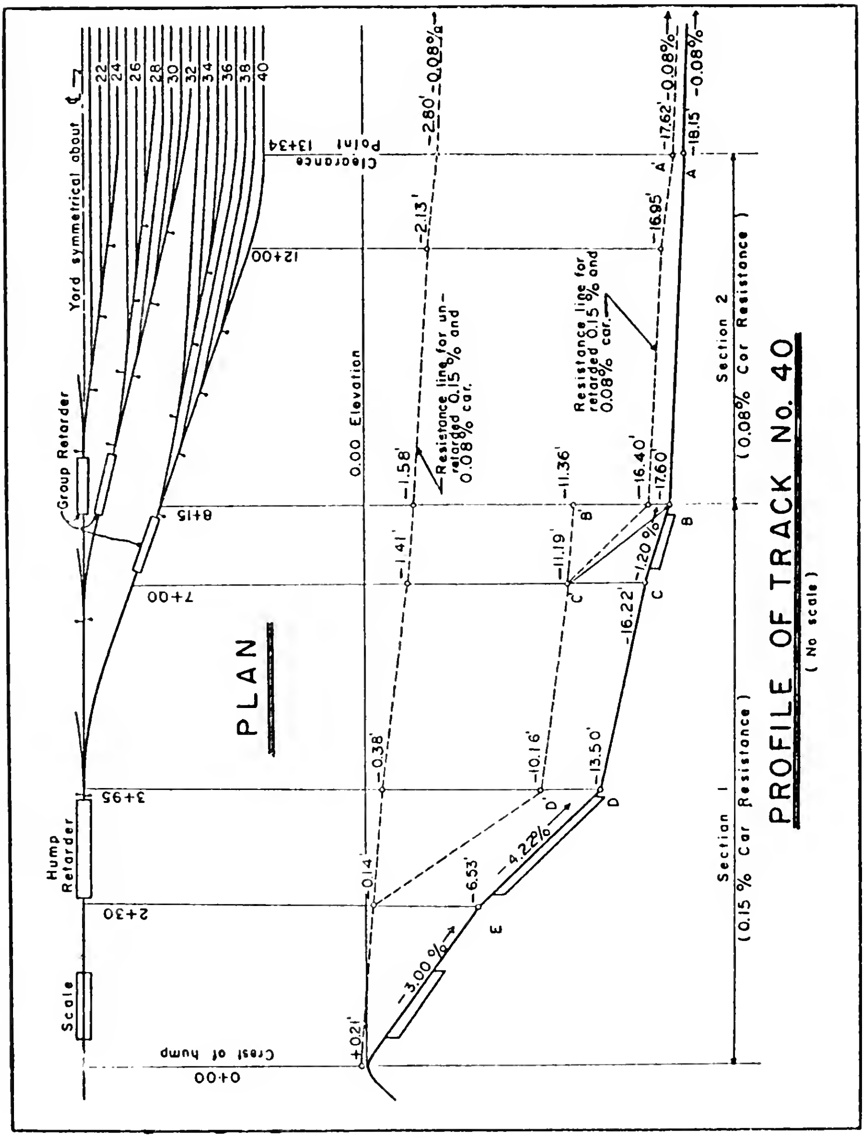

Yard symmetrical about ℄
22
24
26
28
30
32
34
36
38
40
Group Retarder
Hump Retarder
Scale
Clearance Point 13+34
12+00
8+15
7+00
3+95
2+30
0+00
Crest of hump
PLAN
0.00 Elevation
-2.80' -0.08%
-2.13'
Resistance line for unretarded 0.15% and 0.08% car.
-1.58'
-1.41'
-0.38'
-0.14'
+0.21'
-11.36'
B'
-11.19'
C'
-10.16'
D'
-13.50'
D
-6.53'
E
-3.00%
-4.22%
-1.20%
-16.22'
C
-16.40'
-17.60'
B
Resistance line for retarded 0.15% and 0.08% car.
-16.95'
-17.62' -0.08%
A'
-18.15' -0.08%
A
Section 1
(0.15% Car Resistance)
Section 2
(0.08% Car Resistance)
PROFILE OF TRACK No. 40
(No scale)

Fig. 3.

Point C is located by using a 1.2 percent gradient between B and C.

Point E has been located by the 3.0 percent gradient because of scale requirements.

Point D is established after determining the lengths of the group and hump retarders.

$(VH)_{H+O} = 17.60 + 0.21 - (815)\ (0.0015) - (22.65)\ (0.025) = 16.02$ ft.

Let $(VH)_O = 6.24$ ft, then $(VH)_H = 9.78$ ft.

Let the minimum exit velocity be 10 mph from the master retarder.

10 mph = 3.34 ft VH

Elevation of point $D = -9.78 - (395)\ (0.0015) - 3.34 + 0.21 = -13.50$ ft.

Having completed the ground profile, the resistance line of the unretarded 0.15 and 0.08 per cent car is drawn, as shown in Fig. 3. To obtain the resistance line of the fully retarded 0.15 percent car, point D′ is plotted 3.34 feet above point D, equal to the velocity head for 10 mph. Points C′ and B′ are then plotted to yield grades parallel to those of the resistance line of the unretarded car. The total retardation required is 6.24 ft + 9.78 ft = 16.02 ft. If, however, the retardation furnished is greater than 16.02 ft, the hump height may be increased to utilize the full capacity furnished and/or reduce the amount of grading.

All rolling-resistance values used in the example are accepted empirical averages susceptible of modification after more research data are obtained. In analyzing an existing yard or in designing a new one, the designer must recognize that the same car will have a different apparent rolling resistance in Section 1 than it will have in Section 2 because it is generally accelerating in Section 1 and decelerating in Section 2. It is noted that this fact has been considered in the example for both hard-rolling cars and easy-rolling cars.

2.5 FLAT CLASSIFICATION YARDS DESIGN

2.5.1 General

(Material being developed).

2.5.2 Gradients

(Material being developed).

2.5.3 Design factors

(Material being developed).

Part 3

Freight Delivery and Transfer

FOREWORD

This part deals with the engineering aspects of freight (commodities, merchandise, etc.) handling at the points of origin and delivery, in carload lot or less-than-carload lot, or in the consolidation of LCL freight from a greater to a lesser number of cars, or vice versa, or where it is desired to transfer packaged freight from foreign line cars into home line cars for forwarding to destination. The facilities are essentially supplementary units and should be so located, so designed, and so operated in relation to each other and to the lines tributary to them, as to give the most economical results for the railway as a whole.

CONTENTS

3.1 FREIGHT HOUSES

3.1.1 General

(a) Where there is a choice of sites, the following factors should be considered in the selection:

(1) highway accessibility,
(2) nearness to city pick-up,
(3) space for future expansion,
(4) proximity to existing switching service,
(5) space for a new yard or proximity to existing supporting yard,
(6) the possible inclusion of rail-truck freight facilities,
(7) economies of location near terminal yards even though remote from city, and
(8) relative land values.

(b) The ultimate size of the freight house should be determined in advance from consideration of the type and average amount of traffic to be handled through it in the first instance, the variation of the peak from average requirements and the probable growth of requirements during the period in which the cost of the structure can be amortized. The initial size should be determined by the immediate needs.

(c) One factor in obtaining minimum operating costs will result when house tracks are placed between inbound and outbound freight houses or platforms with trucking connections. This factor applies to all large facilities. These connections can be in the form of tunnels, grade crossings, trucking bridges, or by extending the trucking platform around the stub ends of tracks.

(d) The factors of design for a freight house, such as car capacity, tailboard frontage, floor area, width of house, platforms, conveyors, bridges, ramps and roadways; and in the case of a two-level house, the capacity of elevators if used, should be so correlated that no one factor will limit the capacity of the house.

(e) The design and layout of the facilities should be such as to require the minimum amount of labor to handle freight, and where economically feasible, mechanization should be exploited to the maximum.

(f) The economies of protecting the facility and operation from adverse weather should be considered.

3.1.2 Dimensions

(a) The size and shape of the house should take into consideration the following:

(1) the number of house tracks,
(2) the number of cars to be set,
(3) total tailboard length,
(4) platform space required,
(5) location of roof columns,
(6) type of operation to be accommodated, such as transfer of freight between car and car, between car and truck, forwarder, shipping association, etc., and
(7) the type of mechanical freight-handling equipment to be used, if any.

(b) Platform widths should be arrived at by allowing from 6 to 8 ft for each conveyor or motorized travel lane, with sufficient standing space outside of travel lanes for parking freight trucks. Standing space 10 to 15 ft wide adjacent to car side and that much or more at tailboard side is desirable. Larger standing areas may be required, depending on the amount of freight and length of time it is to be held on floor.

(c) Space should be provided for offices, toilets, locker and lunch room, warm and cool rooms, cooperage shop, storage for blocking and bulkhead material, and maintenance shop for platform equipment.

3.1.3 Two-Level Structure

(a) Conditions under which a two-level freight house are required are exceptional rather than ordinary. Under certain topographical or other physical conditions, such as separate track and highway levels, the two-level house may provide the only economical solution, eliminating teamways, ramps, and avoiding interference between teaming and switching movements.

(b) A two-level freight house occupies less land area per ton of capacity than a one-level freight house, but the cost of construction may be greater, and the building cannot be altered as readily to meet changing conditions.

(c) Trucking costs in a properly designed two-level freight house are less than in a one-level freight house of the same capacity, but this is somewhat offset by the cost of elevating freight. Although mechanical handling by towing conveyors has not been applied to two-level freight houses, that method should be considered in planning new or in modernizing existing houses.

(d) Stowing costs may be less in a two-level outbound freight house than in a one-level outbound freight house if the loading platform is located in the middle of the outbound setting of cars.

(e) A combination inbound and outbound freight house of the two-level type is more economical to operate than separate inbound and outbound freight houses of this type.

(f) A multi-level inbound freight house may prove an economical method of securing additional storage space for freight.

3.1.4 Mechanized Freight-Handling Facilities

(a) Mechanical equipment in a freight house will usually include one or a combination of the following:

(1) mechanical trucks,
(2) tractors towing platform trucks,
(3) fork lifts and
(4) towing conveyors.

(b) Minimum lengths of haul are approximated in a freight-house layout having a width roughly equal to its length. This is an important factor where hand trucking is to be employed. It is much less important with tractor towing operation, and least important with towing conveyors.

(c) When volume justifies their use, conveyor chains, either overhead or encased in floor, towing four-wheel platform trucks can normally handle 90 to 95 percent of the freight-house tonnage.

(d) Towing conveyors are continuous and tow both loaded and empty trucks usually spaced 12 to 18 ft apart. Travel speeds up to 175 ft per min are in use. The conveyor may cross the freight house tracks by means of a trucking bridge or by ramping down to a grade crossing or tunnel with ramp gradients of preferably not more than 6 percent. With floor-type conveyors it is possible to construct grade crossings so that the chain will not have to be disconnected to allow railroad cars to cross.

(e) Stop switches should be placed along conveyor routes at about every other car to control the movement of the chain and to be available in case of emergency.

(f) The capacity of a conveyor line is the product of the number of loaded trucks going by a given point per hour and the net load per truck. The net load used for the design of a particular house should be determined by test where possible.

(g) Up to the present time, freight elevators have been the principal means for vertical transportation of freight; however, with proper ramps, either tractor-trailer or towing conveyor operations are possible and eliminate the need for elevators in multi-level facilities.

3.1.5 Appurtenant Facilities

In the design and construction of a freight house, the following must be considered:

(1) paging and intercommunication systems,
(2) centralized checking,
(3) pneumatic tube systems,
(4) dock offices,
(5) auxiliary toilet facilities,
(6) platform scales,
(7) drinking fountains,
(8) fire protection,
(9) facilities for fueling, storing and maintaining equipment,
(10) overhead crane for handling heavy loads,
(11) facilities for transfer of tank car contents,
(12) highway truck scales if trucking operation is involved, and
(13) freight house canopies.

3.1.6 House Tracks

(a) The capacity of inbound tracks should be such that no more than one change in the inbound setting of cars need be made during a shift of freight-house operations, and this change may be made during the lunch hour.

(b) The capacity of the outbound tracks should be such that the outbound setting of cars may be left undisturbed during the shift of freight-house operations.

(c) There are operating advantages in having a platform adjacent to each track; however, overall economies usually dictate trucking through one or more cars.

(d) Spotting cars to permit trucking through them requires approximately 1⅓ min of switch engine time per car to spot and recouple.

(e) State regulations and type of cars to be set will usually dictate track-centers, side clearance, and platform heights. When refrigerator cars are to be used, tracks preferably should be depressed and platform set 8 ft from center line of track.

3.1.7 Freight Transfer Stations

(a) A freight transfer station should be provided where it is desired to consolidate LCL freight from a greater into a lesser number of cars, or vice versa, or where it is desired to transfer package freight from foreign line cars into home line cars for forwarding to destination.

(b) The width of transfer platform should be sufficient to accommodate:

(1) the parking of trucking equipment at track sides, and

(2) lanes for movement of the type of equipment used in moving freight from car to car.

3.2 TEAM YARDS

3.2.1 General

(a) Location

The location of a team yard should be such that it will be convenient for use by shippers and consignees, and also as convenient as possible to a freight house, so that the receipt and shipment of freight may be easily under control of the freight agent's force.

(b) Equipment

(1) A crane for handling heavy freight should be provided when required.

(2) A motor truck scale, with office, should be provided near the main entrance to the team yard when required.

(c) Tracks

(1) Switching tracks for holding and working cars should be provided in the immediate vicinity of the team tracks and so arranged as to facilitate the switching of these tracks.

(2) The spacing of tracks, where multiple team tracks are built, may be fixed by regulatory bodies, but it is recommended that the maximum distance between track centers be 13 ft.

(3) The distance between track centers where the driveway is located between tracks, should be 10 ft greater than the width of the driveway.

3.3 DRIVEWAYS (FREIGHT HOUSE AND TEAM YARD)

(a) Freight house and team yard driveways should be paved and maintained in good condition.

(b) The width of a freight house driveway should allow trucks to be backed up to the freight house at right angles and leave additional room for two thoroughfare lanes for moving vehicles.

(c) Team-track driveways normally should be of sufficient width to allow the longest single unit trucks using the driveway to stand at right angles to the car, with sufficient space remaining in front of the truck to allow another truck of maximum width to pass.

(d) Team yard driveways should be hard-surfaced and have at least 60 ft clear width between cars.

(e) Driveways between buildings or between a building and a team track should have preferably a clear width of 110 to 150 ft, with the latter dimension to be used if parking is allowed in the center of the driveway. Driveways at ends of buildings should be not less than 60 ft in width.

(f) Inspection and hold yard two-lane driveways may have a clear width of 22 ft between cars.

(g) Stub-ended driveways serving team tracks should be avoided. Where team tracks are more than 20 cars long (per single track), intermediate connecting cross drives should be provided. In large team track developments where exceptionally long tracks are provided, cross drives should be introduced so that 14 cars per track is the maximum length between any two drives.

(h) For other information and data see Chapter 6—Buildings.

Part 4

Specialized Freight Terminals

FOREWORD

This part deals with the engineering and economic problems of location, design, construction and operation of freight terminals for the expeditious handling of a single type commodity or merchandise as opposed to the handling of several types of commodity or merchandise as in Part 3.

CONTENTS

4.1 WATERFRONT

4.1.1 General

A water-front terminal provides facilities for the transfer of shipments or cargoes from ship or barge to railway cars or trucks, and from railway cars or trucks to ship or barge. The facilities consist of docks, wharves, piers and warehouses, with loading and unloading equipment and necessary railway tracks and roadways for transfer purposes.

The waterside may be an ocean, lake or river, but is usually a harbor on one of these. A dock is the facility at which ships are moored. A dock may be parallel to the shore line, in which case it is called a wharf. If a dock is built at an angle ranging from acute to right to the shore line, where ships can be moored on both sides, the structure is called a pier. Wharves and piers may be open or covered, depending on the protection needed for the commodity handled. Some piers are used for short-term storage as well as the transfer of goods.

4.1.2 Design

In designing a water-front terminal consideration must be given to the type and quantity of freight to be handled, and to the trackage and track arrangement required so that proper switching to and from docks can be provided. The facilities on land are provided to economically load and unload commodities. Docks should also be equipped with necessary conveyors, pipelines, car dumpers, cranes, hoppers and any other facility necessary to handle special commodities.

4.1.3 Equipment

Large structural cranes may be built over docks to extend over ships to facilitate the handling of loads. Conveyor systems may be built to move commodities in bulk or in units. Some important docks specialize in handling one commodity, such as ores, coal, grain, fruit (bananas), automobiles or equipment, or to transfer railway cars and certain merchandise.

4.1.4 Track Facilities

(a) Wharves may be served by tracks parallel to the wharf. Occasionally wharves are equipped with tracks constructed adjacent to the water's edge, and goods are handled directly between the ship and railway cars.

(b) Piers are usually provided with tracks running down their center or along the edge. Transfer bridges are used for handling railway cars to and from ships, car floats or ferries.

(c) Various yards for railway cars are a part of a water-front terminal. A storage yard is usually necessary for cars held for loading or unloading and to accumulate special cars for a particular ship. A classification yard, with or without receiving and departure yards, storage and car repair yard, may be provided, depending upon the volume of traffic handled.

4.1.5 Storage

Adequate storage space—ground pier or covered warehouse—is essential for commodities awaiting shipment. The arrangement of these yards and storage space is important so there will be the minimum of interference in handling cars to and from the yards and unloading spots.

4.2 RAIL-TRUCK

4.2.1 Types of Facilities

(a) *End loading* of railroad cars is accomplished by backing the tractor-trailer combination on a flat car or string of cars from a platform or ramp constructed to car-floor height.

(b) *Side loading* can be accomplished by the use of a fork lift truck, a platform at car-floor height, or by the use of special equipment which permits separation of the trailer body from its wheels and transfer of the body to a flat car.

(c) *Overhead loading* can be accomplished by the use of a traveling, overhead rail-mounted or tire-mounted crane. Either the entire trailer or the trailer body without wheels can be handled from the roadway adjacent to the track.

The three types of facilities described above are illustrated by Figs. 4 to 6, incl.

4.2.2 Design factors

Determining factors relative to the location of the facility depend upon the potential volume of traffic, its origin and destination within the service area, the convenience of highway access and the necessity for economical and expeditious movement of railroad cars. As many as 8 (90-ft) cars in a string can be efficiently used in end loading operations. A trailer parking area of at least one and one-half times the trailer capacity of the loading tracks should be planned. Many installations have a parking area with a capacity two or three times the track capacities.

There may be advantages to have the track area depressed in relation to the parking area, driveways and ramps. The tracks used to spot cars for loading should be on tangent. The curvature of approach tracks should be limited to 400-ft radius (14 deg 20 min).

The larger operations will require an office and locker room at the site. A truck scale may be required. Fencing may be worthwhile to assist policing. Drainage of track, driveway and parking area must be considered. Communication facilities within and beyond the operation area should be provided for efficiency. Facilities for repair of truck and tie-down equipment may be required.

4.2.3 Paving requirements

The type of paving or surfacing of parking area, driveways and ramps should be selected to suit the intensity of use anticipated. The ramps may be of wood, concrete or earth-filled crib construction. Platform walkways adjacent to tracks should be considered to provide easy movement of men from one car to another. Portable ramps can be used to eliminate need to turn cars. Traffic lines will facilitate parking and handling of equipment.

4.2.4 Electrical facilities

Lighting and power outlets in the track area should be furnished to facilitate tie-down operations. Parking areas should be lighted if there is considerable night operation.

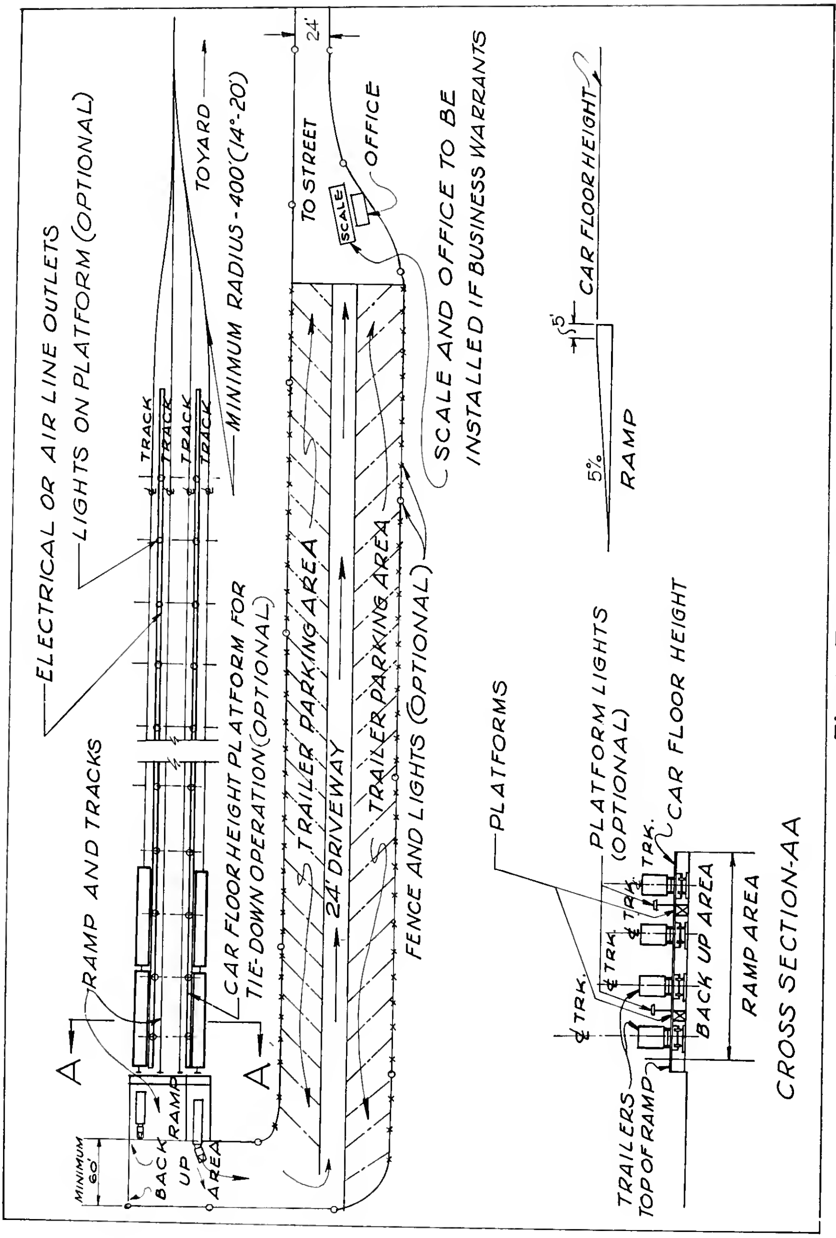


Fig. 4—End loading.

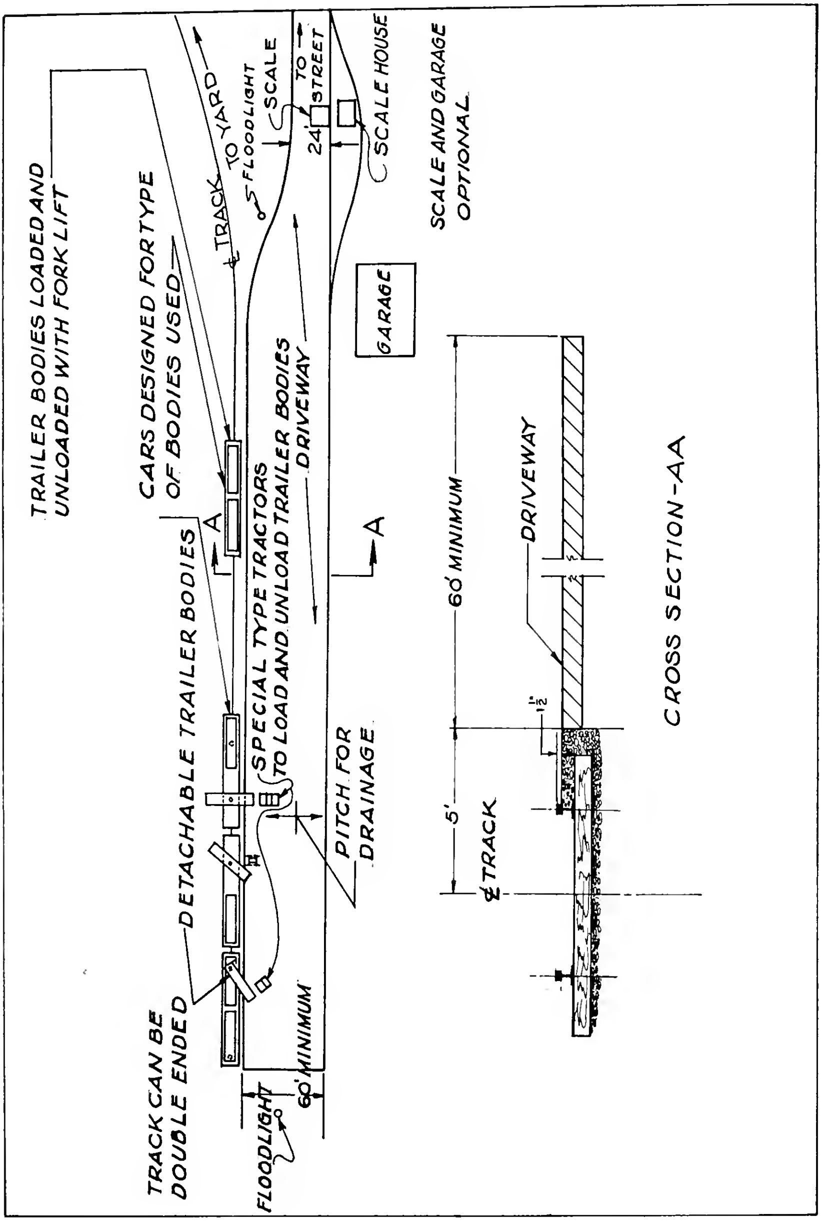


Fig. 5—Side loading.

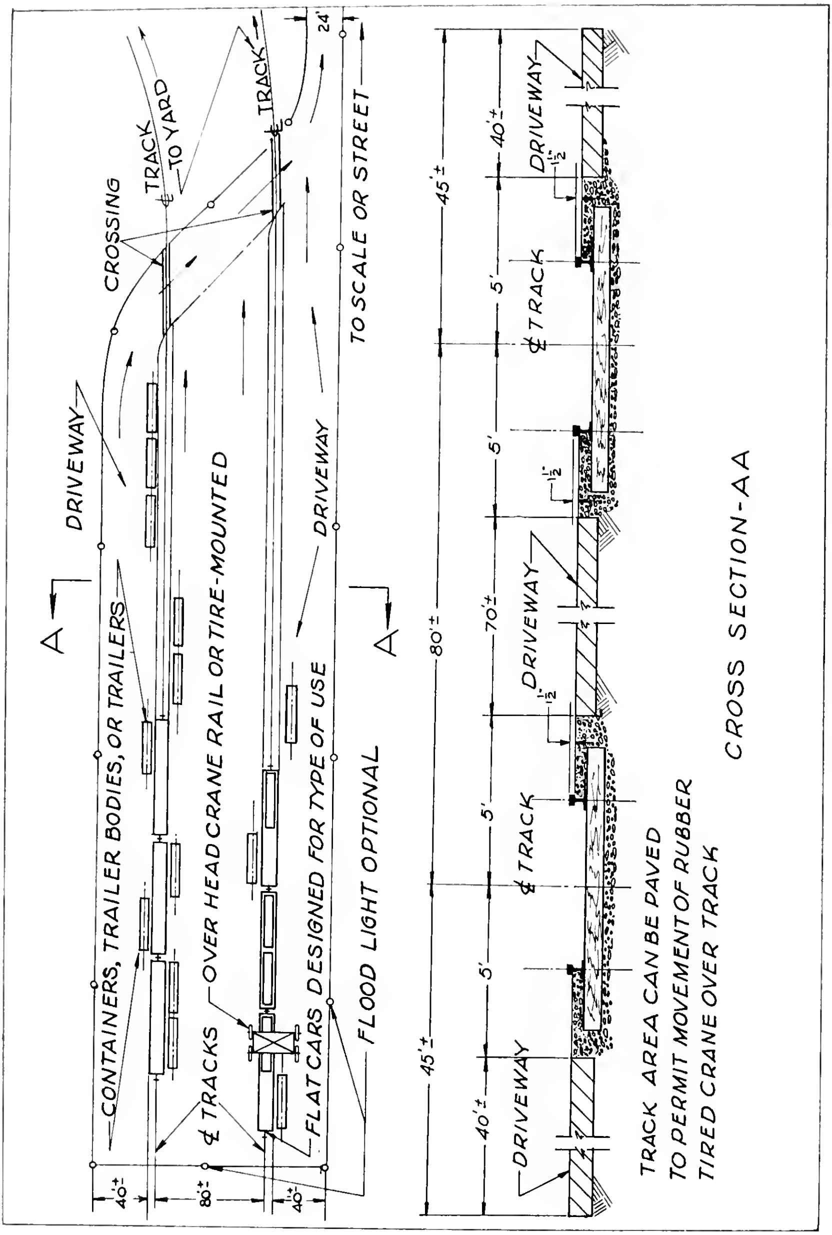


Fig. 6—Overhead loading.

4.3 AUTOMOBILE AND TRUCK TRANSPORT

4.3.1 Automobile Transport

4.3.1.1 General

The loading and unloading of finished automobiles requires equipment and plant that contribute to the overall expeditious distribution from assembly plants to local dealers. Automobile companies place a premium upon total time in transit and do consider all aspects of equipment utilization, interest charges and delivered auto condition.

Loading is usually accomplished at an assembly plant, on automobile company property, by the automobile company or its contractor. The actual facilities utilized are similar in nature to the unloading facilities; however, there are exceptions which must be given consideration on an individual basis. Exceptions can vary from loading inside the plant with multi-level cars handled by a transfer table to and from a support yard to simply driving the finished vehicle to a more conventional loading facility located at some convenient point other than the plant itself.

Unloading, on the other hand, is usually accomplished by the rail carrier or its contractor, on railroad company property, utilizing facilities provided by the railroad company. The contractor engaged by the railroad company to actually perform the unloading task will more than likely be the same organization engaged by an individual automobile company to prepare and deliver units via highway to dealers. It is, therefore, suggested that close consultation between all entities involved in the automobile distribution process be maintained during the design phase in order to assure an efficient and usable facility.

Examination of facilities now in existence discloses a wide variety of sizes, shapes, equipment, trackage, etc., as dictated by such factors as availability of real estate, proximity to highway networks and volumes of vehicles handled. A typical flow diagram of an unloading area is shown as Fig. 7. Certain factors are germane to most all auto unloading or loading facilities. They are enumerated below from the unloading viewpoint; however, the factors apply equally as well to loading areas, given appropriate modification for volume.

4.3.1.2 Location

Location of the unloading area should be selected for its proximity to dealers in the area to be distributed to in order to reduce highway mileage to the minimum. It should be located with respect to the railroads main trackage so as to minimize switching, spotting and pulling delays. Consideration should also be given to the potential of vandalism so as to avoid missile damage and theft.

4.3.1.3 Size

The size of the unloading facility, its trackage, ramping and vehicle storage areas, should be large enough to handle the maximum expected load under the proposed operating conditions. Some of the conditions to be considered are: the average work week, type and quantity of vehicles handled and the number of agencies using the same facilities. The auto production and distribution process by its very nature requires a considerable degree of advance planning including volume predictions. All of the auto maufacturers can and do make rather good volume predictions which can be utilized for planning purposes.

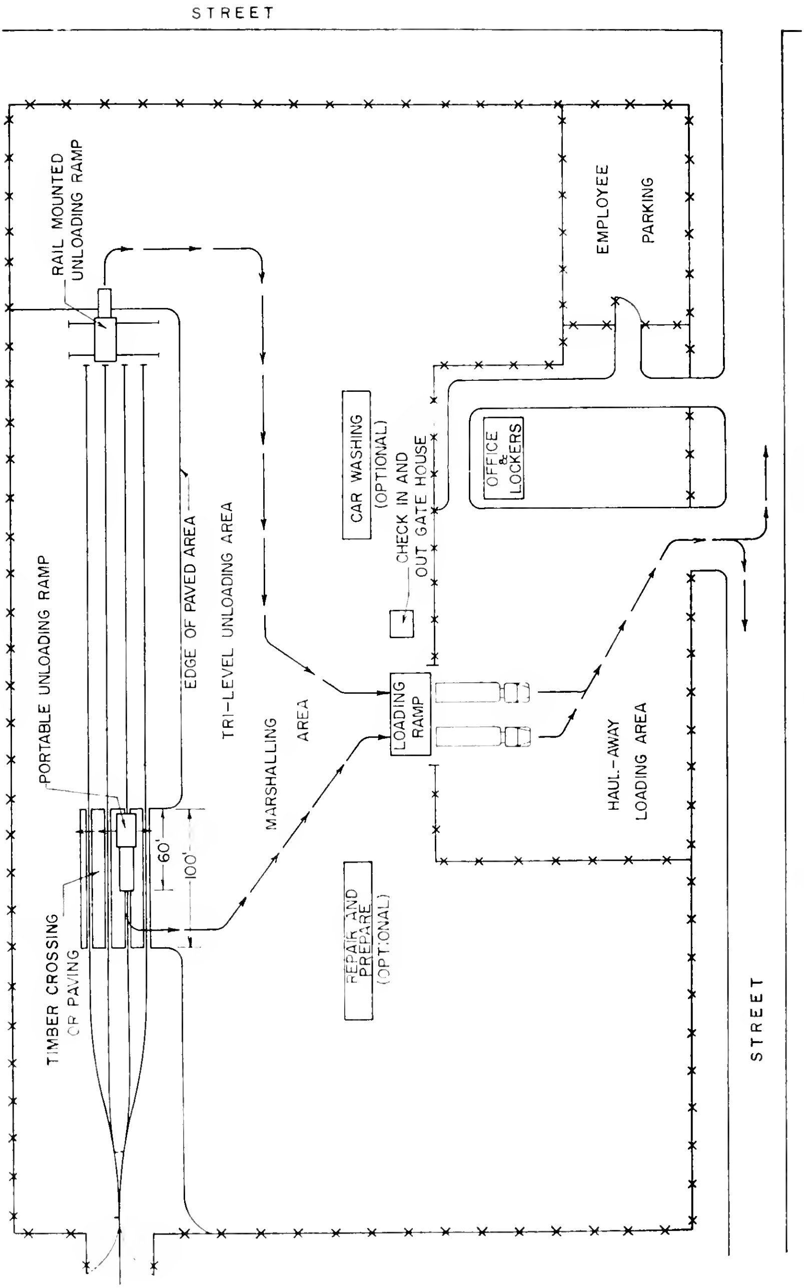


Fig. 7—Typical flow diagram of unloading area.

4.3.1.4 Buildings

Office space, washrooms and locker facilities should be adequate to provide for future needs of the operation. Communication facilities required should be provided for. Local conditions may require space for maintenance of highway tractors and predelivery preparation of autos, including washing and undercoating.

4.3.1.5 Surfaces—operating and storage areas

It is recommended that vehicular operating and storage areas be paved and as flat as possible, limiting loading and unloading angles to eliminate bumper damage. The area should be graded to provide proper drainage.

Parking spaces should be clearly marked in an arrangement with ample center distances, thereby maximizing turning radii and minimizing door contact.

4.3.1.6 Security

The entire area should be fenced and of such a nature as to discourage unauthorized entry and theft. A common solution is barbed-wire-topped chain link fencing. Gating and fencing should be so arranged as to segregate new car storage from employee parking. To minimize the possibility of theft, one auto manufacturer recommends that new vehicles can only be driven out of the storage area over a haulaway dock. Provision for checking employees and visitors in and out should be made. Locking devices on all gates are recommended.

4.3.1.7 Lighting

Lights should be provided for the entire area of sufficient intensity to be adequate for loading, unloading, inspection and/or security.

4.3.1.8 Multi-level unloading area

This area should be placed as close as possible to the center of operations in order to minimize travel distances.

(a) Unloading Tracks: The number and length of these tracks will be dependent upon the volume of rail cars handled and the availability of switching service. Rail cars and thence the autos on them may not always be oriented in the same direction, thereby making it desirable to provide for unloading multi-levels from either end. Since the backing of automobiles from rail cars is not permitted, the alternative to providing facilities to unload from either end of the rail car is to turn cars on a wye or turntable prior to unloading. This may not be desirable from an operating or time standpoint. Track centers and surfacing between tracks should be sufficient to allow passage of service vehicles for the purpose of alleviating the problems of flat tires, missing wheels, dead batteries, lack of gasoline and others that may occur with the automobiles.

(b) Unloading Equipment: Unloading equipment should allow quick drive-off of automobiles. Where economically justifiable, the ramp should be power controlled vertically for adjustment to deck levels as well as horizontally to adjoining tracks. Manufacturers should be consulted regarding maximum ramp angle permitted. At points where it is considered advisable to provide unloading in either direction, one of two methods, other than simply turning the car, can be employed. Ramps may be mounted on flanged wheels and rails perpendicular to the unloading tracks. This method requires a certain amount of switching to orient the rail cars with the appropriate ramp. The second method is to mount the ramps on rubber tires, pave the unloading track area, and move the ramp to the cars to be unloaded.

4.3.1.9 Haul-away loading area

The provision of a loading dock where highway trailers can be spotted for loading is recommended in order to reduce loading angle and decrease loading time. The preference of the specific contractor should be determined to assure compatability with his equipment, the dimensions and extent of, or even the need for, this feature.

4.3.2 Vertically Loaded Automobiles

4.3.2.1 General

Factors regarding location, size, buildings, surfacing, security and lighting enumerated for automobiles on conventional tri-levels apply equally as well to vertically loaded small autos. The rail car itself differs from multi-level rail equipment in that automobiles are loaded vertically. Five doors, holding three autos each, on either side of the car, actually serve the combined functions of loading, unloading and securement devices. The car design requires special consideration, as explained below, for anyone engaged in planning an unloading area for such cars.

4.3.2.2 Unloading track and area

The number of tracks and their lengths will be dependent upon the predicted volume of rail cars. A paved area 60 ft wide is recommended on both sides of the car to provide adequate unloading and maneuvering space. See Fig. 8 for dimensions.

4.3.2.3 Unloading equipment

The car doors themselves serve as ramps for loading and unloading, therefore, no special fixed equipment will be required. A mobile machine having the reach and capacity to open and close the doors, must be available.

4.3.3 Truck Transport

4.3.3.1 General

Factors regarding location, size, buildings, surfacing, security and lighting enumerated above for automobiles apply equally as well to trucks. The rail equipment and the placement of the trucks on the rail equipment differs. Trucks with cabs, but without bodies, are commonly shipped in "saddleback" fashion on a specially equipped flat car. Thus, the use of a crane is required for loading and unloading. While the loading may be done at a plant site exclusively devoted to trucks, the unloading operation can conveniently be incorporated into and made a part of a typical automobile unloading facility.

4.3.3.2 Unloading track

Truck shipping volumes being considerably less than autos, a single track set apart from, but adjacent to, auto facilities should suffice. Volume and economic considerations will dictate the degree of separation from, and/or incorporation within, auto facilities.

4.3.3.3 Unloading facilities

Trucks loaded in "saddelback" fashion must be removed from the truck they have been set upon and secured to for transport to a level position on the car deck

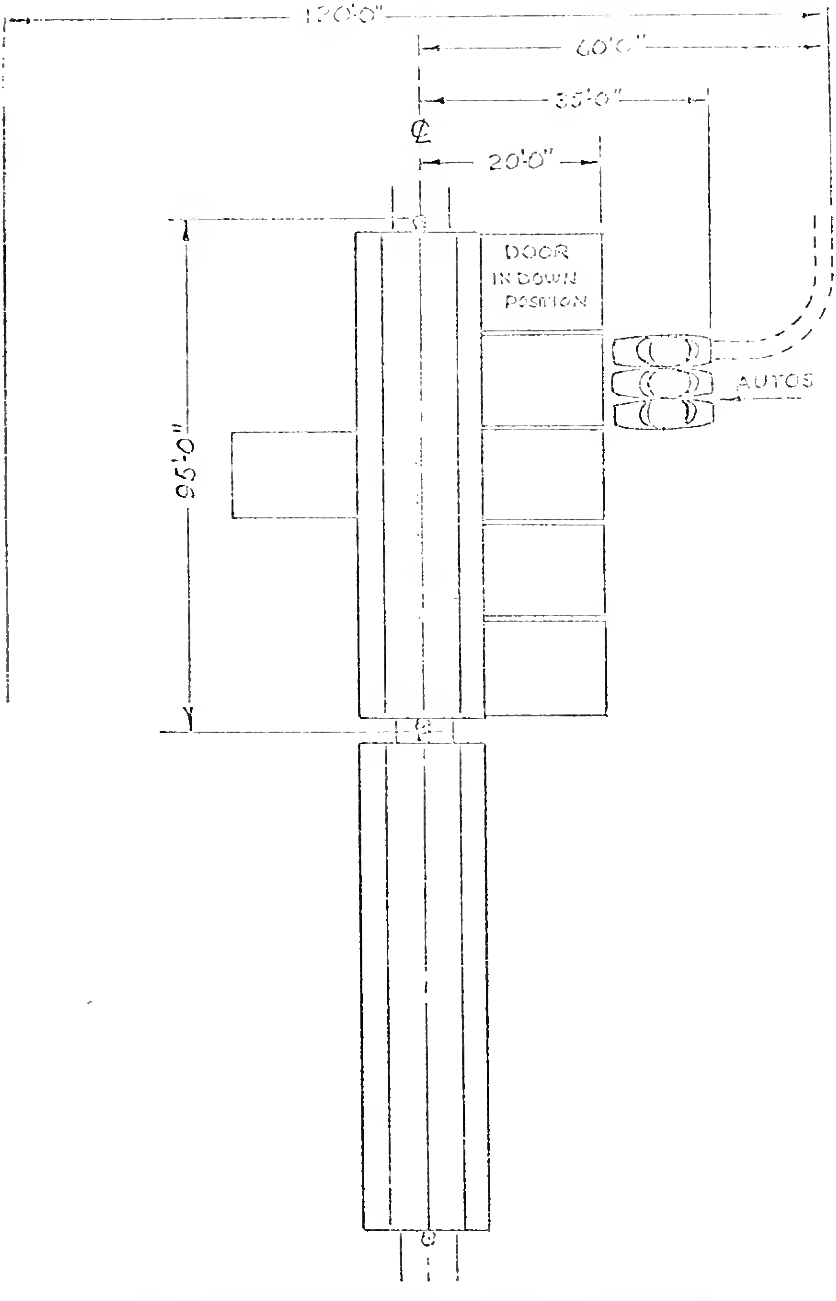
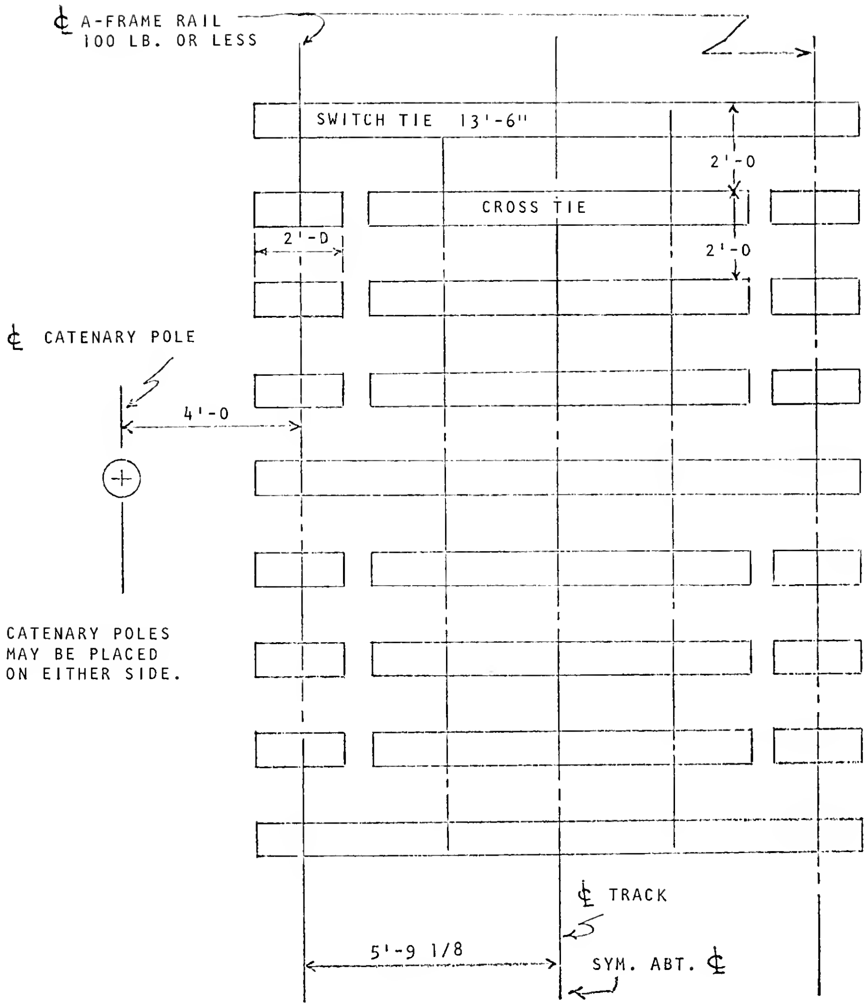


Fig. 8—Typical unloading area for autos loaded vertically.



CATENARY POLES
MAY BE PLACED
ON EITHER SIDE.

NOTE: A-FRAME CRANE ELECTRICALLY
PROPELLED. HAS DOUBLE
FLANGED WHEELS.
TOTAL WIDTH 15'0.
SPACE REQUIRED FOR THIS
FACILITY, 17'3.

Fig. 9—Typical layout for "A" frame truck unloading.

before being started and driven from the car. The job can be accomplished by a mobile crane of sufficient capacity operated adjacent to the rail car where volume is light and the need only occasional. Where volumes require a greater degree of specialization, it is recommended that an "A" frame crane, track mounted and electrically operated with running rails located outside of regular track rails, be provided. The "A" frame straddles the car to be unloaded and can be positioned to handle any car spotted within its reach. Fig. 9 details a tie layout to accommodate the "A" frame. Access to the unloading track for pre-starting service should be given consideration. Air supply sufficient to release truck brakes is a necessity.

4.4 BULK-SOLID

4.4.1 Grain Elevators

4.4.1.1 General

(a) Track facilities to serve large grain elevators involve special yard design. Co-operation between the elevator engineer and the railway engineer is essential to the development of a satisfactory plan.

(b) The location of elevator site, type and capacity of elevator, topography and local conditions will influence the arrangement of tracks.

(c) When selecting the site consideration should be given to property values, possible arrangement of connections to plant tracks, local railway operating conditions, and future expansion of elevator plant and of existing railway facilities.

(d) Proposed method of railway operation should be established and approved by the elevator operating company and operating officials of the railway.

4.4.1.2 Types

There are three general types of grain elevators, viz., (1) rail to rail, (2) rail to water, and (3) water to rail. Specific plants may be combinations of these types.

4.4.1.3 Tracks

4.4.1.3.1 Loading and unloading

(a) The number and capacity of unloading tracks will depend upon the type, arrangement and capacity of elevator unloading facilities, but may be limited in some cases by the space available.

(b) The car capacity of the tracks above and below the loading or unloading facilities should be the same.

(c) Where the car capacity of the unloading tracks on each side of the unloading facilities is equal to the normal daily unloading capacity of the elevator plant during the grain handling season, and where the car capacity of the loading tracks on each side of the loading facilities is equal to the normal daily business handled, the plant switching will be reduced to a minimum.

(d) Double-ended tracks will permit the continuous movement of cars in one direction and facilitate switching.

(e) Spur unloading tracks may necessitate switching cars through unloading shed and over unloading facilities, requiring the use of idler cars. Locomotives should not be permitted to enter the unloading shed.

(f) Adverse gradients and curvature in tracks will limit the capacity of car haul and should be avoided. An assisting gradient to and from the loading and unloading facilities should be provided. A short runoff gradient below the unloading facilities will speed up the movement of empty cars.

(g) Where car unloaders are used, the track arrangement should provide for the relative increased capacity of this device. A small plant locomotive or other special car handling equipment should be considered in connection with car unloaders. Flexibility of track layout in the vicinity of car unloader, to facilitate the operation of plant locomotive, should be given special attention.

(h) Loading tracks may be located on the same or opposite side of "workhouse" from unloading tracks.

(i) Certain unloading tracks may be used for loading or to augment the capacity of the loading tracks.

(j) Some of the auxiliary buildings, such as storeroom and dust house, may be served by the loading tracks.

4.4.1.3.2 Other tracks

(a) A running track, located outside of unloading shed, should be provided where double ended tracks are installed.

(b) A separate track should be provided to serve the power house.

4.4.1.4 Storage yard

(a) The use of a separate storage yard will require additional handling of cars; therefore careful consideration should be given to the advisability of such a yard.

(b) Where the elevator is located near an existing yard and sufficient capacity is available, or can be economically provided, a separate storage yard may not be required.

(c) A separate storage yard may be justified where it can be used to augment the existing yard during seasonal increases in business, or where the elevator is located some distance from the main or an auxiliary yard.

(d) The capacity of either the loading or unloading tracks, or both, may influence the necessity for a separate storage yard, as well as the capacity of such a yard.

(e) Facilities for inspection of cars and lading should be provided.

4.4.2 Handling systems for granular material

(To be developed).

4.5 BULK-LIQUID

(To be developed).

4.6 MERCHANDISE TERMINAL

4.6.1 Produce terminals

4.6.1.1 General

(a) Produce terminals are designed for expeditious and economical distribution of fruits, vegetables, and sometimes dairy products, eggs and poultry, meat and meat products, frozen foods and sea foods, and dry groceries.

(b) Terminals should be located and designed to handle peak business.

(c) A union terminal serving the entire trade of a community is preferable.

(d) The location must be convenient for dealers, with easy access over wide and well improved highways and easy gradients. It should have convenient railway connections. A location adjoining a railway terminal yard is advantageous.

4.6.1.2 Functions of railway and marketing faciilties

A produce terminal should be considered to include (a) railway facilities and (b) wholesale marketing facilities.

(a) Railway facilities include the primary units for handling carload shipments prior to distribution or reconsigning. Any or all of the following facilities may be required:

1. Receiving and delivery yard.
2. Hold and inspection yard; with or without supplemental classification tracks.
3. Team yard.
4. Buildings for sorting, reconditioning and transferring of lading.
5. Administration building.
6. Motor truck scales.
7. Buildings for coopering and supplies.
8. Buildings for heaters and supplies.
9. Rest rooms for yard crews, stevedores, truck operators and laborers.
10. Incinerator.
11. Communication facilities.
12. Yard lighting.
13. Icing facilities.
14. A track system for serving the yards.
15. A system of driveways for movements to and from the team yard and the hold and inspection yard.
16. Fire protection facilities.

(b) Wholesale marketing facilities include units for the sale and distribution of produce and may be situated adjacent to or within easy access of the railway facilities. In either case certain units should be served directly by railway tracks. Any or all of the following units may be required:

1. Buildings divided into separate stores.
2. Buildings for display and private sales.
3. Buildings for display and auction.
4. Auction rooms.
5. Offices, restaurants, etc.
6. Cold storage warehouse.
7. Bulk delivery platforms.
8. Ripening facilities.
9. Reconditioning facilities.
10. Motor truck and other scales.
11. Incinerator.
12. Communication facilities.
13. Fire protection facilities.
14. Farmers' market.
15. A railway track system serving the buildings.
16. Driveways serving the buildings.
17. Separate buildings for individual large firms.
18. Adequate parking areas.

4.6.1.3 Layouts

4.6.1.3.1 Track

(a) The track layout should be as compact and flexible as possible, and extensive enough to take care of traffic without delay. It is governed by the number of cars handled at peak periods, the different kinds of produce received, and the average standing time until cars are released.

(b) A receiving and delivery yard is sometimes desirable for receiving transfers from various roads and for assembling outbound empties and reconsigned cars.

(c) A hold and inspection yard is sometimes provided. This yard should have two-lane driveways between pairs of tracks to permit access for inspection and icing from trucks. Inspection platforms are sometimes provided. It may be a separate yard or combined with the receiving and delivery yard or with a small classification yard.

(d) Team yards should have ample standing capacity. Extremely long tracks should be avoided.

(e) Track centers should be not less than 13 ft.

4.6.1.3.2 Buildings

(a) Ample floor space should be provided for mechanical handling from cars to warehouse floor, display of produce and assembly of various lots for delivery to trucks.

(b) The column spacing should be given careful study and be as wide as possible, consistent with economic design.

(c) The back-up space for trucks should be as liberal as possible.

4.6.1.3.3 Platforms

(a) Platforms used for inspection or jointly for inspection and handling of produce should be not less than 12 ft in width, 3 ft 5 in above top of rail when the center line of tangent track is 5 ft 9 in from the platform, or 4 ft 7 in above top of rail when the center line of tangent track is 8 ft 0 in from the platform. Platforms should be covered, and light and water should be provided. Roof supports should be located to minimize interference with handling crates. Space for crate storage and repairs is usually required.

(b) House platforms, when served by both highway vehicles and railway cars, should be 4 ft 4 in above top of rail and 8 ft from the center line of tangent track.

(c) Clearances must comply with state regulations.

4.6.1.4 Facilities

4.6.1.4.1 Garbage and refuse disposal

Cars should be thoroughly cleaned after unloading, and all refuse and garbage removed from platforms, buildings, etc. Cleaning of cars may be accomplished on a one-spot basis with mechanized devices. Special equipment such as sweepers, dump carts, etc., should be provided in large terminals. Garbage may be handled by city collection, by contract, or incinerated. An incinerator, if required, should be of ample capacity to handle each day's collection in 6 to 8 hr, conveniently located, and designed to burn garbage having a high water content.

4.6.1.4.2 Icing

All cars in team and hold and inspection yards should be accessible for icing, which is usually done by contract with local dealers. Access may be from narrow driveways or from icing platforms.

4.6.1.4.3 Miscellaneous

(a) Ample drainage is essential for buildings and yards.

(b) Floodlighting the entire area is desirable in addition to local lighting.

(c) The entire area should be strongly and closely fenced to prevent trespass.

(d) Definitely assigned entrances and exits should be provided.

(e) A cold storage warehouse, if required, should have suitable track service and convenient means of communication with other buildings.

(f) Adequate parking space should be provided.

(g) Motor truck scales, when required, should be located at a point convenient for the drivers and near the freight office. The location should not interfere with truck movements in the driveways.

Part 5

Locomotive Facilities

FOREWORD

In the establishment or modification of any large railway terminal it is necessary to determine whether separate locomotive facilities should be provided for freight and passenger equipment, or whether both types should be handled in a single facility. Convenience, expedition, low unit operating costs and carrying charges involved in these alternatives must be given proper consideration. Usually a single facility is more efficient and produces lower unit operating costs.

The locomotive facilities must be correlated to all other faciilties for efficient handling of each locomotive. Servicing facilities required for the various types of locomotives should be arranged in an efficient sequence.

CONTENTS

5.1 GENERAL

5.1.1 Requirements

(a) In the case where only one company is involved which has locomotive facilities that can be readily enlarged to meet all requirements, economy will favor the retention of such facilities in service unless it is prohibitively remote from either the passenger station or the center of freight activities.

(b) In the case of joint freight facilities it may be advisable, as in joint passenger terminals, to substitute new joint freight locomotive facilities for several layouts unless existing separate facilities are merely coordinated and delegated to joint management where it will be advisable to rely upon the existing facilities.

(c) New locomotive facilities should be located to minimize (1) usage of tracks on which there are other movements, (2) reverse or conflicting movements, (3) light engine mileage in the movement of locomotives to and from their trains. 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, transportation and mechanical departments. This study should include consideration of the following data, keeping future expansion in mind:

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 hostled, 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.

5.1.2 Site Selection

The selection of a proper site requires a study of all factors affecting costs of construction and operation, including cost of preparing site; foundation conditions and drainage; sewage disposal, water supply and electricity; relation to existing or proposed yards and to passenger and freight stations; labor supply, including housing facilities and transportation; tax rates; and availability of public fire fighting apparatus and stations.

5.1.3 Track layout

(a) All locomotives should preferably enter the locomotive facilities from the same end; a separate exit should be provided for flexibility in movement to insure that the facilities will not be tied up in case of trouble at the entrance.

(b) 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. Where climatic conditions permit outside storage sufficient tracks should be provided near the exit for holding locomotives already prepared for service.

(c) The layout should provide at least one runaround track for flexibility.

(d) At the ends of locomotive runs where the operation requires quick turnaround service, facilities should be provided for standing locomotives, sanding, fueling and watering with or without inspection pits.

5.1.4 Buildings

5.1.4.1 Office

Adequate office facilities should be provided for the officer in charge of the terminal and his staff.

5.1.4.2 Amenity and service

One or more structures of fire-retardant construction should be provided at a convenient location to house the following:

(a) Locker, toilet and washrooms for employees.
(b) Storehouse for flagging equipment, supplies, oil, lanterns, etc.

5.1.4.3 Reference

Complete information on the design of shop buildings and other buildings required in an engine terminal, together with pits and other appurtenances, will be found in Chapter 6—Buildings.

5.1.5 Miscellaneous facilities

5.1.5.1 Communications

(a) Telephone
(b) Radio
(c) Paging—Talk-back speakers
(d) Pneumatic tube (if necessary)

5.1.5.2 Lighting

The entire locomotive terminal area should be provided with adequate lighting.

5.2 SERVICING FACILITIES

5.2.1 Fueling Stations

(a) Coaling Stations

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. Coal stations may be arranged readily to deliver coal on one or more tracks. Each location should be studied separately on the most suitable track arrangement for that particular installation selected.

(b) Fuel Oil Stations

At locations where oil is used as a fuel for locomotives, facilities must be provided for unloading, storing and delivering such oil. In cases where the fuel oil used is a heavy type, facilities must be provided for heating such oil while being unloaded as well as in storage so that pumping may be completed in a minimum length of time.

In the design and construction of fueling stations at locomotive facilities provisions should be included to prevent the pollution and contamination of public waters from spilled fuels and oils through surface and subsurface waters, sewers and other conduits.

5.2.2 Watering

Sufficient watering facilities should be provided to serve all locomotives entering and leaving the terminal.

5.2.3 Sanding

Sanding facilities should be provided to serve all locomotives entering and leaving the terminal. Usually these facilities are situated adjacent to the fuel and water facilities so that locomotives can be completely serviced at one location.

5.2.4 Washing

(a) Steam locomotives

Facilities should be provided for washing locomotives between the cinder pit and the turntable. Either a washing platform or pit should be constructed with adequate drainage and illumination.

(b) Diesel and electric locomotives

Washing facilities should be placed on the lead track when possible. Brushes and spray pipes may be so arranged that the operation is automatic when the locomotive shunts a track circuit at the entrance to the washer. Some hand washing of a locomotive may be necessary. A washing platform with or without a wash pit to facilitate cleaning the underside of a locomotive may be found desirable.

5.2.5 Boiler Washing

(a) In diesel, diesel-electric, and electric locomotive facilities, boiler-washing facilities should be provided for heat generating boilers on locomotives used in passenger, mail and express service.

(b) In steam-locomotive facilities, boiler-washing facilities should be provided for all locomotives.

5.2.6 Turning Locomotives

Unless the locomotives to be handled are exclusively of the 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.

5.2.7 Portable Servicing

Portable servicing units consisting of a truck equipped with sand and fueling facilities may be desirable for servicing diesel switch engines at a large terminal.

5.3 INSPECTION PITS

Inspection pits are usually located on the inbound track near the entrance to the terminal, except such a pit as described in 5.4.1(g). These pits should have:

(a) Suitable depth for inspection of the locomotives.
(b) Length not less than the longest locomotive to be inspected.
(c) Adequate drainage.

(d) Stairway for convenient access and/or tunnel direct to the inspectors' office.

(e) Fixtures for lighting and service outlets.

(f) Telephone supplemented by a pneumatic tube system for communication with the shop supervisor's office.

5.4 DIESEL, DIESEL-ELECTRIC AND ELECTRIC

5.4.1 Shop Building and Appurtenances

(a) The size of the building is determined by the length of units and the number to be housed simultaneously. A rectangular structure is ideal to serve the requirements. When locomotives are pooled, the back shop work will be done at one or more system shops, and the building for such work will generally be much larger and have more facilities than the building for running repairs at terminals located between such system shops. The structure, however, should be so designed as to provide facilities for either running repairs or heavy repairs as outlined above, and should include a machine shop, store room, parts cleaning and parts-conditioning room, wheel supply and storage, lunch and locker room, wash rooms, tool rooms, toilets and office.

(b) Materials used in construction should be fire-retardant.

(c) The number and length of tracks should be sufficient to accommodate all of the locomotives to be housed at any one time. Stub-end heavy repair tracks may have certain economic advantages, and if such a layout is used there should be at least one through running repair track along side of the heavy repair tracks. The desirable distance between track centers should not be less than 23 ft, which allows for a 12-ft wide working platform.

(d) The length of pits should accommodate the longest locomotive consists.

(e) Wheel storage facilities adjacent to repair shops should be provided to assure a convenient supply of wheels, including wheels with their traction motors attached.

(f) The lubricating oil facilities may be handled in the repair shop proper or in a separate structure. Fire-retardant construction should be employed. Meters should be provided to measure accurately the lubricating oil delivered to the units. The tanks for new lubricating oil should be of sufficient size to handle oil in carload lots. Facilities may be provided for reclaiming worn and dirty lubricating oil and should include tanks to collect the reclaimed oil.

(g) When pooled locomotives receive schedule maintenance there will be no need for them to enter the shop building for days at a time. If such conditions exist at the terminal a track with an inspection pit adjacent to the shop building will in most instances reduce the number of tracks in the shop building by at least one. Such a pit should be long enough to accommodate several sets of locomotive units and should be near enough to the shop building for the shop supervisor to direct the activities of the employees on this pit. Fueling and sanding facilities could be located along this track. With such an arrangement it will mean that a locomotive may be placed on the pit track by the road crew, at which point it will be spotted for the necessary fueling, sanding and other servicing and can remain there until ordered for departure, at which time the road crew may move the locomotive out of the engine terminal. This will result in real economy, since hostling required within the shop building area will be eliminated.

(h) The electric trolley and other wires should be terminated outside of the shop building handling electric locomotives.

5.4.2 Blow-down Facilities

Standard stone ballast grouted with cement or a concrete slab should be provided on the outbound track for locomotives used in passenger service on which there are steam generating units for train heating.

5.5 STEAM

5.5.1 Enginehouse

(a) The circular form of enginehouse is preferable under ordinary conditions for steam locomotives. The structure should provide facilities for running repairs, heavy repairs, machine shop, store room, wheel supply and storage, lunch and locker rooms, wash rooms, tool rooms, toilets and office. The length of stall along center line of tracks should be at least 20 ft greater than the over-all 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 the turntable opposite the enginehouse and in line with pit tracks are sometimes desirable.

(b) The track layout should be designed so that locomotives which do not require turning may be serviced without crossing the turntable.

(c) 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.

(d) Sufficient tangent should be provided on all turntable approach tracks to permit all engine trucks to be on straight track before passing onto turntable.

5.5.2 Blow-off Facilities

If the number of engines serviced justifies the installation of a separate blow-off pit, it should be furnished. These blow-off pits may be located between the engine washing facilities and the turntable, or on the outbound engine lead. The blow-off pit should be of a permanent type of construction and should be provided with sufficient drainage. The pit should be large enough to prevent overflowing when in use.

5.5.3 Cinder Handling

Locomotive cinders must be disposed of, and facilities will have to be provided for handling cinders. There are several types of cinder-handling facilities, including:

(a) Cinders discharged directly on the track and removed by shoveling.

(b) Shallow shoveling pits.

(c) Water pits, where cinders are discharged into pits containing water, from which they are removed and loaded into cars by either a locomotive or overhead crane.

(d) A depressed track beside or between the incoming tracks, deep enough to accommodate cars into which cinders are chuted directly from the locomotives.

(e) Mechanical plant where cinders are discharged into hoppers and thence into buckets or continuous conveyors into cars.

The track arrangement in the cinder-handling facility must be studied to provide sufficient standing capacity to accommodate all locomotives which cannot be immediately serviced, and crossovers and other connections so that locomotives requiring preferred attention may be dispatched ahead of others with a minimum of interference.

Part 6

Passenger Facilities

FOREWORD

The designation "passenger facilities" as here employed, comprising mass transit and commuter service, includes all the facilities for the passenger station proper, mail and express service, track and street approaches, such other auxiliary or accessory features as may be included within a prescribed boundary or terminal zone, and, where desirable and practicable, a locomotive terminal, a coach yard, and the appurtenant switching facilities.

CONTENTS

6.1 GENERAL

(a) Studies for such passenger facilities should be made by a committee, representing all the parties at interest, composed of engineering, transportation, mechanical, signal and traffic officers. Preferably the officer to be placed in charge of the property for operating purposes should be made a member of that committee.

(b) Consistent with the magnitude and importance of the task, men having expert knowledge of the various phases of the problem should be employed under the direction of the committee to study the whole situation. These experts should determine and report on all necessary requirements of the terminal.

(c) The engineer having charge of the design of the contemplated facilities, accompanied when practicable by members of the committee or its representatives, should make investigations by personal inspection of terminal situations somewhat similar to the one in contemplation; talk with responsible officers of similar terminals; examine the facilities there provided and see how they function; obtain comments from the men operatingthe terminals visited; get their suggestions as to improvements which experience has taught them might be made to advantage. He should also accumulate and study reports that have been written covering particular properties, and also the books and articles that have been written upon the general subject; and seek information from all available sources.

(d) The handling of mail and express, and the conjunction thereof with the handling of baggage, are essential and integral parts of passenger terminal operation. The necessary facilities should be planned in cooperation with the express and postal officials concerned.

(e) A passenger terminal project should be so located and designed as to coordinate as far as reasonably practicable with other civic activities. Frequently it is found desirable to make general civic improvements at the same time the terminal is being constructed. Modification of street approaches is almost always involved. The costs should be assumed by the parties benefited. Close cooperation between the terminal committee, the planning board of the city, executive officers of the city, and perhaps other civic groups, if necessary in order that such new legislation as may be necessary shall be fair and equitable to all parties at interest.

(f) The designer must realize that a large passenger terminal is subject to vicissitudes of weather, to delays and derailments to trains, to late connections, to power failures, to surges in traffic, to bad-order equipment, to special trains or cars requiring special handling, to excursion travel, and to jubilees, conventions and special functions at irregular periods.

(g) The relations which should exist between business handled and the size of facilities is subject to variation due to local conditions, class of traffic, type of service rendered, large variation in estimates of normal rush-hour business handled, and the varying ideas of what constitutes adequate service. Table 2 outlines the relations. Committee 6—Buildings, should be consulted in the design of such facilities.

6.2 SITE

The site for the terminal should have a balanced maximum composed of the following characteristics:

(a) Accessibility—having due regard to modern methods of transportation, land values, and economic requirements.

TABLE 2

RELATIONS WHICH SHOULD EXIST BETWEEN BUSINESS HANDLED AND THE SIZE OF THROUGH PASSENGER STATION FACILITIES

Station Facility	*Unit*	*Number or Size of Facility Required for the Normal Number of Rush-Hour Passengers Indicated*								
		250	500	750	1000	1500	2000	3000	4000	5000
1. Area of main waiting room	100 sq ft	30	53	72	89	112	128	155	178	200
2. Seating capacity of main waiting room	No. of seats	143	213	270	315	400	465	570	665	750
3. Area of women's waiting room	100 sq ft	5	7	9	11	14	17	23	29	35
4. Total area for waiting purposes	100 sq ft	55	88	116	137	167	195	238	275	306
5. Total seats in waiting areas	No. of seats	190	300	390	470	590	700	880	1050	1200
6. Total area of lobby, concourse and all waiting rooms	100 sq ft	80	152	208	256	320	376	472	552	624
7. Area of men's toilet rooms	100 sq ft	4	6	8	10	13	15	20	26	31
8. Number of men's water closets	Number	6	9	12	15	19	23	29	35	41
9. Number of urinals	Number	5	8	10	12	15	17	20	23	25
10. Number of men's lavatories	Number	3	5	7	9	11	13	18	22	26
11. Area of women's toilet rooms	100 sq ft	3	4	5	6	8	10	13	16	18
12. Number of women's water closets	Number	7	9	12	14	17	19	23	27	30
13. Number of women's lavatories	Number	3	5	7	9	11	13	17	21	25
14. Area of ticket offices	100 sq ft	4	7	9	11	14	17	21	26	-----
15. Number of ticket windows	Number	3	5	7	8	11	13	16	18	21
16. Number of telephone booths	Number	3	4	5	7	10	13	19	25	31
17. Area of telegraph facilities	Sq ft	100	130	150	170	210	230	280	310	330
18. Total area of dining and lunch rooms	100 sq ft	9	14	19	24	34	43	63	83	102
19. Total number of seats in dining and lunch rooms	Number	34	53	72	93	129	173	249	327	407
20. Area of kitchen	100 sq ft	5	8	11	14	20	26	38	50	62
21. Area of news stand	Sq ft	115	185	240	290	380	450	565	695	820
22. Number of barber chairs	Number	2	3	3	4	4	5	6	7	8

	Unit	*Baggage Facilities Required for the Indicated Number of Pieces of Baggage Handled Daily*								
		250	500	750	1000	1500	2000	3000	4000	5000
23. Area of baggage room	100 sq ft	20	33	45	60	87	112	166	219	272
24. Baggage room tail-board frontage	Lin' ft	38	62	79	95	125	150	194	230	263

	Unit	*Parcel Check Room Facilities Required for the Indicated Number of Parcels Handled Daily*								
		250	500	750	1000	1500	2000			
25. Area of parcel check room	100 sq ft	4	6	8	10	14	18			

	Unit	*Hand-Baggage Facilities Required for the Indicated Number of Pieces of Hand-Baggage Handled Daily*								
		250	500	750	1000	1500	2000	3000		
26. Area of hand-baggage facilities	100 sq ft	4	6	7	8	10	12	16		

(b) Sufficient size and suitable shape to provide for a proper number and length of tracks, and to provide for future growth of both.

(c) Ease of approach from all the associated rail lines, without excessive curvature or gradient, and preferably without grade crossings.

(d) Room for proper by-pass tracks and for the spread of ladder tracks, to provide for free movement and to prevent a tie-up of the yard from derailment at the throat.

(e) Room for auxiliary facilities conveniently located, such as:

(1) Baggage, mail and express.
(2) Parking space for sleeping, private and business cars.
(3) Locomotive terminal.
(4) Coach yard.
(5) Automobile parking.

6.3 TRACK ARRANGEMENT

(a) The track layout should be such as may be required to accommodate straight-forwardly and without interference the contemplated schedule movement of trains and the tributary switching movements to and from the station, with a proper margin for extra sections or delayed trains, as well as for any predictable increase in volume of traffic.

(b) The track layout should be designed with length between turnouts as required for the proper signal indications, and necessary clearances as required for operation of track circuits so that a system of fixed signals or interlocking may be installed whenever desired without restricting the use of any of the routes or the necessity of additional track changes.

(c) Station tracks should be provided sufficient in number to accommodate at one time the contemplated schedule movement of trains, with a liberal margin for extra sections and off-schedule arrivals or departures, and should be of such clear length and lateral spacing as may be required to fit the station platform layout and to accommodate without congestion the essential functions of the station platform service. While the number of station tracks is largely fixed by the number of trains to be accommodated at periods of maximum density, it also to some extent may depend upon the type and size of the station, the lengths of the station tracks, the design of the throat, the proximity of the coach yard and locomotive terminal facilities, the character of traffic, and the method of operation.

(d) Sufficient throat tracks should be provided to permit at least two simultaneous parallel movements. The track layout should be sufficiently flexible to provide for complete interchange of routes. A ratio of from 2.5 to 3.0 station tracks to 1 throat track should be adequate if the throat is properly designed.

(e) A sufficient number of station tracks long enough to accommodate the maximum length trains, and so located as to assure flexibility of operation, should be provided. Possibility of future increase in length of trains should be considered.

(f) The through and loop types of station are superior to the stub station from the standpoint of train operation.

(g) Loop tracks for turning trains generally expedite service and effect economies.

(h) The possibilties of using the station tracks for other service, such as freight interchange, when not in use for their normal purpose, should be studied.

(i) Freight or industry connections on the station approach tracks or on lines within or adjacent to the terminal zone should be so arranged as to avoid or minimize interference with passenger train traffic.

6.4 STATION PROPER

6.4.1 General

The station proper includes all the facilities required for the complete accommodation of passengers and their belongings between the public entrances and the trains; also such facilities as the railway company shall provide for the handling of mail and express. It comprises:

(a) The main building, which includes all of the facilities directly needed for the comfort and convenience of passengers prior to their departure or subsequent to their arrival on trains.

(b) All thoroughfares connecting the main building with the station platforms, such as fixed or moving stairways, elevators, ramps, and other passageways and outside concourses.

(c) The station tracks and the appurtenant platforms on which passengers, baggage, mail and express are loaded upon or unloaded from trains, including the elevators, ramps, or other runways, upon which baggage, express and mail are trucked to or from the station platform.

(d) All other buildings to accommodate the assembly and the public receipt and delivery of baggage, express or mail.

(e) All roadways, platforms and parking spaces to accommodate taxicabs and other public and private vehicles, handling people to and from the station, including all housing and shelter thereof not embraced in the main building.

6.4.2 Main Building Areas

6.4.2.1 General

(a) The principal floor areas should include a lobby, a waiting room or rooms, a passenger concourse, and a separate women's powder room, or any combination of these facilities.

(b) All of the essential functions of the main building should be served on a common floor level, or levels so nearly common as to be connected by moderate ramps, and so related if possible to the station track level that no stairways shall be required to reach the station platform level in stub end stations or to reach the thoroughfares over or under the tracks, as the case may be, in through stations.

(c) The lobby should front upon the principal public entrances and exits, and it, solely or together with the passenger concourse, should be the business area of the station. The principal station facilities, such as information booths, ticket office, baggage check counter, parcel check room, telephone and telegraph facilities, parcel checking lockers, etc., should be located in proper sequence along the line of travel and clearly indicated to avoid confusion and to reduce the walking distance of passengers to a minimum.

(d) An adequate and conspicuous train bulletin board and a public announcing system should be provided.

(e) The general waiting room, if only one is provided separately from the passenger concourse, may well be placed at one side of the line of travel but as convenient as practictable to the passenger concourse.

(f) If the function of the general waiting room is to be served in common with that of the passenger concourse, provision must be made for all the requirements of a waiting room, with seating facilities so situated as not to intrude upon the maximum areas required for passage of persons to and from the train gates or for those assembling thereat.

6.4.2.2 Concourses

(a) Unless its function is combined with that of a waiting room, a separate passenger concourse is essential in a large station. Such a concourse is used effectively in many stations as a passageway which permits arriving passengers to reach the street or departing passengers to enter from the street without passing through the lobby.

(b) It should be possible, and is exceedingly advantageous in the case of suburban service, for passengers to proceed directly to and fro between the passenger concourse and the street without passing through waiting room or blocking its exits.

(c) The elimination of conflicting lines of travel is very desirable and should receive careful study in the design of the station, particularly as regards the segregation of inbound from outbound passengers, and of commuters from through passengers.

(d) The required clear width of passenger concourse depends upon the character and amount of traffic and the number of its entrances and exits. The concourse should be large enough to permit the gathering of a full trainload at a gate without a blockade, but should be so arranged that it will not be a convenient thoroughfare for people who are not passengers.

(e) A train concourse is advantageous, as it permits serving one station platform by several gates or, conversely, the serving of several platforms from one train gate. In stub stations it permits trucking from one platform to another without entering the passenger concourse.

(f) A clear width of 20 ft for a train concourse is adequate if it is not used extensively for trucking.

6.4.2.3 Ticket offices

(a) Ticket offices should be located adjacent to the direct line of travel, so arranged that passengers waiting to secure tickets will not interfere with the general flow of traffic.

(b) Windows, counters, and automatic ticket machines may be provided along the passenger concourse for the sale of local tickets.

(c) Where a large number of commutation tickets are issued during the last 2 or 3 days of the month, portable booths located in the passenger concourse may be desirable.

6.4.2.4 Parcel rooms and parcel checking lockers

The baggage check rooms should be easily accessible to inbound and outbound passengers and where the amount of business justifies, separate counters should be provided for receiving and delivering baggage. Self-service checking lockers should be installed at convenient locations.

6.4.2.5 Toilet and washroom facilities

Pay toilets and pay washroom facilities should be provided. However, there should be an adequate number of free toilets and lavatories.

6.4.2.6 Leased and rental areas

(a) Concessions

(1) Concessions of proper character have proved profitable in most stations and are desirable, not only from a revenue-producing standpoint, but as a facility which adds to the comfort or convenience of the passenger,

(2) The number and character of these concessions can be greatly expanded in terminals located in cities of large size, with benefit and profit to all concerned.

(3) Concessions, to be successful, must be so located as to be conspicuous and easy of access. They must be neat and attractive in appearance and well lighted, and concessionaires should be experienced, responsible and progressive.

(4) Booths opening directly on to the corridor, where service is rapid, appeal more to the commuter, while stores appeal to the through traveler and particuarly to the transfer passenger who has time to spare.

(b) Office space

(1) The practice of constructing rentable office space in connection with passenger stations under proper circumstances offers opportunities for assisting in carrying the interest charge resulting from the construction of stations.

(2) If the station building is surmounted by an office building, the entrances to the latter should be independent of the station so that office employees will not be required to pass through the station. Consideration, however, should be given in the design of certain station facilities to the possible patronage by occupants of the office building.

6.4.3 Station Platforms

6.4.3.1 General

In planning a passenger terminal it is important to devise a coordinated arrangement between the track layout and the station proper which will, at reasonable cost, provide maximum convenience, expedition, and economy in rendering all the platform services.

Particularly at heavy duty stations, it is extremely desirable that baggage, mail and express trucks shall not ordinarily have to traverse or occupy platform space being used for the accommodation of passengers.

Determination of the type of platform (i.e., combined or separate trucking and passenger) best suited to a particular situation is dependent upon the character and volume of the various kinds of traffic handled, the type of station (i.e., stub, through or loop), the location and type of approaches to the platforms for the various kinds of traffic, the relation of the various approaches to each other, the relative lengths of platforms and trains, space available for station track and platform development, and the method of operation. Because there are so many variables involved, final conclusion as to the best arrangement in any case can hardly be reached without thorough study. All factors affecting a particular situation must be analyzed before this determination can be made.

6.4.3.2 Platform arrangement

6.4.3.2.1 Heavy traffic

(a) For a *through station,* with track level below or above the station floor level (preferably the latter), combined platforms should be installed, sufficient in length to permit berthing the passenger carrying cars in the center zone leaving the end zones clear for trucking. Passengers would reach or leave the platforms via ramps, stairways or escalators at the middle of the platforms; and trucks would reach or leave the platforms by elevators or ramps, at or near the ends connected with subway runways and assembly areas. If platforms cannot be built to such length or if two trains are regularly berthed on the same track simultaneously, interference between passengers and trucking will result and the installation of separate platforms may be justified.

(b) For a *loop station,* the same assembly as above specified for a through station should be provided, but with truck elevators near only the forward ends of the platforms.

(c) For a *stub station,* with tracks at same level as station floor:

(1) If all trains back in, combined platforms should be installed. Provision should be made for all trucks to reach or leave the station platforms near the outer ends, via elevators or ramps connecting with subway facilities.

(2) If inbound trains head in, separate platforms should be provided for passengers and trucks, the latter to reach or leave their platforms via elevators or ramps connecting with subway facilities.

The type (2) layout requires so much more area and platform construction than type (1) that type (2) is preferable only when the backing in of all trains is impracticable or when the volume of traffic handled is such that the increased cost of land and facilities required by type (2) is justified by the elimination of interference on the platforms.

(d) In all cases where truck elevators or ramps are provided, truck runways at grade across the tracks should also be provided to meet demands.

6.4.3.2.2 Light traffic

At stations where both passenger and truck movements will be relatively light and train arrivals and departures will occur mostly at separate intervals, a careful predetermination of the balance between investment and advantage may be required to decide whether or not grade separation is justified, either for passengers or for trucks, and which method of rendering the platform services is to be selected.

In such situations, and also at some heavy-duty stations where attainment of the ideal seems impracticable or too costly, there may be warrant for designing the station platforms for the combined use of trucks and passengers throughout their length.

In the case of combined platforms on which the loading and unloading of baggage, mail and express is confined to the end sections thereof, and trucking through the areas devoted to the loading and unloading of passengers is not permitted, platform widths may be the same as for exclusive passenger platforms.

6.4.3.3 Design data

(a) Combined passenger and trucking platforms at heavy duty stations should be at least 20 ft in width, assuming a row of columns located in the center of the platform.

(b) Exclusive passenger platforms should have a minimum width of 13 ft, which is sufficient to accommodate the passengers from one arriving train, one line of travel for passengers to a departing train, and a row of columns in the center of the platform. This width will normally meet all requirements for through passenger train operation, as it is seldom necessary to berth two arriving trains simultaneously at the same platform.

(c) Exclusive trucking platforms without columns should have a minimum width of 11 ft to permit 2 trucks to pass. Where the volume of trucking is sufficient to justify 3 lanes, a minimum of 16 ft should be provided to avoid blocking the platform when 2 trucks are serving cars on opposite sides. If columns are necessary, platform widths should be increased accordingly and columns located so as not to interfere with trucking lanes.

(d) In combined passenger and trucking platforms in through stations, it is desirable to have a clear width of approximately 6 ft on one side of the stairs to permit trucking operations past the stairs.

(e) In stations where a large number of passengers must be handled quickly, the relation of platform elevation to height of car floor should be considered to expedite the handling of passengers. However, high platforms interfere to some extent with the switching and inspection of equipment.

(f) In a through station, the location on the station platform of the approach to the concourse has a bearing on the required capacity of the approach. If it is located at the end of the platform, the concentration will be but one-half as intense as if it is located at the middle of the platform, although the duration of the maximum intensity of congestion will be much less in the latter case than in the former. If a double approach is located at the center, the intensity of the concentration will be the same as in the first case, and the duration of the maximum intensity of congestion will be the same as in the second case.

(g) In large terminals where a large quantity of U. S. storage mail is handled, belt conveyors should be installed to move the bags of inbound mail from the cars to a primary sorting platform if not directly to the post office. From a primary sorting platform belt conveyors can be used to move the mail to secondary sorting platforms. Electromechanical sorting systems have been installed in metropolitan area stations to handle the large number of separations from a primary sorting platform.

To expedite the handling of mail an ideal arrangement is to locate the Post Office Department building adjacent to the railroad station or on air rights over railroad terminal property. Belt conveyors can be used to move the mail sacks and parcels between the post office building and the station building.

6.4.3.4 Elevators and escalators

(a) Baggage elevators are desirable at both ends of combined passenger and trucking platforms in large passenger stations where trains operate in both directions through the station, to reduce the interference between trucking operations and passengers.

(b) Under normal conditions, passenger elevators are not recommended as approaches to individual passenger platforms. They may be desirable as a supplement to stairways for the use of the aged and infirm.

(c) A single elevator or escalator should not be relied upon as the sole means of approach to a station platform.

(d) Escalators have a maximum carrying capacity of approximately 5000 passengers per hour for 32-in width and 8000 passengers per hour for 48 in. They are being used successfully in both suburban and through passenger service.

6.4.3.5 Ramps

6.4.3.5.1 Passenger

(a) Ramps provide ideal means for movement of passengers to and from station platforms if they can be so installed as not to increase materially the distance traveled by passengers, and do not materially decrease the space on the station platform available for the accommodation of trains. Good results can be accomplished in many cases by the use of both stairways and ramps.

(b) The gradient for passenger ramps preferably should not exceed 7 percent. The ramp surface should be finished with an abrasive or non-skid material.

6.4.3.5.2 Trucking

(a) Ramps are a very desirable means of providing vertical transportation for trucking operations, if the design of the station is such as to permit their installation without a material sacrifice in space.

(b) Ramp gradients in excess of 8 percent are not recommended. The ramp surface should be finished with an abrasive or non-skid material.

(c) In stub terminals where separate passenger and trucking platforms are used and the baggage, mail and express facilities are located below the tracks, the utilization of the end of the exclusive trucking platforms adjacent to the concourse permits the installation of trucking ramps without sacrifice of space.

(d) The minimum clear width which should be considered for trucking ramps designed to accommodate one line of traffic is 6 ft, and for two lines of traffic is 11 ft.

6.4.4 Characteristic Requirements of Passengers

6.4.4.1 Through passengers

(a) Transfer passengers occupy a station for a maximum length of time and require more extensive facilities per passenger than resident through passengers.

(b) Decreasing the time interval between incoming and outgoing trains decreases requirements per passenger for waiting room space and for certain other facilities.

(c) The number of passengers handled during the rush hour does not alone determine the size or number of facilities required. Local conditions must be studied, as they affect requirements for any particular situation.

(d) The size or number of facilities must be modified to make allowance for:

(1) Time of arriving and departing trains, and the span in minutes between them.

(2) The ratio between passeengers commencing or terminating their journey and transfer passengers.

(3) Number of hold-over passengers arriving or departing outside of the rush hour but occupying space and requiring service during a portion of the rush hour.

(4) Departure from a reasonably uniform spread of passengers entering and departing within the rush hour.

6.4.4.2 Suburban or commuter passengers

(a) Suburban passengers occupy a station for a minimum length of time and move faster than the through passenger, and therefore requirements in the way of station facilities per passenger are substantially less for a suburban passenger than for a through traveler.

(b) When suburban business is heavy, it is desirable to separate the through and suburban service, as their requirements are not similar. This may be done by handling the two classes of service at:

1. Different levels. This requires electrification.
2. Different sides or ends of the station.
3. Different stations, one beyond the other.

(c) Indicator boards are the only directional information required, as a rule, by commuters. They should show track number, scheduled leaving time, and essential identification of train.

6.4.5 Services and Utilities

6.4.5.1 Communication facilities

Teletype machines, telautographs, pneumatic tubes, audible intercommunication systems, and other electronic devices, may be used to advantage to supplement telephones for the rapid transmission of operating information between train directors, station master, information booth, bulletin board and other strategic points. A public address system should be provided for announcing train information.

6.4.5.2 Electrical service outlets at station tracks

Electrical service outlets at station tracks should preferably be located between adjacent tracks, except in stations having separate trucking platforms. Direct-current battery charging outlets, when serving two tracks, should have two receptacles and should be located at intervals of two average car lengths along those tracks used regularly for holding passenger cars for extended periods. Air-conditioning outlets for 220-v ac, when serving two tracks, should have two receptacles, and should be located at intervals of one average car length along those tracks used regularly for holding either direct-mechanical or electro-mechanical air-conditioned passenger cars.

6.4.5.3 Steam, air, water and telephone connections

(a) Steam connections should be provided at all station tracks on which cars will stand without locomotive attached. For stub tracks, steam connections should be located at the ends, one connection for each track. For through tracks, they should be placed to serve each track at the point or points where the rear of a train would normally be placed.

(b) Air connections should be provided at all tracks where the method of operation and servicing requires that an air brake test be made while the train is standing without locomotive attached. When air connections are installed, they should be placed at the same locations as steam connections. At stations where equipment may be watered, hydrants spaced two car lengths apart (preferably serving two tracks) should be provided.

(c) At the points where air and steam connections are located on station tracks, a telephone jack may be provided to permit the connecting of the train telephone line to the main station switchboard.

6.4.6 Accessibility and Parking

(a) Street approaches should receive particular attention in the overall planning to provide convenient access and sufficient capacity but by-passing areas of traffic congestion. Separate routes should be provided so that pedestrian traffic and vehicular traffic can be safely and expeditiously handled. Ample accommodation for vehicles handling mail, baggage and express should be provided in a manner that will not impede the free movement of public transportation vehicles, private conveyances, and pedestrian traffic.

(b) The desirability of providing subways for pedestrians to reach the opposite sidewalks of adjoining streets without crossing at grade should be considered. Subsequent installation of service facilities may make it impractical to provide such passageways in the future.

(c) Ample provision should be made for convenient access to public transportation services and taxicab service within or adjacent to the station. It is essential that taxicabs be able to promptly reach an unloading point, move freely to a holding area, and to reach a loading point for passengers leaving the station without interference to other vehicular traffic.

(d) Adequate parking space convenient to the station for railroad patrons is desirable. In some places, pay-parking facilities for private automobiles have been provided for the accommodation of patrons. See AREA Proceedings, Vol. 60, 1959, page 294.

6.5 COACH YARDS

6.5.1 General

(a) It is desirable that coach yards and their appurtenant facilities, incidental to car inspecting, repairing, battery charging, cleaning, icing and watering, and all servicing of passenger train equipment, should be an integral feature of every large passenger terminal, whether or not more than one railway is accommodated, and whether or not the forces so engaged are in the charge of the terminal management.

(b) In some joint terminals each line retains jurisdiction of all such forces provided for servicing its own equipment. The Pullman Company always does so. The plan of having all servicing of railway equipment performed with terminal forces would seem in any case to deserve consideration.

(c) It is definitely preferable to have all coach yard switching performed by and under full control of the terminal management in all cases of joint operation where the coach yard is an integral part of the joint terminal, but not otherwise ordinarily.

(d) Facilities usually provided in a coach yard will in most cases be satisfactory for servicing streamline trains of light weight non-articulated equipment. However, separate and specially equipped tracks are frequently provided for servicing certain streamline trains, either articulated or non-articulated which, together with the locomotive, are regularly operated as a unit, usually in quick turn-around service.

(e) Although separate facilities may be provided for particular trains or types of equipment, the servicing of all passenger train equipment in a single yard is desirable.

(f) It is common practice to hold trains for cleaning and waiting for less than 24 hr on 1 track.

6.5.2 Location

(a) The coach yard should be placed convenient to the station and mechanical facilities.

(b) The location of a coach yard should be determined by the economic balance among the following factors:

(1) Available sites.
(2) Land values.
(3) Cost of construction.
(4) Convenience to the station and other facilities.
(5) Cost of moving equipment between station, coach yard and engine house.
(6) Possible need for future expansion.

6.5.3 Capacity

The capacity required in a coach yard depends upon:

(a) Number of cars and trains to be handled.
(b) Class of equipment.
(c) Standard of maintenance.
(d) Schedule of equipment layover.
(e) Frequency of cleaning.

6.5.4 Types

There are two general types of coach yard layouts: Stub track and through track. There is also an intermediate type made up of through tracks, but operated generally as two systems of stub tracks. Operation is most efficient in a system of through tracks.

6.5.5 Tracks

(a) Tracks of equal length and equal to the length of the longest trains give greatest operating efficiency.

(b) A uniform spacing of not less than 20 ft between track centers is desirable for tracks on which servicing work is done. Where platforms between them are obstructed by supports to overhead service lines, brake shoe racks or above-platform service outlets, such obstructions should be located off center of platforms to provide a wider passageway on one side. Where there are no above-platform obstructions, and where other conditions make it necessary, the spacing may be reduced. However, consideration should be given to the clear platform width required for the proper performance of servicing work and the clearances required for trucking equipment.

(c) Coach yard tracks used for storage of extra cars do not require particularly wide spacing or any special car servicing features other than steam for cold weather storage and possibly electricity for battery charging and air-conditioning equipment.

(d) Tracks should be arranged in groups at the leads to facilitate switching. Auxiliary leads and tail tracks of ample length should be provided.

(e) Curvature of tracks should not be less than 457-ft radius (12 deg 34 min) through turnouts or otherwise.

(f) Coach yard tracks should be placed on as nearly a level gradient as possible. For equipment with friction bearings, the gradient should not exceed 0.3 percent, and for roller or anti-friction bearings not more than 0.1 percent.

(g) A wye or loop track should be provided for turning equipment. Movements on a loop track are more expeditious.

(h) Special tracks for making up or breaking up trains are sometimes required.

(i) Only light or running repairs are made in a coach yard.

(j) The track bed in coach yards should be well drained.

(k) In the interests of cleanliness, sanitation and possible reduced maintenance expense, consideration should be given to track construction calling for rails supported by longitudinal concrete slabs with paving between slabs to present a completely paved area which can be washed. Such construction is especially desirable for tracks at commissary platforms or on which diners are re-stocked.

6.5.6 Platforms

(a) Platforms should be placed between all tracks on which cars are to be serviced.

(b) Platform construction preferably should be of concrete, crowned not less than $\frac{3}{16}$ in to the ft. The width will vary with the track centers and the type of construction supporting adjacent tracks. The edge of a platform adjacent to a track constructed with ties and ballast usually is placed level with top of rail and approximately 5 ft 6 in from the center of the track. With this type of construction a combination curb and gutter should be placed along the edges of platforms with gutters sloped longitudinally to inlets spaced for proper drainage. The gutter section should provide for a curtain wall of suitable depth to cut off excessive seepage to the platform bed. If any service lines are to be carried below the surface, the platform or curb and gutter section should provide for conduits as required.

6.5.7 Supply Lines and Service Outlets

(a) In larger yards having a number of through tracks, and where it is desired to keep servicing lines below ground, generally it will be found advantageous to carry the supply lines across the yard in a tunnel or pipe conduit, centrally located and with outlet boxes to serve each track.

(b) Water hydrants should be spaced at distances apart equivalent to the average length of cars. Although hydrants are frequently placed in alternate spaces between tracks, there is substantial advantage in locating them between all tracks. Frost protection should be provided where necessary. Construction of water hydrant outlets should comply with requirements prescribed by the United States Public Health Service and other bodies having jurisdiction over such installations.

(c) Hot water is usually provided at convenient locations.

(d) Low-pressure air connections for cleaning should be spaced the same as cold water hydrants. For testing airbrakes, high-pressure air connection should be provided through a double connection at the center of the track, or through a single connection at each end of each track.

(e) Electrical service outlets in coach yards having alternately wide and narrow track centers, preferably should be located in the center of the narrow service platform. In coach yards having uniform track centers, outlets preferably should be located at the edge of the platform, each outlet serving only one track. Direct-current battery charging outlets when serving two tracks, should have two receptacles and should be located at intervals of one average car length. When serving only one track, the outlets may be located either at intervals of one average car length, with one receptacle, or at intervals of two average car lengths, with two receptacles. Air-conditioning outlet for 220-v ac, when serving two tracks, should have two receptacles and should be located at intervals of either one or two average car lengths, preferably one, along those tracks used for servicing either direct-mechanical or electro-mechanical air-conditioned passenger cars. When serving only one track, these outlets may be located at intervals of either one average car length, with one receptacle at each location, or two average car lengths, with two receptacles.

(f) Steam supply connections should be provided in the same manner as air connections for testing air brakes.

6.5.8 Inspection and Repair Pits

(a) Where underneath inspection of standing cars is desired, one or more pits equal in length to the longest train may be justified. These may be combination inspection and repair pits depending on their location in the yard. If underneath inspection of cars in motion is desired, a short pit located on the yard lead or the mechanical washer track may be used. Where rails are elevated above adjacent paved areas, inspection and repair work will be facilitated to some extent, especially under conditions of heavy snow, but such elevation will make ramps in platform paving necessary at fire and service roadways which cross the yard.

(b) Pit construction preferably should be of concrete. The rails can rest directly on the concrete walls, if desired, without plates and cushions, and be anchored in place by bolted down rail clips; however, better results will generally be experienced with rails installed on bearing plates and cushions. The pit should be well drained and equipped with recessed flood lights for general lighting and receptacles for service lights and small tools.

(c) Where all inbound trains pass over a single pit for inspection, other tracks should be provided for servicing and repair work. Work performed at such a single pit should be confined to inspection only and the oiling of bearings while cars are spotted over it should be avoided if possible.

(d) Where servicing and light repair work is done on an inspection pit, several tracks, each with a full train length pit may be required, the number depending on the number and schedule of the trains to be serviced and the length of time required to service each train. A multiple-track pit arrangement should provide for several wheel drop pits with jacking pads so spaced that several wheels can be dropped simultaneously on any given track with a minimum of car spotting. Each track should also be provided with the other facilities for the complete servicing of cars, such as paved platforms, service outlets for water, air, steam and electricity, and an adequate drainage system.

(e) An average depth of pits for car inspection and light repairs of about 38 in below the top of running rails will provide good working space below cars, although depths ranging from 25 to 54 in are in use.

(f) Concrete jacking pads should be provided along car repair track pits. The pads should be built integrally with the track pit walls and extend laterally each side a minimum of 6 ft, from the center of the track, and for a sufficient distance along the track each way from the drop pits to provide proper jacking space. On track pits assigned to repair work only, continuous jacking pads extending the full length of the pit are desirable.

(g) An inside width of 3 ft for repair pits will provide a ledge for jacking or blocking on the inner side of rails.

(h) A jacking pad, at least one car in length and continuous between rails for center jacking, is sometimes provided beyond the repair pit on one or more repair tracks.

(i) Consideration should be given to covering at least a portion of the area devoted to car servicing and repair work. The protection afforded by a building with semi-covered sides, preferably of fireproof construction, will reduce the expense of conditioning trains and expedite repair work under unfavorable weather conditions. Complete housing of pits on tracks assigned to repair work is desirable, but at repair pits where wheels are changed or truck work is performed the housing should be at least sufficient to cover a car spotted either way over the wheel drop pits and provide a passageway at end of car. The extent of the enclosure and heating should depend on the severity of the climate.

(j) At coach yards where locomotives operating on unit or streamline trains are handled, special facilities usually are necessary. These facilities depend upon the types of locomotive equipment and the service required.

6.5.9 Other Facilities

(a) The yard should be sufficiently lighted for night operation. General lighting can be provided by flood lights on high poles or towers, or by lights suspended well above top of car level and spaced about a car length apart between tracks. General lighting at lower levels is less satisfactory than higher level lighting because of shadows, improper light for top of car work and interference with switching and other operations due to glare. However, when the general lighting system cannot be adapted to provide the additional light frequently desired at certain points in the yard, supplemental lights on low standards, either fixed or portable, may be used.

(b) Provision should be made for sufficient storage of car wheels. Double wheel tracks for mounted wheels should be spaced 6 in between track centers. If extra or replacement power units or trucks are stored on wheel tracks, adequate housing for these units should be provided.

(c) A mechanical train washer is well adapted to washing the sides of trains, especially streamline trains, including diesel locomotives. Mechanical washing of train roofs is also desirable, but due to variations in car heights and roof contours, as well as to numerous roof obstructions on present equipment, mechanical washing is usually confined to the sides, roofs and ends being washed by hand. The track served by a mechanical washer should be tangent through the washer and for at least one car length each way. Where possible, the washer should be at a fixed location on a track over which all inbound trains to be washed can be moved. Where conditions make it necessary however, a washer of the portable type, mounted on cross rails to serve two or more tracks may be used. Separate washing platforms are usually provided for locomotives which do not lend themselves to mechanical washing.

(d) Suitable cleaning facilities should be provided for rugs and carpets which are removed from cars for cleaning. Air cleaning is usually done on open platforms, preferably roofed over, but shampooing facilities should be enclosed.

(e) Car pullers are frequently provided to reduce switching. The portable, electric-powered type is flexible and well adapted to this service.

(f) In yards where diners are restocked, commissary facilities will be required.

(g) Other facilities, some or all of which may be needed, include:

(1) Service building providing offices, toilet, wash, locker and lunch rooms
(2) Storehouse
(3) Building providing space for necessary repair shops
(4) Refuse disposal
(5) Fire protection
(6) Bottling plant for refilling gas cylinders
(7) Locomotive fuel oil storage with lines to distributing points.

6.6 MODERNIZATION

(a) Because of changes in habits and in facilities available for travel to and from terminals, less waiting time in the station is now the rule, but passengers expect better and more modern, though not necessarily bigger accommodations in the concourse and waiting room, when buying tickets or checking baggage, in the toilet facilities and in general service conveniences. These should be provided when major changes are made.

(b) A single, combined, waiting room can be substituted to advantage for the old arrangement of two separate rooms, but a proper and attractive powder room for women should be provided.

(c) Substitution of a closed-in concourse, with a tight partition between it and the train shed in place of an open grill, with a sufficient supply of heat to make it comfortable for passengers in winter weather is desirable and is becoming a general practice, as it will permit the use of the concourse as an adjunct to the waiting room. Many passengers prefer to wait where they can see the trains if they can do so without discomfort.

(d) Care should be taken to make it inconvenient for non-passengers to use the concourse and passages as thoroughfares, as such use may interfere with patrons of the railroads.

(e) Directional signs should be given particular attention. They should be displayed conspicuously, easy to see but not gaudy, and they should be repeated so that if a passenger going in the wrong direction misses one, another farther along will set him right. This is especially important where corridors are long and winding and facilities are at different levels.

(f) Improvement at the ticket counter by the substitution of larger openings for the former narrow grilled windows or, at points where it is feasible to do so, the replacement of the windows and grills by an open counter makes for a more friendly atmosphere. Provision for protection of the money and the ticket stock should not be overlooked.

(g) Generally, coin-locked pay toilets should be substituted for some of the former free toilets and, at the larger terminals at least, coin-locked dressing rooms and baths may be provided where warranted.

(h) Substitution of air conditioning (heating and cooling), properly planned, will often result in a reduced cost for its operation and maintenance, as well as providing better service.

(i) Adequate provision for parking private automobiles while waiting for trains should be provided if practicable.

(j) During a modernization program, consideration should be given to possibilities of overloading the existing electric, water, and steam facilities. Provisions should be made to increase the capacity of these facilities to a safe level.

Part 7

Other Yard and Terminal Facilities

FOREWORD

This part deals with the several and various components necessary for the function and operation of railways. Although these components such as store facilities, material yards, etc. are normally located or situated in yards and terminals they are not intrinsic to them.

CONTENTS

7.1 STORES

7.1.1 General

The stores department is responsible for the ordering, care, control and economic distribution, and in some instances for the accounting of materials and supplies needed for, or reclaimed from, the construction, maintenance and operation of the railroad. The size and extent of its facilities will vary in accordance with the requirements of the road. It is important to consult the chief stores officer and receive his approval concerning any plans for the construction, alteration or elimination of stores facilities.

7.1.2 Types

There are three types of stores, namely, general, district, and local.

(a) The general store, also known as a system or regional store, is the largest store unit of the stores department. It should be located on available railroad property and usually at a convenient point where large quantities of materials and supplies can be efficiently received, handled, stored and shipped. The location of this store will also be greatly influenced by the traffic problem created in the handling of these shipments and by the freight charges involved on off-line items received. The general store will also operate reclamation and scrap yards where needed.

(b) The district and local stores have the same characteristics and functions as the general stores, except that they are much smaller. These stores are generally established on larger railroads at various points to expedite the handling of materials and supplies. Such stores operate under the jurisdiction of the general store.

Stationary, office supplies and maintenance of way materials are normally handled by the general store. Maintenance-of-way materials, however, are generally handled in separate facilities. Dining car service supplies, including foodstuffs, may be handled by the general store, but in many instances such items are handled separately at major terminals in a local store, called a commissary.

7.1.3 Buildings and Structures

Storehouse buildings for the handling of all materials requiring inside storage should be constructed so as to create the most efficient and expeditious material storage and handling methods. Office space to house the necessary personnel to handle the records and accounting for the store's operation may be part of a storehouse building if suitable. Platform, docks, ramps, racks and shelters are erected according to the needs. All storage buildings and related facilities should be served with tracks and hard-surface driveways for the efficient handling of materials by rail or by truck. It is often possible to pave the track area so that one platform at car-floor level can serve both means of handling.

7.2 STORAGE

7.2.1 Material Yards

There are numerous items used in maintenance of way and of equipment that can be stored out of doors; these items are handled in material yards. Whenever possible, such yards should be located adjacent to the storehouse area so that trackage can be kept to a minimum. Material is stored on permanent racks and platforms, and the areas between should be paved to facilitate the operation of rubber-tired handling equipment such as trucks, loaders, cranes, etc.

The storage of heavy items in a material yard is usually at a separate location served by at least two tracks and an overhead crane or other types of cranes of suitable capacity. The material is stored in the area between the tracks, one track being used for receiving, the other for shipping.

The ideal scrap yard has a receiving and a shipping track with the sorting area in between and served by an overhead crane of suitable capacity. The sorting area should be hard surfaced and the driveways serving it paved to support the heavy wheel loadings of truck cranes and trailers used to handle scrap within the yard. All cranes should be equipped with magnets.

7.2.2 Lumber and Timber Yards

Lumber products are not generally kept in large quantities at the general storehouse, but are frequently shipped direct from the dealer to the point of application. However a certain quantity of lumber, cross and switch ties, bridge timber and poles must be stored. These products require outside storage; unseasoned materials should be stored on permanent racks in covered storage so they can season properly; treated timbers should be stored in the manner approved by the stores department to prevent loss by fire. The areas between the racks should be paved and the piles so arranged that fork-lift tractors or truck cranes can handle these materials into and out or onto and off freight equipment on a track serving the storage yard. This track is usually in the center of the yard unless the area is too large, then two or more tracks serving storage areas on both sides of each track are required, and the tracks, if possible, are connected at both ends.

7.2.3 Reserve Oil

The stores department may be called upon to provide large storage reserves for fuel oils. When the size and location of the facilities have been determined, the tanks should be installed in accordance with the requirements set forth by the governing ordinances, building and fire codes.

7.3 RECLAMATION

7.3.1 Plant—General

The reclamation plant is usually located at the same point and adjacent to the scrap yard to minimize handling of materials. The reclamation shop building should be situated between a receiving and a shipping track, the latter depressed to facilitate the loading of materials coming out of the plant for forwarding to points of application or storage. The size of the shop will vary with the amount and type of reclamation to be done. Paved roads parallel to the tracks are needed for the operation of truck cranes; a large area adjacent to the tracks and the shop building should be paved so that materials can be transported in and out of the building with motorized equipment.

7.3.2 Rail Plant

Rail requires special handling in general reclamation, and the plant to handle it should be separate from other plants. The plant layout should be designed for the rapid turnover of rail and would consist of receiving and shipping tracks served by overhead or other types of cranes, with the area between the tracks used for the straightening presses, the cropping operation, drilling rack, hardening apparatus, welding and classifying prior to loading.

Manual Recommendations

Committee 6—Buildings

Report on Assignment 1

Design Criteria for Maintenance of Way Equipment Repair Shops

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Your committee submits for adoption the following new Part 9 for Chapter 6 of the Manual.

Part 9

Design Criteria for Centralized Maintenance of Way Equipment Repair Shops

9.1 FOREWORD

9.1.1 A maintenance of way equipment repair complex provides a facility for the overhauling, rebuilding and modifying of roadway machines, work equipment and specialized power tools, which are used in maintenance of way operations.

9.2 SCOPE AND PURPOSE

9.2.1 The purpose of these criteria is to provide a description and layout of facilities for a centralized work equipment shop and to recommend equipment service areas. Figures 1, 2 and 3 are shown as aids in visualizing a typical repair shop and the layout of equipment and service areas.

9.2.2 Heating, lighting, plumbing and other incidental mechanical items would be a part of these buildings; however, they are not included in these criteria.

9.3 OPERATIONS

9.3.1 The major operations performed in a centralized maintenance of way repair complex are dismantling, cleaning, repairing, reassembling and painting.

9.3.2 These operations are supported by other incidental services, such as, carpentry, steel fabricating, forging, welding, testing, etc., in order to make it possible to perform minor repairs to small tools, as well as major overhauls to self-powered equipment.

9.4 LOCATION

9.4.1 The location of a centralized work equipment shop should be as close to the center of the railroad as practical, with consideration being given to the availability of suitable land, rail service, available manpower, housing, etc.

9.4.2 Approximately 25 acres are required for a large complex.

9.4.3 Some railroads have converted existing shop buildings into maintenance of way equipment repair shops and when this is done, the location of the repair complex may not be at the most desirable location.

9.4.4 If existing buildings are to be used, consideration should be given to the amount of travel time required to bring the equipment into the shop.

9.5 ORGANIZATION

9.5.1 The shop is normally a part of the engineering department and operates under the jurisdiction of the chief engineer, with the superintendent of work equipment as the immediate supervisor.

9.5.2 On a large railroad, the superintendent and staff will operate a shop of 200 employees, more or less, of various crafts.

9.5.3 On a small railroad, fewer employees are required to perform the necessary operations; however, the organization would remain essentially the same.

9.6 TYPICAL FACILITY ARRANGEMENT

9.6.1 The complex, as shown in Figure 1, is comprised of three buildings with adequate support facilities, such as cleaning vats, storage areas, lead and yard tracks.

9.6.2 Building 1 is the wash area and houses the cleaning vats. Building 2 is the main shop, which is shown on Figure 2, and building 3 contains the offices.

9.6.3 The main shop building should be constructed to support the overhead cranes and other smaller cranes throughout the shop.

9.6.4 Buildings 1 and 2 should be adequately equipped with compressed air, oxyacetylene and electric arc welding outlets at convenient locations, and they should have overhead motorized doors of sufficient size so as not to restrict the movement of large equipment in and out of the buildings.

9.7 MATERIAL HANDLING EQUIPMENT

9.7.1 Material-handling equipment is a prime necessity since units weighing up to 150 tons may be handled. The shop buildings should have overhead traveling cranes, bracket cranes, and post cranes for the movement of material within the various areas. An 8-ton wagon crane is recommended for inaccessible areas. Small turntables at strategic locations should be placed within the shop to facilitate the moving of equipment to various tracks.

9.7.2 A three-wheeled cart with flat bed in the back is recommended to transport individual parts. Fork lifts are recommended to move material on pallets. Full size railroad cars, such as riding cars, flat cars, weed spray cars, and similar track-mounted equipment may be moved over the shop tracks by use of a heavy duty rubber tire tractor or shop mule.

9.7.3 Figure 3 lists special shops, equipment repair and the material handling equipment recommended for each area.

9.8 PAINT SHOP (AREA "A")

9.8.1 Machines, when repaired, are painted and stenciled in this shop. It should be equipped with a ramp or hoist to allow painting the underside of machines and have adequate bracket cranes.

9.8.2 The painting should be performed in a booth of sufficient size to accommodate the largest piece of equipment expected to be repaired. The shop should also have air filtration equipment to dissipate the paint fog to prevent its being exhausted into the atmosphere.

9.8.3 A sprinkler or fire-suppression system, explosion-proof lighting, heating and ventilation equipment should be provided, as required by local codes and regulatory agencies.

9.8.4 The paint shop operation should be supported by steam cleaning and washing facilities. Provide facilities in the drainage system to accumulate sludge and oil.

9.9 CARPENTER SHOP (AREA "B")

9.9.1 All wooden assemblies for roadway machines and work equipment are fabricated, or repaired, in this area, including repairs to wooden portions of motor-car decks.

9.9.2 All boxes and crates are made in this area for items requiring them, and wooden shields installed on windshield glasses to protect them from vandalism during shipment.

9.9.3 Canopy tops, windshields, electric windshield wipers, and lights are installed on motor cars after they have been released from Motor Car Repair Area "C".

9.9.4 All replacement of glass and repairs to seats and canvas items are made in this area, which should contain a canvas rack, large cutting table and an industrial-type sewing machine.

9.10 MOTOR CAR REPAIR (AREA "C")

9.10.1 In this area motor cars are stripped, repaired and reassembled. Area should be equipped with a single dry pedestal grinder, solvent vat, test stands, work bench, hydraulic press and sufficient storage for new and rebuilt engines and transmissions.

9.11 SHOP EQUIPMENT REPAIR AND MAINTENANCE (AREA "D")

9.11.1 This area should have adequate work benches and material storage bins for the maintenance machinist in charge of repairs to shop machines, cranes, power plant and other terminal facilities.

9.11.2 The area should be equipped for storing and handling of materials needed by shop electricians in their terminal maintenance work.

9.11.3 All electrical assemblies from light plants and electric welders, electric power tools, and track maintenance junction boxes are repaired in this area.

9.12 PAINT SHOP STORAGE (AREA "E")

9.12.1 This area is used for the storage of non-flammable paint supplies, stencils, brushes, etc. The flammable materials are stored in a room adjacent to Area "A", on the outside of the main building.

9.12.2 Particular attention should be given to this area with regard to insurance and local fire regulations.

9.12.3 A sprinkler system or fire-suppression system should be considered.

9.13 ENGINE REBUILD AREA (AREA "F")

9.13.1 All large gasoline and diesel engines are stripped, repaired, reassembled, and such items as carburetors, fuel pumps, and air cleaners are rebuilt in this area.

9.13.2 Machine work is performed in this shop, such as reboring cylinders, line boring of main bearings, grinding and fitting of pistons, fitting and applying wrist pins, facing of valve seats, grinding of valves, and reassembling block and internal engine parts.

9.13.3 One- and two-cylinder air-cooled engines, rail saws, small light plants and other such items are repaired and tested in this area on an engine test-out stand.

9.13.4 Large gasoline and diesel engines should be tested on engine dynamometer test stands and fine adjustments made before engines are released from the shop. Engines should be broken in at full operating RPM's for approximately four hours before being taken off the test stands.

9.13.5 Noise and air pollution are important factors in the design of this area, which must be in compliance with local codes and regulatory agencies.

9.13.6 Standby and repaired engines should be stored in this area until needed. All single- and twin-cylinder track motor-car engines are stripped, reworked and reassembled.

9.13.7 Provide a 25-ton hydraulic press and engine rebuilding stands to facilitate the handling of engine units while they are undergoing repairs and testing.

9.13.8 Provisions should be made for storage of gas and diesel engine and transmission assemblies. Repaired assemblies are either used at the facility or shipped to line of road for installation on out-of-service machines.

9.14 MACHINE SHOP (AREA "G")

9.14.1 This shop should be equipped with various types and sizes of lathes, boring mills, drill presses, grinders, milling machines, hydraulic press with a capability of handling any and all types of machine work required by centralized work equipment shop.

9.15 HYDRAULIC AND ELECTRIC REPAIR (AREA "H")

9.15.1 All hydraulic assemblies and component parts stripped from engines are placed on pallets and moved to the receiving area of this shop, where all makes and types of hydraulic equipment, such as pumps, rams, valves and motors are rebuilt.

9.15.2 This area should be easy to clean so that dust will be kept to a minimum.

9.15.3 A complete parts inventory of all hydraulic assemblies and components are maintained in the shop.

9.15.4 This area should be equipped with a hydraulic test stand on which rebuilt assemblies can be tested before they are released for reinstallation on the individual machines undergoing repair, or placed in the hydraulic unit storage area.

9.15.5 All hydraulic hoses used in connection with repairs to the equipment throughout the entire complex are fabricated in this area. The area should be equipped with adequate hose and fitting storage bins, band saw, hydraulic press, drill press, grinders, a hose cut-off machine and hose fitting application machine.

9.15.6 Provision should be made for the rebuilding of all electric vibrator motors and main tamping generators from track maintainers and tamping power jacks. The area should have an overhead trolley system to allow the motors and generators to be stripped, reassembled and tested on an "assembly line" basis.

9.15.7 Provision should be made for hydraulic presses strategically placed, double dry grinders, stator coil cutter and sand blast cabinet for cleaning stator housings after the coils have been removed.

9.15.8 Vibrator motor test stand should be provided that will permit several motors to be tested simultaneously.

9.15.9 An approved type furnace for removal of insulation from copper wire should be provided.

9.15.10 Space should be provided for a large and small insulation cutter, insulation folder, coil winder drives, coil taping machine, stator hold stands and an approved type furnace for removal of insulation from scrap stator coils.

9.15.11 Large tamping motor generators are tested, and all rewound stators, armatures and field windings are dipped into insulating varnish and baked in an oven.

9.16 LUNCH AND LOCKER ROOMS (AREA "I")

9.16.1 Lunch and locker room facilities should be provided as required by applicable codes, and provisions should also be made for lunch tables and vending machines.

9.17 TOILET FACILITIES (AREAS "J" AND "Q")

9.17.1 Toilet facilities and water coolers should be provided for shop forces at centralized locations to minimize the away-from-work station time.

9.17.2 The number of fixtures required is governed by applicable codes and will vary depending on the location.

9.18 TOOL ROOM (AREAS "K" AND "P")

9.18.1 Tool room or rooms with required security are to be conveniently located to the shops they serve, and should stock all power and hand tools used throughout the various areas.

9.19 STORES OFFICE (AREA "L")

9.19.1 A stores office large enough to accommodate the storekeeper and staff should be provided adjacent to the store area.

9.20 STORE AREA (AREA "M")

9.20.1 The store area should be located as near as possible to the center of the complex and should be complete with racks and bins.

9.20.2 Proper attention should be given to providing adequate security.

9.21 STEEL FABRICATION AREA (AREA "N")

9.21.1 Space should be provided for use as a repair and test area for all types of radiators and fuel tanks. A cleaning and test vat should be provided.

9.21.2 Adjustable booths should be provided for steel fabrication or repair of assemblies made by boilermakers. Individual, 5-ft-high, canvas or plastic shields should completely surround each booth to protect other employees from the electric flash created by wire fed welders.

9.21.3 Space should be allocated for storage racks for bar steel, sheet steel, angle iron and pipe.

9.22 SHEET METAL SHOP (AREA "O")

9.22.1 All sheet-metal fabrication work and repairs to the sheet-metal guards and shrouds for various machines are performed in this shop. Area should be equipped with adequate machinery to handle any and all types of sheet-metal work.

9.23 BLACKSMITH SHOP (AREA "R")

9.23.1 An electronic eye semi-automatic shape cutting machine should be located in this shop, complete with steel racks, a large heating furnace and a machinist welding booth, where tamping shoes are reclaimed.

9.23.2 A forge, a large and small hammer, double dry grinder, welding booths, exhaust ducting, a normalizing furnace, and other equipment and storage areas, as outlined on Figure 3, should be located in this area.

9.24 CONCLUSION

9.24.1 The maintenance of way equipment repair complex, as outlined in these criteria, is representative of an entirely new facility. It is realized, however, that existing facilities may be converted to a repair shop, and the configuration of the yards and buildings may not be ideally suited for performing the repair work on an assembly line basis. Some repair facilities are located in smaller shops at outlying districts, which cannot adequately serve the needs of the entire railroad, but an attempt should be made to arrange the shop similar to those in Figures 1 and 2, to minimize unnecessary movement of material and equipment.

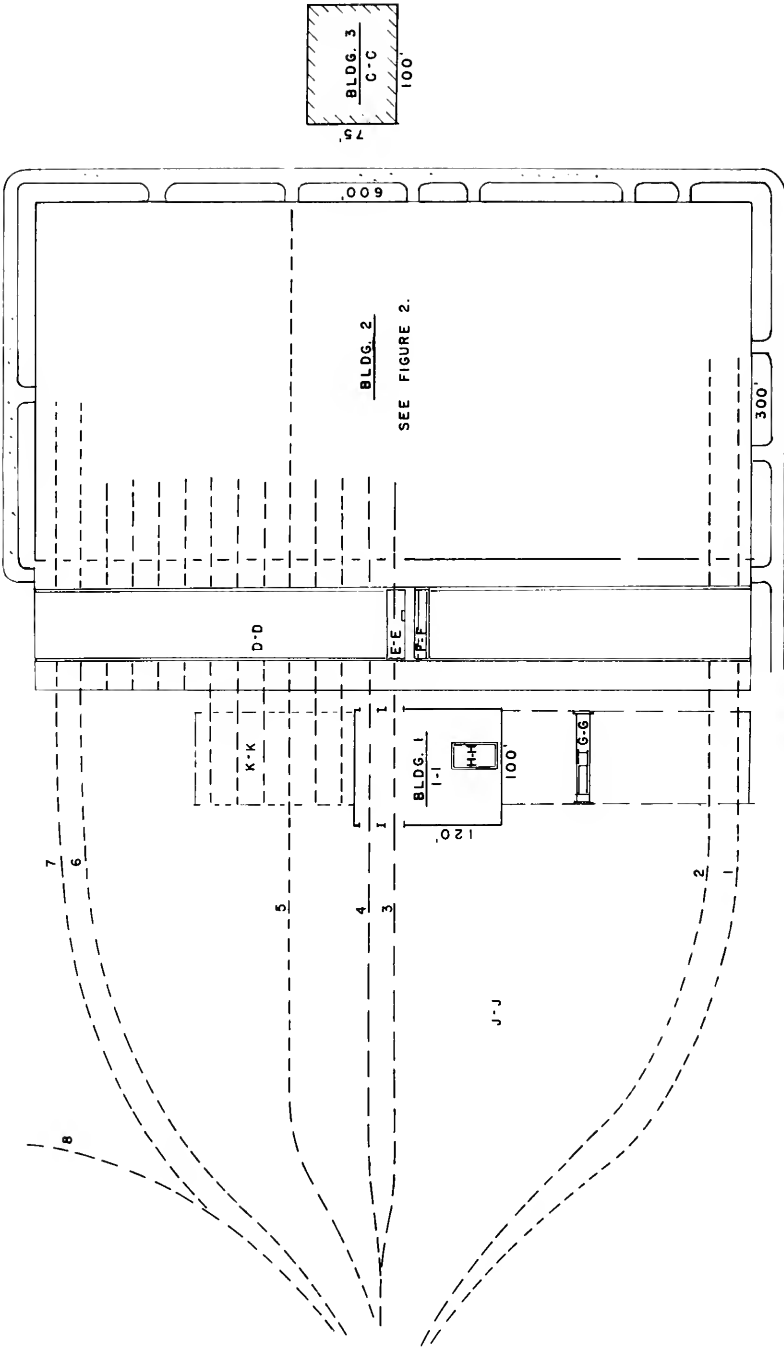


Figure 1—A typical centralized maintenance-of-way equipment repair facility.

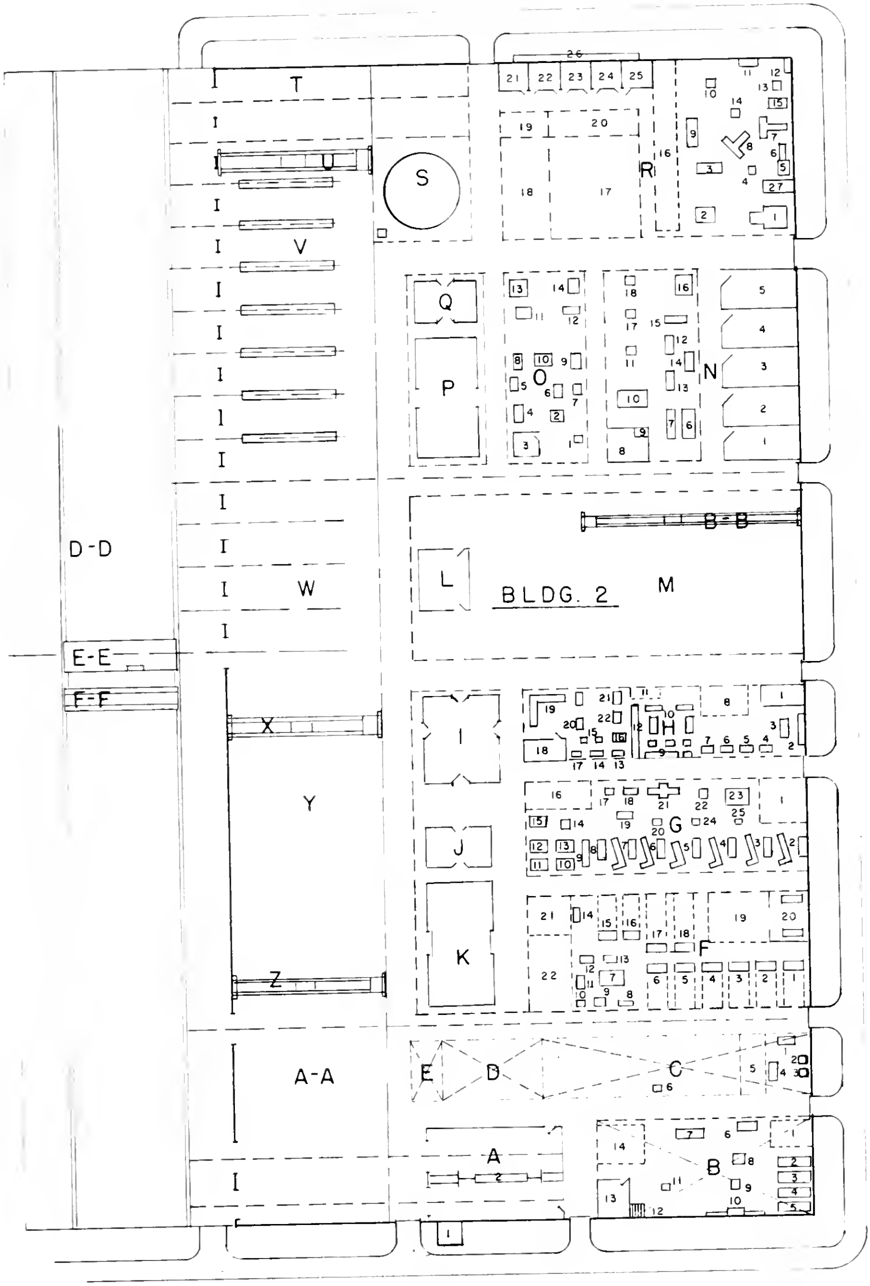


Figure 2

Figure 3—LEGEND OF DETAILS FOR TYPICAL MAINTENANCE OF WAY EQUIPMENT REPAIR FACILITIES

A. PAINT SHOP
  1. Paint Storage
  2. Filter Ducting

B. CARPENTER SHOP
  1. Carpenter Shop Storage
  2–5. Lumber and Trailers
  6. Plywood Rack
  7. Work Bench
  8. Table Saw
  9. Planer
  10. Radial Arm Saw
  11. Band Saw
  12. Glass Rack
  13. Upholstery and Canvas Shop
  14. Packing and Crating Area

C. MOTOR CAR REPAIR
  1. Solvent Vat
  2–3. Test Stands
  4. Work Bench
  5. Engine & Transmission Storage
  6. Hydraulic Press

D. SHOP EQUIPMENT REPAIR & MAINTENANCE

E. PAINT SHOP STORAGE

F. ENGINE REBUILD AREA
  1–6. Diesel Engine Rebuild Area
  7. Assembly Bench
  8. Line Boring Machine
  9. Pin Fitter
  10. Valve Grinder
  11. Cylinder Boring Machine
  12–13. Cleaning Solvent Vat
  14. Carburetor Repair
  15–18. Gas Engine Rebuild Area
  19. Dynamometer Storage Area
  20. Dynamometer Test Stands
  21. Gas Engine Storage Area
  22. Diesel Engine Storage Area

G. MACHINE SHOP AREA
  1. Storage Area
  2–7. Lathe Area
  8. Metal Spray Bench
  9. Crankshaft Grinder
  10. Surface Grinder
  11. Horizontal Miller
  12. Layout Table
  13. Universal Grinder
  14. Internal Grinder
  15. Universal Miller
  16. Machine Shop Storage Area
  17–18. Drill Press
  19. Layout Bench
  20. Double Dry Grinder
  21. Boring Mill
  22. Band Saw
  23. Tubing and Steel Rack
  24. Hydraulic Press
  25. Tool Grinder

H. HYDRAULIC AND ELECTRICAL REPAIR AREA
  1. Tested Unit Storage Area
  2. Test Bench
  3. Bench
  4–7. Hydraulic Units Repair Area
  8. Hydraulic Shop Work Storage Area
  9. Hydraulic Hose Cutting Bench
  10. Hydraulic Hose Fabrication Area
  11. Storage Area
  12. Hose and Fitting Bins
  13. Oven
  14. Wire Rack
  15. Coil Winders
  16. Dip Vat
  17. Sandblast Cabinet
  18. Battery Room
  19. Generator and Motor Repair Area
  20. Sun Test Stand
  21–22. Rewind Bench

I. LUNCH ROOM

J. TOILET FACILITIES

K. TOOL ROOM

L. STORES OFFICE

M. STOREHOUSE

N. SHEET STEEL FABRICATION AREA
  1. Radiator & Fuel Tank Repair Area
  2–5. Adjustable Booth for Steel Fabrication
  6. Bar Steel & Angle Iron Rack
  7. Pipe Rack

Figure 3 (Continued)

8. Air Reservoir & Fuel Tank Test Area
9. Hydro Test
10. Oxygraph Table
11. Drill Press
12. Brake
13. Rolls
14. Forming Table
15. Shear
16. Steel Rack
17. Double Dry Grinder
18. Band Saw

O. SHEETMETAL SHOP
- 1. Threading Machine
- 2. Forming Table
- 3. Heli-Arc Welder
- 4. Spot Welder
- 5. Circle Cutter
- 6. Band Saw
- 7. Rotex Punch
- 8. Brake
- 9. Rolls
- 10. Forming Table
- 11–12. Shears
- 13. Aluminum Rack
- 14. Sheet Steel Rack

P. TOOL ROOM

Q. TOILET FACILITIES

R. BLACKSMITH SHOP
- 1. Oxygraph Machine
- 2. Steel Plate Storage
- 3. Forming Table
- 4. Anvil
- 5. Forge
- 6. Quenching Tank
- 7. Small Hammer
- 8. Large Hammer
- 9. Forming Table
- 10. Pipe Bender
- 11–12. Benches
- 13. Double Dry Grinder
- 14. Vise
- 15. Furnace
- 16. Work Storage Area
- 17. Sheet Steel Fabrication Storage Area
- 18. Sheetmetal Shop Work Storage Area
- 19. Tamping Shoe Reclaim Area
- 20. Welding Work Storage Area
- 21–25. Welding Booths
- 26. Exhaust Ducting
- 27. Normalizing Furnace

S. HEAVY ASSEMBLY REPAIR & RECLAIM AREA

T. PILE DRIVER REPAIR AREA

U. 150-TON O.H. TRAVELING CRANE

V. HEAVY ROADWAY MACHINE REPAIR AREA

W. LOADING AREA

X. 30-TON O.H. TRAVELING CRANE

Y. INTERMEDIATE ROADWAY MACHINE REPAIR AREA

Z. 15-TON O.H. TRAVELING CRANE

A-A. RAIL & TIE GANG EQUIPMENT REPAIR AREA

B-B. 15-TON O.H. TRAVELING CRANE

C-C. OFFICE BUILDING

D-D. TRANSFER PIT

E-E. TRANSFER TABLE

F-F. TRANSFER TABLE TRAILER

G-G. 30-TON O.H. TRAVELING CRANE

H-H. CLEANING VATS

I-I. LYE VAT WASH AREA

J-J. STORAGE AREA

K-K. CAR & EQUIPMENT STORAGE AREA TRACKS

LEAD IN TRACKS:
- 1. "Circus" Train, Car Repair & Paint Shop Lead
- 2. "Circus" Train Loading & Paint Shop Lead
- 3. Loading Track
- 4. Loading Track
- 5. Holding Track
- 6. Test Track & Heavy Equipment
- 7. Test Track & Heavy Equipment
- 8. Pile Driver Test Track

Report on Assignment 2

Design Criteria for Elevated Yard Office Buildings

W. C. Humphreys *(chairman subcommittee)*, A. C. Cayou, H. R. Helker, R. J. Martens, G. J. Bleul, L. S. Newman, P. W. Peterson, R. E. Phillips, H. A. Shannon.

Your committee submits for adoption the following new Part 10 for Chapter 6 of the Manual.

Part 10

Elevated Yardmasters' Towers

10.1 FOREWORD

The elevated yardmasters' tower is a natural development which resulted from the experience of railroads that located supervisory personnel in elevated structures at strategic points in modern classification yards. Based on this experience, many railroads decided to provide elevated towers for yardmasters in all types of yards to increase their supervisory potential.

The elevated yardmasters' tower permits the yardmaster to visually supervise yard crews and yard engine operations, and thus develop greater switching efficiency through better switch crew utilization. The elevated tower also permits better utilization of yard tracks.

Elevated yardmasters' towers are most effective in yards where more than one yard crew is working at the same time. The towers are generally located at the switching end or lead end of the yard.

10.2 SITE CONSIDERATIONS

Inasmuch as the primary function of the elevated yardmasters' towers is critical observation, the location is probably the most important consideration. The optimum height from top of rail to the observation tower floor is generally considered to be 30 to 40 ft. The site location should be determined by the track geometry of the particular yard location. As a rule of thumb, the tower should be 50 ft back from the switching lead to permit observation of switching operations, and at the center line of the classification tracks to permit maximum observation down the lines of classification tracks.

Many yards are located within urban areas, and are crossed by overhead structures carrying vehicular traffic. These structures often make it quite difficult to determine the best height and location for constructing a tower. In these cases, it is extremely helpful to secure a basket-mounted high-reach mobile crane and have the local operating supervisor ride the basket, and adjust the height and location until he determines the position which is most suitable for the tower. The tower floor can then be located in accordance with these field-determined dimensions.

10.3 TYPES

Elevated yardmasters' towers may be constructed as part of the upper story of a multi-story yard building, as an additional story to an existing yard building, or as an individual prefabricated metal observation tower supported by a structural frame.

Inasmuch as individual yardmasters' towers are purely functional structures, economic considerations generally dictate that they be constructed of structural steel. Size, height, location, and other considerations, however, may indicate that they be constructed of reinforced concrete, preformed concrete members, or masonry.

10.3.1 Towers Constructed as Part of Yard Buildings (See Figures 1–4)

An elevated yardmasters' tower may sometimes be constructed as part of the upper story or on top of a new multi-story yard building. This has the advantage of reducing the tower construction cost inasmuch as the supporting structure is provided by the multi-story building structure, and square-foot job costs will be substantially reduced. In addition, costs of bringing services and utilities to the tower are virtually eliminated, as these costs, which can be considerable, would be chargeable to the main building structure.

The main disadvantage of constructing an elevated tower as part of a multi-story building is that, generally, operating requirements dictate that a yard transportation building be constructed at a site which is not the most advantageous for locating a yardmasters' tower.

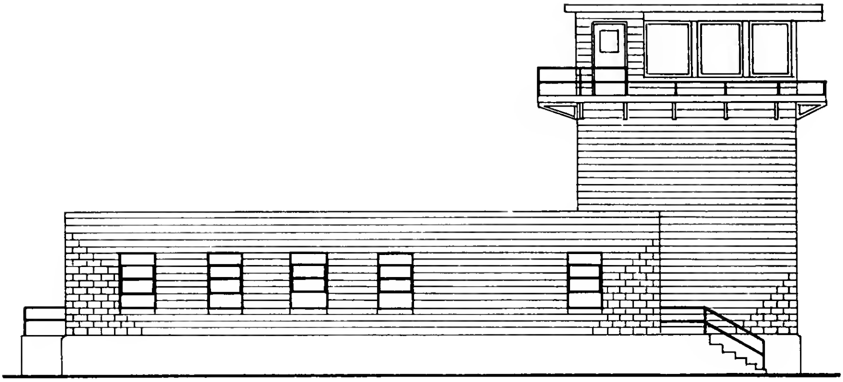
10.3.2 Towers Constructed as an Addition to an Existing Building

In some instances, elevated yardmasters' towers are constructed on the roof of an existing building. The generally accepted theory is that this is cheaper than building a separate tower on a structural steel tower frame. Experience, however, indicates that in most cases the cost of remodeling and structurally strengthening an existing building, together with the cost of a new tower cabin, is close to or the same as the cost of a new separate tower. In addition, constructing a tower on an existing building has the same disadvantage as constructing it as part of a new multi-story building, in that existing buildings are generally not located at a suitable site for a yardmaster's tower.

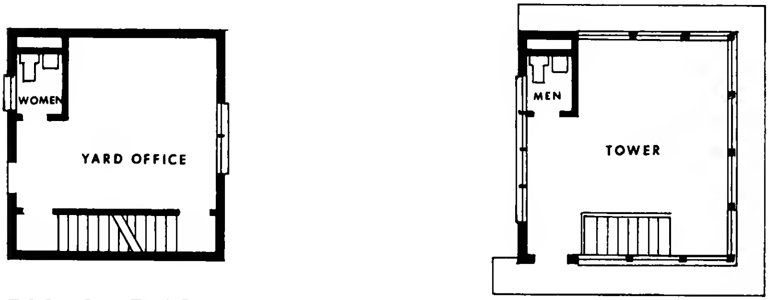
10.3.3 Individual Prefabricated Towers (See Figure 5)

Individual prefabricated yardmasters' towers have the advantage of being almost completely flexible with respect to location. Inasmuch as the location of a tower has a direct bearing on its main function of observation, this is a prime consideration. A standard elevated yardmasters' tower plan can be developed which takes advantage of standard components and shop fabrication. A standard 30-ft-high tower can be varied in height between 30 ft and 40 ft by varying the pedestal height of the concrete foundation on which the tower is supported.

(Text continued on page 178)

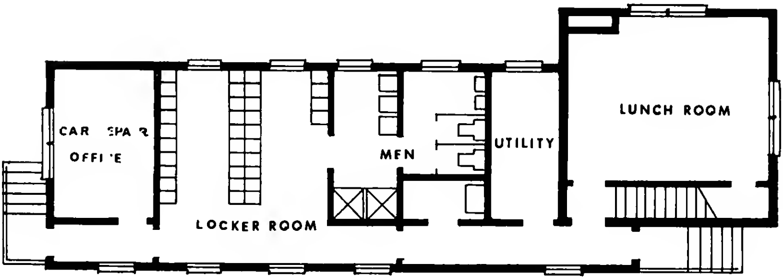


ELEVATION



SECOND FLOOR

THIRD FLOOR



FIRST FLOOR

Figure 1

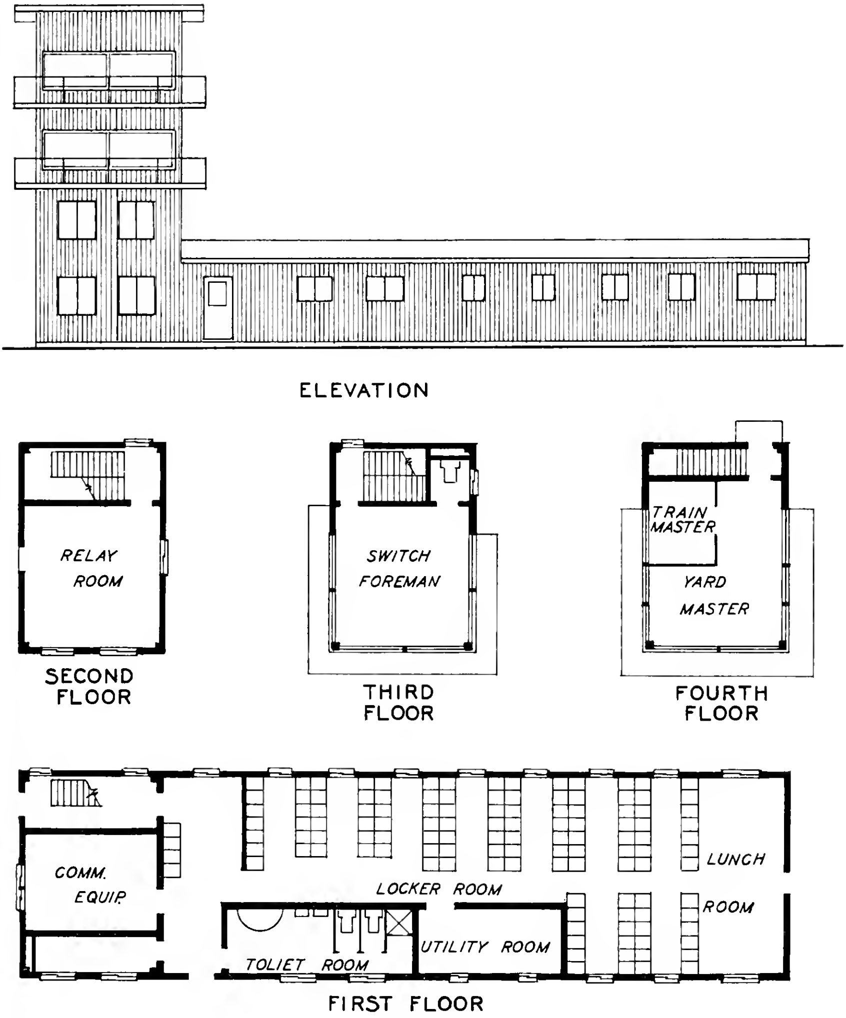

ELEVATION
RELAY ROOM
SECOND FLOOR
SWITCH FOREMAN
THIRD FLOOR
TRAIN MASTER
YARD MASTER
FOURTH FLOOR
COMM. EQUIP.
LOCKER ROOM
LUNCH ROOM
UTILITY ROOM
TOLIET ROOM
FIRST FLOOR

Figure 2

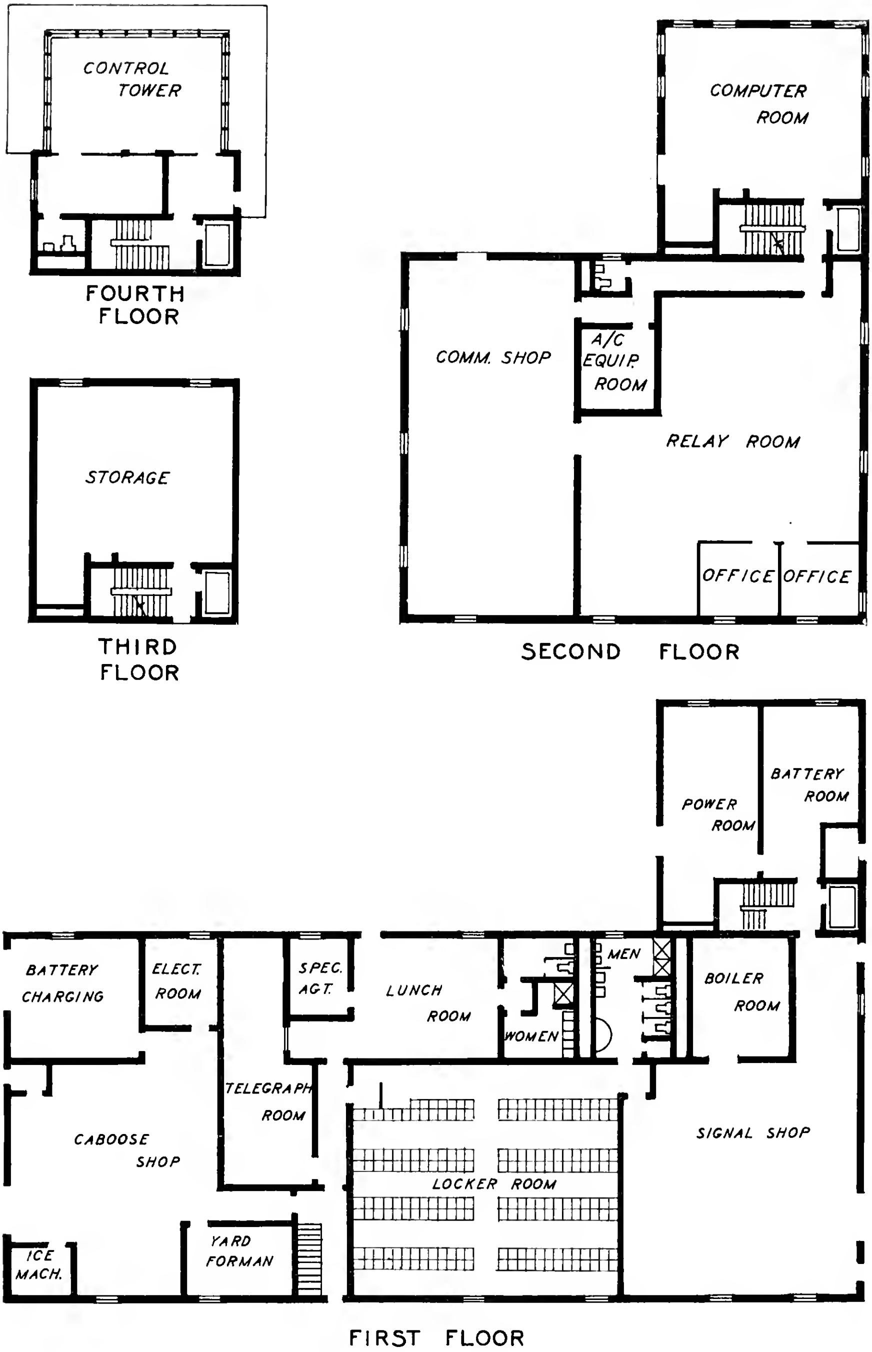
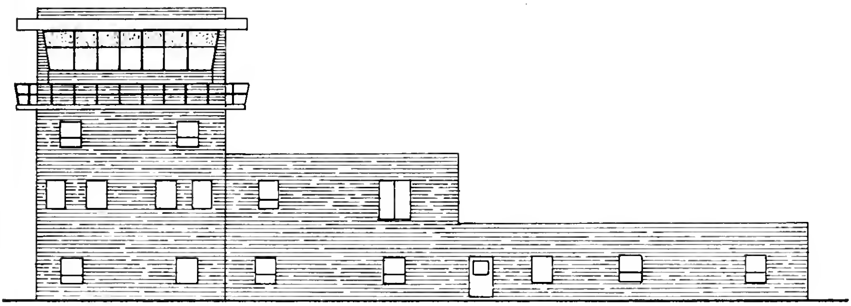
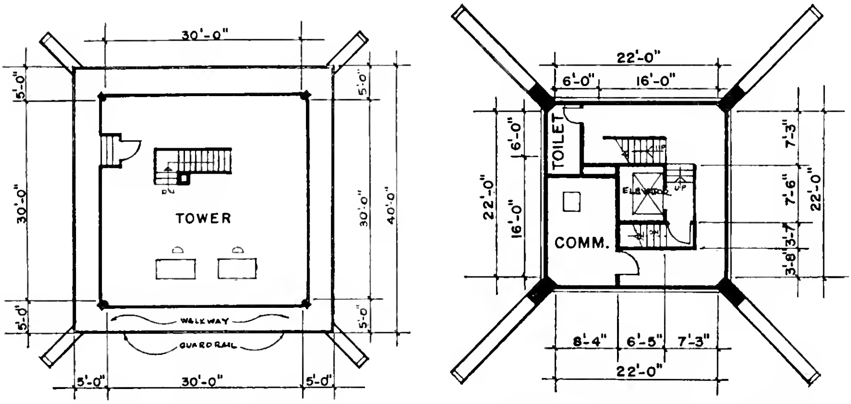

CONTROL TOWER
FOURTH FLOOR
STORAGE
THIRD FLOOR
COMPUTER ROOM
COMM. SHOP
A/C EQUIP. ROOM
RELAY ROOM
OFFICE
OFFICE
SECOND FLOOR
POWER ROOM
BATTERY ROOM
BATTERY CHARGING
ELECT. ROOM
SPEC. AGT.
LUNCH ROOM
MEN
WOMEN
BOILER ROOM
TELEGRAPH ROOM
CABOOSE SHOP
LOCKER ROOM
SIGNAL SHOP
ICE MACH.
YARD FORMAN
FIRST FLOOR

Figure 3



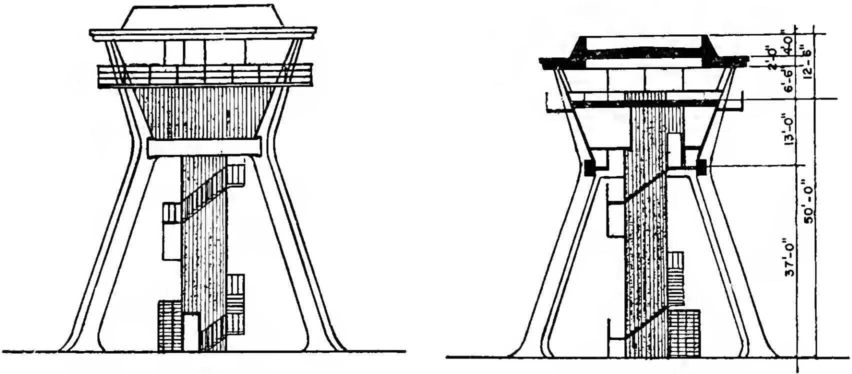
ELEVATION

Figure 4



TOWER FLOOR PLAN

UTILITY FLOOR PLAN



TOWER ELEVATION

CROSS SECTION

Figure 5

10.4 TOWER CONSTRUCTION

10.4.1 General Construction Materials

The materials used in the construction of a tower which is part of a new building will, of course, be determined by the construction and aesthetics of the overall building structure. Lightweight, fire-resistant, standard components should be used for towers constructed on top of existing buildings, and in the construction of individual elevated towers. The types of materials to be considered in the construction of towers are structural steel or aluminum tube framing, masonry, concrete, standard window wall components, insulated metal wall components, and metal flooring and roof decking materials. The finish flooring material may be vinyl, or vinyl asbestos tile, or some other similar material which is easy to maintain. Consideration may also be given to carpeting. Acoustical treatment is an important consideration, though not essential. The installation of adequate insulating materials is of prime importance due to the extensive exposure of the towers and the large areas of glass required for observation.

Access to a tower constructed as part of a new building is usually by means of interior stairs. Access to a tower constructed on top of an existing building may be by means of interior stairs, or by extending existing stair towers. It is usually more practical, however, to construct a new access stair on the outside of the building. Access stairs for individual elevated towers are usually open-metal stairways constructed around the outside and framed into the structural tower frame.

The inclusion of elevators should be considered in the design of towers, particularly where they are included as part of a multi-story building or where an individual tower is to be constructed over 30 ft in height.

10.4.2 Mechanical and Electrical Facilities and Equipment

Yardmasters' towers of all types should be provided with easily accessible toilet facilities. Individual towers should have toilets included as part of the elevated tower cabin. Towers constructed as part of a new multi-story building or on top of an existing building, should have toilets located either in the tower, or close by on an adjacent floor. Water supply lines and drainage lines for individual towers should be insulated and heat traced to prevent freezing.

Yardmasters' towers should be adequately heated and air-conditioned. Special consideration must be given to the heating and cooling design due to the exposure factor and large amounts of exposed glass surface. Although any type fuel and heating system can be used for heating the tower, electric heating has many advantages. Electric heating is particularly suited to individual elevated towers. The heating can be either combined with the cooling in through wall units or be individual base-board units or unit heaters.

Care must be given in the design of the lighting to incorporate the adjustments and flexibility required to provide the most ideal conditions possible to perform the outside observance task at all times of the day and night, under various outside lighting conditions.

Good general lighting must be provided, also spot or individual shielded lighting for reading panels, consoles, switch lists, etc. Lighting fixture rheostats must be installed on all general lighting to furnish the required contrast between inside and outside natural lighting conditions.

Outside yard lighting must be designed and located in conjunction with the tower design and location, so that it will not blind the tower occupant, but rather augment his observation task.

10.5 SPECIAL FEATURES

10.5.1 Tower Size

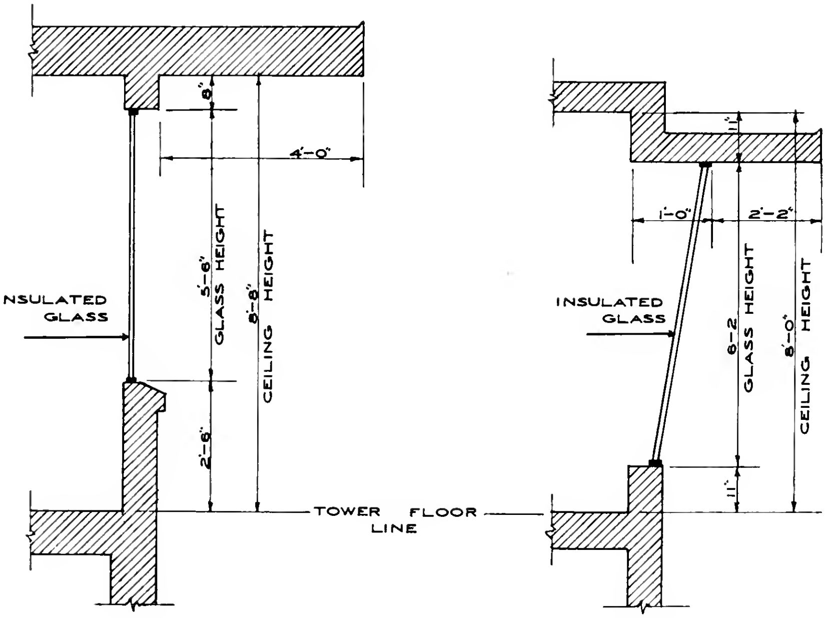
The tower should be minimal in size and the floor plan developed on the basis of only the equipment to be installed in the tower, with minimal space around the equipment for circulation and servicing the equipment. The location of equipment is important in developing the maximum visibility factor of the tower. A nominal 10 ft x 12 ft size is adequate in most cases for a one-man tower.

10.5.2 Tower Glazing and Glass (See Figure 6)

Glazing should be located only on the faces of the tower where observation will be required. This is usually on three tower walls, with the fourth wall used for a door, toilet rooms, service panels, etc.

A study should be made with the personnel responsible for the operation to determine the best orientation of the tower to permit the optimum required observation.

The lower glass line should be dictated by line of sight, but generally should be as close to the floor as possible, allowing enough space for radiation, service outlets, conduits, etc. The upper glass line should be located approximately 5 ft 6 in above the floor, or at the eye line for a man who is standing. As the points of observation are all below eye level in the yard, any glass above this point is superfluous. Elimination of glass above eye level reduces sun glare and sky brightness.



VERTICAL GLASS SLOPED GLASS

TYPICAL TOWER GLASS DETAILS

Figure 6

It is extremely desirable to use double glazing for all windows to reduce heat loss and eliminate the possibility of condensation and fogging of glass.

The use of heat-reducing and glare-reducing glass is not recommended as it reduces night visibility, and this is the time when visibility is most critical. The additional heat gain can be compensated for during the day by providing more air conditioning, but there is no way to compensate for the visibility loss.

Tower windows may be installed vertically or sloped. There are proponents of both schools of thought who will vigorously defend their position. Some studies have indicated that there are no advantages in installing sloped windows, and that there are, in fact, some disadvantages. Sloping windows put additional stress on the glass and make it more susceptible to cracking. This is especially true of insulating glass. Sloping glass also tends to increase distortion and reduce vision as the sight line passes through a greater thickness and density of glass. Each individual will have to develop his own set of facts and make his own decision of this feature of the design.

The use of vertical pivoted sash for towers is desirable as it permits washing windows from inside, and may eliminate the need of an outside catwalk. If fixed sash is used, a catwalk should be provided for washing windows.

The maximum standard-size sash should be used. Generally, the use of vertical mullions is not a problem; however, care should be taken not to locate a mullion in the center of a critical viewing area.

10.5.3 Tower Roof Overhang

Towers should be constructed with adequate roof overhang to reduce sun glare, sky brightness, and heat transfer. It may be necessary under certain conditions to install venetian blinds or transparent colored sun screens.

10.5.4 Tower Relocation

Individual prefabricated yardmasters' towers have the added advantage of being relocatable. They are usually constructed in two main sections. The structural steel tower frame can be fabricated in one or more sections, and the tower cabin fabricated in another section. The stairs are also fabricated in sections. When the need arises to relocate a tower to a different location, the tower can be dismantled and relocated to a new location.

Manual Recommendations

Committee 33—Electrical Energy Utilization

Report on Assignment 1

Electrification Economics

R. J. Berti *(chairman, subcommittee)*, W. H. Brodski, W. S. Gordon, M. F. Gowing, D. T. Jones, H. C. Kendall, K. L. Lawson, M. D. Meeker, A. G. Raabe, R. P. Reiff, B. A. Ross, L. D. Tufts, K. B. Ullman.

Your committee submits for adoption the following Part 1 for new Chapter 33 of the Manual.

Part 1

Method of Making Electrification Economic Studies

1.1 GENERAL

1.1.1 Objective

The prime objective of an electrification economic study is to determine if electric operation of a particular railroad is more advantageous than operation with another form of power which may or may not be in actual use. This is written from the commercial viewpoint of a privately operated railroad.

1.1.2 Basic Procedure

Each identifiable cost associated with the different types of power must be quantified for economic comparison. Since most electrification studies will cover a period between 20 and 50 years into the future, costs should be separated into two basic categories: initial one-time expenses, and annual costs which are subject to continuing inflation. Separate inflation rates should be specified for each annual cost to properly compare types of power over a long period of time. Extra care should be taken in determining inflation rates since they will be compounded over the life of the study. Intangible costs and benefits or liabilities should be listed for review at the end of the study, unless they are directly associated with a tangible cost.

1.1.3 System Operation

Prior to any detailed analysis, the segment(s) of railroad to be studied must be precisely defined as well as the basic parameters of operation. Train size, speed, frequency, etc., should be made constant for all types of power studied to permit a valid initial comparison. The detailed study should include the economic effects of changing the operating parameters to that most favorable to each type of power being compared.

1.1.4 Electrical Distribution Systems

A cursory review of the various types of electrical distribution systems: third-rail direct current, 12.5-kv alternating-current catenary, 50-kv alternating-current catenary, etc., should be made to determine which system or combination of systems is most applicable for the specific case under study. Detailed analyses can start after this preliminary determination is made.

1.1.5 Data

A base year should be chosen from which all data can be projected. The data for this base year must be as reliable as possible, thus considerable effort should be spent to review all sources of information for their accuracy and completeness.

1.2 TRAFFIC

1.2.1 Gross Ton Miles

Freight Traffic—The most common unit for computing energy and maintenance costs is the gross-ton-mile. The number of gross-ton-miles operated over the railroad under study should be thoroughly reviewed to ascertain what percentage of the total could be hauled electrically. Locals or trains that would travel only a short distance over electrified territory may be moved more economically using non-electric locomotives. Total annual gross-ton-miles can then serve as a base for computing energy and maintenance cost for both electric and non-electric systems.

1.2.2 Passenger Trains

Due to the high acceleration and speed required of passenger trains, they are frequently treated separately from the freight service. If they are present and being dealt with independently, the gross-ton-miles generated by the passenger trains should be subtracted from the total being hauled electrically. Since passenger trains outside the northeast have only minimal impact on electrification studies, their economics are not covered in this outline.

1.2.3 Train Size and Speed

For proper comparison of energy demands, the size and speed of typical trains should be specified for operation electrically or with other forms of power. Initially, this parameter should be the same for any type of power; however, as the study becomes more detailed, it may become obvious that one type of power is more economical using a different train size and speed. For evaluation purposes, any changes in train size and speed should be a separate portion of the study.

1.2.4 Traffic Projection

The facts reviewed in the study for traffic projection are very critical. A large growth rate when compounded over many years can saturate the existing track and signal system creating a requirement for CTC or additional mainline track. Negative growth rate can impact the study outcome by causing savings to diminish in the future.

1.2.5 Train Schedules

The average daily traffic must be specified by number of trains, size of trains, and the timetable schedule of trains. The maximum daily traffic must be specified in the same manner. The minimum acceptable train performance (train speed, size and frequency) under emergency conditions (substation outage, excessive train density, etc.) should be specified.

1.3 CAPITAL EQUIPMENT COSTS

1.3.1 Locomotives

Based on the traffic, terrain, train size and schedules, the electric locomotives' weight, wheel configuration, power and speed capabilities can be selected. This selection should be carefully coordinated with the builders of electric locomotives to insure the commercial availability and a valid cost estimate. Locomotives with prime movers other than standard diesel engines should likewise be selected with care.

If the electrified system is to be compared to diesel locomotives it should be determined whether to use existing types of diesel-electrics or for comparison use a new model not yet manufactured. As with electrics, the various manufacturers should be consulted to insure reliable cost data.

Extreme care should be taken to insure that enough locomotives of each type have been provided to cover peak traffic periods, allow downtime for scheduled and unscheduled maintenance, and provide for possible future schedule changes which would require more locomotives with the same traffic. Past experience has shown the electric locomotive to have a higher availability and utilization than other types. Computer generated speed-time-distance calculations can be of great assistance. Energy and power-time-distance calculations made at the same time are invaluable in computing electric power consumption and cost as well as diesel fuel consumption and cost.

1.3.2 Locomotive Facilities

The existing mechanical facilities should be thoroughly reviewed to determine what changes will be necessary to maintain electric locomotives. Some of the more modern diesel facilities can be used for electric locomotive maintenance with virtually no changes, while old roundhouse operations may be totally unfit for any maintenance work.

Main-line electrification may segment the remaining diesel service to such a great extent that new diesel maintenance shops must be built to care for the diesels running branch lines and locals. Maintenance facilities for both diesels and electrics should be an important factor in determining the end points for an initial electrification project.

High-voltage catenary is not to be recommended inside a maintenance shop where the risk of employee injury is much greater due to the type of work being done. If it becomes necessary to have high-voltage inside a shop, special warning devices should be installed to alert all workers when the high-voltage is energized. Locomotive cleaning and sanding facilities, which will be used by both diesels and electrics, should be checked to insure safe operation with the electric locomotives while the power is on.

1.3.3 Power Generating Facilities

Railroads still face some locations where it is more economical to build an electric generating station than it is to buy power from the local utility company. Locations may exist where local power is unavailable. If railroad owned power generation is to be considered, studies by specialized electric utility engineers will be required to determine capital, operating and maintenance costs.

1.3.4 Power Distribution Systems

A study should be made to determine the electrical power demand of each portion of the railroad to be electrified. The utility companies should be consulted to locate transmission lines in the area suitable for use by the railroad. On a high-voltage system, it is advisable to try and arrange for adjacent substations to be served by different transmission lines in order to minimize the possibility of power failure which would affect more than one substation. For substations located at the end of an electrified system, consideration should be given to the installation of two transformers connected to two different transmission lines to minimize the possibility of power failure. Sizing of the transmission line will be based on maximum present and future load. It is frequently more economical to put up heavier wire or a few more insulators for a higher voltage transmission line during initial construction than it is to retrofit after the load demand has increased. Single-phase unbalance problems may be encountered and could require special substation connections.

1.3.5 Substations

Substations are used to step the high transmission line voltage down to the voltage used on the catenary or third rail. The alternating current is also converted to direct current at a substation when required for third rail.

Equipment used in a substation should be capable of handling high overloads for relatively short periods of time without failure. Substation transformers can be sized to permit initial loads with no forced cooling; later, forced cooling can be added to support the increased traffic at minimal cost. It is common practice to assume that a substation will be called upon to supply half of an adjacent substation's load during an emergency. Railway substation transformers should be equipped with extra bracing to prevent damage during a short circuit. Either manual and/or remote control should be provided for each substation. Provisions should be made to have a spare, mobile substation which will serve in an active capacity when not being used as a replacement. For substations located at the end of an electrified system, consideration should be given to the installation of two transformers connected to two different transmission lines to minimize the possibility of power failure.

Phase breaks at or between substations should be equipped with manual or remote controlled switch gear to permit isolating or energizing adjacent catenary sections.

If remote control of substation and phase breaks is contemplated the cost of a central control point and telemetry circuits cannot be overlooked.

1.3.6 Power Transfer

Two primary methods are used to transfer electrical power to the railway vehicle, third rail and overhead wire. The cost of third rail includes the special contact rail, insulators, long ties or special brackets to mount on the short ties, third-rail covers, right-of-way fencing, miscellaneous hardware and installation labor costs. Ice and heavy snow cause electrical troubles with third-rail systems in many parts of the world.

Overhead wire comes in several different configurations with vehicle operating speed being the determining factor. Simple trolley wire can be used for yards or track where the speed of multiple unit consists will not exceed 30 mph. European tests have shown that stitched trolley wire can sustain speeds of 60 mph with multiple-unit consists. However, the current capacity of standard trolley wire may limit trolley wire use to relatively low power situations. The simple sagged catenary is generally sufficient for speeds up to 120 mph. Compound or stitched catenary is usually recommended for operation of trains above 120 mph. Virtually all new catenary construction is of the constant-tension design which has proven able to minimize trouble. At certain locations where power demand is extremely heavy, auxiliary parallel feeders hung from the supports may be more economical than increasing the size of the catenary wire or adding more substations. Catenary construction costs are generally more dependent on terrain than third-rail costs due to the variation in support distance. Costs for overhead catenary should include wire, insulators, supports, support foundations, tensioning devices, miscellaneous hardware, and all the labor to install the system.

Construction of both third-rail and overhead systems will disrupt railway traffic and require special material trains. Expenses for special train crews, extra train crews and items such as flagman protection, should be added to the cost of construction.

1.3.7 Clearance Modification

Situations will arise with both third-rail and overhead system where the electrical clearance requirements will necessitate the modification of nearby structures such as platforms, bridges and tunnels. Extremely high modification costs may dictate a lower voltage or, in some cases, a short segment of electrically dead catenary or third-rail.

1.3.8 Signal Modification

Because of electrical interference from the traction power system, electrification is not compatible with most types of signals used in the United States. A detailed analysis should be made by the signal department to determine the best type of modification to make signals compatible with the particular form of electrification being considered. Trackside signal lines must be shielded from alternating current power systems. The cost to upgrade a signal system, such as installing cab signals, should not be charged to electrification.

1.3.9 Communications

Most open-wire communications circuits near an alternating-current power source must be either shielded or converted to microwave. Microwave is frequently used for the long-distance circuits while shielded cable can be used for local distribution circuits. Modern thyristor locomotives have been known to generate various forms of signals which radiate beyond the railway property line. Special shielding of power circuits may be required in urban areas to prevent interference with public communications systems.

1.4 ANNUAL OPERATING EXPENSES

1.4.1 General

The annual operating expenses are critical in any electrification study and should be very carefully derived. The electrification of a railroad has the potential to affect virtually every cost encountered in daily operations. The difference in operating expenses between two or more propulsion systems is what creates a return on investment and determines which system is the most economical when compared to the initial capital costs.

1.4.2 Fuel and Energy

The cost of energy or fuel delivered to locomotives must be ascertained for each system being studied. Fuel costs should include all transportation, pumping and labor costs. Electric energy bills usually include a demand charge, energy charge, fuel adjustment and possibly a rental on some fixed equipment. If the cost of fuel and energy are changing at different rates, separate inflation factors should be developed for each. Attempts to increase the electrical load factor frequently result in train rescheduling and a separate option in the final analysis of electrification.

1.4.3 Train Crew Wages

Train crews may be paid on a basis that will change after electrification. Fewer locomotives with less weight on drivers could reduce the wages earned by the engine crew. Higher acceleration and top speed could reduce overtime or possibly the number of crews required to operate a particular section of railroad.

1.4.4 Locomotive Maintenance

The cost of maintaining locomotives using different sources of power is usually one of the most important aspects of any electrification study and frequently requires the most time and effort to determine precisely.

All costs associated with maintaining each type of locomotive should be carefully derived to insure that a true comparison is given. If possible each cost should be broken down into labor and material for application of the appropriate inflation factor. It is essential that all subdivisions of locomotive maintenance cost be included in the total. Some of the more frequent subdivisions include: locomotive repairs, superintendency, shop machinery, power plant machinery, locomotive servicing, maintaining power plants, maintaining fueling facilities, maintaining maintenance shops, insurance, unemployment insurance, hospital insurance, personal injuries, health and welfare benefits, old age retirement, and supplemental annuities. Recently, it has become a relatively common practice to capitalize the very heavy repairs or rebuilding of locomotives; these costs should be taken into account. The total maintenance cost is most easily used when apportioned on a gross ton mile basis.

However, greater accuracy can be achieved if the total cost can be divided into portions which are predominantly a function of unit miles operated, horsepower-hours generated, or chronological age.

The cost of maintaining diesel electric locomotives can be easily obtained from existing records, while costs associated with maintaining a modern electrical locomotive are frequently difficult to obtain from experience in North America. Cost projections by electrical locomotive builders can form the basis for the total cost, but extensive research should be done to determine the cost being experienced by users of electric locomotives. Electrification studies frequently refer to electric locomotive maintenance cost as a per cent of the diesel locomotive maintenance cost on a gross ton mile basis.

1.4.5 Catenary Maintenance

While modern constant-tensioned simple catenary systems are much cheaper to maintain than the old variable-tensioned compound systems, a certain amount of adjustment, wire replacement and repair after derailments will be required. Catenary maintenance costs are influenced by terrain, trackwork complexity, climate and rail traffic. Existing electrified systems should be reviewed to evaluate the catenary maintenance requirements and costs prior to making projections for a new system.

Third-rail maintenance should be treated in the same manner as catenary maintenance.

1.4.6 Substations and Transmission Line Maintenance

The cost of periodically inspecting transformer oil, switch gear operation, substation facilities, supervisory control systems, and clearing trees from the vicinity of transmission lines should be estimated. This is frequently done by taking a small percentage of the initial installation cost as being the annual maintenance cost.

1.4.7 Signal and Communications Maintenance

Eliminating the open line wire on poles frequently associated with the existing signal system usually means less maintenance of the system.

If cab signals or other signal improvements are separately justified, no effect will be felt on the electrification economics. However, if electrification is the justification, such as installing CTC in order to reduce the miles of catenary, all savings should be credited to electrification.

1.4.8 Taxes

The large expenses required for electrification should be thoroughly reviewed by tax specialists to determine the effects on taxes paid by the company. The increased valuation frequently increases property taxes while the savings when translated to increased income can cause greater income taxes.

The effect on taxes made by various investment tax credits, depreciation reserves, and possibly existing unused tax credits should be thoroughly reviewed.

1.5 FINANCING

Top financial officers for the railroad should be consulted to determine which of the many financial arrangements would be best suited to the particular system being studied. Cash-flow studies of the construction period are frequently requested by both railroad officials and investment bankers. Cash-flow projections for a period of 30 or more years after the project is completed is a necessity for making return-on-investment calculations.

1.6 MAINTENANCE OF WAY CHANGES

Installation of catenary or third rail will cause some changes in maintenance of way techniques. Third-rail operation will require about 20% of the annual new ties to be longer than standard. In addition to the increased material cost of the long tie, labor to unfasten and re-attach the third-rail chair and insulator must be included. Care must be exercised by tampers around impedance bonds, ground wires, and third rails. The size of maintenance equipment is frequently restricted by a third-rail system.

Cranes and wrecking derrick booms should be equipped with insulated pantographs or shields when working under catenary to avoid a grounding contact with the wire. Snow plows or spreaders operating with wings will be restricted by catenary supports. All equipment should be grounded to provide a positive electrical path for accidental contact with energized circuits.

1.7 INTANGIBLE BENEFITS AND LIABILITIES

During an electrification study, many items will appear which have little monetary impact, but which offer distinct benefits or liabilities for electric operation. Electrification has a positive impact on line-of-road failures, pollution control, noise and exhaust emissions, performance with overload capability, performance with superior wheel-slip systems, and the option to use different types of fuel. The catenary can be tapped at remote locations to provide power for signals, power switches, switch heaters, lights, and wayside buildings.

Negative aspects of electrification involve additional work when clearing wrecks, partial or total system shutdown for large power failures, safety problems with the exposed electrical system, and possible under-utilization of locomotives. Extra training will be required for those responsible for maintaining both electric and diesel locomotives.

Manual Recommendations

Committee 13—Environmental Engineering

Report on Assignment 4

Industrial Hygiene

R. S. Bryan, Jr. *(chairman, subcommittee),* W. D. Peters *(vice chairman, subcommittee),* W. H. Melgren, T. A. Tennyson, R. Singer.

Your committee submits for adoption and publication in Part 4, Chapter 13 of the Manual, the following new Section 4.7 Sanitation Requirements for Portable Housing Units.

4.7 SANITATION REQUIREMENTS FOR PORTABLE HOUSING UNITS

4.7.1 General

(a) The term "Portable Housing Unit" or "Portable Accommodation Unit" covers all self-contained living accommodations which can be readily lifted from the deck of a flatcar or any other temporary foundation.

(b) Portable housing units should be inspected every six months under a preventive maintenance schedule. This schedule should include the electrical system, the water and sewage disposal systems, all appliances, heating systems, the general condition of the unit as well as good housekeeping practices.

4.7.2 Utilization of Units

(a) Units are to be kept clean and tidy, floors are to be washed at regular intervals, particularly around appliances. All washing facilities are to be kept in a clean and sanitary condition and grating at shower stalls must be cleaned periodically.

(b) Burning cigarettes ancd matches must not be placed or extinguished on counter tops or linoleum floors, as damage will result. "USE ASH TRAYS."

(c) Under no circumstances must burning matches, cigarettes or ashes be deposited in recirculating flush-type chemical toilets. These units are constructed of ABS plastic material and will become easily damaged, causing inefficient operation of the unit.

(d) Do not deposit paper towels, wet-strength tissue paper or other articles in toilets. Use toilet tissue only. These units are equipped with a self-cleaning filter and will become clogged if other types of paper are used.

(e) If toilets other than recirculating flush-type chemical toilets are used, follow the instructions issued with the toilet unit.

(f) All refuse must be placed in covered receptacles provided.

(g) Each employee is responsible for maintaining his quarters in a clean and tidy condition.

4.7.3 Sanitation

4.7.3.1 General

(a) It is imperative that the area around all housing units be kept clear of all refuse and sewage. In no way is it permissible to drain sewage on the ground between or adjacent to the tracks.

(b) Cleanliness and sanitary conditions must always be maintained around toilet and wash facilities.

(c) The person in charge of the housing units should be responsible to ensure that sanitary regulations are strictly adhered to.

(d) Local regulations must be met with regard to disposal of all waste, garbage and drainage of water and sewer lines.

4.7.3.2 Drinking Water

(a) Water for human consumption must be obtained from a source approved by health authorities. Water obtained from a *doubtful source,* such as wells, lakes and rivers must be chlorinated. A simple method of water purification is as follows: Add 1 ounce of commercial bleach solution (5.25% sodium hypochlorite) to 5 U.S. gallons of water *or* one 5-grain Halazone tablet to 4 U.S. gallons of water. If Halazone tablets are used, allow one-half hour for purification period due to tablet dissolving slowly.

(b) *Water Containers and Systems for Drinking Water and Culinary Purposes:* All containers used for this purpose shall be tightly covered and provided with a tap outlet. They shall be sterilized once a week, or more often, if necessary by filling the container and adding 1 ounce of commercial bleach for a 5-gallon container; 10 ounces will sterilize a 50-gallon container. Closed water systems equipped with filters require flushing and sterilization annually; systems with no filters require flushing and sterilization every three months or more often if contamination is suspected. Individual disposable cups and dispensers shall be provided and used for drinking water. *Common drinking cups or dippers are prohibited.*

4.7.3.3 Refrigerators

(a) Ice boxes should not be used unless essential, and when used shall be emptied and washed out weekly with a sterilizing solution. Electric refrigerators shall be emptied, defrosted and washed out once a month. (Use 1 teaspoonful of chlorox to 1 ounce of detergent-bactericide in a 1½-gallon pail of hot water.) An open container of baking soda placed in refrigerators will assist in odor control and should be replaced each month. In case of a breakdown, it is essential perishable foods be obtained on a day-to-day basis, particularly in warm weather.

4.7.3.4 Dishes and Utensils

(a) After each meal, all dishes, utensils and equipment shall be washed and sterilized using 1 ounce of detergent-bactericide powder to 1 gallon of hot water in a sink filled with hot water. Change water every 30 minutes. Cracked or chipped dishes and damaged table utensils shall not be used and are to be replaced. Clean dishes shall be stored in an enclosed cabinet above floor level.

4.7.3.5 Insect Control

(a) It is essential that all kitchen, dining, food storage and personal wash areas be kept free of flies, cockroaches and other insects. All doors, windows, and roof vents shall be properly screened and screen doors kept securely closed. A sufficient supply of insecticide and spray containers shall be kept on hand. Use of vapour strips is not recommended.

4.7.3.6 Cleaning of Kitchen, Dining, Food Storage and Personal Wash Areas

(a) Floors are to be swept and washed each day. All table tops in food and dining areas shall be covered with a smooth, seamless, impervious material and shall be washed following each meal using 1 ounce of chlorox to 1 U.S. gallon of hot water. Shelving and cupboards shall be maintained in a clean and orderly condition at all times. The use of food and vegetables storage bins shall be eliminated. Food preparation areas surrounding cook stoves are to be thoroughly cleaned and kept free from food spills, grease accumulations, etc. Foods shall be removed from tables following each meal and not replaced until 20 minutes before the next meal serving time. *Any food that is unfit or of a suspicious nature is to be condemned and replaced.* The walls of all kitchen and dining areas shall be washed down a minimum of every six months and more frequently if required, using ½ cup chlorox to 1 U.S. gallon of hot water.

4.7.3.7 Personal Cleanliness

(a) Cooking and food-handling personnel shall wash their hands thoroughly with hot water and soap before starting work and after each visit to the toilet. Signs shall be posted to this effect. Cooks and all food-handling personnel shall wear clean, white clothing and aprons and shall carry current medical cards.

4.7.3.8 Garbage and Waste Disposal

(a) Polyethylene or plastic bags shall be supplied and used as garbage pail liners and shall be disposed of in accordance with local regulations, or by burying in a covered garbage pit where permitted. A garbage pit shall be prepared (where permitted) and located not less than 100 ft from the kitchen car. When the gang moves, covers will be removed and pits filled completely with earth. All liquid waste water shall be removed by approved drainage hoses or pipes to municipal sewers, where available, or to prepared sump pits, covered, located not less than 50 ft from any gang car or unit. When this method is used, sump pits are to be completely filled and covered with earth when the gang moves.

4.7.3.9 Toilets

(a) *Recirculating Toilets* in portable accommodation units and other equipment shall be given a thorough cleaning and recharging every 5 to 8 days, or when liquid appears in the bottom of the bowl. To empty the recirculating toilet: (1) ensure drainage piping to sewer or sump pit is properly attached to exterior toilet drains; (2) open the valve after removing the front skirt; (3) allow waste to thoroughly drain through drainage hose or pipe to sewer, sump pit, or tank truck; (4) open and close valve as required to rinse thoroughly and flush system several times using clean water; (5) close valve and replace skirt; (6) pour three measured gallons of water into toilet bowl, press flush button and add deodorant-bactericide, in accordance with manufacturers instructions, into bowl while it is flushing. Once recharged, it will operate effectively for approximately 80 usages over a 5- to 8-day period. Care is to be exercised to ensure that overfilling in the recharge routine above does not occur, causing damage and malfunction of the toilet. *Whether pit privies or sump pits for recirculating toilets are used, extreme caution is to be exercised to ensure that pollution of any water course or well does not occur.*

(b) If other type toilets are used, they must be in compliance with local health and sanitary regulations.

4.7.3.10 Bunk Cars and Accommodation Units

(a) All areas shall be kept in a neat and tidy condition at all times. The floors shall be swept and washed a minimum of once per week or more frequently if required. All windows shall be screened. All units and bedding shall be aired regularly, preferably once per week. Outside work clothing should not be kept or hung in sleeping areas, but should be kept in areas provided for this purpose. In portable accommodation units, the summer circulating fan system is to be used at all times in warm weather. The hanging of washing in rooms or sleeping areas is prohibited. All washing is to be hung only in areas provided for this purpose. All windows shall be thoroughly washed inside and out a minimum of twice yearly.

4.7.4 Shut-Down of Units

(a) If units are to be shut-down for any lengthy period, the following steps should be taken:

1. Drain all toilets and flush thoroughly.
2. Drain *all* water systems in all type units.
3. Open all faucets at sinks and showers.

Manual Recommendations

Special Committee on Concrete Ties

J. R. Williams *(chairman, committee)*, R. J. Brueske, K. C. Edscorn, W. E. Fuhr, C. L. Gatton, M. B. Hansen, D. L. Jerman, T. C. Netherton, E. L. Robinson, G. H. Way, J. W. Weber.

Your committee submits for adoption and publication as Part 10 of Chapter 3 of the Manual the following performance specifications for concrete ties and fastenings. These specifications are a revised version of the preliminary specifications published in Bulletin 644, September–October 1973. The corrections to the preliminary specifications published in Bulletin 650, November–December 1974, have been incorporated therein.

Part 10

Concrete Ties (and Fastenings)

CONTENTS

FOREWORD

This specification is intended to provide necessary guidance in the design, manufacture and use of concrete ties and their components for main line standard gage railway track systems. The specification contains minimum performance requirements of components for concrete tie railway track based on a variety of permissible tie spacings and ballast depths. Track constructed of tie and fastener components meeting the specifications applicable to the anticipated usage should be expected to give satisfactory performance under current AAR-approved maximum axle loads.

The specification covers materials, physical dimensions, and structural strength of prestressed monoblock and prestressed and conventionally reinforced two-block concrete ties. In addition, longitudinal and lateral load restraint requirements as well as the electrical performance requirements of rail fastener and tie combinations are given. Laboratory tests for the determination of the suitability of new designs are specified, as are necessary quality-control procedures during manufacture. The specification does not cover techniques nor equipment for the manufacture of concrete ties or fastenings.

Where current specifications or recommended practices of other technical societies, such as the American Society for Testing and Materials or the American Concrete Institute, are appropriate, they are made part of this specification by reference.

The following definitions are applicable to this specification:

1. Cross Tie—A transverse component of a track system whose functions are the control of track gage and the transmitting of rail loads to ballast.
2. Fastening—A component or group of components of a track system which affixes the rail to the cross ties.
3. Flexure Strength—Resistance to bending.
4. Insert—A device for securing an assembly and/or the rail to the tie. It may be cast in the tie at the time of manufacture or placed in a cored, cast or drilled hole in the tie.
5. Lateral Load—A load, or vector component of a load, at the gage corner of the rail parallel to the longitudinal axis of the tie, and perpendicular to the rail.
6. Longitudinal Load—A load along the longitudinal axis of a rail.
7. Negative Bending—Bending of a concrete tie by application of load that produces tension in the top surface of the tie.
8. Positive Bending—Bending of a concrete tie by application of a load that produces tension in the bottom surface of the tie.
9. Prestressing Tendon—A strand, wire or bar, within a concrete member, which under tension, precompresses the concrete.
10. Prestressed Tie—A tie utilizing precompressed concrete and prestressing tendons to resist flexure. Under design loads the tensile strength of the concrete in the tension faces of the tie is not exceeded.
11. Prestressed-Reinforced Tie—A reinforced concrete tie which, in addition to longitudinal reinforcing steel, uses prestressing tendons to resist bending but in which tension exceeding the tensile strength of the concrete may occur in the precompressed concrete under design loads. If cracks do occur, the resulting crack widths do not exceed specified values.

12. Pretensioned Concrete Tie—A prestressed concrete tie using pretension tendons to precompress concrete.
13. Posttensioned Concrete Tie—A prestressed concrete tie using posttension tendons to precompress concrete.
14. Posttensioned Tendon—A reinforcing member which adds structural strength to a prestressed concrete tie by placing it in compression. This member is tensioned after the setting of concrete.
15. Pretension Tendon (strand or wire)—A reinforcing member which adds structural strength to a prestressed concrete tie by placing it in compression. This member is tensioned prior to the placement of concrete.
16. Rail Seat—The area of the canted plane of a tie on which rail rests that lies within the confines of the rail base.
17. Reinforced Concrete Tie—A tie reinforced with deformed steel bars, welded wire fabric, deformed wire, or bar or rod mats and using nonprecompressed concrete. Under design loads the tensile strength of the concrete in the tension faces of the tie is exceeded; however, the resulting crack widths do not exceed specified values.
18. Reinforcement or Reinforcing Steel—Steel, excluding prestressing tendons, introduced within a concrete tie to improve its structural strength.
19. Structural Crack—A crack originating in the tensile face of the tie, extending to the outermost level of reinforcement or prestressing tendons and which increases in size under application of increasing load.
20. Vertical Load—A load or vector component of a load, at right angles to a line joining the two rail seats of the tie and normal to the longitudinal axis of the rail.

10.1 GENERAL CONSIDERATIONS

10.1.1 INTRODUCTION

In supporting and guiding railway vehicles, the track structure must restrain repeated lateral, vertical and longitudinal forces. As elements of the track structure, individual cross ties receive loads from the rails or fastenings and in turn transmit loads to the ballast and subgrade. Consequently, the design of a tie affects and is affected by characteristics of other components of the track structure. The use of concrete railway ties introduces different considerations into the design and installation of track systems. When such systems are properly designed and the component parts properly interrelated, installed and maintained, concrete railway tie systems can provide track of superior quality.

The analysis of requirements for such systems must necessarily involve not only the tie but all components of the track system, their interdependency and the conditions under which they must be applied. Thus, concrete tie track systems involve:

- The rail, tie, fastenings, ballast, subgrade and base,
- The quality of each component, method of manufacture, installation and maintenance,
- The direction, magnitude and frequency of traffic-imposed loads; the effect of environmental factors such as temperature and weather and the overall economics of installation and maintenance, and

- The need to support train weights and guide railway vehicles while restraining repeated lateral, vertical and longitudinal forces.

The performance specifications which follow provide the basic guidance needed in the selection, design and application of concrete railroad tie systems. Success in their application will require careful supervision on the part of the engineer to ensure that all components meet required standards and that the system is properly installed and maintained.

10.1.2 VERTICAL LOADS

10.1.2.1 Tie Spacing

The spacing affects rail flexure stress, compressive stress on ballast and roadbed and the flexure stress generated in the ties themselves. For a given set of tie dimensions and wheel loads, the consequences of increasing tie spacing are higher rail bending moments and stresses within the individual ties. For the case of constant tie, ballast and subgrade characteristics, wider tie spacings bring about larger track depression per unit of wheel load, i.e., lowered track modulus. Conversely, reduction of tie spacing lowers unit stress and increases track modulus.

These specifications cover concrete ties intended for track designs using center-to-center spacings of cross ties of between 20 and 30 inches.

10.1.2.2 Cross Tie Dimensions

Use of longer, wider, or stiffer ties which increase the tie-to-ballast bearing area has many of the same effects as reducing tie spacing. There are, however, limits beyond which an increase in tie size is ineffectual in reducing track stress and increasing track modulus. The concentration of tie-to-ballast load decreases with lateral distance from the rail. The rate of decrease of load with distance is higher for flexible tie materials and designs. There is, therefore, a point beyond which lengthening tie design will fail to significantly reduce unit bearing load. There are, in addition, required right-of-way clearances and machinery limitations which restrict tie length.

Widening tie design has similar benefits to increases in tie length. Widening tie design, however, beyond the point where it is practical to compact ballast beneath the tie is ineffective.

These specifications cover tie designs between 7 ft 5 inches and 9 ft 0 inches in length and between 8 inches and 13 inches in width at their bottom surface.

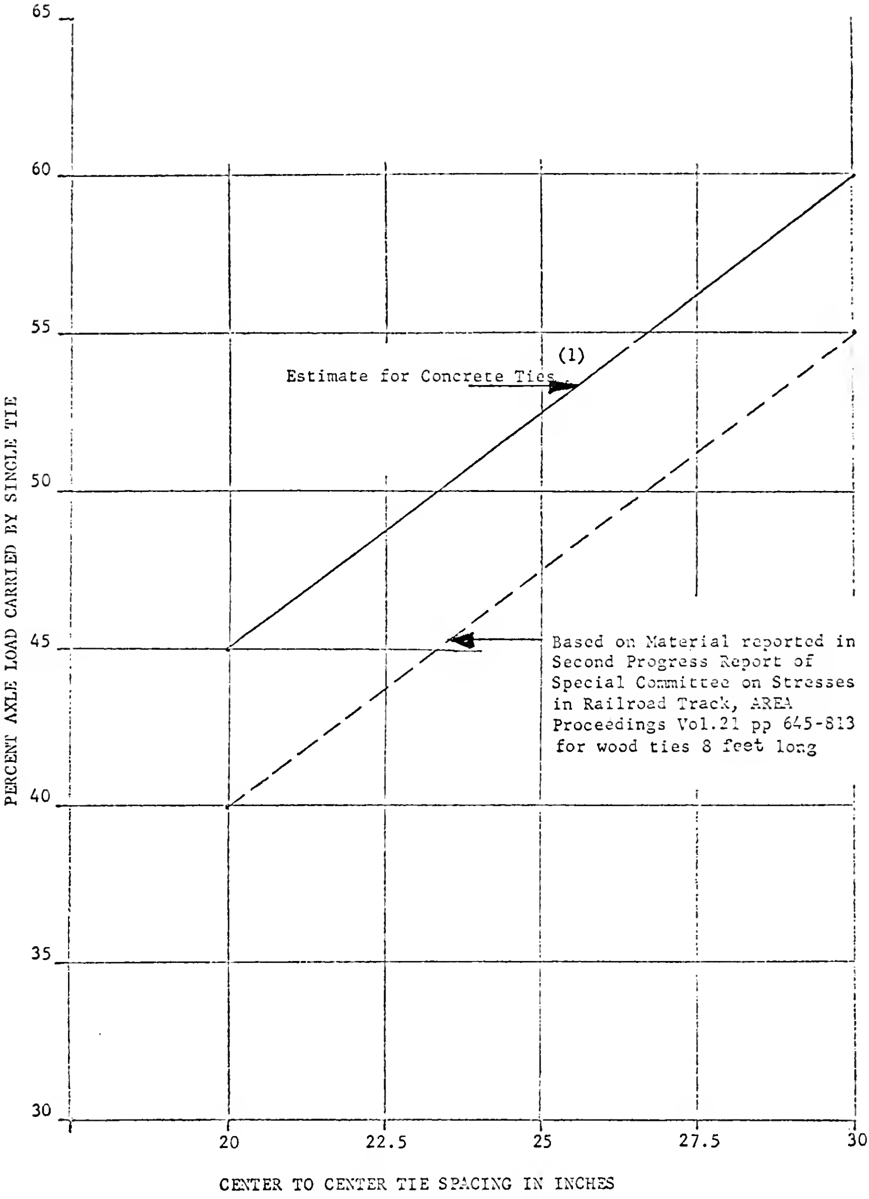
10.1.2.3 Load Distribution

The foregoing discussion and the requirements following presume that wheel loads applied to the rail will be distributed by the rail to several ties. This distribution of loads has been confirmed in field investigations. The distribution of load is dependent upon tie and axle spacing, ballast and subgrade reaction, and rail rigidity. The percentage of wheel-to-rail load carried by an individual tie varies from location to location. A conservative estimate of the distribution is given in Figure 10.1.2.3.1. While rail stiffness does influence these percentages, its effect is small compared to other factors. For the sake of simplification, the distribution factors are shown only as a function of tie spacing. The values chosen are intended to offset variations resulting from other influences.

10.1.2.4 Impact Factors

The requirements of these specifications are based on calculations including

Fig. 10.1.2.3.1—Approximate percent of axle load carried by individual tie.



(1) Based on an increase of 10% due to greater mass and stiffness of concrete ties.

an assumed impact factor. This factor is a percentage increase over static vertical loads intended to estimate the dynamic effect of wheel and rail irregularities. An impact factor of 150 percent has been assumed.

10.1.2.5 Ballast and Subgrade

In addition to tie size and spacing, ballast depth and subgrade modulus are also significant in the manner a particular track design restrains vertical loading. Increasing ballast depth tends to spread individual tie loads over a wider area of subgrade, thereby reducing the unit subgrade load and consequent track depression. Thus the effect of increased ballast depth can be similar, within limits, to that of reduced tie spacing. Stiffer subgrades do not require as low a ballast pressure as more flexible subgrades. Consequently, they are better able to tolerate wider tie spacings, smaller ties, more shallow ballast depths, or all three without failure or excessive track depression.

10.1.2.5.1 Ballast and Ballast Pressure

The engineer must insure that the design of track does not result in over-stress of ballast or subgrade. To do so, consideration must be given to wheel loads, distribution factor, impact factor, unit bearing capacities of the ballast and subgrade, and to cross tie dimensions and spacing.

10.1.2.5.1.1 Ballast Pressure

While tie-to-ballast pressure is not uniformly distributed across or along the bottom of a cross tie, an approximate calculation can be made of "average" pressure at the bottom of the tie. The maximum ballast pressure has been found to occur several inches below this interface. Consequently, the calculated value of average ballast pressure at the bottom of the tie understates the maximum ballast pressure. The average pressure at the tie bottom is equal to axle load, modified by distribution and impact factors, and divided by the bearing area of the tie:

$$\text{Average Ballast Pressure (psi)} = \frac{2P\left[1 + \frac{IF}{100}\right]\left(\frac{DF}{100}\right)}{A}$$ [*]

where: P = wheel load in pounds.
IF = Impact factor in percent.
DF = distribution factor in percent (from Figure 10.1.2.3.1).
A = bearing area of cross ties in square inches.

The recommended ballast pressure should not exceed 85 psi for high-quality, abrasion-resistant ballast. If lower quality ballast materials are used, the ballast pressure should be reduced accordingly.

10.1.2.5.1.2 Subgrade Pressure

The pressure exerted by ballast on the subgrade depends upon the tie-to-ballast

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[*] For example: Given 8 ft 6 inches long by 12 inches wide concrete ties, what is the calculated value of bearing pressure for a locomotive with 30,000-lb wheel load if the ties are to be spaced at 28 inches?

$$\begin{aligned}\text{Average Ballast Pressure (psi)} &= 2P\,\frac{\left[1 + \frac{IF}{100}\right]\left(\frac{DF}{100}\right)}{A}\\ &= \frac{60{,}000\ (2.5)\ (.57)}{102 \times 12}\\ &= 69.9\ \text{psi}\end{aligned}$$

pressure, the load distribution pattern through the ballast, and the depth of ballast. Refer to Section 10.12.

10.1.3 LATERAL LOADS

The lateral loads generated by moving railway equipment are applied by wheel treads and flanges to the rails, which in turn must be held in place by fastenings, ties and ballast.

Lateral stiffness of rail distributes lateral loads to fasteners and their ties. Structural strength of fastenings and ties hold the rail to gage. The mass of ties, friction between the ties and ballast, lateral bearing area of ties (end surface), and the mass of ballast all act to restrain lateral tie movement.

Lateral track stability can, therefore, be increased by decreasing tie spacing of ties of similar dimensions, increasing tie mass, increasing end bearing area of ties per unit length of track, and by increasing frictional resistance between ties and ballast. Structural strength of fastenings must be commensurate with the lateral load individual ties restrain, which in turn is determined by lateral rail stiffness and tie spacing.

The magnitude of lateral loads which must be restrained depends not only upon the dimensions, configuration, weight, speed and tracking characteristics of the equipment, but also upon the geometric characteristics of the track structure. Both the gross geometry—whether the track is straight, curved or how sharply curved—and the detail geometry—the irregularities and small deviations from design—influence the magnitude of lateral load.

These specifications cover fasteners capable of restraining individual lateral wheel-to-rail loads of up to 14,000 pounds per linear foot of track when these lateral loads are accompanied by vertical loads of a similar magnitude.

10.1.4 LONGITUDINAL LOADS

The longitudinal load developed by the combination of thermal stress in continuous welded rail and by traffic is transferred by the fastenings to the ties and ultimately restrained by mass internal friction of ballast. Consequently, the longitudinal bearing area (side area) of ties per unit of track length, friction between bottom of ties and ballast, and physical properties of ballast ultimately determine the track resistance to longitudinal movement. Resistance to rail movement with respect to ties is determined by the characteristics of fasteners. While total restraint of longitudinal rail movement is generally desirable, there are situations where such restraint is impractical or undesirable. In conventional track construction, the limiting factor in longitudinal restraint is most often ballast resistance. These specifications, therefore, apply to track designs incorporating a minimum of 210 square inches of side of tie area per linear foot of track and to fasteners for use on such track, offering 1480 lb resistance to longitudinal rail movement per linear foot of rail.

10.1.5 RAIL

10.1.5.1 Flexure Requirement

The interaction of rail and ties has been discussed in Articles 10.1.3 and 10.1.4 with respect to distribution factors, tie spacing, and vertical loads. The flexure stress generated in rail under load is a function of applied bending moment and the section modulus of rail. Rail bending moment is in turn determined by wheel load, axle spacing, and track modulus. Most modern rail sections are capable of bearing current wheel loads on tie spacings of up to 30 inches with normal ballast support without distress. It is recommended that the engineer calculate the maximum bending stress for rail sections lighter than 100 lb/yd if their use is anticipated. The following equation may be used for this purpose:

$$S = \frac{Mc}{I} = \frac{Pc}{I}\sqrt[4]{\frac{EI}{64\mu}}$$ [**]

Where: S = maximum fiber stress in rail (psi).
c = distance from neutral axis to outer edge of base or head (inches).
I = moment of inertia of rail section (inches^4).
E = modulus of elasticity of steel (psi).
μ = track modulus (pounds/inch/inch).
P = wheel load (pounds).
$M = P\sqrt[4]{\frac{EI}{64\mu}}$ = bending moment (inch-pounds).[***]

10.1.5.2 Rail Joints

(a) To achieve the maximum benefits and economy from the use of concrete railroad ties it is recommended that, in main-line track, they be used in conjunction with continuous welded rail. If concrete ties are used in conventional bolted track or at the ends of continuous welded rail, care should be exercised to see that the juncture of two rails does not occur over a concrete tie. The magnitude of impacts on a tie placed under the juncture of two rails could be destructive to the rail seat and fastenings in high-speed track.

(b) It is recommended that concrete ties not be installed within the limits of insulated joints or within the limits of special timber dimensions of turnouts and crossovers.

10.1.5.3 Effect of Mass on Track Stability

(Under development)

10.2 MATERIAL

10.2.1 GENERAL

Because it is impractical at this time to provide a performance test to assure the durability of concrete ties and their accessories, it is necessary to include specifications for the materials used in their manufacture. Deviation from the material specifications may only be made with the prior approval of the engineer.

[**] For example: Given track modulus of 3,000 lb/inch/inch and 90-lb RA-A rail with $I = 38.7$ inches^4 and $c = 2.54$ inches, what tensile stress is developed under a 30,000-lb wheel load?

$$S = \frac{Pc}{I}\sqrt[4]{\frac{EI}{64\mu}}$$

$$= \frac{30{,}000\ (2.54)}{38.7}\sqrt[4]{\frac{(30)\ (10)^6\ (38.7)}{64\ (3{,}000)}}$$

$$= 1968.9\left(\sqrt[4]{6046.8}\right) = 17{,}362 \text{ psi}$$

[***] First Progress Report of the Special Committee on Stresses in Track, Vol. 19 AREA proceedings, p. 887.

10.2.2 CONCRETE

The minimum 28-day-design compressive strength of concrete used for concrete ties shall be 7000 psi as determined by ASTM Method of Test C 39. The test cylinders shall be made and stored as specified in ASTM Specification C 31.(1)

10.2.2.1 Cement

Cement shall be portland cement and shall meet the requirements of ASTM Specification C 150. Air-entraining cement, if used, shall also meet the requirements of ASTM C 150.

10.2.2.2 Aggregates

Both fine and coarse aggregates shall meet the requirements of the AREA Specifications for Aggregates, Part 1, Section C, Chapter 8 of the AREA Manual.

10.2.2.3 Mixing Water

Mixing water shall meet the requirements of the AREA Specifications for Mixing Water, Part 1, Section D, Chapter 8 of the AREA Manual. In addition, the mixing water, including that portion of the mixing water contributed in the form of free moisture on the aggregates, shall not contain deleterious amounts of chloride ion.(2)

10.2.2.4 Admixtures

Additives containing chlorides shall not be used.

10.2.2.5 Curing

It is recommended that the concrete be cured by a method or procedure such as set forth in Part 1, Section P, Chapter 8 of the AREA Manual.

10.2.3 METAL REINFORCEMENT

10.2.3.1

Wire and strands for tendons in prestressed concrete shall conform to "Specifications for Uncoated Seven-Wire Stress-Relieved Strand and Wire for Prestressed Concrete" (ASTM A 421). Strands or wire not specifically itemized in ASTM A 416 or A 421, including strands with constructions other than those listed in A 416, may be used provided they conform to at least the minimum requirements of these ASTM specifications and have no properties which make them less satisfactory than those listed in ASTM A 416 or A 421.

10.2.3.2

High-strength alloy steel bars for posttensioning tendons shall be proof-stressed during manufacture to 85 percent of the minimum guaranteed tensile strength. After proof stressing, bars shall be subjected to a stress-relieving heat treatment to produce the prescribed physical properties. After processing, the physical properties of the bars when tested on full sections, shall conform to the

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(1) If the results of performance tests demonstrate satisfactorily to the user that the resistance to abrasion and weathering of the concrete is adequate in the railway track environment, the provisions of this requirement may be waived.

(2) A chloride ion content greater than 400 ppm might be considered detrimental, and it is recommended that levels well below this value be maintained if practicable.

Chloride ions contained in the aggregate and in admixtures should be considered in evaluating the acceptability of total chloride ion content of the mixing water. (From the commentary to ACI 318–71).

following minimum properties: Yield strength (0.2 percent offset): 0.85 f's where f'_s is the ultimate strength of the prestressing steel. Elongation at rupture in 20 diameters: 4 percent. Reduction of area at rupture: 20 percent.

10.2.3.3

Reinforcing bars shall conform to one of the following specifications, except that yield strength shall correspond to that determined by tests on full-size bars; and for reinforcing bars with a specified yield strength of the reinforcing steel, f_y, exceeding 60,000 psi, f_y shall be the stress corresponding to a strain of 0.35 percent:

(a) "Specifications for Deformed Billet-Steel Bars for Concrete Reinforcement" (ASTM A 615).

(b) "Specifications for Rail-Steel Deformed Bars for Concrete Reinforcement" (ASTM A 616). If bars meeting these specifications are to be bent, they shall also meet the bending requirements of ASTM A 615 for Grade 60.

(c) "Specifications for Axle-Steel Deformed Bars for Concrete Reinforcement" (ASTM A 617).

10.2.3.4

Plain bars for spiral reinforcement shall conform only to the strength requirements and minimum elongation of the appropriate specification prescribed in Art. 10.2.3.3.

10.2.3.5

Reinforcement to be welded shall be indicated on the drawings and the welding procedure to be used shall be specified. The ASTM specification shall be supplemented by requirements assuring satisfactory weldability by this procedure in conformity with "Recommended Practices for Welding Reinforcing Steel, Metal Inserts, and Connections in Reinforced Concrete Construction" (AWS D 12.1). The supplementary specification requirements shall be designated in the order, and conformance with these requirements shall be confirmed by the supplier at the time of delivery.

10.2.3.6

Bar and rod mats for concrete reinforcement shall be the clipped type conforming to "Specifications for Fabricated Steel Bar or Rod Mats for Concrete Reinforcement" (ASTM A 184).

10.2.3.7

Plain wire for spiral reinforcement shall conform to "Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement" (ASTM A 82), except that f_y shall be the stress corresponding to a strain of 0.35 percent if the yield strength specified in the design exceeds 60,000 psi.

10.2.3.8

Welded plain wire fabric for concrete reinforcement shall conform to "Specifications for Welded Steel Wire Fabric for Concrete Reinforcement" (ASTM A 185), and to the stipulation of Art. 10.2.3.7 regarding measurement of f_y, except that welded intersections shall be spaced not farther apart than 12 inches in the direction of the principal reinforcement.

10.2.3.9

Deformed wire for concrete reinforcement shall conform to "Specifications for Deformed Steel Wire for Concrete Reinforcement" (ASTM A 496), except that wire shall not be smaller than size D-4⁽³⁾ and that f_y shall be the stress corresponding to a strain of 0.35 percent if the yield strength specified in the design exceeds 60,000 psi.

10.2.3.10

Welded deformed wire fabric for concrete reinforcement shall conform to "Specifications for Welded Deformed Steel Wire Fabric for Concrete Reinforcement" (ASTM A 947) and to the stipulation of Art. 10.2.3.9 regarding measurement of f_y, except that welded intersections shall be spaced not farther apart than 16 inches in the direction of the principal reinforcement.

10.2.3.11

Steel pipe or tubing for composite members shall conform to one of the following:

(a) Grade B, ASTM A 53.
(b) ASTM A 500.
(c) ASTM A 501.
(d) Grade specified by the manufacturer and supported by design and test data subject to the approval of the engineer.

10.2.3.12

Structural steel used in conjunction with reinforcing for composite members shall conform to one of the following:

(a) ASTM A 36.
(b) ASTM A 242.
(c) ASTM A 440.
(d) ASTM A 441.
(e) ASTM A 588.
(f) Grade specified by manufacturer and supported by design and test data subject to the approval of the engineer.

10.2.3.13 Reinforcement Placement and Spacing

The placement and spacing of reinforcement, prestressing steel and prestressing ducts shall be in accordance with all applicable requirements of the AREA Manual, Chapter 8, Part 1, Section H—Metal Reinforcement Placing, as revised in 1970 except that tolerances for placing shall meet the requirements of Art. 10.3.2.12.

10.2.3.13a Supports

Reinforcement, prestressing steel, and ducts shall be accurately placed and adequately supported before concrete is placed and shall be secured against displacement within permitted tolerances. Welding of crossing bars shall not be permitted for assembly of reinforcement unless authorized by the engineer.

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(3) Deformed wire is denoted by the letter "D", followed by a number indicating the wire's cross sectional area in hundredths of a square inch. Thus, the minimum size deformed wire permitted in this specification must have a cross sectional area of 0.04 square inches.

10.2.4 TIE PADS

Abrasion-resistant pads or abrasion-, vibration- and impact-reducing pads shall be used between the rail and concrete ties on all main-line or other heavy-traffic tracks to minimize the possibility of abrasive action in the rail bearing area of the ties. It is recommended that such pads also be used on other trackage.

10.2.4.1 Polyethylene Bearing Pads

Polyethylene bearing pads, if used, shall be black high-density plastic, 60 to 65 D-Durometer, meeting current ASTM Specification D 1248, Type III, Grade 3. Hardness shall be stable between +140 F and —40 F.

10.2.4.2 Elastomeric Bearing Pads

Elastomeric bearing pads, if used, shall be of weather- and petroleum-resistant materials. Values for the following ASTM Test Method Specifications are under study:

(a) ASTM Test Method D 573 for aging in air.
(b) ASTM Test Method D 395, Method B, for compression set.
(c) ASTM Test Method D 518, Procedure A and D 518–61, for resistance to the atmospheric ozone.
(d) ASTM Test Method D 471 for resistance to water.
(e) ASTM Test Method D 471 for resistance to oil.

The hardness of such pads shall be between 60 and 80 A-Durometer as specified by the purchaser. A tolerance of ± 5 shall be permitted from that specified. Pads using ridges, grooves or other patterns are permissible, providing that such patterns do not reduce the protection offered by the pad.

10.2.4.3 Other Types of Bearing Pads

Bearing pads may also be made of nylon, laminated fiber, wood or other abrasion-resistant material. Such pads shall be used only with the approval of the engineer and shall meet specifications provided by the engineer.

10.2.5 INSULATION

Insulation shall be used where necessary to prevent interference with signal systems and deterioration of the fastening system through electrical leakage.

10.2.5.1 Nylon Insulators

Nylon insulators, if used, shall meet the requirements of the current ASTM Specification D 789, Type 1, Grade 2, Specification for Nylon Injection Molding and Extrusion Materials.

10.2.5.2 Other Insulating Materials

Other insulating materials such as epoxy coatings and fiberglass may be used if desired as long as they provide sufficient protection against electrical leakage and meet the approval of the engineer. (See Art. 10.9.1.14).

10.2.6 FASTENINGS

All fastening components, including hardware cast into the tie, shall be suitably resistant to corrosion and able to withstand repeated loads within the railway track environment without fatigue failure or excessive maintenance requirements. Use of metals of widely divergent electrical potential in contact or close proximity to one another is not recommended.

10.2.6.1 Cap Screws and Rail Clips

Cap screws used with rail clips shall be a minimum of ¾ inch in diameter and of sufficient length to provide a minimum engagement of 1 inch but not to exceed 1½ inches. They shall have a minimum proof load of 28,400 lb.

10.3 TIE DIMENSIONS, CONFIGURATION AND WEIGHT

10.3.1 SPECIAL CONSIDERATIONS

10.3.1.1 Track Machinery Limitations

In addition to those considerations covered in Section 10.1 General Considerations, the following maximum dimensions will permit tamping with many present-day ballast tamping machines and will allow other related work to be handled in a mechanized manner:

(a) Tie width = 13 inches
(b) Tie depth = 10 inches
(c) Tie length = 9 ft 6 inches

10.3.1.2 Weight

For ease of handling it is recommended that the weight of tie not exceed approximately 800 lb.

10.3.2 REQUIREMENTS

10.3.2.1 Length

The overall nominal length of concrete ties shall not be less than 7 ft 5 inches nor more than 9 ft 6 inches. A tolerance of plus ½ inch or minus ⅛ inch from nominal length is permitted.

10.3.2.2 Width

The minimum width of ballast bearing area of tie shall not be less than 8 inches. Width of tie at top surface from rail seat area to end of tie shall not be less than 6 inches. The maximum width must not exceed 13 inches. Tolerance of ± ⅛ inch from nominal width is permitted.

10.3.2.3 Minimum Depth

The minimum design depth of any section of tie shall not be less than 6 inches. A manufacturing tolerance of + ¼ inch and — ⅛ inch is permitted from design depth.

10.3.2.4 Maximum Depth

Maximum design depth of any section of the tie shall not be more than 10 inches. A manufacturing tolerance of + ¼ and — ⅛ inch is permitted from design depth.

10.3.2.5 Track Gage

The concrete tie/rail fastening system shall hold track gage to ± 1/16 inch from that specified, exclusive of mill tolerance in rail. Ties shall normally be manufactured for 4 ft 8½ inches track gage. If track gage other than 4 ft 8½ inches is desired, it shall be so specified by the engineer. The center line of the tie shall be within ¼ inch of the center line of track gage.

10.3.2.6 Rail Cant

The rail seat shall provide for a cant of 1 in 40 ± 2 toward center line of tie unless otherwise specified.

10.3.2.7 Rail Seat Plane

The rail seat shall be a flat smooth surface, ± 1/32 inch.

10.3.2.8 Differential Tilt of Rail Seats

A differential tilt in the direction of the rail of one rail seat to the other shall (on a width of 6 inches) not exceed 1/16 inch.

10.3.2.9 Protrusion of Pretensioning Tendons

Strands of wires shall not project more than 1 inch beyond the ends of the ties.

10.3.2.10 End of Posttensioning Tendons

To protect against corrosion, the ends of posttensioning tendons shall not protrude beyond the ends of the ties and shall be covered to the extent specified in Art. 10.3.2.11 with concrete, epoxy grout or other material approved by the engineer.

10.3.2.11 Concrete Protection for Reinforcement Against Corrosion

The following minimum specified cover for reinforcement, prestressing tendons, ducts, or prestressing end fittings(4) shall be as follows:

(a) Prestressed, precast cross ties (pretensioned or post-tensioned) .... ¾ inch

(b) Reinforced, precast cross ties:
  No. 6 bars, ¾-inch wire, and smaller .... ¾ inch
  Other bars .... one bar diameter

10.3.2.12 Tolerances for Placing Reinforcement

(a) The tolerance for clear concrete protection (cover) and for depth, *d*,(5) for reinforcing steel shall be ± ⅛ inch; for prestressing tendons ± 1/16 inch.

(b) The tolerance for longitudinal location of bends in reinforcing bars shall be ± 2 inches.

(c) The tolerance for the location of ends of reinforcing bars shall be ± ½ inch.

10.3.2.13 Surface Finish

(a) The top and side surfaces of the ties shall present a smooth, uniform appearance. A random scattering of surface voids will not be cause for rejection. Heavy concentrations of surface voids or evidence of improper mixing, vibrating or curing will be cause for rejection.

(b) The ends of the ties need not be flat planes or surfaces, but there shall be no evidence of tearing of the concrete where the prestressing strands emerge or of any void in contact with a strand.

(c) Occasional spalling of a small portion of rail seat shoulders may occur during the stripping operation. Such spalling will not be cause for rejection unless it involves that portion of a shoulder against which the heel of rail fastening clip bears.

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(4) This does not apply to the ends of pretensioning tendons which may protrude from the end of the tie. See also Art. 10.3.2.9.

(5) Distance from extreme compression fiber to centroid of tension reinforcement.

(d) Concrete ties shall be marked with indented or raised letters or numerals to identify the manufacturer, type of tie and year of manufacture as approved by the engineer.

10.4 FLEXURAL STRENGTH OF PRESTRESSED MONOBLOCK TIES

10.4.1 FLEXURAL PERFORMANCE REQUIREMENTS FOR PRESTRESSED MONOBLOCK DESIGNS

TABLE I

Length[1]	*Spacing*[2] *(Inches)*	*Required Flexural Capacity (Inch-Kips) Without Cracking*			
		Rail Seat +	*Rail Seat—*[3]	*Center —*	*Center +*
8′-0	21	220	115	200	90
	24	220	115	220	90
	27	220	115	240	90
	30	220	115	260	90
8′-3	21	225	115	200	90
	24	235	115	210	90
	27	250	115	220	95
	30	260	115	230	100
8′-6	21	225	115	200	90
	24	250	115	200	90
	27	275	115	200	100
	30	300	115	200	110
8′-9	21	250	115	200	95
	24	275	115	200	100
	27	300	115	200	110
	30	325	115	200	120
9′-0	21	275	115	200	100
	24	300	115	200	105
	27	325	115	200	115
	30	350	115	200	125

(1) For existing tie designs having reduced bottom width at center of tie: The rail seat and center positive flexural requirements shall be increased by 10% and the center negative flexural requirements shall be decreased by 10% (but shall not be less than 150 inch-kips) because of the redistributed ballast reaction associated with such designs.

(2) For tie spacings other than those shown, flexure requirements shall be determined by interpolation.

(3) The values shown in the Rail Seat (—) column are based on elastic fastenings having an overall vertical upward spring rate in the range of 200,000 to 350,000 lb per inch. (This spring rate is not necessarily linear and should be determined in the 0.00 to 0.02 inch deflection range. The Rail Seat negative values may not be adequate for more rigid fastenings.

10.4.2 DESIGN CONSIDERATIONS

10.4.2.1

As well as satisfying the criteria in Table I, prestressed concrete monoblock ties must also comply with other criteria which accord with good design practice as laid down in ACI Code 318.

10.4.2.2

It is recommended that the maximum precompression after all losses at any point in the cross ties should not exceed 2,500 psi.

10.4.2.3

Furthermore, in the case of ties to which the rails are to be fastened by elastic fastening systems, there should be a minimum pre-compressive stress at any vertical cross section through the rail seat area of 150 psi after all losses and without any applied load. Because the precessional wave just ahead of the wheels will create an uplift force from the rails to the ties and because the magnitude of this force will depend, among other things, on the weight of the ties and the rigidity of the fastening system, this minimum pre-compressive stress should be higher for rigid fastening systems.

10.4.3 TEST REQUIREMENTS FOR APPROVING THE DESIGN OF A MONO-BLOCK TIE

10.4.3.1

The minimum negative and positive flexural capacity at the rail seats of the tie shall be as shown in Table I for the tie length and spacing to be used when tested in accordance with the Rail Seat Vertical Load Test described in Art. 10.9.1.4.

10.4.3.2

The minimum negative flexural capacity at the center of the tie shall be as shown in Table I for the tie length and spacing to be used when tested in accordance with the Negative Bending Moment Test described in Art. 10.9.1.6.

10.4.3.3

The minimum positive flexural capacity at the center of the tie shall be as shown in Table I for the tie length and spacing to be used when tested in accordance with the Positive Bending Moment Test described in Art. 10.9.1.7.

10.4.3.4

The tie must meet the requirements of the Rail Seat Repeated-Load Test described in Art. 10.9.1.5.

10.4.3.5

The tie must meet the requirements of the Bond Development or Tension Anchorage Test described in Art. 10.9.1.8.

10.5 FLEXURAL STRENGTH OF TWO-BLOCK TIES

10.5.1 FLEXURAL PERFORMANCE REQUIREMENTS FOR TWO-BLOCK DESIGNS

TABLE II

REQUIRED FLEXURAL CAPACITY (INCH-KIPS)(3)

Length Tie Block Inches	*Tie(2) Spacing Inches*	*Railseat—Positive(3)*		*Railseat—Negative(4)*	
		Reinf. Tie	*P/S Tie(1)*	*Reinf. Tie*	*P/S Tie(1)*
30	21	150	150	105	105
	24	150	150	105	105
	27	150	150	105	105
	30	150	155	105	110
33	21	150	150	105	105
	24	150	150	105	105
	27	150	155	105	110
	30	155	170	110	120
36	21	150	150	105	105
	24	150	155	105	110
	27	155	170	110	120
	30	170	185	120	130
39	21	205	225	145	160
	24	225	250	160	175
	27	250	275	175	195
	30	270	300	190	210
42	21	250	275	175	195
	24	270	300	190	210
	27	295	325	210	230
	30	315	350	225	245

(1) Prestressed or prestressed-reinforced.

(2) For tie spacings other than those shown, the flexure requirements shall be determined by interpolation.

(3) The values shown in the Rail Seat-Postive, P/S Tie column above have been increased by 10% to allow for long-term losses in prestressed ties. The resulting values and the values shown in the Rail Seat-Positive, Reinf. Tie column above have been rounded off to the next larger increment of 5 inch-kips. Where applicable they also have been increased to a minimum of 150 inch-kips.

(4) 0.7 × Rail Seat-Positive requirement rounded to the next larger increment of 5 inch-kips.

10.5.1.1 Allowable Cracking

(a) Reinforced cross ties when subjected to loads producing flexure in the blocks must crack in order for the main reinforcement to work. Corrosion of steel reinforcement is related to crack width and external environment. The maximum crack width allowed in Art. 10.5.1.1e, Table III, should not contribute to corrosion of steel reinforcement under normal railroad environments.

(b) Cracks shall be measured on the side surfaces of the tie blocks at a level directly opposite the reinforcement closest to the tension face of the tie. If it is not possible to measure a crack at this level due to chipping of the concrete or surface imperfections, measurements shall be taken equidistant above and below this level and the two values averaged to obtain the width of the crack.

(c) Cracks shall be measured using a hand-held graduated microscope of sufficient power and accuracy to measure crack widths to the nearest 0.001 inch.

(d) Cracks shall not extend to prestressing tendons or longitudinal reinforcing steel of less than ⅜ inch diameter.

10.5.1.1e Table III

*No. of Cracks**	*Max. Width—Inch*	*Avg. Width—Inch*
1	0.006	-----
2	0.006	0.005
3	0.006	0.004
4 or more	0.006	0.003

*Per side per tie block

10.5.2 TEST REQUIREMENTS FOR APPROVING THE DESIGN OF A TWO-BLOCK TIE

10.5.2.1

The minimum positive and negative flexural capacity of the tie blocks shall be as shown in Table II for the tie block length and tie spacing to be used when tested in accordance with the Rail Seat Positive and Rail Seat Negative Moment Tests described in Arts. 10.10.1.4 and 10.10.1.5.

10.5.2.2

The ties must meet the requirements of the Rail Seat Ultimate Load Test described in Art. 10.10.1.9.

10.5.2.3

The ties must meet the requirements of the Rail Seat Repeated Load Test described in Art. 10.10.1.8.

10.5.2.4

The ties must meet the requirements of the Center Negative and Center Positive Bending Moment Tests described in Arts. 10.10.1.6 and 10.10.1.7.

10.6 LONGITUDINAL RAIL RESTRAINT

10.6.1 REQUIREMENTS

Fastenings for concrete ties must have the ability to restrain longitudinal movement of rail as determined by test procedure specified in Art. 10.9.1.12, as follows:

21-inch tie spacing, 2600 lb per tie per rail.
24-inch tie spacing, 2900 lb per tie per rail.
27-inch tie spacing, 3300 lb per tie per rail.
30-inch tie spacing, 3700 lb per tie per rail.

Welded rail must be laid at the proper temperature range or additional anchorage provided at the ends of strings.

10.7 LATERAL RAIL RESTRAINT

10.7.1 RAIL FASTENING REQUIREMENTS

(a) Track constructed of concrete ties and appropriate fasteners shall not experience gage widening of more than ¼ inch when lateral wheel loads of 35,000 lb are applied to one rail. (See Art. 10.9.1.13 for design tests.)

(b) If a concrete shoulder is used to restrain the lateral movement of the rail, a suitable bearing surface shall be provided to transmit the lateral forces to the tie.

(c) Inserts shall be arranged to distribute the load uniformly in the body of the tie and through the rail bearing area. The rail support insert shall withstand a pullout force of 12,000 lb. (See Arts. 10.9.1.9.1, 10.9.1.11 and 10.9.1.13 for design tests.)

10.8 ELECTRICAL PROPERTIES

10.8.1 REQUIREMENTS

Individual concrete cross ties for use in signal circuit tracks together with their fastenings should be electrically isolated from the running rails so as to provide a minimum impedance of 20,000 ohms per tie when a-c energy of 10 volts, 60 Hertz is applied. (See Art. 10.9.1.14 for test procedure.)

10.9 TESTING OF MONOBLOCK TIES

10.9.1 DESIGN TESTS OF MONOBLOCK TIES

Prior to approval of concrete tie designs, monoblock concrete ties of the design under study shall be subjected to testing for compliance with these specifications. The tests specified herein shall be performed at testing facilities approved by the engineer within 30 days of casting.

From a lot of not less than ten ties produced in accordance with these specifications, four ties will be selected at random by the engineer for laboratory testing. For design testing of fastenings, the manufacturer shall also furnish a section of the tie or a concrete block with rail seat and rail fastening system identical to the concrete ties furnished for testing.

The tie block and each of the four ties submitted for testing shall be carefully measured and examined to determine their compliance with the requirements of Sections 10.2 and 10.3. Upon satisfactory completion of this examinatin, the tie block and two ties, which shall be known and identified as Tie "1" and Tie "2", shall be subjected to performance tests specified in Arts. 10.9.1.4, 10.9.1.5, 10.9.1.6, 10.9.1.7, 10.9.1.8, 10.9.1.9, 10.9.1.10, 10.9.1.11, and 10.9.1.12. The remaining two ties, which will be known and identified as Ties "3" and "4", will be retained by the engineer for further test use (Art 10.9.1.14) and as a control for dimensional tolerances and surface appearance of ties subsequently manufactured.

10.9.1.1 Sequence of Design Tests (Tie "1")

The sequence of design performance tests using Tie "1" shall be as follows:

(a) Rail Seat Vertical Load Tests (described in Art. 10.9.1.4)—Shall be performed on one rail seat, hereinafter designated rail seat A.

(b) Negative Bending Moment Test (described in Art. 10.9.1.6).

(c) Positive Bending Moment Test (described in Art. 10.9.1.7).

(d) Rail Seat Vertical Load Test (described in Art. 10.9.1.4)—Shall be performed on the other rail seat, hereinafter designated rail seat B.

(e) Rail Seat Repeated Load Test (described in Art. 10.9.1.5)—Shall be performed on rail seat B.

(f) Bond Development, Tendon Anchorage, and Ultimate Load Test (described in Art. 10.9.1.8)—Shall be performed on rail seat A.

10.9.1.2 Sequence of Design Tests (Tie "2")

The sequence of design performance tests using Tie "2" shall be as follows:

(a) Fastening Insert Test (described in Art. 10.9.1.9)—Shall be performed on all inserts.

(b) Fastening Uplift Test (described in Art. 10.9.1.10)—Shall be performed on one rail seat.

(c) Electrical Resistance and Impedance Test (described in Art. 10.9.1.14).

10.9.1.3 Sequence of Design Tests (Tie Block)

The sequence of design performance tests using the tie blocks shall be as follows:

(a) Fastening Repeated Load Test (described in Art. 10.9.1.11).

(b) Fastening Longitudinal Restraint Test (described in Art. 10.9.1.12).

(c) Fastening Lateral Restraint Test (described in Art. 10.9.1.13).

10.9.1.4 Rail Seat Vertical Load Test

With the tie supported and loaded as shown in Figure VII, a load increasing at a rate not greater than 5 kips per minute shall be applied until the load (P) required to produce the specified rail seat negative moment from Art. 10.4.1, Table I is obtained. This load shall be held for not less than 3 minutes, during which time an inspection shall be made to determine if structural cracking occurs. In like manner, the tie shall be supported and loaded as shown in Figure I to produce the rail seat positive moment from Art. 10.4.1, Table I. An illuminated 5-power magnifying glass may be used to locate cracks. If structural cracking does not occur, the requirements of each portion of this test will have been met.

10.9.1.5 Rail Seat Repeated-Load Test

Following the vertical load test on rail seat B, the load shall be increased at a rate of 5 kips per minute until the tie is cracked from its bottom surface up to the level of the lower layer of reinforcement.

After removal of the static rail seat load necessary to produce cracking, and substitution of ¼-inch pads for those shown in Figure I, the tie shall be subjected to 3 million cycles of repeated loading with each cycle varying uniformly from 4 kips to the value of $1.1P$. The repeated loading shall not exceed 600 cycles per minute. If, after the application of 3 million cycles, the tie can support the rail seat load ($1.1P$), the requirements of this test will have been met.

10.9.1.6 Negative Bending Moment Test

With the tie supported and loaded as shown in Figure II, a load increasing at a rate not greater than 5 kips per minute shall be applied until the load required to produce the specified negative center design moment from Table I is obtained.

The load shall be held for not less than 3 minutes, during which time an inspection shall be made to determine if structural cracking occurs. An illuminated, 5-power magnifying glass may be used to locate cracks. If structural cracking does not occur the requirements of this test will have been met.

10.9.1.7 Positive Bending Moment Test

With the tie supported and loaded as shown in Figure III, a load increasing at a rate not greater than 5 kips per minute shall be applied until the load required to produce the specified positive center design moment from Table I is obtained. The load shall be held for not less than 3 minutes during which time an inspection shall be made to determine if structural cracking occurs. An illuminated, 5-power magnifying glass may be used to locate cracks. If structural cracking does not occur, the requirements of this test will have been met.

10.9.1.8 Bond Development, Tendon Anchorage, and Ultimate Load Test

(a) Pretensioned concrete ties shall be tested for bond development, and ultimate strength as specified below:

(1) With the tie supported and loaded at rail seat A as shown in Figure I, a load increasing at a rate not greater than 5 kips per minute shall be applied as follows:

(i) If initial cracking occurs at or above 1.1*P*, a total load of 1.5*P* shall be applied (the load *P* shall be as determined in "Rail Seat Vertical Load Test" for positive moment).

(ii) If initial cracking occurs below 1.1*P*, a total load of 1.75*P* shall be applied.

If there is no more than 0.001-inch strand slippage determined by an extensometer reading to 1/10,000 suitably attached to the end of the tie, the requirements of this test will have been met. The load shall then be increased until ultimate failure occurs and the maximum load obtained shall be recorded.

(b) Post-tensioned concrete ties shall be tested for tendon anchorage, and ultimate strength as specified below:

With the tie supported and loaded as shown in Figure I, a load increasing at a rate not greater than 5 kips per minute shall be applied until a total load equal to that specified in Art. 10.9.1.8 (a), (i), or (ii) is obtained. If the tie can support this load for a period of not less than 5 minutes, the requirements of this test will have been met. The load shall then be increased until ultimate failure of the tie occurs, and the maximum load obtained shall be recorded.

10.9.1.9 Fastening Insert Tests

(a) Threaded-Type Inserts

To determine the ability of threaded inserts to resist the bolt tension and ability of the concrete rail seat to carry any differential vertical load between the rail and the concrete tie, the following test shall be performed on each insert as shown on Figure IV. An axial load of 12 kips shall be applied to each insert separately and held for not less than 3 minutes, during which time an inspection shall be made to determine if there is any slippage of the insert or any severe cracking of the concrete. If such failures occur, then the requirements of this test will not have been met. Inability of the insert itself to resist the 12-kip load shall also constitute failure of this test.

Following successful completion of the insert pullout test, the following test shall be performed on each rail fastening insert to determine its ability to resist turning. A high-strength shoulder bolt of the proper diameter for the insert being tested and having a threaded length of 1⅜ inches shall be threaded into the insert and torqued to 150 percent of the torque recommended by the fastener manufacturer for normal installation. The load shall be held for not less than 3 minutes. Ability of the insert to resist this torque shall constitute passage of this test.

(b) Other Fastening Inserts

Other fastening inserts shall be subject to the pull-out tests and torque test (if applicable) in accordance with the manufacturer's recommendations and as approved by the engineer.

10.9.1.10 Fastening Uplift Test

An 18- to 20-inch piece of the proper section of rail shall be secured to one rail seat using a complete rail fastening assembly, including pads, bolts, clips and associated hardware, as recommended by the manufacturer of the rail fastening system. In accordance with the loading diagram in Figure V, an incremental load shall be applied to the rail. The load P (measured load plus unsupported tie weight plus frame weight) at which separation of the rail from pad or pad from rail seat (whichever occurs first) shall be recorded. The load shall then be completely released. A load of $2P$ shall then be applied. The inserts shall not pull out or loosen in the concrete and no component of fastening system shall fracture nor shall the rail be released.

10.9.1.11 Fastening Repeated-Load Test

(a) An 18- to 20-inch section of new rail from which loose mill scale has been removed by wiping with a cloth shall be secured to the rail seat in the tie block using a complete rail fastening assembly. In accordance with the loading diagram in Figure V determine the load P that will just cause separation of the rail from the rail seat pad or the pad from the rail seat whichever occurs first. This load may be determined during the Fastening Uplift Test described in Article 10.9.1.10 in which case a new set of fastening clips shall be used for the repeated load test.

(b) An 18- to 20-inch section of new rail from which loose mill scale has been removed by wiping with a cloth shall be secured to the rail seat in the tie block using a complete rail fastening assembly. In accordance with the loading diagram in Figure VI, alternating downward and upward loads shall be applied at an angle of 20° to the vertical axis of the rail at a rate not to exceed 300 cycles per minute for 3 million cycles. The rail shall be free to rotate under the applied loads. One cycle shall consist of both a downward and an upward load. The magnitude of the upward load shall be $0.6P$ where P is the load determined in part (a) of this article. If springs are used to generate the upward load the downward load shall be 30 kips plus $0.6P$. If a double-acting hydraulic ram is used to generate both the upward and the downward load, the downward load shall be 30 kips.

This repeated load test may generate heat in elastomeric rail seat pads. Heat build-up in such pads must not be allowed to exceed 140 F. Heat build-up can be controlled by reducing the rate of load application or by providing periods of rest to allow cooling of the pad to take place.

Rupture failure of any component of the fastening system shall constitute failure of this test.

For this test, retorqueing of threaded elements subsequent to the completion of 500,000 cycles of load shall not be permitted without the written approval of the engineer.

10.9.1.12 Fastening Longitudinal Restraint Test

Following the performance of the Fastening Repeated Load Test, above, and without disturbing the rail fastening assembly in any manner other than retorqueing anchor bolts, the tie and fastening shall be subjected to a longitudinal restraint test. A longitudinal load shall be applied as shown in Figure X in increments of 500 lb with readings taken of longitudinal rail displacement after each increment. Readings of rail displacement shall be the average of the readings of two dial indicators reading to 1/1000th of an inch, one placed on each side of the rail with their plungers parallel to the longitudinal axis of the rail. The load shall be applied in a direction coinciding with the longitudinal axis of the rail. The load shall be increased incrementally until a load of the value specified in Art. 10.6.1 for the anticipated tie spacing is reached. This load shall be held for not less than 15 minutes. The rail shall not move more than 0.25 inch during the initial 3-minute period, and there shall be no further movement of the rail after the initial 3 minutes. The fastening shall be capable of meeting the requirements of this test in either direction. If these criteria are met, the tie and fastenings will have successfully passed this test.

10.9.1.13 Lateral Load Restraint Test

With a suitable length of new rail of the size to be used in the track affixed to the tie block in a manner appropriate to the fastening being used, the entire assembly is supported and loaded as shown in Figure XI. The loading head is to be fixed against translation and rotation. The wood block shall be 10-in x 10-in x ¾-in thick, 5 ply, exterior grade plywood.

(a) A preload of 20 kips is to be applied to the rail to seat the rail in the fastening. Upon release of the preload, a zero reading is to be taken on the dial indicators which measure rail translation. Load is to be applied at a rate not to exceed 5 kips per minute until either 41 kips has been applied or the rail base has translated ⅛ inch, whichever occurs first. Inability of the fastening to carry the 41 kip load with ⅛ inch or less of rail translation shall constitute failure of this test. Complete failure of any component of the tie or fastening is cause for rejection.

(b) With all load removed from the rail, a roller nest is placed between the fixed loading head and the wood block on the rail head. The roller nest shall not offer resistance to lateral movement of the rail head. After taking zero readings on the dial indicators, which measure gage widening and rail translation, a load of 20.5 kips is to be applied at a rate not to exceed 5 kips per minute. Rail rotation, gage widening less rail translation, greater than ¼ inch shall constitute failure of this test.

10.9.1.14 Electrical Impedance Test

(a) Two short pieces of rail are affixed to the tie, selected from Ties "3" and "4", using tie pads, insulators and fastenings in a manner appropriate to the fastening system to be used.

(b) The complete assembly shall be immersed in water for a minimum of 6 hours.

(c) Within 1 hour after removal from water an a-c 10-volt 60-Hertz potential is applied across the two rails for a period of 15 minutes. If the rails are rusty or contain mill scale, the contact points must be cleaned.

(d) The current flow in amperes is read using an a-c ammeter and the impedance determined by dividing the voltage (10) by the current flow in amperes.

(e) If the ohmic impedance determined in (c) above exceeds 20,000 ohms, the tie will have passed the test.

10.9.1.15 Electrical Short Test

The two inserts of each rail seat shall be connected together electrically and the tie checked for an electrical short between the two rail seats. The check shall be made by connecting one side of a commercial 110 volt a-c potential to one rail seat and the other side through a 75-watt light bulb to the opposite rail seat. Lighting of the bulb indicates direct short circuit.

10.9.2 PRODUCTION QUALITY CONTROL OF MONOBLOCK TIES

After the tie and rail fastening system have passed the tests in Art. 10.9.1 and have been approved by the engineer, further production of these items may proceed without further design testing. During production of such an approved design, quality-control tests must be performed to assure a uniform, high-quality product.

10.9.2.1 Daily Production Quality-Control Tests

The following production quality-control tests shall be performed prior to delivery and within 30 days of manufacture on one tie selected at random from every 200 ties or fraction thereof produced each day:

(a) The distance from center of track to center of rail seats shall be verified and, by use of a template, the rail seat configuration and insert location shall be verified for compliance with the requirements of Art. 10.3.2.

(b) The Rail Seat Vertical Load Test, Art. 10.9.1.4, shall be performed.

(c) The Fastening Insert Test, Art. 10.9.1.9, shall be performed on one insert per tie.

(d) The Electrical Short Test, Art. 10.9.1.15, if applicable, shall be performed.

10.9.2.2 Additional Quality-Control Tests

To assure the production of cross ties and rail fastenings which comply with these specifications, the manufacturer shall institute whatever additional quality-control tests, including concrete compressive strength tests (see Art. 10.2.2), he may deem necessary.

10.9.2.3 Failure to Pass Production Quality-Control Test

Should any test tie fail the tests required by Art. 10.9.2.1, two additional ties from that same 200-tie lot shall be tested. In the event either of these ties fails, 100 percent of the remainder of the 200-tie lot shall be either tested or rejected.

10.9.2.4 Disposition of Test Ties

Ties that pass the testing requirements and are not cracked or otherwise damaged after testing will be considered acceptable for use in track.

10.9.2.5 Bond Development or Tendon Anchorage Quality-Control Test

One tie selected at random from every 2,000 ties produced shall be subjected to the Bond Development or Tendonage Anchorage Test described in Art. 10.9.1.8. If the tie does not meet the requirements of 10.9.1.8, three additional ties shall be tested, and if any of the three ties do not meet the requirements of 10.9.1.8, the entire lot may be rejected at the option of the engineer

10.9.2.6 Location for Inspection and Quality-Control Testing

Quality-control testing of production ties may be performed at any test facility, including such facilities at the manufacturer's plant, provided they meet the approval of the engineer. Testing may be observed by the engineer or his designated representative if he so elects. Two copies of the results of all such tests shall be submitted to the engineer within 7 days of the performance of the tests.

10.10 TESTING OF TWO-BLOCK TIES

10.10.1 DESIGN TESTS OF TWO-BLOCK TIES

Prior to approval of two-block tie designs, concrete ties of the design under study shall be subjected to testing for compliance with these specifications. The tests specified herein shall be performed at testing facilities approved by the engineer within 30 days of casting.

From a lot of not less than ten ties produced in accordance with these specifications four ties will be selected at random by the engineer for laboratory testing. For design testing of fasteners the manufacturer shall also furnish a section of the tie or a concrete block with rail seat and rail fastening system identical to the concrete ties furnished for testing.

The tie block and each of the four ties submitted for testing shall be carefully measured and examined to determine their compliance with the requirements of Sections 10.2 and 10.3. Upon satisfactory completion of this examination, the tie block and the two ties, which shall be known and identified as Ties "1" and "2", shall be submitted to performance tests. The remaining two ties, which will be known and identified as Ties "3" and "4", will be retained for further use and as a control for dimensional tolerances and surface appearances of ties subsequently manufactured.

10.10.1.1 Sequence of Tests (Tie "1")

The sequence of design tests performed with Tie "1" shall be as follows:

(a) Rail Seat Positive Moment Test (described in Art. 10.10.1.4) shall be performed on each rail seat.

(b) Rail Seat Negative Moment Test (described in Art. 10.10.1.5) shall be performed on each rail seat.

(c) Center Negative Bending Moment Test (described in Art. 10.10.1.6).

(d) Center Positive Bending Moment Test (described in Art. 10.10.1.7).

(e) Rail Seat Repeated Load Test (described in Art. 10.10.1.8).

(f) Rail Seat Ultimate Load Test (described in Art. 10.10.1.9).

10.10.1.2 Sequence of Tests (Tie "2")

The sequence of design tests performed with Tie "2" shall be as follows:

(a) Fastening Insert Tests (described in Art. 10.10.1.10) shall be performed on all inserts.

(b) Fastening Uplift Test (described in Art. 10.10.1.11) shall be performed on one rail seat.

(c) Electrical Resistance and Impedance Test (described in Art. 10.10.1.15).

10.10.1.3 Sequence of Tests (Tie Block)

The sequence of design tests performed with the tie block shall be as follows:

(a) Fastening Repeated Load Test (described in Art. 10.10.1.12).

(b) Fastening Longitudinal Restraint Test (described in Art. 10.10.1.13).

(c) Fastening Lateral Restraint Test (described in Art. 10.10.1.14).

10.10.1.4 Rail Seat Positive Bending Moment Test

With tie supported and loaded as shown in Figure I, a load increasing at a rate not greater than 5 kips per minute shall be applied until the load (*P*) required to produce the specified rail seat design positive moment from Art. 10.5.2, Design Flexural Requirements for Two-Block Ties, Table II, is obtained. This load shall be held for not less than 3 minutes, during which time an inspection shall be made to determine if structural cracking occurs. An illuminated 5-power magnifying glass may be used to locate cracks. If structural cracking does not occur or (in the case of reinforced or partially prestressed ties) crack widths do not exceed the widths specified in Art. 10.5.1.3 (c), the requirements of this test will have been met.

10.10.1.5 Rail Seat Negative Bending Moment Test

With tie supported and loaded as shown in Figure VII, a load increasing at a rate not greater than 5 kips per minute shall be applied until the load (*P*) required to produce the specified rail seat design negative moment from Table II is obtained. This load shall be held for not less than 3 minutes, during which time an inspection shall be made to determine if structural cracking occurs. If structural cracking does not occur, or (in the case of reinforced or partially prestressed ties) crack widths do not exceed the widths specified in Art. 10.5.1.3 (c), the requirements of this test will have been met.

10.10.1.6 Center Negative Bending Moment Test

With the tie supported and loaded as shown in Figure VIII, a load increasing at a rate not greater than 5 kips per minute shall be applied until a load of 7 kips causing a moment of 35,000 inch-pounds has been reached. If structural cracking does not occur on the gage faces of the blocks and the deflection at the center of the ties does not exceed 0.5 inch, the requirements of this test will have been met.

10.10.1.7 Center Positive Bending Moment Test

With the tie supported and loaded as shown in Figure IX, a load increasing at a rate not greater than 5 kips per minute shall be applied until a load of 7 kips causing a moment of 35,000 inch-pounds has been reached. If structural cracking does not occur on the gage faces of the blocks and the deflection at the center of the ties does not exceed 0.5 inch, the requirements of this test will have been met.

10.10.1.8 Rail Seat Repeated-Load Test

With the tie supported and loaded as shown in Figure I, one rail seat of the ties shall be subjected to 3 million cycles of repeated loading with each cycle varying uniformly from 4 kips to the value (1.1*P*) required to produce the specified rail seat positive bending moment from Table II.

The repeated loading shall not exceed 600 cycles per minute. If, after the application of 3 million cycles, the tie can support the load (1.1*P*), the requirements of this test will have been met.

10.10.1.9 Rail Seat Overload and Ultimate Load Test

With the tie supported and the other rail seat loaded as shown in Figure I, a load increasing at a rate not greater than 5 kips per minute shall be applied until a total load of 1.75*P* is obtained. If the tie can support this load for a period of not less than 5 minutes, the requirements of this test will have been met. The load shall then be increased until ultimate failure of the tie occurs, and the maximum load obtained shall be recorded.

10.10.1.10 Fastening Insert Tests

(a) Threaded-Type Inserts

The test procedure specified in Art. 10.9.1.9 (a) shall be used to determine the acceptability of threaded-type inserts.

(b) Other Fastening Inserts

Other fastening inserts shall be subject to the pull-out tests and torque tests (if applicable) in accordance with the manufacturer's recommendations and as approved by the engineer.

10.10.1.11 Fastening Uplift Test

An 18- to 20-inch piece of rail of the proper section shall be secured to one rail seat using a complete rail fastening assembly, including pads, bolts, clips, and associated hardware, as recommended by the manufacturer of the rail fastening system. In accordance with the loading diagram in Figure V, an 18-kip load shall be applied and held for not less than 3 minutes. The inserts shall not pull out or loosen in the concrete and no component of the rail fastening system shall suffer any permanent deformation.

10.10.1.12 Fastening Repeated-Load Test

The Fastening Repeated-Load Test shall be performed following the test procedure specified in Art. 10.9.1.11.

10.10.1.13 Fastening Longitudinal Restraint Test

Following the performance of the Fastening Repeated-Load Test, Art. 10.10.1.12, and without disturbing the rail fastening assembly in any manner other than retorqueing anchor bolts, the Fastening Longitudinal Restraint Test shall be performed following the test procedure specified in Art. 10.9.1.12.

10.10.1.14 Fastening Lateral Restraint Test

The tie and fastening shall be tested for lateral restraint following the test procedure specified in Art. 10.9.1.13.

10.10.1.15 Electrical Impedance Test

The tie and fastening shall be tested for electrical conductivity following the test procedure specified in Art. 10.9.1.14.

10.10.2 PRODUCTION QUALITY CONTROL OF TWO-BLOCK TIES

After a tie and rail fastening system have passed the tests in Art. 10.10.1 and have been approved by the engineer, further production of these items may proceed without further design testing. During production of such an approved design, quality-control tests must be performed to assure a uniform high-quality product.

10.10.2.1 Daily Production Quality-Control Tests

The following production quality-control tests shall be performed prior to delivery and within 30 days of manufacture on one tie selected at random from every 200 ties or fraction thereof produced each day.

(a) The distance from center of the tie to the center of the rail seats shall be verified and by use of a template, the rail seat configuration (including shoulders and inserts if they are used) shall be verified for compliance with the requirements of Art. 10.3.2.

(b) The Rail Seat Positive Moment Test, Art. 10.10.1.4, shall be performed.

(c) The Fastener Insert Test, Art. 10.9.1.9, shall be performed.

(d) The Electrical Impedance Tests, Art. 10.9.1.14, if applicable, shall be performed.

10.10.2.2 Additional Quality-Control Tests

To assure the production of cross ties and rail fastenings which comply with these specifications, the manufacturer shall institute whatever additional quality-control test, including concrete compressive strength tests (see Art. 10.2.2.1), he may deem necessary.

10.10.2.3 Failure to Pass Production Quality-Control Test

Should any test tie fail the tests required by Art. 10.10.2.1 above, two additional ties from that same 200-tie lot shall be tested. In the event either of these ties fails, 100 percent of the remainder of the 200-tie lot shall be either tested or rejected.

10.10.2.4 Disposition of Test Ties

Ties that pass the testing requirements and are not cracked or otherwise damaged after testing will be considered acceptable for use in track.

10.10.2.5 Rail Seat Overload Quality-Control Test

One tie selected at random from every 2,000 ties produced shall be subjected to the Rail Seat Overload Load Test described in Art. 10.10.1.9. If the tie does not meet the requirements of Art. 10.10.1.9, three additional ties shall be selected at random and tested. If any of the three additional ties do not meet the requirements of Art. 10.10.1.9, the entire lot may be rejected at the option of the engineer.

10.10.2.6 Location for Inspection and Quality-Control Testing

Quality-control testing and inspection of production ties may be performed at any test facility, including such facilities at the manufacturer's plant, provided they meet the approval of the engineer. The engineer shall be notified in advance of dates scheduled for quality-control tests. Testing may be observed by the engineer or his designated representative if he so elects. Two copies of all such tests shall be submitted to the engineer within 7 days of the performance of the tests.

10.11 RECOMMENDED PRACTICES FOR SHIPPING, HANDLING, APPLICATION AND USE

10.11.1 SHIPPING

Concrete ties should be shipped in open-top cars. Ties must be securely braced for transportation to prevent any movement that will cause damage. Ties shall be shipped in a horizontal position and braced with wooden spacer blocks in such a manner that the top surface or cast-in-place hardware does not contact ties loaded above. Ties shall not be loaded higher than the top of the cars nor more than six layers deep. The purchaser shall specify the size of shipments in accordance with unloading facilities.

10.11.1.1 Protection of Threaded Inserts

If cast-in-place threaded inserts are included in ties, they shall be protected against entry of water and foreign matter by means of a plastic cap, plug or other suitable device approved by the engineer. Caps or plugs shall be placed in position at the time of manufacture, left in place during shipping and not removed until fastenings are affixed to the ties.

10.11.2 HANDLING

Unnecessary handling, redistribution and reloading of concrete ties should be avoided. To the extent practical, ties should be distributed in proper position for use without further handling. They shall be unloaded from cars in a manner that will not damage the ties. In no case shall ties be dropped from a truck or car to the roadbed.

10.11.3 PLACEMENT AND INITIAL ROADBED SUPPORT

In new construction care must be taken to insure that all concrete cross ties are uniformly supported on the roadbed and that no center-binding conditions develop prior to ballasting and tamping. If the subgrade condition indicates that there is inadequate or non-uniform support for the ties before placement of ballast, a minimum layer of 3 inches of ballast should be placed, leveled and compacted before placement of ties. Ties shall be installed at right angles to the center line of track at the designed spacing prior to rail installation.

10.11.4 PLACEMENT OF RAIL AND FASTENINGS IN NEW CONSTRUCTION

10.11.4.1 Tie Pads

It is reconmmended that tie pads be shipped independently of the ties. Rail seats should be clean and ties properly positioned prior to placement of pads. Pads should be accurately positioned and centered on the rail seat. Use of adhesive may be desirable to hold pads in place until rail is unloaded and fastened.

10.11.4.2 Rail

Rail must not be dropped into place. Where continuous welded rail is to be used, the use of rollers is recommended to facilitate its unloading and reduce the risk of dislocating ties and tie pads.

10.11.4.3 Joints

If jointed rail is to be used (see Art. 10.1.5.2) special fastenings may be required within joint bar limits. Care must be exercised to see that such fastenings are clearly distinguishable and ordered in the proper amount. Care should also be taken to see that the actual juncture of two rails does not occur directly over a tie.

10.11.4.4 Fastenings

It is recommended that fastenings be shipped independently of ties. Where more than one type of fastening, such as gage and field fastenings or special joint fastenings, are to be used they shall be clearly marked to avoid confusion and avoid difficulties during their distribution and application. Fastenings shall be applied in the manner appropriate to their design and approved by their manufacturer. If threaded fasteners are used, the shank at the screw shall be dipped in petrolatum before assembly.

10.11.4.5

In corrosive environments, consideration should be given to protecting the external components of fastenings.

10.11.5 TAMPING

Tamping of concrete ties should be in accordance with the provisions of Chapter 5 of the Manual.

10.11.6 TRACK GEOMETRY

(a) It is recommended that concrete ties be installed on curves only if the curves have AREA-recommended, or equal, spiral approach and departure transitions.

(b) It is recommended that concrete ties not be installed in curves designed for an unbalanced superelevation greater than 3 inches.

10.12 BALLAST

10.12.1 GENERAL CHARACTERISTICS

Prepared ballast for use with concrete ties shall be of hard, strong, angular, durable particles, free from injurious amounts of deleterious substances and conforming to the requirements of these specifications. The most successful concrete tie installations to date have used sound granite, trap rock, or similar types of ballast and such types of ballast are, therefore recommended for use in conjunction with concrete ties. Current and proposed research may indicate that other ballast materials also could be satisfactory.

10.12.2 QUALITY REQUIREMENTS

(Under study.)

10.12.3 GRADING REQUIREMENTS

Ballast grading requirements shall be in conformity with Chapter 1 of the Manual.

10.12.4 HANDLING

Ballast shall be handled at the producing plant in such a manner that it is kept clean and free from segregation. It shall be loaded only into cars which are in good order, tight enough to prevent leakage and waste of material, and which are clean and free from rubbish or any substance which would foul or damage the ballast. The producer should not store ballast in cone-shape piles or make repeated passes of his equipment over the same levels in stock pile area. The supplier's proposed method of handling ballast shall be subject to the approval of the engineer.

10.12.5 INSPECTION

If material loaded or being loaded does not conform to these specifications, the inspector shall notify the supplier to stop further loading until the fault has been corrected and dispose of all of the defective material without cost to the railroad. The engineer reserves the right to reject any car of ballast arriving at the site for unloading that does not conform to the specifications.

10.12.6 TESTING

Prior to installation, the supplier shall provide the engineer with certified test results of ballast classification, quality, and grading as conducted by a testing laboratory accepted by the engineer. If, during ballast installation, the supplier changes the source of ballast, additional certified test results shall be provided. The supplier shall receive concurrence of the engineer as to the use of testing laboratory to make the aforementioned tests.

Samples of the finished product for gradation and other required tests shall be taken from each 4,000 tons of prepared ballast, unless otherwise ordered by the engineer. The sample shall be representative and shall weigh not less than 150 lb.

The supplier shall certify that ballast delivered to the railroad is typical of that upon which specified tests have been made.

10.13 COMMENTARY

10.13.1 FLEXURAL STRENGTH OF MONOBLOCK TIES

Monoblock ties are stiff structural members that are loaded by the rails from the top and are supported on the ballast at the bottom. The loads applied at the top combined with the support reactions at the bottom will produce flexure in the ties. Maximum flexure occurs at the rail seats and at the center. Flexure is influenced by a number of factors discussed in Section 10.1 General Considerations.

10.13.1.1 Wheel Loads

In order to give satisfactory service a prestressed monoblock concrete tie should be capable of withstanding without cracking the maximum loads likely to be found in service.

10.13.1.2 Rail Seat Load

The rail seat load is that load transmitted by the rail to the rail seat of the tie. It is the design wheel load modified by the distribution and impact factors. For various tie spacings the following rail seat loads are used to determine the flexure requirements in Art. 10.4.2, Table I:

Spacing, Inches	*Rail Seat Load, Pounds*
30	61,500
27	57,050
24	52,600
21	48,150

As rail seat loads are reduced so also are the flexural requirements of ties and the unit pressures on the ballast and subgrade.

10.13.1.3 Ballast Reaction

The load transmitted to the tie is resisted by the ballast at the interface between the bottom of the tie and the ballast. Immediately following tamping the ballast reaction is concentrated under the tamped portions of the tie with little if any reaction occurring under the center portion of the tie. This condition usually produces positive flexure at the rail seats and the tie center. Over a period of time, because of repeated loads, vibration and crushing of ballast, the ballast will gradually compact, moving away from the areas of greatest concentration. The tie, therefore, settles slightly into the ballast, allowing the center portion of the tie to pick up a portion of the load thus reducing the amount of load carried by the tie ends.

Redistribution of ballast reaction will continue until eventually a condition of uniform ballast reaction over the entire length of the tie is *approached.* This support condition produces positive flexure at the rail seats and negative flexure at the center of tie. It also makes possible a simple analysis for flexure in the tie by using the formulas:

$$(1)\quad M_r = \frac{W L_1^2}{2}$$

where

M_r = Moment at the rail seat.
W = Total vertical load in pounds/inch of tie length.
L_1 = Distance from center line of rail to end of tie.

$$(2)\quad M_c = \frac{WL_2^2}{8} - M_r \text{ or } \frac{W(L_2^2 - 4L_1^2)}{8}$$

where

M_c = Moment at center of tie.
L_2 = Distance center to center of rails.
W = Total vertical load in pounds/inch of tie length $= \dfrac{2(\text{Rail Seat Load})}{2L_1 + L_2}$
M_r = Moment at the rail seat.
L_1 = Distance from center line of rail to end of tie.

To insure ties that will not crack under normal service conditions the bending moments produced by this approach are considered adequate.

10.13.2 FLEXURAL STRENGTH OF TWO-BLOCK TIES

Two-block ties consist of two blocks of concrete connected by a third member. Under load, flexure will occur in the end blocks, and while flexure does occur in the connecting element, its flexural resistance is relatively small, thus one block is able to deflect with respect to the other.

Consideration of distribution factor, impact factor, wheel loads, rail seat loads, and tie spacings are the same as for monoblock ties.

10.13.2.1 Ballast Reaction

For two-block ties each tie block must distribute a full rail seat load to the ballast. Assuming this distribution over a period of time will *approach* uniformity, the flexural requirements for a tie block may be determined by the formula

$$M_r = \frac{wL^2}{2}$$

where

M_r = Moment at the rail seat.
w = Rail seat load in pounds/inch of tie block length.
L is assumed to be one-half the length of the tie block.

The magnitude of the terms w and L are influenced by tie block length. This influences the flexural requirements.

Flexural requirements for five lengths of tie blocks and four tie spacings are shown in Table II. Flexural requirements for block lengths other than those shown may be calculated, but in no case should the rail seat positive flexural capacity be less than 150 inch-kips.

10.13.2.2 Tie Flexibility

The connecting element of two-block ties should be sufficiently stiff to maintain track gage and tie integrity during handling, track construction and track maintenance. Under load, non-uniform ballast support reactions may cause differential deflection between the blocks of a tie. The connecting element must therefore be flexible enough to accept the maximum deflections likely to occur in track without damage to the element or to the concrete blocks.

Minimum stiffness and specific deflection without damage requirements have therefore been made a part of these specifications.

10.13.3 LONGITUDINAL RAIL RESTRAINT

Rail must be restrained to avoid excessive longitudinal movement. Longitudinal movement of rail can be induced by temperature change and/or traffic.

10.13.3.1 Temperature-Induced Loads

The longitudinal force due to temperature change may be determined using the formula

$$\frac{(F-J)^2 S}{2RAE} = D$$

Where $F =$ Total force in pounds required to fully restrain rail against any rail movement due to temperature variation from the rail temperature at laying. (Use formula $F = As\Delta T$, where $A =$ area of rail cross section in square inches. $s =$ internal temperature stress developed in the rail by the restraining forces. $s = 30{,}000{,}000 \times 1° \times 0.0000065 = 195$ psi. $\Delta T =$ temperature change from mean laying temperature in degrees F)

$J =$ Joint restraint (say $J = 0$).

$S =$ Average tie spacing in inches.

$R =$ Average tie resistance in pounds per tie per rail.

$A =$ Area of rail cross section in square inches.

$E =$ Modulus of elasticity (30,000,000 psi).

$D =$ Maximum rail end movement (say 0.375 inch).

Solving for R:

$$R = \frac{F^2 S}{2DAE} = \frac{35{,}870{,}087{,}236S}{291{,}375{,}000} = 123.1S$$

Where $F = 75° \times 195 \times 12.95 = 189{,}394$ lb

$D = 0.375$ inch

$A = 12.95$ sq inches

$E = 30{,}000{,}000$ psi

$S = 21$ inches, 24 inches, 27 inches, 30 inches.

For 21-inch tie spacing: $R = 2585$ lb (say 2.6 kips)

For 24-inch tie spacing: $R = 2955$ lb (say 2.9 kips)

For 27-inch tie spacing: $R = 3324$ lb (say 3.3 kips)

For 30-inch tie spacing: $R = 3693$ lb (say 3.7 kips)

10.13.3.2 Traffic-Induced Loads

Only the larger of traffic-induced loads due to traction or braking need be considered as they cannot occur together at a single point on a rail. This force is approximately 10 kips.

10.13.3.3 Tie Spacing

Since only about 50 percent of the load on a rail is carried by the tie directly under it with the two adjacent ties carrying the remainder, we can arrive at the *maximum* force expected for ties spaced as follows:

21-inch spacing, 50% of 10 kips + 2.6 kips = 7.6 kips
24-inch spacing, 50% of 10 kips + 2.9 kips = 7.9 kips
27-inch spacing, 50% of 10 kips + 3.3 kips = 8.3 kips
30-inch spacing, 50% of 10 kips + 3.7 kips = 8.7 kips

Since the greater weight of train should provide an increased friction between rail and tie and between tie and ballast, it is felt traffic-induced loads can be ignored insofar as longitudinal restraint is concerned.

The restraint provided between rail and tie, however, need not exceed the ability of ballast section to restrain the movement of ties longitudinally in the ballast section. It may also be assumed that, in continuous welded rail, some of the longitudinal force due to both braking and traction is transmitted ahead and behind and absorbed by ties not under or adjacent to the load. In studies made by AREA as reported in Vol. 56, 1955, the maximum individual tie pressure was recorded as 2930 lb. This was in gravel ballast with ties spaced an average of 19.5 inches (24 ties per rail). The study further concluded that, in gravel ballast, the holding power of such ballast, not frozen, should not be considered to exceed 1200 lb per anchor. Slag, limestone and granite ballast should be able to provide greater resistance to tie movement.

Concrete ties should at least equal the restraining ability of timber ties.

10.13.4 LATERAL RAIL RESTRAINT

Truck instability may occur in the wheel-rail interface due to excessive forces interacting between the wheel and rail in the lateral direction. These lateral forces tend to cause wheel flanges to climb the gage side of the rail when there is excessive lateral flange pressure in relation to actual vertical loads. These lateral pressures are caused by one or more of the following conditions:

(a) Nosing or hunting of truck assemblies at a repetitive frequency.
(b) Centrifugal forces on curved track.
(c) Impact due to irregular wheel and/or rail alinement or configuration.
(d) Rotational acceleration of the vehicle body due to curvature changes.
(e) Wheel friction from curve negotiation.

10.13.4.1 Lateral Forces

A rational determination of lateral force requirements on track fastenings would be to develop lateral and overturning reactions in the rail base to the degree that the wheel flanges will climb the rail before the rail would overturn. This limit may be determined by considering the ratio of lateral force to vertical load necessary to cause flange climbing.

Studies made⁽¹⁾ show that a ratio of vertical loads (P_v) to lateral forces (P_l) approaching unity will permit the wheel flanges to climb the rail. Therefore, using vertical wheel loads of 35,000 lb generated by a high-horsepower 6-axle locomotive as design criteria for maximum vertical loading (P_v), then we could expect a maximum lateral pressure (P_l) to also be in the order of 35,000 lb. Consequently, consideration of the individual lateral forces referred to in Art. 10.13.4 need not be considered since lateral forces greater than 35,000 lb would cause wheels to climb.

10.13.4.2 Lateral Force Distribution

Reference to Fig. 10.2.3.1 covering the distribution of vertical loads to ties indicates that the tie directly under the load will receive from 45 percent (20-inch centers) to 60 percent (30-inch centers) of the imposed vertical load while adjacent ties will each receive one-half of the balance. This distribution of loading is a function of the rigidity of the track structure, which is greatest about the horizontal axis.

However, rail stressed about the vertical axis by pressure induced by a wheel flange, has increased stability caused by torsional rigidity of the rail and the effect of the weight from wheels of adjoining trucks. The calculations to compare the two conditions of loading are complex, but for our purposes the resistance to bending in the vertical and horizontal axis are in the same order of magnitude under these conditions. Therefore, lateral loads applied to the tie may be expected to be distributed in a manner similar to vertical loads.

Based on the foregoing, the tie fastening system accommodates the following design stresses in combination:

Horizontal Reaction:

Lateral Force × Distribution Factor (DF)

Vertical Reaction:

$$\left[\left(\text{Lateral Force} \times \frac{\text{Rail Height}}{\text{Rail Base}}\right) - \left(\frac{\text{Vertical Load}}{2}\right)\right] \times \text{DF}$$

10.13.5 ELECTRICAL PROPERTIES

10.13.5.1 Signal Circuits

The engineer must give consideration to the electrical environment in selecting concrete tie designs and specifications. While concrete is not a good conductor of electricity, it does not have sufficient resistance or impedance, particularly when steel reinforcement is in close proximity to rail fastening components, to insure trouble-free operations of signal appliances depending upon electrical isolation of the rail if the rails are not insulated from the concrete. From the viewpoint of signal operation, the value of concern is the impedance per 1,000 ft of track rather than the impedance per tie. The former includes electrical leakage through ballast as well as the ties which can be expected to perform in wet trackage, and under a variety of voltages, both ac and dc.

10.13.5.2 Electric Traction

Electric propulsion systems most often rely upon ground return through trackage for circuit completion. Under these circumstances, it is desirable that the impedance between rails and ground (ballast and subsoil) not exceed certain maximum values.

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(1) British Railways, Japanese National Railways and the Association of American Railroads.

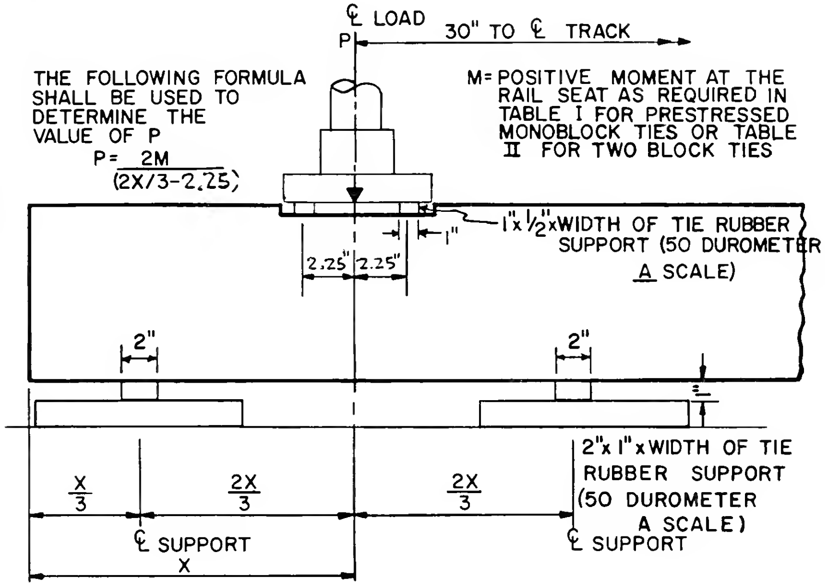
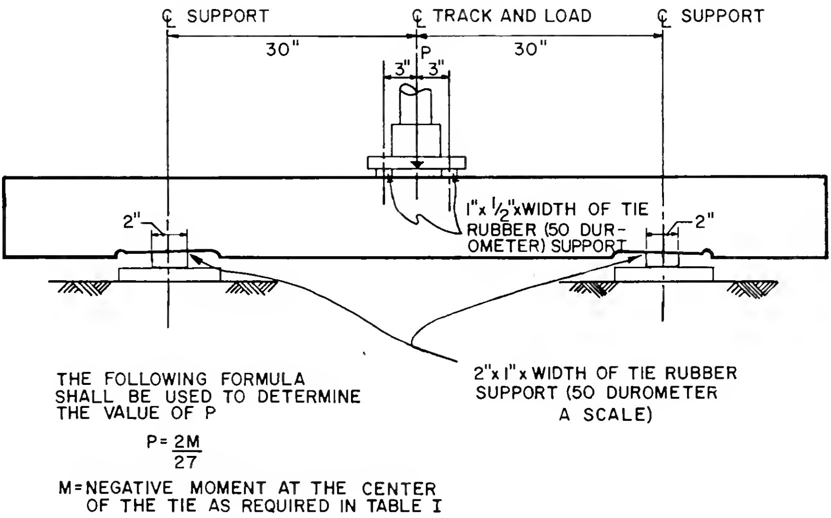
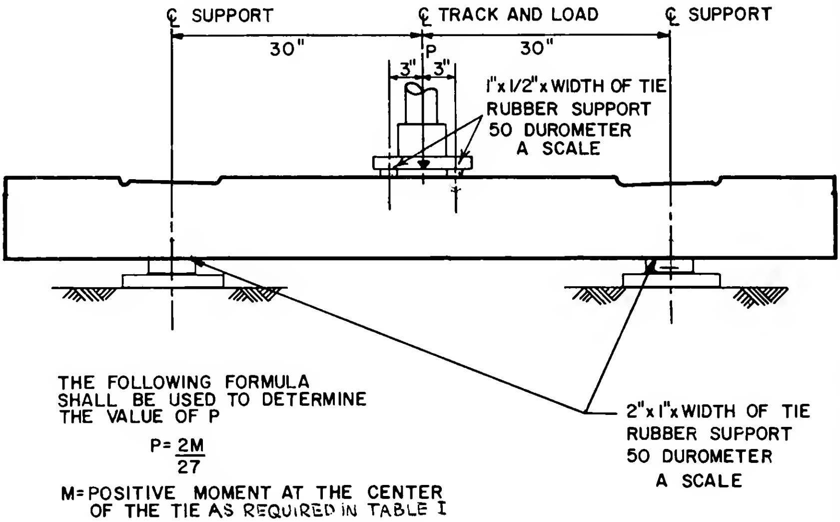


FIGURE I POSITIVE RAIL SEAT MOMENT TEST



TIE CENTER NEGATIVE MOMENT TEST FIGURE II



TIE CENTER POSITIVE MOMENT TEST

FIGURE III

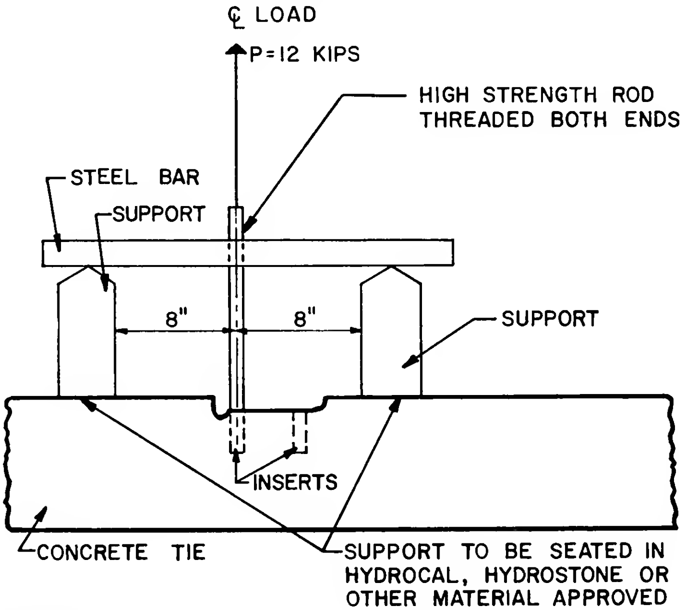
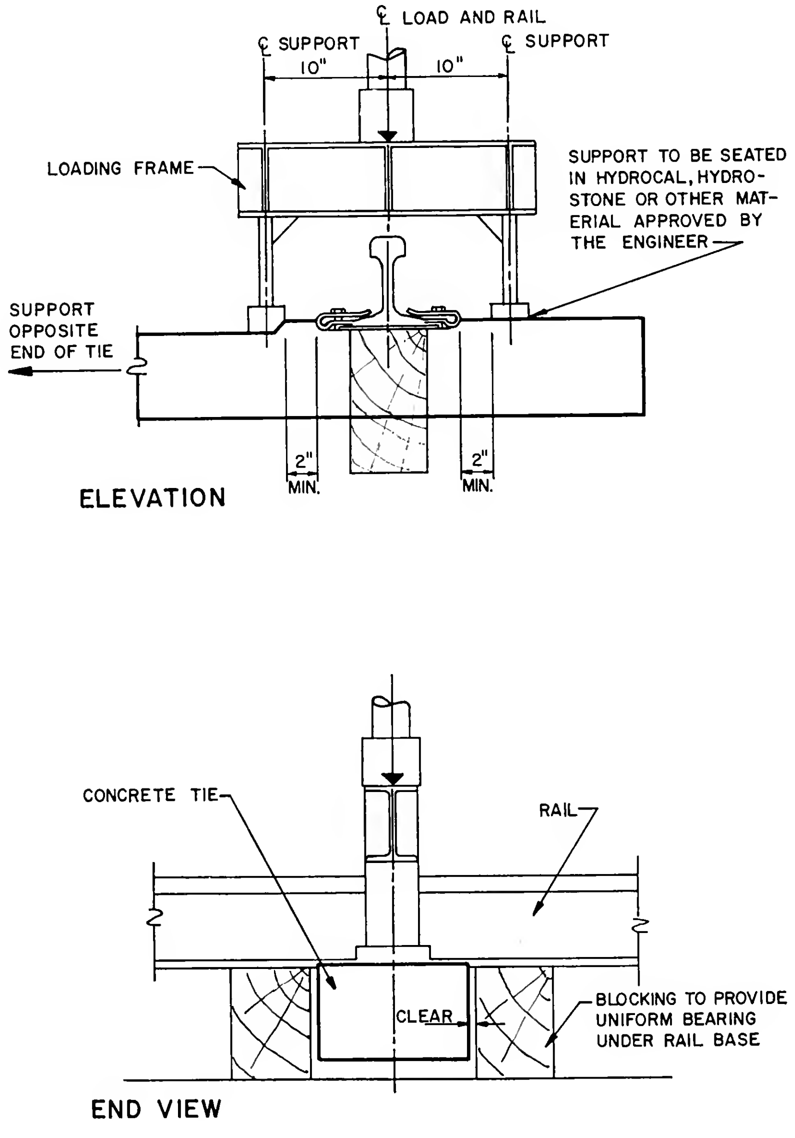


FIGURE IV

INSERT PULLOUT TEST



FASTENER UPLIFT TEST FIGURE V

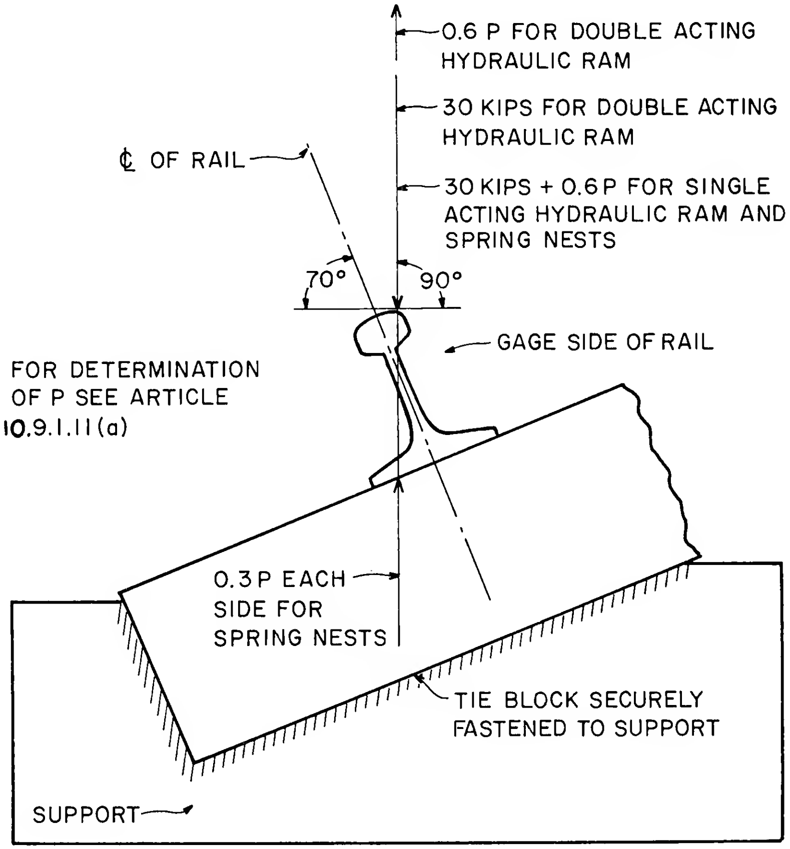


FIGURE VI FASTENING REPEATED LOAD TEST

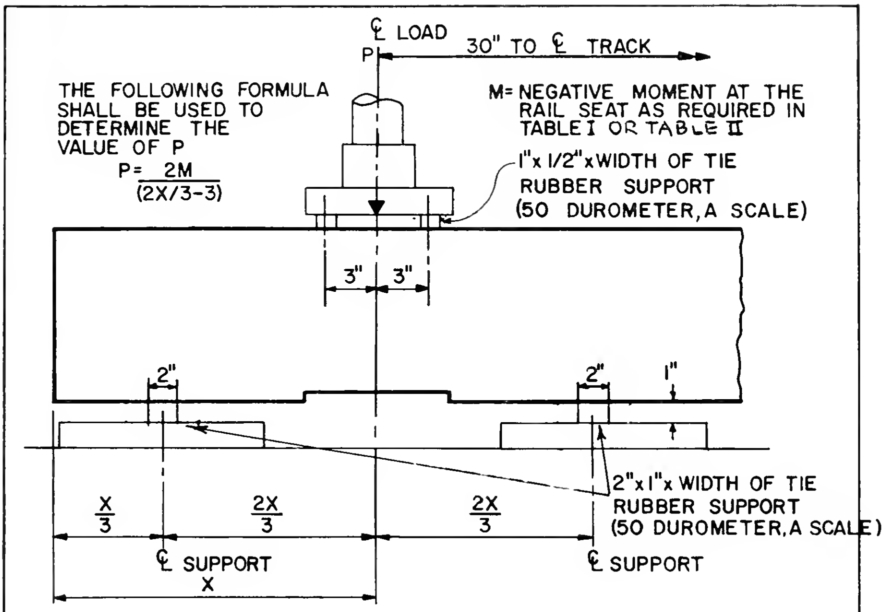
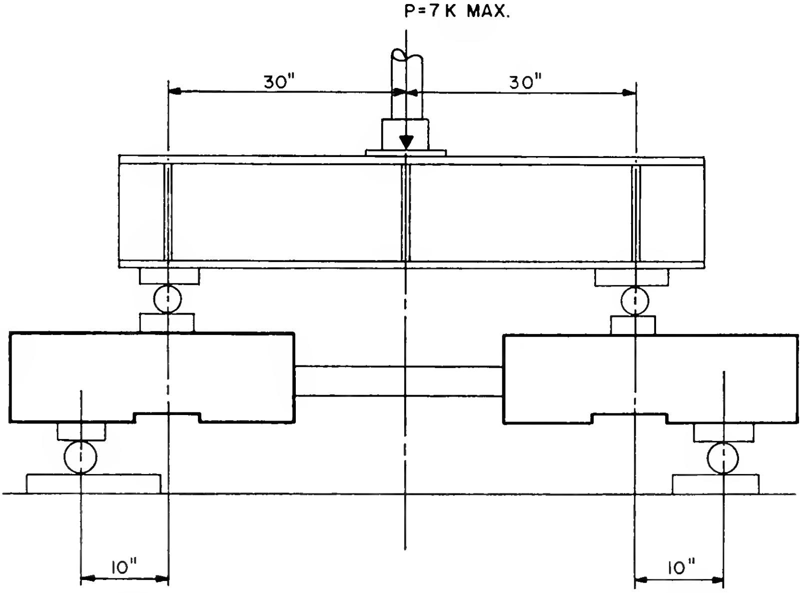
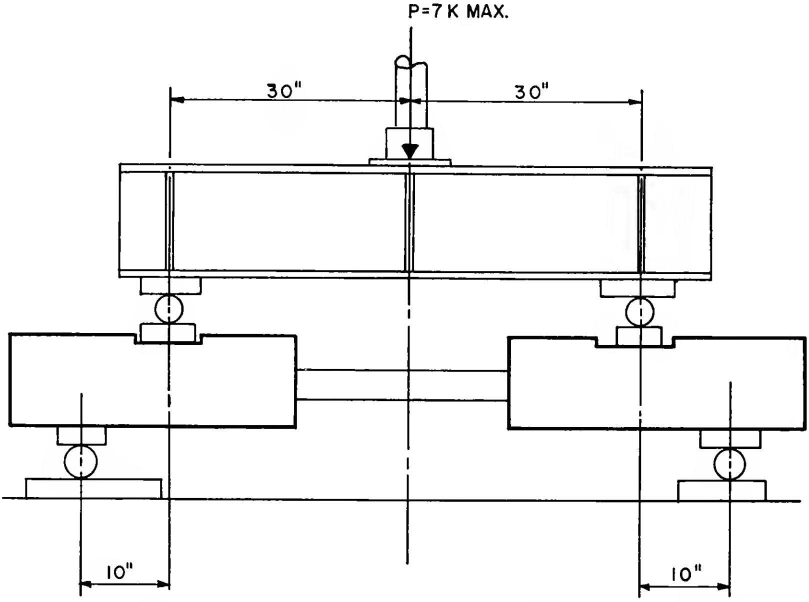


FIGURE VII RAIL SEAT NEGATIVE MOMENT TEST



TWO BLOCK TIE CENTER NEGATIVE BENDING TEST FIGURE VIII



TWO BLOCK TIE CENTER POSITIVE BENDING TEST FIGURE IX

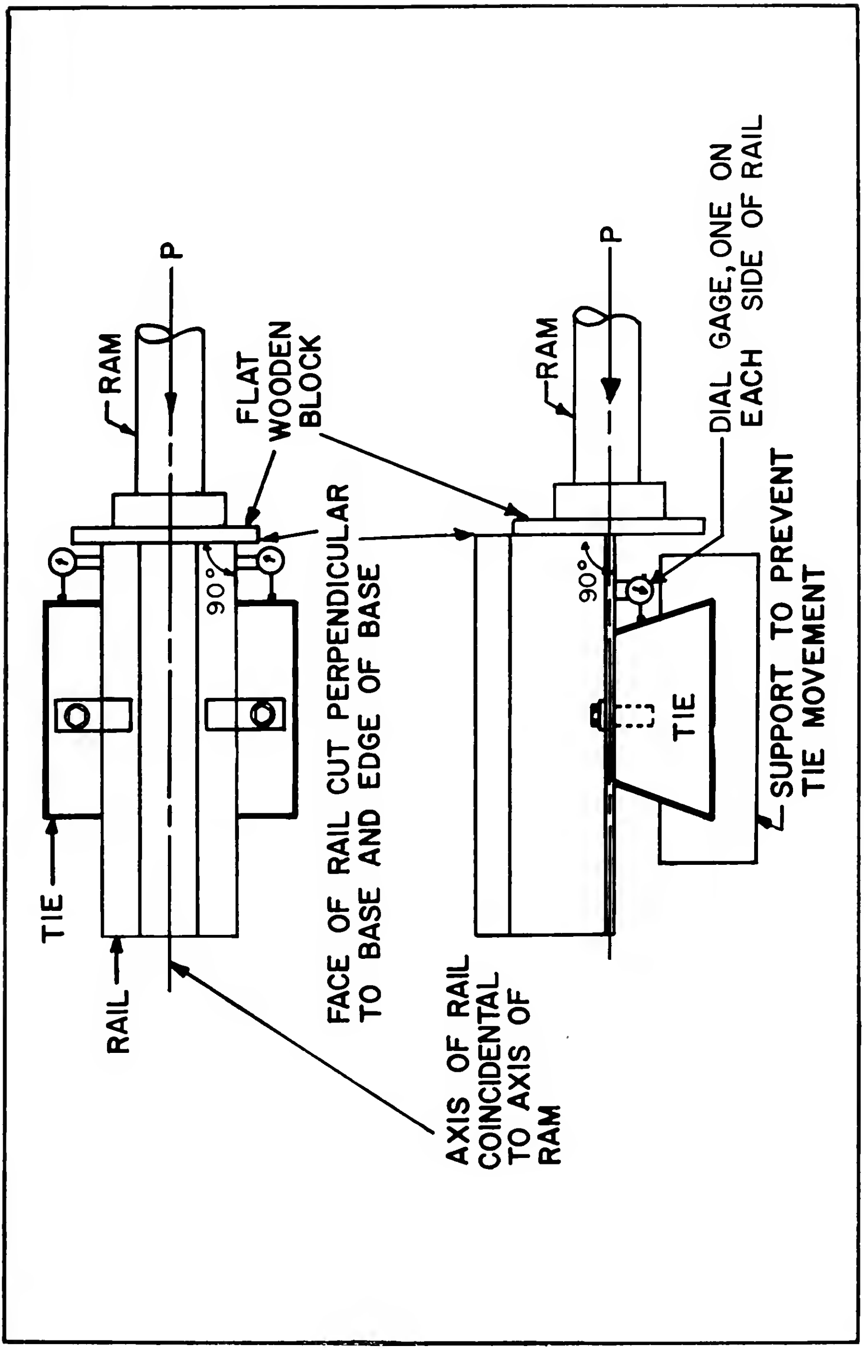


FIGURE X FASTENING LONGITUDINAL RESTRAINT TEST

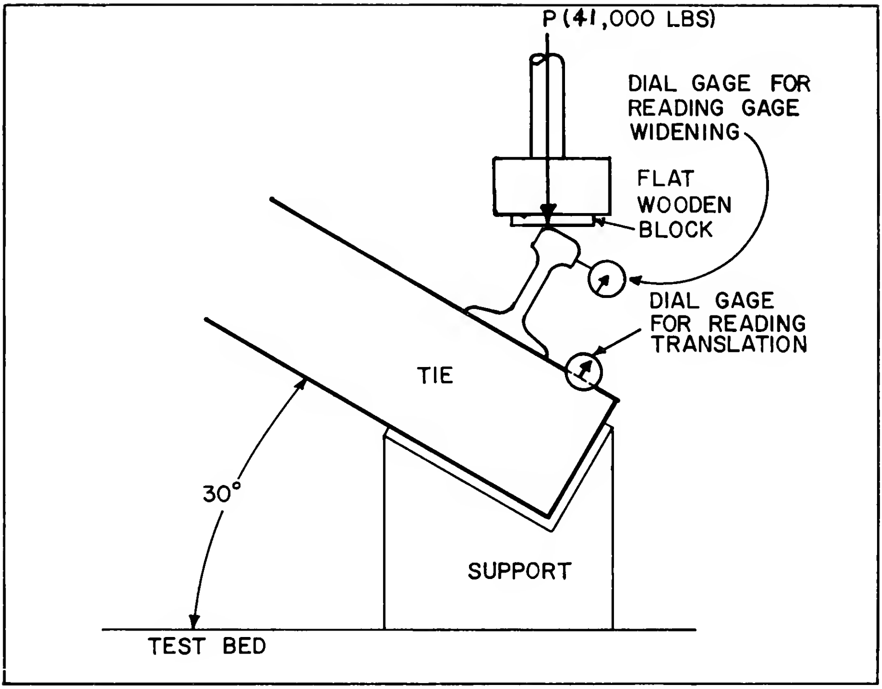


FIGURE XI FASTENING LATERAL RESTRAINT TEST

Manual Recommendations

Committee 1—Roadway and Ballast

Report on Assignment 1

Roadbed

F. L. Peckover *(chairman, subcommittee)*, J. R. Blacklock, D. H. Cook, G. W. Deblin, W. A. Eshbaugh, J. B. Haegler, H. O. Ireland, H. W. Legro, F. H. McGuigan, W. G. Murphy, J. E. Newby, S. R. Pettit, P. J. Seidel, W. M. Snow.

Your committee recommends for adoption and publication in the Manual as an addition to present Manual material in Part 1—Roadbed, the recommended practice Section 1.4—Maintenance, as published in Bulletin 651, January–February 1975, pages 282 to 297, with the following editorial changes:

Page 287, Fig. 1.4.4—change to Fig. 1.4.2.

Page 288, Art. 1.4.2.2, 2nd last sentence—change Fig. 1.4.4 to Fig. 1.4.2.

Page 291, Table 1.4.4—change to Table 1.4.1.

Page 290, Art. 1.4.3.3.3, last sentence—change Table 1.4.4 to Table 1.4.1.

Page 297, References, item 3—change "To be presented . . ." to: Peckover, F. L., Treatment of Rock Falls on Railway Lines, Bul. 653, June–July 1975, p. 471–503.

If Section 1.4—Maintenance, is approved for publication in Part 1—Roadbed, of Chapter 1 of the Manual, the following editorial changes in Section 1.1—Exploration and Testing, and Section 1.2—Design, will be necessary:

Art. 1.1.2.3, para. 1, last line (p. 1–1–4): delete "Section 1.4—Maintenance," substitute "Article 1.4.3."

Art. 1.2.1, para. 3 (p. 1–1–11): delete "(to be prepared)," substitute "softening and squeezing of subgrade, frost heaving of track, rock falls, failures of earth slopes, and control of erosion."

Art. 1.2.2.1.4, para. 6, last sentence (p. 1–1–14): delete "(see Section 1.4—Maintenance)."

Art. 1.2.2.1.7, para. 3, last sentence (p. 1–1–19): delete "under Section 1.4—Maintenance, on. . ." Substitute "in Article 1.4.2 on maintenance of . . ."

Art. 1.2.2.2.6, 2nd sentence (p. 1–1–21): delete "Section 1.4—Maintenance," substitute "Articles 1.4.3 and 1.4.5."

Art. 1.2.3.6, last para. (p. 1–1–26): delete "Section 1.3—Construction," substitute "Article 1.3.5."

Art. 1.2.3.7, 3rd para., 2nd sentence (p. 1–1–26): delete "Section 1.4—Maintenance," substitute "Article 1.4.5."

Table 1.2.5 (p. 1–1–32): increase print size for table number and title, for improved reference purposes.

Art. 1.2.4.3.3, 1st para., 2nd sentence (p. 1–1–28): delete "Culverts," substitute "Culverts and Drainage Pipe."

References (p. 1–1–30), item (2): delete: "Chicago," substitute "New York."

Art. 1.2.5.3, 3rd para., 2nd line) (p. 1–1–31): after "sub-ballast" add "(see Article 1.4.1.2.)."

Art. 1.2.5.5, 5th para., last line (p. 1–1–35): delete "Section 1.4—Maintenance," substitute "Article 1.4.1.4."

Report on Assignment 9

Vegetation Control

H. C. Archdeacon *(chairman, subcommittee)*, H. E. Bartlett, R. H. Bogle, Jr., E. B. Grant, T. J. Hernandez, P. R. Houghton, D. N. Johnston, H. E. McQueen, J. M. Nunn, G. D. Santolla, W. H. Stumm.

Your committee submits for adoption and publication in Part 9—Vegetation Control, Chapter 1 of the Manual, the accompanying Table 3—Susceptibility of Woody Species to Herbicide Treatments.

TABLE 3 - SUSCEPTIBILITY OF WOODY SPECIES TO HERBICIDE TREATMENTS

The following treatments are typical of those frequently used. This list is not intended to be exhaustive. Additional information on other chemicals is available through federal and state agencies, university extension services and suppliers. The letter code for treatments is not intended to imply any order of preference, but is used solely to conserve space on the following table:

STEM FOLIAGE SPRAYS

A. 2, 4-DP plus 2, 4-D. 2 lb. plus 2 lb. per 100 gal. water.
B. Ester amine and oil soluble amine of 2, 4-D plus 2, 4, 5-T. 2 lb. plus 2 lb. per 100 gal. water.
C. 10 gal. Ammonium Sulfamate solution plus 1 qt. surfactant per 100 gal. water.
D. Picloram plus 2, 4-D. ½ lb. plus 2 lb. per 100 gal. water.
E. Dicamba plus 2, 4, 5-T (or 2, 4-D). 1 lb. plus 2 lbs. per 100 gal. water.

DORMANT CANE SPRAYS

F. Ester of 2, 4-D plus 2, 4, 5-T. 3 lb. plus 3 lb. per 100 gal. oil.

STUMP OR BASAL SPRAY

G. Ester of 2, 4-D plus 2, 4, 5-T. 8 lb. plus 8 lb. per 100 gal. oil.

AERIAL SPRAY

H. Ester of 2, 4-D plus 2, 4, 5-T. 6 lb. plus 6 lb. as invert emulsion or as conventional through microfoil or other drift control devices or additives.

DRY PELLET APPLICATIONS

I. Picloram 10% pellets. 60 to 85 lbs. per acre.

SUSCEPTIBILITY CODE

S - Susceptible (over 90% rootkill)
S-I - Susceptible to Intermediate (70% to 90% rootkill)
I - Intermediate (50% to 70% rootkill)
I-R - Intermediate to Resistant (30% to 50% rootkill)
R - Resistant (less than 30% rootkill)

TABLE 3 (CONTINUED) - SUSCEPTIBILITY OF WOODY SPECIES TO HERBICIDE TREATMENTS

SPECIES	A	B	C	D	E	F	G	H	I
Acacia farnesiana huisache		I	I		I-R	S-I	S-I		S
Alder (Alnus spp.)									
Common (A. serrulata)	S	S	I	S	S	S	S	S	S-I
Red (A. rubra)	S	S	I	S	S	S	S	S	I
Speckled (A. incana)	S	S	I	S	S	S	S	S	S-I
Apple (Malus spp.)									
Common (M. pumila)	I	I-R	R	I	S-I	I	S	I	S
Crab (M. ionesis)	I	S	I-R	S	S-I	S	S	S	
Arborvitae, eastern (Thuja occidentalis)	S-I	R	I-R	S	S	S	I-R		S
Ash (Fraxinus spp.)									
Blue (F. quadrangulata)	S	S	I	S-I	S	S	S	R	S-I
Red (F. Pennsylvanica)	I	I-R	I-R	R	S	S	S	R	
Oregon (F. latifolia)		S	S-I		S	S	S	R	I
White (F. americana)	I-R	I-R	I-R	R	S	S	S	R	
Black (F. nigra)		I	I-R		S	S		R	S
Aspen, quaking (Populus tremuloides)	S	S-I	S	S	S	S-I	S	S	
Azalea (Rhododendron spp.)									
Piedmont (R. conescens)		I-R	I	I	I	S-I	S-I	R	
Western (R. occidentale)		S	I			S	S-I	R	
Barberry, Allegheny (Berberis canadensis)		S	I-R		S	I	S	S	
Basswood (Tilia americana)	I-R	I-R	I-R	S	S	S-I	S	R	
Bayberry, north (Myrica Pennsylvania)	S	S	S-I	S	I	S	S	S	
Bearberry (Arctostaphylos uvaursi)		I	I		I	I	S	S	
Beech, American (Fagus grandifolia)	I-R	I-R	I	S-I	S-I	S-I	S-I	R	S
Birch (Betula spp.)									
Yellow (B. lutea)	S	S	S-I	S	S	S	S	S	S
River (B. nigra)	S	S	S-I	S	S	S	S	S	S
Gray (B. populifolia)	S	S	S-I	S	S	S	S	S	S
Paper (B. alba var. papyrifera)	S	S	S-I	S	S	S	S	S	S
Black (B. lenta)	S	S	S-I	S	S	S	S	S	S
Blackberry (Rubus spp.)	S-I	S	S-I	S	S	S	S	S	S

TABLE 3 (CONTINUED) - SUSCEPTIBILITY OF WOODY SPECIES TO HERBICIDE TREATMENTS

SPECIES	A	B	C	D	E	F	G	H	I
Blackgum (Nyssa sylvatica)	I	I	I-R	S-I	S	S	S	S	S
Blueberry (Vaccinium spp.)		I	I-R		S	S-I	S	R	S
Boxelder (Acer negundo)	S-I	S-I	S	S-I	S	S-I	S	I	S-I
Broom scotch (Gytisum scoparius)		I	I-R		I		S	S	
Buckbrush, coral berry (symphoricarpus orbiculatus)	S	S	I	S	I	S	S-I	I-R	S
Buckeye (Aesculus spp.)									
Ohio (A. glabra)	I-R	I	R			S	S	I-R	
Sweet, yellow (A. octandra)		I	R			S	S	I-R	
Buckthorn (Rhamnus spp.)									
California (R. California)		S-I	R		I	S-I	S	I	
Common (R. Cathartica)		I	R		I	S-I	S	I	
Hollyleaf, redberry (R. Crocea var. ilicifolia)		I	R		I	S-I	S	I	
Butternut (juglans cinerea)	I-R	I	I-R			S-I	S	I-R	S
Button bush, common (Cophalanthus occidentalis)	S-I	I	R	S-I	I	S-I	S	I-R	S
Cascara, buckthorn (Rhamnus purshiana)		I-R	I-R		S-I	S-I	S	R	
Catalpa (Catalpa spp.)									
Eastern (C. bignoniodes)		I	S		I	S-I	S	I-R	S
Western (C. speciosa)		I			I	S-I	S	I-R	
Ceanothus (Ceonothus spp.)									
Blue blossom (C. thyrsiflorus)		S		S	I	S	S	S	
Chapparal white thorn(C. leucodermis)		S	S-I		I	S	S	S	
Varnishleaf (C. velutinus var. laevigatus)	S-I	S			I	S	S	S	
Deerbush (C. integerrimus)	S-I	S		S	I	S	S	S	
Wedgeleaf (C. cuneatus)		S				S	S	S	
Mountain whitethorn (C. Cordulatus)		S		S		S	S	S	
Jersey tea (C. americanus)		S				S	S	S	
Jimbrush (C. sorediatus)		S				S	S	S	
Cedar (Juniperus spp.)									
Eastern red (J. Virginiana)	I	R	S	S-I	S	S-I	S-I	R	S
Southern red (J. silicicola)	I	R	S	S-I	S	S-I	S-I	R	S
Chamise, greasewood(Adenostoma Fasciculatum)		S-I	R	S-I	I		S	S	S
Cherry (Prunus spp.)									
Black (P. serotina)	S-I	S	S	S	S	S-I	S-I	I	S
Sweet (P. avium)	S	S	S	S	S	S	S	I	S
Choke (P. virginiana)	S	S	S	S	S	S	S	S-I	S

TABLE 3 (CONTINUED) - SUSCEPTIBILITY OF WOODY SPECIES TO HERBICIDE TREATMENTS

SPECIES	A	B	C	D	E	F	G	H	I
Chestnut (Castenea dentata)	S	S	S-I	S	S	S	S	S	
Chinkapin, Allegheny (Castenea pumila)		S			I	S	S	I-R	
Chinaberry (melia azedarach)		I-R	I-R			I	S	R	
Coffeetree (Gymnocladus dioicus)		S-I	S				S	S-I	
Condulia, lotewood (Condulia obtusifolia)		S					S-I		
Cottonwood (Populus spp.)									
Plains (P. sargentii)		S-I	S	S		S-I	S	S-I	S
Rio Grande (P. Wializeni)		I					S	S-I	S
Eastern (P. deltoides)	S	S-I	S	S-I		S-I	S	S	S
Downy, black (P. heterophylla)		S-I	S				S		S
Coyote brush (Baccharis pilularlis)		S	R		I		S	I	
Creosotebush (Larrea divaricata)		I	R		S-I		S-I	I	S
Christmasberry, toyon (Photinia arbutifolia)		S-I	I		I		S	I	
Currant (Ribes spp.)									
Gooseberry (R. montigenum)		S	I	S	S		S	S-I	S
Nutmeg (R. glutinasum)		S	I		S		S	S-I	
Prickley (R. lacustre)		S	I		S		S	S-I	
Sierra (R. nevadense)		S	I	S	S		S	S-I	
Sticky (R. viscosissimun)		S	I		S		S	S-I	
Stink (R. bracteosum)		S	I	S	S		S	S-I	
Trailing black (R. laxiflorum)		S	I		S		S	S-I	
Wax (R. cereum)		S	I		S		S	S-I	
Western black (R. petiolare)		S	I	S	S		S	S-I	
Winter (R. sanguineum)		S	I		S		S	S-I	
Cypress (Taxodium spp.)									
Common baldcypress (T. distichum)	I-R	R	S	I	I	I	I	R	S
Pond baldcypress (T. ascendens)		R	S	I	I	I	I	R	S
Dangleberry (Gaylussacia Frondosa)		I	I		R		S		
Deervetch, broom (Lotus scoparius)		S			I		S	S-I	
Devil-s - walkingstick(Aralia spinosa)	I	S-I	S		I	S	S	S	
Dewberry (Rubus spp.)	I	I	R	S-I			S	I-R	S
Dogwood (Cornus spp.)									
Pacific (C. nuttalli)	S-I	S	S		S	S	S	I	
Flowering (C. Florida)		S	S	S	S	S	S	I	
Elder (Sambucus spp.)									
Pacific red (S. callicarpa)		S-I	S-I		S	S-I	S-I	I	S
Blueberry (S. cerulea)		S-I	S-I		S	S-I	S-I	I	S
Common (S. Canadensis)		S-I	S-I	R	S	S-I	S-I	I	S

TABLE 3 (CONTINUED) - SUSCEPTIBILITY OF WOODY SPECIES TO HERBICIDE TREATMENTS

SPECIES	A	B	C	D	E	F	G	H	I
Elm (Ulmus spp.)									
American (U. Americana)	I	I	R	S	S	S-I	S	I	S
Slippery (U. Fulva)	I	I	R	S-I	S	S-I	S	I	S
Winged (U. alata)	I	I	R	S-I	S	S-I	S	I	S
Evergreenchinkapin (Castanopsis spp.)									
Sierra (C. Sempervirens)		I			I	S-I	S	I	
Golden (C. Chrysophylla var. minor)		S-I			I	S-I	S	I	
Filbert beaked; hazel (Corylus cornuta)	S	S	S-I	S	I-R	S	S	S	S
Fir (Abies spp.)									
White (A. concolor)	I	R	S	S	S	S-I	S-I	R	S
Balsam (A. balsamea)	I	I-R	S	S-I	S	S-I	S-I	R	S
Grand (A. grandis)	I-R	R	S	S	S	S-I	S-I	R	S
Noble (A. procera)	I-R	R	S	S	S	S-I	S-I	R	S
Gallberry, inkberry (Ilex glabra)		S-I			I-R	S-I	S-I	I	
Goldenweed, fleece(Haplopappus arborescens)		S							S
Gooseberry (Ribes spp.)									
California (R. Californicum)		S	I	S	I		S	S-I	
Canada (R. oxyacanthoides)		S	I				S	S-I	
Desert (R. velutinum)		S	I		I-R		S	S-I	
Hupa (R. marshallii)		S	I				S	S-I	
Sierra (R. roezlii)		S	I	S	I-R		S	S-I	
Siskiyou (R. binominatum)		S	I	S	R		S	S-I	
Tulare (R. tularense)		S	I				S	S-I	
Whitestem (R. inerme)		S	I				S	S-I	
Gorse, common (Ulex europeus)		S	I		I		S	S-I	S
Granjeno (Celtis pullida)		S-I					S	S-I	S
Grape, riverbank (vitis riparia)		S	R	S-I	S-I		S	S-I	S
N. fox grape (V. labrusca)		S			S-I		S		
Greasewood, black (Sarcobatus vermiculatis)		S	R		I		S	I	
Greenbrier, catbrier (Smilax rotundifolia)		I-R	R	I	I			R	
Hackberry (Celtis occidentalis)		S-I	R	S-I	I	S	S-I	I	S
Hawthorn (Cratsegus spp.)									
Cockspur thorn (C. crus-galli)	I	I	R	S	I	I	S-I	I-R	S
Scarlet (C. coccinea)		I				S-I			
Flestry (C. succulenta)									

TABLE 3 (CONTINUED) - SUSCEPTIBILITY OF WOODY SPECIES TO HERBICIDE TREATMENTS

SPECIES	A	B	C	D	E	F	G	H	I
Hazel (Corylus spp.)									
California (C. Californica)		S	S	S	S	S	S	S	
American (see filbert)		S	S	S	S	S		S	S
Hemlock (Tsuga canadensis)	I	R	S	S	S	S-I	S-I	R	S
Hickory (Carya spp.)									
Bitternut (C. cordiformis)	S-I	S-I	S-I	S-I	S	S-I	S	S-I	S-I
Mockernut (C. tomentosa)	S-I	S-I	S-I	S-I	S	S-I			S-I
Pecan (C. pecan)	S-I	S-I	S-I	S-I					S-I
Pignut (C. glabra)	S-I	S-I				S-I			S
Shagbark (C. orata)	S-I	S-I	S-I	S-I	S	S-I			S
Shellbark (C. laciniosa)	S-I	S-I	S-I		S	S-I			S
Holly (Ilex americana)		I	I	S-I	S	S-I	S	I-R	S-I
Honeylocust (Gleditsia triacanthos)	I	S-I	S	S-I	S	S-I	S-I	S-I	S
Honeysuckle (Loniecra japonica)	S-I	S-I	R	S	S	S	S	S-I	S
Hophornbeam (Ostrya virginiana)		S	I	S	S	S	S	I-R	S
Hornbeam, America (Carpinus caroliniana)		S	S	S	S	S	S	I-R	S
Horsebrush, littleaf (Tetradymia glabrata)		I-R					S-I	I-R	
Horsechestnut (see Buckeye)									
Hydrangea, smooth (Hydrangea aborescens)		S	S	S	S	S	S		
Juniper (Juniperus spp.)									
Alligator (J. deppeana)	I	R	I	I	S-I	I	I-R	R	S-I
One-seeded (J. monasperma)		R		I	S-I	I			S-I
Utah (J. osteosperma)	I	R			S-I	I			
Western (J. occidentalis)		R			S-I	I			
Kalmia (Kalmia spp.)									
Lambkill (K. angustifolia)		I-R	R	I	R	I	I-R	R	S-I
Mountainlaurel (K. latifolia)	I-R	R	R	I-R	I-R	I			I
Larch (Larix spp.)									
Eastern (L. decidua)	I-R	R	R	I-R	I-R	I	S-I	I-R	I
Western (L. occidentalis)		I-R			I-R	I			
Leatherwood, Atlantic (Direa palustris)		S	S		I-R	S	S	S	
Lilac (Syringa vulgaris)		S-I			I-R	S	S	S-I	
Locust (Robinia pseudoacacia)	S-I	S-I	S	S	S	I	S-I	S	
Madrome, Pacific (Arbutis menziesii)		S				S	S	S	S
Manzanita (Arctostapylos spp.)									
Howell (A. hispidula)		S		S					
Greenleaf (A. patula)		S	R			S	S	S	
Hairy (A. columbiana)	S	S		S	I-R	S	S		
Whiteleaf (A. viscida)		S				S			

TABLE 3 (CONTINUED) - SUSCEPTIBILITY OF WOODY SPECIES TO HERBICIDE TREATMENTS

SPECIES	A	B	C	D	E	F	G	H	I
Magnolia (Magnolia spp.)									
Cucumbertree (M. acuminata)	I	S-I	S		I-R	S	S	S-I	S-I
Sweetbay (M. virginiana)	R	R	R	I	I-R	I		I	
Maple (Acer spp.)									
Red (A. rubrum)	R	I	R	S-I	S-I	S	S	I-R	S
Silver (A. saccharinum)	I-R	S	S	S	S-I	S			S
Sugar (A. saccarophorum)	S-I	I-R	I	I	S-I	S-I			S
Vine (A. circinatum)	R	I-R	R	I	S-I	S-I			S
Bigleaf (A. macrophylla)		R	R	I	S-I	S-I			S
Mesquite, honey(Prosopis juliflora var. glandulosa)	R	S	R	S-I	I-R	S	S		S
Velvet (Prosopis juliflora var. velutina)		S	R		I-R	S	S		
Mockorange (Philadelphus virginalus)	S-I	S-I				S	S	S	
Mountainmahogany (Cerocarpus spp.)		I						I	
Mountain misery, bear clover (Chamaebatia foliolosa)		I						I	S
Mulberry, red (Morus rubra)		I-R	R		I-R	I	S-I	I-R	S
Oak (Quercus spp.)									
Black (Q. nigra)	S-I	S-I	S	S-I	S-I	S	S	S-I	S-I
Blackjack (Q. marilandica)	S-I	S-I	S	S-I	S-I	S-I			S-I
Bur (Q. macrocarpa)	S	S	S		S-I	S			S-I
Canyon live (Q. chrysolepis)		S-1				S			S-I
California scrub (Q. dumoaa		I				S			
California white (Q. lobata)		S				S			
Chestnut (Q. prinus)	S-I	S	S-I	I	S-I	S			
Live (Q. virginiana)	S-I	S-I	S-I		S-I	S			
Pin (Q. palustris)	S	S-I	S-I		S-I	S			S-I
Post (Q. stellata)	S	S	S	S-I	S-I	S			
Laurel (Q. laurifolia)		S-I	S-I	S-I		S			
Red (Q. rubra var. borealis)	S	S-I	S-I	I	S-I	S-I			S-I
Scarlet (Q. coccinea)	S	S-I	I	I	S-I	S-I			
Swamp white (Q. bicolor)		S	S	S-I		S			
Oregon white (Q. garryana)		S	S			S			
White (Q. alba)	S	S	S	S-I	S-I	S			S-I
Ocean spray (Halodiscus discolor)		S-I				S-I		S	
Oregongrape (Mahonia aquifolia)		I	I			S-I		I-R	
Osageorange (Maclura pomifera)		S	R		I	S	S	S-I	S
Palmetto (Saval palmetto)		S-I	R		I-R		S	S-I	
Pecan (Carya illinoensis)		I	I		I	S-I	S	S-I	

TABLE 3 (CONTINUED) - SUSCEPTIBILITY OF WOODY SPECIES TO HERBICIDE TREATMENTS

SPECIES	A	B	C	D	E	F	G	H	I
Persimmon (Diospyros virginiana)		I	R	S	S	I	S-I	S-I	S
Pine (Pine spp.)									
E. White (P. strobus)	S-I	R	S	S	S	S	S-I	I-R	S
Loblolly (P. taeda)	S-I	R	S	S	S	S			S
Lodgepole (P. contarta)	S-I	R	S	S	S	S			S
Longleaf (P. palustris)	S-I	R	S	S	S	S			S
Pitch (P. rigida)	S-I	R	S	S	S	S			S
Ponderosa (P. ponderosa)	S-I	R			S	S			S
Red (P. resionsa)		I	S	S	S	S			S
Shortleaf (P. echinata)	I	R	S	S	S	S			S
Slash (P. caribaea)	S-I	I	S	S	S	S			S
Sugar (P. lambertiana)		I			S	S			S
Table mountain (P. pugens)	S-I	I			S	S			
Virginia (P. virginiana)	S-I	R	I	S	S-I	S			S
Western white (P. monticola)		I	S		S	S			S
Jack (P. banksiona)	S-I	I	S	S	S	S			S
Plum (Prunus spp.)									
Chickasaw (P. angustifolia)		S	S		I	S	S	S	
American (P. americana)	S-I	S-I	S		I	S			
Allegheny (P. alleghenlensis)		S			I	S			S
Poison ivy (Rhus radicans)	S-I	S-I	S		S-I			S-I	
Poison oak (Rhus spp.)									
Common (R. toxicodendron)	S-I	S	S	S-I	I		S-I		S
Pacific (R. diversiloba)		S	S		I				
Poplar, balsam (Populus balsamifera)	S	S-I	S-I	S	S-I	S-I	S	S	S
White (P. alba)		S-I				S-I			
Pricklyash, common (Zanthoxylum americanum)	S-I	I	I-R		S-I		S-I	S	S
Pricklypear (Opuntia spp.)									
Fragile (O. fragilis)		I	R	S	I-R		S	I	S
Mission (O. megacantha)		I							S
Plains (O. polyacantha)		I							S
Spreading (O. humifusa)		I							
Privet, swamp (Forestiera acuminata)	R	I-R	R		I	S	S		S
Rabbitbrush (Chrysothamnus spp.)									
Douglas (C. viscidiflorus)		I-R	R					S	
Greene (C. greenci)		I		S	I				
Southwest (C. pulchellus)		I-R			I				

TABLE 3 (CONTINUED) - SUSCEPTIBILITY OF WOODY SPECIES TO HERBICIDE TREATMENTS

SPECIES	A	B	C	D	E	F	G	H	I
Raspberry (Rubus spp.)									
Red (R. idaeus)		S-I	I	S	S				S
Black (R. occidentalis)		S-I	I	S	S				S
Redbus (Cercis spp.)									
Eastern (C. Canadensis)	S-I	I	S	S	S-I	S-I	S	S-I	S
Western (C. occidentalis)		I	S	S	S-I	S-I			S
Redwood (Sequoia sempervirens)	I	I			S	S	S	I	
Redcedar, western (Thuja plicata)	I	R	S	S-I	S-I	I	I	R	S
Rhododendron (Rhododendron spp.)									
Canadian (R. Canadense)		R	R	I		I	I-R	R	
Pacific (R. macrophyllum)		R				I			
Rosebay (R. maximum)	R	R	R	I	I	I			
Rose (Rose spp.)									
Arkansas (R. arkansana)		I	R					S-I	
California (R. Californica)		I							
Cherokee (R. laevigata)		I	R		S				
McCartney (R. bracteata)	S-I	S-I	R	S	S				S
Multiflora (R. multiflora)	S-I	I	R	S	S-I				S
Sweetbriar (R. eglanteria)		I	R						
Sagebrush (Artemisia spp.)									
Big (A. tridentata)	S	S	R	S	I-R			S	
Black (A. nova)		S		S	I-R				
California (A. Californica)		S		S	I-R				
Sand (A. filifolia)	S	S		S	I-R				
Silver (A. cana)		S		S	I-R				
Salal (Gaultheria shallon)	I-R	I-R	R		I-R				
Salmonberry (Rubus spectabilis)	S-I	S-I	R		S-I			I	
Saltbush, fourwing (Atriplex canescens)	S	S	R					S-I	
Saltcedar (Tamarix pentendra)	I	I	I	S-I	I-R		S-I	S-I	S
Sassafras, common (Sassafras albidum)	S-I	S-I	S-I	S	S-I	I		S	S
Serviceberry (Amalanchier spp.)									
Allegheny (A. laevis)	I	S-I				S		I	S
Pacific (A. florida)		S-I				S			
Saskatoon (A. alnifolia)	S	S-I			S-I	S			
Shadblow (A. Canadensis)		S			S-I	S			
Snowberry (Symphoricarpos spp.)									
Common (S. alba)	S	S			I			I	
Western (S. occidentalis)		S			I				

TABLE 3 (CONTINUED) - SUSCEPTIBILITY OF WOODY SPECIES TO HERBICIDE TREATMENTS

SPECIES	A	B	C	D	E	F	G	H	I
Sourwood (Oxydendrum arboreum)	I	I-R	R	I	I	S	S-I	I	S
Spicebush, common (Lindera benzoin)	S	S	S	S	I	S	S	S-I	S
Spirea (Spiraea spp.)									
Hardhack (S. tomentosa)	I	I	I		I-R		S	S-I	S
Meadowsweet (S. alba)		S	I		I-R				
Spruce (Picea spp.)									
Black (P. mariana)	I	R	R	I	S-I	S-I	S-I	R	S
Engelmann (P. engelmanni)	I-R	R	R		S-I	S-I			S
Norway (P. abies)	I	R	R	I	S-I	S-I			S
Red (P. rubens)	I	R	R		S-I	I			S
Sitka (P. sitchensis)	I-R	R	R		S-I	I			S
White (P. glauca)	I	R	R		S-I	I			S
Sumac (Rhus spp.)									
Fragrant (R. aromatica)	S	S-I	R	S	S	S-I	S-I	S	S
Laurel (R. laurina)		S	R	S		S-I			S
Poison (R. vernix)		S	R			S-I			S
Smooth (R. glabra)		S-I	S-I	S	S	S-I			S
Staghorn (R. typhina)	S	S-I	S-I	S	S	S-I			S
Sweetfern (Comptonia peregrina)		S-I	I		I			I-R	
Sweetgum (Liquidambor styraciflua)	S-I	S	S	I	I	S	S	S	S
Sycamore (Platanus occidentalis)	S	S	S	S	S-I	S	S	S	S
Tamarack (Larix laricina)	S-I	I	I		S-I	S	S-I	I-R	S
Tamarisk (See Saltcedar)									
Tanoak (Lithocarpus densiflorus)		S			I-R	S	S	S-I	
Tarbush (Flourensia cernua)		I	R		R			I	
Tassajillo (See Pricklypear)									
Thimbleberry, western (Rubus parviflorus)		I			I			I-R	S
Titi (Cliftonia monophylla)		S			R	S-I	S-I	S-I	S
Tree-of-heaven (Ailanthus altissima)	S	S-I	I		R	S	S	I	S
Trumpetvine (Campsis radicans)	I	I	R	S-I	S			I-R	S-I
Tulip tree (Liriodendron styraciflua)	S	S-I	I	S	S-I	S	S	S-I	S
Viburnum (Viburnum spp.)									
Arrowwood (V. dentatum)	S	I	I		I	S-I	S	I-R	S
Mapleleaf (V. acerifolium)		I	I		I	S-I			S
Nannyberry (V. lentago)	I	I	I			S-I		S	
Blackhaw (V. rufidulum)	I	I	S-I		I	S-I			S
Virginia creeper (Parthenocissus quinquefolia)	I	I	R		I-R			I-R	

TABLE 3 (CONTINUED) - SUSCEPTIBILITY OF WOODY SPECIES TO HERBICIDE TREATMENTS

SPECIES	A	B	C	D	E	F	G	H	I
Wahoo, eastern (Euonymus atropurpureus)		S-I			I-R	S	S	I	
Walnut (Juglans nigra)		S	S	S	I-R	S	S	S-I	S
Waxmyrtle (Myrica spp.)									
Pacific (M. californica)	I	I	R		R	S-I	S	I-R	S
Southern (M. cerifera)	I	I	R		R	S-I		I	S
Whitebrush (Aloysia lycioides)		I			R			I	
Willow (Salix spp.)									
Black (S. nigra)	S-I	S-I	S	S	S	I	S	S	S
Ditchbank (S. interior)	S-I	S-I	S			I		S	S
Pacific (S. lasiandra)			S						S
Red (S. laevigata)		S-I				I			S
Sandbar (S. exigua)		S-I	S						S
White (S. alba)		S-I							
Yellow (S. lutea)		S-I							
Witchhazel (Hamamelis spp.)									
Common (H. virginiana)	S	S	S		S	S	S	S	S
Southern (H. macrophylla)					S				
Yaupon (Ilex vomitoria)		I	I	S-I	R			I-R	
Yerbasanta (Eriodictyon spp.)									
California (E. Californicum)		S-I			I-R			I	
Narrowleaf (E. angustifolium)		S-I			I-R				
Woolly (E. crassifolium)		S-I							
Yellowwood (Cladrastislutea)		S-I			I-R	S	S	I	
Yew (Taxus spp.)									
Florida (T. floridana)	S-I	R			S-I	S-I	S-I	R	S
Pacific (T. brevifolia)		I-R			S-I	S-I			S
Yucca (Yucca elata)	S-I	I	R		I-R		S	S-I	S

Manual Recommendations

Committee 15—Steel Structures

Report on Assignment B

Revision of Manual

D. L. Nord *(chairman, Subcommittee on Revision of Manual),* J. G. Clark *(chairman, Subcommittee on Bibliography and Technical Explanation of Various Requirements in AREA Specifications Relating to Steel Structures),* R. I. Simkins *(chairman, Subcommittee on Continuous Welded Rail on Bridges),* A. J. Wood *(chairman, Subcommittee on Welded Steel Railway Bridges),* D. S. Bechly, A. B. Belfield, Jr., E. S. Birkenwald, E. Bond, T. J. Boyle, J. C. Bridgefarmer, H. L. Chamberlain, H. B. Cundiff, L. F. Currier, E. J. Daily, A. C. Danks, J. W. Davidson, F. P. Drew, J. L. Durkee, G. F. Fox, J. W. Hartmann, J. M. Hayes, G. E. Henry, C. A. Hughes, L. R. Hurd, M. L. Koehler, R. C. McMaster, D. V. Messman, W. H. Munse, G. E. Morris, R. D. Nordstrom, A. L. Piepmeier, M. Schifilacqua, A. E. Schmidt, F. D. Sears, H. Solarte, A. P. Sousa, J. E. Stallmeyer, Z. L. Szeliski, J. D. Tapp, Jr., W. M. Thatcher, R. N. Wagnon, C. R. Wahlen, R. H. Wengenroth, W. Wilbur.

Your committee submits for adoption the following revisions to the SPECIFICATIONS FOR STEEL RAILWAY BRIDGES, Chapter 15 of the Manual:

Page 15–1–15, Art. 1.3.14.3—Unit stresses for combinations of loads, and page 15–2–7, Art. 2.3.2.3—Unit stresses for combinations of loads, revise as follows:

Change title of Articles by adding the words "or wind forces only."

Redesignate subarticle 2.3.2.3 (c) as 2.3.2.3 (d).

Redesignate subarticles 1.3.14.3 (b) and 2.3.2.3 (b) as 1.3.14.3 (c) and 2.3.2.3 (c), respectively.

Revise the last lines in present articles 1.3.14.3 (b) and 2.3.2.3 (b) to read ". . . provisions of (a) or (b) alone," and delete the word "other" in the second line.

Subarticles 1.3.14.3 (a) and 2.3.2.3 (a) to remain as written.

Add new subarticles 1.3.14.3 (b) and 2.3.2.3 (b) to read:

"(b) The basic allowable unit stresses of Section 1.4 shall be used in the proportioning of members subject to stresses resulting from wind force only, as specified in Art. 1.3.8."

On page 15–1–18, change Art. 1.4.2 to read as follows:

1.4.2 Weld Metal

(a) Groove Welds	
Tension or compression	20,000 psi
Shear	12,500
(b) Fillet Welds	
Shear, regardless of direction of applied force.	
Electrodes or electrode-flux combinations with:	
60,000 psi Tensile Strength	*16,500
70,000 psi Tensile Strength	*19,000

*but not to exceed 12,500 psi shear stress on base metal.

On page 15–2–10, change Art. 2.4.2 to read as follows:

2.4.2 Weld Metal

In the formulas, F_y = yield point of base metal as specified in Art. 2.2.1

(a) Groove Welds

Tension or compression	.55 F_y
Shear	.35 F_y

(b) Fillet Welds

Shear, regardless of direction of applied force.

Electrodes or electrode-flux combinations with:

70,000 psi Tensile Strength	*19,000 psi
80,000 psi Tensile Strength	*22,000

*but not to exceed 0.35 F_y shear stress on base metal.

On page 15–1–34, delete subarticle (e) of Art. 1.11.4 and redesignate subarticles (f), (g), (h) and (i) of Art. 1.11.4 as (e), (f), (g) and (h), respectively.

On page 15–9–19, delete reference to Paragraph (e) in Art. 9.1.11.4 and redesignate the references to Paragraphs (f), (g), (h) and (i) in Art. 9.1.11.4 as (e), (f), (g) and (h), respectively. Change the word "paragraph" to "subarticle" wherever it appears in Art. 9.1.11.4.

On page 15–3–5, delete Art. 3.1.12 (b).

Revise, as follows, proposed new Section 8.3—Anchorage of Decks and Rails on Steel Bridges, as published in Bulletin 650, November–December 1974, pages 242–245:

Art. 8.3.4.1 Movable spans: Add new paragraph as follows:

"(b) Deck and rails shall be anchored to the movable span as specified by the engineer to prevent movement during opening and closing."

Delete all of Art. 8.3.5 and change designation of Art. 8.3.6 to 8.3.5.

Your committee also submits for adoption the following editorial changes in the SPECIFICATIONS FOR STEEL RAILWAY BRIDGES, Chapter 15 of the Manual:

On page 15–2–2, Art. 2.2.1 (c): change the requirements for forged steel from A 235 or A 237 to A 668.

On page 15–2–2, Art. 2.2.1 (c): change the table for high-strength structural steel as follows:

1. The thickness limitation column for A 572, Grade 60, be changed from "To 1, incl." to "To 1¼, incl.".
2. The thickness limitation column for A 572, Grade 50, be changed from "To 1½, incl." to "To 2, incl.".
3. The applicable to shape column for A 588, F_y 50,000 be changed to "All."
4. The applicable to shape column for A 588, F_y 46,000 be changed to "None."
5. The applicable to shape column for A 572, Grade 50, be changed to "Groups 1, 2, 3 and 4."
6. The applicable to shape column for A 572, Grade 42, be changed to "Group 5."

On page 15–1–11, revise Art. 1.3.8 to read:

"(a) The wind force on the unloaded bridge shall be taken at 50 lb per sq ft of surface as defined in Art. 1.3.7."

On page 15–1–3, revise Art. 1.2.1 as follows:

1. Change the requirement for forged steel from A 235, Class E, to A 688, Class D.
2. Delete wrought iron.

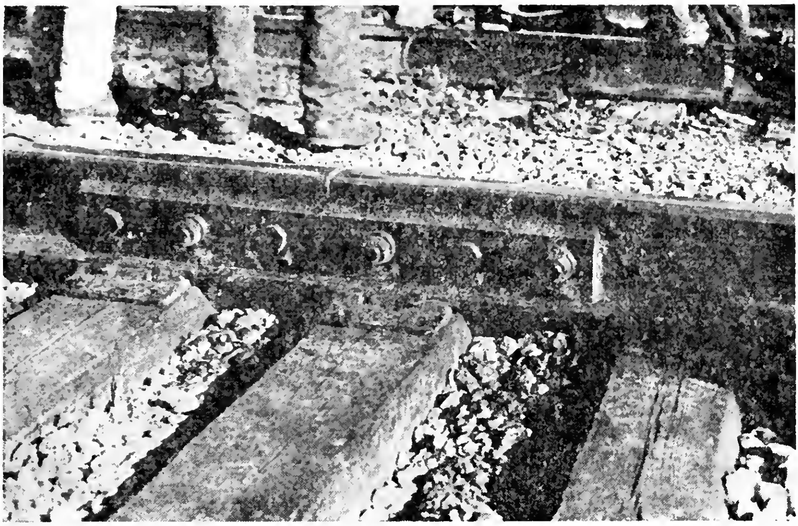
On page 15–1–3, Art. 1.2.1 (a): change "Specifications" to "Designations" and move "current" to modify requirements.

On page 15–2–2, make the following changes:

1. In Art. 2.2.1 (a), change "Specifications" to "Designations" and move "current" to modify requirements.
2. In Art. 2.2.1 (c), add footnote 4 at bottom of table: ("4" to be added to all but first column at left)

"4 These data are for information only and are current as of May, 1975."

On page 15–9–4, delete the last sentence of the first paragraph and insert the bibliography reference (2) between the words "tests" and "were" in the next to last sentence of the first paragraph.



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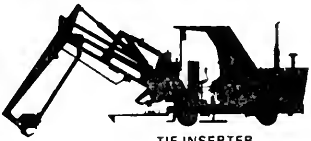
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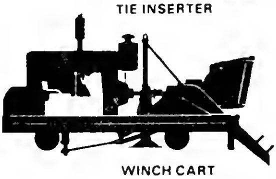
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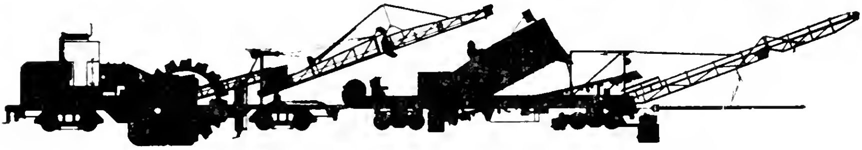
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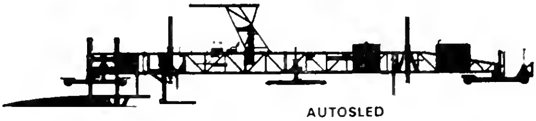
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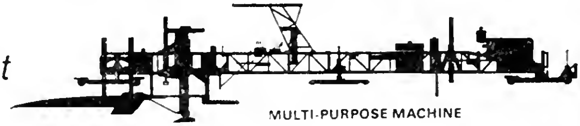
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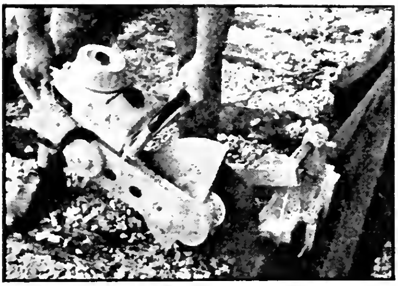

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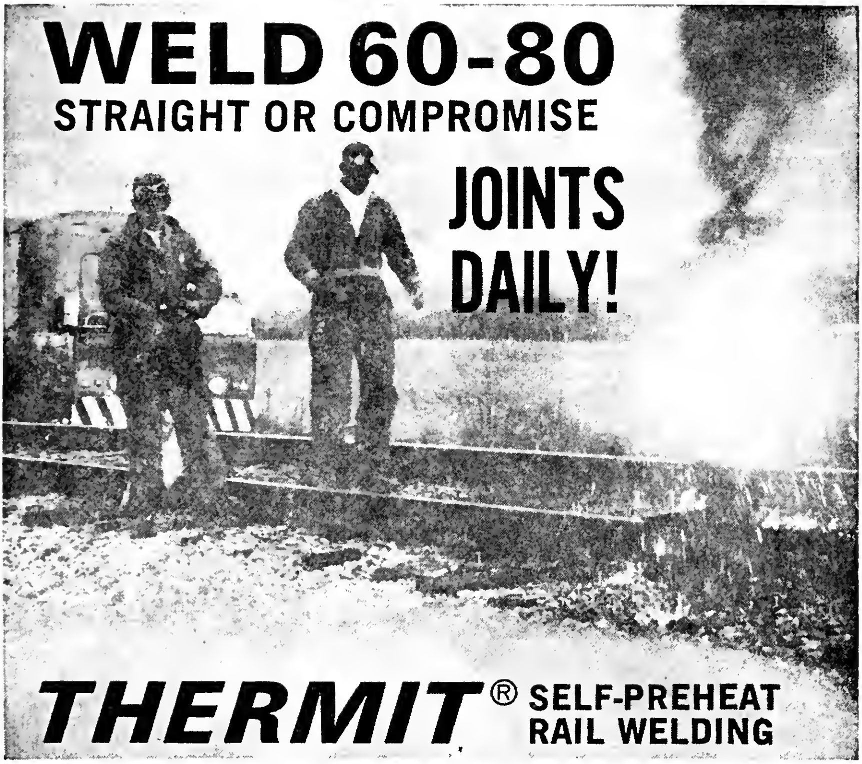
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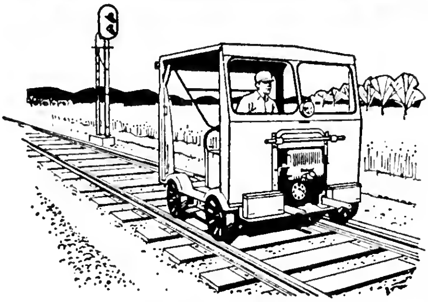

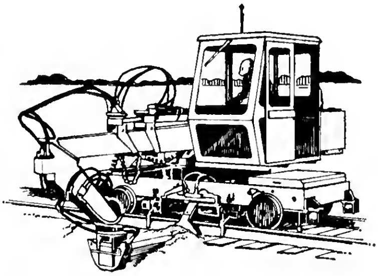

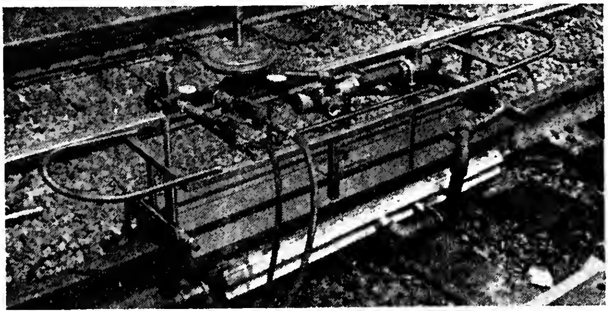

PART 2

REPORTS OF COMMITTEES

Note: Discussion on subcommittee reports herein closes on January 20, 1976.

Report of Committee 9—Highways

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H. L. Woltman
C. H. Worboys
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your Committee reports on the following subjects:

B. Revision of Manual.
Progress report submitted as information .... page 256

1. Grade Crossing Inventory and Accident Report Forms, Records and practices.
Information is being gathered and the committee expects to develop recommendations for new report forms and signs in the coming year.

2. Merits and Economics of Types of Grade Crossing Surfaces.
Report on performance of railbound concrete slab crossing on EJ&E in Griffith, Ind. .... page 257

3. Summary Reporting of Significant Publications on Grade Crossing Safety.
Summarized reports furnished as information .... page 258

4. Evaluation of Developments in Passive and Non-Train-Actuated Grade Crossing Warnings.
No report for past year's activity.

5. Study of Motor Vehicle Codes and Drivers' Licensing Practices.
Progress report submitted as information .... page 263

6. Air Rights for Highways Over Railroad Property.

   No report for past year's activity. Highway Research Board's Report No. 142 has recently been released and it will be reviewed by the committee.

7. Evaluation of Developments in Train-Actuated Grade Crossing Warnings, Collaborating as Necessary or Desirable with Communication and Signal Section, AAR.

   No report for past year's activity.

8. Investigate Uses and Types of Rumble Strips and Their Adaptability for Approaches to Highway-Railway Grade Crossings.

   Progress report submitted as information .... page 264

9. Study of Public Pedestrian Crossings.

   Progress report submitted as information .... page 266

10. Summary Reporting of Administration of State Crossing Safety Programs.

    A new subject. No report for past year's activity.

THE COMMITTEE ON HIGHWAYS,
C. A. CHRISTENSEN, *Chairman.*

Report on Assignment B

Revision of Manual

J. E. SPANGLER *(chairman, subcommittee)*, J. M. BATES, C. A. CHRISTENSEN, L. T. CERNY, J. W. CRUIKSHANK, F. DAUGHERTY, R. V. GILBERT, H. D. HAHN, C. I. HARTSELL, D. P. INSANA, P. G. JEFFERIS, R. V. LOFTUS, R. F. MACDONALD, G. U. MENTJES, J. C. MILLER, G. S. MUNRO, R. E. SKINNER, DAVID VEITCH, W. E. WEBSTER, JR., C. H. WORBOYS.

Consideration is now being given to revisions in portions of the miscellaneous section of Chapter 9 of the Manual. Proposals include the substitution of the DOT–AAR Crossing Inventory Form for the Highway Grade Crossing Record now shown on pages 9-M-6 and 9-M-7, changes in the Accident Report on pages 9-M-4 and 9-M-5, revision of the type of barriers used in closing grade crossings and at dead-end streets on pages 9-M-2 and 9-M-3, and deletion of sample sheets showing record of delays at grade crossings (pages 9-M-8 and 9-M-9).

Report on Assignment 2

Merits and Economics of Types of Grade Crossing Surfaces

P. A. Shuster *(chairman, subcommittee)*, W. B. Calder, L. T. Cerny, C. A. Christensen, J. W. Cruikshank, T. P. Cunningham, R. A. Downey, R. V. Gilbert, H. D. Hahn, C. I. Hartsell, Wm. J. Hedley, A. O. Kruse, R. V. Loftus, G. S. Munro, R. D. Pamperl, R. H. Patterson, F. E. Rosencranz, C. Shoemaker, W. E. Webster, Jr., C. H. Worboys.

On page 159 of Volume 74 of the AREA Proceedings, there is a report on an inspection of a new design concrete slab crossing in the vicinity of Dusseldorf, Germany, by a committee member.

In October of 1973, the Elgin, Joliet & Eastern Railway installed four of these crossings at Broad Street in Griffith, Indiana, at the request of the city. The city contributed the additional cost of these slabs over the cost of the solid timber crossing that the railroad had intended to install at its own cost. The initial reaction to the crossing by the city was very favorable, with smooth riding qualities evident to the motorists. However, within five months of the time of installation, various problems started to occur, especially the breaking of the hardware holding the rail to the steel rod which runs under the rail (in this design crossing there is no direct attachment of the crossing slabs to the cross ties, only attachment to the bar running under the rail). The washers and bolts and spring clips experienced breakage and the concrete-filled bags supporting the slabs on top of the tie experienced an approximate 15% failure rate. An additional problem was the fact that the insulation, which is required if this crossing is used with track circuits, did not hold up and numerous calls of the signal maintainer were necessary on overtime. Considerable bridge and building time was also required for maintenance of the crossings.

At present, maintenance is stabilized at approximately one gang day (four men per gang) every two months. The manufacturer has been working with the railroad, and at various times redesigned hardware and insulation were substituted for that already in the crossing. The manufacturer has now proposed a new type insulation for the two crossings which are in signal territory and a new reactive spring washer to absorb some of the stresses in the hold-down hardware.

In view of the above it is the opinion of this committee that this crossing should still be regarded as in the developmental stage, especially if use on heavy-duty trackage is involved. During all this time the highway riding qualities have remained smooth, but this has been only with considerable maintenance on the railroad's part. The opinion of the railway is that it would have been better to install the railroad's standard full-depth timber crossing, as this design can often go with no maintenance for ten or more years under similar conditions. The subcommittee intends to report further on additional developments on this particular crossing.

This is a progress report submitted as information.

Report on Assignment 3

Summary Reporting of Significant Publications on Grade Crossing Safety

H. L. Michael *(chairman, subcommittee),* L. L. George *(vice chairman, subcommittee),* W. W. Allen, J. P. Bolling, A. L. Carpenter, L. T. Cerny, C. A. Christensen, M. D. Kenyon, A. O. Kruse, R. V. Loftus, P. J. McCue, R. A. Mather, R. D. Pamperl, R. H. Patterson, H. A. Richards, R. E. Skinner, C. W. Smith, J. R. Summers, David Veitch, J. L. Whitmeyer, H. J. Wilkins, H. L. Woltman.

INTRODUCTION

The Subcommittee assignment continues to be the reporting in summary format of significant publications or developments in grade crossing safety. This year four publications and progress on several significant research projects in grade crossing protection are reported.

"The Effectiveness of Automatic Protection in Reducing Accident Frequency and Severity at Public Grade Crossings in California," California Public Utilities Commission, Transportation Division, and Railroad Operation and Safety Branch, Traffic Engineering Section, San Francisco, California,

June 30, 1974.

This report is more comprehensive than were previous annual studies of this same title. The executive summary of the report, slightly modified in the opening paragraph, summarizes the content very well and follows.

This study was sponsored by the Office of Traffic Safety of California to assist the California Public Utilities Commission in performing its duties related to grade crossing regulation, to determine the scope of the vehicle-train accident problem in California, to gauge the effectiveness of various types of warning devices being currently advocated by the Commission, and to critically investigate the possible use of warrants or criteria to assist in recommending where monies should be spent on railroad-highway grade crossing warning improvements. The study provides information regarding the installation of various warning devices and the cost to the public.

The project was segregated into four separate studies based upon: (1) a questionnaire mailed to all cities and counties in California; (2) an examination of the before-and-after accident histories of 1,552 grade crossings currently protected by automatic devices; (3) a summary of the actual and estimated costs of installing automatic warning devices at 1,296 locations; and (4) an examination of the feasibility of using warrants or criteria to assist in placing grade crossing warning devices.

The questionnaire designed to appraise local concern and awareness of the vehicle-train accident problem in California was mailed to 380 cities and counties. The local governmental agencies were requested to describe their decision-making processes, including whether or not they used specific warrants or criteria, how they rated the relative importance of several physical conditions common to many pre-existing hazard indices, sufficiency rating and regression equations and how they specifically felt about the grade crossing program as handled by the Public Utilities Commission.

The effectiveness analysis was designed to assess the capacity of various warning devices in reducing the number of vehicle-train accidents and their related deaths and injuries. In all, 1,552 locations were chosen where automatic warning was installed between January 1, 1960, and December 31, 1970. Compared, for each crossing, were the number of accidents, deaths and injuries per year, and the number of deaths and injuries per accident.

In order to gauge the installation costs of automatic warning, 1,296 locations were chosen where automatic warning was proposed or installed between January 1, 1966, and December 31, 1973. In addition to listing the actual or estimated installation cost at each location, each crossing's previous warning devices, number of tracks, railroad, type of device installed and the proposed year of installation were documented.

To examine the possible use of warrants or criteria in the installation of automatic signals, 115 locations were chosen at random from the 1,552 crossings used as input locations for the effectiveness analysis. Only crossings presently protected by automatic devices were chosen for the purpose of examining past policies of the Commission as it concerns warning improvement to try to pinpoint any discernible patterns. The detailed information on each crossing was used to: (1) develop a regression equation to predict accident rates; (2) compare several hazard indices and sufficiency rating equations; and (3) explore the use of joint study or a limited diagnostic approach.

The four separate studies included in this project have shown or at least indicated the following:

(1) There is little concern among local governmental agencies regarding the grade crossing situation in California as it exists today.

(2) Many agencies feel the financial responsibility for installation of automatic warning should be borne by the State or Federal government.

(3) The use of warrants or criteria to assist in the installation of automatic warning is not widespread, although many agencies feel the State should adopt criteria or warrants in some form.

(4) Local agency engineers responded that average daily vehicular traffic, daily train traffic, corner visibility, vehicular and train speed, in that order, are the most important physical characteristics to be considered when contemplating a grade crossing warning improvement.

(5) Responses to the questionnaire ranged between criticism of the "dictatorial and seemingly arbitrary way in which the Commission staff administers the program" to praise for the grade crossing program and a desire for the retention of the informal manner as presently pursued by the Commission staff.

(6) Vehicle-train accidents and casualties between 1965 and 1972 were reduced by 41%.

(7) The 1,552 locations examined experienced a 69% reduction in the number of vehicle-train accidents per year, an 86% reduction in deaths and an 80% reduction in the number of injuries per crossing year after the installation of automatic warning devices.

(8) Due to their ability to seize the attention of approaching motorists, both flashing-light signals and flashing lights with automatic gates offer the ability to drastically reduce the number of vehicle-train accidents and related casualties.

(9) Keeping in mind severely limited functional definitions, urban grade crossings bear significantly higher vehicle-train accident rates than rural crossings do, and are less affected by the installation of automatic signals in terms of accident reduction.

(10) Automatic warning has its limitations, but will go a long way toward the elimination of vehicle-train accidents if combined with good driver judgment.

(11) The benefits enjoyed from the installation of automatic warning come at the expense of significant public and private investment, the cost of installing flashing lights averaging $8,919 and automatic gates $18,682 over the 1966 to 1973 period.

(12) By 1973, the average cost of installing flashing lights and automatic gates had risen to $10,671 and $23,534, respectively.

(13) Some factors which appear to affect the installation cost of automatic warning include the geometrics and physical conditions of the crossing, the type of device installed, the proximity of adjacent grade crossings protected by automatic devices, the complexity and sophistication of track circuitry required, and finally, the railroad involved.

(14) In addition to the installation cost, automatic warning requires significant periodic maintenance. For the year 1972, using a $30 per relative unit cost, this amounted to $456 average at crossings protected by flashing lights and $949 at crossings protected by automatic gates.

(15) Large volumes of research material are presently available concerning methods of determining urgency or priority of warning improvement of railroad crossings.

(16) No universal agreement has been reached between the interested parties on the conclusions of the past studies, and the actual methods of approach from hazard index equations and sufficiency ratings to predictive equations resulting from regression analyses have come under attack.

(17) The attempt to design a regression analysis approach to predict future accident rates from simultaneous combinations of several independent variables did not prove fruitful. It is the staff's opinion that this is due to the lack of accurate data over the study period and the small sample size because of the low incidence of vehicle-train accidents.

(18) Hazard index and sufficiency rating equations generally address themselves to improvement priorities and not to the most efficient type of warning device.

(19) Due to the multiplicity of characteristics found in California's transportation network, it is the Commission staff's position that single equations cannot be adopted with good conscience on a statewide basis.

(20) The method favored by the study staff incorporates the expertise of all parties involved, and is based upon the joint recommendations of railroad, local agency, and Commission engineers. The limited diagnostic

method is dependent upon accurate, complete, up-to-date information on each crossing within a jurisdiction and is adaptable to any number of computational priority determinations.

(21) The key word is cooperation backed by a genuine realization of the needs and constraints of the parties involved. Any method or set of warrants, or criteria, used to assist in determining grade crossing warning improvements will run into difficulty for the simple reason that three separate and distinct organizations are involved, each with its own needs, constraints and responsibilities. To encourage participation, any method adopted must remain flexible and receptive to all parties concerned.

PROCEEDINGS, 1974 NATIONAL CONFERENCE ON RAILROAD-HIGHWAY CROSSING SAFETY, SPONSORED BY U.S. DEPT. OF TRANSPORTATION, AUGUST 19–22, 1974.

The report contains many brief articles on railroad-highway crossing safety by practitioners from all parts of the United States. The contents are best summarized briefly by a listing of the titles of these articles.

Partners in Railroad-Highway Grade Crossing Improvement Programs
Establishing a Grade Crossing Safety Program
Partners in Improvement and Establishing a Crossing Safety Program
New Approaches to Program Management
Establishing the Program Mix
Urban Railroad Relocation
Research and New Developments
National Crossing Inventory and Numbering
Proposed National Railroad-Highway Crossing Inventory
Accident and Accident Severity Prediction Equations
New Passive Devices (Pooled Fund Research Project)
In-Vehicle Warning Systems for Railroad Grade Crossing Applications
Model for Evaluation of Alternative Grade Crossing Resources
Rail Safety/Grade Crossing Warning Research Program

"RAILROAD-HIGHWAY VEHICULAR MOVEMENT WARNING DEVICES AT GRADE CROSSINGS," IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. IA-11, NO. 2, MARCH–APRIL 1975, PAUL LONGRIGG.

The abstract of this paper is as follows:

"Railroad operations have for many years been plagued with poor safety performance at grade crossings. Many lives are lost each year in accidents at crossings, to say nothing of costly injuries and property damage sustained. The situation has gotten worse with the advent of soundproofed cars, being driven at high speed in conditions of poor visibility. Clearly, then, some improved method of warning motorists as they approach a grade crossing is needed. Analysis of a critical encounter between a road vehicle and a locomotive reveal that the presently used equipment is inadequate to meet the needs of present-day high-speed vehicles. A system of vehicular movement warning devices is described in this paper that might improve to some extent the safety of grade crossing operations. Two methods are detailed. One involves static directional sonic devices positioned at the crossing;

warning activation is made on a real-time closing velocity determination. The other system employs a special variety of cattle-guard in the roadway, to issue a tactile warning. Both systems are designed to give adequate warning to a motorist in a critical encounter situation as he approaches the crossing with a convergent locomotive on the track(s). A bonus feature in the use of selectively activated static directional sound warning sources would be the curtailment of urban noise levels, where trains presently use the mobile audible source to issue warnings."

First Year Review: Protection and Advance Warning Signs at Railroad-Highway Grade Crossings, Minnesota Highway Department, St. Paul, Minnesota, December 1974

This brief report summarizes the condition of the signs and the accidents at grade crossings on two Burlington Northern lines where new or improved existing protection signs and advance warning signs were installed in 1973. The findings were that 7.4% of the signs had been vandalized (gunshot damage) in the first year although some of these were still satisfactory for use. Thirteen of 580 signs were missing and seven others were in need of replacement or re-erection.

A comparison of accidents during the year with accidents during previous periods is also made. No conclusions, however, could be reached as the after-period number of accidents were so few.

RESEARCH IN PROGRESS

Considerable research and implementation continued in the area of railroad-highway grade crossing safety. The Norfolk & Western Railway reports two new studies on passive signing in Ohio using yellow crossbucks with black border with an auxiliary information sign, "Look for Train," also being used in one of the studies.

The State of Florida is carrying out the mandate of legislation effective July 1, 1972, which placed regulatory authority over public rail-highway crossings in the Department of Transportation and directed that a program be adopted which would eliminate hazards at such crossings. A five-year program for warning devices has been adopted with completion in 1980. A total of 2,991 crossings are to be signalized.

The Lieutenant Governor's Conference at its meeting in 1974 adopted the following Resolution:

> WHEREAS, the rail-highway grade crossing is one of the most critical areas of traffic accidents in the nation, involving 7,000 injuries and 1,500 deaths annually on our streets, roads and highways; and,
>
> WHEREAS, accidents at dangerous crossings can be completely eliminated; and,
>
> WHEREAS, there is an urgent need to afford relief to the environment and to avoid the economic loss to society from traffic delays at rail-highway grade crossings in both urban and rural areas;
>
> BE IT RESOLVED, that the Congress is requested to appropriate sufficient funds for mandatory use to eliminate hazardous rail-highway grade crossings both on and off the Federal-aid system by constructing overpasses and underpasses, relocating streets or highways to eliminate grade crossings and closing unnecessary grade crossings.

CONCLUSION

The availability of funds under the 1973 Safety Act passed by Congress emphasized the importance of improving safety at railroad-highway grade crossings and provided funds for initiation of such improvements. Although the State highway departments appeared to be slow in initiating such a program, there are clear indications that effective programs are being developed and that many improvements will be made. It should be emphasized, however, that, as Georgia officials recently pointed out, the funds allocated for 1974–75–76 will only permit improvement of about 5% of the total grade crossings in that State. Obviously much additional work is required.

In view of these facts and the growing activity in the grade crossing field, it is recommended that the assignment of this subcommittee be continued as it currently exists.

Report on Assignment 5

Study of Motor Vehicle Codes and Drivers' Licensing Practices

A. O. Kruse *(chairman, subcommittee)*, H. W. Barnes, J. M. Bates, J. P. Bolling, W. B. Calder, A. L. Carpenter, L. T. Cerny, C. A. Christensen, M. D. Kenyon, R. A. Mather, G. U. Mentjes, J. E. Reynolds, P. L. Sehnert, P. A. Shuster, J. R. Summers, R. F. Spars, H. J. Wilkins, H. L. Woltman.

In January of 1975 your committee sent letters to the Governor's safety representatives of all of the States and Territories forwarding a copy of a model section entitled, "Railroad Grade Crossing Information for Driver License Manuals."

Replies were received from 19 States, the District of Columbia and three Territories. All replies indicated that favorable consideration would be given to including the information in future editions of the States' drivers' manuals where this information is not now a part of the manual.

The committee plans to make further contact with those States which have not responded.

This is a progress report submitted as information.

Report on Assignment 8

Investigate Uses and Types of Rumble Strips and Their Adaptability for Approaches to Highway-Railway Grade Crossings

R. E. SKINNER *(chairman, subcommittee)*, W. B. CALDER, L. T. CERNY, C. A. CHRISTENSEN, R. A. DOWNEY, L. L. GEORGE, C. I. HARTSELL, J. C. MILLER, G. S. MUNRO, R. H. PATTERSON, F. E. ROSENCRANZ, P. L. SEHNERT, P. A. SHUSTER, W. E. WEBSTER, JR., H. J. WILKINS, C. H. WORBOYS.

The use of "rumble strips" as a traffic control device continues to be a subject of interest to many people in the highway, academic and railroad fields. As evidence of this interest, the following is a partial list of a number of publications related to this subject.

1. "Effect of Rumble Strips on Traffic Control and Driver Behavior," M. L. Kermit and T. C. Hein, Highway Research Board *Proceedings,* Vol. 41, 1962, pp 469–482.
2. "Rumble Strips at Hazardous Locations," *Better Roads,* Vol. 35, No. 1, Jan. 1964, pp 16–21.
3. "Effect of Rumble Strips at Rural Stop Locations on Traffic Operation," R. D. Owens, Highway Research Record, 170, 1967, pp 35–55.
   A comprehensive investigation of the influence of rumble strips on traffic operations at rural stop locations showed that a reduction in traffic speed, better stop sign observance and a decreasing trend in accidents were obtained.
4. "Rumble Strips Used as a Traffic Control Device," *Highway Focus,* Vol. 4, No. 3, 1972, pp 35–41.
   Twenty-Three experimental rumble strips used on approaches to nine intersections to give audible warning of dangers ahead. Three different Rumble Strip configurations were used and a before and after accident survey showed that rumble strips can be used as a temporary method of warning motorists. They are of little value as permanent installations.
5. "Use of a Rumble Strip to Reduce Maintenance and Increase Driving Safety," R. Cahoon, Highway Research Board, Special Report 107, 1970, pp 89–98.
   An experiment to design recessed rumble strips to give the same effect as raised markers. These recessed rumble strips can be used in areas where snow plows are operated.
6. "Use of Rumble Strips to Reduce Maintenance and Increase Driving Safety," K. D. Fairmont, Utah State Department of Highways, Interim Report 1968.
7. "Development of an Effective Rumble Strip Pattern," W. R. Belles, *Traffic Engineering,* Vol. 37, No. 7, 1969, pp 22–25.
   The type, purpose and action of various rumble strips installed in the various states are described. The problems associated with an experimental rumble installation on durability and effectivness in reducing accidents are also discussed.

8. "Rumble Strips Revisited," M. L. Kermit, *Traffic Engineering*, Vol. 38, No. 5, 1968, pp 26–30.
   Accident figures before and after the installation of rumble strips.
9. "In Further Support of Rumble Strips," D. W. Hoyt, *Traffic Engineering*.
   Discusses accident reduction at nine rumble strip installations in Illinois and presents pertinent data in support of this highway feature as an effective safety device.
10. "Rumble Strips for Safety," G. J. Lindman, *Highway Focus*.
    Some traffic control devices become so familiar that they do not register in a driver's mind, while monotonous roads can lead a driver into a semi-conscious state. Rumble strips can correct this problem by alerting a driver through an audible noise and vibration through the steering wheel. Accident data before and after installation are presented.
11. "Grooved Rumble Strips as a Traffic Control Device in Pennsylvania," R. W. Taylor, A Thesis in Civil Engineering, November, 1974, Pennsylvania State University, Graduate School, Department of Civil Engineering.
    A conclusion is drawn that grooved rumble strips are effective in reducing accidents, especially in concrete pavements. The writer, however, suggests rumble strips be used as an interim measure (three years) until a more lasting design change can be incorporated, for example, traffic signal installation.

This is a progress report submitted as information with the recommendation that this assignment be continued in order that further information can be developed and reported to the Association.

Report on Assignment 9

Study of Public Pedestrian Crossings

J. L. Whitmeyer *(chairman, subcommittee)*, W. W. Allen, W. B. Calder, A. L. Carpenter, L. T. Cerny, C. A. Christensen, J. W. Cruikshank, T. P. Cunningham, F. Daugherty, H. D. Hahn, C. I. Hartsell, Wm. J. Hedley, D. P. Insana, R. F. MacDonald, G. U. Mentjes, J. C. Miller, J. E. Spangler, R. F. Spars, D. Veitch, C. H. Worboys.

Pedestrian grade crossings are an important safety issue to both the railroads and public jurisdictions. Although relatively few such crossings exist as compared to vehicular grade crossings, which pedestrians also use, increasing attention is being directed to improve site conditions and warnings for pedestrian use.

Unique signs and automatic warning signals for pedestrian crossings have been developed in three states (see accompanying appendices). These signs and devices closely follow the pattern of standards found in the Manual on Uniform Traffic Control Devices relating to at-grade railroad crossings. Although standard railroad type flashing signals, gates and bells are in use at some crossings, variations range from a single flashing-light signal with one red light in each direction to a vertical pair of flashing yellow lights and sign. A few signals are fitted with the larger 12-inch roundels for maximum light distribution. The automatic bell continues to be an effective audible warning to pedestrians, whether used alone or in conjunction with lights. Railroads favor signs and signal devices which are stock items for simplified maintenance and economic reasons.

Of growing importance and concern are the "bikeway" crossing proposals resulting from recent legislation. A California city is actively considering the adoption of standards to cover at-grade bicycle crossings and pathways on railroad property. Their proposal calls for the use of one red flashing-light signal with back light and bell at each crossing to include a sign to read "BICYCLES ONLY," similar to the State's standard pedestrian sign.

Railroad opposition to pedestrian and bicycle crossings is often overruled by State authority. A recent Wisconsin order specified a crossing should be 8 ft wide, composed of black top with a flange plank, provided with cross bucks, arterial "STOP" signs and advance warning signs. The city was obligated to remove vegetation in the immediate vicinity of the crossing. Subsequently, the railroad granted an easement to the city for the public bicycle trail crossing cross its right-of-way.

Conversely, cooperation between a railroad and a public agency often results in a negotiated license agreement, and can result in a private crossing under control of the railroad with the city indemnifying the railroad through public liability and property damage insurance naming the city and railroad as co-insured.

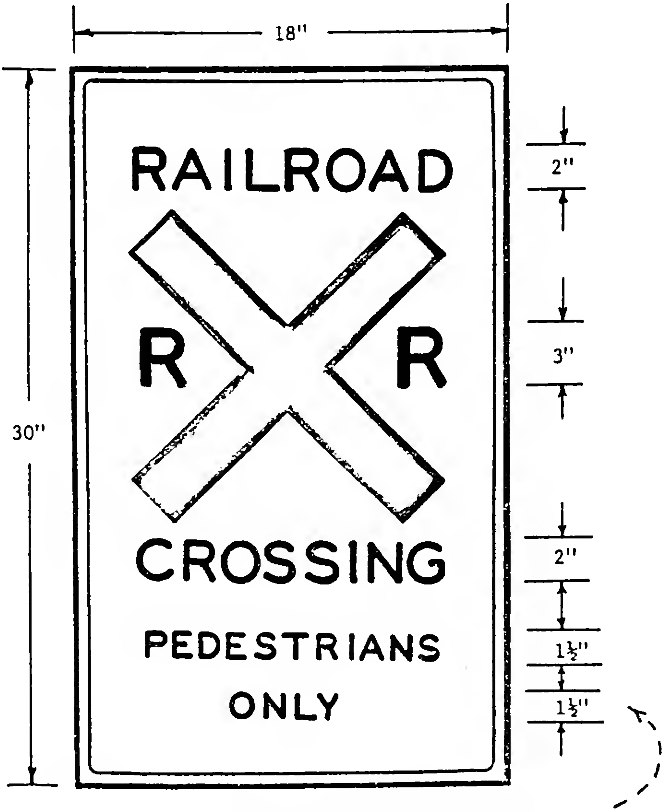
A California committee composed of representatives from the railroads, cities, State and Commission is actively engaged in a study of bicycle crossings with particular emphasis on probable need for bikeway crossings of railroads separate from highway crossing, the type of crossing construction which should be considered, possible use of dismount barriers and need for automatic warning devices. The report is expected to be available in late 1976.

This report is submitted as information with recommendation that the subject be continued.

Appendix A

California Public Utilities Commission

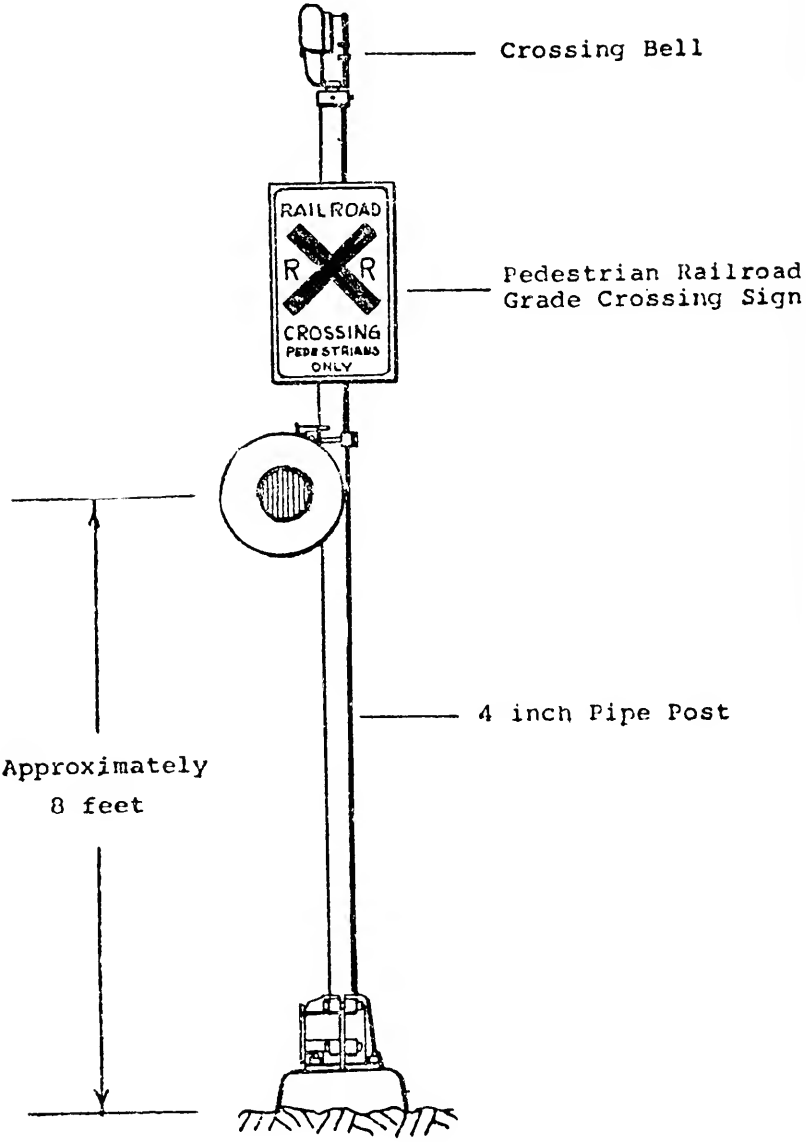
PEDESTRIAN RAILROAD GRADE CROSSING SIGN



Black Lettering on White or
Reflectorized Silver Background

Appendix B

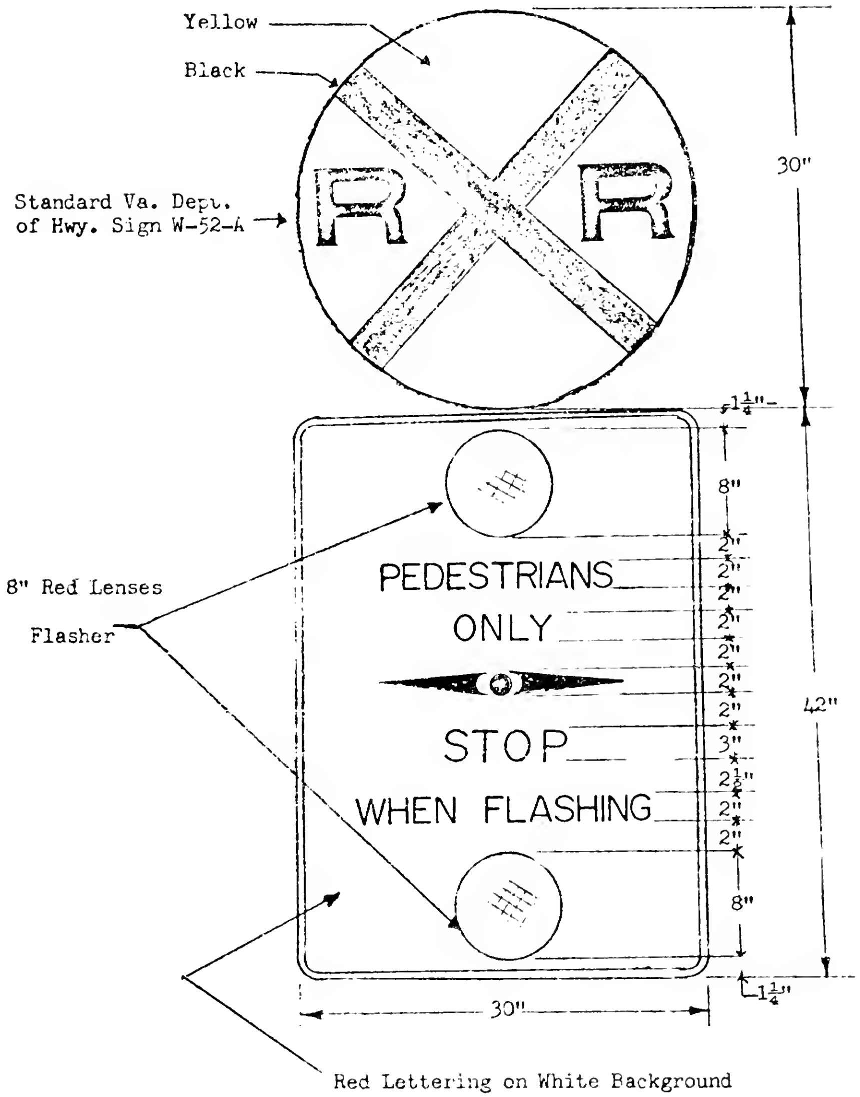
PEDESTRIAN CROSSING PROTECTION
Flashing-light Type



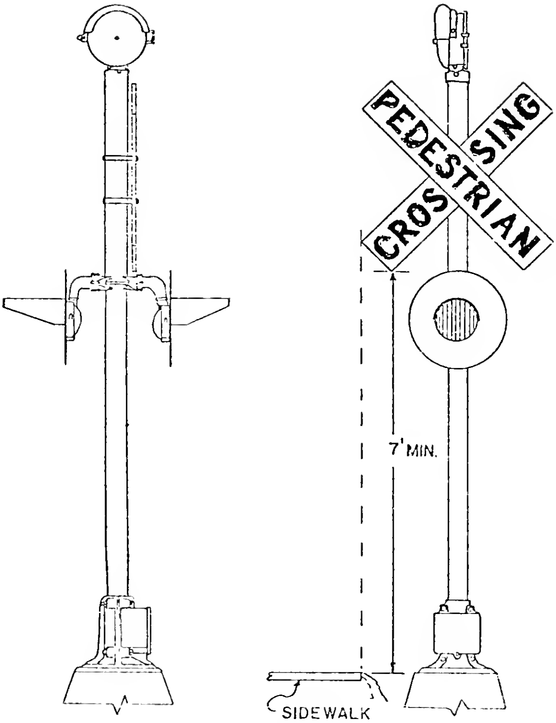
Appendix C

RECOMMENDED BY TRAFFIC ENGINEERING DIVISION, CITY OF CHESAPEAKE, VIRGINIA

Pedestrian Railroad Grade Crossing Sign



Appendix D



Public Utility Commissioner of Oregon, Railroad Division, Standard No. 2P Pedestrian Flashing Light Signal (Preliminary).

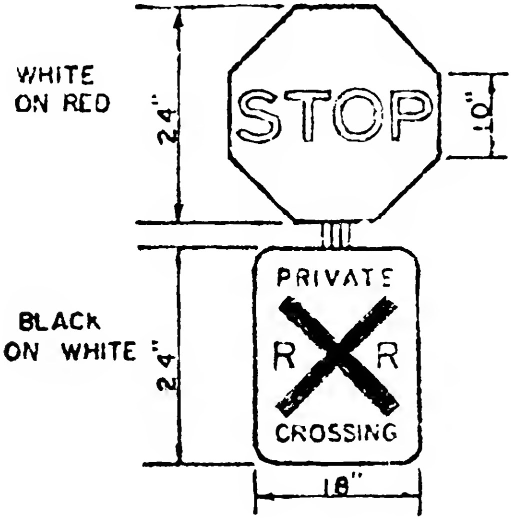
APPENDIX E

DEPARTMENT OF PUBLIC WORKS

BUREAU OF ENGINEERING

CITY OF DES MOINES, IOWA

Project: BICYCLE TRAILS



Report of Committee 11—Engineering Records and Property Accounting

R. D. Igou, *Chairman*
L. F. Grabowski,
Vice Chairman
G. R. Gallagher,
Secretary
M. F. McCorcle
P. G. McDermott
W. C. Kanan
R. L. Ealy
A. P. Hammond, Jr.
C. J. McDonald
C. E. Bynane
J. C. Kirchen
F. B. Baldwin (E)
P. J. Beyer, Jr.
J. M. Bourne
W. F. Burt
R. H. Campbell
J. R. Cressman
R. M. Davis
C. R. Dolan
W. V. Eller
L. D. Farrar
J. R. Geary
C. C. Haire (E)
M. J. Hebert
P. J. Hendricksen
E. H. Hofmann
P. R. Holmes
J. J. Hoolahan
L. W. Howard
N. J. Hull, Jr.
G. F. Ingraham
J. W. Kelly
W. F. Liszewski
R. W. Lively
J. G. Maher
J. L. Manthey
D. C. Maris
J. C. McKeague
S. Miller, Jr.
G. L. Muchow
R. F. Nelson
J. J. O'Hara
C. F. Olson
A. H. Patterson
H. L. Restall (E)
J. M. Randles
P. W. Roberts
R. S. Shaw, Jr.
V. E. Smith
E. E. Strickland
J. B. Styles
T. A. Valacak
H. R. Williams
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association

Your committee reports on the following subjects:

B. Revision of Manual.
No revisions to report.

2. Bibliography.
Progress report, submitted as information .... page 274

3. Office and Drafting Practices.
No report. AFE field inventory reports and as-built plans under study.

4. Special Studies.
No report. Methods for preparing standard form AFE estimates by mechanized process under study.

5. Application of Data Processing.
Final report on simplified methods of allocating recorded cost of reported units, submitted as information .... page 274

6. Valuation and Depreciation.
Progress report, submitted as information .... page 276

7. Revision and Interpretation of ICC Accounting Classifications.
Progress report, submitted as information .... page 277

The Committee on Engineering Records and Property Accounting,
R. D. Igou, *Chairman*

Report on Assignment 2

Bibliography

P. G. McDermott *(chairman, subcommittee)*, P. J. Beyer, Jr., J. R. Cressman, C. R. Dolan, L. D. Farrar, A. P. Hammond, R. D. Igou, J. L. Manthey, J. J. O'Hara, E. E. Strickland, T. A. Valacak.

Your committee submits the following report of progress, presenting additional references with annotations.

OFFICE PROCEDURE

Reprographics, September 1974, page 13, "Pre-printed Overlay Film Saves Drafting Time."

A forward-looking manager will always look for new techniques that eliminate repetitive drafting chores.

Modern Office Procedures, June 1974, "Calculators: More for the Money;" "Jackets: A Compact Way to Dress Up a File System."

Reprographics, October 1974, page 4, "Reprographics Techniques—Basic Photofabrication Terminology."

A new concept involving the production of parts through the use of chemical rather than physical action.

Reprographics, October 1974, page 11, "Quantity Production of Computerized Engineering Drawings."

Substitution of keyboards and lightpens for pencils and straightedges.

Modern Railroads, February 1975, pages 51–53. "What Price Money."

This article focuses on the problem of how can railroads carry and finance debt at 12% when they are only earning 4%.

Progressive Railroading, March 1975, pages 31–34. "The Future of Engineering—M/W Management."

The key to understanding our present position and future expectations is to acknowledge that certain management techniques will be needed.

Report on Assignment 5

Application of Data Processing

A. P. Hammond, Jr. *(co-chairman, Subcommittee on Accounting Phases)*, C. J. McDonald *(co-chairman, Subcommittee on Engineering Phases)*, C. E. Bynane, R. H. Campbell, C. R. Dolan, R. L. Ealy, W. V. Eller, G. R. Gallagher, J. G. Kirchen, W. F. Liszewski, J. B. Styles, H. R. Williams.

METHODS OF ALLOCATING RECORDED COSTS TO REPORTED UNITS IN THE TRACK ACCOUNTS

The compilation of ledger values for the track accounts is becoming increasingly burdensome. It is recognized throughout the industry, particularly by those in valuation and property accounting work, that steps must be taken to develop a less complicated, yet acceptable, method of compiling these ledger values.

A simplified method of allocating costs recorded in the books of accounts to the reported track account units, or so-called "average pricing," is considered to be the best solution to the problem. In selection of a system, the units to be used and the method of developing the unit cost to be applied will vary for different carriers depending upon the type and condition of the basic record and the detail reflected therein.

This report is presented as a brief summary of the answers to a questionnaire submitted to members of the full committee.

1. The valuation section was selected as the primary segment for balancing costs and averaging unit costs.
2. Most members recommend allocating average unit costs on a weighted basis to main tracks, branch lines and side tracks by valuation sections to units in the track accounts.
3. Nearly all the members responding would compile actual units of Account 3, Grading, for ledger value purposes and several would do the same for Account 11, Ballast, due to the wide variation used in construction. The majority of the members would consolidate units by rail pattern weights or by homogenous rail groups for the other track accounts. Most carriers who maintain detailed track records would continue to use actual recorded quantities in allocating average unit costs to develop ledger values.
4. Establishing units for controlling averages in the track accounts other than Account 10, Other Track Material, poses little difficulty. The same results can be obtained whether units such as cubic yard, each, mbm., cwt., gross ton, net ton, track foot, track mile, etc. . . . , or combinations such as gross ton per track mile are used. Account 10, Other Track Material, has numerous minor units currently recorded in the property records, and most members recommend consolidating these units into a few major units for controlling averages. Three possible units are:
   (a) Rail displacement materials . . . unit each or cwt (includes frogs, switches, crossing frogs, etc.).
   (b) Track fastenings . . . unit each or cwt (includes joints, tie plates, anchors, etc.).
   (c) Other items . . . unit each or cwt (includes bumping posts, rail flange lubricators, etc.).

In conclusion the committee believes that there is a need for a pricing system to be developed entailing the restructuring of valuation, field and accounting reporting. These reports must interface with the computer in order to produce the required records, controls and reports.

Report on Assignment 6

Valuation and Depreciation

C. E. Bynane *(chairman, subcommittee)*, J. R. Cressman, W. V. Eller, G. R. Gallagher, L. F. Grabowski, M. J. Hebert, P. J. Hendricksen, E. H. Hofmann, P. R. Holmes, N. J. Hull, Jr., R. D. Igou, J. G. Maher, D. C. Maris, P. G. McDermott, C. J. McDonald, S. Miller, Jr., J. B. Styles, H. R. Williams.

(A) CURRENT DEVELOPMENTS IN CONNECTION WITH REGULATORY BODIES AND COURTS

ICC Bureau of Accounts

During the fiscal year 1975 the Commission continued its five-year cyclical review of equipment depreciation and the Accounting and Valuation Board issued 32 railroad equipment depreciation orders. Depreciation analyses of all road property accounts for all eligible Class I railroads were completed during fiscal 1975 and 51 railroad road property depreciation orders were issued.

The road property depreciation analyses of all eligible Class I railroads reinforced the tentative findings of the fiscal 1974 study for 14 Class I carriers in that the results were in line with expectations, and the anticipated large deficiency in past accrued depreciation has not developed. As mentioned in last year's report of this subcommittee, problems with salvage determination and experience were particularly troublesome in the deprication analysis and the chief of the Depreciation Branch has advised the chairman of this subcommittee that he would welcome input from Committee 11 members on their views with respect to a more satisfactory method of accounting for salvage proceeds.

As information, an Interim Coordinator's report on Ex Parte 271, Net Investment—Railroad Rate Base and Rate of Return, by Commissioner Dale W. Hardin was issued on March 3, 1975, 345 ICC 410, and summarizes the findings of the preliminary analysis of the 1974 road property depreciation study for the 14 Class I railroads. The report is well worth reading, particularly with respect to the discussion about Accounts 3, 5 and 39 (grading, tunnels and subways, and public improvements—construction).

Internal Revenue Service

Closely related to the discussion about Accounts 3 and 5 in the above-mentioned Coordinator's report to the ICC is one of the issues decided in favor of the taxpayer, Chesapeake & Ohio Railway and affiliated companies versus the Commissioner of Internal Revenue, Docket Nos. 5904–70, 5646–71.64 TC-No. 35, filed June 2, 1975, wherein it was decided that petitioner's (C&O) investment in grading and tunnel bores had, as a result of obsolescence foreseeable in 1954, reasonably determinable useful lives such as to entitle petitioner to depreciation deductions for such investment in tax years 1954 through 1963.

In the same decision there are two other subjects treated and decided, one being ratable depreciation of track structures based on obsolescence foreseeable in 1954 wherein the taxpayer's petition for such deduction was denied, the other subject being the determination of the fair market value of petitioner's recovered reusable rail wherein the court developed its version of a compromise between the IRS and petitioner's versions which produced an interesting and apparently favorable result for the petitioner.

The above-mentioned decision in full is recommended reading for everybody interested in valuation and depreciation.

Report on Assignment 7

Revisions and Interpretations of ICC Accounting Classifications

J. G. KIRCHEN *(chairman, subcommittee)*, J. M. BOURNE, J. R. GEARY, N. J. HULL, G. F. INGRAHAM, J. W. KELLY, W. F. LISZEWSKI, J. G. MAHER, D. C. MARIS, P. G. MCDERMOTT, J. MCKEAGUE, S. MILLER, P. W. ROBERTS, T. A. VALACAK.

This is a progress report, presented as information, on changes affecting engineering records and property accounting only.

ICC Order No. 32153 (Sub. No. 5) with a service date of January 22, 1975, Accounting for Accumulated Depreciation on Improvements to Leased Property, establishes a new and separate Account 733, Accrued Depreciation; Improvements on Leased Property, and transfers these amounts from Account 785 which now is Accrued Liability; Leased Property, and will include only the lessee's unsettled liabilities to the lessor. Effective January 1, 1975.

Notice of Proposed Rulemaking and Order No. 36125 with a service date of April 11, 1975, Reporting Extraordinary, Unusual or Infrequently Occurring Events and Transaction; Prior Period Adjustments; the Effects of Disposal of a Segment of a Business. These include instructions for clarifying the criteria for extraordinary items, for prior period adjustments and reporting rules for certain accounting changes and provides new guidelines for determining materiality. Also, definitions for a segment of a business and related accounting terms and instructions for reporting the operating results and gain or loss on disposal of a segment.

Notice of Proposed Rulemaking and Order No. 36137 with a service date of May 20, 1975, Revision of Rules on Classification of Carriers. This proposal would increase the minimum railway operating revenue from $5 to $10-million for Class I carriers and establish time period for qualifying and changing classifications.

Notice of Proposed Rulemaking and Order No. 36141 with a service date of April 1, 1975, Corporate Disclosure Regulations, would require carriers to reveal in their annual reports details of their parents and subsidiaries, who votes their common stock, business affiliations of the company's principal officers and executives and details of long- and short-term debt and financing lease arrangements.

Report of Committee 14—Yards and Terminals

B. H. Price, *Chairman*

P. C. White,
Vice Chairman

G. H. Chabot, *Secretary*

R. F. Beck
H. L. Bishop
J. F. Chandler
H. B. Christianson
A. W. Niemeyer
C. E. Stoecker
P. E. Van Cleve
J. Zaenger
R. P. Ainslie
M. J. Anderson
J. K. Aust
R. O. Balsters
A. E. Biermann
W. O. Boessneck (E)
R. O. Bradley
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Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

The committee has completed its work on the revision of Chapter 14 of the Manual, and properly voted on and approved the revision by letter ballot. The revised material is published in Part I of this Bulletin. Revision of the glossary, as it pertains to Chapter 14, is now in progress.

1. Classification Yards:
   (a) Gradients for Flat and Saucer Yards.
   Final report, submitted as information, with the recommendation that it be considered as possible future Manual material ...... page 280
   (b) Yard and Terminal Design Criteria to Decrease Car Detention.
   Final report, submitted as information .... page 283
2. Bulk Material Handling System, Collaborating as Necessary or Desirable with Committees 6, 8 and 15.

Work is progressing on this subject but no report will be available for at least a year. The committee has expressed willingness to present an illustrated feature on this subject at the Annual Technical Conference in March.

3. Terminal Facilities for Handling Solid Waste Material from an Ecology Standpoint, Collaborating as Necessary or Desirable with Committee 13.

   No progress has been made on this subject since it was assigned. However, a new subcommittee chairman has been appointed and it is anticipated that substantial progress will be made in the next year.

4. Car Rollability Research.

   There has been no activity concerning this subject pending further advice and direction from the Association.

5. Trends in Intermodal Facilities.

   Progress is being made on this subject and it is anticipated that the subcommittee will make its report in 1976.

6. Facilities for Line Repair and Servicing of Diesel Locomotives, Collaborating as Necessary or Desirable with Committees 6 and 13.

   A preliminary report has been written and is being revised. The report on this subject should be submitted to the Association in 1976.

7. Yard System Design for Two-Stage Switching.

   No progress to report on this subject at this time.

THE COMMITTEE ON YARDS AND TERMINALS,
B. H. PRICE, *Chairman.*

Report on Assignment 1a

Gradients For Flat and Saucer Yards

P. E. VAN CLEVE *(chairman, subcommittee)*, R. O. BALSTERS, R. F. BECK, R. E. BREDBERG, C. M. BURNETTE, G. H. CHABOT, D. V. CLAYTON, A. V. DASBURG, F. D. DAY, P. J. DEIVERNOIS, JR., R. D. DYKMAN, J. N. HAGAN, D. C. HASTINGS, L. J. HELD, F. A. HESS, J. B. KERBY, J. A. LEMAIRE, B. H. PRICE, JR., R. J. SAMOSKA, P. C. WHITE.

This progress report is submitted as information, for possible future Manual material.

This report is confined primarily to the "flat" or "saucer" yard, where cars are classified by the shuttling movement of the switch engine, with the cars being "drilled" or "kicked" to roll freely into the classification tracks. Not included in the scope of this report are the retarder-less low hump yard or the flat yard where cars are shoved to rest.

While the flat and saucer yards (hereafter referred to collectively as flat yards) far outnumber any other type of yard in use, apparently only a few were constructed with gradient design as a primary consideration. In most cases, the apparent overriding factors were such things as topographical restraints, grading costs, space limitations, and conformance with fixed elevations, such as adjoining main-line profile and public grade crossings.

An analysis of subcommittee member responses to this assignment indicates that during the past decade or two greater emphasis has been placed on designing and building flat yards with optimum gradients for switching.

A review of flat yards where gradient has been a major design factor indicates the following preference for gradients in the direction of switching (see Figure 1):

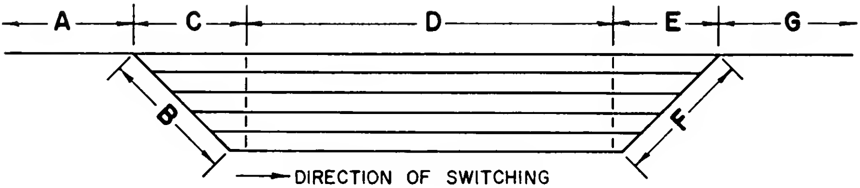

FIGURE I. Flat Yard for Single Direction Switching

Segment A—Switching Lead (or Drill Track). Gradient here is not critical since cars are normally released on or close to the ladder (Segment B). However, since this segment accommodates constant bi-directional movement, the gradient should be relatively flat, with 0.00 percent preferred.

Segments B and C—Ladder and Switch to Clearance Point. The preferred gradient is "slightly" accelerating, which means that the grade must descend sufficiently to overcome rolling resistances, including switch and curve resistance. The preferred gradients for these segments range from –0.20 percent to –0.30 percent, although one railroad used a 0 percent grade for the ladder, probably on the premise that cars would be released near the switch of their classification track.

Segment D—Clearance Point to Clearance Point. The preferred design gradient for this segment is "slightly" decelerating, ranging from –0.10 percent to 0.00 percent.

Segments E, F, G—"Leaving" End of Yard. Segments E and F should have sufficient plus gradient to prevent roll-outs, and thus minimize the need for retarders or skates. The percent gradient selected is not too important if the yard is to be used only for single-direction switching.

However, when conditions permit, it is highly desirable to design a flat yard for switching at both ends, even when current operations might not require double-end switching. Thus, the flat yard for double-end switching would have gradients G, F, and E, the same as A, B, and C, respectively, and gradient D would be either level or slightly descending from each end toward the center. The yard profile would resemble a saucer.

While the Manual for Railway Engineering contains virtually no design information for flat yards, the engineer can and should review the section of the Manual on hump classification yard design, as much of this material can be applied to flat yard design. Having done this, a summary of the primary considerations for flat yard design is as follows:

1. Objective

The ideal objective is the design of a series of gradients so that each car will roll to and stop at the far end of the classification yard, or will roll to coupling at an acceptable speed. The following objectives are the minimum to be expected:

(a) Deliver cars having a practical maximum rolling resistance to the clearance point under adverse weather conditions.

(b) Deliver cars of most frequently occurring rolling resistance to the far end of the yard, or to some desired intermediate point, if block size does not require filling the track.

(c) Permit maximum switching rate and acceptable coupling speeds.

2. Rolling Resistance

The designer must be familiar with car rollability and the factors which contribute to rolling resistance. The yard gradients must be tailored for the prevailing climatic conditions, including wind speed, wind direction, temperature, rain and snow. Gradients must be compensated for resistances from turnouts, curves, gage, and possible track irregularities.

3. Equipment and Commodities

The designer should be familiar with the type of equipment to be used and commodities to be handled. A predominance of roller-bearing or non-roller-bearing cars will affect gradient selection. In a yard where mostly empty cars or bulk commodities are handled, it is possible that gradients can be increased, thus creating higher impacts, but increasing the percentage of cars that will couple.

4. Yard Configuration

If possible, a track should be designated for each classification to be made. However, it should be remembered that a flat yard is best suited to a situation where the number of switching cuts is small. While fairly large volumes of cars can be handled in a flat yard, a large number of cuts reduces its effectiveness.

Body tracks should preferably be on tangent and of sufficient capacity to hold the volumes of each classification under normal circumstances.

Ladders should be designed to minimize distance to clearance point, and provide maximum yard capacity. Switches should be as close together as possible for efficient hand throwing. Multiple frog angle ladders allow the designer to provide a compact layout; however, when hand throw switches are used, the layout must be such that all switch stands are on the outside of the ladder. Inside switch stands should be used only when push-button power switching is provided.

5. Gradients

In a flat-yard drilling operation, the car when it is uncoupled is not unlike the car leaving a group retarder in a hump yard, in that each car has just departed from its last point of human control. Hence the basic design formula for the hump yard from group retarder to clearance point could be applied to flat yard design, as follows:

Drop from uncoupling point to clearance point $= SR_e + \Delta C + SW + a$

where

S = Distance in feet

R_e = Rolling resistance for easy rolling car expressed decimally

Δ = Curvature in degrees of central angle

C = Curve resistance in feet of drop per degree of central angle

Sw = Switch resistance in feet

a = Difference in velocity head at clearance and velocity head at uncoupling point for easy rolling cars.

The gradients in the body tracks must not produce unacceptable acceleration of easy-rolling cars.

6. Drainage

The flat yard will have a natural tendency to contain water, since its profile will usually take the shape of a saucer. Good drainage is imperative to maintain good track grade, alignment and structure. In most cases, a subsurface drainage system will be required, unless the subgrade is very porous.

Report on Assignment 1b

Yard and Terminal Design Criteria to Decrease Car Detention

R. F. Beck *(chairman, subcommittee)*, R. P. Ainslie, C. M. Burnette, G. H. Chabot, H. B. Christianson, D. V. Clayton, A. V. Dasburg, F. D. Day, P. J. DeIvernois, Jr., J. N. Hagan, D. C. Hastings, F. A. Hess, C. F. Intlekofer, J. B. Kerby, J. A. LeMaire, S. J. Levy, E. T. Lucey, J. G. Martin, H. J. McNally, W. L. Patterson, B. H. Price, W. A. Schoelwer, J. G. Skeen, W. D. Slater, C. E. Stoecker, L. G. Tieman, H. Watts, P. C. White, J. R. Zebrowski.

This report is submitted as information, with the recommendation that the subject be discontinued.

The basic fundamentals of good yard and terminal design have not changed throughout the years. Newer operating and organization concepts, together with the introduction of sophisticated equipment, provide us with an opportunity to increase operating efficiency, thus decreasing car detention time. However, the basic fundamentals of yarding the train, classifying the cars and departing the train in the minimum amount of time and at the least cost have not changed. Therefore, the criteria for yard and terminal design cannot concern itself solely with the physical plant, but must also include the design of the organization and the operating plan. In other words, the design criteria must be viewed as a major system with both the designer and operator playing an integral part. Failure of any one of the many subsystems can increase car detention time, and this important concept must be recognized by all concerned.

Continuous new developments in the data processing field, together with newer organization concepts have made possible computerized, real-time car movement and information systems. Railway operations are a fertile field for this new technology and substantial progress can be made in operating efficiency, thus reducing cost and at the same time improving customer service. Movement of cars through the receiving, classification, and departure functions is an integral part of such a system. Such a system maintains a perpetual inventory of cars by track location in which all cars are under the constant surveillance of the system, thus providing for maximum car utilization. Car information and location on a real-time and exception basis are immediately available via an increasing variety of output devices which are an indispensable aid to the planning process. Such systems also permit the exercise of overall control of yard and terminal operations and can be made an integral part of a railroad-wide management information system. The key to the success of such systems is the development of a complete and dependable car record as soon as possible. This is of paramount importance because such information is vital to the financial, statistical, cost, traffic, accounting and other staff functions.

The computer and related interface equipment have made possible the virtual complete automation of the entire classification operation. Automatic car identification coupled with mini-computers and other devices can automatically input car information into the system. Thus the complete control of receiving, classification and departure operations becomes but a subsystem of the overall car movement and information system.

The following overall and specific criteria should be considered when attempting to reduce car detention time. All of the items listed may or may not bear on any particular installation depending upon the type of facility being studied. The following information also directly relates to flat yards although some modification of the criteria may be required.

I. Determine Workload for the Terminal

A. Forecast rail network transport demand.

B. Estimate demands on the terminal:

1. Number and size of car blocks.
2. Train schedules.
3. Interchange, industry, intermodal and other services.

II. Overall Design Considerations Relating to Terminal Operations

A. Avoid interference between movements, minimize total car movement, and optimize all transportation operations:

1. Track and related facilities:
    - (a) strategically located crossovers, connections, leads, and tracks,
    - (b) ample running tracks and escape routes for arriving, switching, classification, departure, and other movements,
    - (c) dual hump tracks and scissor crossovers,
    - (d) remote control power operated switches, route control, shove indicators, and signaling,
    - (e) track facilities for special transportation functions including auxiliary, local, through yards, etc.,
    - (f) sufficient space between tracks for yard lighting, specialized equipment, car inspection, and running repairs,
    - (g) space for expansion,
    - (h) dragging equipment and broken flange detectors, journal and track oilers,
    - (i) movement sensors, automatic car identification and blue flag systems,
    - (j) yard cleaning equipment, switch heaters, snow blowers, and related snow removal equipment.

2. Ancillary facilities:
    (a) lighting for safe and optimum night operations,
    (b) towers and control facilities to monitor and manage operations, combined where possible, to avoid duplication,
    (c) communication systems including radio, loudspeakers, pneumatic tube systems, digital displays and printouts, television and teletype,
    (d) roadways, parking areas, drainage, noise and pollution control, sewage disposal, water supply, fire protection, etc.,
    (e) engine and caboose servicing, car repair, car cleaning, piggyback, refrigerator servicing and other facilities at strategic locations,
    (f) crew, office, and miscellaneous buildings,
    (g) noise level and other environmental considerations.
3. Speed the movement of cars through receiving, classification, departure and other terminal yards and tracks:
    (a) computerized automatic humping, switching, speed control, weighing, distance to go, etc.,
    (b) real time and historical digital print and readouts of all car movement information required by transportation operation,
    (c) all car movement information required by other departments,
    (d) automatic trouble-shooting information.
4. Reliable facilities:
    (a) easy to maintain facilities, holding down time to a minimum,
    (b) level of maintenance to limit derailment and program downtime of facilities based upon an overall sound preventive maintenance program,
    (c) backup systems in important areas such as power supply, communications, and computer systems,
    (d) safety and security of operation.
5. Trained personnel and the simplest operating procedures and equipment.

B. Use two stage or other forms of multiple pass sorting wherever:
1. The desired number of blocks greatly exceeds the number of available classification tracks, or
2. Numerous blocks are desired for a train.

III. Specific Design Considerations Relating to Car Movement

A. Receive cars quickly with minimum interference:
1. Track design to avoid interference between moves.
2. Sufficient trackage for near-peak requirements.
3. Tracks of sufficient capacity to avoid doubling.
4. Alignment and gradients to eliminate derailments and runouts.

B. Classify cars at a maximum practical rate consistent with the overall transportation operations:
1. Weigh cars accurately and economically without slowing the humping rate.
2. Avoid catchups in the classification area:
    (a) bleed cars thoroughly to avoid sticking brakes,
    (b) speed movement throughout all classification tracks as much as possible,
    (c) multiple cuts, where permissible.

3. Utilize the best economical track arrangements, gradients, and control systems based upon AREA recommendations taking into account:
    - (a) wind, temperature, snow, sleet, fog, moisture, storms,
    - (b) type of traffic including long, short, empty and loaded cars,
    - (c) range of rolling resistance,
    - (d) predominance of resistance for type of cars handled,
    - (e) easy separation of cuts,
    - (f) minimum distances between crest and clearance points, utilizing lap switches,
    - (g) capacity of retarders to handle design parameters,
    - (h) capacity of control system and components,
    - (i) track curvature,
    - (j) starting cars that have been stopped in the retarders.
4. Release cars from retarders at speeds consistent with minimum car and lading damage:
    - (a) use of decelerating gradients immediately beyond the group retarders with as short a switching length as possible with maximum turnout speeds,
    - (b) design for as low a curvature as possible together with the optimum number of tracks per group consistent with the foregoing,
    - (c) provide non-accelerating gradients on tangent track for preponderance of cars humped,
    - (d) provide devices to assist cars around curves to help reduce the range of rolling resistance,
    - (e) deliver cars to clearance point at the most advantageous speed,
    - (f) design for optimum track length in classification yard consistent with operating requirement keeping in mind the range of rolling resistance.

C. Provide for as continuous a classification operation as practical by considering:
1. Interference between road, yard, and hump engines.
2. Travel time between receiving yards and the hump lead.
3. Time between successive cuts on the hump lead.
4. Escape routes for trimmers and other moves from the hump end.
5. Caboosing time through efficient track layout and servicing facilities.

D. Reduce hump engine trimming time to an absolute minimum:
1. Classify cars to the correct track.
2. Minimize catchups by correct design and control systems.
3. Assign classifications to serve the maximum spread of cars being humped.
4. Provide an optimum number of classification tracks.

E. Remove cars and trains from the classification yard promptly:
1. Skates, retarders, uphill gradients or other means of avoiding runouts.
2. Recoupling aids to keep couplers open.
3. Long leads to interior of groups to speed up operation and reduce travel time. Design leads to minimize travel time in pull down operations.
4. Coordinate all mechanical and transportation departure functions, preferably from one location.
5. Track centers as wide as possible to permit mechanized inspections.
6. Sufficient yard air.
7. Efficient waybill procedures.
8. Track facilities similar to those recommended for receiving yards.

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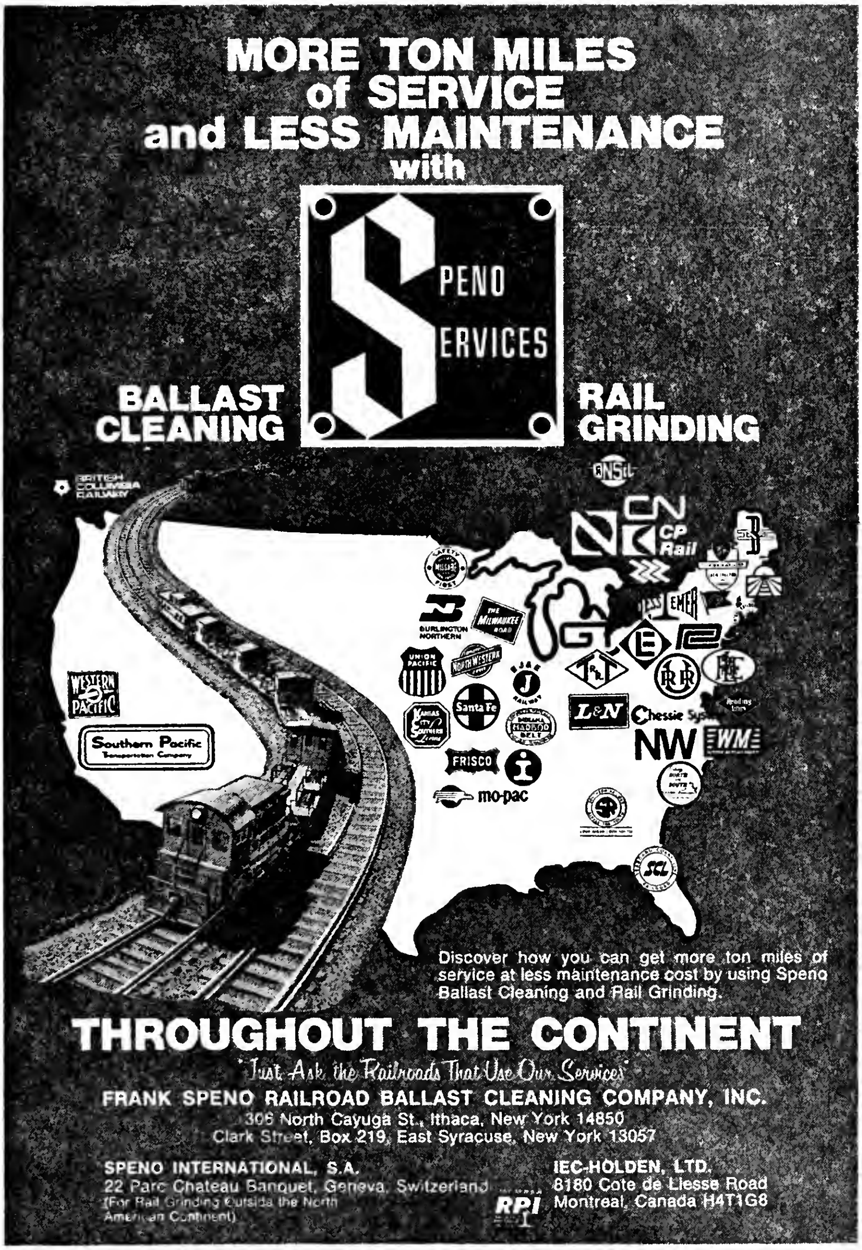

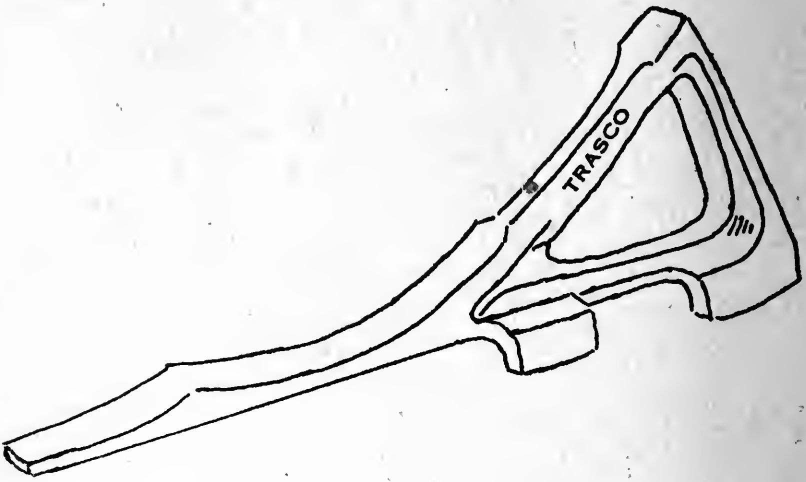
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J. E. Stallmeyer

American Railway Engineering Association—Bulletin

Bulletin 656 **January–February 1976**
Proceedings Volume 77*

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REPORTS OF COMMITTEES

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* Proceedings Volume 77 (1976) will consist of AREA Bulletins 654, September–October 1975; 655, November–December 1975; 656, January–February 1976; and 658, June–July 1976 (Technical Conference Report issue). Blue-covered Bulletin 657, April–May 1976 (the Directory issue), is not a part of the Annual Proceedings of the Association.

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Committee

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
Proposed Belt Conveyor Scale Rules, submitted as information ..... page 288

1. Location of Scales for Coupled-in-Motion Weighing.
Progress report, presented as information .... page 295

2. Survey of All Scales in America Used for Weighing Railroad Cars.
No report.

3. Statistical Data for Coupled-in-Motion Weighing and Testing.
An advance report on this assignment was published in Bulletin 654, September–October 1975.

4. NBS Handbook 44 Joint Study with State Weights and Measures Officials.
No report.

The Special Committee on Scales,
F. D. Day, *Chairman.*

Report on Assignment B

Revision of Manual

L. L. Lowery *(chairman, subcommittee)*, all members of the Special Committee on Scales.

Your committee presents, as information only, the following belt conveyor scale rules. These rules, with possible minor revisions, will be submitted for adoption and publication in the Manual in 1976, following letter ballot approval by the committee.

PROPOSED BELT CONVEYOR SCALE RULES

S.2.28 BELT CONVEYOR SCALES

S.2.28.1 Definition

The following is intended to apply to devices installed on belt conveyors for the purpose of weighing bulk materials carried by conveyors to ascertain weights, and to the system to which they are applied and become part of.

S.2.28.2 Capacity

The system should be designed and rated so that material flowing over the scale will remain within 50% to 98% of scale capacity and should be adequate and constant.

S.2.28.3 Conveyors

(a) Each conveyor on which a belt scale is located should be rigid in design and so constructed that it is free from vibration and is not subject to stress that would cause any deflection. It should not exceed 1,000 ft in length from center of head pulley to center of tail pulley.

(b) Each conveyor on which a belt scale is located should be equipped with a gravity take-up that is of adequate weight so as not to allow slippage of the belt on the drive pulley. With such weight properly weighted, the belt should remain in contact with all troughing idlers in the weight-sensing element area at all times.

(c) The conveyor on which the scale is located should be free from interference from all other operations.

(d) The system should be so designed that the complete contents of each individual car may be guaranteed to pass over the scale.

(e) Incline of the conveyor belt should not be in excess of 18 to 20 degrees.

S.2.28.4 Infeeds

(a) Sufficient impact idlers should be provided in the conveyor under each infeed so as not to cause a deflection of the belt during the time material is being introduced.

(b) All infeed gates, feeders, etc., should be positive in action and so designed that material will flow freely through them when opened or placed in operation. They should also be positive in their closing action so that leakage does not occur.

S.2.28.5 Instrumentation

(a) A rate-of-flow indicator should be installed and correctly calibrated. The indicator should also be equipped with a 24-hour disc or strip chart to serve as a permanent record, along with a high and low cut-off alarm system. This is to help prevent under or overloading of the scale. The alarm should be operational at not lower than 35% or greater than 98% of scale capacity. The type of alarm used (i.e., audio or visual) should be determined by the merits of each individual application. Such system should not be outfitted with a switch to disconnect either the chart or alarm system. Any exceptions to this rule will be at the discretion of the serving rail carrier or its agent.

(b) A fast-count totalizer should be installed and should register in units of 1/10 of a ton, or as determined by the serving rail carrier.

(c) A ticket or tape printer (determined by each individual application) and printing to the equivalent numerals as indicated in (b), should be installed. It is essential that the printer mounting will guarantee vibration-free operation.

S.2.28.6 Cabinets

(a) Scale and instrumentation cabinets should be purged with clean, dry air.

(b) Where scales and component parts are subject to a rapid or extreme change in temperature, heaters should be installed as suggested by manufacturer.

(c) Scales located near large bodies of water, operations that require use of quantities of water, or any area of high humidity, should have heaters installed in scales and/or instrumentation as suggested by manufacturer.

S.2.28.7 Protection of Scales and Instrumentation

(a) Scales and especially instrumentation should be protected from the elements by weather-proof structures. Control rooms that house instruments should be air purged with air conditioning, fans with filters, heaters, etc., so that a dust-free area of greater density will be created on the inside than is outside. Such system is required to preserve all electronic instruments.

(b) Scale housing and instrumentation should be securely locked.

S.2.28.8 Wind Screens

Wind screens should be erected around the entire weighing element.

S.2.28.9 Guards

(a) Sufficient guards should be erected around "live" scale parts located near walk-ways so that persons will not touch such parts or deposit equipment in their vicinity.

(b) In some cases, "live" parts of scales should be painted in contrasting colors so as to warn persons against touching them. The application of this Rule will be at the discretion of the serving carrier or its agent.

S.2.28.10 Interference

Hydraulic machinery, large motors, or any equipment which will cause excessive vibration or noise should not be placed in, or affixed to, the control room.

S.2.28.11 Access to Scale

Adequate access to scale should be provided. This includes a walk-way, step, etc., so that servicing can be accomplished with ease.

S.2.28.12 Simulated Load Testing Equipment

Adequate simulated load testing equipment, to be applied on the belt over the weight-sensing element, approximating 80% of the rated capacity of the weighing system, is required. A suitable storage area should be provided so that such equipment does not rust or deteriorate from abrasive or coating action. See S.2.28.15.

Note: The following suggested practices, if followed, will greatly facilitate testing and operation of the system.

1. At least two persons or more on location should be thoroughly familiar with the scale and its operation.
2. Control over entire system should be exercised by the scale operator to insure adequate loading of the weighing device.
3. Unauthorized personnel should be discouraged from loitering in the scale and instrumentation areas.
4. Where test chains are used, adequate cables, bridles, hooks, etc., should be provided to hold the chains in place on the belt as recommended by the scale manufacturer.

S.2.28.13 Tolerance Values

(a) Material Test Tolerance

All belt scales should be material-tested and adjusted to within 0.25% with repeatability. The spread between plus or minus figures should not exceed 0.25%.

(b) Maintenance Tolerance

All belt scales should maintain a 0.5% tolerance between material used. The spread between plus or minus figures should not exceed 0.5%.

(c) Zero Tolerance

All belt scales should maintain a zero balance of 0.1% for 10 minutes before use, and after sufficient warm-up of the belt.

(d) Repeatability Tolerance

All belt conveyor scales using simulated load testing equipment should be tested for a repeatability of not greater than 0.1% for at least 5 consecutive tests. The spread between plus or minus figures should not exceed 0.1%.

S.2.28.14 Types of Tests Defined

(a) Material Testing

All belt conveyor scales should be material-tested before acceptance. Three to five such tests are required, with 10 to 15 car (or in some cases heavy truck) loads per test. If the weighing system is designed for individual car weights, the weight of each individual car should be in tolerance.

(b) Maintenance Testing

All belt conveyor scales should be maintained within a 0.5% tolerance between material tests, by using a simulated load test. Such tests should be conducted on a weekly basis, preferably as soon after actual use of the belt as possible.

(c) Repeatability Test

All belt conveyor scales should be tested for repeatability each time a Maintenance Test is made and before Material Tests are run.

S.2.28.15 Standard Procedure for Tests

(a) Scale and entire installation should be checked for conformity with the above-listed rules and regulations. The scale and all component parts should be completely installed and in good operating condition before any tests will be made.

(b) The belt length and weight of chains per foot should be accurately measured so as to determine tons per foot of belt travel during chain tests.

(c) The belt should be run at least 20 minutes before test begins in order to warm it up. At temperatures below 40 F, the warm-up time should be of longer duration.

(d) Following warm-up, belt should be run for at least 10 minutes to determine zero of scale. During this time, the zero reading should be constant.

(e) After establishing that the scale holds its zero, 10 circuits of the belt should be run with the simulated load testing equipment in place on belt. In some instances, where the belt is long, only three circuits of the belt are required.

If test chains are used, they should be held securely in place on the belt as the scale manufacturer recommends.

If tests utilizing other than the above methods are contemplated, the approval of the serving rail carrier or its agent should be secured.

Note: When other than test chains are used, only idlers of the highest quality and requiring lubrication daily should be used. Such idlers should be installed on the weighing element and for at least five idler spaces before, and for at least five idler spaces after, the weighing element. Further, each week correct idler level should be determined with a string level. If any one, or more, of the above named idlers are out of level, the scale should not be used until correction is made. Idlers with worn bearings should be replaced.

(f) Five more simulated load tests should then be run, with results of each test reading within 0.1% of the first test outlined in paragraph (e) above. This will establish repeatability.

(g) If the scale has repeatability, 15 loads should then be weighed over the scale, at 50% to 98% capacity. A load is construed as a rail car load or truck load of high capacity.

Note: In instances where procurement of rail cars proves difficult, 10 loads per test may be substituted. This is a calibration test and may have to be made several times in order to bring the weighing device within the acceptable tolerance of 0.25%.

(h) After the scale has been properly calibrated, three separate material tests, all within 0.25% with material being loaded at 50% to 98% of capacity, should then be made. Each test should consist of 15 loads. (Here again 10 loads per test may be substituted in the event rail cars are difficult to obtain.)

(i) Following three successful material tests, five simulated load tests should again be made in order to establish a calibration factor, if needed.

(j) On successful completion of all tests, the scale should again be checked for zero. At this time, it will also be established that a service contract has been consummated with a qualified belt scale service organization.

(k) Material scale tests should be made once every six months, or as directed by the serving rail carrier or its agent.

(l) The material acceptance tolerance of 0.25% should be maintained for 30 days, and at any time the scale is overhauled or material tested by an authorized scale man.

(m) A maintenance tolerance of 0.5% should be maintained by the user at all times after the scale is accepted. This may be assured by conducting tests at least once a week as outlined in paragraph (i) above, using the established calibration factor.

(n) The rail carrier should be contacted at least two weeks before material tests are made to insure that sufficient cars are available.

(o) Copies of weekly tests should be made available to the serving rail carrier or its agent.

(p) Proof of weight for belt conveyor scales should be in the form of a printed weight ticket and rate-of-flow chart showing the scale was utilized between 50% and 98% of its capacity. The rate-of-flow chart should be dated corresponding with cars in loading or unloading sequence. All of these records should be preserved together.

(q) In instances where material testing can be satisfactorily performed weekly, Simulated Load Tests are not required. Copies of weekly tests, however, should be made available to the serving rail carrier or its agent. (See S.2.28.12)

Definition of Terms Used in Connection with Belt Conveyor Scales

AIR PURGE: The act of creating an atmosphere greater on the inside than outside, using clean, dry air, to discourage dust and other foreign matter.

BELT CONVEYOR: An endless moving belt for transporting material from place to place.*

BELT CONVEYOR SCALE; (BELT SCALE); (CONVEYOR SCALE): A device installed on a belt conveyor to measure the weight of bulk material being conveyed.*

BEND PULLEY: A roller placed on the return side (underside) of a conveyor belt to turn its direction or to measure speed of belt.

CABLE CONVEYOR: A belt conveyor utilizing cable or rope as the supporting member for the conveyor on which the idlers are mounted.

CALIBRATED PLATE: A suitable metal plate, provided by the scale manufacturer, determined to have the same effect on a nuclear scale as a specified load or bulk material on the belt conveyor. A calibrated plate is the equivalent of a test chain or test weights used with other types of belt conveyor scales.*

CHAIN: See *Test Chain.*

CHART RECORDER: A device used with a belt conveyor scale which records the rate-of-flow of bulk material over the scale at any given time. A recorded chart together with a record of weight constitutes proof of weight.

CONCAVE CURVE: A change in the angle of inclination of a belt conveyor where the center of the curve is above the conveyor.*

CONVEX CURVE: A change in the angle of inclination of a belt conveyor where the center of the curve is below the conveyor.*

CONVEYOR STRINGERS: Support members for the conveyor on which the idlers are mounted.

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* Taken from National Bureau of Standards Handbook 44.

Counter (Remote): A numerical display in a location remote from the scale showing the tons (or pounds) of material that have been conveyed over the scale.

Disc Chart: See *Chart Recorder.*

Drive: The device or apparatus used to transmit energy from a motor to move the conveyor belt.

Feeders: See *Infeed.*

Gate: See *Infeed.*

Gravity Type Wipers: A scraping or wiping device used to clean residue from the belt on the return side (underside) of the belt in the vicinity of the head pulley. The wiper is affixed to one end of an arm which has a weight hanging from the other end. The weight is such that the wiper is held against the belt.

Head Pulley: The pulley at the discharge end of the belt conveyor. The power drive to drive the belt is generally applied to the head pulley.*

Idler Space: The center-to-center distance between idler rollers measured parallel to the belt.*

Idler Frame: The frame or device which holds the idler rollers, affixed to the conveyor stringers.

Idler or Idler Rollers: Freely turning cylinders mounted on a frame to support the conveyor belt. For a flat belt the idlers may consist of one or more horizontal cylinders transverse to the direction of belt travel. For a troughed belt, the idler will consist of one or more horizontal cylinders and one or more cylinders at an angle to the horizontal to lift the sides of the belt to form a trough.*

Infeed: The gate, short belt, vibrator feeder, stroker feeder, etc., that deposits material on the belt conveyor to be weighed.

Integrator: The "heart" of the belt conveyor scale. A device which integrates the speed of the belt with the weight of the material to produce tons (or pounds) per hour. The integrator may be electronic or mechanical and may be one of numerous patented designs.

Lagged Pulley: See *Swedged Pulley.*

Loading Point: The location at which material to be conveyed is applied to the conveyor.

Master Totalizer: See *Totalizer.*

Nuclear Type (non-contract) Scale: A device consisting of a source of nuclear radiation and a detector for that radiation. Absorption of radiation determines the mass of the material passing between the source and the detector.*

Printer: A device used to imprint on tickets, tape, or other papers, the tons (or pounds) of material that have passed over the scale in a given time. (Such as per car or per train weights.)

Pulley: A cylindrical roller over which the belt passes to change direction, such as the head pulley or tail pulley or bend pulley.

Rate-of-Speed Detector: A device usually operated in conjunction with electronic load cell belt conveyor scales which transmits the speed of the belt to the integrator. Several types are in use, the most popular being either a small generator whose voltage output is in direct relationship to the speed of the belt;

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* Taken from National Bureau of Standards Handbook 44.

or a slotted disc mounted between a photo electric cell and light source which converts each pulse of light to an electronic signal to the integrator.

Rated Capacity: That value representing the weight that can be delivered by the device in one hour.*

Registration: The unit of weight in which the scale is calibrated, such as 5,000 lb, tons, long tons, metric tons, etc.

Rope Conveyor: See *Cable Conveyor.*

Simulated Weight Test: A test using artificial means of loading the scale to determine the performance of a belt conveyor scale.*

Skirting: Stationary side boards or sections of belt conveyor attached to the conveyor support frame or other stationary support to prevent the bulk material from falling off the side of the belt.* Usually used at infeeds.

Snubbed Pulley: See *Swedged Pulley.*

Stringer: See *Conveyor Stringer.*

Strip Chart: See *Chart Recorder.*

Strip Heater: A thermostatically controlled heading strip (usually of the Calrod type) used to heat the scale or component parts sufficiently to prevent condensation.

Swedged Pulley: A drive pulley with a vulcanized rubber coating molded in a high friction pattern to prevent slippage of the belt under load.

Swivel Idler: An idler frame pivoted in its center to the idler stringers so that it may change position. Tracking idlers are mounted beside the troughing idlers so that if the belt rides off center the pressure on the tracking idler forces the swivel idler to turn, thus realigning the belt on the conveying idlers.

Tail Pulley: The pulley at the opposite end of the conveyor from the head pulley.*

Take-up: A device to assure sufficient tension in a conveyor belt that the belt will be positively driven by the drive pulley. A gravity take-up consists of a horizontal pulley free to move in either the vertical or horizontal direction with the dead weights applied to the pulley shaft to provide the tension required. A jack or screw take-up consists of a device that must be manually adjusted to move the tail pulley to increase or decrease tension. A hydraulic take-up consists of hydraulic cylinders mounted on either side of both ends of the tail pulley. When properly activated, the hydraulic cylinders will move the tail pulley to increase or decrease tension on the belt.

Take-up Guides: Guides or tracks on either side of the gravity take-up weight to prevent horizontal movement of that weight.

Test Chain: A device consisting of a series of rollers or wheels linked together in such a manner as to assure uniformity of weight and freedom of motion to reduce wear, with consequent loss of weight to a minimum.*

Totalizer: A device used with a belt conveyor scale to indicate the weight of material which has been conveyed over the scale. The master weight totalizer is the primary indicating element of the belt conveyor scale. An auxiliary vernier counter used for scale calibration is not (necessarily) part of the master weight totalizer. Auxiliary remote totalizers may be provided. The totalizer shows the accumulated weight and may be non-resettable or may be reset to zero to measure a definite amount of material conveyed.

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* Taken from National Bureau of Standards Handbook 44.

Tracking Idlers: Usually small cylinders vertically mounted on shafts affixed to a swivel idler frame. The purpose is to allow the side of the belt to rub against the tracking idler, forcing the swivel idler frame to turn, thus realigning the belt.

Training Idlers: Idlers of special design or mounting intended to shift the belt sideways on the conveyor to assure the belt is centered on the conveying idlers.*

Tripper: A device for unloading a belt conveyor at a point between the loading point and the head pulley.*

Wing Pulley: A pulley usually used as the tail pulley, made of widely spaced metal bars in order to set up a vibration to shake loose material off the underside (return side) of the belt. The use of such a pulley is definitely not recommended unless the conveyor stringers under the scale are thoroughly braced with their own support.

Wiper: See *Gravity Type Wiper.*

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* Taken from National Bureau of Standards Handbook 44.

Report on Assignment 1

Location of Scales for Railroad Coupled-in-Motion Weighing

E. Szaks *(chairman, subcommittee)*, R. F. Beck, H. E. Buchanan, J. L. Dahlrot, O. C. Denz, J. L. Finnell, J. A. Hawley, I. M. Hawver, V. L. Lowery, E. J. Micono, N. S. Patel, K. D. Tidwell.

A SUGGESTED GUIDE FOR SELECTING A COUPLED-IN-MOTION WEIGHING SYSTEM SITE

The prerequisites in selecting a site for installation of a coupled-in-motion weighing system are those which will permit the entire train to be weighed to move over the predetermined point in such a manner that the effects upon weight transfer from car to car will be minimized in weighing functions. The train must approach the facility and move over the weighing device at a constant, steady speed of between 3 to 5 mph, but not to exceed 6 mph. The train should be moved over the facility in a slow, steady movement, that is, one in which the train is not being pulled with the (diesel) locomotive throttle in more than the first or second position, generating about 200 amp of power, so as to prevent the train being stretched severely. At the same time, the train should not be bunched, or shoved by its rear end, as a result of using either the independent or dynamic brakes. The train handling must be such as to prevent all slack action. All automatic air brakes and hand brakes on cars must be fully released.

The number of cars to be handled at a given time over the weighing device should be given careful consideration. The maximum number of cars to be handled in a single train may dictate the grade and curvature which can be tolerated to maintain the proper weighing speed, and at the same time cause cars to move over the device in such a manner as to produce acceptable results. Generally, the site selection should be such that the existing grade and curvature will so compensate for each other that cars will move over the device in a non-accelerating mode.

Additionally, the device should be located so that a train originating and having cars to be weighed would pass over the weighing device without change of consist or train-order standing. The foregoing condition is one requiring special consideration where car identification may become a concern. Bi-directional use of the device, either pushing or pulling, should be an item to be recognized.

The coupled-in-motion type of weighing requires a high standard of maintenance, in fact, a standard approaching perfection of maintenance work. The high standard of maintenance is necessary to insure that the approach and retreat, the ballasted track on either end of the device, and the weight or load-receiving elements will be stable in that the dynamics of moving cars will be minimized.

Before a site is definitely selected, a test train or trains having the proposed consist to be weighed should be run over the site. Observers on both the engine and on the ground should carefully check the actual train handling requirements at the proposed site.

It is desirable to prepare a questionnaire which might point out a number of items necessary to be considered for the proposed location of the weighing device. Questions contained in the evaluation are oriented to stimulate interest in planning for operating or transportation conditions, construction, maintenance and other factors which may have an effect upon the location of the weighing system. There are seven general scopes listed as items to be followed. These seven scopes are outlined as follows:

1. Train Handling

1.1. What will be the maximum number of cars handled in a train or cut of cars at one time?

1.2. What will be the minimum number of cars handled in a train or cut of cars at one time?

1.3. Can the train speed be reduced without use of the automatic air brake as the train approaches the scale site?

1.4. Must train be stopped before being weighed?

1.5. If stopped, can a speed of 5 mph be attained before reaching the scale site without slack action?

1.6. Will train brakes be fully released?

1.7. Can train speed be controlled using diesel dynamic brake?

1.8. Can train speed be controlled using diesel independent brake?

1.9. Will train be shoved by its rear end moving over scale?

1.10. Will train be bunched moving over track scale?

1.11. Will engineer use throttle to pull train over track scale?

1.12. Will engineer use more than throttle position No. 2 or about 200 amp power to pull train over scale?

1.13. Will train be stretched moving over scale?

1.14. If stretched, can vertical movement of couplers be observed?

1.15. Can slack action be prevented?

1.16. Will train drift over the scale site?

1.17. If the train is stopped on the scale for any reason, can it be started again without slack action?

1.18. If stop is made on scale, can the train be started without taking slack?

2. Train Operation

2.1. Will train be delayed approaching track scale due to train handling characteristics?

2.2. Will following trains be critically delayed?

2.3. Will opposing trains be critically delayed?

2.4. Does the track scale location permit holding a train to be weighed?

2.5. Does the track scale location permit holding a train that has been weighed?

2.6. Must all trains pulling over the track, pull over track scale? (Maximum speed 10 mph)

2.7. Will difficulty be encountered in train handling account of slack action, the result of grade conditions?

2.8. Will difficulty be encountered in train handling because of over-speed?

2.9. Will train stall on scale?

2.10. Is scale location desirable for bi-directional weighing?

2.11. Is scale location desirable for westbound weighing only?

2.12. Is scale location desirable for eastbound weighing only?

2.13. Will train consist be changed due to set-off westbound?

2.14. Will train consist be changed due to pickup westbound?

2.15. Will train consist be changed due to set-off eastbound?

2.16. Will train consist be changed due to pickup eastbound?

2.17. Will scale location adversely affect train operation beyond the scale site?

2.18. Will train operation leaving scale be adversely affected critically account of wet rail conditions otherwise not encountered?

3. Physical Characteristics

(Within 200 car lengths maximum cut or train length in both directions from track scale location)

3.1. Is grade satisfactory approaching scale? To satisfy 1.9 and 1.12.

3.2. Is grade satisfactory leaving scale? To satisfy 1.9 and 1.12.

3.3. Is track alignment less than 4° approaching the scale site?

3.4. Is track alignment less than 4° leaving the scale site?

3.5. Can a train or cut of cars move over the scale without the use of sand under the locomotive?

4. Easy Accessibility to Scale

4.1. During construction?

4.2. For daily maintenance?

4.3. For supervising operations?

4.4. To prevent vandalism?

5. Local Operations

5.1. Will scale location interfere with local or mine run operations?

5.2. Will scale location adversely affect local operations?

5.3. Does scale location require dead or running rail design?

6. Scale Geography

6.1. Will scale location interfere with operations during construction period?

6.2. Will scale be located so as to be affected by high water conditions?

6.3. Will snow conditions affect operation of scale?

6.4. Will winter snow and ice accumulation be controlled?

6.5. Can scale location be adapted to bi-directional weighing?

6.6. Will scale location permit push and pull weighing in both directions?

6.7. Is scale attendant required? Will remote ACI be used?

6.8. Is the use of a spring switch at the exit end of scale pullout track objectionable?

6.9. Will the scale be located within yard limits?
  6.9.1. Will the location of the device reflect delay to switching operations?

6.10. Will the scale be outside of yard limits?

6.11. Will operating, transportation or maintenance agreements enter into the selection of a scale site?

6.12. When the weighing system fails, what course of action will be followed? (Load Cells) (Cabling)
  6.12.1. Take trains to another location for weighing?
  6.12.2. Back train over the scale installation and attempt to rerun or reweigh?
  6.12.3. Hold train for scale to be repaired?

6.13. Is the location of the proposed scale proper from an operating standpoint?

6.14. Would another location of the proposed scale be preferred from an operating standpoint?

6.15. If another location should be considered, please explain.

6.16. What types of freight will be weighed on the proposed device?

6.17. What types of cars will be weighed?

6.18. Can weight, rate, freight charges and other information be applied to "waybill" without delay to the train?

6.19. Must a completed "waybill" document accompany the car after it has been weighed, or may it travel with another type of document?

7. Testing Requirements

7.1. Will device location permit testing at the required intervals without undue delay?

7.2. Are rail cars readily available for testing purposes?

7.3. Are crews readily available for testing?

7.4. Is a static scale readily available for coupled-in-motion testing procedures, if it be necessary?

7.5. Does the static scale used for comparison purposes meet a strain test of zero error?

7.6. Refer to AREA Manual, Chapter 14, Part S—Scales (1973), Items S.1.1 and S.1.1.2.

Report of Committee 22—Economics of Railway Construction and Maintenance

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Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
A complete revision of Chapter 22 of the Manual was published in Bulletin 645, November–December 1973. Portions of the new material were reviewed and revised during the past year, and the entire new chapter, as revised, has been approved by the Board of Direction. It will be issued in the 1975 Manual Supplement.

1. Analysis of Operations of Railways That Have Substantially Reduced the Cost of Construction and Maintenance of Way Work.
Progress report, submitted as information .... page 301

2. Study to Establish New Equated Mileage Parameters.
Study is in progress and will be continued.

3. Economics of Producing Continuous Welded Rail by In-Track Welding.
Study has been made and a report on this subject will be submitted in the committee's next report.

4. Use of Track Analyzer Car in Inspection of Track and Maintenance Planning.

   A progress report is being prepared.

5. Comparative Costs of Cleaning Ballast Vs. Ballast Replacement in Track Rehabilitation.

   Final report, submitted as information .... page 312

6. Economics of Installing Bonded Insulated Joints in Field Vs. Shop Fabrication, and Economics of Bonded Joints Vs. Field Welds to Connect CWR.

   Final report, submitted as information .... page 318

7. Determine the Economics of Work Equipment Vs. Small Machines or Hand Labor on High-Density Lines with Limited Track Time.

   No report.

THE COMMITTEE ON ECONOMICS OF RAILWAY
CONSTRUCTION AND MAINTENANCE,
H. C. MINTEER, *Chairman.*

Charles Ray Wright
1885-1974

Charles Ray Wright, retired assistant chief engineer of the former New York, Chicago & St. Louis Railroad (now part of the Norfolk & Western Railway), passed away at his home in Cleveland, Ohio, on September 4, 1974, at the age of 89.

Mr. Wright was born at Ravenna, Ohio, on June 10, 1885. He was educated in the public schools and the Case Institute of Applied Science and entered the service of the NYC & St L in the engineering department on April 16, 1906. After serving in various positions in the engineering department, he was appointed division engineer on September 15, 1919, serving in that capacity on several divisions until his appointment as assistant chief engineer on September 1, 1940. He retired on July 1, 1955, after more than 49 years of continuous railroad service.

Mr. Wright joined the AREA in 1920 and was for many years an active and valuable member of Committee 22. After his retirement, he was elected a Member Emeritus.

Report on Assignment 1

Analysis of Operations of Railways That Have Substantially Reduced the Cost of Construction and Maintenance of Way Work

J. T. Sullivan *(chairman, subcommittee)*, Arlie Bornhoft, L. B. Cann, Jr., A. W. Carlson, W. H. Hoar, B. G. Hudson, R. W. Preisendefer, W. B. Stackhouse, D. D. Thomas, J. T. Ward, H. E. Wilson.

This report is submitted as information. It deals with the Canadian Pacific Limited, Weston Frog and Switch Manufacturing Shop at Winnipeg, Manitoba, Canada. This report further deals with the double-tracking of the Canadian National Railways' Prairie Region utilizing concrete crossties and welded rail. Information for this report was obtained in conjunction with a meeting of Committee 22 held on June 9 and 10, 1975, at Winnipeg.

The CP's Weston Frog and Switch Manufacturing Shop fabricates all types of special trackwork products for exclusive use on the CP system. Research, development, and engineering is performed by the office of the chief engineer with all trackwork production under the supervision of the motive power and rolling stock department in accordance with CP and AREA specifications.

The present shop is the outgrowth of two separate system shops now integrated into one shop centrally located at the mid-point of the CP system. Research for the modernization of this shop started in 1969 with complete investigation into each manufacturing phase to facilitate use of existing machinery and select the most modern equipment to meet present and future trackwork production requirements. Originally, the former shops, located at Winnipeg and Montreal, employed approximately 145, but with modernization and improved manufacturing techniques, this force has been reduced to 75, including supervision. Shop construction commenced in 1971 in conjunction with machinery procurements, etc., and trackwork production continued on a reduced scale. Completion of the shop was in late 1972, although the CP is continually upgrading with small machines, tooling, jigs, fixtures to constantly improve techniques and productivity.

This shop manufactures parts for a complete turnout, including heel-block assemblies, guard rails, switch stand assemblies, plates, switch points, frogs, and bolts. Also, special rail assemblies, rail-bound manganese and diamond crossings, and double-slip switches are fabricated. Insulated gage plates, riser slide plates, turnout plates, special flat seat tie plates, and miscellaneous cut seat plates are produced.

The rail required for trackwork products is brought into the shop area via rail where it is off-loaded by overhead gantry cranes. The cranes then handle the rail into a cropping saw where it is cut to various lengths for product manufacture. From this location, the precut sections are moved into the main shop building by means of a conveyor which passes through the wall of the building. Once inside, the sections are handled by overhead cranes to the various product manufacturing locations.

When manufacturing switch points, the necessary straps are fastened to the precut rail sections, the clamped assembly is placed into a drill where all holes are drilled simultaneously, and from there, the drilled section is passed to milling machines which are programmed for final machining of the appropriate point. The two mainline rail sections for the CP are 132 RE and 115 RE with considerable maintenance requirements for existing 130 RE-HF and 100 RE-HF sections. Switch point production in these sections consists of 11 ft, 16 ft 6 in., and 22 ft lengths with limited quantities of 13 ft and 39 ft curved points for use in No. 20 turnouts.

The CP uses the built-up design guard rail with adjustable blocks with all 132-lb and 115-lb rails produced in special chrome rail. Guard rail lengths are 8 ft 3 in., 11 ft 6 in., 13 ft 8 in., and 18 ft. Manganese steel guard rails are no longer used on the CP.

Complete heelblock assemblies for four-hole design, fixed position, with no sliding heel are fabricated. The assemblies consist of block, joint bars and shoulder bolts, complete.

Switch stands are complete assemblies for use as ground, low intermediate and high position complete with eye bolts, masts, and targets.

Rail-bound manganese steel frogs are machined and assembled. In addition, some spring frogs are manufactured for specific locations. To supplement new frog requirements, the CP has two reclamation frog shops located at Montreal and Lethbridge. The rebuilds are primarily rail-bound manganese with some built-up and solid manganese.

All new frog construction utilizes special chrome rail with explosive depth hardening of the manganese steel insert castings. Approximately 15 miles from the shop area, the CP has an area for performance of depth hardening. At this location, there is a work platform approximately 5 ft in height, 10 to 12 ft in width, and approximately 30 ft long. This structure is built with wooden timber sidewalls with the center filled with sand. Transport to this site is by specially equipped truck with a bed and boom for handling the steel inserts. The truck is also equipped with a special box for movement of explosives from the storage magazine to the work platform.

The casting is placed on the sand bed of the platform, thoroughly cleaned, and adhesive added to the clean casting before applying sheet type explosive. The explosion is then set off from a remote position by a detonator, with each casting

Fig. 1—Preparing frog casting for depth hardening.

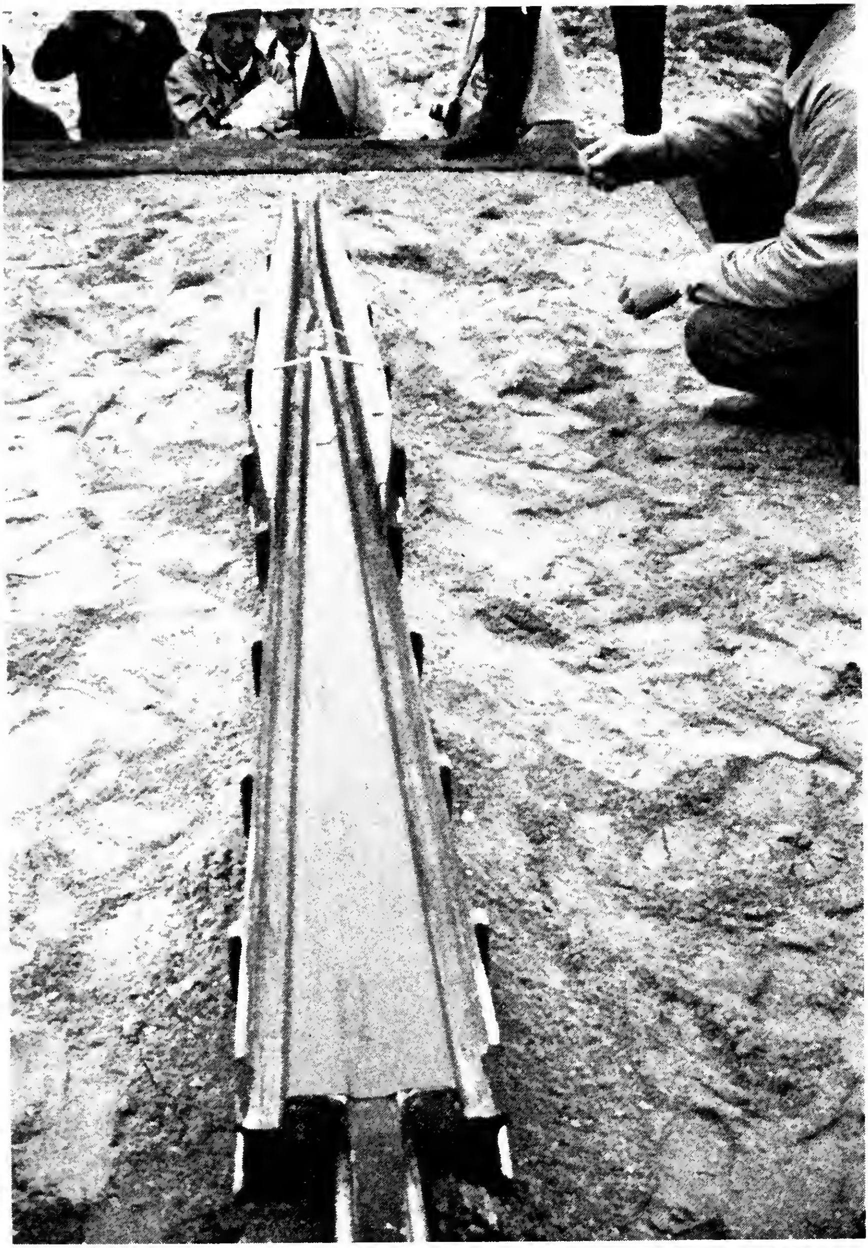

Fig. 2—Frog casting ready for explosion.

receiving three blasts. The first shock results in approximately 300 Brinell hardness, the second 340 to 350, and the third 375. Depth hardening by this process has proven able to provide a service life of 100,000,000 to 120,000,000 tons where previously 60,000,000 tons was normal for a frog casting on the CP line. At the present time, this method of depth hardening costs approximately $250 per casting.

Weston Frog and Switch Manufacturing Shop
1974 Production

Switch points (varying lengths)	1,663	each
Guard rail assembly	492	each
Heelblock assembly	294	each
Switch stand assembly	484	each
Plates (various types)	23,000	each
Frogs (new)	454	each
Frogs (reclaimed)	600	each
Special rail assemblies	2,641	tons

This modern shop is well equipped to supply the needs of the CP.

The CP is well pleased with the results of their operation and feel that the expenditures for construction have been economically justified by results to date.

DOUBLE-TRACKING ON THE CANADIAN NATIONAL

On June 10, Committee 22 inspected new mainline track construction being performed by the Canadian National Railways on its Prairie Region. The CN is constructing a second mainline from Winnipeg to Portage on the Rivers subdivision, Mile 6.87 to Mile 52.17. The project calls for the installation of two-directional double-track CTC with intermediate signals for following moves. Track will be signalled for 80 mph operation. Double high-speed crossovers will be installed at Mile 14.3 and a passing track will be constructed at Mile 32 to Mile 33.5 which is to be situated between the two main tracks where it may be used as a crossover as well as for overtake in both directions by trains on either track. At the Assiniboine River bridge, Mile 50.5, single track will be maintained wih No. 20 equilateral turnouts placed at both ends which will give additional capabilities. The new alinement will have a paralleling track on 15-ft track centers with the existing line.

The track section is to be built using concrete crossties on 24-in. centers carrying 132 RE rail in 1,170-ft strings. Project calls for 496,566 lin ft of 132-lb continuous welded rail. The strings are being joined by thermite welding in the field. Approximately 121,000 concrete crossties will be installed. New turnouts will include four No. 20 equilaterals, eight No. 20 turnouts, eighteen No. 12 turnouts and one 132-lb manganese diamond. Three prestressed bridges are to be located at Mile 17.3, Mile 30.8 and Mile 49.3. This project will include 12 power switches, 34 CTC signals, approximately 250,000 ft of underground cable, 750,000 ft of line wire, 170 DC track circuits, and 12 compressed air snow removal systems at four sites.

Grading is being performed by a contractor, and it is estimated that 450,000 cu yd of material will be moved when constructing the subgrade. Approximately 392,000 cu yd of sub-ballast is to be brought by air-dump cars from River Manitoba, a 200-mile round trip. The subgrade cross-section is to have no less than 21 in. of pit-run sub-ballast topped with 12 in. of crushed rock ballast under the tie, giving full depth of crushed rock of 18 in. once the cribs have been filled. Approximately

(Text continued on page 309)

Fig. 3—Concrete ties and welded rail on the CN.

Fig. 4—Thermite welding on the CN.

Fig. 5—No. 20 turnout under construction.

Fig. 6—Unloading concrete crossties onto the roadbed.

Fig. 7—Distributing and spacing concrete crossties.

238,000 cu yd of crushed-rock ballast will be brought in by work train from Watcomb, a 600-mile round trip.

Concrete crossties are transported on special tie cars with each car having six bundles of 30 ties each, or 180 ties per car. The ties are off-loaded through use of an off-track mobile crane driving on compacted subgrade and utilizing a specially manufactured steel tie-handling rack. The rack is placed under the bundle, lifted from the car, and placed at intervals on two wooden ties positioned on the subgrade. Unloading of ties is dependent upon the amount of track time; however, the operation is capable of unloading as many as eight carloads per worktrain day.

Once the ties are unloaded on the roadbed, they are distributed through the use of a rubber-tired straddle-axled crane and another special lifting device. The ties are handled six at a time from the bundles and placed at the proper spacing. Proper alinement of ties is controlled by a specially made gage which runs on the near rail of the adjacent track. The concrete crossties are manufactured to CN specifications, rail fasteners are applied by a six-man gang using sledge hammers; however, this process is to be mechanized in the near future.

Once ties are unloaded and properly spaced, welded rail is unloaded from a rail train to the ties. The rail is off-loaded from the end of a rail car of the worktrain occupying the dead track to specially designed rollers. This eliminates delays incurred by heavy mainline traffic. Once the rail is placed on the tie seat, the tie pad is applied, after which the rail is fastened to the tie.

In summary, the project which started in 1973 is scheduled for completion in 1976 and will result in a double-track mainline track structure consisting of concrete crossties and 132-lb welded rail. In 1974 this section of the CN's track handled 40 trains per day with 43.8 million gross tons. Annual tonnage is expected to increase to 80 million gross tons in 1980 and 85 million gross tons in 1985.

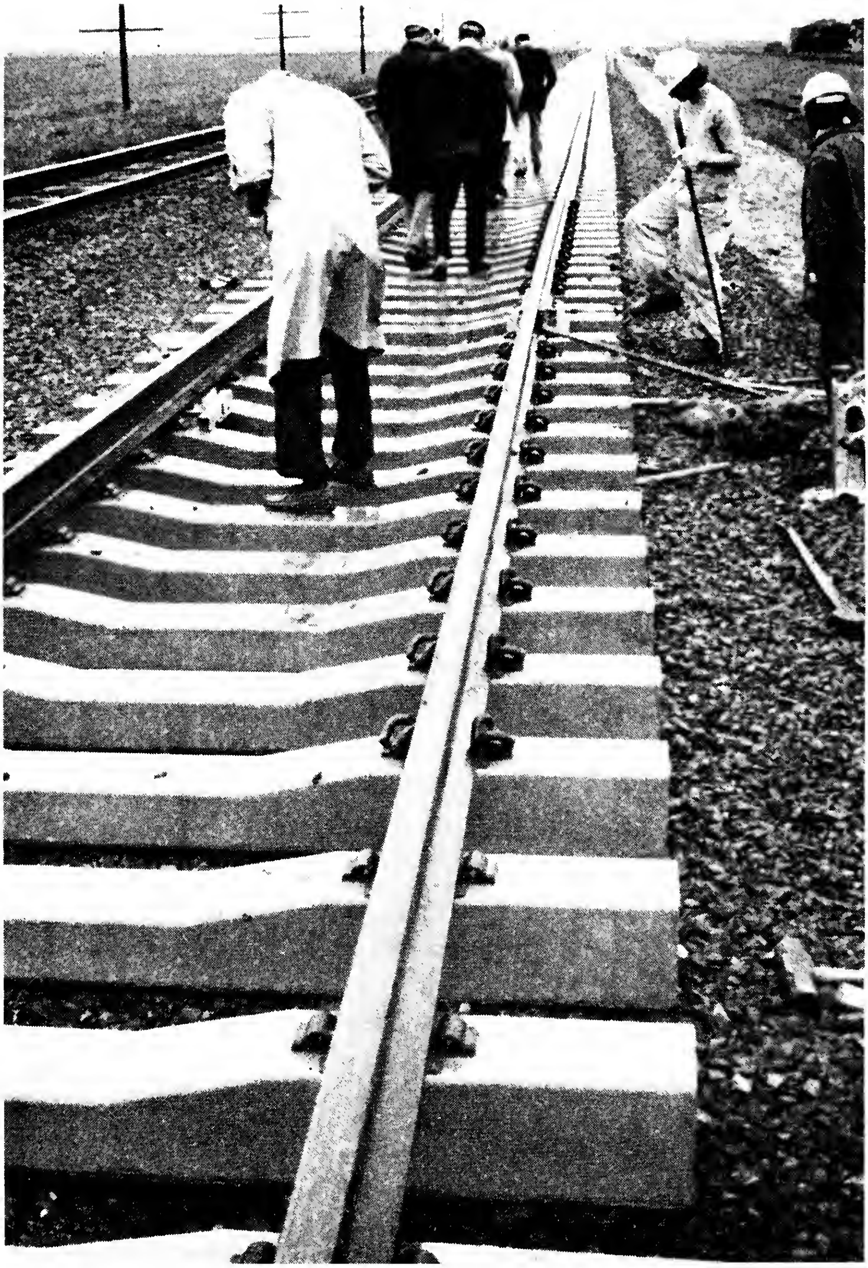

Fig. 8—Applying rail fasteners.

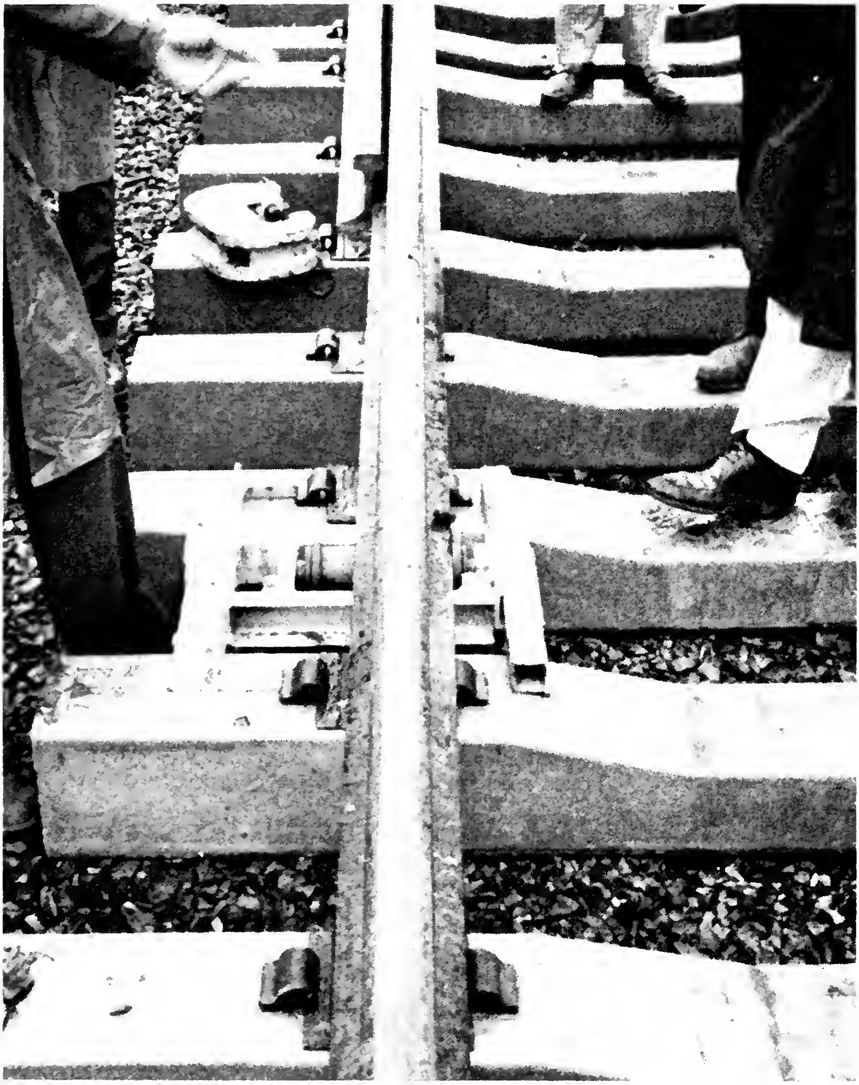

Fig. 9—Portable roller used in unloading welded rail from worktrain to concrete ties on roadbed.

Report on Assignment 5

Comparative Costs of Cleaning Ballast Versus Ballast Replacement In Track Rehabilitation

W. J. Jones *(chairman, subcommittee)*, A. S. Barr, J. S. Busby, J. R. Clark, H. W. Kellogg, Guy Liljeblad, E. T. Myers, Mike Rougas, G. E. Scholze, J. E. Sunderland.

Your subcommittee submits the following report as information. Comments and criticisms are welcome.

Cutbacks in rail and tie renewals are commonplace during periods of depressed business activity because of the large amount of money involved in such items. To a lesser extent, retrenchments also occur in reballasting programs. However, by and large, a certain amount of maintenance money is expended for ballast in the day-to-day maintenance of track.

In the aggregate, the value of ballast that is consumed annually represents a sizeable sum. The AAR reported that Class I carriers spent $36,837,000 for ballast in 1973 and $45,183,000 in 1974, excluding transportation costs.

Ballast Is Indispensable to the Safety of Track

Unless a full ballast section (of quality material) is maintained at all times, track will develop irregularities in surface, line, and gage. The number of slow orders required will rise. Joint pumping will increase, accelerating joint wear and rail-end batter. Partially exposed ties are more vulnerable to destruction by a derailed wheel. Threat of sun-kinks will multiply. The overall result will be a sharp increase in the cost of ordinary track maintenance or a reduction in maintenance standards. Thus, it is apparent that a relatively substantial quantity of ballast must be provided almost daily, on almost all roads.

There are 330,000 miles of railroad track in this country. Assuming an average of 2,500 cu yd of ballast per mile and a cost of $4.00 per yard for ballast in place (conservative at today's prices), we find that ballast represents an asset worth $3.3 billion. Accordingly, everything practical should be done to protect this investment and, concurrently, to economize in ballast expenditures, wherever possible.

An adequate ballast section is indispensable to the efficient maintenance of every class of track. Basically, ballast consists of selected materials placed on the roadbed for the purpose of holding the track to the desired line and surface. For ballast to be considered "adequate," it must possess specific physical properties and it must meet fixed functional requirements.

Requirements of Good Ballast

Good ballast should be sound, hard, tough, clean, heavy, sharp-faced and nonconductive. Desirably, ballast should be available in abundant supply, close to the point of use, and at an economical price per cubic yard. Ballast gradation between minimum and maximum allowable sizes should be such as to permit ballast to compact readily in the track.

To be functionally satisfactory, ballast should:

1. Provide a firm bearing for the ties and distribute the wheel loads uniformly over the roadbed.

2. Provide proper drainage.
3. Afford a means for the elimination or reduction of capillary action.
4. Fill the spaces between the ties and form a shoulder from tie ends to subgrade, thereby holding the ties in the proper position, while resisting lateral forces exerted by the wheel against the rail.
5. Retard vegetal growth within the track area.
6. Facilitate track work, particularly during periods of rainy weather.
7. Provide resilient and elastic support of ties and rail.

Foul Ballast Adversely Affects Maintenance

With respect to the physical properties of good ballast, all of them are relatively permanent by nature, except one—cleanliness. Ballast commences to get dirty soon after it is put in track and subjected to traffic. Fine particles of dirt and other foreign matter enter the ballast from spilled lading, locomotive sanding, wind- and water-carried soils, subgrade material working into the ballast, and attrition of the ballast itself.

Water enters the ballast from above as rainfall and from below by capillary action. When water and dirt combine, drainage is impaired. Vegetal growth is encouraged; ties pump; line and surface deteriorate; and wear of rail, fastenings and ties accelerates. Ballast loses its resiliency and is no longer capable of properly distributing loads from the track to the subgrade. Moreover, as determined recently in the Track-Train Dynamics studies, increased lateral forces are encountered in track with frozen ballast, or tightly consolidated ballast polluted by sand.

As the ballast becomes fouled, track maintenance becomes more difficult and more expensive. The condition soon reaches the point that something must be done. The maintenance manager must decide whether to clean part or all of the ballast section, plow out the dirty ballast and provide an entire new section of fresh ballast, or make a nominal surfacing raise on existing ballast and fill in the voids surrounding the ties with fresh ballast.

Source of Information

In order to learn what is being done in this regard and to develop the cost associated with current practices, a questionnaire was sent to representatives of 30 railroads. Twelve written replies were received and verbal information was supplied from four others. The answers were tabulated and unweighted averages computed without regard for miles of lines maintained, tonnages carried, etc.

The replies were quite similar and are summarized as follows:

1. Quality ballast is preferred over inferior grades, even though first cost is greater and longer haul involved.
2. Ballast supply is adequate for all needs for all responding roads.
3. Ballast cars are in short supply on two-thirds of the roads responding to questionnaire.
4. Average cost of ballast is $2.70 per cubic yard, FOB car.[1]
5. Ballast is hauled an average of 155 miles from source to point of use.
6. Ballast moves on, and is unloaded by, through freight in the majority of cases. When not unloaded by through freight, cars are set out for pick-up and dumping by work train.
7. Average cost of work train is $525 for a 12-hour day.

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[1] All prices, wages, rates, etc., are based on 1974 figures.

8. In retimbering ahead of surfacing operation, an average of 611 cross ties per mile are installed by the tie gang at an average labor cost per tie of 0.65 man-hour.[2] This compares to 0.19 man-hour per tie where ties are installed in conjunction with operation of undertrack plow. (Cost figure for ties renewed while undercutting-cleaning was not available.)
9. An average of 414 cu yd of ballast per mile are required for 2-in. surfacing raise and 700 cu yd for 3-in. raise, compared to 2,528 cu yd behind plow and 525 cu yd with undercutter-cleaner.
10. An average of 420 track feet per hour are undercut and cleaned, 6 in. below bottom of ties. Daily production with undertrack plow is 3,660 ft.
11. Surfacing raises are made every 4 to 5 years. Interval between undercutting-cleaning is 9 years. Customarily, the undertrack plow is used only once at a given location, to dispose of an inferior quality or heavily polluted ballast.
12. The majority of the respondents advised that their interest in undercutting-cleaning would heighten if they could be assured of 1,000 ft per hour production.

Advantages of Undercutting-Cleaning

1. Removing all the ballast from the track to a specified depth below the bottom of tie, screening out the dirt, sand and other undesirable material, and returning the clean ballast to the track for making an appropriate raise is the only sure way of restoring resiliency and drainage to the track.
2. Established grades are preserved. This is particularly important with respect to meeting existing track crossings and road crossings at grade, bridge ends, station platforms and turnouts. Also, established grade relationship with adjoining tracks is not disturbed, thus precluding the need for reworking or raising walkways and inner track areas.
3. Vertical clearances in tunnels and beneath overhead structures are not adversely affected. Occasionally, opportunity exists to improve upon the clearance.
4. Subgrade widths remain unaltered, thereby avoiding the expense involved in restoring or widening embankments to adequately support the track or to prevent loss of ballast.
5. It helps to preserve dwindling resources of ballast material.

Disadvantages

1. Rate of progress with present equipment is relatively slow. Usually a minimum of three to four hours undisturbed track occupancy is necessary to justify the expense of set-up and making run-off. Excessive train delays are frequent. (Improvements are being made in the design and method of operation of the equipment aimed at speeding up undercutting-cleaning.)
2. A substantial portion of ballast is wasted. For efficiency of cleaning operation, screen openings must be large enough for pollutants to pass freely, at an acceptable rate of production. Too large a screen opening results in an increase in ballast wastage. Too small an opening causes the screen to overload or results in a less than satisfactory job of cleaning.

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[2] Average hourly rate for laborer is $4.624, and for foreman $5.565.

3. During periods of restricted maintenance allowances, there may not be sufficient allowance to support the operation.
4. To be economically feasible, there must be enough work for the undercutter-cleaner to justify the cost of the equipment.
5. The cleaning operation produces a lot of dust which is drawing more and more attention by ecologists. Some incorporated areas prohibit the use of ballast cleaning equipment and issue citations when the equipment is operated.

Shoulder Ballast Cleaning

Shoulder ballast cleaning produces worthwhile benefits. However, this operation is not to be performed in lieu of undercutting-cleaning nor is shoulder ballast cleaning considered as a substitute for a surfacing raise.

The ballast in the shoulders makes up 35% to 40% of the total ballast section. It is essential for the shoulders to be kept open so that water will not impound in the track. Keeping the shoulders clean will aid in preventing the formation of "mud-socks" at tie ends. Additionally, clean shoulders will permit some leaching out of dirt and sand from the "cribs" and "eyes." Unfortunately, however, once the ballast under the ties is fouled and consolidated to the point that it has lost its cushion, and drainage is impaired, shoulder cleaning cannot materially mitigate the problem.

Application of Undertrack Plow

It is not economical to contend with an inferior grade of ballast. For years native materials, gravels, cinders, soft sedimentary rock and other materials—locally available—were frequently used as ballast on branch lines, secondary mains and—in some cases—on primary mains, due to the ease of accessibility and cost of such ballast. However, the increase in axle loads and the increase in train speeds soon proved the inadequacy of subquality ballast. The sooner it is replaced with quality ballast, the better, from all standpoints.

The quickest and most economical way to dispose of unwanted ballast is by use of the undertrack plow. There are locations, however, where, due to physical restrictions and clearances, it is not feasible to plow, e.g., through station platforms, in tunnels and beneath overhead structures with tight vertical clearance.

The principal advantage of the undertrack plow in skeletonizing track is its high-production capacity. Other advantages are: (1) Ties are renewed at very low unit cost, (2) Selection of ties for renewal is facilitated and a better job of marking is possible since the whole tie is visible, and (3) Where necessary, track realignment is performed with minimum effort.

Disadvantages are: (1) Track must be occupied by maintenance crew for a relatively long period of time before track is readied for resumption of traffic; (2) The operation usually results in heavy tie renewals, which could represent too large a percentage of the available tie program; (3) Adjustments must be made in grade at crossings, bridge ends and switches, else other methods must be employed to remove ballast in approach to such fixed grade points; (4) A large quantity of ballast must be available on a daily basis to fill in the skeletonized track. This requires an adequate supply of ballast cars to keep the program moving forward (two-thirds of the respondents to questionnaire advised that ballast cars were in short supply); and (5) Slow orders are usually extensive in length and duration and involve comparatively low speeds.

Pros and Cons in Making Surfacing Raises

Historically, it has been the practice on the majority of railroads in this country for tracks to be given periodic surfacing raises to improve the riding quality. Except for special locations, such as on mountain grades where locomotive sanding occurs, and in isolated locations, e.g., where ballast section has been fouled with silt from flooding, very little out-of-face cleaning of ballast is done. The majority of returns to questionnaire indicates that ballast cleaning has never been performed on those properties. Instead, whenever ballast fails to function as intended, a nominal track raise is made on the old ballast and fresh ballast is brought in to fill the voids around the ties.

With modern machinery, supported by a relatively small crew, it is possible to surface track quickly and economically. Other advantages are: (1) Maintenance of existing tie bed compaction, (2) Does not require taking track out of service very long, and (3) Does not require a large quantity of ballast at any one time, nor a large number of ballast cars.

Disadvantages are considerable. Principal ones are: (1) Benefits are short-lived and value of new ballast is not fully realized since track is raised on existing ballast (with varying degrees of contamination) and new ballast is spread as top-coat on top of the ballast section; (2) What clean ballast there is in the cribs that finds its way beneath the ties is subject to rapid contamination from the dirty ballast below; (3) Frequent raising of track surface, coupled with normal deterioration of embankments, results in placing track on a pinnacle. To correct this condition requires restoration and/or widening of the subgrade to prevent loss of ballast and creation of centerbound track; (4) Bridge structures and crossings must be raised compatible to raise in track grade. This involves extra expense.

SUMMARY

1. A clean ballast section is essential to the economical maintenance of track.

2. When ballast fouls to the point of losing its resiliency and cushion, the cost of track maintenance rises, or the track standard must be reduced.

3. Ballast in track represents a sizeable investment.

4. Average cost of high-speed primary main line ballast is $2.70 per cubic yard, FOB car, at loading site. Cost of transporting and placing ballast, including ownership, operation and maintenance of equipment expense plus maintenance of way labor, etc., brings the cost of ballast in place to $4.00, or more, per cubic yard.

5. There is approximately one-half (0.5) cubic yard of ballast per lineal foot of track, where standard ballast section calls for 8 in. of ballast under the tie. This equates to a ballast value in excess of $2.00 per foot of track.

6. Thus, if track can be undercut to a depth of 8 in. and the ballast screened at a cost of less than $1.60 per foot, then undercutting-cleaning is the economical method to adopt. (It is assumed that 20% of the ballast will be lost in the cleaning process when much of the minus ¾-in. material passes through the screen with the dirt and sand.) From Appendix A we find that cost to clean ballast computes to $1.06 per track foot.

7. Undercutting-cleaning provides the most positive and practical method of restoring ballast to its original condition. However, it is recognized that there can

be local considerations precluding the use of the undercutter-cleaner. In such cases, of necessity, other methods must be employed to reinstate those properties and functions inherent in good ballast, so that ballast will fulfill all of its intended functions.

APPENDIX A

ESTIMATED COST TO CLEAN BALLAST WITH THE UNDERCUTTER-CLEANER

ASSUMPTIONS

New machine cost—$500,000
Machine life—12 years
Interest at 8% on undepreciated value

ANNUAL COST

Depreciation	$ 41,670	
Interest	21,600	
Maintenance	50,000	
Fuel and supplies	25,000	
Mechanic (including additives)	19,500	$157,770
Labor: (Including additives)		
Operators (2)	39,000	
Laborers (Foreman + 8 men)	115,080	154,080
TOTAL		$311,850

PRODUCTION

An average of 420 ft/hour, 3 hours daily, working 90% of the time.[3]

420 × 3 × 5 × 52 (.90) = 294,840 track feet

COST TO UNDERCUT AND CLEAN PER TRACK FOOT $1.06

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[3] The new equipment being manufactured offers increased production and efficiency with almost 100% assurance of further economies.

Report on Assignment 6

Economics of Installing Bonded Insulated Joints in Field Vs. Shop Fabrication and Economics of Bonded Joints Vs. Field Welds to Connect CWR

A. E. Shaw, Jr. *(chairman, subcommittee)*, R. J. Aschmeyer, A. Bornhoft, W. Glavin, C. R. Harrell, J. R. Miller, G. G. Phillips, D. D. Thomas, H. J. Umberger, J. T. Ward.

ECONOMICS OF INSTALLING BONDED INSULATED JOINTS IN FIELD VS. SHOP FABRICATION

The bonded insulated joint has been in production and available to the industry for about 5 years. Presently, they are manufactured by at least 3 companies and in appearance and construction, they are very similar. The joint consists of a special steel joint bar with a permanently bonded insulation material on the side of the bar toward the rail. This bar is bonded to the rail joint by epoxy material and held in place by either high-strength bolts or fasteners.

The procedure for installation in the field is fairly complex and must be adhered to or failures will result. A typical instruction for installing, broken into functions, is as follows:

1. *Cut and Drill*
   - (a) Rail is cut with rail saw if necessary. Care must be taken to ensure a vertical cut.
   - (b) Rail holes are located using templet.
   - (c) Rail holes are drilled with single rail drill using flat-head drill bits, 1-5/16 in.
   - (d) Grinder deburrs and hones holes carefully. Rail brand and any burrs on rail ends are ground off.
   - (e) Rail ends are flame-hardened with oxyacetylene torch.
2. *Sandblasting*
   - (a) Sand-blast rail ends about 19 in. from each end to remove all scale and rust.
3. *Apply Bars*
   - (a) Rail ends are examined to see if they are in tension or compression.
   - (b) In compression, a hydraulic jack opens the ends, the end post is inserted, and the jack removed.
   - (c) In light tension, sufficient anchors are removed and rails are pulled with railpuller to the end post, and anchors are replaced. If gap remains, it is closed by heating.
   - (d) Blast-cleaned areas of rails are washed with special solvent.
   - (e) Heat is directed to the sides of the rail until the top of the head reaches 200 F.

(f) At temperature, the blast-cleaned area is lightly washed with solvent, the rail hole bushings are installed and the joint bars, which have been spread with epoxy cement during the preparation of the rails, are put in place.

(g) High-strength bolts or fasteners are used. They are put through one bar and the bar is moved into position against the rail. This allows a visible check to see that they do not push out the rail hole bushings. The other bar (flange side) is mounted on the protruding bolts or fasteners.

(h) The bolts or fasteners are pulled up from the center alternately to each end.

(i) Heat is applied and bars are brought to 200 F. At 200 F, heat is cut back and bars maintained at 200 F for 10 minutes.

4. In Service

(a) If rail traffic is expected, the joint is cooled to 150 F with water spray from a garden sprayer.

(b) Because elapsed time of all functions is approximately one hour, however, because advance joints are in preparation, the average time is much lower.

Some railroads feel, to ensure quality control, they cannot use field-installed joints; therefore, they have the bonded insulated joint made up in a piece of rail at a shop and then this section of rail is installed in track by field welding the two ends or the use of standard joint bars. An analysis has been made of various railroads and transit companies comparing the installation of bonded insulated joints, which are fabricated at a shop, shipped to the field, and then installed in track vs. bonded insulated joints installed directly in track.

A questionnaire was sent to 32 railroads and 6 transit companies representative of the industry. Twenty-six railroads and five transit companies responded. Of these companies, all but three railroads are using bonded insulated joints to varying degrees. Three transit companies use them, one does not, and one could supply no information. Ten railroads and two transit companies use only shop fabrication. Four railroads and one transit company use field application only. The remainder of the respondents use both shop and field installations.

For shop fabrication, five railroads and one transit company reported using 39-ft lengths of rail including the insulated joint. Four railroads reported using 13-ft lengths. The remaining railroads and transit companies use rail lengths varying from 11 to 26 ft, including the joints. Eleven companies stated they did not offset the joint in the rail for balance in handling and eight reported they did. In general, the companies using longer lengths of rail offset the joint.

All respondents reported either using fully heat-treated rail, mill end-hardened or field end-hardened rail in both shop and field installation of joints. Eighteen respondents reported AREA specifications for end squareness to be satisfactory for installation of bonded insulated joints. Four reported squareness to be unsatisfactory and recut each piece, placing the end post between the mating cut ends.

Failure rate, defined as a joint which had epoxy cement bond failure within 30 days after being installed in track, has been negligible. Most companies reported no failures, and those that reported failures indicated they were less than 1% with the exception of one railroad which indicated it had 75% failure in field-applied joints. However, this same railroad reported no failures in shop-fabricated joints. One railroad with over 7,000 shop-fabricated joints installed within the last five years reported no failures.

The number of bonded insulated joints in track as reported by the different companies varied greatly from 2–7,000 but, of course, this is to be expected as the length of time they have been in use varied from one to five years. The railroad reporting 7,000 joints in track also reported using them the longest. Also, the various railroads and transit companies surveyed had vastly different mileages and operating conditions.

All of the companies surveyed indicated they were well satisfied with the success of this type of joint and most indicated they intended to use more of them in the future. Several were awaiting results of their tests before moving further. One railroad reported using standard joint bars to fasten shop-fabricated joints to adjacent rails, one reported using both joint bars and field welding. The remainder of respondents reported field welding of the joint assembly.

The cost of shop fabrication of bonded insulated joints varied so greatly, as reported by the respondents, that an average figure would be meaningless. Various manufacturers report they charge $20 to $35 for installation of a joint on rail received at their shop. Material costs of joint and shipping of rail to and from shop are additional. One large railroad, which reported having over 7,000 bonded joints in track, indicated the cost to fabricate in their shop to be $35 per joint. The average cost of installing the section of rail, including bonded insulated joints by respondents who field weld them in track, was $210 each.

The average cost of field installation of bonded insulated joints was reported to be $120 each. The question was asked as to the estimate of annual savings by using bonded joints vs. other types. All reported not enough experience as yet to compare. A number of companies felt the savings would be substantial as time went on.

The bonded insulated joint has been around for a relatively short time; however, judging from the response and answers to the questionnaires sent out, its acceptance and use is certainly reducing the labor cost of maintaining the many thousands of insulated joints in use over the country. It appears the field installation is more economical.

ECONOMICS OF BONDED JOINTS VS. FIELD WELDS TO CONNECT CWR

The laying of continuous welded rail has markedly reduced maintenance by eliminating nearly all of the bolted joints, but on those remaining, connecting the strings together, maintenance has increased greatly because of stresses they are subjected to in cold weather with resulting excessive end gaps, broken and damaged bolts, and in severe cases, pull-aparts. In addition, the large end gaps cause excessive normal batter with more than normal surfacing required.

In order to determine the economics of connecting strings of CWR together with field welds vs. bonded joints, an analysis has been made of various railroads and transit companies as to their practice. A questionnaire was sent to 32 railroads and 6 transit companies representative of the industry.

Five transit companies returned the questionnaire; three reported they used thermite type field welds for connecting strings of CWR, and the other two did not or had no information. The cost of installation, including material, ranged from $80 to $400 per joint with an average of $240. No transit companies reported using bonded joints. Failure of field welds was reported very low, less than 2 percent.

Twenty-six railroads responded and of them, two have no welded rail, and two have welded rail but use standard joint bars for connecting the strings. The remaining lines use thermite type field welds for connecting strings of CWR. Two lines also use bonded joints, three railroads either use bars which have been ground at the center to fit over the upset material of the weld, or a "safety strap." One line uses these only on high side of curves 2° and over.

Costs of installing field welds ranged from $60 to $150 with the average being $94 each. The average cost of installing bars or "safety straps" was reported to be $33 a joint.

Failure rate was reported very low on both field welds and bonded joints—less than 2 percent.

The results of the survey indicate there are few railroads using bonded joints to connect strings of CWR and there appears to be no economic savings by so doing.

Report of Committee 13—Environmental Engineering

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H. L. McMullin (E)

Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

Under way is the continual updating of "Glossary of Terms" and "Directories of Pollution Control Agencies."

1. Water Pollution Control.

Progress report on "Box and Hopper Car Cleaning," presented as information . . . . page 325

2. Air Pollution Control.

The assignment to "Investigate Guide Standards, Including Instrumentation for Preliminary Measurements of Stationary Stack Emissions," will be continued to include latest government requirements.

3. Land Pollution Control.

No report.

4. Industrial Hygiene.

Section 4.7 "Sanitation Requirements for Portable Housing Units," was published in Part 1 of Bulletin 655, November–December 1975, with the recommendation that it be adopted and published in the Manual.

5. Plant Utilities.

No report.

6. Corrosion Control.
   Progress report, "Use of Plastic Pipe," presented as information .... page 327

7. Noise Pollution Control.
   No report.

THE COMMITTEE ON ENVIRONMENTAL ENGINEERING,
C. E. DEGEER, *Chairman.*

John L. Engler
1915-1975

John L. Engler, construction engineer for the Atchison, Topeka & Santa Fe Railway at Topeka, Kansas, died on February 5, 1975, at Topeka.

Mr. Engler was born on June 16, 1915, at Chapman, Kansas, and was graduated from Chapman High School. He received his degree in civil engineering from Kansas State University, Manhattan, Kansas, and joined the Santa Fe Railway in 1937 as a chainman at Topeka. During 1938 and 1939 he worked for the Kansas State Highway Commission, returning to the Santa Fe Railway in June 1939.

Mr. Engler entered military service in 1941, and following World War II he worked as an admeasurer for the Panama Canal and as a design engineer for the U.S. Bureau of Reclamation in Nebraska before returning to the Santa Fe in 1953 at Topeka. Mr. Engler was promoted to assistant engineer in 1956 and construction engineer with headquarters in Topeka in 1971.

We of Committee 13 knew John as dedicated engineer who contributed much to the work of our committee.

Report on Assignment 1

Water Pollution Control

R. C. Brownlee *(chairman, subcommittee)*, R. G. Bielenberg, L. R. Burdge, C. E. DeGeer, J. W. Gwyn, D. J. Inman, E. S. Johnson, R. M. Lindenmuth, P. M. Miller, R. J. Thompson, D. R. York.

PROBLEMS IN THE DISPOSAL OF WASTE FROM BOX CAR AND HOPPER CAR CLEANING

Your committee submits as information the following report pertaining to the disposal of wastes from box car and hopper car washing, with the intention of developing further information and data for eventual submission for publication in the Manual.

General

As with other railroad pollution problems, in order to reduce the initial pollution, and to obtain the most economical and efficient control, it is essential to have the cooperation of all departments of the railroad. To insure this cooperation, it is most desirable to have pollution control administered by the chief executive officer of the railroad.

Waste from box car and hopper car washing facilities presents a most difficult problem for treatment and disposal. Large facilities present little chance for inventory or pre-inspection of the cars, and the logistics involved in switching the cars to avoid shock loadings on the treating facilities make this practice unfeasible. Treatment facilities must therefore be designed on the basis that concentrations of pollutant constituents in wastewater will be variable and impossible to anticipate. Technology is available for the treatment of practically all organic compounds; however, removal of high concentrations of dissolved solids common to washwaters is difficult and expensive.

Precleaning Cars

Dissolved salts and other solids cannot be treated biologically and cannot be filtered. A logical approach to the problem of high concentrations of dissolved solids in the wastewater is to remove the soluble solids from the cars in a dry form rather than attempting to remove them from solution in the wastewater.

Box cars can be hand-swept or vacuumed, provided that consideration be given to health hazards, control of air pollution, and collection and disposal of the dry material. Precleaning of hopper cars can be accomplished to varying degrees by opening the hopper doors ahead of the washer facility. The cars may be vibrated with mechanical vibrators or shaken with an engine to facilitate removal of dry material. Sand or grit blasting of hopper cars has been considered by some railroads. Pollution control, health hazards and disposal of dry materials must be given proper consideration.

Washwater Characteristics

Commodities commonly carried by box and hopper cars and which find their way into the wastewaters from washing facilities can generally be classified as "organic" or "inorganic." Organic materials such as grains, sugar, cereals, oils, and meals contribute high concentrations of BOD and suspended solids to the wastewater.

Inorganics common to car washer wastewaters include: potash which contributes high concentrations of chlorides and potassium in dissolved forms; cement and lime which raise the pH of the wastewater and combine with insolubles to form deposits in the drain lines; fertilizers which are soluble in water and contribute nutrients such as sulphates, nitrogen compounds and phosphates; borates which are somewhat soluble in water and toxic to many plants; sand, coal and ores which are slightly soluble and may contribute heavy metals to the wastewater.

Common problems associated with treatment of car washer wastewater include the removal of suspended solids, reduction of BOD, identification and containment of toxic compounds, the adjustment of pH, and the difficult problem of excessive concentrations of dissolved solids. Removal of nutrients must also be considered.

Treatment Methods

Generally, primary treatment of wastewater from car washer facilities should accomplish the removal of floating and settleable solids. Primary treatment should include ponding of the wastewater in order to buffer shock loads resulting from washing cars containing the same type of commodity.

Primary treatment facilities should include a sloping pad on the washer facility to retain heavy settleable solids, a small grit chamber at the edge of the pad with a solids dragout device for removal of floating and settleable solids, and a settling pond sized to buffer shock loads and afford retention time for clarification of smaller floating and settleable solids.

Secondary treatment of wastewater may include lagoons, aeration equipment or trickling filters. In favorable climates reasonably efficient BOD removal can be accomplished by floculative and aerobic lagoons. Additional biological treatment is accomplished by surface aerators in lagoons, diffused aeration in lagoons, spray ponds, activated sludge facilities and trickling filters. Activated sludge plants are available from vendors as packaged plants ready to set on foundations.

Tertiary treatment for removal of suspended solids and nutrients can be accomplished by floculation-sedimentation, air floatation systems and various other methods for stripping nutrients.

Receiving Waters

The degree of treatment required will vary according to the pollutant contents of the wastewater and the effluent criteria that are required for discharge into streams or municipal sewers, based on the economics involved. Generally, the allowable limitation on concentrations of dissolved solids and nutrients make the discharge of wastewater into storm sewers or other open waterways and lakes impossible even with extensive pretreatment of the wastewater. Evaporation ponds and irrigation offer alternatives in certain areas which have favorable climatic conditions and where sufficient property is available to accommodate these methods. Consideration must be given to suppression of odors and the prevention of percolation of wastewater into groundwater strata. Generally, it is more economical to discharge the wastes into municipal sanitary sewers as it requires less treatment.

Summary

Remember—clear water is not necessarily clean water. Wastewater which has been conventionally treated for the removal of BOD, suspended solids and other objectionable constituents may still contain extremely high concentrations of dissolved salts. This treated wastewater, although it may appear clean, can actually be unfit for discharge into waterways or even municipal sanitary sewers.

The major problems associated with the disposal of wastewater from box car and hopper car washing lies not in conventional treatment of the effluent, but in the reduction of the concentration of dissolved solids. From the standpoint of waste disposal, it is infinitely easier to handle soluble solids in their dry form than to dissolve them in the washwater and then try to remove them from the wastewater.

Report on Assignment 6

Corrosion Control

D. S. Krieter *(chairman, subcommittee)*, J. H. Flett, F. O. Klemstine, W. D. Mason, Jr., R. G. Michael.

Your committee submits the following report on the Use of Plastic Pipe as information.

USE OF PLASTIC PIPE

GENERAL

Plastic pipe can be used in a variety of piping applications in the railroad industry where strength, chemical resistance and ease of installation play important roles. Plastic pipe is found in such railroad applications as water mains, chemical feed lines for cooling towers and waste treatment facilities, drainage lines and locomotive wash racks. It is the intent of this committee report to serve as a guide in selecting the proper type of plastic pipe based on the material to be handled. Since plastic pipe in many cases is competitive in cost with steel, it is important to check the operating conditions for such parameters as high temperature and/or pressure since the use of plastic pipe under these conditions is largely restricted.

By far the most commonly used types of plastic pipe are polyethylene and polyvinyl chloride (PVC). Certain variations of these exist in the form of high- and low-density polyethylene and chlorinated polyvinyl chloride (CPVC). In addition, there is available a polypropylene pipe which, although less common than PVC and polyethylene, has certain desirable characteristics. There is also a widespread use of acrylonitrile butadiene styrene (ABS) and polyester and epoxy glass reinforced pipe. The application for each type of pipe depends not only on the operating temperature and pressure of the material to be transported, but on the chemistry of the material and in some cases, location. The general physical and chemical characteristics of each type of pipe are briefly outlined in the following sections, and care should be taken to avoid selecting a plastic pipe which may be wholly unsuitable for the intended application.

The polyethylene pipes generally have the lowest operating temperatures and pressure ranges followed by PVC, ABS, CPVC and glass fiber reinforced epoxy in that order. Among the most common uses for polyethylene pipe include low-pressure water systems; small above-ground drainage lines; natural gas lines; distilled, demineralized, and zeolite water lines; corrosive liquids and gases.

Polyvinyl chloride pipe (PVC) finds widespread use in pressure piping and drainage systems, water service, drain, waste and vent systems, gas service, chemical feed piping and water well casings. This type of pipe is definitely not suitable for piping certain petroleum products (e.g., gasoline, fuel oil).

Chlorinated polyvinyl chloride (CPVC) pipe is used mainly for hot- and cold-water distribution systems and hot and cold chemical piping.

Acrylonitrile butadiene stryene pipe (ABS) is used in many railroad applications involving drain, waste and vent systems, pressure piping and drainage systems, water service and gas service.

Glass fiber reinforced epoxy, being one of the most durable types of plastic pipe, is usually used for severe piping conditions where the other types are not suitable. One of the most prominent railroad uses is in locomotive wash rack piping where hot corrosive chemicals are piped under high pressure.

POLYETHYLENE PLASTIC PIPE

Properties

Generally, they are insoluble below 50 C, but at higher temperatures high- and low-density polyethylenes are soluble in hydrocarbons and chlorinated hydrocarbons. The polyethylene pipes are decomposed by strong oxidizing agents (fuming HNO_3 and H_2SO_4), slowly attacked by halogens and chlorinating agents (chlorosulphonic acid, phosgene, thionyl chloride). Solvents at elevated temperatures include: toluene, xylene, tetralin, carbon tetrachloride, trichloroethylene and perchloroethylene. They are relatively insoluble and unaffected by polar solvents (alcohols, esters, ketones), vegetable oils, water, alkalis, most concentrated acids (including HF) and at room temperature, ozone (in absence of ultra-violet light).

Moisture

Polyethylene pipe is very resistant to water with an increase in weight after immersion at 20 C (68 F) for a year, of less than 0.2%. Higher temperatures could bring about a chemical change with an increase in water absorption. As previously mentioned, polyethylene is widely used for chemical feed lines under ambient temperature conditions.

Permeability

Transmission of gases and vapors would be least in high-density polyethylene pipe. Permeability with organic vapors is lowest with strongly polar materials and rises according to the following general order: alcohols, acids, nitroderivatives, aldehydes and ketones, esters, ethers, hydrocarbons and halogenated hydrocarbons.

Melting Point

For low-density polyethylene pipe this range would be 109–125 C (228–257 F), and for high-density pipe, 130–135 C (266–275 F).

Mechanical and Physical Properties

It is difficult to correlate the stress-strain properties of polyethylene pipe with basic characteristics such as density, crytallinity and melt flow index, since the conditions of preparation of the specimen and the test itself greatly affect the results. In general, however, properties involving small deformations (e.g., modulus, creep) depend upon crystallinity and thus upon density; for large deformations (e.g., tensile strength, creep rupture), molecular weight and branching appear to be determining factors.

POLYPROPYLENE PLASTIC PIPE

Properties

Polypropylene pipe can be decomposed by strong oxidizing agents (e.g., HNO_3, bromine, oleum), especially when warm (i.e., very readily attacked by hot concentrated H_2SO_4). It is dissolved only at elevated temperatures by aromatic hydrocarbons (e.g., xylene, tetralin, decalin), and chlorinated hydrocarbons (e.g., chloroform, trichloroethylene) above 80 C (176 F). It is swollen by aromatic hydrocarbons and chlorinated hydrocarbons at room temperature, also by esters, ethers and by various aqueous oxidizing agents (e.g., 10% HNO_3, 10% $KMnO_4$, dilute H_2O_2). It is relatively unaffected by many organic liquids at room temperature (e.g., alcohols, glycols), and aqueous solutions including moderately concentrated acids and alkalis but less satisfactorily above 60 C (140 F). In brief, polypropylene pipe is more readily oxidized than polyethylene, the rate of attack and range of reagents increasing with temperature use, and may not be suitable for use in certain types of chemical feeding applications.

Moisture

The increase of weight of polypropylene pipe after six months submergence in aqueous environment at 20 C (68 F) is under 0.5%; at 60 C (140 F) it is under 2%.

Mechanical and Physical Properties

Tensile strength of general-purpose polypropylene pipe is 2.8 to 3.5 kg/mm^2 (4,126 to 5,426 psi).

Impact strength of general-purpose grade is 0.4 to 2.2 ft-lb/in. of notch; of high-impact grade, 1.5 to 12 ft-lb/in. of notch. Polypropylene pipe has poor impact strength at sub-zero temperatures, as the glass temperature lies between 4 and —12 C (39 and 10 F), and its use under these circumstances should be avoided.

POLYVINYL CHLORIDE PIPE

Properties

Polyvinyl chloride pipe can be dissolved by tetrahydrofuran, cyclohexanone, methyl ethyl ketone and dimethylformamide, also by mixtures of solvents such as acetone with carbon disulfide, carbon tetrachloride or benzene and ethyl acetate with carbon tetrachloride. PVC pipe can become swollen by aromatic and chlorinated hydrocarbons, nitroparaffins, acetic anhydride, aniline and acetone. It is, however, relatively unaffected by water, concentrated alkalis, non-oxidizing acids, hypochlorite solutions, aliphatic hydrocarbons, oils and ozone. Decomposition can occur, however, by concentrated oxidizing acids (H_2SO_4, HNO_3, H_2CrO_4) which slowly attack the polymer. The particular rate of decomposition may be increased in the presence of lime or iron or their compounds.

Generally for PVC pipe, chemical stability is good and weatherability is excellent, but it is adversely affected by ultra-violet light. Rigid PVC surface absorption of water after 32 days immersion at 20 C (68 F) was 5 g/m^2 (0.001 lb/ft^2), for the plasticized PVC this is as high as 200 g/m^2 (0.04 lb/ft^2). Absorption increases greatly with temperature. Rigid PVC pipe is brittle below —40 C (—40 F), hard and tough at room temperature and softens at 80 to 85 C (176 to 185 F). Plasticized PVC is flexible down to —50 C (—58 F) and serviceable up to 75 C (167 F). In air above 100 C (212 F) both rigid and plasticized PVC decompose, and full decomposition occurs above 180 C (356 F). This pipe finds widespread use as underground water mains.

Mechanical Properties

Tensile strength of rigid PVC = 4.25 to 5.6 kg/mm^2 (6044.8 to 7964.9 psi) and falls with a rise of temperature.

Compression strength of rigid PVC is 5.6 to 6.7 kg/mm^2 (7964.8 to 9529.4 psi).

Impact strength of rigid PVC is 0.8 ft-lb/in. of notch; the elastic modulus (Young's) of rigid PVC is about 280 kg/mm^2 (394,244 psi).

POLYESTER AND EPOXY PIPE (GLASS REINFORCED)

Properties

The properties given relate to the general-purpose grades of polyester and epoxy pipes available. These pipes are relatively unaffected by aliphatic hydrocarbons (petrol, mineral oils, non-polar chlorinated hydrocarbons (carbon tetrachloride, tetrachloroethylene), alcohol, non-oxidizing acids, organic acids and salt solutions. Polyester pipe can be decomposed by polar chlorinated hydrocarbons (chloroform, trichloroethylene), ketones, phenol, aniline, esters (ethyl acetate), alkalis and oxidizing acids.

Water resistance for polyester pipe is generally very good with an average weight increase after one year in water at 25 C (77 F) of approximately 1.1%.

Mechanical Properties

At low-temperatures, glass-reinforced polyester pipe exhibits increases in certain properties due to stiffening. Among these are the tensile, flexural and compression strengths which are reported to rise to values as much as 50 to 100% higher than at 25 C (77 F). Due to the many kinds of polyester and epoxy reinforced pipes currently on the market, it becomes very difficult to accurately summarize such parameters as tensile and compression strengths of this class, and it is suggested that the user contact the manufacturer for specifications on a particular application. The fiber glass reinforced pipes seem to be a popular choice for locomotive wash rack piping and condensate return lines to boilers. This is due not only to ease of installation and cost, but long-run serviceability under extreme pH and pressure conditions. Certain grades of epoxy fiber glass pipe have successfully been used in chemical feed lines for locomotive wash rack at pressure of 400 psi and temperature of 60 C (140 F).

REFERENCES

1. *The Chemist's Companion,* John Wiley and Sons, Inc., New York; 1972, pp. 414–416.
2. *Handbook of Common Polymers,* Chemical Rubber Company, Cleveland, Ohio, 1971, pp. 3–13, 22–27, 110–119, 258, 268–271.
3. *Textbook of Polymer Science,* John Wiley and Sons, Inc., New York, 1971, pp. 4, 124, 215, 386–388, 419–422, 506–507.
4. W. J. Engle, *Air Force Civil Engineer,* Vol. 10, No. 4, 1969, pp. 32–
5. M. F. Obrecht and J. R. Myers, *Heating/Piping/Air Conditioning,* August 1973, p. 59.
6. I. C. Brown et al, *Plastic Pipe and Its Uses on Railroads,* AREA Proceedings, Vol. 61, 1960, pp. 303–306.

Plastic Pipe - Properties & Uses[4]

Material	Standards	Applications	Properties	Max. Temp. Operating	Joining Methods
Polyethylene a.Type 1, Grade 4 b.Type 2, Grade 3 c.Type 3, Grade 3	ASTM D-2239 ASTM D-2447 ASTM D-2513(g)	low pressure water systems, natural gas, zeolite & distilled water, corrosive liquids & gases	good low temp. performance, good chemical & crush resistance, excellent impact strength & flexibility	120°F (49°C)	insert fittings, butt welding, heat fusion, external compression fittings, transition fittings
Polyvinyl Chloride (PVC)	ASTM D-2241 ASTM D-2466(f) ASTM D-2467(f) ASTM D-2513(g) ASTM D-2564(s)	pressure piping & drains, vent systems, gas service, chemical piping, water well casing	high tensile strength, excellent chemical resistance, fire resistant, non-toxic, good crush & impact strength	140°F (60°C)	solvent welding, threaded, flanged, compression fitting, transition, bell ring, rubber gasket
Chlorinated Polyvinyl Chloride (CPVC)	ASTM D-1785 ASTM D-2241 ASTM D-2466(f) ASTM D-2467(f)	hot & cold water distribution, hot & cold chemical piping	excellent chemical resistance, high tensile strength, good crush & impact strength, fire resistant, non-toxic	190°F (88°C)	solvent welding, flanged compression & transition fittings, "O" rings, rubber gasket
Acrylonitrile-Butadiene-Styrene (ABS)	ASTM D-2527 ASTM D-2282 ASTM D-2465(f) ASTM D-2468(f) ASTM D-2469(f) ASTM D-2235(s)	drain, waste, vent & water service systems, pressure piping, gas service	good chemical resistance, good crush resistance, non-toxic, good impact strength at low temp.	150°F (65°C)	solvent welding, transition fittings
Glass Fiber Reinforced Epoxy	Mil-F-2245A Type 2 Class A Type 3 Class B	cold & hot water pressure piping, pressure chemical piping	high impact strength, good crush resistance, chemical resistant, low thermal conductivity, high tensile strength, small coefficient of thermal linear expansion	Type 2- 200°F (93°C) Type 3- 300°F (149°C)	threaded, adhesive bonding, flanged

Report of Committee 27—Maintenance of Way Work Equipment

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J. T. Smith
S. E. Tracy (E)
C. R. Turner
J. L. Van Meter
S. W. Walker
N. White
J. W. Winger
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

No report.

1. Reliability Engineering as Applicable to Work Equipment Design and Manufacture.

No report.

2. Machine Design—Hydraulic and Electrical Systems.

Progress report, presented as information .... page 334

3. Machine Design—Engines.

No report.

4. Machine Design—Drive Train, Including Clutch, Transmission, Final Drive and Power Take-Offs.

No report.

5. Machine Design—Bearings, Suspension, Frame and Brakes.

No report.

6. Study Design of Cars Used by Maintenance of Way Department, Such as Ballast Cars, Equipment Transport, Tie Cars, Rail Cars, Etc.

   No report.

7. Temperature Compensated Stress-Adjustment Equipment for Use During or After Laying CWR, Collaborating as Necessary or Desirable with Committee 4.

   No report.

8. Applied Metallurgy—Maintenance of Way Work Equipment.

   No report.

9. Data Processing for Work Equipment Evaluation, Information and Control, Collaborating as Necessary or Desirable with Committee 32.

   No report.

THE COMMITTEE ON MAINTENANCE OF WAY WORK EQUIPMENT,
F. H. SMITH, *Chairman.*

Report on Assignment 2

Machine Design—Hydraulic and Electrical Systems

J. P. ZOLLMAN *(chairman, subcommittee)*, L. E. CONNER, D. C. JOHNSON, M. E. KERNS, A. E. MORRISS, JR., DAVE SCHULZ, C. R. TURNER, J. L. VAN METER.

Your committee submits the following report as *information* for *guidance* of equipment manufacturers and railway maintenance personnel in the design, construction and evaluation of hydraulic systems.

Hydraulic systems shall conform to the specifications of the National Fluid Power Association (NFPA), American National Standards Institute (ANSI) and International Standards Organization (ISO), except that where a conflict occurs, the following will apply:

1. Upon completion of manufacture and before any operation shall begin, all parts of the hydraulic system shall be clean and free from scale, rust, dirt and any other contaminant. Threads, flares, holes, cuts and machining must be deburred and cleaned.

2. Hydraulic reservoirs of 10-gal capacity or larger shall be designed with the following considerations:

   a. Place the baffle(s) in the reservoir so as to separate the pump inlet port from the settling part of the reservoir. The baffle(s) should direct the flow toward the reservoir walls for maximum cooling capacity and maximum lay-over time.

   b. Provide sufficiently large access panels for complete periodic cleaning, maintenance and inspection.

   c. Provide an air inlet large enough to maintain conditions of Item 12. The air inlet shall be equipped with a 25 micron or finer filter. A cartridge type is preferred.

d. Provide a filler with at least a 100-mesh screen protected from external damage with a minimum capacity of 5 gal per minute with 500 SSU fluid viscosity and with a filler cap that can be locked with a large railroad padlock.

e. Provide thermometer to indicate reservoir operating temperature at the add-point fluid level and protected from damage.

f. Provide a static fluid level gage to show full-point and add-point protected from damage.

g. When immersion heaters are provided to control fluid viscosity during cold weather start-up, place the heater(s) so removal is possible without draining reservoir.

h. A non-integral reservoir is preferred.

3. Fluid temperature shall not exceed 180 F maximum in the reservoir outlets while operating in a 110 F ambient temperature. The minimum fluid temperature after 45 minutes operation shall be 85 F with ambient temperature of 20 F.

4. A full-flow testing tee(s) shall be provided adjacent to the pressure side of hydraulic pump(s). A return-line full-flow tee shall be placed ahead of return line filter.

5. Where failure of power plant or pump can immobilize components in a position which could prevent moving the machine, an emergency hand pump shall be provided in the circuit. Large machines shall be equipped with battery-operated emergency pump where more than 5 minutes are required to move all components within the clearance diagram of the track occupied, by means of a hand pump.

6. The total return and/or pressure line flow shall pass through filters rated at 25 microns or finer equipped with a condition indicator.

a. In closed loop systems, filtration as recommended by pump manufacturer will apply.

b. Magnetic particle attraction shall be provided in the filters or reservoir.

c. Filtration of the return flow from the pilot section of pilot-operated valves is not required.

7. All hydraulic hose assemblies exposed to the below-listed pressures, or less pressure, must have reusable screw-together hose fittings. On all metallic wire-reinforced hose using reusable hose fittings, the outermost layer of wire reinforcement must be braided for fitting retention.

Pressure PSI	*Hose I.D. Size (Inches)*
5500	¼
4500	⅜
4000	½
3250	⅝
3000	¾
2500	1
2250	1¼
1750	1½
1250	2

a. Hoses must be protected from abrasion, excessive bending and excessive heat.

b. Hose and fluid conductors must have a bursting pressure safety factor of four.

c. Hose is preferred. Where tubing is used, 37-degree flared ends are required.

8. Tubing and piping shall be mounted to minimize vibration, and tubing shall have only gentle bends to change direction or compensate for thermal expansion. Tube bend radii shall not be less than three times the inside diameter.

9. Wherever practicable, valves shall be manifold mounted.

10. Complete circuit diagram shall be provided. Only NFPA, ANSI and ISO symbols shall be used in graphical diagrams. Pictorial and cutaway diagrams are also permissible where they add to the ease of understanding the circuit. Diagrams shall be large enough to be easily followed for trouble shooting.

11. Galvanized pipe and fittings shall not be used.

12. The vacuum at the pump inlet(s) shall not be more than 60% of pump manufacturer's recommendations or 4 inches mercury, whichever is less at standard conditions. Test opening shall be provided.

Report of Committee 28—Clearances

L. Schmitz, *Chairman*
L. R. Beattie,
Vice Chairman
J. E. Beran, *Secretary*

R. R. Snyder
D. W. LaPorte
E. E. Kessler
W. S. Tustin
F. A. Svec
M. L. Power
P. T. Sarris
E. Berendt
E. S. Birkenwald (E)
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G. M. Buck
R. P. Christman
J. E. Cosky
J. A. Crawford
S. M. Dahl (E)
M. E. Dust
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G. E. Henry
J. C. Hobbs
G. P. Huhlein
L. R. Hurd

C. F. Intlekofer
E. W. Jantz
R. G. Klouda
A. J. Kozak
E. C. Lawson
G. W. Martyn
A. Mooney
J. R. Moore
W. E. Morgus
F. B. Persels
C. E. Peterson (E)
R. T. Pritchett
W. P. Silcox
E. C. Smith
C. H. Stephenson
J. E. Teall
W. J. Trezise
M. Van Kuiken
M. E. Vosseller

Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

No report.

1. Investigate the Practicability of Using Disposable Coded Placards for Identifying Shipments of Excessive Dimension and/or Weight that Could Be Used in Conjunction with the Automatic Car Identification System.

The title and purpose of this subcommittee has been revised to "Investigate the Practicability of Using Disposable Placards or Other Appropriate Marking for Identifying Shipments of Excessive Dimensions and/or Weight." This change was felt necessary due to the Automatic Car Identification System not being fully developed as intended and a standard, easily recognized placard being more practical and better serving the purpose of identifying these loads. Current placards of various railroads are now being studied as a possible basis for a new common design.

2. Compilation of the Railroad Clearance Requirements of the Various States.

State clearance law changes are continuing to be compiled and a revised tabulation will be published when a significant revision or revisions are accumulated.

3. Investigate New Methods and Development of Equipment for Recording Measurements of Clearance of Structures Along Right-of-Way and Overall Dimensions of Cars and Loads.

   Progress report, submitted as information .... page 339

4. Restudy and Possibly Revise "Clearance Diagrams—Fixed Obstructions," Now in the Manual.

   No report.

5. Revise "Suggested Methods of Presenting Published Clearances," Now in the Manual.

   A suggested new format has been developed for presenting clearance information in *Railway Line Clearances.* However, it was felt that a canvas of subscribers by questionnaire, using the suggested format as a basis, could coordinate the needs and desires of all concerned in a final design that would be the most acceptable and usable by the greater majority if not all who use the publication. This will be done in the near future.

9. Investigate the Possibility of Including the Truck Center Dimension of All Cars in the Official Railway Equipment Register, Collaborating as Necessary or Desirable with the Mechanical Division, AAR.

   This investigation has just been completed and it was found to be possible to include this additional information in the publication by action of the individual railroads and car owners. A formal report is now being prepared.

THE COMMITTEE ON CLEARANCES,
L. SCHMITZ, *Chairman.*

Report on Assignment 3

Investigate New Methods and Development of Equipment for Recording Measurements of Clearances of Structures Along Right-of-Way and Overall Dimensions of Cars and Loads

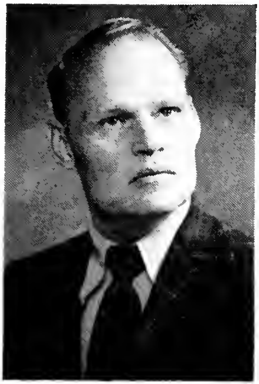
W. S. TUSTIN *(chairman, subcommittee)*, E. BERENDT, C. W. FARREL, G. P. HUHLEIN, R. G. KLOUDA, W. E. MORGUS, R. R. SNYDER.

A questionnaire submitted to all members of Committee 28 requesting information on their methods of obtaining clearances and clearing shipments resulted in replies from 20 railroads. Of this representative 20, 11 railroads reported obtaining their field clearance measurements manually with a survey party, three reported a combination of the manual method and the use of a "feeler" type clearance car, three reported use of the "feeler" type clearance car only, and the remaining three reported use of a photographic "scope" car. Two new methods mentioned were stereoscopic photography used by the Swiss Federal Railways and a system using photoelectric cells. However, these methods are not currently being used in this country and there was not enough information available for proper evaluation.

Five railroads of the representative 20 reported using computers in clearing oversize shipments on their lines, the remaining 15 using the old clearance chart method, however, three of these indicated they were currently developing computer programs.

Investigation on this subcommittee assignment has been completed and a final report now being prepared detailing the various current methods of obtaining clearance information in this country. This will be submitted for possible inclusion in the Manual when completed.

Report of Committee 6—Buildings



W. C. STURM, *Chairman*
E. P. BOHN,
Vice Chairman
O. C. DENZ, *Secretary*

T. H. SEEP
J. G. ROBERTSON
W. C. HUMPHREYS
RICHARD HALE
J. A. COMEAU
D. A. BESSEY
W. F. ARMSTRONG
S. D. ARNDT
F. R. BARTLETT
G. J. BLEUL
G. J. CHAMRAZ
F. D. DAY
C. M. DIEHL
G. W. FABRIN
C. S. GRAVES (E)
A. R. GUALTIERI
W. G. HARDING (E)
J. W. HAYES
H. R. HELKER
S. B. HOLT
K. E. HORNUNG
C. R. MADELEY
R. J. MARTENS
R. W. MILBAUER
L. S. NEWMAN
JOHN NORMAN
L. A. PALAGI
T. F. PEEL
P. W. PETERSON
R. E. PHILLIPS
R. D. POWRIE
R. F. ROBERTS
J. H. RUMP
J. E. SCHAUB (E)
H. A. SHANNON, JR.
J. S. SMITH
S. C. URBAN
W. M. WEHNER
T. S. WILLIAMS (E)
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

Subcommittee assisted on Assignments 1 and 2 in placing report in decimal format for publication as Manual material. Subcommittee to review Chapter 6 of the Manual for possible revision and upgrading.

1. Design Criteria for Maintenance of Way Equipment Repair Shops.

Final report, submitted for adoption and publication in the Manual, was printed in Part 1 of Bulletin 655, November–December 1975.

2. Design Criteria for Elevated Yard Office Buildings.

Final report, submitted for adoption and publication in the Manual, was printed in Part 1 of Bulletin 655, November–December 1975.

3. Design Criteria for Freight Forwarding Facilities.

Outline for proposed report reviewed at summer meeting.

4. Inspection and Maintenance of Railway Buildings.

A series of reports on various components of railway buildings will be submitted under this assignment. The first report, which will cover inspection and maintenance of roofs, will be published in 1976.

5. Architectural Design Competition.

Report on progress of the Competition and the Competition Problem submitted as information .... page 342

THE COMMITTEE ON BUILDINGS,
WALTER CARSON STURM, *Chairman*.

Report on Assignment 5

Architectural Design Competition

D. A. Bessey *(chairman, subcommittee)*, E. P. Bohn, J. A. Comeau, F. D. Day, G. W. Fabrin, R. Hale, J. W. Hayes, S. B. Holt, K. E. Hornung, W. C. Humphreys, C. R. Madeley, R. J. Martens, R. W. Milbauer, L. S. Newman, L. A. Palagi, P. W. Peterson, R. E. Phillips, R. D. Powrie, J. G. Robertson, J. H. Rump, H. A. Shannon, W. C. Sturm, S. G. Urban.

Your committee submits the following report, as information, on the direction of an Architectural Design Competition for college and University students:

GENERAL STATEMENT

The AREA Board of Direction at its meeting on March 25, 1975, approved the funding of an Architectural Design Competition for college and university students during the Fall of 1975.

In staffing the architectural or building departments of railway companies it is necessary to familiarize the architectural students throughout the United States and Canada with railroad architecture and to bring about an awareness of employment opportunities in the railroad industry. There is a definite need to improve communications between the railroad industry and colleges and universities having architectural programs.

The idea of conducting an Architectural Design Competition was originally proposed in 1971 which resulted in the formation of a special subcommittee to contact various universities and to prepare a preliminary draft of the program. Upon receiving favorable response from the universities, the subcommittee proceeded to develop the program.

The building selected by the committee for the competition was a control tower and service building for a railroad classification yard. It was felt by the committee that this type of building would offer the participating student a challenging and informative project.

The preliminary draft of the Competition was sent to 79 colleges and universities in the United States and 10 in Canada; as of October 1, 1975, 27 universities, 24 in the United States and 3 in Canada, have elected to participate. Approximately 800 students will be involved in the Competition. A representative of Committee 6 has been assigned to each school participating. He will act as an advisor, who will assist the school's architectural staff in matters dealing with the Competition. D. A. Bessey, a former chairman of Committee 6, has been appointed director of the Competition and will administer the Competition for the committee.

The entries will be judged by a panel of seven railroad architects who are members of Committee 6 and who represent a general cross section throughout the United States and Canada. All entries are to be submitted to the director of the Competition by January 31, 1976, and will be judged in mid-February.

Cash awards of $500 for first prize, $250 for second prize and 5 honorable mentions of $50 each have been authorized by the Association. The winning student will be invited to appear at the Annual Technical Meeting of the AREA to be held at the Palmer House in Chicago, and will give a presentation of his winning entry on March 23 as part of a special feature to be presented by Committee 6.

The members of Committee 6 have devoted considerable time and effort in the preparation and implementation of the Competition. The committee is looking forward to an interesting and worthwhile relationship between the railroad industry and the architectural students in colleges and universities throughout the United States and Canada.

LIST OF PARTICIPATING UNIVERSITIES

University of Arkansas
Fayetteville, Arkansas
E. F. Jones, Chairman

University of Arizona
Tucson, Arizona
Robert E. McConnell, Dean

Arizona State University
Tempe, Arizona
Robert G. Hershberger, Dean

Ball State University
Muncie, Indiana
Anthony J. Costello, Dean

Boston Architectural Center
Boston, Massachusetts
Sanford R. Greenfield, Director

University of California
Berkeley, California
Richard C. Peters, Chairman

Catholic University of America
Washington, D. C.
Forrest Wilson, Chairman

Clemson University
Clemson, South Carolina
Harlan E. McClure, Dean

University of Colorado
Boulder, Colorado
Robert C. Utzinger, Director

University of Detroit
Detroit, Michigan
Bruno Leon, Dean

Georgia Institute of Technology
Atlanta, Georgia
Paul M. Heffernan, Director

Harvard University
Cambridge, Massachusetts
George Anselevicius, Chairman

University of Illinois
Urbana, Illinois
G. Day Ding, Head

University of Kentucky
Lexington, Kentucky
Anthony Eardley, Dean

University of Minnesota
Minneapolis, Minnesota
Ralph Rapson, Head

University of Nebraska
Lincoln, Nebraska
W. Cecil Steward, Dean

University of Notre Dame
South Bend, Indiana
Ambrose M. Richardson, Chairman

Oklahoma State University
Stillwater, Oklahoma
Mark T. Jaroszewicz, Head

University of Oregon
Eugene, Oregon
Wilmot G. Gilland, Head

Pratt Institute
Brooklyn, New York
Alan J. Forrest, Director

Rhode Island School of Design
Providence, Rhode Island
Derek Bradford, Dean

University of Southern California
Los Angeles, California
Gerald G. Weisbach, Asso. Dean

Texas Tech University
Lubbock, Texas
Nolan E. Barrick, Chairman

Tuskegee Institute
Tuskegee, Alabama
Charles C. Hight, Head

University of Calgary
Calgary, Alberta, Canada
James McKeller, Head

Nova Scotia Technical College
Halifax, Nova Scotia, Canada
P. Manning, Director

University of Waterloo
Waterloo, Ontario, Canada
Fraser Watts, Director

RULES OF THE COMPETITION AND PROGRAM

AMERICAN
RAILWAY
ENGINEERING
ASSOCIATION

ARCHITECTURAL COMPETITION

CONTROL TOWER
AND
SERVICE BUILDING
FOR
RAILROAD
CLASSIFICATION YARD

COMMITTEE
6
BUILDINGS

AMERICAN RAILWAY ENGINEERING ASSOCIATION

The American Railway Engineering Association is a non-profit organization whose objective is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways. Founded in 1899, its membership is primarily composed of employees of the Engineering Departments of Railway Companies. Committee 6, which is sponsoring this Competition, is the Buildings Committee of the American Railway Engineering Association, whose membership consists of Architects, Building Engineers and Designers.

RULES OF THE COMPETITION

Judging of the Competition

The entries in the Competition will be impartially judged based on aptness of the solution and originality of design. The judges will be

R. Hale, Architect, Atchison, Topeka & Santa Fe Railway, Los Angeles, Calif.
AA in Architecture, Los Angeles City College and BA in Architecture, University of Southern California. License: California & Arizona. Certified: NCARB.

K. E. Hornung, Assistant Chief Engineer—Structures, The Milwaukee Road, Chicago.
Architectural Engineering, Iowa State, and BA, University of Minnesota. License: Illinois, Iowa, Minnesota and Wisconsin.

W. C. Humphreys, Architect, Penn Central Transportation Company, Philadelphia, Pa.
Illinois Institute of Technology, Chicago, and Pratt Institute, Brooklyn, N. Y. License: Illinois, New York, Pennsylvania, Minnesota, Connecticut and New Jersey.

L. S. Newman, General Architect, St. Louis–San Francisco Railway, Springfield, Mo.
BA in Architecture, Oklahoma State University, Stillwater, Okla. License: Missouri and Tennessee.

L. A. Palagi, Architect, Ellington Miller Co., Chicago.
Illinois Institute of Technology. License: Illinois.

R. D. Powrie, Senior Architect, Canadian Pacific Rail, Montreal, Que.
BA, University of Toronto. License: Order of Architects of Quebec.

S. G. Urban, Architect (Retired), Missouri Pacific Railroad.
Master of Architecture, Washington University, St. Louis, Mo. License: Missouri and Texas.

Method of Submission

Entries shall be submitted on two white illustration boards measuring 30 inches by 40 inches securely fastened together. No name or school affiliation shall appear on the face of the board. Name and address of entrant together with school affiliation shall be placed on the reverse side of each board in an area 3 inches by 5 inches and shall be covered by an opaque white index card securely taped so name, address and affiliation cannot be seen. Boards shall be shipped together so that both parts of each entry may be numbered upon arrival. Boards shall be titled as shown in Exhibit 1.

Date of Submission

Entries shall be sent to the Director of the Competition:

D. A. Bessey, Architect
Chicago, Milwaukee, St. Paul & Pacific Railroad
Room 809, 516 W. Jackson Blvd.
Chicago, Illinois 60606 (Telephone: 312–236–7600)

Entries must be received prior to midnight, January 31, 1976, to be considered. Winners will be notified no later than February 20, 1976.

Awards

The following awards will be made:

First Prize	$500
Second Prize	$250
Honorable Mention (5)	$ 50 each

Drawings to Become Property of AREA

All drawings entered will become the property of the American Railway Engineering Association. Drawings may be published in the Proceedings of the Association and in industry trade publications at the discretion of the Association.

Winner to Appear at Annual Technical Conference

The first-place winner will be invited to appear at the Annual Technical Conference of the Association to be held at the Palmer House, Chicago, on March 23, 1976. Winner shall be prepared to give a 10-minute oral presentation of his entry. Travel, lodging and food for the winner shall be arranged and paid for by the Association.

Presentation Requirements

The "Design Presentation" should be considered as the presentation normally given by an architect to a client. It should be executed in a professional manner. Presentation requirements are as follows:

1. Site plan at 1/16″ = 1′–0″
2. All floor plans at ⅛″ = 1′–0″ with indication of furniture and equipment
3. Two elevations at ⅛″ = 1′–0″ indicating finish materials
4. Cross section at ¼″ = 1′–0″ indicating materials used in consruction
5. Perspective of building

Note: Site plan, floor plans, elevation and section to be done in black and white. Color may be used on perspective only.

Inquiries

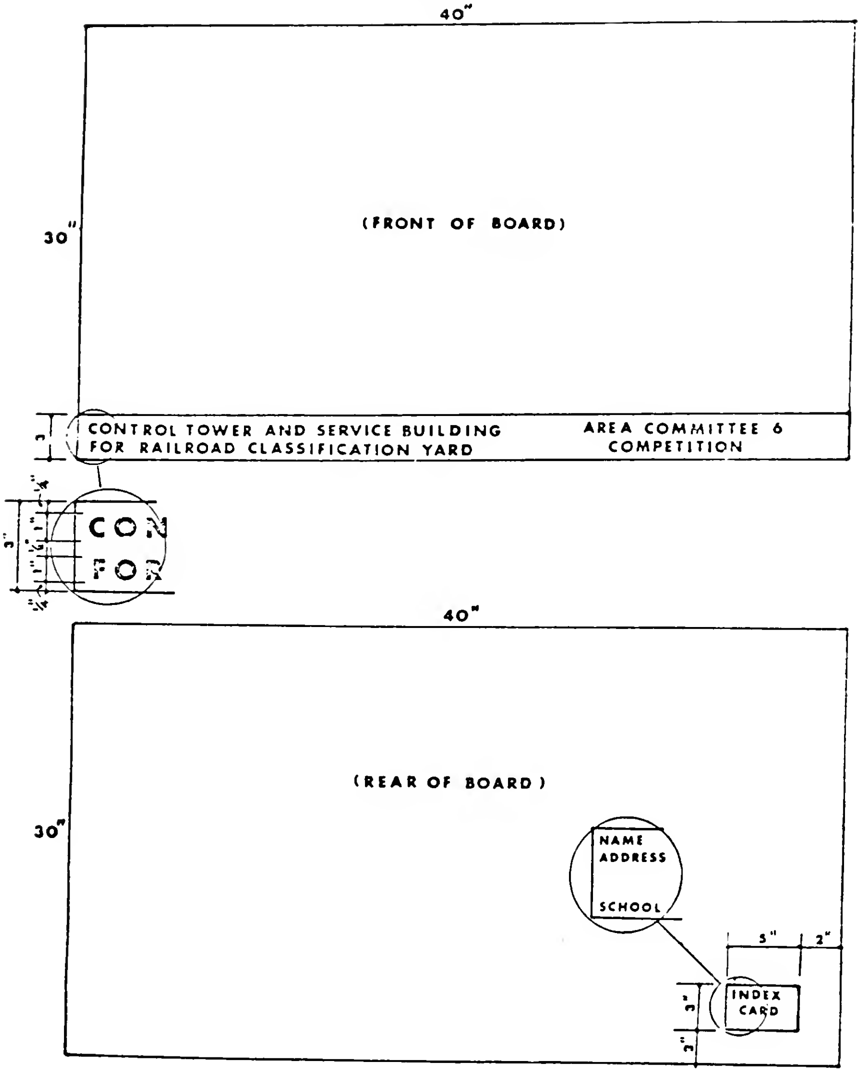
Inquiries shall be made to the director of the Competition and his decisions shall be final and binding.

Note: A draft of a report on Elevated Yardmaster's Towers prepared by AREA Committee 6 and containing recommendations for the design of this type of structure is attached. It is to be noted that information included in this report is of recommendatory nature and is not binding upon the railroads or participants in the competition but is submitted as information only.

W. C. STURM, *Chairman*
Senior Project Engineer
Elgin, Joliet & Eastern Railway
Joliet, Ill.

E. P. BOHN, *Vice Chairman*
Engineer Buildings
Louisville & Nashville Railroad
Louisville, Ky.

Exhibit 1


40"
30"
(FRONT OF BOARD)
CONTROL TOWER AND SERVICE BUILDING
FOR RAILROAD CLASSIFICATION YARD
AREA COMMITTEE 6
COMPETITION
3"
¼"
1"
½"
1"
¼"
3"
CO
FO
40"
(REAR OF BOARD)
30"
NAME
ADDRESS
SCHOOL
5"
2"
INDEX
CARD
3"
2"

THE PROBLEM

General Scope

The problem consists of a design for a Control and Service Bulding for a railroad classification yard. A classification yard is a railroad facility that receives freight trains and individual freight cars that are uncoupled and classified into numerous yard tracks where trains are made up and dispatched to various destinations. The particular type of classification yard in this problem is commonly called a "hump yard." The operation of the hump yard involves the uncoupling of cars at the top of an incline allowing the cars to move by gravity down the incline and be automatically switched into various yard tracks. There are devices called retarders that apply pressure against the wheels of the freight cars as they move down the incline which regulate their speed. The Building in the problem is the central control point for the entire hump yard operation.

The Building will house air compressors which produce compressed air to operate the retarding equipment. There will also be shop facilities to maintain the equipment, welfare and washroom facilities for employees, electronic equipment, computer room and the operators control station.

Site Information

The Building will be located south of the classification yard tracks as indicated on the site plan (Exhibit 2).

Provide parking facilities for 30 automobiles which shall be located south of the building and separated from the railroad yard operation.

The railroad property line is parallel to the main hump track and is located 200 ft south of the proposed building location. Parallel to the railroad right-of-way line is a frontage road with a 100-ft right-of-way. Beyond the frontage road is a four-lane interstate highway with a residential development located south of the interstate highway.

There is a mass transit bus line operating on the frontage road.

Zoning Ordinances

A nearby airport restricts the total height of buildings to 45 ft.

Building Code

Current edition of Uniform Building Code or National Building Code of Canada.

Fire Limits

Building shall be of fire-resistant construction.

Building Design Criteria

1. Compressor room with a minimum of 600 sq ft containing two air compressors. The compressors measure 5 ft x 10 ft x 6 ft high, weigh 8,000 lb each and are mounted on vibration absorption pads. The electric control cabinet for the compressors will be wall-mounted with a dimension of 2 ft deep x 18 ft long x 6 ft high.
2. Small elevator—maximum four passengers.
3. Mechanical room for heating and air-conditioning equipment.
4. Shop and storage room for moderately heavy bench work. Area shall be a minimum of 500 sq ft and shall be used for repairing "car retarding equipment." The largest component of this equipment weighs 300 lb.

5. Washroom facilities for yard switching crews and maintenance personnel, consisting of locker room, toilet room and lunch room area. The vending machines are to be located in the lunch room area. Locker room to accommodate seventy 18- x 18- x 72-in. lockers. Lockers may be back to back. A maximum of 30 personnel will occupy this space at any one time.

6. Electronic equipment room with minimum of 800 sq ft. The equipment which controls the operation of the car retarders and switching is mounted on shelf type racks 2 ft wide x 4 ft long and 8 ft 6 in. high. The equipment racks are installed in rows with a minimum of 4-ft aisles between racks with access to both sides of racks.

7. Storage room of a minimum of 200 sq ft for electronic parts which shall be adjacent to electronic equipment room.

8. An area for light bench work to repair electronic component. The largest of these components weighs 20 lb. This repair function is a one-person operation.

9. Communication equipment area with a minimum of 200 sq ft.

10. Operators control room with a minimum of 200 sq ft. The room shall contain a control console which is an 8 ft long x 3 ft wide table. The operator sitting at the table shall have a clear view to the east, north and west and shall be able to view the ground at a point 70 ft north of the building and beyond. The top of the table shall be 35 ft above ground level.

11. Computer room with a minimum of 500 sq ft, which shall contain a raised floor 12 in. above the structural floor which shall contain power and control cables for the computer equipment.

12. Office for computer room supervisor and two clerks.

13. Toilet facilities for control room operator and computer room personnel. There will be a maximum of four people of each sex at any one time and there shall be separate toilet facilities for men and women.

General Information

The railroad yard and the general site in the vicinity of the building shall be restricted to railroad employees only.

The hump yard operation is carried out 24 hours a day, seven days a week.

The building shall be air-conditioned.

There shall be two air reservoir tanks located east or west of the building and relatively close to the compressor room. Tank size is 8 ft in diameter and 30 ft long.

The car retarder system produces a high-frequency sound of 120 decibels at 100 ft.

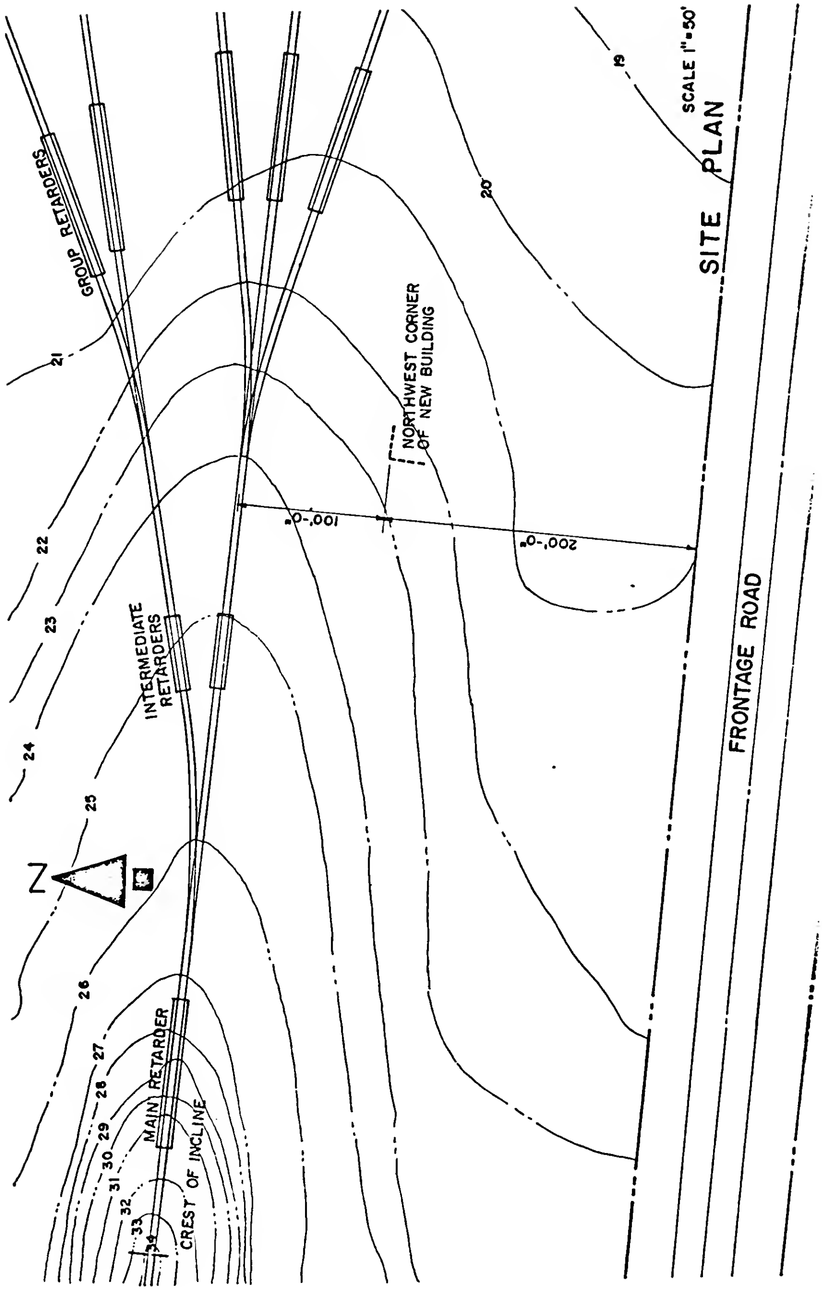

SITE PLAN
SCALE 1"=50'
GROUP RETARDERS
INTERMEDIATE RETARDERS
MAIN RETARDER
CREST OF INCLINE
NORTHWEST CORNER OF NEW BUILDING
100'-0"
200'-0"
FRONTAGE ROAD
N
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

Exhibit 2

Report of Committee 7—Timber Structures

W. S. Stokely,
Chairman
J. A. Gustafson,
Vice Chairman
J. W. Chambers,
Secretary

J. Budzileni
J. M. Helm
J. H. Huzy
G. N. Sells
R. C. Moody
H. R. Stokes
B. J. King
G. K. Clem
M. J. Marlow
R. E. Anderson
T. E. Brassel
F. H. Cramer (E)
M. J. Crespo
A. R. Dahlberg
B. E. Daniels
H. E. Dearing
K. L. DeBlois (E)
D. J. Engle
S. L. Goldberg
D. C. Gould
R. W. Gunther
J. A. Hawley
W. C. Kirkland
D. I. Kjellman
H. G. Kriegel
L. R. Kubacki
R. E. Kuehner
C. V. Lund (E)
D. H. McKibben
C. H. Newlin
W. A. Oliver
N. I. Pinson
R. P. Rasho
J. J. Ridgeway
D. V. Sartore
F. E. Schneider (E)
J. W. Storer
R. W. Thompson, Jr.
W. A. Thompson
J. B. Werner
N. E. Whitney
A. Youhanaie
S. J. Zajchowski
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

No report.

2. Grading Rules and Classification of Lumber for Railway Use; Specifications for Structural Timber, Collaborating with Other Organizations Interested.

No report.

3. Specification for Design of Wood Bridges and Trestles.

No report.

4. Methods of Fireproofing Wood Bridges and Trestles, Including Fire-Retardant Paints.

Final report, submitted as information .... page 352

5. Design of Structural Glued-Laminated Wood Bridges and Trestles.

No report.

7. Repeated Loading of Timber Structures.

No report.

8. Protection of Pile Cut-Offs; Protection of Piling Against Marine Organisms by Means Other Than Preservative.

No report.

9. Study of In-Place Preservative Treatment of Timber Trestles.
No report.

10. Non-Destructive Testing of Wood.
No report.

The Committee on Timber Structures,
W. S. Stokely, *Chairman.*

Report on Assignment 4

Methods of Fireproofing Wood Bridges and Trestles, Including Fire-Retardant Paints

G. N. Sells *(chairman, subcommittee)*, B. J. King, M. J. Marlow, B. E. Daniels, D. H. McKibben, N. E. Whitney, J. B. Werner, J. W. Storer, H. G. Kriegel.

Your committee submits the following report as information. Due to the inactivity of research in this field, the committee recommends that the subject be discontinued until such time as new products are available and warrant the re-creation of a subcommittee.

The reader is directed to reports on this topic in the reports of Committee 7 contained in AREA Proceedings, Volumes 40, 42, 51, 54, 55, 56, 57, 59, 61, 62 and 64.

Currently there are two products being actively marketed in the area of timber fireproofing. Both are known by proprietary names. One of the products is designed to be applied to a completed structure, the second is applied to the timber members by a plant process prior to assembly to a structure.

A member road reports the following experience with an applied type product placed in service in July of 1974.

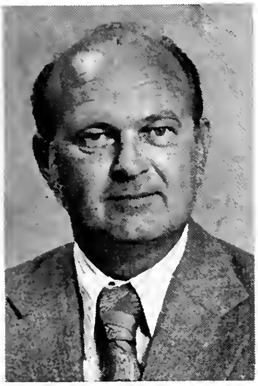
The material was applied to twenty 6-pile bents averaging 8 ft in height with one pair of sway braces (no sash brace) and the exposed sides of caps, stringers and decking.

An estimated 9300 sq ft of surface in the bents and decking was coated with approximately 345 gal of the material to a thickness of 45 mils. Spraying time was approximately 1200 sq ft per hour.

The installation was made very closely following the manufacturer's recommendations and guidelines with one exception. The pump was placed directly in the drum and, in the other bung, a pressure relief valve and gage were inserted, making the drum a pressure pot instead of using the prescribed pressure pot. This eliminated the labor of transferring the material as well as cleaning up the pressure pot.

Sufficient time has not yet elapsed to fully evaluate the durability of the material; however, one inspection, at age 7 months, showed no change in the appearance or features of the material as applied.

Report of Committee 8—Concrete Structures and Foundations



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W. R. Wilson (E)

Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman and vice chairman are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

No manual recommendations made this year.

1. Design of Masonry Structures, Collaborating as Necessary or Desirable with Committees 1, 5, 6, 7, 15 and 28.

Brief status statement .... page 354

2. Foundations and Earth Pressures, Collaborating as Necessary or Desirable with Committees 1, 6, 7 and 15.

Brief progress report, submitted as information .... page 355

3. Waterproofing for Railway Structures, Collaborating as Necessary or Desirable with Committees 6, 7 and 15.

Brief progress report, submitted as information .... page 355

4. Concrete Components for Timber Trestles, Collaborating as Necessary or Desirable with Committee 7.

   Brief progres report, including drawing, submitted as information . . page 355

5. Pier Protection (Fender Systems) at Spans on Navigable Streams, Collaborating as Necessary or Desirable with Committees 7 and 15.

   Brief progress report, submitted as information .... page 357

THE COMMITTEE ON CONCRETE STRUCTURES AND FOUNDATIONS,
T. L. FULLER, *Chairman.*

Report on Assignment 1

Design of Masonry Structures

J. R. MOORE *(chairman, subcommittee)*, W. F. BAKER, W. E. BRAKENSIEK, J. W. DEVALLE, J. T. DOHERTY, R. A. DORSCH, M. E. DUST, F. C. EDMONDS, J. A. ERSKINE, T. L. FULLER, G. W. GABERT, W. L. GAMBLE, E. F. GRECCO, W. A. HAMILTON, C. W. HARMAN, W. R. HYMA, F. A. KEMPE, F. W. KLAIBER, R. H. LEE, G. F. LEYH, J. K. LYNCH, J. F. MARSH, R. E. PEARSON, J. E. PETERSON, E. D. RIPPLE, J. H. SAWYER, J. E. SCROGGS, R. K. SHORTT, L. F. SPAINE, A. TEDESKO, M. FUAT TIGRAK, W. J. VENUTI, J. W. WEBER, J. O. WHITLOCK, J. R. WILLIAMS, W. R. WILSON.

The subcommittee is continuing work on changing design loading to E-80 from E-72 and other upgrading of the design portions of Chapter 8 of the Manual.

Work has continued on ultimate strength load factor design as a possible alternate to working stress design for concrete bridges. Standard concrete spans (designed by working stress method) are being analyzed by load factor design and ultimate strength methods to develop correlations between the methods.

Report on Assignment 2

Foundations and Earth Pressures

G. W. Cooke *(chairman, subcommittee)*, G. F. Dalquist, M. T. Davisson, B. M. Dornblatt, B. Fast, P. Haven, II, R. J. Hallawell, J. D. Holladay, T. R. Kealey, R. H. Kendall, E. F. Manley, E. C. Mardorf, D. Novick, M. P. Schindler, J. R. Shafer, W. B. Stanczyk.

Revisions to Manual material submitted for adoption were published in Bulletin 650. This included entire new Part 3—Specifications for Design of Spread Footings.

Work is in progress on revisions to Part 4—Pile Foundations, and to Drilled Shafts and Caissons, originally published as information in Bulletin 641, January–February 1973.

Work is in progress to discover reasons for inconsistencies in the results obtained using the Coulomb and Boussinesq formula in Part 20 for point, line and strip surcharge loadings.

Report on Assignment 3

Waterproofing for Railway Structures

J. M. Williams *(chairman, subcommittee)*, E. R. Blewitt, W. P. Hendrix, A. K. Howe, J. R. Iwinski, L. Lange, M. Pikarsky, H. D. Reilly, E. E. Runde, R. G. Stilling.

Work is in progress for possible inclusion of ethylene-propylene-diene-monomer (EPDM) as an alternate to butyl membrane or rubberized asphalt and plastic film membrane.

Report on Assignment 4

Concrete Components for Timber Trestles

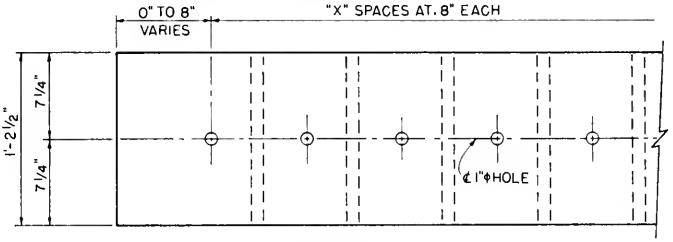
J. R. Williams *(chairman, subcommittee)*, W. F. Baker, J. W. DeValle, G. W. Harman, J. R. Iwinski, E. E. Runde, J. E. Scroggs.

The subcommittee has completed plans for a precast, prestressed concrete cap/sill for usage in timber trestles. This was developed to meet the various requirements of railroads presently using concrete caps in conjunction with suppliers of those caps. Standardization on the recommended cap should benefit both users and suppliers. Typical connection details were not developed, as it is felt that these details come under the jurisdiction of Committee 7—Timber Structures.

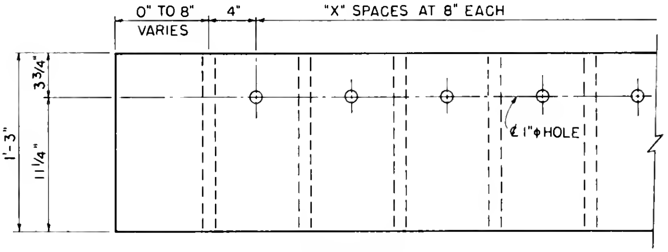
Details of cap/sill are shown as information in the accompanying drawing. (See page 356).

AMERICAN RAILWAY ENGINEERING ASSOCIATION

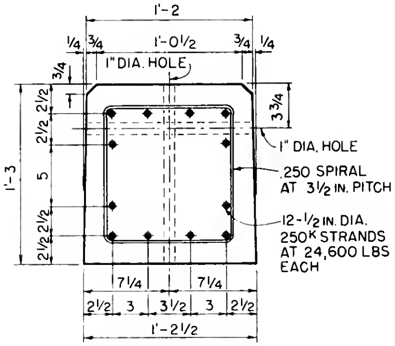
PRESTRESSED CONCRETE CAP AND/OR SILL FOR TIMBER PILE TRESTLE



PLAN VIEW



ELEVATION



TYPICAL SECTION

GENERAL NOTES

1. CAP TO BE MANUFACTURED IN ACCORDANCE WITH A.R.E.A. SPECIFICATION 8-17.
2. CONCRETE = 6,000 PSI AT 28 DAYS
3. CEMENT = A.S.T.M. C150 UNLESS NOTED
4. AGGREGATES = ¾" MAX.
5. STRAND = A.S.T.M. A416
6. REINFORCING = A.S.T.M. A82
7. FINISH = AS FORMED, FREE FROM HONEYCOMBS OR VOIDS
8. ALL HOLES TO BE OPEN, FULL SIZE AND TRUE. CLOSED OR MISALIGNED HOLES MUST BE REAMED OUT TO FULL SIZE BEFORE LEAVING PLANT.
9. TAPERED CAP WEIGHS 222 LBS. PER LIN. FT. RECTANGULAR CAP 14½"x15", WEIGHS 226 LBS. PER LIN. FT.
10. IT IS INTENDED THAT THE UNIT WILL BE CAST IN THE UP-SIDE DOWN MANNER SO THAT THE BEARING SURFACE FOR THE STRINGERS WILL BE SMOOTH AND FLAT. THE TAPER SHOWN IS FOR EASE OF REMOVAL FROM FORMS. THE UNIT MAY BE CAST IN THE RECTANGULAR SHAPE WITHOUT TAPER AT THE OPTION OF THE MANUFACTURER.
11. FOR DETAILS OF HARDWARE AND FASTENINGS REFER TO CHAPTER 7 OF THE MANUAL.

TOLERANCES

OVERALL DIMENSIONS:

LENGTH	-2 IN.
WIDTH	±¼ IN.
DEPTH	±⅛ IN.

ALIGNMENT:

VARIATION FROM STRAIGHT LINE

HORIZONTALLY	±¼ IN.
VERTICALLY	±⅛ IN.

HOLE SPACING: 8 IN.	±½ IN.

THE ¾" CHAMFER AT THE TOP CORNERS SHALL BE SPECIFIED AS A MAXIMUM.

Report on Assignment 5

Pier Protection (Fender Systems) at Spans on Navigable Streams

T. R. Kealey *(chairman, subcommittee)*, W. F. Baker, R. J. Brueske, J. W. DeValle, T. L. Fuller, C. W. Harman, W. R. Hyma, J. R. Iwinski, E. E. Runde, J. E. Scroggs, J. O. Whitlock, J. R. Williams.

This is the first year of this subcommittee. Work is in progress in preparation of design factors for fender systems, exposure conditions, study of forces exerted by moving vessels and types of fender systems presently being utilized.

Report of Committee 15—Steel Structures

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Hernan Solarte
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J. E. Stallmeyer
Z. L. Szeliski
E. S. Thoden
W. M. Thatcher
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C. R. Wahlen
R. H. Wengenroth
W. Wilbur
E. N. Wilson
A. J. Wood
J. A. Zeleznikar

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

Revisions to Specifications for Steel Railway Bridges submitted for adoption were published in Part 1 of Bulletin 655, November–December 1975.

1. Develop Criteria for the Design of Unloading Pits, Collaborating with Committees 7 and 8.

No report.

2. Obtain Data From Which the Frequency of Occurrence of Maximum Stress in Steel Railway Bridges May Be Determined Under Service Loading.

No report.

3. Protection of Steel Surfaces.

No report.

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman and vice chairman, are the subcommittee chairmen.

7. Bibliography and Technical Explanation of Various Requirements in AREA Specifications Relating to Iron and Steel Structures.

   No report.

10. Continuous Welded Rail on Bridges, Collaborating as Necessary or Desirable with Committee 4.

    Revisions to Specifications submitted for adoption were published in Part 1 of Bulletin 655, November–December 1975.

THE COMMITTEE ON STEEL STRUCTURES,
L. F. CURRIER, *Chairman.*

Roland Parker Davis
1884-1974

Roland Parker Davis, Life Member of the American Railway Engineering Association and Member Emeritus of Committee 15—Steel Structures, died on December 11, 1974, at his home in Morgantown, West Virginia.

He became a Member of AREA in 1914 and a Life Member in 1949. He had been a member of Committee 15 for many years and became Member Emeritus upon his retirement from West Virginia University in 1955. He is well remembered for his wise counsel during his tenure on Committee 15. He contributed much to the development of specifications for the design of steel bridges.

He was born on August 2, 1884, at Beverly, Massachusetts, the son of Parker Stephen and Julia Andrews Davis. Upon completing his education in the public schools at Beverly, he entered the Massachusetts Institute of Technology from which he received the S. B. degree in 1906. After working as a draftsman for the American Bridge Company for one year, he resumed his education, entering Cornell University from which he was graduated with the M.C.E. degree in 1908. He was married to Bessie Belle Strantzch of Springfield, Missouri, on June 16, 1910.

Dr. Davis continued at Cornell University, serving as an instructor in engineering while pursuing studies and research leading to his doctorate, which was awarded in 1914. He joined the faculty of West Virginia University in 1911, as associate professor in the Department of Civil Engineering. He subsequently served as professor and head of structural engineering, associate dean of the college of engineering, and in 1932 was elevated to the position of dean of the College of Engineering which he held until his retirement in 1955.

In addition to his teaching appointments at West Virginia University, he also served the State of West Virginia as bridge engineer beginning in 1914. He was influential in organizing the State Road Commission of West Virginia, which was formed in 1919. When its headquarters were moved from Morgantown to Charleston, he continued to serve as a consultant to the Commission's bridge department.

Although his services were largely devoted to the State of West Virginia, he served as a consultant in connection with the design and construction of the Thatcher Ferry Bridge over the Panama Canal, completed in 1962.

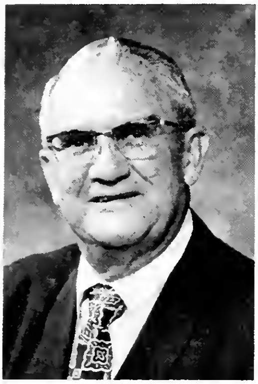
He was active in several professional and technical organizations. He served as a director of the American Society of Civil Engineers from 1937 to 1939. He was vice president of ASCE in 1940. He was made an Honorary Member of ASCE in 1968. He was a member of Tau Beta Pi and Sigma Xi, and a National Honor Member of Chi Epsilon. He had been a member of the Kiwanis for over 50 years.

He was the co-author of two major books, both written in collaboration with the late Professor H. S. Jacoby of Cornell University: *Foundations of Bridges and Buildings,* 1914 and 1925, and *Timber Design and Construction,* 1929.

He is survived by his wife, Bessie Belle Strantzch Davis; a nephew who grew up in his home, J. A. W. Davis; a brother, Clifford Davis of Massachusetts; a sister, Mrs. Elsie Davis Upton of Beverly, Massachusetts; and several other nieces and nephews.

E. S. Birkenwald
J. M. Hayes

Report of Committee 1—Roadway and Ballast



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E. H. Steel
W. H. Stumm
F. A. Tijan, Jr.
R. H. Uhrich
S. S. Vinton (E)
M. E. Vosseller
J. B. Wackenhut
A. J. Wegmann (E)

Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Roadbed.

   Publication in the Manual of Section 1.4—Maintenance, was recommended in Part 1 of the November–December 1975 Bulletin. This completes revision of the entire Part 1—Roadbed, of the Manual.

2. Ballast.

   Progress report on ballast research presented as information .... page 364

3. Natural Waterways.

   A draft of a proposed revision to Part 3, Section 34, has been completed and will be ready for publication in the November–December 1976 Bulletin.

4. Culverts and Drainage Pipe.

   A study is underway to investigate the need for test specifications for aluminum pipe and its application in the railroad roadway.

5. Pipelines.

   Consideration is being given to provide recommendations for use of casing pipe larger than 42-inch diameter.

6. Fences.

   No report.

8. Tunnels.

   No report.

9. Vegetation Control.

   A Manual addition, Table 3—Susceptibility of Woody Species has been published in Part 1 of the November–December 1975 Bulletin. Part 9 of the Manual requires constant review due to environmental control laws concerning the use of some chemicals. This is a continuous task for your committee.

THE COMMITTEE ON ROADWAY AND BALLAST,
E. L. ROBINSON, *Chairman.*

Report on Assignment 2

Ballast

C. E. WEBB *(chairman, subcommittee)*, R. H. BEEDER, R. J. BENNETT, E. W. BURKHARDT, H. K. EGGLESTON, G. E. ELLIS, R. D. HELLWEG, J. K. LYNCH, F. P. NICHOLS, R. H. PETERSON, W. B. PETERSON, R. H. UHRICH.

The following report on ballast research is presented as information.

BALLAST AND FOUNDATION MATERIALS RESEARCH PROGRAM

The Department of Civil Engineering of the University of Illinois at Urbana–Champaign is currently conducting a broadbased research program in the areas of ballast and subgrade materials, via a contract with the Association of American Railroads. This AAR–U of I contract is part of a larger project sponsored by the U.S. Department of Transportation, Federal Railroad Administration.

A review committee consisting of W. S. Autrey, chief engineer System, Atchison, Topeka & Santa Fe, R. M. Brown, chief engineer, Union Pacific, C. E. Webb, assistant vice president, Southern Railway, and F. L. Peckover, engineer of geotechnical services, Canadian National, was established for this program.

The general extent of the research is to conduct an investigation of the physical properties, behavioral characteristics, and associated economics of commonly employed railroad ballast and foundation (subgrade) materials.

The nature of the six phases of activity of the project as well as their status are as follows.

PHASE I: TECHNICAL DATA BASES

The relevant literature pertaining to the pertinent properties of granular materials and fine-grained soils, ballast materials, and analytical structural models, has reen reviewed. A report entitled, "Technical Data Bases Report," has been completed.

PHASE II: DEVELOPMENT OF A STRUCTURAL MODEL AND MATERIALS EVALUATION PROCEDURES

A "mechanistic structural analysis model" has been developed and testing procedures established for evaluating the properties of the ballast and foundation materials needed as inputs to the structural model. The finite element structural analysis model considers the stress-dependent behavior of the ballast and foundation materials. The structural model output includes stresses and displacements in the ballast and foundation materials, tie plate reactions, rail moments and deflections, and tie moments and deflection. A report entitled, "Development of a Structural Model and Materials Evaluation Procedures," has been completed.

PHASE III: PARAMETER STUDIES AND SENSITIVITY ANALYSES

The structural model was utilized to establish the effects of major design parameters on the response of the track support system. The parameters considered included: 1) subgrade soil resilience properties, 2) ballast and sub-ballast material resilience properties, 3) ballast and sub-ballast thicknesses, 4) ballast-tie parameters, and 5) rail-tie parameters. A summary report for Phase III is being prepared for submission to AAR.

PHASE IV: MATERIALS EVALUATION STUDY

A series of laboratory tests are being conducted with selected foundation soils and ballast and sub-ballast materials to determine their pertinent engineering properties. The ballast, sub-ballast, and foundation materials selected for inclusion in the laboratory study represent a range in both engineering properties and types and sources of materials. In addition to the standard AREA specification tests, repeated-load triaxial tests (elastic and permanent deformation measurements), particle index tests, crushing value tests, lateral restraint capability tests, and ballast degradation tests (1×10^6 load repetitions) are being conducted. Phase IV activities have not yet been completed.

PHASE V: ECONOMIC EVALUATION

Costs associated with the use of various types of ballast material will be identified and the cost effectiveness of the ballast materials ranked both as to transportation costs and stability. Phase V has not yet been completed.

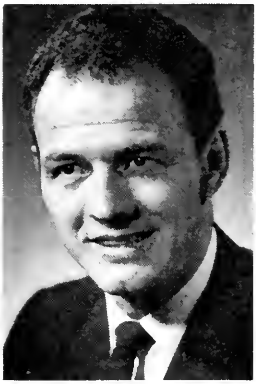
PHASE VI: PREPARATION OF CONCLUSIONS, SUMMARY AND RECOMMENDATIONS

Data and information obtained from the technical literature and that developed in the project will be summarized and analyzed. Appropriate conclusions and recommendations will be developed and areas of technological need will be identified.

The principal project investigators are Dr. Q. L. Robnett, Dr. M. R. Thompson, and Dr. W. W. Hay of the University of Illinois. The principal investigator on the entire contract is Dr. Gregory C. Martin from the Association of American Railroads.

The availability of completed reports can be obtained by writing to the Association of American Railroads Technical Center, 3140 S. Federal St., Chicago, IL 60616.

Report of Committee 3—Ties and Wood Preservation



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H. E. Richardson
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K. W. Schoeneberg
G. D. Summers
R. C. Weller
F. M. Whitmore
J. L. Williams
E. L. Woods
R. G. Zeitlow
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

Revision of Manual Parts 1 to 9 was completed in 1973, submitted for review and approval to the Board Committee on Publications and the AREA Board of Direction and has now been approved for publication. Further revisions to Part 10, Specification for Concrete Ties (and Fastenings), have been proposed and the revised specification was published in Part 1 of the November–December 1975 Bulletin, for reconsideration.

2. Cross and Switch Ties.

Report on 1975 treating plant inspection .... page 368

3. Wood Preservatives.

Brief progress report on investigation of 3 APR6 preservative is presented as information .... page 368

4. Preservative Treatment of Forest Products.

No report.

5. Service Records of Forest Products.

(a) Annual Tie Renewal Statistics as Compiled by the Economics and Finance Department, AAR.

These statistics were published as an advance report in Bulletin 654, September–October 1975.

(b) Investigate Suitability of Imported Cross Ties.
A brief progress report is presented as information .... page 369

6. Collaborate with AAR Research Department and Other Organizations in Research and Other Matters of Mutual Interest.

No report.

THE COMMITTEE ON TIES AND WOOD PRESERVATION,
C. P. BIRD, *Chairman.*

Report on Assignment 2

Cross and Switch Ties

J. T. SKERCZAK *(chairman, subcommittee)*, H. C. ARCHDEACON, W. W. BARNETTE, C. P. BIRD, C. A. BURDELL, M. J. CRESPO, E. M. CUMMINGS, F. J. FUDGE, J. K. GLOSTER, J. E. HINSON, M. A. LANE, G. H. NASH, H. A. RICHARDSON, R. H. SAVAGE, K. W. SCHOENEBERG, R. C. WELLER, R. G. ZIETLOW.

EXTENT OF ADHERENCE TO SPECIFICATIONS FOR CROSS AND SWITCH TIES AS OBSERVED ON FIELD INSPECTION

On May 21st, 1975, 12 members of Committee 3 inspected cross and switch ties at a treating plant in Muncy, Pa. The plant was found to be neat and clean with very good drainage and generally excellent housekeeping. Ties were stacked 9 x 2 for the Reading Company and 9 x 1 for the Penn Central to a height of 17 rows.

Ties in storage were predominantly mixed oak with lesser amounts of mixed hardwoods. Ties were inspected visually at unloader-separator-trimmer. Quality was generally good, selective dowelling being used for anti-splitting control. Tie sizes were in accordance with AREA specifications.

The plant treats approximately 1,200,000 ties annually with 60/40 and 80/20 creosote-coal tar solutions, to net retentions of 6 and 7 lb per cu ft, using vapor drying and Rueping methods, adhering to AREA specifications.

Report on Assignment 3

Wood Preservatives

R. J. SHELTON *(chairman, subcommittee)*, C. P. BIRD, C. A. BURDELL, L. C. COLLISTER, D. L. DAVIES, F. J. FUDGE, J. E. HINSON, G. H. WAY.

Your committee submits the following progress report as information, pertaining to the evaluation of "3APR6" as a wood preservative.

In 1974, Subcommittee 3 was approached by an eastern manufacturer of wood preservatives to evaluate for approval its preservative, "3APR6."

The preservative and process were described as a water-soluble monomer introduced into the wood cells in a closed cylinder by first applying a high vacuum for one-half hour followed by introduction of the liquid monomer into the cylinder under pressure for one-half hour to help increase penetration. Polymerization of the monomer then takes place in the wood.

Upon visiting the plant, the subcommittee decided that the preservative may have some merit and should be evaluated. It was verified that 21 ties which had been treated with "3APR6" had been in service at Easton, Pennsylvania for over seven years. A visit to this site was scheduled for the joint field trip of the AREA Committee and RTA Research Group for May 22, 1975. Three of the 21 ties were marked for removal for further testing. One-half of each of these ties was shipped to the Forest Utilization Lab at Mississippi State University for soil block and strength tests. These ties have been removed and the tests at Mississippi State University are now under way.

The manufacturer is also having several independent laboratories evaluate its "3APR6." Plate wear tests will be run, but plans for this test have not been finalized.

At present, the subcommittee is not trying to draw any conclusions as to the merit of the product, but is collecting as much data from as many different sources as possible. After these data are collected, it will be reviewed by Subcommittee 3, at which time we will make recommendations to Committee 3 as to the acceptance of "3APR6" as a preservative for ties and wood products.

Report on Assignment 5

Service Records of Forest Products

K. C. Edscorn *(chairman, subcommittee)*, L. C. Collister, M. J. Crespo, E. M. Cummings, J. K. Gloster, H. E. Richardson, R. H. Savage, G. D. Summers.

Your committee submits the following report, as information, on the beginning of its investigation to determine the suitability of various woods which have been imported into the United States for use as cross ties.

In order that it might be determined which railroads have foreign species of wood in use as cross ties, a letter was sent to the 17 largest Class I roads asking them to list the number and species in track as well as date of installation, location, type of preservative treatment and class of track. Replies were received from 10 railroads only 4 of which indicated they have installations of foreign woods. These are shown in the accompanying table. (See pages 370–371).

We will continue to gather information about the service and durability of the current installations so that progress on this assignment can be reported in subsequent Bulletins. It is obvious that several years of service will be required before a sound evaluation can be made.

CROSS TIES OF FOREIGN WOODS

MISSOURI PACIFIC RAILROAD

Species in Track

Common Name	*Botanical Name*	*Where Produced*	*Number Installed*	*Date Installed*	*Location of Installation*	*Preservative and Retention*	*Class of Track*
Bullet Tree	Bucida buceras	Br. Honduras	10	Sept., 1975	MP 90.5 Howardton Jct. Ill.	Untreated	Main
My Lady	Asidiosperma megalocarpum	"	10	"	"	"	"
Sapodilla	Achras zapota	"	10	"	"	"	"
Katalosh	Dalbergia Stevensonii	"	10	"	"	"	"
PENN CENTRAL TRANSPORTATION COMPANY							
Honduras Pine	Pinus oocarpa	Honduras	1100	1975	Indpls–St. Louis (PRR Trk 2 MP 131.4–132.5)		Main
"	"	"	1013	1975	(PRR Trk 2 MP 137.5–138.4)		"
"	"	"	642	1975	(NYC Trk 2 MP 62.8–63.5)		"
"	"	"	900	1975	Lancaster, PA Trk 1 MP 64–66		"
"	"	"	431	1975	St. Davids, PA Trk 4 E & W MP 14		"
"	"	"	609	1975	So. Philadelphia, PA New Greenwich Yd and Hump		Yard Hump

SEABOARD COAST LINE RAILROAD							
Pracuuba	Mora excelsa	Amazon Basin, Brazil	17	May, 1975	Callahan, Fla.	8-lb 60/40 CCT Solution	5
Tento	Unknown	"	2	"	"	"	5
Acupurana	Same as Batesia floribunda	"	12	"	"	"	5
Anani	Symphonia globulifera	"	90	"	"	"	5
Jutai–Acu	Hymenaea sp	"	11	"	"	"	5
Pracaxi	Pentaclethra macroloba	"	35	"	"	"	5
Cupiuba	Goupia glaba	"	32	"	"	"	5
Tauary	Eschweilera sp	"	4	"	"	"	5
Tachi	Tachigalia sp	"	7	"	"	"	5
Paranari	Parinari	"	24	"	"	"	5
Parica	Parkia	"	2	"	"	"	5
Jacareuba	Calophyllum brasiliense	"	14	"	"	"	5
Andiroba	Carapa guianensis	"	6	"	"	"	5
Mandioqueira	Qualea sp	"	17	"	"	"	5
Quaruba	Abarema jupunba	"	19	"	"	"	5
Tamaquari	Caraipa sp	"	19	"	"	"	5
Honduras Pine	Pinus oocarpa	Honduras (Highlands)	90,000	1974–75	System	12-lb 60/40 CCT Solution	Various
SOUTHERN RAILWAY							
Sande	Brosimum utile	Ecuador	1000 7"x9"x8'6"	April, 1971	MP 80–81 Millen, Ga.	8-lb 60/40 CCTS	Main
Chanul	Humiria procera	Ecuador					

Report of Committee 4—Rail

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G. H. Way
C. E. Weller
S. T. Wiecek
H. M. Williamson
M. J. Wisnowski
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman, and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

No report.

1. Collaborate with AISI Technical Subcommittee, Welding Contractors, Suppliers of Field Welding, Rail Grinding and Rail Testing Contractors on Matters of Mutual Interest.

No report.

2. Collaborate with AISI Technical Committee on Rail and Joint Bars in Research and Other Matters of Mutual Interest.

(a) Study the subject of obtaining rails longer than 39 ft., looking to developing the optimum length of rail that will be acceptable, based on handling methods, supply of cars for shipping, the number of rails which can be obtained from steel company ingot molds, and other necessary considerations.

No report.

3. Rail Failure Statistics.
   Brief status statement, included in Commentary.
4. Up-date Data on Methods and Equipment for Making Welding Repairs to Rail and Turnouts.
   No report.
5. Rail Research and Development.
   Progress report, submitted as information .... page 376
6. Joint bars: Design, Specifications, Service Tests, Including Insulated Joints and Compromise Joints.
   No report.
7. Laying of Continuous Welded Rail.
   Statistics showing track miles of CWR laid by years since 1933, submitted as information .... page 376
8. Maintenance of Continuous Welded Rail.
   Brief status statement, included in Commentary.
9. Standardization of Rail Sections.
   Progress report, submitted as information .... page 382
10. Effect of Heavy Wheel Loads on Rail.
    No report.
11. Field Welding.
    No report.
12. CWR Field Handbook.
    Brief status statement, included in Commentary.

COMMENTARY

On September 27, 1975, recommendation was submitted by Chairman Brown of Committee 4 to the Board of Direction for approval to consolidate Assignment 3, "Rail Failure Statistics," and Assignment 9, "Standardization of Rail Sections," into one revised Assignment 3, "Rail Statistics."

In the past, reports on both Assignments 3 and 9 of Committee 4 have been confined to rail statistics, Assignment 3 covering a compilation of data on rail failures illustrated by numerous statistics and graphs, and Assignment 9, a brief statistical summary of the annual tonnage rolled and shipped from Canadian and United States rail mills in each individual rail section.

In connection with Assignment 3, the last report of rail failure statistics was made in Bulletin 641 of January–February 1973. These statistics were discontinued in 1973 as it was recognized that the statistics being assembled had little or no value as efforts were being made to compile these numbers from all railroads in the country and the majority of the roads that were attempting to report did not maintain the records that were necessary to furnish Committee 4 with reliable statistics; consequently, the statistics that were published weren't realistic.

Since that time, however, the FRA and Congress have become deeply involved in the problem of upgrading railroads throughout the country and in so doing have been attempting to develop numbers from any source to support the effort. The condition of rail in tracks of the American Railroads is, of course, one of the primary problems within the industry and one of the largest items of expense required to upgrade the properties that are in trouble. Consequently, the FRA has been attempting to assemble data for its own use and for presentation before congressional committees on these rail conditions, and both FRA and congressional committees have been critical of the fact that the AREA, representing the engineering arm of the industry, doesn't have any statistics such as those we attempted to assemble on rail failures to further their study of our problems.

When this matter was brought up at the last Rail Committee meeting in Chicago on June 16–17, 1975, it was discussed thoroughly and it was the consensus of all present that we should attempt to assemble such statistics to the extent that they are available from major roads which do maintain reliable records on rail defects. Consequently, it was concluded that we would again attempt to assemble such statistics only from those roads who can furnish reliable numbers and at least have these available for future reference within the industry and available to Government agencies for their use as required.

As stated above, both of these assignments are primarily confined to rail statistics which are very beneficial and worthwhile; however, compilation of rail statistical data does not require or justify the assignment of two separate subcommittees presently represented by 27 different members of Committee 4 and it was therefore recommended assignments 3 and 9 be consolidated into one revised Assignment 3, "Rail Statistics." This recommendation was approved by the Board of Direction at its meeting November 13, 1975.

It also has been apparent Committee 4 has an area of conflict with Committee 5—Track, as Chapter 5–5–4, "Laying Continuous Welded Rail (CWR)," and Chapter 5–5–4.1, "Maintenance of Continuous Welded Rail," are also the same subjects of Committee 4—Rail, Assignments 7 and 8, respectively.

In view of this conflict, Committee 4 presented this matter to the Board of Direction and on November 13, 1975, the Board transferred Assignments 7 (Laying of Continuous Welded Rail), 8 (Maintenance of Continuous Welded Rail) and 12 (CWR Field Handbook) from Committee 4—Rail to Committee 5—Track.

THE COMMITTEE ON RAIL,
R. M. BROWN, *Chairman.*

Report on Assignment 5

Rail Research and Development

W. J. Cruse *(chairman, subcommittee)*, B. G. Anderson, R. M. Brown, Daniel Danyluk, A. R. DeRosa, G. H. Geiger, R. E. Gorsuch, R. E. Haacke, W. H. Huffman, T. B. Hutcheson, H. F. Longhelt, W. S. Lovelace, T. C. MacKenzie, A. B. Merritt, Jr., J. L. Merritt, C. O. Penney, J. M. Rankin, W. A. Smith, R. K. Steele, D. H. Stone, G. H. Way, M. J. Wisnowski.

Advance progress report was published in Bulletin 654, September–October 1975.

Field inspections were carried out as a cooperative effort of the Rail Research and Development Subcommittee of AREA Committee 4—Rail, the AISI Technical Subcommittee on Rail and Accessories and the AAR Research and Test Department.

On July 30, 1975, an inspection was made of a service test installation of fully heat-treated, induction head-hardened, intermediate manganese and standard control-cooled rail on the Chessie System in the vicinity of Oakland, Maryland. On August 19, 20 and 21 inspections of service test installation of fully heat-treated, induction head-hardened, high silicon and standard control-cooled rail on the Burlington Northern in Montana and Washington were made. The report of their findings will be made available in 1976.

As information, the Ad Hoc Committee on Rail Research, made up of representatives of AREA, AAR and AISI, have contacted a number of railroads throughout this country and Canada and, with their cooperation, established a number of new rail test sites for gathering rail defect statistics. This effort is part of the ongoing cooperative research work having to do with the study of rail defects and the metallurgy of rail steels.

Report on Assignment 7

Laying of Continuous Welded Rail

G. H. Maxwell *(chairman, subcommittee)*, R. M. Brown, Daniel Danyluk, A. R. DeRosa, Emil Eskengren, A. H. Galbraith, R. G. Garland, W. J. Gilbert, R. L. Gray, R. E. Haacke, L. A. Logsdon, H. F. Longhelt, A. B. Merritt, Jr., B. J. Murphy, R. C. Postels, R. B. Rhode, H. L. Rose, A. E. Shaw, Jr., B. D. Sorrels, E. H. Waring, C. E. Weller.

Your committee submits as information the following statistics showing the number of track miles of CWR laid by years for the period 1933 to 1974, inclusive.

Track Miles of CWR Reported By Individual Roads Through 1974

	Oxyacetylene				Electric Flash				
	New		Secondhand		New		Secondhand		
Name of Railroad	*Main Trk.*	*Siding & Yd.*	*Main Trk.*	*Siding & Yd.*	*Main Trk.*	*Siding & Yd.*	*Main Trk.*	*Siding & Yd.*	*TOTAL CWR ON PROPERTY*
Akron, Canton & Youngstown	—	—	—	—	—	—	8.4	—	8.4
Alaska Railroad	—	—	—	—	—	—	—	—	—
Algoma Central	—	—	—	—	—	—	—	—	—
Alquippa & Southern	—	—	—	—	—	—	—	—	—
Alton & Southern	—	—	—	—	—	—	—	—	—
Apalachicola Northern	—	—	—	—	—	—	—	—	—
Ashley, Drew & Northern	—	—	—	—	—	—	—	—	—
Atchison, Topeka & Santa Fe	471.62	—	5.40	—	3296.62	—	1294.78	100.23	5168.65
Atlanta & St. Andrews Bay	—	—	—	—	17.2	2.5	—	—	19.70
Atlanta & West Point	—	—	—	—	—	—	—	—	—
Aroostook Valley	—	—	—	—	—	—	—	—	—
Bangor & Aroostook	—	—	—	—	—	—	—	—	—
Belt Ry. Co. of Chicago	3.83	—	—	—	—	—	5.50	—	9.33
Bessemer & Lake Erie	—	—	—	—	73.98	2.38	117.04	9.63	203.03
Boston & Maine	14.7	—	8.9	—	—	—	10.9	—	34.50
Burlington Northern	352.0	—	—	—	2991.74	—	404.68	—	3748.42
Central R.R. of New Jersey	1.3	—	9.3	.7	—	—	1.5	—	12.80
Chessie System	—	—	—	—	2157.3	—	2405.3	359.3	4921.90
Chesapeake Western	—	—	—	—	—	—	—	—	—
Chicago & Illinois Midland	5.4	—	—	—	—	—	—	—	5.40
Chicago & Western Indiana	—	—	—	—	—	—	—	—	—
Chicago & North Western	—	—	—	—	259.3	—	250.2	5.0	514.50
Chicago, Milwaukee, St. Paul & Pac.	—	—	—	—	—	—	—	—	—
Chicago, Rock Island & Pacific	—	—	—	—	502.96	—	299.20	5.58	807.74
Chicago South Shore & So. Bend	37.66	—	—	—	—	—	—	—	37.66
Chicago Union Station Co.	—	.88	—	—	—	—	—	—	.88
Cincinnati Union Terminal Co.	—	—	—	—	—	—	—	—	—
Chicago, West Pullman & Southern	—	.19‡	—	—	—	—	—	—	.19‡
Clinchfield	71.8	—	—	—	40.8	—	—	—	112.60

TRACK MILES OF CWR REPORTED BY INDIVIDUAL ROADS THROUGH 1974 (CONT.)

	Oxyacetylene				*Electric Flash*				
	New		*Secondhand*		*New*		*Secondhand*		
Name of Railroad	*Main Trk.*	*Siding & Yd.*	*Main Trk.*	*Siding & Yd.*	*Main Trk.*	*Siding & Yd.*	*Main Trk.*	*Siding & Yd.*	*TOTAL CWR ON PROPERTY*
Colorado & Southern	—	—	—	—	46.58	—	—	—	46.58
Colorado & Wyoming	—	—	—	—	—	—	—	—	—
Delaware & Hudson	—	—	—	—	70.04	—	95.98	—	166.02
Denver & Rio Grande Western	52.0	—	—	—	200.0	—	39.0	2.0	293.00
Des Moines Union	—	—	—	—	—	—	—	—	—
Detroit & Toledo Shore Line	—	—	—	—	0.38	—	2.32	—	2.70
Detroit, Toledo & Ironton	—	—	—	—	—	—	—	—	—
Duluth Missabe & Iron Range	.80	—	—	—	65.4	—	5.4	—	71.60
East Erie Commercial	—	—	—	—	—	—	—	—	—
Elgin, Joliet & Eastern	—	—	—	—	—	—	—	—	—
Erie Lackawanna	—	—	—	—	119.93	—	208.42	—	328.35
Florida East Coast	—	—	—	—	140.5	—	95.4	2.1	238.00
Ft. Worth & Denver	—	—	—	—	7.2	—	—	—	7.20
Genesse & Wyoming	—	—	—	—	—	—	—	—	—
Georgia Railroad	—	—	—	—	—	—	—	—	—
Grand Trunk Western	17.43	—	10.13	3.93	100.0	—	10.0	5.0	146.49
Great Western	—	—	—	—	—	—	—	—	—
Green Bay & Western	—	—	—	—	—	—	—	—	—
Harbor Belt Line	—	—	0.41	—	—	—	—	—	0.41
Houston Belt & Terminal	—	—	—	1.85	9.03	—	—	—	10.88
Illinois Central Gulf	845.41	3.95	907.79	42.09	39.03	1.77	0.91	—	1840.95
(Kansas City Southern	5.75	—	—	—	23.70	—	—	—	29.45
(Louisiana & Arkansas									
Kansas City Terminal	—	—	—	—	—	—	11.58	—	11.58
Kentucky & Indiana Terminal	—	—	—	0.51‡	—	—	—	—	0.51‡
Lake Superior & Ishpeming	—	—	—	—	—	—	—	—	—
Lehigh Valley	—	—	6.3	—	—	—	38.81	—	45.11
Long Island	—	—	—	—	57.54	1.00	18.17	—	76.71
Los Angeles Junction	—	—	—	—	—	—	—	—	—

Track Miles of CWR Reported By Individual Roads Through 1974 (cont.)

Name of Railroad	Oxyacetylene				Electric Flash				TOTAL CWR ON PROPERTY
	New		Secondhand		New		Secondhand		
	Main Trk.	Siding & Yd.	Main Trk.	Siding & Yd.	Main Trk.	Siding & Yd.	Main Trk.	Siding & Yd.	
Louisville & Nashville	762.81	2.48	438.41	11.23	327.39	4.07	165.82	3.37	1715.58
Maine Central	—	—	—	—	—	—	—	—	—
Manufacturers	—	—	—	—	—	—	—	—	—
Minnesota Transfer	—	—	—	—	—	—	—	—	—
Mississippi Export	—	—	—	—	—	—	—	—	—
Missouri–Kansas–Texas	—	—	—	—	28.54	—	—	—	28.54
Missouri Pacific	—	—	—	—	2120.80	—	816.3	17.0	2954.10
Monongahela Connecting	—	—	—	—	—	—	—	—	—
Monongahela Ry. & Waynesburg So.	—	—	—	—	48.2	—	—	—	48.20
Montour	—	—	—	—	—	—	—	—	—
Nevada Northern	—	—	—	—	—	—	—	—	—
New York Dock	—	—	—	—	—	—	—	—	—
Norfolk & Western	(Information not available)								1854.23*
Norfolk, Franklin & Danville	—	—	4.0	—	—	—	5.0	—	9.00
Patapsco & Back Rivers	—	—	—	—	—	—	—	—	—
Penn Central Transportation	942.0	—	—	135.0	2004.0	—	904.0	374.0	4359.00
Peoria & Pekin Union	—	—	—	—	—	—	—	—	—
Philadelphia, Bethlehem & N. Eng.	—	—	—	—	—	—	—	—	—
Pittsburgh & Lake Erie	9.7	—	6.5	—	111.1	—	71.8	2.5	201.60
Pittsburgh & Ohio Valley	—	—	—	—	—	—	—	—	—
Pittsburgh & Shawmut	—	—	—	—	—	—	—	—	—
Port Terminal R.R. Assn.	—	—	—	—	18.6	—	—	—	18.60
Quanah, Acme & Pacific	—	—	—	—	—	—	—	—	—
Reading	13.5	—	62.1	1.2	80.8		148.8	—	306.40
Richmond, Fred. & Potomac	58.34	—	—	—	52.92	1.00	28.73	6.06	147.05
St. Louis–San Francisco	135.3	—	—	—	735.58	—	204.03	8.00	1082.91
Sacramento Northern	—	—	—	—	—	—	—	—	—
St. Louis South-Western	—	—	—	—	273.74	—	166.80	—	440.54
St. Paul Union Depot Co.	—	—	—	—	—	—	—	—	—

TRACK MILES OF CWR REPORTED BY INDIVIDUAL ROADS THROUGH 1974 (CONT.)

	Oxyacetylene				*Electric Flash*				
	New		*Secondhand*		*New*		*Secondhand*		*TOTAL*
Name of Railroad	*Main Trk.*	*Siding & Yd.*	*Main Trk.*	*Siding & Yd.*	*Main Trk.*	*Siding & Yd.*	*Main Trk.*	*Siding & Yd.*	*CWR ON PROPERTY*
Sand Springs	—	—	—	—	—	—	—	—	—
Seaboard Coast Line	1278.42	—	859.32	—	128.90	—	—	—	2266.64†
Soo Line	242.17	—	36.25	—	323.17	—	92.87	1.81	696.27
Southern Pacific Trans. Co.	35.90	—	—	—	2316.01	10.16	1459.57	149.76	3971.40
Southern Railway System	—	—	—	—	2890.20	22.80	1997.8	133.5	5044.30
Strasburg Railroad	—	—	—	—	—	—	—	—	—
Terminal R.R. Assn. of St. Louis	—	—	—	—	—	—	—	—	—
Toledo, Peoria & Western	35.0	—	12.7	2.0	9.3	—	29.0	—	88.00
Toledo Terminal	—	—	—	—	9.4	—	2.5	—	11.90
Union	—	—	—	—	5.03	—	—	—	5.03
Union Pacific	10.01	—	—	—	1316.71	1.44	8.85	—	1337.01
Vermont	—	—	—	—	—	—	—	—	—
Western Pacific	—	—	—	—	149.16	—	10.96	—	160.12
Totals	5402.85	7.50	2367.51	198.51	23168.78	47.12	11436.32	1184.84	45667.66*

* Total of 1854.23 not distributed as information not available.
† Siding and Yard Track information not available.
‡ Thermite field type weld.

TRACK MILES OF CWR REPORTED OUTSIDE CONTINENTAL U.S.A.

Canadian National	10.0	—	—	—	3557.0	—	50.0	125.0	3742.0
Canadian Pacific	—	—	—	—	1178.5	—	54.1	—	1232.6
Northern Alberta	—	—	—	—	—	—	—	—	—
Ontario Northland	—	—	—	—	8.0	—	—	—	8.0
Quebec, North Shore & Lab.	—	—	—	—	141.44	9.45	33.63	16.09	200.61
Texas–Mexican	—	—	—	—	—	—	—	—	—
Toronto, Hamilton & Buff.	.58	—	—	—	7.44	10.35	—	—	18.37
	10.58	—	—	—	4892.38	19.80	137.73	141.09	5201.58

TRACK MILES OF CONTINUOUS WELDED RAIL LAID BY YEARS, 1933–1974

			Oxy-acetylene	*Electric Flash*	*Total*
1933	0.16	1955	194.50	72.0	266.50
1934	0.95	1956	372.33	89.10	461.43
1935	4.06	1957	390.47	159.65	550.12
1936	1.52	1958	148.11	312.13	460.24
1937	31.23	1959	378.65	691.92	1070.57
1939	6.04	1960	299.42	961.20	1260.62
1942	5.48	1961	94.13	926.50	1020.63
1943	6.29	1962	310.59	1183.34	1493.93
1944	12.88	1963	497.52	1360.48	1858.00
1945	4.81	1964	586.76	1796.74	2383.50
1946	3.91	1965	700.59	1655.74	2356.33
1947	18.70	1966	746.61	1984.71	2731.32
1948	29.93	1967	784.28	1800.27	2584.55
1949	33.05	1968	643.10	2543.61	3186.71
1950	50.25	1969	674.35	2930.01	3604.36
1951	37.25	1970	800.30	5378.32	6178.62
1952	40.00	1971	504.28	3604.72	4109.00
1953	80.00	1972	422.91	4011.29	4434.20
1954	87.00	1973	465.68	4084.27	4767.37*
		1974	273.79	4183.48	4457.27
					49688.78*

BREAK-DOWN OF CONTINUOUS WELDED RAIL LAID IN 1974—TRACK MILES

	Oxyacetylene		Electric Flash		
	New	Secondhand	New	Secondhand	Totals
Main Track	113.03	147.64	2437.76	1542.39	4240.82
Sidings & Yard Tracks	.31	12.81	6.47	196.86	216.45
	113.34	160.45	2444.23	1739.25	4457.27

* Total includes 217.42 miles reported by Norfolk & Western in 1973, but breakdown not available.

Report on Assignment 9

Standardization of Rail Sections

E. H. WARING *(chairman, subcommittee)*, R. M. BROWN, R. F. BUSH, P. K. CRUCKSHANK, W. J. GILBERT, W. H. HUFFMAN, H. F. LONGFELT, A. B. MERRITT, JR., F. W. MICHAEL, B. J. MURPHY, B. F. OVERBEY, R. C. POSTELS, J. M. RANKIN, I. A. REINER, G. S. TRIEBEL, G. H. WAY, M. J. WISNOWSKI.

During the past year, Subcommittee 9 has secured from the American Iron and Steel Institute Technical Committee on Railroad Materials a summary of the tonnage of rail shipped from Canadian and United States steel mills to North American Railroads. A tabulation of this information is included herewith.

It is noted that 891,382 tons or 87.52% of the total rail shipped was in sections to which it is recommended that purchases of new rail be limited.

CONSOLIDATED REPORT OF RAIL SHIPPED TO NORTH AMERICAN RAILROADS FROM NORTH AMERICAN RAIL PRODUCING MILLS IN 1974 BY WEIGHT AND SECTION

Weight	*Section*	*% Total*	*Tons Shipped*
140*	AREA	6.11	62,203
136*	AREA	14.43	147,033
133	AREA	8.30	84,514
132*	AREA	36.24	369,176
131	AREA	0.01	60
130	AREA	0.05	559
130	PS	0.03	286
122	CB	2.59	26,398
60 KG/M	UIC	0.01	89
119*	AREA	6.08	61,920
115*	AREA	17.19	175,094
112	AREA	0.09	872
100*	AREA	5.61	57,101
100	ARA-A	0.96	9,792
90*	ARA-A	1.86	18,855
85	CP	0.18	1,821
75	BS-11	0.26	2,673
	TOTAL	100.00	1,018,446

* Recommended section

Report of Committee 16—Economics of Plant, Equipment and Operations

M. B. Miller,
Chairman
L. A. Durham, Jr.,
Vice Chairman
M. J. Shearer, Jr.,
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C. Bach
J. W. Barriger (E)
J. W. Barriger
K. W. Bradley
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W. W. Hay
L. W. Haydon
J. P. Holland
M. C. Holowaty
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G. R. Janosko
H. C. Kendall
T. J. Lamphier
R. J. Lane
A. S. Lang
K. L. Lawson
J. H. Marino
R. G. Maughan

R. McCann
R. L. McMurtrie
C. J. Meyer
R. L. Milner (E)
J. Neben
J. F. Partridge
W. L. Paul
J. S. Reed
F. J. Richter
V. J. Roggeveen
A. L. Sams
R. J. Schiefelbein
J. H. Seamon
T. C. Shedd
L. K. Sillcox (E)
M. L. Silver
T. H. Sjostrand
J. J. Stark, Jr.
J. M. Sussman
G. M. Tabor
J. E. Teal (E)
C. L. Towle (E)
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H. Wanaselja
L. E. Ward
F. Wascoe
D. M. Weinroth
D. B. Weinstein
P. B. Wilson
T. D. Wofford, Jr.
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman, and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
No report.

2. Engineering Methods and Economic Considerations Involved in Improving the Quality of Transportation Service.
Final report, presented as information .... page 384

3. Determination of Factors, Including Various Traffic Volumes, Affecting Maintenance of Way Expense and Effect of Using Such Factors, in Terms of Equated Mileage or Other Derived Factors, for Allocation of Available Funds to Maintenance of Way, Collaborating as Necessary or Desirable with Committees 11 and 22.

(a) Additional Maintenance Cost Due to Operating 100-Ton Unit Trains.

No report.

4. Economic Evaluation of Methods for Reducing the Probability of Derailments.

   No report.

5. Economics of Freight Cars with Characteristics Approaching the Limits of Accepted Designs.

   No report.

6. Factors Involved in Rationalization of Railway Systems.

   No report.

7. Applications of Industrial Engineering Functions to the Railroad Industry.

   No report.

8. Economics of Systems for Control of Train Operation.

   No report.

THE COMMITTEE ON ECONOMICS OF PLANT, EQUIPMENT AND OPERATIONS,
M. B. MILLER, *Chairman.*

Report on Assignment 2

Engineering Methods and Economic Considerations Involved in Improving the Quality of Transportation Service

J. R. WILMOT *(chairman, subcommittee)*, D. B. WEINSTEIN *(vice chairman, subcommittee)*, J. W. BARRIGER, W. J. DIXON, G. R. GASPARD, A. J. GELLMAN, J. P. HOLLAND, J. H. MARINO, J. S. REED, T. C. SHEDD, M. L. SILVER, J. M. SUSSMAN, H. WANASELJA, L. E. WARD, F. WASCOE, D. M. WEINROTH.

This is a final report, presented as information.

Quality is an intangible which is not readily susceptible to exact definition or measurement. As anyone who watches TV commercials knows, it means different things to different people and it may mean different things to the same person at different times and in different places.

The scope of this report is confined to quality in railroad freight service. The principal elements of quality in the order of their probable awareness to most customers are:

1. Reliability
   a. In arrival at destination
   b. In elapsed time
   c. In equipment availability

2. Schedule Compatibility with Customer's Requirements
   a. In departure and arrival times
   b. In elapsed time
3. Freedom from loss and damage

Loss and damage, the last item on the preceding list, is different from the others. Both its extent and its cost can be measured, and the railroad industry has long been aware of the desirability of minimizing them. There is a voluminous record of the efforts towards that objective and of occasional accomplishments. This aspect of quality will not be covered in this report.

The proper, or acceptable, level of quality will vary with commodities and with customers. On traffic for which there is intermodal competition the railroads must at least match the quality of the other mode (usually truck) or offer a rate at a discount below the truck rate, or accept the alternative of foregoing the traffic. Here, an economic equation must answer whether the costs to the railroads of bringing their quality of service up to the truck level can be accomplished without increasing rates above those of the truckers. On traffic which is captive to the railroads an unacceptable level of quality will in the short run put the railroad and the customer in an adversary stance both in day-to-day operations and in regulatory proceedings and in the long run will lead the customer to seek production and distribution methods and locations which minimize rail transportation. Normally, improvements in railroad methods and procedures—sometimes in conjunction with modifications in the customer's practices—should be the means of bringing substandard service up to the level required by the customer. Tradeoffs between functions should be sought to hold the rate or the customer's total costs to existing levels. There will be occasions when substandard service reflects a depressed rate, and an improvement in service quality will be contingent upon an upward adjustment of the rate.

At the time when the railroads provided virtually the only intercity freight transportation the quality of service produced by conventional railroad operating practices was the quality expected by customers. These conventional practices were—and frequently still are—oriented toward operating convenience rather than customer service. The growth of other transport modes has been paralleled by changes in industrial production and distribution patterns. A large part of the goods in today's economy are in the hands of companies of national scope with control of, or an overview interest in, their product from raw material source through processing or component production to manufacture or assembly to distribution center. Long hauls may be required between each step, requiring an integration of transportation with production. In this scheme, in order to optimize production schedules, the reliability, or predictability, of transportation movements has taken on much greater importance. Concurrently, centralization of industrial planning has brought a greater sophistication in the treatment of the time value of money, which appears in efforts to minimize investment in goods flowing through the production and distribution process, with resulting lower inventory margins to protect against irregularities in transportation schedule performance. The railroads, as well as industrial companies, have become aware of the time value of money, as is evident from the fact that every car in the railroad-owned fleet is no longer priced for offline rental at one dollar per day.

For the customer who has a traffic movement tied to a particular railroad, service failures or car shortages may stop his production line or leave his dealers out of stock. While this railroad may be the customer's only railroad, this customer is not the railroad's only customer. The railroad's objective is to integrate this customer's traffic into its network in a manner that will produce a profit over a year's time. Satisfying the customer's requirements calls for more accommodation on the part of the railroad than of the customer. For example, railroad schedules and the records by which performance is usually measured are normally in terms of terminal-to-terminal time, but the customer's reliability requirements are in terms of dock-to-dock time.

There must be a meeting of the minds on the level of quality required and the acceptable attainment level. Railroad line-haul service cannot be performed under exactly identical conditions from day to day, and unlike a product, units that do not meet the quality standard cannot be rejected by either a quality-control inspector or the customer.

The association between quality and productivity was pointed out in the report of the Task Force on Railroad Productivity in 1973.[1] This report highlights some of the impediments to greater productivity which must be overcome. One of these is the diffusion of proprietary responsibility among a large number of companies, while at the same time each company, on the average, must share about one-half of its traffic with other companies. The result has been that investments and methods directed at upgrading the quality of service have been more frequent when applied to the half of the traffic which is single-line than to the half which is interline. The interline traffic tends toward longer hauls of higher-rated commodities, but agreement between companies on the costs and benefits of service improvement has not been easy.

The Productivity report brings out that most railroad mergers have been parallel ones, emphasizing cost reductions by avoiding duplications of plant and service. Savings in costs and improvements in service are not mutually exclusive, but, as the report states, trucking company mergers are usually end-to-end, with improvements in service the primary objective. For this reason and others, not all readily adaptable to the railroad industry, a single-line strategy in the trucking industry has resulted in interline hauls with their divided responsibility being exceptional, a feature which should be recognized in railroad service.

The authors of *Improving Railroad Productivity* found five particularly promising areas for innovation, which are: (1) the development of a containerization strategy; (2) a freight car management system; (3) revised train scheduling and operations (especially, shorter, more frequent trains); (4) costing, pricing and profit analysis; and (5) improved management planning. These areas in the context of the report are associated with improved productivity. Throughout the report, however, there is a very clearly implied association between improvement in productivity and improvement in quality of service, revenue and profit.

A recent dialogue on productivity and its association with quality in transportation appeared with the fuel crisis. Several tabulations from neutral sources were published showing energy consumption per ton-mile for various transport modes, with highly favorable rankings for the rail mode. Some trucking industry spokesmen have protested, however, that a truck ton-mile and rail ton-mile are not equal,

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[1] *Improving Railroad Productivity,* Final Report of the Task Force on Railroad Productivity; National Commission on Productivity and the Council of Economic Advisers, November 1973.

because they contend that the former contains a higher quality component, for such factors as speed, reliability and unified control from dock to dock.

The MIT/Southern Railway Study

Probably the most fully documented study on the quality of railroad service—specifically, on the key aspect of reliability—was performed by the Massachusetts Institute of Technology for the Federal Railroad Administration during 1971 and 1972. Following the report of its investigation and research, from November 1972 to January 1974, MIT with FRA funding made a case study on the Southern Railway to implement and apply its findings under actual operating conditions. The results of this case study were published in March 1974.[2]

One region of the Southern was selected for the study, and the first-phase activity was the collection of data on current performance at the levels of origin-destination, corridor, yard, and train, with which reliability was measured. The ability of the Southern's management information system to measure reliability before and after implementation of recommended changes was critical to the success of the case study and such an ability should be a part of any service improvement program.

Sample pages of two regular reliability reports produced by the Southern are illustrated. Figure 1 is a reproduction of one page (for one origin) of a monthly summary of transit time between major terminal pairs on the system. For example, from Origin CINCI (Cincinnati) to Destination NO LA (New Orleans) 785 cars moved during the month, on 639 of which sufficient data were captured for processing in the report. The mean time of the 639 cars was 91 hours. The greatest concentration of traffic in four consecutive 12-hour periods of trip time was 75 percent (see "Four Period" column), the sum of the percentages in frequency distribution columns 6, 7, 8 and 9, by period, with a difference of 1 percentage point due to rounding.

Figure 2 is a reproduction of a page of the supporting detail for Figure 1. The first four lines of data show for the 639 cars measured in Figure 1 the origin and destination terminal times bracketed in 4-hour periods and the total transit time excluding origin and destination terminal time bracketed in 12-hour periods. The following blocks of data show for the cars moving between the origin-and-destination pair by each of several alternate routes the origin and destination time as in the summary block, with the additional breakdown of the total transit time into line-haul time between each terminal in 6-hour brackets and intermediate terminal time in 4-hour brackets.

The Southern is continuing to develop its performance measurement reporting and is using an improved version of the reports illustrated here. Reference is now made to standard trip times, together with other measures which facilitate identification of variations from acceptable performance.

The study team selected situations on the Southern for testing strategies for reliability improvement, based on its prior investigation and research. Any such strategy, it concluded, must achieve one or more of the following results: (1) improve reliability of local service at origin or destination; (2) improve reliability of train connections at intermediate yards; (3) improve the consistency of routing

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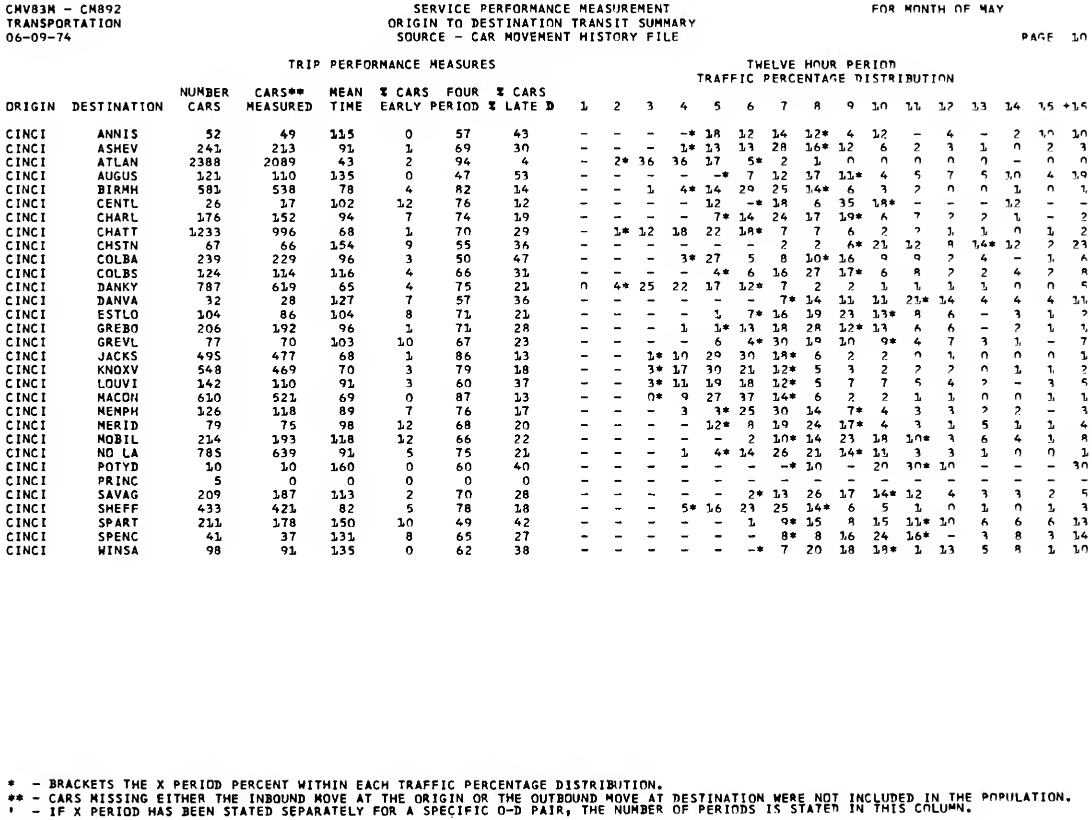
[2] MIT Report No. R74–28, *Improving Railroad Reliability: A Case Study of the Southern Railway;* Studies in Railroad Operations and Economics, Volume 10, by Carl D. Martland.

Figure 1



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CMV83M - CM892                                      SERVICE PERFORMANCE MEASUREMENT                                          FOR MONTH OF MAY
TRANSPORTATION                                   ORIGIN TO DESTINATION TRANSIT SUMMARY
06-09-74                                          SOURCE - CAR MOVEMENT HISTORY FILE                                                                  PAGE  10

                                     TRIP PERFORMANCE MEASURES                                          TWELVE HOUR PERIOD
                                                                                                 TRAFFIC PERCENTAGE DISTRIBUTION
                    NUMBER    CARS**   MEAN % CARS    FOUR  % CARS
ORIGIN  DESTINATION   CARS  MEASURED   TIME  EARLY  PERIOD% LATE D    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15  +15

CINCI   ANNIS           52        49    115      0      57      43    -    -    -    -*  18   12   14   12*   4   12    -    4    -    2   10   10
CINCI   ASHEV          241       213     91      1      69      30    -    -    -    1*  13   13   28   16*  12    6    2    3    1    0    2    3
CINCI   ATLAN         2388      2089     43      2      94       4    -    2*  36   36   17    5*   2    1    0    0    0    0    0    -    0    0
CINCI   AUGUS          121       110    135      0      47      53    -    -    -    -    -*   7   12   17   11*   4    5    7    5   10    4   19
CINCI   BIRMH          581       538     78      4      82      14    -    -    1    4*  14   29   25   14*   6    3    2    0    0    1    0    1
CINCI   CENTL           26        17    102     12      76      12    -    -    -    -   12    -*  18    6   35   18*   -    -    -   12    -    -
CINCI   CHARL          176       152     94      7      74      19    -    -    -    -    7*  14   24   17   19*   6    7    2    2    1    -    2
CINCI   CHATT         1233       996     68      1      70      29    -    1*  12   18   22   18*   7    7    6    2    2    1    1    0    1    2
CINCI   CHSTN           67        66    154      9      55      36    -    -    -    -    -    -    2    2    6*  21   12    9   14*  12    2   23
CINCI   COLBA          239       229     96      3      50      47    -    -    -    3*  27    5    8   10*  16    9    9    2    4    -    1    6
CINCI   COLBS          124       114    116      4      66      31    -    -    -    -    4*   6   16   27   17*   6    8    2    2    4    2    8
CINCI   DANKY          787       619     65      4      75      21    0    4*  25   22   17   12*   7    2    2    1    1    1    1    0    0    5
CINCI   DANVA           32        28    127      7      57      36    -    -    -    -    -    -    7*  14   11   11   21*  14    4    4    4   11
CINCI   ESTLO          104        86    104      8      71      21    -    -    -    -    1    7*  16   19   23   13*   8    6    -    3    1    2
CINCI   GREBO          206       192     96      1      71      28    -    -    -    1    1*  13   18   28   12*  13    6    6    -    2    1    1
CINCI   GREVL           77        70    103     10      67      23    -    -    -    -    6    4*  30   19   10    9*   4    7    3    1    -    7
CINCI   JACKS          495       477     68      1      86      13    -    -    1*  10   29   30   18*   6    2    2    0    1    0    0    0    1
CINCI   KNOXV          548       469     70      3      79      18    -    -    3*  17   30   21   12*   5    3    2    2    2    0    1    1    2
CINCI   LOUVI          142       110     91      3      60      37    -    -    3*  11   19   18   12*   5    7    7    5    4    2    -    3    5
CINCI   MACON          610       521     69      0      87      13    -    -    0*   9   27   37   14*   6    2    2    1    1    0    0    1    1
CINCI   MEMPH          126       118     89      7      76      17    -    -    -    3    3*  25   30   14    7*   4    3    3    2    2    -    3
CINCI   MERID           79        75     98     12      68      20    -    -    -    -   12*   8   19   24   17*   4    3    1    5    1    1    4
CINCI   MOBIL          214       193    118     12      66      22    -    -    -    -    -    2   10*  14   23   18   10*   3    6    4    1    8
CINCI   NO LA          785       639     91      5      75      21    -    -    -    1    4*  14   26   21   14*  11    3    3    1    0    0    1
CINCI   POTYD           10        10    160      0      60      40    -    -    -    -    -    -    -*  10    -   20   30*  10    -    -    -   30
CINCI   PRINC            5         0      0      0       0       0    -    -    -    -    -    -    -    -    -    -    -    -    -    -    -    -
CINCI   SAVAG          209       187    113      2      70      28    -    -    -    -    -    2*  13   26   17   14*  12    4    3    3    2    5
CINCI   SHEFF          433       421     82      5      78      18    -    -    -    5*  16   23   25   14*   6    5    1    0    1    0    1    3
CINCI   SPART          211       178    150     10      49      42    -    -    -    -    -    1    9*  15    8   15   11*  10    6    6    6   13
CINCI   SPENC           41        37    131      8      65      27    -    -    -    -    -    -    8*   8   16   24   16*   -    3    8    3   14
CINCI   WINSA           98        91    135      0      62      38    -    -    -    -    -    -*   7   20   18   19*   1   13    5    8    1   10




*  - BRACKETS THE X PERIOD PERCENT WITHIN EACH TRAFFIC PERCENTAGE DISTRIBUTION.
** - CARS MISSING EITHER THE INBOUND MOVE AT THE ORIGIN OR THE OUTBOUND MOVE AT DESTINATION WERE NOT INCLUDED IN THE POPULATION.
'  - IF X PERIOD HAS BEEN STATED SEPARATELY FOR A SPECIFIC O-D PAIR, THE NUMBER OF PERIODS IS STATED IN THIS COLUMN.
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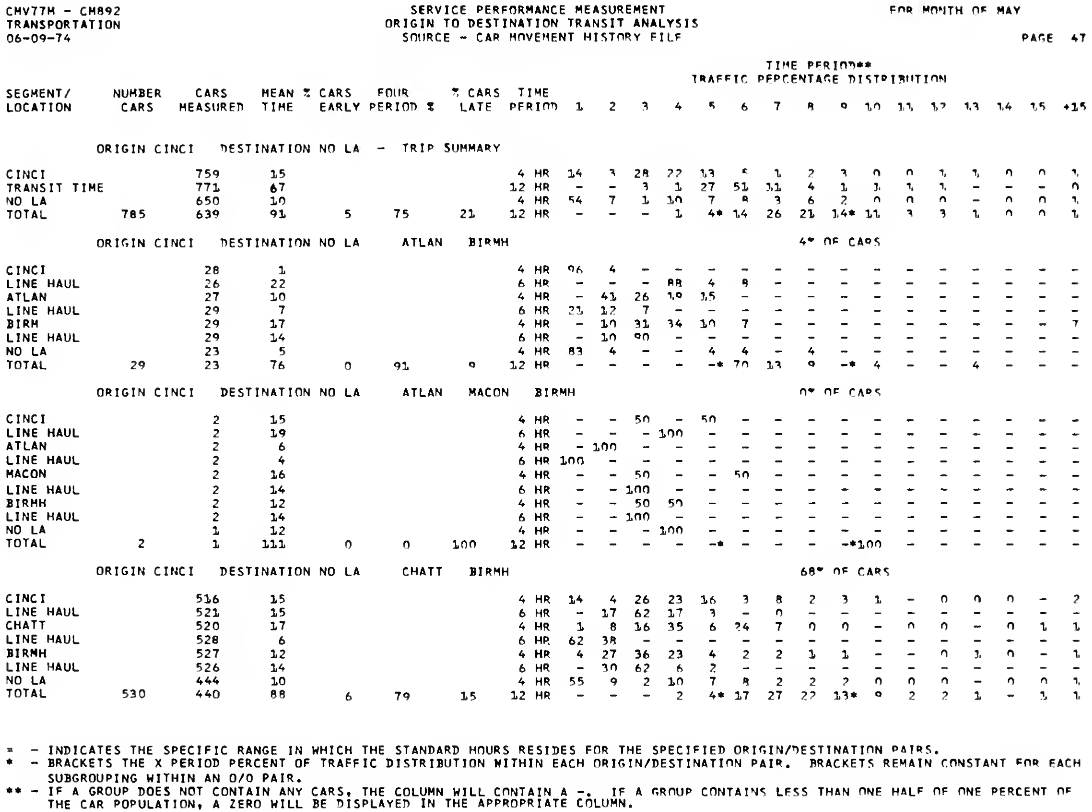
Figure 2



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CMV77M - CM892                        SERVICE PERFORMANCE MEASUREMENT                       FOR MONTH OF MAY
TRANSPORTATION                      ORIGIN TO DESTINATION TRANSIT ANALYSIS
06-09-74                              SOURCE - CAR MOVEMENT HISTORY FILE                                    PAGE  47

                                                                                   TIME PERIOD**
                                                                            TRAFFIC PERCENTAGE DISTRIBUTION
SEGMENT/     NUMBER    CARS    MEAN % CARS   FOUR    % CARS  TIME
LOCATION      CARS   MEASURED  TIME  EARLY PERIOD %   LATE  PERIOD  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  +15


           ORIGIN CINCI   DESTINATION NO LA  -  TRIP SUMMARY

CINCI                   759     15                           4 HR  14   3  28  22  13   5   1   2   3   0   0   1   1   0   0   1
TRANSIT TIME            771     67                          12 HR   -   -   3   1  27  51  11   4   1   1   1   1   -   -   -   0
NO LA                   650     10                           4 HR  54   7   1  10   7   8   3   6   2   0   0   0   -   0   0   1
TOTAL          785      639     91     5     75      21     12 HR   -   -   -   1   4* 14  26  21  14* 11   3   3   1   0   0   1

           ORIGIN CINCI   DESTINATION NO LA     ATLAN    BIRMH                              4% OF CARS

CINCI                    28      1                           4 HR  96   4   -   -   -   -   -   -   -   -   -   -   -   -   -   -
LINE HAUL                26     22                           6 HR   -   -   -  88   4   8   -   -   -   -   -   -   -   -   -   -
ATLAN                    27     10                           4 HR   -  41  26  19  15   -   -   -   -   -   -   -   -   -   -   -
LINE HAUL                29      7                           6 HR  21  12   7   -   -   -   -   -   -   -   -   -   -   -   -   -
BIRM                     29     17                           4 HR   -  10  31  34  10   7   -   -   -   -   -   -   -   -   -   7
LINE HAUL                29     14                           6 HR   -  10  90   -   -   -   -   -   -   -   -   -   -   -   -   -
NO LA                    23      5                           4 HR  83   4   -   -   4   4   -   4   -   -   -   -   -   -   -   -
TOTAL           29       23     76     0     91       9     12 HR   -   -   -   -   -* 70  13   9   -*  4   -   -   4   -   -   -

           ORIGIN CINCI   DESTINATION NO LA     ATLAN    MACON    BIRMH                     0% OF CARS

CINCI                     2     15                           4 HR   -   -  50   -  50   -   -   -   -   -   -   -   -   -   -   -
LINE HAUL                 2     19                           6 HR   -   -   - 100   -   -   -   -   -   -   -   -   -   -   -   -
ATLAN                     2      6                           4 HR   - 100   -   -   -   -   -   -   -   -   -   -   -   -   -   -
LINE HAUL                 2      4                           6 HR 100   -   -   -   -   -   -   -   -   -   -   -   -   -   -   -
MACON                     2     16                           4 HR   -   -  50   -   -  50   -   -   -   -   -   -   -   -   -   -
LINE HAUL                 2     14                           6 HR   -   - 100   -   -   -   -   -   -   -   -   -   -   -   -   -
BIRMH                     2     12                           4 HR   -   -  50  50   -   -   -   -   -   -   -   -   -   -   -   -
LINE HAUL                 2     14                           6 HR   -   - 100   -   -   -   -   -   -   -   -   -   -   -   -   -
NO LA                     1     12                           4 HR   -   -   - 100   -   -   -   -   -   -   -   -   -   -   -   -
TOTAL            2        1    111     0      0     100     12 HR   -   -   -   -   -*  -   -   -   -*100   -   -   -   -   -   -

           ORIGIN CINCI   DESTINATION NO LA     CHATT    BIRMH                              68% OF CARS

CINCI                   516     15                           4 HR  14   4  26  23  16   3   8   2   3   1   -   0   0   0   -   2
LINE HAUL               521     15                           6 HR   -  17  62  17   3   -   0   -   -   -   -   -   -   -   -   -
CHATT                   520     17                           4 HR   1   8  16  35   6  24   7   0   0   -   0   0   -   0   1   1
LINE HAUL               528      6                           6 HR  62  38   -   -   -   -   -   -   -   -   -   -   -   -   -   -
BIRMH                   527     12                           4 HR   4  27  36  23   4   2   2   1   1   -   -   0   1   0   -   1
LINE HAUL               526     14                           6 HR   -  30  62   6   2   -   -   -   -   -   -   -   -   -   -   -
NO LA                   444     10                           4 HR  55   9   2  10   7   8   2   2   2   0   0   0   -   0   0   1
TOTAL          530      440     88     6     79      15     12 HR   -   -   -   2   4* 17  27  22  13*  9   2   2   1   -   1   1


=  - INDICATES THE SPECIFIC RANGE IN WHICH THE STANDARD HOURS RESIDES FOR THE SPECIFIED ORIGIN/DESTINATION PAIRS.
*  - BRACKETS THE X PERIOD PERCENT OF TRAFFIC DISTRIBUTION WITHIN EACH ORIGIN/DESTINATION PAIR.  BRACKETS REMAIN CONSTANT FOR EACH
     SUBGROUPING WITHIN AN O/O PAIR.
** - IF A GROUP DOES NOT CONTAIN ANY CARS, THE COLUMN WILL CONTAIN A -.  IF A GROUP CONTAINS LESS THAN ONE HALF OF ONE PERCENT OF
     THE CAR POPULATION, A ZERO WILL BE DISPLAYED IN THE APPROPRIATE COLUMN.
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between origin and destination; (4) reduce the number of times cars are switched; or (5) reduce the number of extraordinary delays caused by no-bills, misroutes and mechanical failures.

Five distinct tests were made in the case study. These will be described briefly to show the diversity of approaches to the improvement of reliability.

1. The first test situation involved the irregular performance of Trains 93 and 4 between D and A, resulting in very poor service between those points. The implemented recommendations were to operate the trains on a daily schedule rather than irregularly, to operate them beyond A to E with stops only to pick up and set off cars at A, to assign two sets of power exclusively to these trains, and to use the trains for A—E traffic as well as D—E traffic.

2. The problem for which the second test sought a solution was one of long delays on high-cost empty cars between the time they were released by the industry, passed through a satellite yard and departed on an outbound train from the classification yard, A. The trouble was traced to the satellite yard, and the implemented recommendation was that performance standards be set for the satellite yard to the end that all empties in the yard at midnight would arrive at Yard A by 10:00 am and that empties should not remain in the satellite yard more than 20 hours.

3. The third test revolved around poor origin and destination performance on an agricultural commodity originating at local stations and assembled at Yard K for movement on through trains. Investigation disclosed that much of the traffic was humped at two or more classification yards and that connections at Yard K from local trains to 96, the through train handling the traffic, required more than 25 hours on the average. The recommended strategy, which was tested, was to operate Train 96 on a scheduled daily basis rather than irregularly from Yard K to Yard C, to move all traffic for C and beyond in a single block to Yard C, and whenever possible to block cars for C and beyond prior to their arrival at K and thus bypass classification at K.

4. For the fourth test, the problem was that more than 20 percent of the cars from Yard F to Yard E instead of moving direct on Train 34 moved on Train 15 to Yard A, an intermediate point, where they were humped and dispatched on one of several trains, with added transit time of 10 to 40 hours. The recommendations made effective were to move traffic from Yard F to Yard E on Train 34 whenever possible, but, in default, to hold for Train 34 the next day (4 pm) rather than for Train 15 (next day, 8 am), and as a last resort to move traffic on Train 15 only if Yard F is congested or Train 34 will be unable to handle the traffic.

5. The fifth test was directed to the problem at Yard D, which was not unique. Inbound to outbound train connections were unreliable, with approximately 15 percent of the cars humped missing their proper connection, and the time for more than 20 percent of actual connections was in excess of 24 hours. Average scheduled and available yard times were both 13 hours, but average actual yard time was 20 hours. The implemented recommendations were to reschedule one train to depart from Yard D 3 hours later and another train to arrive 2 hours earlier. This was the only

TABLE 1

SUMMARY OF THE TEST PROGRAM

Test No.	Implemented Recommendation		Cars/Day	Increase in Reliability	Decrease in Trip Times	Monthly Decrease In Cost
1.	Operate run-through trains between D and E	Predicted	200	22%	16 hours	$15,000
		Actual	180	14%	19 hours	$15,000
2.	Monitor industrial switching near A	Predicted	60	10%	18 hours	$ 5,000
		Actual	40	15%	21 hours	$ 6,000
3.	Allocate more power and revise local operating procedures for agricultural traffic from K	Predicted	68	25%	18 hours	$ 4,000
		Actual	72	14%	18 hours	$ 6,000
4.	Move through cars only on the runthrough train from F to E *	Predicted	40	10%	12 hours	$ 2,500
		Actual	40	2%*	10 hours*	$ 2,000*
5.	Revise train schedules to reduce unreliable connections at D	Predicted	200	10%	4 hours	$ 4,000
		Actual	210	**	**	**

* This improvement did not result from the test program.
** Comparable results are not available

Source: MIT Report No. R74-23, Table 5-1.

one of the test programs for which the results could not be measured. During the implementation period major network changes on the Southern (significant schedule revisions for six other trains as a result of the opening of the new Sheffield Yard and major roadway work on one of the lines converging on Yard D) obscured the impact of the two schedule changes of the test program.

As depicted in Table 1, the four test programs for which results could be measured were successful in showing improvements in reliability, decreases in transit times, and, in three cases, decreases in costs.

This case study with its three diverse sponsors was unique in its approach to the problem of railroad reliability, and, more important for the railroad industry, in the depth of the reporting of the study, with quantitative results.

The report states that the problem-solving approach and procedure of the test program consisted of the seven following steps: (1) define the objective; (2) measure current performance; (3) identify a manageable set of problems; (4) identify potential solutions; (5) evaluate potential solutions; (6) select and implement the best policies for a trial period; and (7) monitor and record the impacts.

The recommendations which were implemented in the test program evolved under consideration of the following criteria: (1) *Feasibility* of implementation by the Southern on short notice; (2) *Measurability* of predicted and actual impacts; (3) *Effectiveness,* in terms of a substantial improvement in Southern service with a minimal increase in costs; and (4) *Impact,* in terms of important, high-volume traffic movements.

Other Research and Applications

The fully-documented case study on the Southern Railway involved several tests directed at improving service directly, or indirectly through better car utilization, by making localized changes in road and yard schedules, traffic assignment to trains and power assignments.

The subject of quality of service and the need for its improvement is such a broad one that research and applications have been diverse. Local changes with service objectives are, of course, being made somewhere almost every day, but without the benefit to the industry of recorded research and measurement of results. Reported activity is frequently on the development of systemwide concepts or procedures. A brief review of a selection of endeavors on quality improvement follows.

CP Rail.[3] The MINDISC total distribution cost model was developed for use in conjunction with the FRATE operating cost model. Factors considered include the level of reliability customers are willing to pay for, the fact that most trains carry cars with varying levels of customer reliability requirements, and the tradeoffs between advertising faster schedules and seeking maximum reliability with existing schedules. In a test of the model for a train with a specific consumer product, locomotive units were assigned through a range of 2 to 8, and costs were determined for door-to-door transit times from 2.5 to 5 days with 99 percent reliability. For theoretical perfect service total distribution cost was reduced by $2.50 per ton but railroad costs were increased by $5.00 per ton. This illustration was not given to demonstrate that improved service is uneconomic but to show the capability of the model in simulating an idealized level of service, at some level below which it would find the economic optimum level.

Denver & Rio Grande Western.[4] Following research and simulation, the first broad application of a policy of running shorter, faster and more frequent trains was instituted in 1964. Several characteristics of the railroad made it a favorable site for a test of the policy. Perhaps the most significant was the opportunity to eliminate a substantial amount of main-line helper service. A "before and after" comparison of system statistics—in which the effects of the short, fast train policy are reflected—for the years 1963 and 1966 is summarized below:

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[3] "Some Thoughts on the Reliability of Railroading" by Peter J. Detmold, Special Assistant, Research; in Transporting Research Forum Proceedings, 1972, Page 505.

[4] Company documentation.

			Percent Change	
	1963	*1966*	*Actual*	*Adjusted**
Trailing Gross Ton-Miles (Millions)	11,600	14,811	+27.7	—
Crew Costs† (Thousands)	$6,324	$8,772	+38.7	+11.3
Gross Tons per Train	3,481	2,876	−17.4	—
Average Speed (MPH)	22.3	25.4	+13.9	—
Train-Miles (Thousands)	3,333	5,150	+54.5	+26.9
Horsepower per Unit	1,600	2,017	+26.1	—
Unit-Miles (Thousands)	15,223	20,009	+31.4	—
Horsepower-Miles (Millions)	24,357	40,358	+65.7	+38.0
No. of Units	187	187	0	− 1.1
Car-Miles per Car-Day	44.4	53.7	+20.9	—
Car-Days (Thousands)	4,788	4,515	− 5.7	−17.4
Adjusted Increase in Operating Costs			$2,373,000	
Adjusted Savings: Locomotive Ownership			60,000	
Car Hire			3,080,000	
Net Potential Saving			$ 767,000	

* Adjusted to eliminate changes due to increases in wage rates and fringe benefits and in traffic volume.

† Wages and fringe benefits.

Frisco.[5] The Quality Control Section was established in 1964. Among its accomplishments are the TSE Report (Terminal Service Evaluation), measuring elapsed time between pairs of events (e.g., arrival until movement) at 12 terminals, with a summary analysis of missed per diem situations, and train performance summaries of selected trains with exception comparisons of actual movement with schedules in the computer file. These reports influenced decisions to revise priorities in capital improvements because more delays than had been thought were occurring on the road and fewer in terminals, and led to development of a computer-generated train-meet calculator to determine where passing tracks should be extended and to substituting advance sections for second sections whenever possible.

Illinois Central Gulf.[6] A comprehensive study was made of the Memphis terminal, as a test case, to identify proposed rule changes which would enable the railroad to improve the quality of service as a result of more efficient yard operations and better car utilization. The changes are in five categories: labor rules applying to yard crews (*e.g.*, crews to report daily to regular assignments in lieu of calls); labor rules applying to road crews (*e.g.*, crews to put away trains at any number of yards in terminal as directed by yardmaster); labor rules applying to both yard and road crews (*e.g.*, abolish yard limit rules); rules applying to customers (*e.g.*, customers to be charged for rejecting cars which meet their specifications; demurrage charges to be increased); interchange rules (ICC could change designated interchange tracks for deliveries by other railroads on an hour-to-hour basis; per diem to be calculated and prorated on an hourly basis).

Missouri Pacific.[7] TCS (Transportation Control System) was developed with design

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[5] *Railway Age*, July 31, 1972, page 24.

[6] "A Proposal to Improve Railroad Terminal Performance Through Changes in Present Rules" by Larry A. Herndon, Manager, Operating Data Planning; in Transportation Research Forum Proceedings, 1973, Page 213.

[7] "Mopac's Transportation Control System—A System's Approach to Achieving Service Reliability" by Guerdon Sines, Director, Information and Controls Systems; in Transportation Research Forum Proceedings. 1972, Page 513.

objectives to: Increase service reliability through more consistent availability of empties and more consistent movement of loads and empties; reduce transportation costs and maintain them at levels permitting competitive pricing by controlling commitments of cars, power, crews and plant; reduce clerical costs in information generation by reducing the association between peaking in yard and road car activity at terminals and peaking in the accompanying billing and data processing work; improve communication with customers by eliminating redundant forms and messages; improve the quality of management reports by moving from reports of statistical averages toward ones with greater sensitivity to significant variations.

Rock Island.[8] In 1971, with the objective of improving the utilization of covered hopper cars which were in short supply, novel rates were published on corn and soybeans from the Midwest to Gulf ports for export. A series of at least five shipments of not less than 5,000 tons each must be made in not more than 54 cars (up to 64 in light-rail origin territory), which must be committed to a series of consecutive trips, with limited loading and unloading times. The rates are lowest when all the cars are loaded at one elevator, with options for two elevators (a minimum of 15 cars from one elevator) and for any number of elevators in a group (a minimum of 5 cars per elevator). Lower rates are provided in lieu of a mileage allowance when private cars are used. Successive shipments need not be from the same origins. Examples demonstrated rate reductions ranging from 13 to 17 percent and a 22 percent reduction in variable costs. During the first year, while various elevators were in the process of gearing up to take advantage of the rates, 45 trains moved under the provisions of the new tariffs, with an average round-trip turnaround per car of 8.9 days, an improvement over the 10 days estimated when the rates were proposed. Not only was service thus improved, but when compared with average times for single-car shipments in this traffic of 21 days without transit and 28 days when transited, the 21,832 car-days required to move 2,449 carloads represented a saving equivalent to the addition to the fleet of 81 new cars if the traffic had moved in single cars without transit or 128 new cars if the single-car shipments had been transited.

Santa Fe. A new pattern of long-distance freight train scheduling was initiated in 1973. Instead of fleeting trains, which causes congestion on both line of road and in terminals, schedules were adjusted to achieve evenly spaced departures for Chicago–Southern California trains, Chicago–Northern California trains, Chicago–Texas trains, and Chicago–Denver trains. Similar scheduling was done for trains out of Kansas City to the same destinations. A corresponding pattern of east and northbound departures from California, Texas and Denver is in effect. Also, RHF (Regular High Frequency) schedules are in effect between California and Texas. The annulling of trains in the light-traffic direction is prohibited. The results of this type of operation have been more reliable service and better car, locomotive, caboose and facilities utilization.

Southern Pacific.[9] TMIS (Terminal Management Information System) was devel-

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[8] Corn and Soybeans Midwest to Gulf Ports, for Export, 339 ICC 595 (1971), and company documentation.

[9] "Use of Computers in Measuring and Evaluating Terminal Operations" by T. A. Lewis, Special Assistant, Operating and Terminal Systems; in Transportation Research Forum Proceedings, 1973, page 229.

oped, which produces reports of car movements completed, cost per car movement, car movements completed on schedule and average hours per car movement. Further, from a 100% sample of the data, a summary of condensed significant information is produced. An analysis of the results of the system at one terminal disclosed that the cost per car movement was reduced from $10.83 to $9.01, that schedule performance increased from 74 percent to 83 percent, and that the average hours per car movement were reduced from 23.3 to 21.0.

"Studies in Railroad Operations and Economics." A series of reports under the above title has reached 17 volumes, of which the first 15 deal with railroad freight service reliability. The reports cover research performed by the Massachusetts Institute of Technology, with funding for the most part by the Federal Railroad Administration. One-paragraph abstracts of most of the volumes follow.

Volume 1: *Railroad Car Movement Reliability: A Preliminary Study of Line-Haul Operations.* Authors: A. S. Lang and R. M. Reid. Date: October 1970. MIT Report No. R70–74. Sponsoring Agency: Union Pacific Foundation.

Data on road train delays due to various types of mechanical failures and derailments and on the duration of these delays were collected for a total of 1,065 trains operating over a single main-line division during a two-month period. These delays were classified by major type (brake, coupler, and other type of failures, not including engine failures) and by causal factors (train length, trailing tonnage, and track profile) operative at the time of the failure.

Volume 2: *Rail Trip Time Reliability: Evaluation of Performance Measures and Analysis of Trip Time Data.* Author: Carl D. Martland. Date: June 1972. MIT Report No. R72–37. Sponsoring Agency: Federal Railroad Administration, U. S. Department of Transportation.

After evaluating alternative measures within a logistics framework, this report recommends two measures of reliability, the maximum percentage of cars whose trip times fall in a consecutive two or three day period of the trip time distribution (the 2- or 3-day %) and the percentage of cars arriving after this period (the %-late). Nevertheless, a dialogue with shippers is necessary before the most appropriate measures can be determined for a specific situation. Using these measures, origin-to-destination (O–D) data for three railroads are analyzed to discover the nature of O–D reliability. The typical trip time distribution was found to be unimodal with extreme value concentrated on the high side, with a 3-day-% between 60 and 95, and with a %-late less than 25. There is no simple cause of unreliability. Although yard classifications are found to affect reliability much more than does distance, detailed train information is necessary to predict the nature of this impact for a particular O–D pair. In general, however, reducing the number of classifications or improving yard operations will improve both reliability and mean trip times.

Volume 3: *Determinants of Line Haul Reliability.* Authors: Kenneth Belovarac and James T. Kneafsey. Date: June 1972. MIT Report No. R72–38. Sponsoring Agency: FRA.

This work examines in detail the variance in arrival time and its components for a total of 1197 trains operating over three different runs (of a single railroad) varying from 150 to 270 miles in length. Their data showed standard deviations of arrival times which typically ranged from one to three-and-a-half hours for trains operating on a half dozen different schedules. More important, the analysis of their data showed that the variability in departure time, in running time (excluding stops and delays), and in intermediate yard time were the major contributors to arrival time variance. Standard deviations of departure times (from the initial terminal) were on the order of 45 minutes to an hour-and-a-half, of running times from 45 minutes to two-and-a-half hours, and of intermediate yard times from one-half an hour to an hour.

Volume 4: *The Impact of Classification Yard Performance on Rail Trip Time Reliability.* Authors: Robert M. Reid, John D. O'Doherty, Joseph M. Sussman and A. Scheffer Lang. Date: June 1972. MIT Report No. R72–39. Sponsoring Agency: FRA.

Yard reliability emerges as a problem of central importance to overall movement reliability. Detailed studies of three yards suggest that 10 to 20% of all cars miss their most appropriate outbound train connections, although performance varies not only between yards, but between inbound-outbound train pairs at the same yard. It is possible to express the probability of making a connection as an increasing function of the time available to make the connection, since the extra time offsets both arrival delays and congestion delays. The greatest cause of delay, however, is the cancellation of outbound trains or blocks. Extraordinary delays caused by rips and no-bills appear to be a relatively small problem.

Volume 5: *Models for Investigating Rail Trip Time Reliability.* Author: Joseph F. Folk. Date: June 1972. MIT Report No. R72–40. Sponsoring Agency: FRA.

The unreliability of the trip time of railroad freight shipments is often given as the reason for the railroads' loss of traffic to competing modes of transport. This report investigates various operating policies and practices affecting reliability through the use of two simulation models. A network model is developed which simulates the day-to-day movement of cars through a portion of a rail network, while another model simulates the journey of a single car moving through a series of yards. The objectives of these models are similar; namely, to study the *network* effects on reliability of operating policies such as a) holding outbound trains for more traffic, b) cancelling outbound trains, c) altering scheduled connection times at yards, and d) running shorter, more frequent trains between yards. Major conclusions of this report include the result that railroad operating policies *do* have a substantial effect on car movement reliability. Also, improvements in reliability might not necessarily require increases in operating costs, and could lead to improvements in other performance measures as well, such as a decrease in *mean* transit time.

Volume 6: *Some Analyses of Railroad Data.* Author: Joseph F. Folk. Date: June 1972. MIT Report No. R72–41. Sponsoring Agency: FRA.

This report presents data from several railroads on yard, link, and total origin-to-destination performance. Topics analyzed include train arrivals as functions of train length and the day of the week, line haul times, departure times, receiving yard delays, total yard times, missed connections, and trip time standard deviations. Such data analysis is necessary to insure a realistic choice of parameter values and modelling concepts in conjunction with the simulation models discussed in Volume 5, *Models for Investigating Rail Trip Time Reliability*. The data and results given in this report can also be helpful to future work on railroad reliability.

Volume 7: *A Brief Review of Various Network Models*. Author: Joseph F. Folk. Date: June 1972. MIT Report No. R72–42. Sponsoring Agency: FRA.

In the past decade, the railroad industry has developed various types of models to investigate different operating problems and policies, as well as proposed changes in the physical plant of a railroad. This report presents a review, as opposed to an evaluation of a subset of these models which could be called railroad *network* models. Two basic types of network models are reviewed: *simulation* models and *optimization* models. In the network simulation models reviewed, car movements through a network are simulated for a fixed set of train schedules and route structures. Changes in operating policies are tested by making appropriate changes in either the input data deck or the internal logic of the simulation program. "Optimal" operating policies are found through trial-and-error methods. The network optimization models reviewed optimize train schedules (or in one case, a railroad *network*) for a fixed traffic demand. Quantities one might vary in an optimization model include traffic levels, network configuration, cost indexes, and parameters such as train speeds and processing rates at yards.

Volume 8: *Reliability in Railroad Operations*. Authors: A. Scheffer Lang and Carl D. Martland. Date: October 1972. MIT Report No. R72–74. Sponsoring Agency: FRA.

As a first step, the project staff analyzed yard, line-haul, and trip time data from eight railroads and found that unreliability is evident in all phases of rail operations. Yard delays, many of which are caused by unreliable train operations, are the greatest cause of trip time unreliability. Changes in operations, capital improvements, and institutional changes can all help improve reliability. Moreover, capital investment, especially in improved mechanical reliability of equipment, will have a less significant and immediate impact than operating changes such as through-blocked trains and increased schedule adherence. A dialogue between shippers, railroads, labor, and management is critical to the success of a program for improving reliability.

Volume 9: *Reliability in Railroad Operations: Executive Summary*. Authors: Joseph M. Sussman, Carl D. Martland and A. Scheffer Lang. Date: December 1972. MIT Report No. R73–4. Sponsoring Agency: FRA.

As a first step, the project staff analyzed yard, line-haul, and trip time data from eight railroads and found that unreliability is evident in all phases of rail operations. Yard delays, many of which are caused by unreliable train operations, are the greatest cause of trip time unreliability. Changes in operations, capital improvements, and institutional changes can all help improve reliability. Moreover, capital investment, especially in improved mechanical reliability of equipment, will have a less significant and immediate impact than operating changes such as through-blocked trains and increased schedule adherence. A dialogue between shippers, railroads, labor, and management is critical to the success of a program for improving reliability.

Volume 10: *Improving Railroad Reliability: A Case Study of the Southern Railway.* Author: Carl D. Martland. Date: March 1974. MIT Report No. R74–28. Sponsoring Agency: FRA.

This report serves three major functions: it analyzes O–D, yard, and line-haul performance over a large portion of the Southern system; it summarizes a set of procedures for improving reliability on any railroad, and it describes in detail the test program carried out on the Southern. The major product of this research, this test program demonstrated that reliability can be improved in the short run, that this need not initially involve added capital or operating expense, and that this will also result in lower trip times. By changing train schedules and operating procedures for three traffic flows, involving 300 cars/day, Southern improved reliability about 15%, reduced trip times by nearly a day, and saved approximately $25,000/month in car utilization expense.

Volume 11: *Improving Railroad Reliability: A Case Study of the Southern Railway, Executive Summary.* Authors: Joseph M. Sussman and Carl D. Martland. Date: March 1974. MIT Report No. R74–29. Sponsoring Agency: FRA.

This report presents the major results and basic conclusions of this research project. The major product of the project was the test program, which demonstrated that reliability can be improved in the short run, that this need not initially involve added capital or operating expense, and that this will also result in lower trip times. By changing train schedules and operating procedures for three traffic flows involving 300 cars/day, Southern improved reliability about 15%, reduced trip times by nearly a day, and saved approximately $25,000/month in car utilization expense.

Volume 12: *Procedures for Improving Railroad Reliability.* Author: Carl D. Martland. Date: March 1974. MIT Report No. R74–30. Sponsoring Agency: FRA.

This report defines an experimental procedure with which any railroad can start to improve reliability. The success of the test program implemented by the Southern Railway (see Volume 10) demonstrates that the procedure not only works, but offers potential operating and economic benefits to railroads that adopt it. In addition to describing the basic procedure, this report discusses data processing capabilities, alternatives for improving reliability, and methods for evaluating these alternatives. The report closes with recommendations to the government and to the industry for improving railroad reliability.

Volume 15: *A Model of Rail/Truck Competition in the Intercity Freight Market.* Author: Brian C. Kullman. Date: December 1973. MIT Report No. R74–35. Sponsoring Agency: FRA.

This report proposes a model based on the logit function to predict the rail and truck market share for specific city pairs and commodity groups. Effort

> was devoted to the problem of introducing both transport service variables and shipper's logistic variables into the model. The model was calibrated with data from the 1967 Census of Transportation and from various carriers. Significant regressions were obtained from linear logit models once the proper variables were identified. Theoretical monetary values of carriers' services were compared to the empirical values in the model, indicating that shippers pay more for quality service than predicted; this result may be due to bias in the model introduced by use of aggregated and unreliable data. It is concluded that further research using this model form with more disaggregate data could yield significant improvements in results and provide valuable information for public and private transportation planning.

Summary

Quality is not measurable in exact terms, certainly if the subject is a service and not a product. For railroad freight service it is a composite of several elements, varying in relative importance from case to case, which individually are measurable in terms of time or of cars available for loading.

Quality has taken on new significance in the railroad industry with the loss of traffic to other common carrier modes and private carriage, with not-wholly-unrelated increases in railroad costs.

Fortunately, but with a time lag, it has become apparent that computers provide a means of collecting and organizing the masses of data with which individual elements of quality or the inputs to those elements can be measured. With measurement, problem areas can be identified. The results of a corrective change, or tests of alternates, can be measured. Policy concepts can be simulated and their effectiveness measured.

Applications of the quality improvement process have been in some cases localized, directed at spot operating situations, and in other cases of system-wide extent, directed at operating policies or at broad concepts of carrier-customer interface in operations, costs and pricing.

Reports on the cost effectiveness of quality improvement policies have not been frequent, but some of the cases cited in this report show that better service has reduced costs. With proper control, in other cases a net gain may come from the revenue side through added or retained traffic. While traffic was still at near-peak levels in 1974, there was evidence that improving car control procedures in the industry were bringing increases in car utilization with consequent reductions in car shortages and lost traffic.

Economic considerations and a strategy for survival dictate that the proper level of quality of service is the highest level that the railroad can provide at a reasonable profit and which has a perceived value which the customer is willing to pay for. Engineering methods and management controls are the means by which these criteria can be brought into balance for the greatest number of traffic movements.

Report of Committee 24—Engineering Education

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P. S. SETTLE
W. D. SMOAK
R. M. SOBERMAN
D. M. TATE
G. H. WAY
C. E. WELLER
H. M. WILLIAMSON
D. L. WILSON
B. J. WORLEY

Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Recruiting.
   No report.

2. Summer Employment.
   Progress report, presented as information .... page 402

3. Student Cooperative Programs.
   No report.

4. Student Affiliates.
   No report.

5. Continuing Education.
   No report.

6. Speakers.
   No report.

7. Project Case Studies.
   No report.

8. Exchange of Professional Staffs.
   No report.

9. Research Resource Availability.
   No report.

The Committee on Engineering Education,
Dr. B. M. Davidson, *Chairman.*

Report on Assignment 2

Summer Employment

W. A. Oliver *(chairman, subcommittee),* A. M. Cary, A. W. Cooper, J. F. Davison, E. T. Franzen, A. V. Johnston, D. V. Sartore, D. L. Wilson.

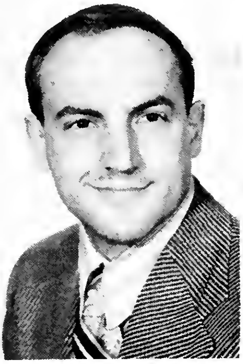
In accordance with its practice, established in 1959, Committee 24 canvassed the railroads during December 1974 concerning their 1975 summer employment needs for engineering students. A brief but formal questionnaire was sent to the chief engineering and maintenance officers and chief personnel officers of the railroads of the United States and Canada requesting information about their requirements for the summer of 1975.

Herewith is a summary of Subcommittee 2 Summer Employment Survey results for 1975. There was a total of 41 of the questionnaires that went to some 125 major railroads requesting information concerning their summer employment needs. Four indicated that they wanted their offerings listed in the Subcommittee 2 letter that goes to 125 engineering colleges.

Such a poor return of questionnaires by the railroads, which return has been decreasing for the past several years, raised a question concerning the value to the railroads of the annual summer employment program carried on by Subcommittee 2 of Committee 24. Consequently, at the meeting of the committee on March 26, 1975, it was decided to discontinue the program temporarily.

The offerings of employment by the four railroads returning favorable questionnaires were tabulated and sent out to the engineering colleges following the regular practice. This tabulation and accompanying letter was placed in the mail on February 26, 1975.

Report of Committee 33—Electrical Energy Utilization



R. U. Cogswell,
Chairman
L. D. Tufts,
Vice Chairman
B. A. Ross,
Special Assistant

H. Rappaport
R. J. Berti
E. C. Anderson
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B. Anderhous
J. A. Angold
A. R. Barker
T. B. Bamford
R. F. Breese
W. H. Brodsky
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R. F. Carter
W. J. Clarke
A. B. Costic
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M. F. Cowing
E. M. Hastings, Jr.
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D. T. Jones
H. C. Kendall
E. W. Koch
K. L. Lawson
A. W. Lewis
K. Loebl
R. W. McKnight
H. S. March
M. D. Meeker, Jr.
K. S. Niemond
A. G. Raabe
R. P. Rieff
E. B. Shew
J. J. Schmidt
M. J. Shearer
W. H. Siemens
J. L. Sinclair
D. M. Twine
K. B. Ullman
E. F. Weitz

Committee

Those whose names are shown in boldface, in addition to the chairman, vice chairman and special assistant, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
A determination has been made on which portions of the old AAR Electrical Manual should come under this committee's responsibility. The technical content of these sections are under review.

1. Electrification Economics.
A complete revision to the Electrification Economics Section of the Manual was submitted for adoption and was published in Part 1 of Bulletin 655, November–December 1975. Work is now focusing on techniques to reduce electrification construction costs.
Paper entitled "Railroad Electrification—A Status Report" is submitted as information .... page 404

2. Electrical Clearances.
Report of committee in regard to clearances under structures on lines that are or may be electrified, along with drawing entitled "Proposed Clearance Specifications to Provide for Electrification," was submitted to letter ballot vote of the Voting Members of the AAR Engineering Division and was overwhelmingly adopted, effective December 12, 1975. Work has commenced on producing an electrified railroad profile diagram.

3. Voltage Standards.
   No report.

4. Catenary/Pantograph Systems.
   No report.

5. Signal and Communications Protection in Electrified Territory.
   No report.

6. Power Supply and Distribution.
   No report.

7. Contact Rails.
   No report.

8. Wire and Cable.
   No report.

9. Illumination.
   No report.

The Committee on Electrical Energy Utilization,
R. U. Cogswell, *Chairman.*

Report on Assignment 1

Electrification Economics

R. J. Berti *(chairman, subcommittee),* W. H. Brodski, W. S. Gordon, M. F. Gowing, D. T. Jones, H. C. Kendall, K. L. Lawson, M. D. Meeker, A. G. Raabe, R. P. Reiff, B. A. Ross, L. D. Tufts, K. B. Ullman.

Your committee presents as information the following status report on railway electrification. It was originally presented at a Western Sectional Meeting of the AAR Communication and Signal Section.

RAILROAD ELECTRIFICATION—A STATUS REPORT

By Hugh C. Kendall

Senior Consultant
Technical Marketing
General Railway Signal Company
A Unit of General Signal

At a recent conference on railroad electrification sponsored by the Railway Systems and Management Association, Keith Campbell, senior executive officer of CP Rail, observed: "The relationship between the American railroad industry and electrification is the history of a flirtation which has been going on for some 70 years. There have been cases, it is true, where the flirtation has led to some tangible results; but where this has happened, the offspring have not been able to carry on the line. The question today is whether the old lady is more attractive than in her youth, and if so, whether the flirtation should be brought to an end by a general application of matrimony and all that goes with it."

There are many who believe that the old lady is indeed more attractive today than she has ever been before. The passage of time has brought about many changes in the electrification picture which bring decision makers once again to the consideration of railroad electrification. All-electric motive power has continued to improve as a result of general technological advances and of specific efforts in other countries with electrified railroads. In addition, the trends in competing modes of transportation show continued problems of congestion and fuel consumption. New knowledge and sensitivity to the depletion of natural and environmental resources, particularly fuels and air quality, also motivate a further evaluation of all-electric motive power as an alternative to diesel-electric operations. These developments heighten the need to review the assumptions, data and results of past studies and to evaluate the current possibilities in a comprehensive and systematic fashion.

In the following paragraphs, I will take up a number of questions which are frequently asked about railroad electrification.

(1) What is meant by high-voltage commercial frequency electrification?

The Association of American Railroads and the American Railway Engineering Association have recommended 25 or 50 kv at 60 Hz for high-voltage electrification. At the present time, two captive coal-hauling railroads in this country have been electrified at high-voltage commercial frequency. Both of these railroads represent new trackage and went into service as electrified operations. The Muskingham Electric Railroad in southeastern Ohio serves the Muskingham River Plant of the Ohio Power Company. This railroad is 15 miles long and is electrified at 25 kv 60 Hz. Two trains are involved in the coal-hauling operation; however, only one train is permitted on the mainline at any given time. On this basis, train separation problems do not exist, and the railroad operates without benefit of a signal system. Provisions for automatic train operation have been incorporated in the system using intermittent wayside devices to control the speed of the trains.

The Black Mesa and Lake Powell Railroad serving the Navajo Electric Generating Station of the Salt River project near Page, Arizona, is electrified at 50 kv 60 Hz. This railroad is 78 miles long. Only one train is involved in the coal-hauling operation, and the railroad operates without benefit of a signal system.

The remaining railroads in this country which have electrified operations use "special power" which is derived from the commercial frequency utility power grid. Portions of the Penn Central, for instance, are electrified at 11 kv, 25 Hz. Conversion equipment is required to supply the "special power" used in these systems. The cost of maintaining and/or replacing conversion equipment as it wears out has become a major factor in the cost of energy used in these operations. The primary reason for the railroads' using "special power" can be traced to insurmountable technical problems in electric motive power design at the time these properties were electrified, making it impractical to use commercial power directly from the utility power grid to feed the catenary.

(2) Why are railroads in this country so far behind foreign railroads in their conversion to electrified operation?

The question is largely one of economics. Railroads in this country are private corporations run for the benefit of stockholders interested in good earnings and long-term corporate growth. American railroads in general, due to government regulations, have been unable to generate sufficient cash from railroad operations to take advantage of the long-term conservation of capital which would be possible by utilizing all-electric as compared to diesel-electric motive power. Capital expenditures by the railroads have been limited, by and large, to those improvements which could be clearly justified on the basis of acceptable rates of return on the capital invested. While electrification has been shown to have a positive rate of return on the projected investment, electrification of high density lines has not been widely adopted by American railroads thus far because of more pressing capital requirements.

Unlike American railroads, foreign railroads are nationalized. Railroad improvements are financed by the federal treasury, with the main purpose being to provide the required transportation services in the best possible manner, with particular emphasis being placed on the conservation of energy and the use of indigenous sources of energy wherever possible. Losses incurred by foreign railroads in providing the overall transportation required run into millions of dollars, but are offset by direct federal subsidies. On this basis, foreign countries, particularly Europe, have rebuilt many of their railroads since World War II by converting directly from steam motive power to all-electric motive power, bypassing the diesel-electric phase. The quantum jump in efficiency between steam and all-electric motive power is only slightly more than the jump from steam to diesel-electric power. The ability of all-electric motive power to utilize a wide range of indigenous energy sources has been an important factor favoring electrification of foreign railroads.

(3) What has created the rebirth of interest in U.S. railroads toward electrification?

The transportation demands placed on U.S. railroads by World War II left the properties in need of large capital expenditures for plant restoration and improvements. The diesel-electric locomotive proved itself during the war as being a quantum jump ahead of the steam locomotive in efficiency and cost of operation. Electrification received a minor rebirth of interest among the railroads immediately after the war as an alternate to diesel-electric motive power. The large amount of capital required for the electrified fixed plant, however, was not available to the railroads. In addition, the promotion of diesel-electric locomotives by their manufacturers was not matched by the manufacturers of all-electric locomotives or by the electric utility industry.

Following the wholesale conversion of railroad motive power from steam to diesel-electric after the war, electrification remained in the background until the mid-60's, at which time it became apparent to railroad managements that diesel-electric motive power purchased in the early 50's was becoming worn out and would shortly require replacement. In reality the longevity of diesel-electric motive power turned out to be much less than what had originally been expected. The interest in electrification at that time, however, was short-lived since many railroads were so heavily committed to keeping their diesel-electric fleet going through a rebuilding program that few managements could be swayed away from short-term thinking.

A major breakthrough in all-electric locomotive design occurred in the mid-60's with the application of thyristors and silicon diodes for locomotive power conversion and control. The dramatic savings in cost and freedom of maintenance of the new solid-state power package as compared to prior technology made headlines in the motive power fraternity.

By the end of the 60's the subject of electrification could no longer be ignored since the second generation of diesel-electric locomotives bought since the war were beginning to wear out. This, coupled with a promotion program on the part of the electric utility industries to sell electricity to the railroads, led to the present rebirth of interest in railroad electrification. The energy crisis has strengthened the cause of electrification since all-electric motive power is the only means by which railroad inter-city freight can be hauled by indigenous fuel other than oil.

(4) What are the primary benefits of electrification to railroad operations?

The performance of an all-electric locomotive is vastly superior to a diesel-electric of the same weight, the reason being the ability of the all-electric locomotive to be operated for short periods of time at a horsepower rating at the rail which greatly exceeds that of the largest diesel-electric locomotives which can be built. Because of sophisticated wheel-slip control, the effective adhesion of an all-electric locomotive can be as much as 50% higher than a diesel-electric. High adhesion performance, coupled with the short-term overload capabilities of all-electric locomotives, has the effect of substantially reducing the number of locomotives required in the motive power fleet.

All-electric locomotive maintenance has been demonstrated to be less than 30% of that required for a diesel-electric, resulting in much greater availability of all-electric motive power. Finally, the life of an all-electric locomotive is generally considered to be well in excess of 30 years as compared to the life of a diesel-electric which is between 12 and 15 years. From a capital conservation standpoint, the longevity of all-electric motive power strongly favors electrification.

(5) What are some of the disadvantges of electrified operations as compared to diesel-electric?

a. The diesel-electric locomotive is an extremely versatile source of motive power, capable of running coast to coast over a number of different railroads merely by servicing it at terminals. Substantial shifts of motive power from one railroad to another to meet seasonal traffic demands is being practiced on a number of U.S. railroads. A typical example of this is the shift in motive power between the Union Pacific and Norfolk & Western whose seasonal traffic peaks occur several months out of phase. The advent of electrification would not end such practices, but would limit the amount of motive power which could be shifted, inasmuch as an electric locomotive fleet would need to remain under a catenary. It can truthfully be said, therefore, that the flexibility of the diesel-electric locomotive as it is presently being exploited by U.S. railroads would be difficult to match by all-electric motive power.

b. The fleeting of trains is a common practice on many railroads. Under such operations a number of trains are dispatched over a relatively short period of time. With diesel-electric locomotives, all that is required to implement such an operation is a sufficient number of locomotivs serviced and ready to go. Using all-electric motive power, however, fleeting practices might need to be curtailed on the basis of the high electric demand charges which might be incurred. The electric bill is usually made up of three distinct parts, namely: demand charge, energy charge and special facilities charge. The demand charge frequently is based on the highest 15- or 30-minute kw load as seen by the electric utility at a given substation. The demand charge frequently accounts for 50% to 70% of the total electric bill. Because of this, effective demand control becomes an important element in minimizing operating costs. The train dispatcher on an electrified railroad for economic reasons must work closely with the power dispatcher. The duties of each dispatcher are clear and well defined; however, they do not necessarily complement one another. For instance, heavy movements of freight at night might be attractive to the power dispatcher because of the availability of power at off-peak rates. Such operations, however, could well be quite unattractive to the train dispatcher.

c. The hazards to personnel posed by a catenary energized at 25–50 kv and located a mere 25 ft off the ground need not be emphasized. The hazards, of course, are great. All employees must be thoroughly trained in proper safety measures. The overhead power system poses additional problems in clearing wrecks, but experience has shown that the catenary can usually be repaired before the track is returned to service.

d. The reliability of high-voltage primary transmission systems is very good; but when a power outage does occur, it could mean that operations must be reduced, or in the extreme case terminated, until power is restored.

(6) What is meant by "modern electrification technology?"

Heavy emphasis on electrification by foreign railroads over the past 20 years has led to a number of technological breakthroughs in the design of all-electric locomotives, catenary structures, substations and communication and signal equipment. Some of these developments are:

a. The successful application of thyristors and silicon diodes to all-electric locomotive power conversion and control packages has made obsolete the use of mercury arc rectifiers and tap changing transformers.

b. The adhesion performance of all-electric locomotives has been substantially enhanced by the development of highly sophisticated wheel-slip control packages as an adjunct to the main solid-state conversion and control packages.

c. Due to the lightweight catenaries involved in high-voltage electrification, low-cost catenary structures have been designed whose material and installation costs are substantially less than for lower voltage catenary systems.

d. Substantial advances have been made in the signal field through the development of ac-immune dc track appliances such as relays, signal mechanisms and switch machines.

Foreign developments have been made largely by commercial firms involved in the supply of electrification material. Some government money has been available to offset development expenditures. Considerable government money has been available to government agencies engaged in electrification research. With the renewed interest in railroad electrification in this country, many U.S. firms have undertaken equipment development programs specifically geared to the electrification needs of North American railroads, which differ in many respects from foreign railroads.

(7) What changes would be required to existing signal facilities to make them compatible with electrification?

The proximity of a high-voltage catenary to open-wire signal and communication lines paralleling the railroad would expose these circuits to the effects of electromagnetic and electrostatic induction. High voltages would be induced into these circuits, creating hazards to personnel as well as introducing the possibility of malfunction of apparatus which is connected to these circuits. In addition, harmonics of the 60-Hz propulsion energy as well as noise would be induced into communication circuits, causing the signal-to-noise ratio to be degraded. Finally, the common use of the track for propulsion current return as well as train detection purposes poses special problems in the track circuit area.

Present signal systems would require modification as follows:

a. Double-rail dc track circuits would require replacement with either single-rail dc track circuits using ac-immune track relays or with double-rail ac track circuits operating at a frequency which is not harmonically related to 60 Hz.

b. Open-wire line circuits must be eliminated or placed in grounded shielded cable, preferably buried along the right-of-way.

c. Instrument housings and all wayside equipment must be properly grounded, and cables interconnecting wayside equipment with instrument housings must be either shielded or kept within specified lengths.

d. Protective devices must be installed to protect personnel and equipment during traction system fault conditions.

e. Open-wire signal power lines carried on catenary supports must be high voltage and suitably insulated in view of the induction effects of the catenary.

f. Rail bonding and cross bonding must be adequate.

g. Switch circuit controllers must be heavy-duty types.

h. Signal heads may have to be relocated for proper sighting due to the catenary supports.

i. The immunity of line relays, switch machines and signal heads used in present signal systems to the effects of electromagnetic and electrostatic induction at 60 Hz is quite high. It is essential, however, that the immunity level of this equipment not be exceeded even under traction system fault conditions. This requirement necessitates an examination of all presently used wayside apparatus to ensure that adequate immunity levels exist. Equipment which cannot measure up must not be used.

(8) How many railroads are actively considering high-voltage electrification at the present time?

Ten railroad systems have electrification studies in progress.

(9) What typical cost figures and assumptions have been used in these studies?

(a) Based upon 1975 constant dollars, the following typical cost figures have been used:

Description	*Typical Figure*
Substations (50KV)	\$12,000–\$20,000/Track Mile*
Catenary (50KV)	\$65,000–\$95,000/Track Mile*
Signal and Communication Conversion	\$28,000/Track Mile
Annual Catenary Maintenance	\$1,000/Track Mile
All-Electric Locomotives	\$125/HP
Diesel-Electric Locomotives	\$150/HP
All-Electric Locomotive Maintenance	\$.22/Unit Mile
Diesel-Electric Locomotive Maintenance	\$.60/Unit Mile
Electric Energy	\$.027/KWH
Diesel Fuel	\$.27/Gal.

(b) The following assumptions have been made:

Electric Energy Requirements	25 KWH/1000 GTM
Diesel Fuel Requirements	1.9 gal/1000 GTM

All-Electric Locomotives Required	3.4–4.5/Million GTM*
Diesel-Electric Locomotives Required	6.8/Million GTM
All-Electric Locomotive Adhesion	28%
Diesel-Electric Locomotive Adhesion	18%
All-Electric Locomotive Life	30 Years
Diesel-Electric Locomotive Life	15 Years
Annual Interest Rate	8.5%
Annual Traffic Growth Rate	3%
Annual Inflation Rate	5%
Annual Electric Energy Inflation Rate	5%
Annual Diesel Fuel Inflation Rate	5%
Electrification Cost Payback Period	12 Years
Electrification Study	2,000 Track Miles

* Dependent upon terrain.

(10) With shortages of electricity and "brown-outs" in certain sections of the country, will there be enough power available to enable railroads to electrify their operations?

If the proposed 20,000 route miles of high-density mainlines in this country were to be electrified by 1990, the electric energy required would be less than 3% of the national supply. New power-plant construction, principally nuclear plants, has been seriously curtailed in recent years due to environmental considerations. The long-range plans of the electric utility industry, however, are adequate to cover the railroad power requirements in the event of future wide-scale electrification. Since considerable electrification is planned to take place in areas which are remote from present generating facilities, it is expected that new generating facilities would be built specifically to serve these areas in the event of electrification. The present limited shortage of electric energy is not expected to be permanent if the electric utility industry is permitted to expand in accordance with present plans.

(11) What is the energy effectiveness of all-electric versus diesel-electric motive power?

The movement of one ton of freight a distance of one mile on level track requires approximately 700 Btu's of energy. It makes little difference whether the freight is moved by all-electric or diesel-electric motive power, from an energy-effectiveness standpoint, since there are inefficiencies associated with each form of motive power. It has been stated that one ton of freight can be moved by rail on level track an equal distance, whether a given amount of fuel oil is consumed by a diesel-electric locomotive or consumed in a boiler at a stationary electric generating plant and utilized by an all-electric-locomotive.

(12) What about the energy cost of using all-electric versus diesel-electric motive power?

A given amount of energy has a price tag which is a function of the form in which the energy is purchased. The price of diesel fuel, for instance, reflects the costs of fuel storage and transportation to where it is needed, over and above the basic cost of the oil itself. The cost of electric energy reflects the costs of storage and transportation of the coal used to produce it, the inefficiencies of stationary generating plants, and the costs of the distribution system, including catenary required to deliver electric energy to its point of use on a railroad. Whereas electric energy over the years has been slowly climbing in price, the cost of diesel fuel has been rising rapidly. Taking all factors into consideration, the energy costs of diesel vs. electric operations on railroads would be approximately the same if diesel fuel cost 27 cents a gallon, electricity cost 2 cents per kwh. For many years, diesel fuel could be purchased by the railroads for approximately 14 cents a gallon, with electric rates at approximately 1.2 cents per kwh. On this basis, electric operations were at a disadvantage as compared to diesel operations from an energy-cost standpoint. During this past year, however, the costs of diesel fuel have skyrocketed in comparison to the present cost of electricity. Under these conditions, electrification has more to offer.

(13) What timetable is foreseen for the electrification of the major high-density mainlines in this country?

There is a wide difference of opinion as to the timetable for railroad electrification in this country; however, it is generally felt that major electrification projects will not take place much before the end of this decade, when sufficient time will have elapsed to iron out the railroad crisis in the northeast, enabling the Federal Government to implement its position with regard to aid to railroads in other parts of the country. Prior to the 80's, however, a number of small electrification projects should be in evidence. These projects will, for the most part, be captive railroad operations involved in hauling coal and ore.

(14) What is the position of the Federal Government toward railroad electrification?

The Federal Railroad Administration stongly favors the electrification of high-density mainlines in this country as a vital step in preserving and strengthening this country's railroads. Legislation which is pending in Congress could be influenced by the position of the FRA in this regard. The FRA has also recommended that funds be made available to the Department of Transportation for research on electrification and the implementation of test trackage for evaluation purposes. The energy crisis has heightened government interest toward railroad electrification as one obvious means to conserve our dwindling supplies of indigenous oil. Railroad electrification is the only means by which inter-city freight could be moved by the railroads using coal or nuclear energy sources.

(15) From an economic standpoint, how much mainline can be justified for electrification?

The recently completed study by the Pan-Technology Consulting Corporation for the Federal Railroad Administration based its conclusions on the economic climate prior to 1973. On this basis electrified operation of mainlines in this country appeared to be warranted if annual traffic densities were above 39 million gross ton miles per mile of track. Under this criterion, approximately 15,000 miles of mainline were considered economically justified. The report further concluded that based on the projected growth of traffic by the year 2000 that 30,000 miles of mainline probably could justify electrification. At that time electrified mainlines were projected to be carrying approximately 80% of the annual traffic tonnage.

(16) What is the single most important reason why railroads in this country are actively looking toward electrification at this time?

Worldwide experience with electrification has pointed out that under practically all conditions, electric motive power offers by far the most efficient and economical means available for the movement of rail traffic.

Foreign Railroad Electrification

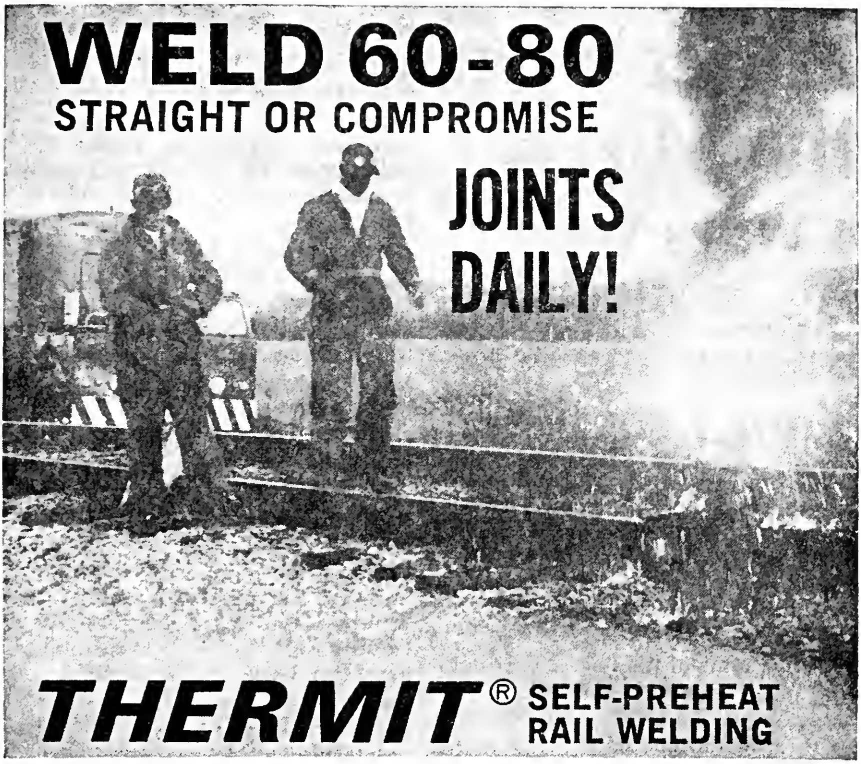
Country	*Route Miles Electrified*	*Percent of Total Route Miles*
Russia	22,780	27
France	5,520	24
West Germany	5,160	28
Italy	4,950	48
Sweden	4,350	61
Japan	3,860	29
Poland	2,180	15
England	2,070	17
Spain	1,970	23
Switzerland	1,790	99
Norway	1,420	54
Austria	1,320	39
Czechoslovakia	1,210	10
Netherlands	1,010	52
Belgium	700	24
Portugal	470	27

U.S. Railroad Electrification

Railroad	*Location*	*Route Miles*	*Propulsion Power*
Illinois Central Gulf	Chicago–Richton, Ill.	37	1,500 Volts DC
Chicago South Shore & South Bend	Chicago–South Bend, Ind.	76	1,500 Volts DC
Erie Lackawanna	Hoboken–Dover, N.J.	80	3,000 Volts DC
Penn Central	New Haven–Washington, D.C. Philadelphia–Harrisburg, Pa.	762	11 KV, 25 Hz AC
Reading	Philadelphia, Pa.	88	12 KV, 25 Hz AC
Muskingum Electric	Zanesville, Ohio	15	25 KV, 60 Hz AC
Black Mesa & Lake Powell	Page, Arizona	78	50 KV, 60 Hz AC
	TOTAL	1136	

U.S. Rapid Transit Systems

System	*Location*	*Route Miles*	*Propulsion Power*
CTA	Chicago, Ill.	89	600 Volts DC
Long Island	New York–Mineola, N.Y.	150	600 Volts DC
MBTA	Boston, Mass.	65	600 Volts DC
NYCTA	New York, N.Y.	251	600 Volts DC
Penn Central	New York–Harmon–White Plains	69	600 Volts DC
Philadelphia Transportation Co.	Philadelphia, Pa.	27	600 Volts DC
PATH	New York–Newark, N.J.	14	600 Volts DC
WMATA	Washington, D.C. (Under Construction)	97	600 Volts DC
PATCO	Philadelphia–Lindenwold, N.J.	15	650 Volts DC
CTS	Cleveland, Ohio	20	650 Volts DC
BART	San Francisco, Calif.	75	1,000 Volts DC
	TOTAL	872	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JOINTS
DAILY!
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Portec's On the Move.

4 Ways We're Aggressively Supporting Your Progress.

Portec's Transportation Products Group has been streamlined and expanded. To provide you with better service for your track and transportation needs. And to develop new products for the challenging years ahead. Listed here are some of the Portec products that have gained world-wide acceptance. Watch for news of further developments — the kind of innovations you expect from a leader like Portec.

Paragon Division

Auto Racks
New Fully Enclosed Multi-Levels with Tri-Fold Doors
Bi-Level Racks
Tri-Level Racks
End Door Enclosure — Multi-Level Racks

Other Equipment
Frame Cars
Cable Reel Cars
Ingot Mold Cars
Special Equipment Components

Railway Products Division

Rail Anchors
Improved Fair®
XL-1 Fair®

Insulated Rail Joints
Poly-Insulated
Portec-Bond
Continuous
Armored Continuous

Components for Insulated Rail Joints
Poly Plates
Double-Filament-Wound Bushings
Blue Ribbon Nylon Epoxy End Posts

Non-Insulated Rail Joints
Portec-Bond
Headfree Toeless
Headfree Flanged
Compromise

Rail Joint Renewal Insulation Kits
Mark II - polymer insulation
Mark III - polymer insulation

Rail and Flange Lubricators
Single Rail
Double Rail
Four Bar Type

Rail Joint Heater
Portable Model 75 - for bonding joints

Ties
Wood Ties
DowMac Concrete Ties

New Products in 1976
Curv-Bloc
Reinforcing Strap for CWR

RMC Division

Track Machines
Anchor Adjusting Machine
AnchorMaster
Auto-Spiker
Ballast Distributor —
    Distributor/Cleaner
BoltMaster
Bridge Tool Machine
Brush Cutter
Clip Tightener
Compressor Cart
LineMaster
Rail and Joint Straightener
Rail Saw-Drill Combination
SpikeMaster
Spiker-Spacer
TieMaster
Tie Plate Broom
Tie Unloader
Track Broom

Tampers
Hydramatic-16
Hydraulic-16
Multi-Purpose 8
Hydraulic 8
Jack
Switch Spot
Spot Switch

Snow Blower
Typhoons
Hurricane Jets

Rail Laying Equipment
Dual Welded Rail Laying Equipment
Gauging Machine
Plug Setter
Rail End Hardening Machine
Rail Oiler
Rail-Laying Auto-Spiker
Rail Anchor Cart
Scrap Loader
Spike Distributor Cart
Tie Plate Gauger

Spot Systems
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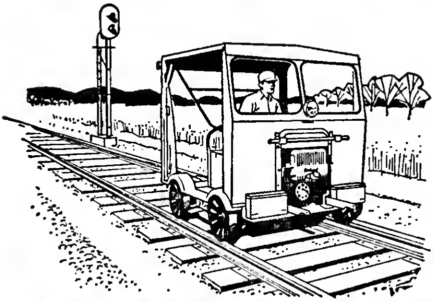

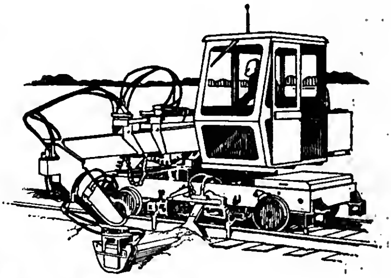

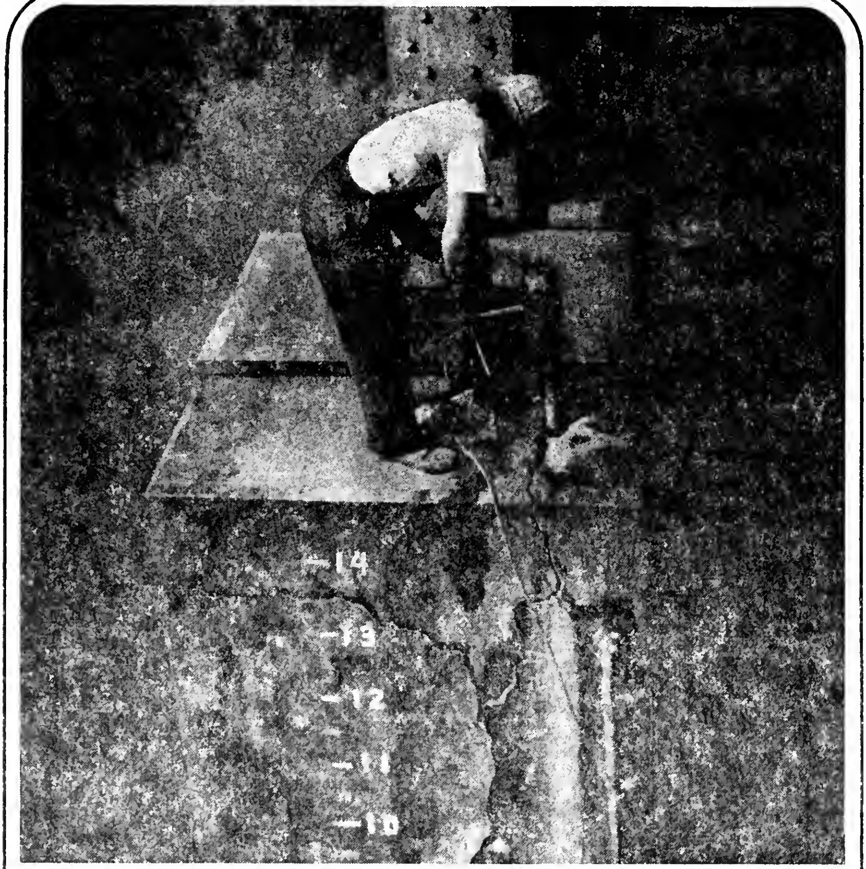
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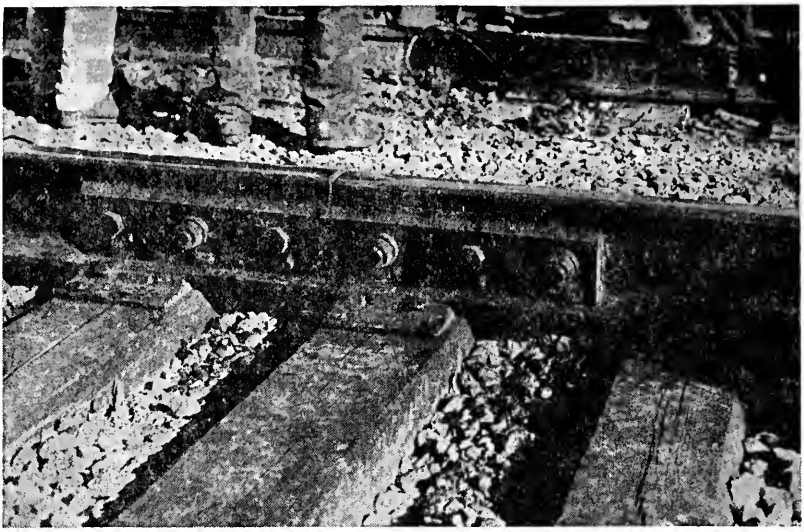

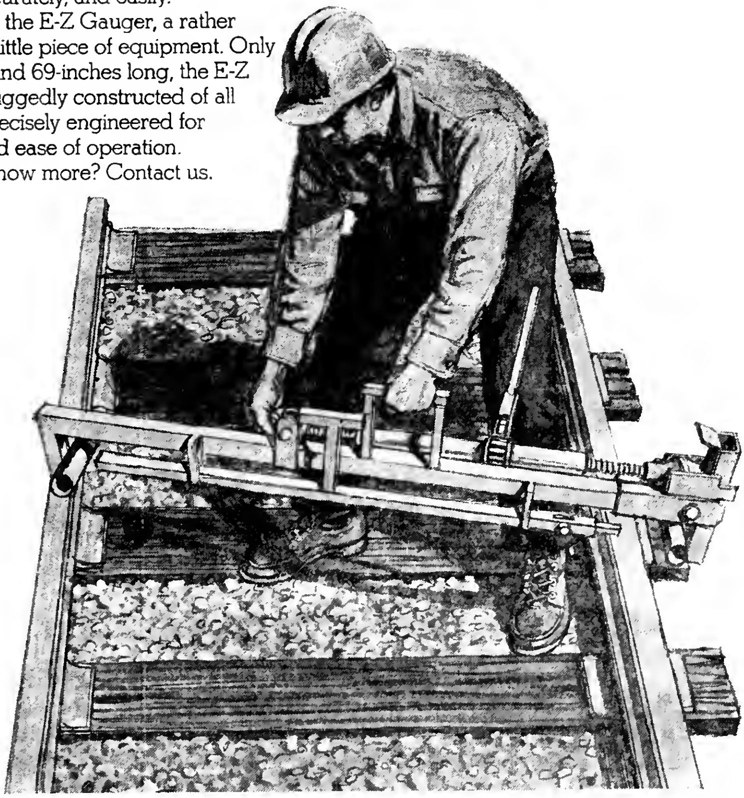

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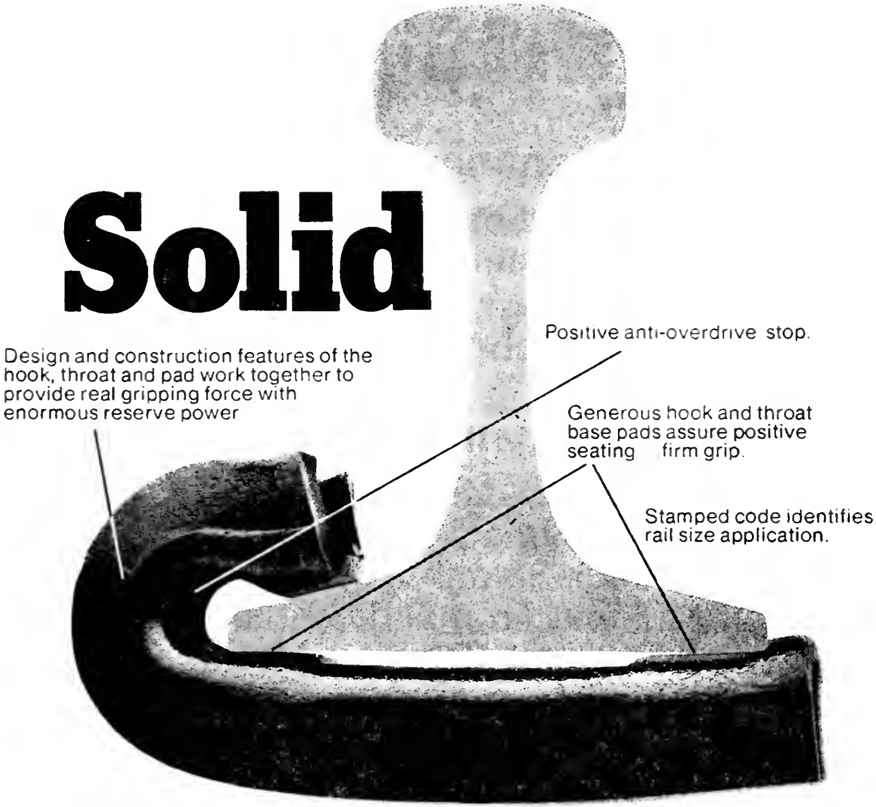

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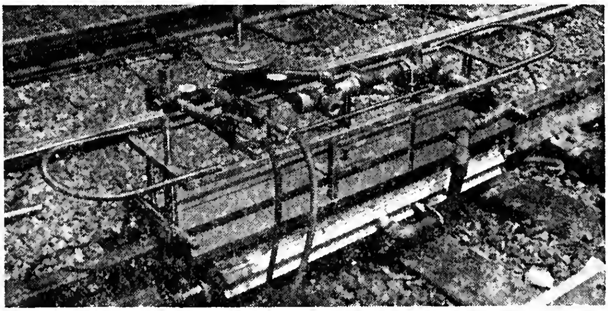

REGIONAL MEETING

OCTOBER 30, 1975

HOTEL VANCOUVER, VANCOUVER, B.C., CANADA

Luncheon Address

By A. F. Joplin

Vice President Operation and Maintenance
CP Rail

This is the time of the year when most of us who are involved in maintenance of way and structures on our various properties are looking back at what we undertook to do during the summer months and are looking forward to what we propose to do in the coming year. In other words, this is budget preparation time. It is also a time when all of us have to give some thought to just exactly where we have been, where we might be going.

I am sure by now you are more than tired of hearing about transportation problems. In both Canada and the United States, there is no lack of "solutions" to the perceived problems of transportation. In Canada and the United States many are certain that the only true way to handle any problem is to nationalize everything in sight or if you don't nationalize it, subsidize it. Many see our economy as a horn of plenty without depth from which pours forth an endless stream of goodies, simply because they say so. Everyone knows how to run a railroad! If you haven't got any ideas and haven't expressed them, then you are in a minority—everyone else has.

Where is the engineer in all this? Mostly he is silent, just busy trying to be part of the solution rather than part of the problem. As a result, his advice and counsel for the most part are just not heard.

It seems to me that in many of the significant undertakings, in both our countries, we are not paying much heed to the lessons to be learned in the development of our economy. We seem to be ignoring the large base of practical common sense developed in our railroad technology in the last 150 years.

I am sure many of you read the August issue of *Fortune,* in which the debacle of BART was detailed. Now you and I know that sooner or later the BART system will be put into acceptable running order. But at what cost? Here is a case where practical down-to-earth philosophy was deserted. Lessons learned elsewhere in our industry were ignored. Any new system as complex as BART is bound to have troubles—these are to be expected—they certainly should be planned for. The stunning fact that escaped the planners was the very simple maxim—which all practicing engineers are familiar with—that if more than 10% of project is new technology, it is going to have serious problems in working out the differences between the drawing board and the real live practical world of meeting the day-to-day requirements effectively and on time.

A very amateurish approach. I chose BART because of its recent emergence, but there are many other areas where the same results can be anticipated. It seems to me that a knowledge of Murphy's Law, which all engineers learn early in their career, would have prevented some of these fiascos.

In both our countries we have large, uninformed groups, extremely critical of railroads, who want to take over our rights-of-way and fill them with passenger trains—all of them travelling at 120 mph. They overlook the most important job we do—carrying our nation's commerce. Just to put this in perspective: last year in the United States some 200,000 route miles of freight railroads grossed $8.5 billion of freight revenue; in the same year Amtrak on 23,941 miles of operating route miles grossed $256.9 million.

In Canada, Canadian National and CP Rail operated 24,000 route miles in freight service for a gross of $2.0 billion and 16,000 route miles of passenger service for a gross revenue of $211 million. You will note I said "gross revenue"—in both of our countries passenger services require a considerable infusion of outside money to keep them alive. Included in the gross revenue of passenger services mentioned above ($211 million), are Government payments amounting to some $113 million. In the Canadian Government's recent paper on Transportation in Canada, it was pointed out that it would have been cheaper in many cases to have purchased bus or air tickets for the train travellers rather than keep the rail passenger services running.

There are many who will say both the railways and the public generally have their priorities all wrong. In seeking to find what services the public will pay for and what services they reject by not using and paying for them, we are missing the big picture of the public good. They say the only answer is to nationalize the services and in some mysterious way this will produce savings and improvements in service. They naively ignore the lessons that can be learned simply by observation of the results in those nations that have experienced the "benefits" of nationalization.

Railroading in Canada and the United States is facing serious problems. Most of these problems arise from the shackles that well meaning but misguided government agencies apply. The justification for this interference, advocated by the amateur meddlers, is that it is supposed to result in more "equitable" rates—a more "responsive" transportation system—claiming that competition can lead to inefficiency and higher costs—yet at the same time holding that railways do not have enough competition and so must be regulated because the marketplace cannot operate freely.

I sometimes get the impression that we have to recognize the presence of a new development which might be called the "bureaucratic empire-building syndrome." Its appeal is subtle and, in my view, Canadians and Americans must be alert to avoid the pitfalls and costs inherent in this trend.

It works this way: A public servant says that "the public wants this or that," or "there is a great need to protect the public from this." In almost every case what is prescribed as the remedy is a larger government role in our business economy. It will be axiomatic, of course, that a whole new apparatus of government will have to be set up to achieve the remedy. Whether it be transport, or oil, or dairy farming, or uranium mining, or whatever, the theme is the same—the government must do something because the people want it. But do they? Do the great majority of the free souls who live on the North American continent really believe a government-operated economy would meet their needs better? Are they really ready to surrender their private initiatives to the politically-oriented activities of the bureaucratic empire builders? I think not. But in our world of instant communications where the most ill-informed can be heard, read, seen and believed, we run a great risk that we will be conned into an economic way of life completely foreign to our needs and instincts—and at great costs.

Governments are not a substitute for informed and well directed market-oriented enterprise. There may be room for governments to set guidelines and policies, and these can be accepted—especially if they have done their homework. But to substitute bureaucrats for trained managers is just plain suicide.

I would not want you to think that I am saying everything we do is perfect—that we have nothing to learn from other cultures from other people—far from it. I recently had the opportunity to visit with the railways in the Soviet Union. I must say I was impressed. We were told they were run at a profit—and they well might be—even using our capitalistic standards. I must say I was impressed by their operating statistics. Nearly half of all freight traffic carried by railways in the world moves on Soviet railways. This is accomplished on 138,000 route-kilometers (equivalent to 82,000 miles) of rail line, one-third of which is two-track and in some cases three-track. With about 2½ times the route miles, the North American railroads produced less than one-third the gross-tonne-kilometers of freight service. The Soviets do not have much of an unprofitable branch line problem. I was also impressed by the four hours to load and the four hours to unload that the Russian shipper achieves. They seem to be able to manage the demurrage question quite well.

In the Soviet Union, a full crew consists of a mechanic and a helper in the engine, and a red flag tied on behind. W. L. Thornton of the Florida East Coast recently wrote a letter to U.S. Congress on archaic work rules. One certainly cannot say that the Soviet railways are at any disadvantage when it comes to full-crew laws.

Despite all our handicaps, the management of our railways on this continent have produced a transportation system which is universally acknowledged as the best in the world. Not only do our railways provide faster and more reliable service, but they do so at charges to the user considerably less than anywhere else in the world. I think if you are going to criticize our railway managers, you also have to give them the credit that is their due for what are, undoubtedly, their successes.

I know it is going to take more than the few voices that are now raised by those working our industry to have any significant impact on the clamor that can be raised by the amateurs. We should not, however, let this stop us from having our say. To this end I have written an editorial—if you cannot beat them, join them. Now this is a pretty amateur editorial. I doubt whether Luther S. Miller *[Railway Age]* or Tom Shedd *[Modern Railroads]* will lose much sleep over my entry into the editorial writing field. It may just point up the kind of difficulty an amateur can get into when he steps out of his field—maybe there is a lesson here. There is only one difficulty with all this: the editorial probably won't get published; thus I am pleased that you provided me with a platform so that my editorial at least gets a hearing. I head it with the title, "Mr. Wellington's Engineer."

MR. WELLINGTON'S ENGINEER

The developing crises of scarce resources and the forecasted demands on all segments of economy, in particular transportation, are occupying considerable public thought and debate. When you add to this the impact of inflation, tight money, public participation as external constraints, the ability of engineering organizations to function effectively is reduced. In searching for answers to ameliorate these external problems, insufficient attention has been given to the many ways engineers can effectively perform their work.

A. M. Wellington wrote the pre-emptive work on railroad construction, "The Economic Theory of Railway Location," at the turn of the century. When defining engineering, he said: "To define it rudely but not inaptly, it is the art of doing that well with one dollar which any bungler can do with two after a fashion," and he added, "and yet there is no field of professional labor in which a limited amount of modest incompetency, at $150 per month, can set so many picks and shovels and locomotives at work to no purpose whatever." Much has been said—and most of it in a derogatory nature—regarding the lack of the ability to see the big picture in planning rail facilities, the reluctance to accept the new "space age" technology or the acknowledgement of human values and social impact in developing transportation systems—in particular, rail systems for freight and passengers.

Some writers enjoy emphasizing negative things. They enjoy being critical. We can accept that as part of the job and can live with it. We have to make correct decisions even if they are unpopular.

Not all engineering has been developed with the imagination that it should have had. In many cases it is possible to improve the aesthetic and human values at little or no cost. There is surely one matter in which engineers could do more. Certainly we should attempt to inform politicians and persuade them to tell the public truthfully what are the real costs of things being demanded, whether this be some exotic form of passenger transport or artificially constructed freight rates to foster the development of one region of the country over another.

In some instances, leaders of public thought, attributing Talleyrand's remarks regarding war and professionals to either Winston Churchill or Abraham Lincoln, will say that these are much too important matters to be dealt with by generals. As a result a veritable babble of opinions and recommendations are spewed forth or are proposed as simple solutions to the difficult choices which we must make in meeting the demands for transportation. These "solutions" are for the most part ill-informed or not informed at all, or very thoughtful and comprehensive—depending on which side of the argument you are. One thing for certain—they are loudly stated.

At no time has the need for making the right decisions been more necessary. The creation of capital in the next decade both in Canada and in the United States is likely to fall far short of the "demands" that are being created in our society by expectations raised by those who advocate the "free lunch" theory of nationalized industries or who say "business can afford it." This is no time to ignore the lessons painfully learned by the diligent and professional application of our particular craft and art. This is no time for the armchair generals to learn the basic truths about applying science and technology in sorting out the dilemma we face in matching our demands to our ability to produce—now is the time to pay heed to Mr. Wellington's definition of "engineering."

Railway Signalling

By H. W. Trawick

Engineer of Signals
CP Rail

It's a pleasure for me to participate in this AREA Regional Meeting. Even though signals are a part of the maintenance of way department on our railway, and many other railways have a similar type of organization, there seems to be insufficient interplay between signals people and other maintenance of way staff.

One of our regional engineers, some years ago, used to refer to his signal staff as the "mystery boys." He wasn't quite sure what they did, nor why, as long as there were no train delays at signals and they stayed within their budget. On the other hand the "mystery boys" were never too eager to share their problems and experiences with others. A strange attitude—and while it is not so prevalent these days it still exists. Perhaps gatherings such as this will help to change it even further.

So for the next few minutes I will talk a little about some of the history of signals and control systems and about some of the things we do in signals and why we do them the way we do. Hopefully this will dispel, if it exists, some of the "mystery."

The purpose of a railway signal department is to provide safe and efficient train operation—of course at a reasonable cost. The emphasis is on safety but over the years it has developed that signal systems have much to offer the railway in the way of efficiency and expedition of train movements. In the early days of railroading as soon as a railway could afford a second engine, the problem of keeping them apart had to be considered. So railway operations developed a simple system of time spacing by timetable. However, if one train lost time train crews had to rely on sight to maintain safety. A meet with two trains was often a problem especially if they did not sight one another in the vicinity of a siding. When the trains met one another on-line, violent arguments occurred as to which train was to back up.

One solution that was developed was to erect a post, a "block post," alongside the track, and the first train to arrive at the post had the right-of-way and the other had to back to the siding. This system, however, had its problems when the race for the post ended in a tie.

As traffic and train speeds increased, more reliable systems had to be developed. One system, about 1830, used a ball or a basket hoisted on a mast. When the track was clear the ball was hoisted to the top of the mast. When an operator at one station sighted the ball at the next station, through his telescope, he hoisted the ball to the top of the mast as a signal for his train to proceed. This was the first "high ball." Some of these ball signals remained in use for many years and eventually the telegraph message replaced the telescope.

One time, on a railway using ball signals, when a train arrived at a station considerably behind schedule, the conductor received a scathing message from his superintendent enquiring as to the reason for the delay. The conductor's somewhat colorful message in reply read: "Held by the balls at Bellow's Falls."

However, the common method of controlling trains was the timetable. This was fine as long as trains all ran on time; however, delays were inevitable, sometimes of course they were of very long duration.

One day in about 1856 a railway superintendent was riding a train operating under timetable scheduling and was forced to wait at Station "D" for a train that was considerably late. Eventually the irritated superintendent sent a telegram to Station "B" to hold the opposing train until the arrival of his train. The engineman in the superintendent's train did not want to proceed because this was against the rules. Finally, the superintendent put the instructions to move in writing and gave it to the engineman. Thus, the first train order was born, and this is the basis for timetable and train order operation still much in use today.

Some other concerns in operating trains were how to control them at junctions and at crossings with other lines. Systems were developed using wires or rods and pipes connected to signals which by now were of the semaphore type, and operated by levers. Eventually the mechanical interlocking machine was developed and an ingenious arrangement of dogs and latches assured that signals were displayed in proper sequence to trains. These were the early "solid state" systems.

In 1872 Dr. William Robinson invented the track circuit and his invention led to the automatic operation of signals by the train itself. Modern signalling has evolved from this development and the basis of signalling on this continent is still the track circuit.

Since this is the basis of our modern signal system let's briefly see how it operates. The rails form the conductors for the circuit. At one end a battery is connected across the rails and a relay is connected across the other end. The current flows down one rail through the relay and back to the battery; holding the relay energized. Note that this closes a relay contact which holds the signal clear. When a train arrives on this section of track the signal must assume the "stop" position. The wheels and axles are conductors of electrical energy and now current flows through them instead of the relay. This causes the contact to open and the signal goes to stop. This is an oversimplified illustration of a track circuit and signal system but it illustrates the basic principles.

Now there are many types of track circuits employing fairly sophisticated equipment, and they may vary in length from 50 ft long to 15,000 ft long or more. Some are straight dc, some use ac. There are coded track circuits which operate on a basis of several pulses or cycles per minute, such as code rates of 75, 120 and 180 per minute. These can be used to convey information between signals, as well as merely detecting the presence of a train. Other types of track circuits operate at higher frequencies in the audio frequency range. These may be superimposed on top of a dc circuit for certain purposes, such as control of highway crossing signals, and may reduce the need for insulated joints. Other systems are in use which detect the motion of a train. At a highway crossing when the system detects that a train has stopped or reversed and is no longer moving toward the crossing, it may cause the crossing signals to stop operating.

If I spent considerable time discussing the track circuit it is because it is the basic element of all modern signal systems, particularly on this continent. Other systems without track circuits have occasionally been used, usually where track circuits may be difficult to operate—for example where steel ties are used. Such systems cannot detect broken rails and obstructions on the track. Detecting switch point position may also be complex. Because of the deficiencies in systems that do not continuously detect the presence of a train, they have not been acceptable on North American railways.

As was said earlier safety is a prime factor in signalling. You have seen how the track circuit contributes: when the circuit is unoccupied the relay is energized; if the circuit is interfered with for any reason it causes the relay to de-energize and this creates the safe condition.

Let's look a little further at how safety is provided in a system. Everyone has heard the term "Fail-Safe." AAR defines it this way: "A term used to designate a signalling design principle, the objective of which is to eliminate the hazardous effects of a failure of a component or system." Additionally, General Order E-14 of the Railway Transport Committee contains this clause: "The apparatus shall, so far as possible, be installed and circuits so arranged that failure of any part of the system affecting the safety of train operation will cause all signals affected to give the most restrictive indications which conditions require." The Federal Railroad Administration in the United States has a similar regulation.

In order to meet these regulations and principles all elements of a system must be considered. It is necessary then to consider the following:

Design
Installation
Apparatus
Inspection
Testing
Maintenance

In designing a system, as far as possible, the "closed circuit" principle must be followed. This principle provides a normally energized control function which, when energy is interrupted, causes the control function to assume its most restrictive condition. Where possible, relay contacts are inserted in both positive and negative sides of vital circuits. Standby power systems are provided in the event of failure of primary power supplies. Changed conditions in one control circuit must not adversely affect another circuit. Installation of equipment must be strictly in accordance with approved plans, procedures and practices.

Apparatus used in signal systems is built to extremely rugged and reliable standards. For example, relays used in circuits affecting safety are constructed such that gravity will force contacts from the energized position when no current is available at the relay coils. Relay contacts are manufactured of materials that will not weld together when subjected to surges or overloads. They are sealed in rugged, weather-resistant, transparent covers.

Before signal systems are placed in service, inspections and tests are made to assure that the system is installed according to approved plans and that it does function as intended. It must not only be known that plans and installations are correct, but they must be observed to be correct by operational tests that verify that all signals display proper aspects for all conditions of train operation.

Of course, after systems are placed in operation they must be adequately maintained. Signal maintainers and other signal staff must be vigilant to determine that all systems will operate as intended. There are many rules which detail frequency and types of tests that must be carried out on signal systems to assure they are in proper operating condition. This also requires alertness on the part of others in the maintenance of way department to assure that insulated joints are properly maintained, that connections to the track are not broken or disturbed, that switches are properly adjusted.

In addition to railway or block signals, there are many other systems and devices on a railway whose purpose is to provide safe operations. Everyone is of course familiar with the highway crossing signal. All the principles outlined above, so far as possible, are used in these systems. It is discouraging to the signalmen that in spite of the best efforts of many people, so many motorists are so careless at crossings.

Some other safety items on the railway are slide and falling-rock detectors, dragging-equipment detectors, hot-box detectors and others. CP Rail is presently in the process of installing a cracked-wheel detector on a developmental basis. This system uses high-frequency soundwaves to examine a car or locomotive wheel while a train moves over a special rail section. When the system detects a wheel flaw it provides an automatic alarm in addition to recording the defect on an event recorder.

We have essentially been discussing the safety of systems, now let us see how they can improve efficiency and expedite train operations.

Eventually, to improve safety automatic block signals were added to the timetable and train order system. However, unless operators are readily available to deliver orders to trains, changes to meets and passes cannot be easily made. In heavier traffic territories where there is a delay to one train, there may be a snowball effect and several delays may occur to many trains.

Suppose we could devise a means of combining our automatic block systems and the delivery of train orders or operating instructions to a station. We might have the dispatcher located at a control console which would be connected to each station to which he would dispatch orders, and the control console could automatically receive reports on train location and field conditions.

Well, if we do that, we come up with a CTC system. Instead of getting reports and issuing instructions only at the stations we can do these things at every siding end. All operating instructions to the train can be conveyed by the signals. Additionally, reports of track condition, train location and signal position is reported to the dispatcher at his console.

If we want to further improve our operations we can easily add power switch machines so that now the dispatcher can control all the switches.

Now let's look at a typical console. By means of lights the dispatcher knows the position of every train on his territory, and the position of signals and switches.

CTC is really a combination of two systems. One is the safety system using all vital components which are located in the field. The other system is a communicating link that connects the dispatcher to the locations in the field, such as switches and signals at siding ends. The field or vital system determines the location of trains; it interlocks signals and switches so that dangerous situations will not occur, even in the event of a dispatcher error. For example, it will not allow signals to be displayed for conflicting movements or for movement over an open switch. It is the field or vital system that reacts to broken rails, snow slides or other events that may cause unsafe conditions. The communication link merely provides a connection from field to dispatcher and in operation the dispatcher uses it to request actions in the field and it informs the dispatcher of field conditions. It is not a vital system and it may use microwave, radio, open line wire or cable. Frequently electronic or solid-state equipment is used in this link.

Here are some of the benefits of CTC:

1. Increases safety.
2. Reduces delays due to meets and passes.
3. Provides operating flexibility to handle delays or emergencies.
4. Eliminates unnecessary stops.
5. Permits better use of personnel.

In our comparisons on CP Rail of territories where CTC has replaced timetable and train order operation we have found average time savings of 30 minutes to 1 hour for freight trains per subdivision, depending upon the type of territory.

Operationally, CTC is a very simple system and engineman needs only watch the signals—green for go, red for stop, with certain other signals conveying other types of information.

CTC also provides a real benefit in large and congested terminals. In complex areas with the dispatcher coordinating all movements, efficiency is increased for both through trains and switching movements.

Some railways are now considering the use of a digital computer in the dispatcher's office to further assist the dispatcher in doing his job better. Train graphs can be replaced by automatic printouts. Many meets can be made automatically. A dispatcher may test out on the computer various alternatives for meets and passes to determine how it may be done most advantageously. This may well be useful in scheduling time for work gangs to provide more on-track time.

Information concerning trains, such as consist, length of train, times at various points may be displayed on cathode ray tubes. If required, information can be displayed for use of the superintendent, transportation department and others on CRT's located at remote points.

The computer may be used to make certain system checks and provide information useful to the signal maintenance staff concerning equipment condition.

We are now in the early stages of such a study at one control office on CP Rail.

On CP Rail the signal department has been involved with automatic car identification since its inception. As you know this is an optical system using a high-intensity light source directed to a reflective label on rolling stock. The system detects reflected light from the labels and translates it into car number and ownership.

ACI is now a controversial matter and is under special study by the AAR Research and Test Department. Some railways have not made use of ACI, and even those that have to date have not been too diligent in label maintenance. The result is that the percentage of good label readability is only about 85%.

The Operating-Transportation General Committee of AAR is now considering the Research Department report and will make a recommendation to the AAR Board of Directors as to whether the present optical system should be scrapped and some new system introduced.

A personal opinion is that the present system should be retained and improved along with a reasonable effort by railways to maintain labels. That opinion is based on the fact the ACI is a useful railway tool, that 50–75 million dollars have been invested in it, and that if a new system could be chosen today, it is likely not to find ready acceptance and railway would probably not have an ACI system for about 10 years.

Another aspect of the signalman's work is in the hump yard. Our most modern yard is Alyth Yard in Calgary. Many new developments of equipment and ideas went into Alyth and even after 4 years much of it still serves as a model for new yards being built today.

The basic requirement at Alyth was how to design a yard capable of handling large volumes of traffic and fit it into a confined area. The basic objective was to supply tools that would permit supervisors to do a better job. This meant the system would perform all routine, repetitive tasks, provide meaningful information in a form and at a time convenient to the user. He then has the means to make decisions required.

There must also be means to improve communications so that decisions can be acted upon. The central device to achieve the objectives is the digital computer. Other devices include CRT's, teleprinters, ACI scanners, an electronic scale, locomotive speed control, radar and many others.

Just about every aspect of railway signalling is used at Alyth Yard.

I have attempted to tell you some of the things we do as signalmen. I hope I have created a little interest in the work of signalmen toward improving our railway operations.

Because the track circuit is the basic element of signalling, I discussed it at some length. Another reason was that this is in an area where your people are very much involved. Remember the design of this element is such that interference or improper conditions cause it to drop out. Therefore we rely on you to maintain switches in proper adjustment, to provide clean ballast, to avoid damage to bonds and track connections by track machinery, to maintain insulated joints. If these are not properly done, the result may be train delays and in some cases create unsafe conditions.

I hold you earlier the story of the regional engineer who referred to his signal people as "mystery boys." The reason for that reference is because he didn't understand their work and he really didn't care to understand—but just keep things running smoothly.

Unfortunately that is the attitude of many maintenance of way engineers. They are preoccupied with their major sphere, their own area of experience; and so they should be, because nothing is more basic to a railway than the ballast, the ties, the rails, the bridges, the buildings. Signals are an adjunct but they are an operations adjunct, and in your signal engineer you have an operating man on your staff. Encourage him to communicate and deal directly with operations officers. Involve him in your planning as early as possible. Signal requirements may have a major influence on your plan. He can give you the operations viewpoint. He has to be in on early planning because he is faced with long lead times in obtaining equipment. Signal equipment does not come off the shelf, it must be tailor-made to suit operating requirements.

In conclusion, use your signal engineer, give him the responsibility and also the authority to achieve his purpose, and the purpose of all of us—to provide safe and efficient train operation.

Railway Bridges on Canadian National's Mountain Region

By L. R. Morris
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Introduction

The main routes of Canadian National's Mountain Region generally speaking were built in the period 1912 to 1914. The Region consists of Alberta, British Columbia, a small portion of Saskatchewan, and a line into the Northwest Territories, and presently has about 5,000 miles of trackage. The major bridges were built with steel superstructures and concrete substructures, while the smaller bridges were of wood trestle construction.

Through the years, barring fires, floods, derailments, collisions and similar disasters, bridge problems have been relatively minor. The original designers may have been overly cautious from our present-day point of view, but praise God they were. We still are blessed with excellent bridges, many of which have carried traffic for over 60 years.

Permanent Bridges

There are about 400 permanent bridges on CN's Mountain Region, many of which were built at the time of original construction. In general they consisted of two major types. One was the familiar viaduct on concrete pedestals, the other consisted of steel girders or trusses on concrete piers. Many of them had wood trestle approaches, and the bridge extended from bank to bank of the river. Design in those early days was very simple. The design data sheets for a girder, for instance, consisted of no more than a few lines. They were all riveted construction, of course, and usually the details were kept quite simple. The piers were mostly of concrete construction and even though very little was known about the design of concrete mixes, many of our piers are still in good condition. The decks of the steel bridges almost invariably consisted of timber ties supporting the rails.

Today, many of the bridges built 60 years ago are still carrying traffic and performing very well. It is a tribute to the original designers that maintenance costs have been low. Painting has been carried out on a more or less regular cycle —ranging from 5 years in the damp, coastal climates, to 20 years in the dry, windy prairies. Timber decks, which were untreated in the early days, had to be replaced on about a 10-year cycle in the warm, damp areas and a 20-year cycle in the dry, cold areas.

In 1929 creosoted ties were first used, but only on a selected basis. Being the cautious lot railway bridge engineers are, it was not until the mid-50's that it was finally proven to us that treatment was always a good thing and from then on all new decks were fully creosoted. It is interesting to note that some 1929 treated ties are still in service on our main line.

In 1970, thanks to an idea gleaned from the Rock Island Railroad, we started a program of replacing some timber decks with pre-tensioned concrete slabs supporting a ballasted track and we now have about 20 such decks. There are limitations to this application, of course, because on through truss bridges the clearance is restrictive, and on many girders the cost of strengthening to take the extra weight is prohibitive.

Wood Trestles

Up until just a few years ago, the standard bridge for small crossings was the wood trestle. In fact it still is the standard bridge for our branch lines. At the present time, we have about 700 wood trestles on the Region.

The original timber was always untreated, but in 1929 our first fully treated ballasted-deck wood trestle was built and today many are still in existence. However, that old cautious nature prevented the full-scale use of treated timber until the mid-50's. The intervening 25 years saw some fully treated structures, some partially treated, and some untreated.

The ballasted-deck, fully treated timber trestle has been the finest, most economical structure for railway bridges ever devised and would still be if conditions were the same as in the past. However, times change, and whether we like it or not, and whether we call it progress or not, we have to face it.

First of all, traffic volumes, car weights and speeds increased significantly. This in itself would not necessarily have changed the picture regarding wood trestles. If a wood trestle is perfectly built and by that I mean timbers well-seasoned, straight and true, cut-offs dead level, connections perfectly fitting, piles straight and unchecked, then it can still stand a fair amount of modern traffic. However, within the last 20 or 25 years, many other things started to change. It became harder and harder to get sound, seasoned timber and piling. We received poorer materials, experienced carelessness in construction and there wasn't time for the old pride in craftsmanship. As a result, we have many wood trestles with twisted caps and stringers, poor cut-offs, small diameter and crooked piles and other assorted ills.

With the onslaught of modern rail traffic—130-ton cars, unit trains, higher speeds—the wood trestle literally started to fall apart. Splitting and checking of piles and caps accelerated; ties actually started to break up before their expected life-span was over; bolts would loosen up excessively and in some instances piles were driven down under the dynamic forces of unit trains.

There is the possibility of a perfectly fitting wood trestle, built of sound timber and piling, being able to stand up to a certain amount of modern rail traffic. However, another culprit entered the picture, or rather finally became significant. Through the years trestle fires would occur from time to time, and they were pretty well accepted. After the panic of a bridge burn-out was over, the statistics would be dragged out and the overall losses due to bridge fires would be assessed against the cost of eliminating wood bridges; and the conclusion would be that it would not pay to take any major steps to change the situation. As a trestle on the main line came up for rebuild, it sometimes would be built with permanent materials, but very often a new wood trestle would be the replacement. This policy resulted in very little reduction in the total number of wood trestles.

However, it is one thing to look at statistics on a sheet of paper and quite another to be faced with your main line cut because of a bridge fire, for two or three weeks. At a time like that the statistics don't seem to impress your executive management. And when you get two such fires just one day apart, then a major change in thinking results.

This then, was our situation late in 1969. There was a total of about 800 wood trestles on the Region, 350 of them on main, critical routes, and 100 of these on heavy-traffic, unit-train territory. And the projections for traffic volume in the future were staggering. As a result, a large program of elimination of wood trestles was started in 1970 and since then over 100 have been replaced, with the program continuing.

As an additional and in a sense an interim measure towards reducing losses due to trestle and deck fires, a program of spraying a fire retardant coating on all open-deck trestles and steel bridges on our main routes, was begun in 1971 and is nearly completed.

Wood Trestle Replacements

Replacements of wood trestles have taken several forms. Wherever possible, we will install culverts and fill. Culverts almost always are corrugated steel. Many things prevent the installation of culverts and fill, of course. Soil conditions may be poor; hydraulics may dictate against the practice; the provision for fish passage may be too costly; source of fill material may be too far away; property problems may be impossible to solve.

Permanent bridges have taken several forms. For longer spans, welded plate girders are used, with either concrete or steel decks, and ballasted track. Shorter spans, up to about 45 ft, consist of pre-tensioned concrete box beams, post-tensioned transversely, or steel beams with concrete slab decks, or steel beams with steel deck plates. Substructures consist of conventional piers, steel H-piles, or steel pipe piles filled with concrete, with concrete caps, or steel H-piles with steel beam caps.

New bridges are sometimes constructed on a permanent line diversion, especially a large structure, but many of the smaller bridges are built on the existing alignment. The need to keep interference with traffic to a minimum accounts for the rather odd appearance of many of our piers. Piles are driven outside the existing trestle, on either side, and they then require a much longer cap than normal. However, this enables the entire substructure to be built with very little interference to rail traffic. The spans are then placed with a one-day shut-down of the line. We naturally try to keep the track closures to a minimum and replace as many spans in one day as possible. Our biggest single project of this nature was a 44-hour closure in which 14 wood bridges were replaced with permanent structures. Generally, however, we work the projects in smaller groups of 3 or 4 replacements in a closure of about 12 hours. A very cooperative and patient transportation department makes this program possible.

Inspections

Our programs of replacements and repairs are based on various inspections made on a continual basis. Steel bridges are inspected in detail annually. Concrete substructures are inspected in detail on a much longer cycle, depending on condition. River bed soundings are taken in varying cycles depending on stream bed and flow conditions. Timber trestles are inspected at least annually but in many cases much more frequently. As a timber bridge reaches a point where decay could be starting, borings are taken to assess the incidence of loss of sound material. In spite of our fairly rapid replacement of wood trestles on main routes, we still have a total of about 700 left on the Region, and of these over 400 are on branch lines, the replacement of which are made with new wood trestles if they cannot be filled.

Naturally these trestles are kept going for as long as possible and we have carried out a good deal of in-place treatment. Piling is dug out and wrapped with a preservative-coated bandage and backfilled. Above-ground piling and timber is bored and filled with preservative. This operation is coupled with a full-scale inspection by boring, the holes being filled with preservative before being plugged. A good deal of our inspection and in-place treatment is carried out by contract rather than with our own crews.

An area with which we have not so far been troubled is that of metal fatigue. Thanks to the conservative designs in the beginning, and the fact that 1912 is not really old compared with some railway bridges in other parts of the continent, our steel bridges have given no trouble along these lines. We have under extensive study, however, a bridge built in 1905, to quite a light design, by the Federal Government. This bridge is used by three railways and since CN is the major user, we have been charged with the responsibility of inspection and assessment of structural sufficiency. The results of the current study will serve the dual purpose of evaluation of the bridge itself, as well as establish a pattern of future studies of other bridges.

Disasters

One of the things we try to avoid in all areas of life, and the field of railway bridges is no exception, is that of accidents and disasters. However, they do happen. And in spite of the financial losses to the company, and the headaches and heartaches of all those involved, they are very often extremely interesting and certainly are the items that make the news. Therefore a dissertation on CN's Mountain Region bridges would not be complete without stating that we are not immune to such happenings.

Fires have already been mentioned. We have had ships destroy portions of bridges; ice rise up suddenly above the pedestals of a viaduct and push it over; major piers scoured out and collapse taking their spans with them; flood waters take out 2 pedestals of a 4-legged tower and do no further damage (the tower remained upright!); derailments destroy decks and truss spans; rock slides, and snow slides take out spans (one steel span was never found!). We have survived all of these disasters and learned a good deal from them.

New Lines

Not all of CN's Mountain Region was built in the period 1912–1914. Several new lines have been built since that time, notably the Kitimat branch in Northern British Columbia, the Great Slave Lake Railway in Northern Alberta and the Northwest Territories, and the Alberta Resources Railway in Northern Alberta. These have included a considerable number of bridges.

The new structures on these lines are of several types, generally following the old pattern of steel viaducts, or girders and trusses on concrete substructures. The steel structures are all-welded, with field connections of high-strength bolts. Generally decks have been of treated timber, but I believe we will be looking at all ballasted decks in the future.

The total inventory of bridges presently on the Region is over 1100. With the program of replacement of wood trestles only one-third along the way, and the possibility of new lines being built in the near future, the subject of railway bridges will be with us for many years to come.

Investigation into Causes of Rail Corrugations

By J. Kalousek, R. Klein
CP Rail

1. INTRODUCTION

During the last decade, CP Rail has experienced a substantial increase in traffic density accompanied by the introduction of 100-ton-capacity cars and increased locomotive horsepower. These advances increased the productivity of our rail transportation network and improved the competitiveness of our operations. On the other hand, these changes have been associated with increased wear and tear of the permanent way. Substantial wear and abrasion was first experienced on the high rail. To combat this problem, curve lubricators were introduced with a great deal of success. However, reduced flange abrasion resulted in an increase in the incidence of rail corrugation.

Rail corrugations we experience most are those with a wavelength (pitch) in the range of 8 to 28 inches. In order to avoid any confusion, it should be mentioned that two other types of rail corrugations are known to railroaders. One type has a wavelength in the range of 2 to 3 inches and is often referred to as "washboard rail" or "roaring rail." It is the type of rail corrugation which has recently received most of the attention in railroading and scientific literature(1, 2, 3). The other type of rail corrugation, mentioned in current literature(7), has a wavelength in the range of 72 to 108 inches, but it may also be categorized by some railroaders as track irregularities. In this paper, we are solely concerned with the observations, formation mechanics and possible cures for rail corrugations with a wavelength of 8 to 28 inches (4, 5, 6).

2. OBSERVATIONS

Rail corrugations predominantly appear on the running surface of the low rail in a curve as seen in Figure 1. These rail corrugations are always associated with flaking of rail metal as may be observed at the center of focus. They usually appear opposite the location where wheel flanges contact the high rail. They also are deeper toward the field side of the rail.

Rail corrugations may also occur on the high rail as shown in Figure 2. The characteristic flaked or slightly shelled pattern may be observed on the high rail illustrated in this figure. The corrugations valleys are at the locations of most intense flaking and they are deepest at the gauge corner of the rail.

Occasionally, we find corrugations on tangent track as shown in Figure 3 but this is not too common. In this particular location, the growth of corrugations has been accentuated by over-lubrication of the track and the absence of grinding. This section of track is located on a bridge and grinding was not carried out because of the risk of fire. The occurrence of rail corrugations on the high rail and tangent track is rather infrequent on CP Rail lines. The rail corrugations forming on low rails are predominant and, therefore, we will devote most of our attention to them.

Figure 4 shows the field side of the low rail where the rail corrugations are in the initial stage of their development. The areas on the railhead which are not hatched point to the increased rate of plastic flow of metal in the surface layer of the railhead. These locations may be classified as the "low spots" or "valleys" of rail corrugations. Plastic flow may be also observed in the neighboring hatched areas, but this flow is uniform over large sections of rail and is not of concern. The reason for the difference between these two modes of plastic flow can be found in a closer examination of surface cracks.

Figure 5 shows that the top surface of the rail is flaked. Closer examination of the flakes and associated crack pattern reveals more intense flaking and the occurrence of more critical cracks in the corrugation valleys. This suggests that the formation of corrugation valleys is associated with increased plastic flow of metal which has been accentuated by an increased incidence of cracks and depletion of metal from the railroad through flaking.

This trend may be already observed on rails not yet corrugated. Figure 6 shows a low rail, which has accumulated approximately 8 MGT of traffic. To reveal the initial stages of crack development on the rail surface, grease was wiped away in two locations. The location on the right-hand side, the close-up of which is shown in Figure 7, exhibits a single longitudinal crack. The location on the left-hand side of the same rail (Figure 8) exhibits two longitudinal cracks. This spontaneous non-uniformity in crack initiation indicates that these cracks are of a surface fatigue origin and that corrugation formation mechanics might be related to surface fatigue. For this reason, we have investigated the cracks in more detail with a Scanning Electron Microscope and discovered a large incidence of spherical particles as shown in Figure 9. The magnification is approximately 1,250 diameters. These spherical particles are typical of surface fatigue failures of lubricated machine components such as roller bearings, gears and also rails, thus confirming the surface fatigue nature of rail flaking.

The question now arises as to how we can relate the surface fatigue and plastic flow of metal to formation of rail corrugations. The answer to this question is rather complex since additional factors such as the distribution and magnitude of contact stresses, tangential forces, dynamical loadings, strength of rail material, lubrication and wear play a significant role in corrugation formation mechanics.

3. FORMATION MECHANICS OF RAIL CORRUGATIONS

The explanation of rail corrugation formation may be simplified, if we consider first the plastic flow of railhead metal and then surface fatigue. Other factors influencing corrugation formation mechanics will be dealt with within these two subsections.

3.1 Plastic Flow

Perhaps the best way to start the explanation of plastic flow is to consider the basic aspects of Hertzian theory of contact stresses. The contact stresses may be assessed if the wheel and rail are represented by two cylinders crossing each other, as shown in Figure 10A.

The area of contact between these two cylinders is usually ellipitical. A knowledge of mechanical properties of wheel and rail materials together with the knowledge of contact geometry enable us to calculate the contact stresses. Their distribution is shown graphically in Figure 10B. The maximum value of vertical stress σ_z can be designated as maximum pressure P_{max} since all contact stresses are compressive. It is convenient to use P_{max} as a basic parameter describing the dis-

(Text continued on page 439)

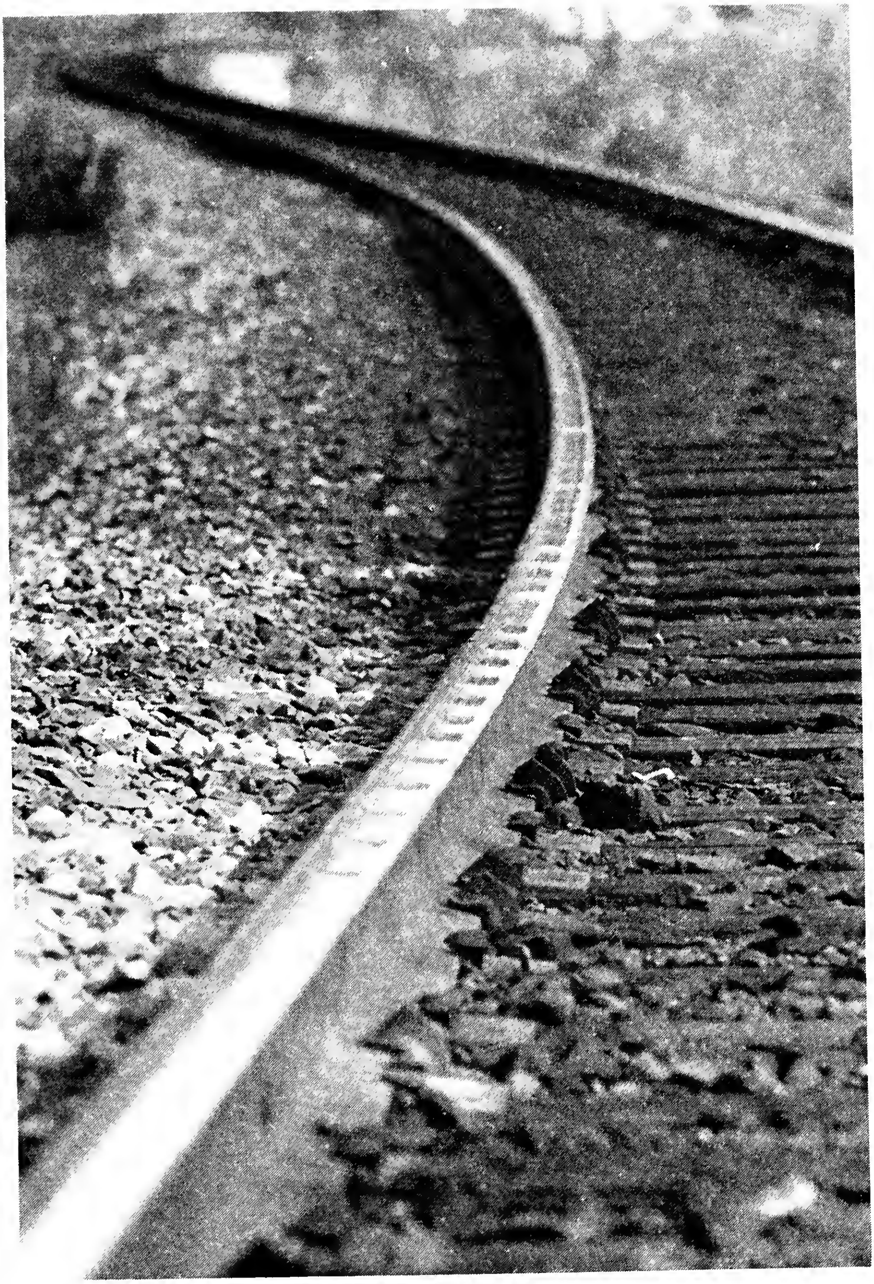


Figure 1

Figure 2

Figure 3

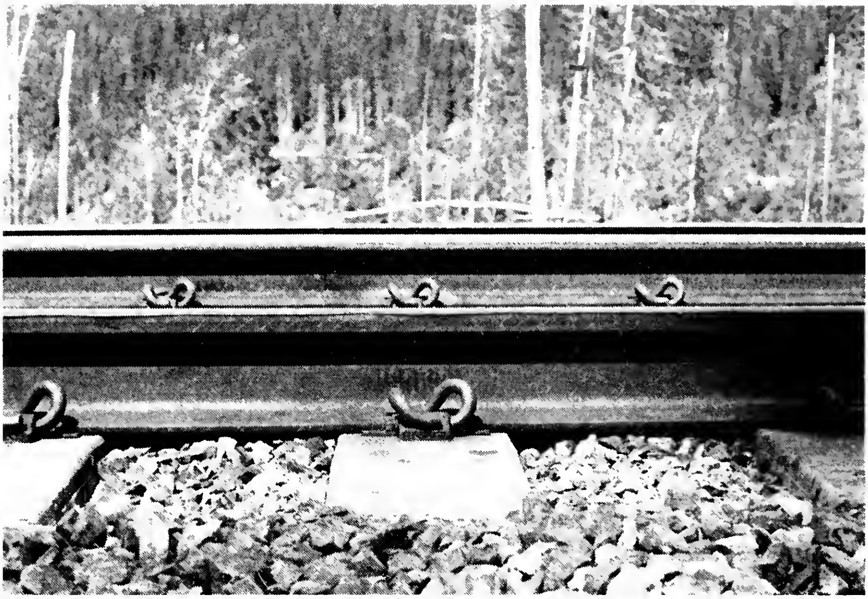


Figure 4

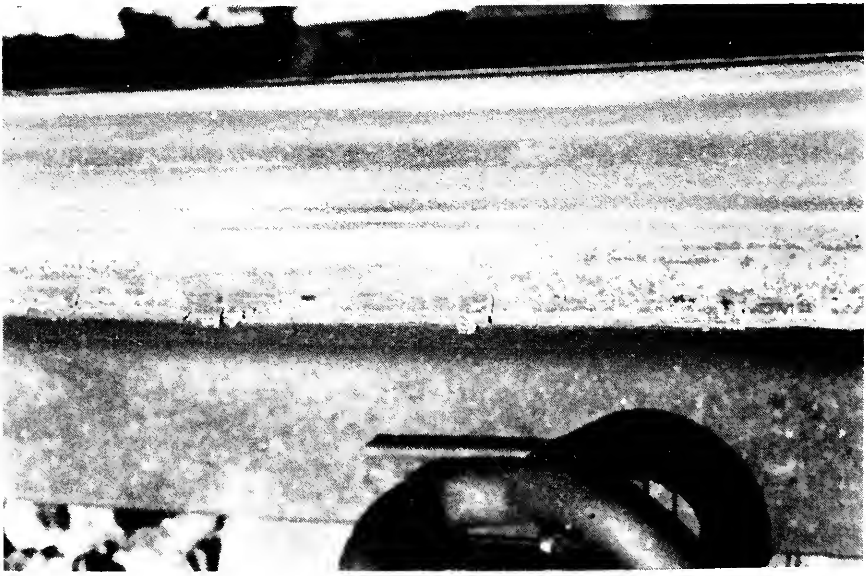


Figure 5

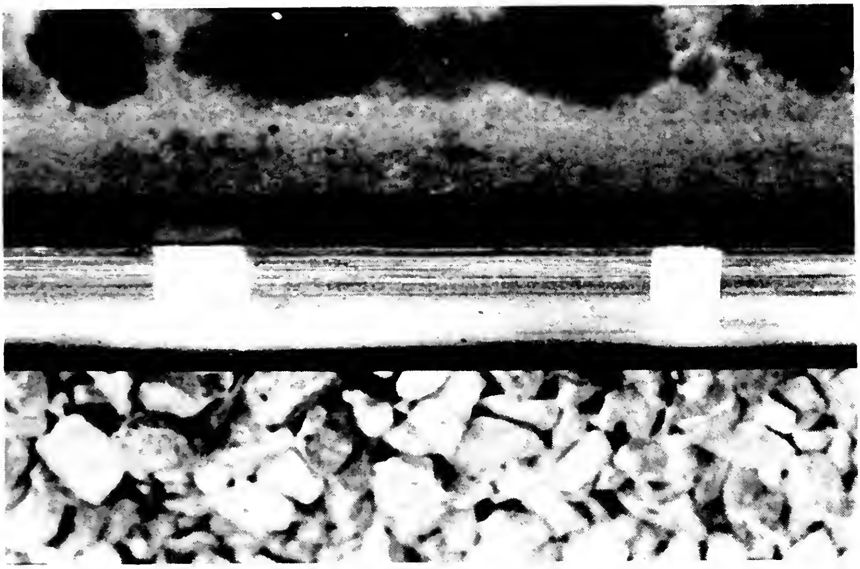


Figure 6

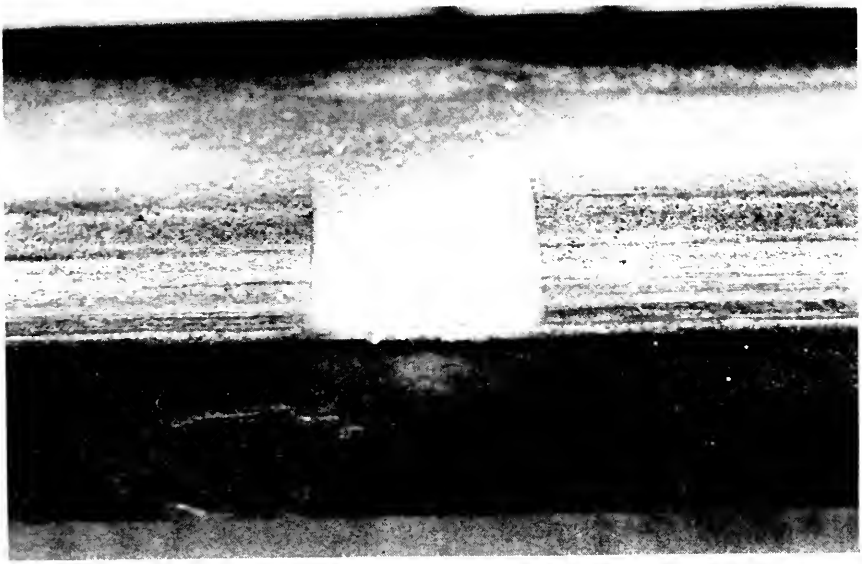
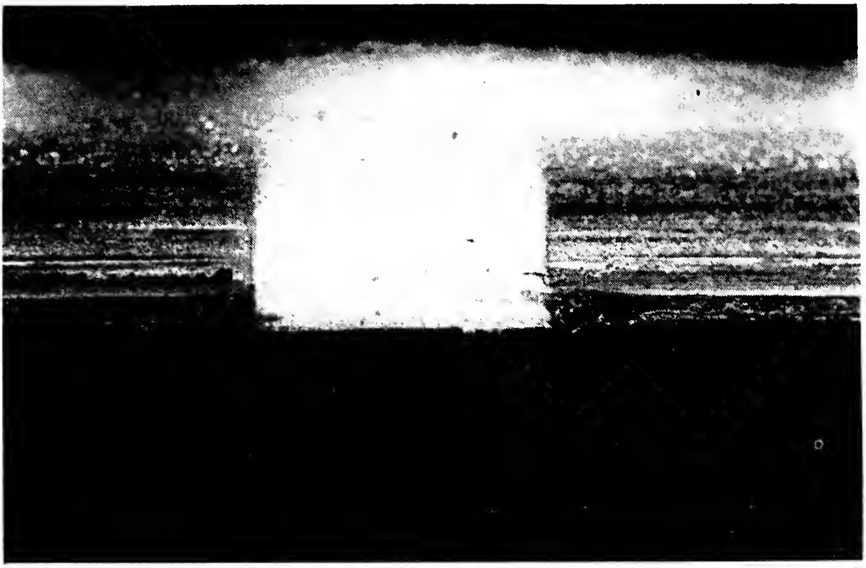


Figure 7



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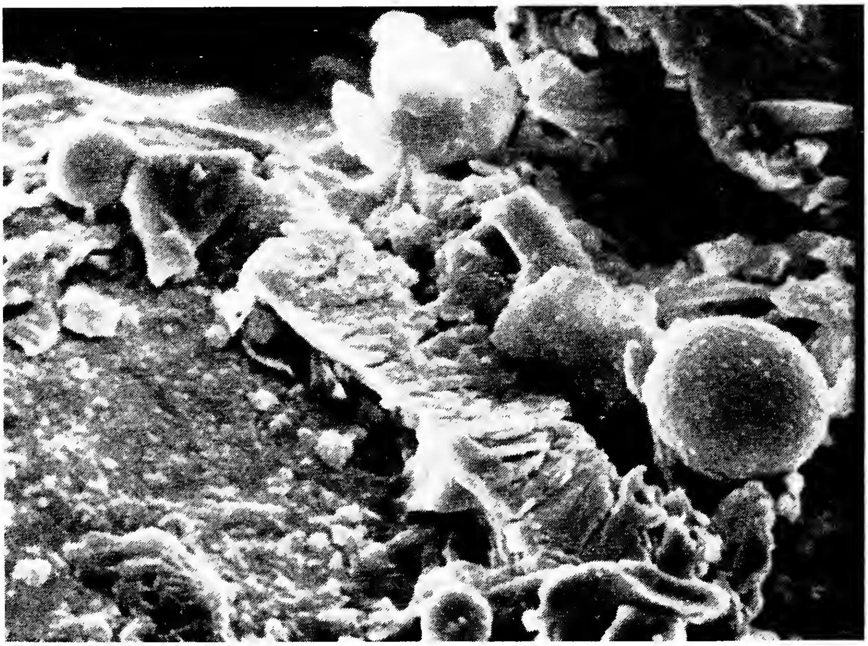
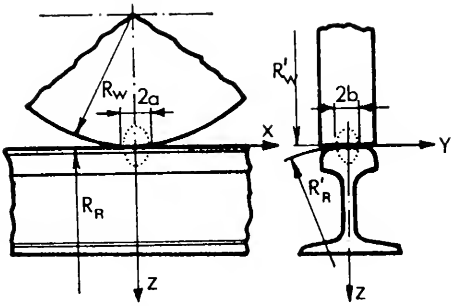
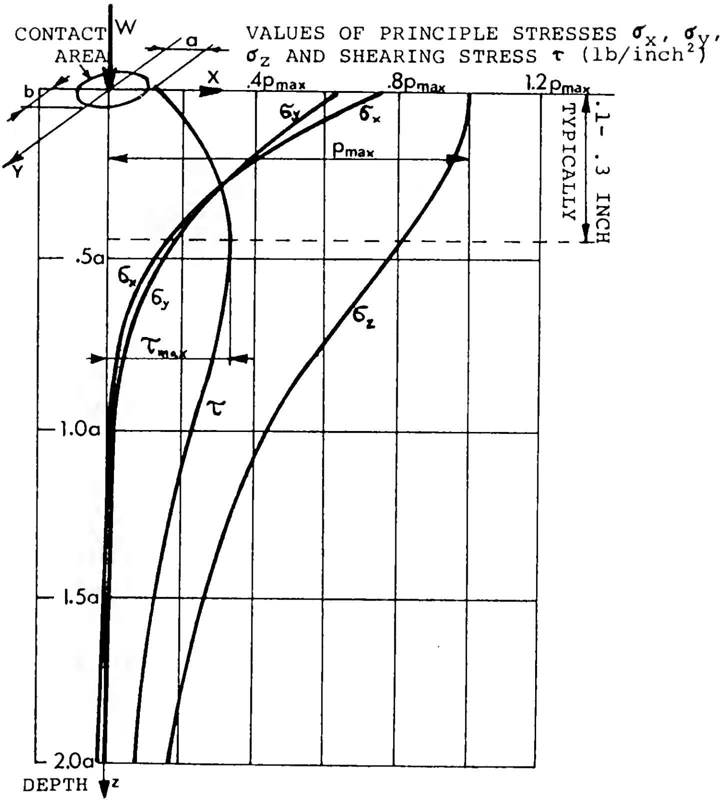


Figure 9

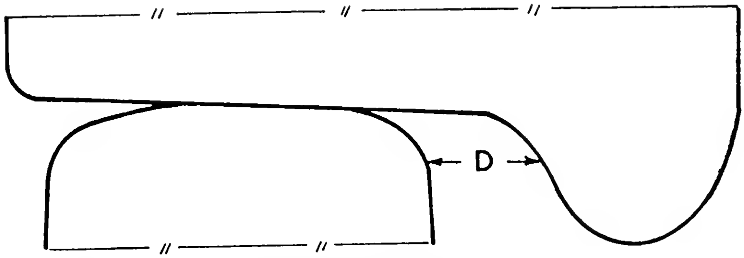


(A) IDEALIZED CONTACT BETWEEN RAIL HEAD AND WHEEL.

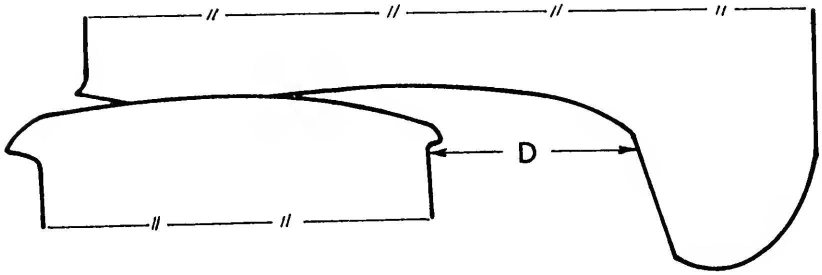


(B) DISTRIBUTION OF STRESSES IN CONTACT ZONE.

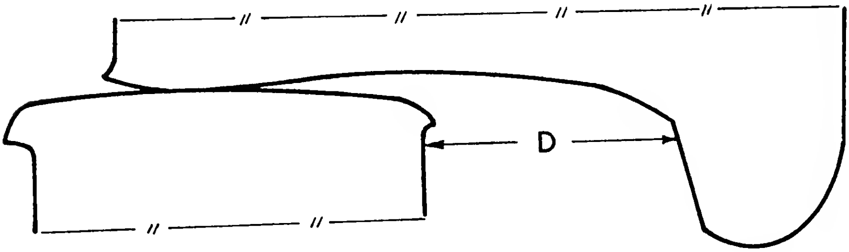
FIGURE 10



(A) D = 3/4" FLANGEWAY CLEARANGE
1/4" WIDE GAUGE (INSTALLED)
1" TOTAL (NEW WHEELS, NEW RAILS)



(B) D = 1" AS IN (A)
1/4" WHEEL FLANGE WEAR
1/4" RAIL SIDE WEAR
1-1/2" TOTAL (WORN WHEELS, WORN RAILS)



(C) D = 1" AS IN (A)
3/8" WHEEL FLANGE WEAR
3/8" RAIL SIDE WEAR
1/4" DYNAMIC GAUGE WIDENING
2" TOTAL (BADLY WORN WHEELS AND RAILS,
HIGH DYNAMICAL LOADINGS)

FIGURE 11: CONTACT GEOMETRY BETWEEN WHEEL AND LOW RAIL IN CURVES.

tribution of contact stresses because for any value of P_{max}, the distribution of principle stresses σ_x, σ_y, σ_z and shearing stress τ resembles that shown in this figure. The stress considered most critical in development of subsurface cracks is the maximum shearing stress τ_{max} which occurs between 0.1–0.3 inch below the running surface of the rail.

This distribution of contact stresses is valid only in the case of static contact between two elastic bodies of perfect shape and smooth surface. Additional factors, which may significantly influence the Hertzian distribution of contact stresses, such as work hardening of wheel/rail materials, presence of surface frictional forces in the zone of contact, lubrication and wear, must be considered if the actual wheel/rail interaction is to be understood.

Three examples of the possible relative positions between wheel and low rail are depicted in Figure 11 for 9°–12° curves. Assuming that the wheelset is in flange contact with the high rail, the relative position of wheel and low rail may be represented for convenience by the distance, *D*, between the wheel flange and gauge side of the rail. With no wear, this distance is comprised of the flange way clearance ¾-inch plus a preset wide gauge of ¼ inch totalling 1 inch as shown in Figure 11A. If both the high rail and wheels are worn by ¼ inch the distance, *D*, between the wheel and low rail is increased to 1½ inches as shown in the second sketch. If we consider severe wear, and add to this the magnitude of dynamical gauge widening ¼ inch, the reversed curvature of the wheel rim (often referred to as the false flange) may be brought very close to the center of the low rail. The contact stresses in terms of P_{max} experienced by wheel and rail under these and other possible conditions are presented in Table 1.

The pressure P_{max} is calculated according to a simplified formula for 36-inch-diameter wheel carrying a 33,000-lb load (which corresponds to a 100-ton capacity

SIMPLIFIED CONTACT STRESS FORMULA FOR P_{max}: $P_{max} = \frac{1}{\Pi} \left(\frac{3}{2}\right)^{\frac{1}{3}} \left[\frac{G\Sigma\left(\frac{1}{R}\right)}{1-\nu} \right]^{\frac{2}{3}} W^{\frac{1}{3}}$ WHERE

$G = 11.5 \times 10^6$ psi; $\nu = .29$ $R_w = 18''$, $R'_w = \infty$, $R'_R = 10''$, $R_R = \infty$, $W = 33{,}000$ lb.

R'_R Variable	P_{max} (psi)	Remarks	R'_w Variable	P_{max} (psi)	Remarks
10	215,800	New rail, new wheel	∞	215,800	New wheel, new rail
15	183,700	Flattened rail, new wheel	-10	108,600	Worn hollow wheel on top of new rail
5	300,400	Edge of rail, new wheel	10	300,400	False flange on top of new rail
3	397,400	Edge of rail, new wheel	5	338,400	False flange on top of new rail
2	504,400	Edge of rail, new wheel	5	773,300	False flange on edge of new rail (R_R = 1.25")
1.25	672,300	Edge of new rail, inflection point of worn wheel	5	436,000	Same as above but empty car W = 5,600 lb.

TABLE 1: CONTACT STRESSES FOR VARIOUS WHEEL RAIL GEOMETRIES.

car). The effect of cross-sectional curvature of railhead on the magnitude of contact stresses is illustrated in the first column, whilst the effect of wheel profile curvatures is presented in the second column. As the effective crown radius of the rail decreases toward the edge of the rail, the magnitude of contact stresses increases. Similarly, as the false flange curvature decreases, the contact stresses increase substantially. No doubt, some of these values exceed the yield stress of the rail material.

It was mentioned previously that the most critical stress in the theory of contact stresses is the maximum shear stress. Therefore, it is desirable to know the yield of material in shear rather than in tension. The yield in shear may be conveniently obtained from a hardness test since the resistance of material to shear is directly proportional to its hardness. From a practical sense, the higher the hardness of rail steel, the better it can withstand the contact stresses. The actual value of the contact stresses above which the rail material will always yield is termed the plasticity limit. The plasticity limits of carbon and chromium rails are approximately 250,000 psi and 320,000 psi, respectively, assuming that the surface layer of rail material has been already work-hardened, say, after the passage of the first train over those rails.

It should be pointed out that the theory of Hertzian stresses is applicable only within the elastic limits of a material and should not be employed to explain plastic flow. When yield occurs, no pressures significantly above the yield can develop within the rail material. Although the stress cannot be built up significantly above the plastic limit, parameter P_{max} may still give the indication of the rate of plastic flow. As P_{max} increases above the plastic limit, so does the rate of plastic flow. Hence, the underlined values in Table 1 illustrate situations where both carbon and chromium rail will yield and exhibit sustained plastic deformation. The numbers underlined by a dashed line refer to situations in which only carbon rail will yield.

Our examination of contact stresses is not over yet since the above mentioned plasticity limits may be applied with reasonable accuracy to tangent track only. In the case of curves, the continuing presence of lateral friction forces must be taken into account. These are shown in Figure 12.

To simplify our analysis, it is assumed that the wheelsets negotiate curves at an equilibrium speed and that the rolling radii of both wheels are the same. When the wheelset rolls forward a distance d, it is displaced laterally a distance Δd due to flanging. Since the wheelset slides rather than rolls in the lateral direction, the amount of force required to laterally displace each wheel is equal to the product of the coefficient of friction, μ, and normal force, W.

It can be shown that the orientation of the lateral components of wheel/low-rail forces are such that the low rail is pushed toward the field side and the wheelset is pushed toward the high rail. On the high rail, the frictional tread force and flange force act simultaneously. The flange force is the sum of the two-wheel frictional forces. The net result is that the high rail is pushed toward the field and the wheelset is pushed toward the center of the curve. It must be emphasized that the frictional tread forces and flange force are directly responsible for increased wear and tear of track in curves. For example, they contribute to "cutting in" of both tie plates on the field side.

At the wheel/rail interface, the tread forces significantly modify the distribution of contact stresses. The higher the coefficient of friction, the closer the maxi-

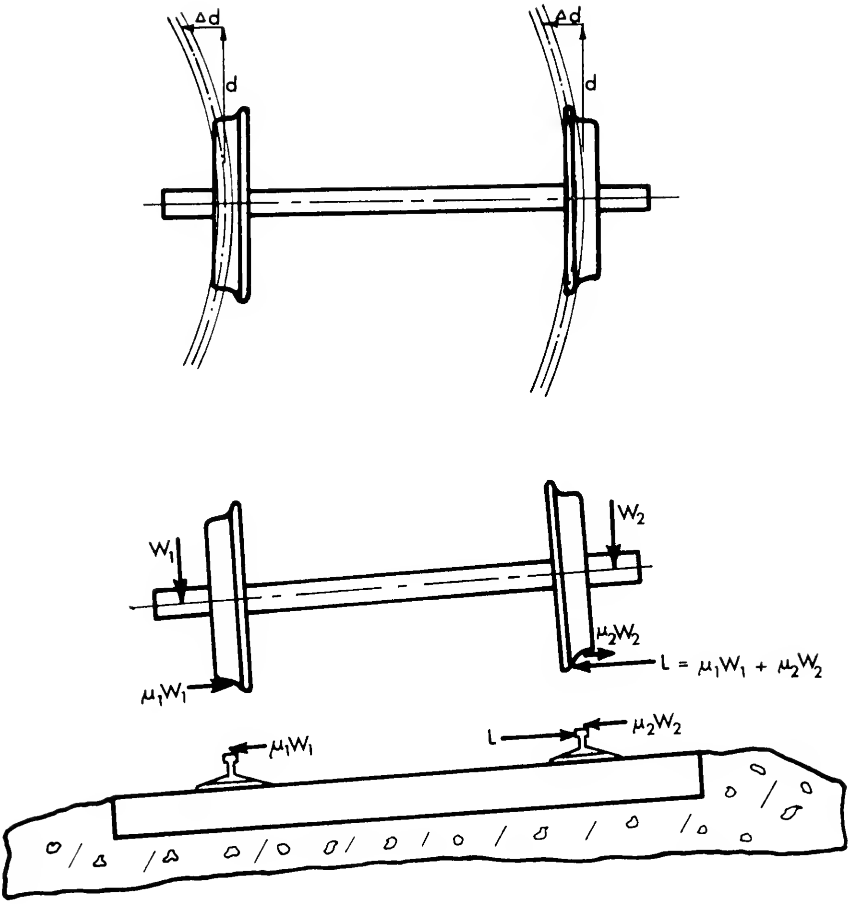


FIGURE 12: LATERAL COMPONENTS OF FORCE VECTOR IN THE WHEEL/RAIL CONTACT ZONE

Type of rail	Carbon P_{max} (psi)	Chromium P_{max} (psi)
Case of pure rolling (tangent track)	250,000	320,000
Case of rolling with frictional lateral forces (curves) $\mu = .26$	185,000	240,000

TABLE 2: MAXIMUM CONTACT STRESSES THE RAIL MATERIAL CAN WITHSTAND WITHOUT SUSTAINED PLASTIC FLOW.

mum shear stress is brought to the surface. This results in a proportionate reduction of the carrying capability of rail material. The extent to which the plasticity limit can be lowered by the tread forces in terms of P_{max} is shown in Table 2. With a coefficient of friction of 0.26, the carbon rail can tolerate only 185,000 psi in curves without sustained plastic flow. For coefficient of friction values lower than 0.26, the plasticity limit increases and at coefficient of friction 0.0, the plasticity limit is maximum. It may be interesting to note that the plasticity limit of chromium rail in curves, approximately 240,000 psi, is somewhat less than the plasticity limit of carbon rail in tangent track. In a practical sense, the values of plasticity limit suggest that each time the false flange runs close to the edge or over the top surface of the rail, both carbon and chromium rail will plastically deform.

Due to the dynamic nature of the track/train interaction, vertical loads, lateral tread forces, dynamic (and static) wide gauge as well as the coefficient of friction in the zone of contact are continuously varying along the rail paths in curves. Hence, the magnitude of contact stresses and the plasticity limit are subject to random fluctuations. However, more experimental work is needed to determine whether the intermittent pounding of peak dynamical forces at exactly the same location on rail produce the corrugation valleys or whether other parameters, such as localized wide gauge and/or development of fatigue cracks governs the initial location of corrugation valleys. It is the opinion of the authors that the random nature of frictional tread force and random initiation of fatigue cracks are most conducive to the formation of rail corrugations.

3.2 Surface Fatigue

Based on the observations described at the beginning of this presentation, it was suggested that plastic flow in combination with surface fatigue are predominantly responsible for the formation of rail corrugation. Plastic flow of rail material was briefly dealt with in the first portion of this presentation and it now remains to cover the subject of surface fatigue.

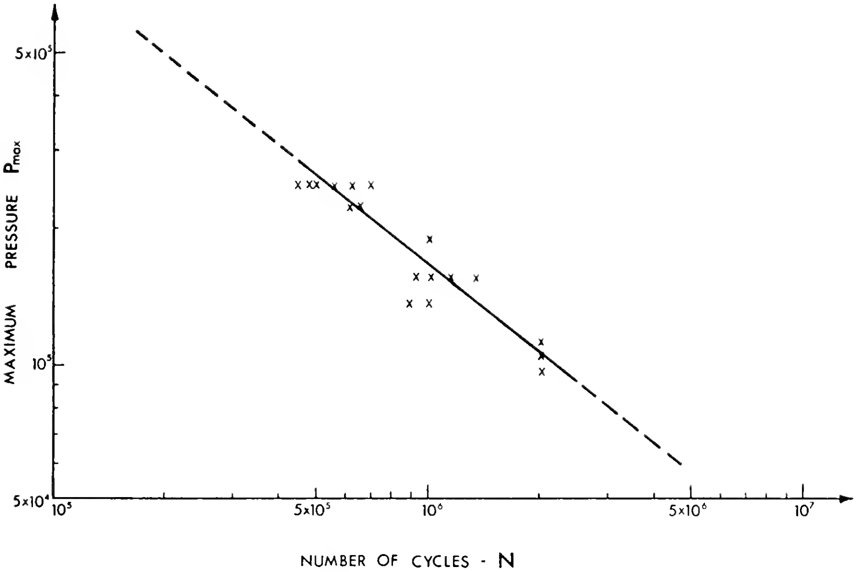


FIGURE 13: SURFACE FATIGUE S-N DIAGRAM

Surface fatigue, sometimes referred to as contact fatigue, deals with surface or subsurface failure of material which is repeatedly in contact with some loading member. Due to the large variety of possible wheel/rail contact geometries and the effect of frictional forces and other parameters on the distribution of contact stresses, contact fatigue failure of rail material can take any of the following forms: pitting, flaking, spalling and shelling. Each of these contact fatigue manifestations can be analyzed in two stages. The first stage is crack initiation and the second is crack propagation. A crack may initiate at two locations: at or very near the surface and a short distance below.

Cracks originating at the surface later develop into flaking and are therefore subject to further analysis. The first stage of crack development arises from a number of loading cycles at a specified load or contact stress. Figure 13 shows a typical surface fatigue "Stress—Number of Cycles" diagram. The number of cycles or number of passages of wheel over a small section of rail are plotted on the horizontal axis. The contact stresses in terms of P_{max}, which take into account the magnitude of load and geometry of contact, are plotted on the vertical axis. The experimental points plotted in this S-N diagram were obtained under full lubrication conditions in the zone of contact and exhibit large scatter which is rather typical of surface fatigue. The surface fatigue diagram shown in Figure 13 describes surface fatigue behavior of plain carbon steel and indicates that the crack develops after accumulation of approximately ½ million cycles at $P_{max} =$ 250,000 psi and after accumulation of 1 million cycles at $P_{max} =$ 150,000 psi. Utilizing this information, it has been calculated that on lines with an annual traffic density of 45–50 MGT, surface cracks develop 30 to 40 days after new carbon rail is placed in service. With chromium rail, this period is extended by 10 to 20 days.

In fact, Figures 6 to 8 show cracks already initiated on the surface of chromium rail which was in service for approximately two months.

If full lubrication is not satisfied and some natural wear occurs, crack initiation and development of flakes may be delayed. Ultimately where there is sufficient wear, fatigue crack initiation may never occur.

Accumulation of lubricant on the rail surfaces plays a significant role in the development of surface fatigue. This is illustrated in more detail in Figure 14. The primary role of the lubricant is to reduce flange wear on the gauge side of the high rail. Nevertheless, the lubricant is gradually squeezed out of the flange contact zone and to insure adequate lubrication in the flange contact zone, the lubricant must be continuously replenished by track-side lubricators. Lubricant "squeezed from" the zone of contact is then deposited on the edge of the wheel flange as well as on the wheel false flange. From the wheel false flange, excess lubricant deposits on the top running surface of the low rail, where it promotes surface fatigue crack development and flaking.

The manner in which lubricant contributes to crack propagation and subsequent flaking is shown in Figure 15. A passing wheel first closes the crack and "locks in" the lubricant (Figure 15A, Section 1–1). During further travel of the wheel (Figure 15A, Section 2–2), the pressure of the lubricant layer within the contacting surface is hydro-dynamically transmitted to the lubricant located at the root of the crack where a maximum pressure, P_{max}, and maximum tangential stress, τ_{max}, act simultaneously. Whilst this mechanism uniformly enhances the growth of a crack in the case of longitudinally oriented cracks (Figure 15B), it usually results in formation of rail corrugations and more severe defects such as transverse fissures with oblique and intersecting cracks (Figure 15C).

The presence of surface cracks and flaking contributes to deterioration of rail life in two ways. Firstly, they disrupt the homogenity of rail metal at the surface and significantly redistribute contact stresses which results in a reduction of resistance to plastic flow. Secondly, the cracks, in combination with the presence of frictional tread force, enhance the depletion of metal from the surface layer of rail metal through flaking.

In summary, the amount of plastic flow and flaking are functions of the vertical load, contact geometry, frictional tread force, initiation and propagation of surface cracks, all of which are random functions in time and/or spatial position. As a consequence, the rate of plastic flow and the rate of flaking are also random functions with time and/or spatial position and are therefore most conducive to the growth of rail corrugations. As the dynamical loads become more severe, the rate of corrugation formation and propagation accelerates.

4. METHODS TO REDUCE OR ELIMINATE RAIL CORRUGATIONS

Perhaps the best way to prevent or reduce the formation of rail corrugations is to eliminate or alleviate the principle contributing factors. These factors may be categorized as follows:

a) *Wheel Rail Contact Geometry*

In this area, it is desirable to eliminate high contact stresses which contribute to plastic flow and early development of surface fatigue cracks. Possible measures to accomplish the above involve:

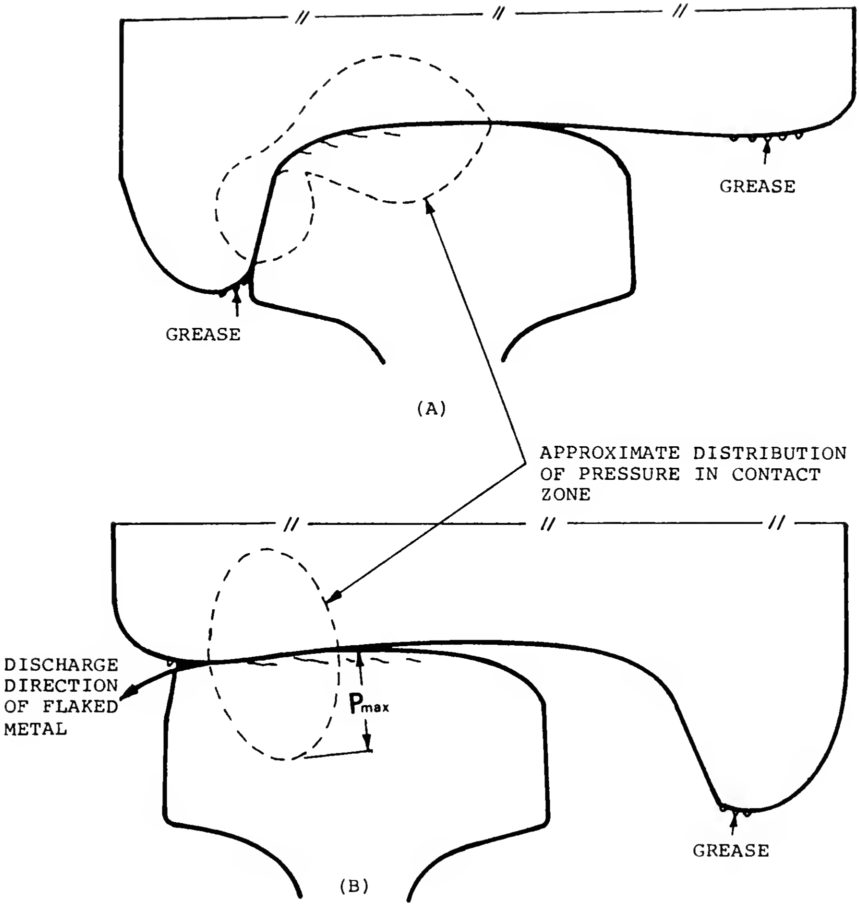


FIGURE 14: RELATIVE POSITIONS OF WHEEL ON RAIL DURING CURVE NEGOTIATION
(A) HIGH RAIL
(B) LOW RAIL

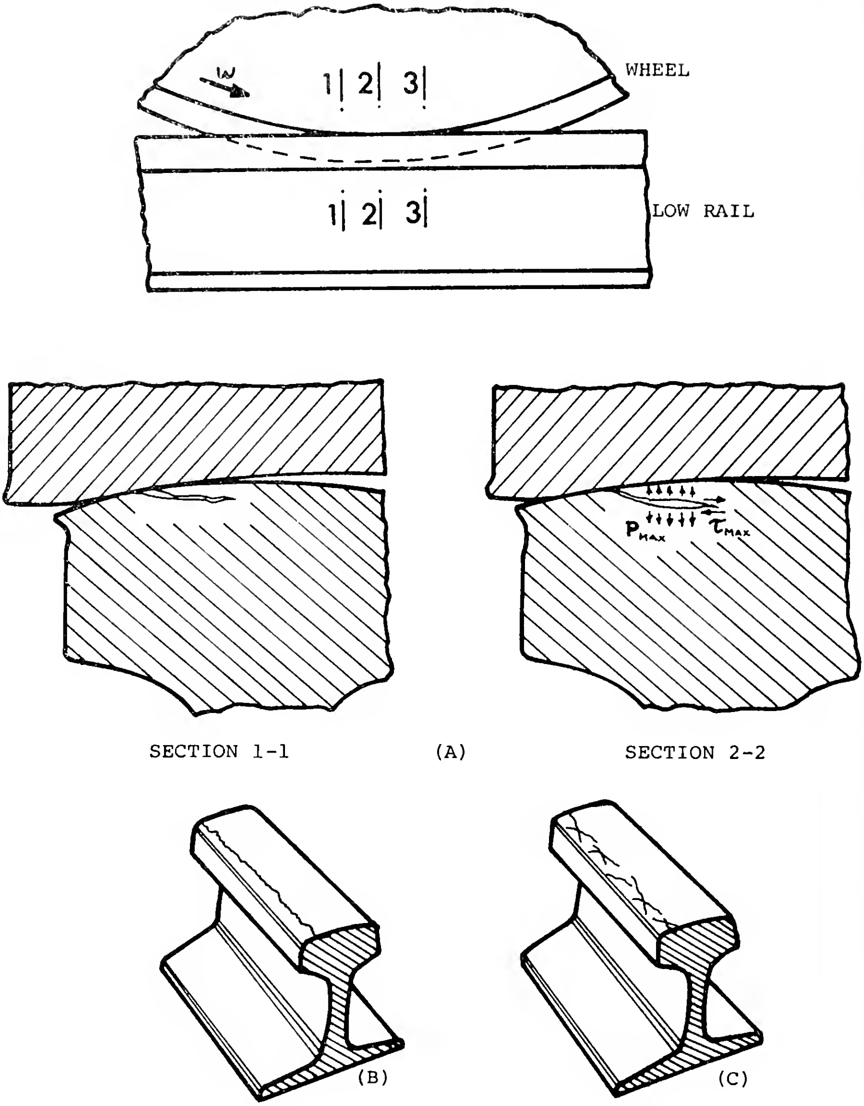


FIGURE 15: SIMPLIFIED MECHANICS OF CRACK PROPAGATION

i) *Elimination of Wide Gauge in Track*
Alleviation of wide gauge may be achieved by installation of longer tie plates, gauge rods, hardwood ties, concrete ties, and/or other possible measures.

ii) *Elimination of False Flanges on Wheels*
Improvement may be accomplished by changing the condemning limits on wheels, relocation of brake shoes into "overhang" position and/or other measures.

iii) *Reduction of Railhead Curvature*
Reduced stresses would result if the field side of the low rail was ground to a shallower radius immediately after being placed in track.

iv) *Modification of AAR Wheel Profile*
Appropriate changes in wheel profile may decrease the level of contact stresses and flange wear.

b) *Lateral Frictional Force*

Flange contact may be minimized by installation of self-steering trucks into unit trains. A few experimental designs of self-steering trucks were recently developed and tested. The results of test programs are encouraging; however, the full utilization of self-steering trucks is hampered by high cost.

c) *Surface Fatigue and Plastic Flow*

Improvements with respect to surface fatigue and plastic flow may best be achieved through improvements in rail metallurgy. The objective of such improvements would be to increase rail strength and hardness while maintaining ductility and fracture toughness.

d) *Friction, Lubrication and Wear (Tribology)*

In this area, an improved lubrication policy should be developed, which would ensure proper lubrication in the zone of flange contact and prevent, at the same time, accumulation of grease on the top surface of the low rail. The resulting increased natural wear on the running surface of low rail would delay development of surface fatigue defects and thus decrease the need for grinding. An optimized lubrication practice would provide an additional benefit of improved adhesion for traction.

e) *Dynamic Loadings*

Any measures aimed at reduction of the magnitude of dynamical loadings through improvements in the design of rolling stock and track maintenance will considerably alleviate the pace of corrugation formation and propagation.

It is certain that a combination of the above changes will have to be implemented, in the next few years, by those railways in North America that are at or approaching traffic levels of 40 MGT per year on sections of their lines.

REFERENCES

1. P. R. Nayak: "Contact Vibrations of a Wheel on a Rail", Journal of Sound and Vibration (1973) 23(2) 277–392.
2. K. Werner: "Corrugation and Pitting of Rolling Surfaces—Are They Contingent Upon Ultrasonics?" Wear 32, (1975) 233–248. (Originally appeared in German in "Eisenbahntechnische Rundschau" 22(1973) 142–149).

3. M. Srinivasan: "Prevention and Cure of Rail Corrugation", Railway Gazette International, March 1975.
4. R. G. Read: "The Rail for High Intensity Mineral Traffic", AREA Bulletin No. 639 (1974) 38–59.
5. F. E. King: "Tests on B.C. South Line Clearwater Subdivision", CNR Technical Research Report, February 28, 1975.
6. J. Kalousek: "Track/Train Dynamics Report No. 4—Rail Corrugations", CP Department of Research, Report No. S488–75, February 1975.
7. "Effective Correction of Long-Wave Rail-Surface Corrugation Wear on Finnish State Railways". Rail Engineering International, February–March 1975, 74–75.

Rock Slope Stability on Railway Projects

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INTRODUCTION

There has been a general increase in rail traffic through the western mountain regions of Canada and the United States in recent years; for example, traffic on the Canadian Pacific in the Pacific Region has almost doubled since 1968. With much of the rail lines constructed in tortuous mountain terrain, numerous high soil and rock cuts result.

It has been a common concept that because most of these cuts are over 50 to over 100 years old the slopes have become stabilized with time. In actual fact the increase in frequency, weight and length of trains in the past decade is increasing stress in the trackside slopes. As a result, unless stabilization programs are developed, an increase in rock fall and slope failures can be expected as the volume of traffic continues to increase.

A number of failures have occurred recently that have caused derailments and loss of life. In addition, the courts in Canada no longer accept slides as an "Act of God."

Fortunately our knowledge of rock mechanics and rock slope stability has increased greatly in the past decade. (Brawner 1966, 1967, Brawner and Milligan, 1971, Hoek and Bray 1974.) Based on this knowledge and experience it is now possible to define most of the potential areas of rock instability and to develop a rational and practical program to improve stability.

This paper defines the factors which contribute to instability of rock slopes and outlines procedures to improve stability. Specific recommendations are suggested for new construction. To illustrate an effective approach, the recent program developed for the Canadian Pacific is described.

FACTORS WHICH INFLUENCE ROCK SLOPE STABILITY

Rock slope stability is influenced by many factors. In order to assess potential problems it is necessary to be familiar with these factors. In addition the program of stabilization selected must take into consideration the cause of instability.

One of the basic concepts is that the assessment of stability must be based on the geologic, hydrologic, climatic, topographic, rail traffic and environmental conditions at the specific site. Most important of all are the geologic conditions. Since the structural geology conditions frequently differ greatly over short distances, each rock slope must be investigated individually. The more important factors which influence stability are summarized below.

a. *Geologic Conditions*

Rock which is sound or has joints which are discontinuous over short distances and which are randomly oriented will stand vertically for great heights. The theoretical height for a vertical slope is given by:

$$H_c = \frac{Q_u}{W_r}$$

Where H_c is the vertical height of the slope in feet
Q_u is the unconfined compressive strength in lb/sq ft
W_r is the unit weight of the rock in pounds.

For example for a soft rock with a strength of 3000 psi the vertical height computed is about 2600 ft.

In nature, vertical slopes of this magnitude are unusual. Consequently it is apparent that weaknesses in the rock diciate the maximum height and angle at which the slope will be stable. These weaknesses include faults, shears, joints, bedding planes, zones of weathering or hydrothermal alteration.

When these weaknesses exist the most important factor is the orientation and dip of the weakness relative to the slope. Figure 1 illustrates various orientations of weaknesses. The most critical conditions are weaknesses or combinations of weakness which dip out of the slope. In these instances if the shear strength along the discontinuity is exceeded, failure will occur. The shear strength is influenced by the roughness along the discontinuity and presence of weak material, such as fault gauge, altered infill, calcite stringers, etc.

b. *Groundwater*

The frictional force developed along a discontinuity is proportional to the normal force acting on the failure plane. If water exists in the discontinuity the normal force is reduced by the buoyant force exerted by the water. With a water table near ground surface the factor of safety of a rock slope is about 35 per cent less than that if the slope were drained.

In areas where freezing temperatures occur stability can be reduced as a result of freezing of the surface of the slope. This restricts drainage and may result in the build up of cleft water pressures in the slope.

c. *Climatic Conditions*

The seasonal variations range from cold winters with heavy snowfall to hot summers with occasional heavy rainstorms. The major effects of the weather on slope stability other than changes in ground-water levels, are the combination of freeze-thaw, wet-dry and chemical alteration. When water accumulates in cracks and freezes, the forces of expansion can be sufficient to move considerable masses of rocks and stability can deteriorate with time. Conditions are normally most critical during freeze/thaw and snow melt periods in the spring.

In tropical climates severe weathering effects are likely to have a great influence on stability.

d. *Vibration*

Vibration stress due to train traffic can lead to rock fall or slope failure. The frequency and length of the vibration influences the stability. Unit trains provide a more uniform frequency, and the great length of these trains increases the length of time the vibration occurs. Both factors tend to reduce stability.

e. *Blasting*

Excavation techniques used in railway construction up until about 5 to 10 years ago gave little consideration to the effect upon the rock. Figure 2 (a) shows the general relationship between weight of explosive, distance from the blast point and particle velocity, which can be related to rock damage. It should be readily apparent that the amount of explosives detonated at one time should be limited. This can be done readily by using delays.

Great advances have been made, particularly in Sweden, to develop controlled blasting (Langefors and Kihlstrom, 1967). Preshear and cushion techniques now allow many rock slopes to be excavated steeper and with lower maintenance requirements. Figure 2 (b).

f. *Earthquakes*

Much of the west coast of North America is in an earthquake active zone. The present state of the art does not yet allow prediction or warning of earthquakes. Large earthquakes can cause major slides in rock, e.g., the major slide on the Madison River in West Yellowstone, Montana, caused by an earthquake with a magnitude of 7.5 to 7.8 on the Richter scale. Lesser earthquakes will frequently result in localized rock fall.

Types of Rock Instability

In order to assess the potential of rock instability it is essential to define the types of failure that present the greatest hazard to the operation of a railway. Different types of failure and different causes of failure require different methods of stabilization. The most frequent types of instability and the most common associated causes are summarized in Figure 3.

The great influence that geology and water have on stability must be recognized.

Evaluation of Stability

The evaluation of rock stability is frequently best considered in two stages. Stage 1 is the gathering of relevant geological, topographic, climatic, hydrologic and train operating data incorporating a site inspection and site mapping. Air photo interpretation is frequently very useful at this stage. Frequently evaluation of data obtained from this program will be sufficient to assess stability and if a potentially dangerous situation is believed to exist, a program to improve stability can be developed. Where the potential of instability is primarily a danger of local rockfall, a Stage 1 program is usually adequate.

When the initial study reveals the potential of large-scale failure or failure which could have serious consequences, a more extensive investigation may be necessary. This may include the necessity to drill boreholes, and orient the core by down-the-hole photography, borehole periscope or other means. The performance of shear tests on joints or infill material, determination of water pressure in the joints using piezometers and the performance of stability computations. These techniques are reasonably well developed. (Hoek, 1975).

Figure 4 shows typical equipment used for such studies.

Very few engineers have extensive experience in rock mechanics so that advisors or consultants should be selected only after a thorough assessment of their qualifications.

Methods of Control

Three major approaches may be used separately, or in combination in the development of a realistic program to control stability.

1. Stabilization.
2. Protection.
3. Warning Systems.

The prime purpose is to provide a reasonably practical degree of safety within the limits of a justifiable expenditure of dollars. However, it must be recognized that *it is physically impossible to protect the railway against all possible failures.* While our kowledge in the field of rock mechanics is advancing rapidly it is not economically or practically possible to locate or predict all of the potentially unstable areas, and secondly, that the money required to provide nearly 100 per cent safety is extremely high.

1. *Stabilization*—Stabilization of rock slopes is justified where the cause and extent of failures or potential failures can be defined and where the cost of the stabilization can be justified.

The method and extent of the stabilization program must be based on a definitive site investigation.

Stabilization procedures include the following:

- Excavation or resloping.
- Drainage (surface and subsurface).
- Surface stabilization.
- Support systems.

Details and comments for stabilization procedures are shown in Figures 5, 6, 7, 8 and 9.

2. *Protection*—Protection involves the prevention of rock from falling on the track. The type of protection depends on the volume, size and frequency of potential falling rock, the geometry of the slope (rolling or free falling rock potential) and the frequency and type of train traffic.

Where large volumes of falling rock occur very expensive procedures such as tunnels or rock sheds can be justified. At other areas, slope or ditch treatment will frequently be effective.

One of the most effective procedures is to develop deep catchment ditches on the inner side of the track. Alternatively, catch walls can be constructed. One of the most efficient and economical types is the gabion wall which can be varied in height and is flexible under impact.

Where rock slopes exist at sidings, consideration should be given to using the outer track for the mainline traffic.

Details and comments of protection procedures are given in Figures 10, 11 12 and 13.

3. *Warning Systems*—Warning systems are used where occasional falls are expected but it is believed the cost of protection or stabilization would be extremely difficult and expensive.

The most common warning system comprises electric fences. These are usually connected into the signal system. With this method there is less than 100 per cent probability of providing sufficient warning to the locomotive engineer so he can stop. For example, if the slide or fall occurs while the train is in the block the engineer will not be warned. In addition some slides are caused by train vibration. In these instances the slide may hit the train behind the locomotive. The Japanese have transmitters connected to fences which improve the probability of warning.

Ice and snow in the winter frequently cause the wires to break. A combined heating and signal cable is suggested as a solution.

In many locations single wire warning systems would be inadequate.

One point of caution is made. Whenever a warning fence is installed it will probably become a permanent installation. Even if stabilization is carried out later, transport commissions or unions may oppose its removal.

Prior to the installation of warning fences any obvious precarious rock on the slope should be removed or scaled.

Considerable research is being carried out to improve warning systems. Such program includes vibration meters, robot patrols, TV monitoring, guided radar, laser detection, etc. None of these as yet has been developed to a state of economical acceptability.

Details and comments for warning procedures are given in Figure 14 and 15.

New Construction

New railway construction, particularly for resource development and reconstruction to provide double trackage, reduced grades or curvature may require rock excavation. The past practice has generally been to specify that new slopes in rock be cut to ¼ to 1 and that shallow "V" type ditches be used. These slopes were not designed according to the strength or quality of the rock. With the knowledge that now exists in rock mechanics, the stable slope angle can be determined with reasonable success and at reasonable cost.

Where the rock strength or where the geologic structure is favorable rock slopes can be cut vertical. This will reduce quantities, allow wider ditches to be used and result in rock falls dropping vertically into the inner ditch instead of bouncing or rolling onto the track. (See Figure 16).

Where geologic structural weaknesses dip out of the slope at a steep angle the slope should be cut to this angle. Figure 1 (c).

Controlled blasting using preshear or cushion blasting should be specified for the excavation of all rock slopes where the geologic structure is oriented favorably for stability. The rock in the slope will be subjected to less damage due to seismic acceleration forces which can break rock and open joints for tens of feet back from the slope. As a result steeper slopes can be excavated and the slopes will ravel less, requiring much less maintenance over the years. Figure 17 shows cut slopes developed using controlled blasting.

A Typical Rock Stability Program

To illustrate a working approach to the development of a rock stability program with the view to reduce the risk of slides and rock falls and to reduce maintenance costs, the program developed with the Canadian Pacific on over 1500 miles of track is described.

For Stage 1, a review of air photographs, topographic maps, climatic data and railway plans was performed. This was followed by an inspection of cut slopes along the track by motor car with a division engineer, a roadmaster or an assistant roadmaster. The stability of the slopes was rated into five categories (Table 1) according to an estimate of the probability of failure. This took into account the geology and rock conditions, slope geometry, ditch dimensions, hydrology and slope seepage and past experience with slides or falls at the site.

A program was instituted to record all slides and rock falls of a size that could be dangerous to train traffic. This form included data on time, location, size, sight visibility, weather conditions preceding movement, type and size of movement, estimated cause of movement, problem created, action taken. Forms such as this lend themselves to computer punch cards and computer retrieval at a later date. Areas of more frequent occurrences should be investigated in detail on a priority basis to assess the need and method of improving stability.

A lecture and site inspection workshop was prepared and attended by engineering staff, roadmasters and foremen. This program described the influence of geology, groundwater, vibration and climatic conditions on stability, outlined methods of assessing stability and described procedures for stabilizing the rock slopes. Numerous case examples were reviewed.

For the Stage 2 program, priority areas where stabilization was considered to be the most urgent were established, a detailed inspection was made of each, stabilization requirements were defined (Figure 18), and specifications were prepared. Construction commenced on these priority areas and continues until the annual budget allocation is expended. At this time further priority areas are being defined to establish next year's program.

REFERENCES

Brawner, C. O., 1966, "Slope Stability in Open Pit Mines," Western Miner, October 1966.

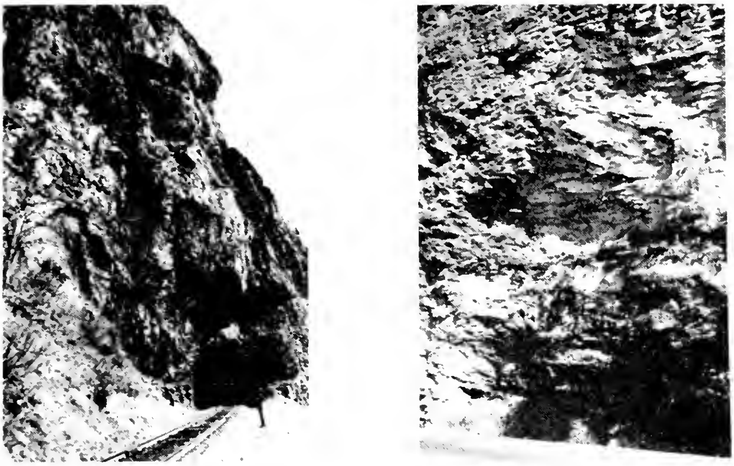
Brawner, C. O., 1967, "Rock Slope Stability in Highway Construction," 48th Conference, Canadian Good Roads Association, 1967.

Brawner, C. O. and Milligan, V., 1971, editors, "Stability in Open Pit Mining," The American Institute of Mining Engineers, New York.

Hoek, E. and Bray, J. W., 1974, "Rock Slope Engineering," The Institution of Mining and Metallurgy, London.

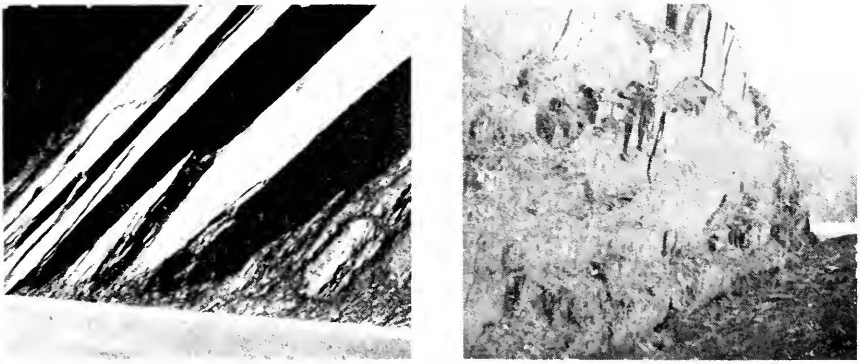
Langefors, V. and Kihlstrom, B., 1967, "The Modern Technique of Rock Blasting," John Wiley and Sons.

Ritchie, A. M., 1963, "The Evaluation of Rockfall and its Control," Highway Record, Vol. 17.



(a) Massive granite rock. Joints have random orientation. This slope can be cut vertically with controlled blasting.

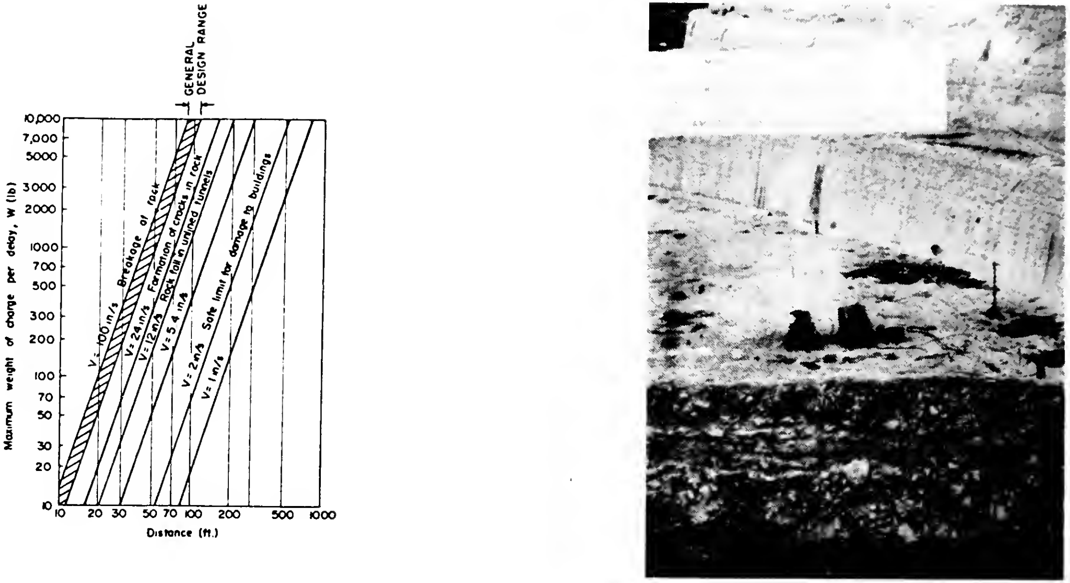
(b) Horizontally bedded soft sedimentary rock. Favorable structural orientation will allow vertical slope.



) Bedded slate with joints dipping out of the slope at 55°. This dip angle controlled the allowable slope angle.

(d) Bedded rock dipping into slope. Ravelling will occur due to cantilever type toppling failure. Slope angle of 70°-75° suggested.

Figure 1 - Rock slopes with different orientations of structural geologic weaknesses, each of which influences stability and stable allowable slope angle.



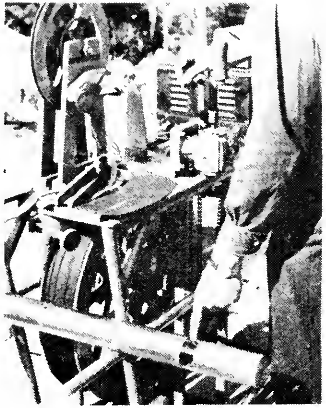
(a) Variation of maximum particle velocity with distance and weight of charge per delay (average rock conditions). As the charge size increases rock breakage extends farther back into the slope resulting in a greater risk of instability and higher maintenance costs.

(b) Comparison of the influence of different blasting procedures on rock. The upper slope has been excavated using controlled preshear techniques. The lower slope resulted from mass volume blasting with widely spaced, heavily loaded holes.

Figure 2 - Influence of blasting on rock slopes.

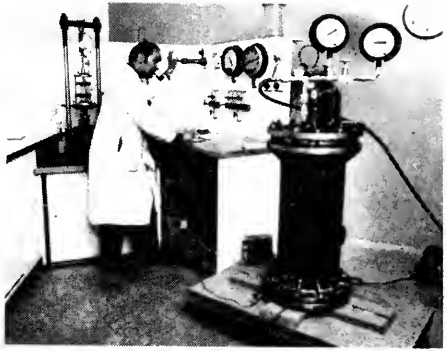
TYPE OF INSTABILITY	FREQUENCY OF OCCURRENCE	MOST COMMON FACTORS CONTRIBUTING TO INSTABILITY
Rock Slides (100 cu. yds. or more)	Very infrequent	Geological weaknesses bounding large rock volumes which dip out of the slope. Weak and weathered rock. High water pressures. Vibrations from trains. Earthquakes.
Block or Wedge Failures	Infrequent	Geological weakness bounding blocks or wedges of rock. High water pressures. Adverse climatic conditions or variations. Vibrations from trains. Earthquakes.
Rock Falls	Ranges from high frequency in steep blocky rock to infrequent in massive rock.	Weathering, temperature change, freezing and thawing, wetting and drying, water pressures in joints, root prying, joints dipping out of the slope, vibration of trains, presence of weak gouge in faults and shear zones which dip out of slope. Some falls originate well above right-of-way. Poor blasting control on new projects.
Running Slopes - Boulders and Talus	Frequent in areas of talus, till slopes and coarse gravel slopes.	Slopes originally cut steeper than the angle of repose, erosion undercutting boulders or more resistant rock.
Debris Avalances	Infrequent	Slides and trees falling into and carried by water in gullies and by snowslides.
Slope Erosion	Frequent in areas of high precipitation. More probable on new construction.	Heavy to very heavy precipitation or snow melt on exposed slopes. Frequently more of a problem on slopes on new construction.

FIGURE 3 - TYPES AND CAUSES OF INSTABILITY

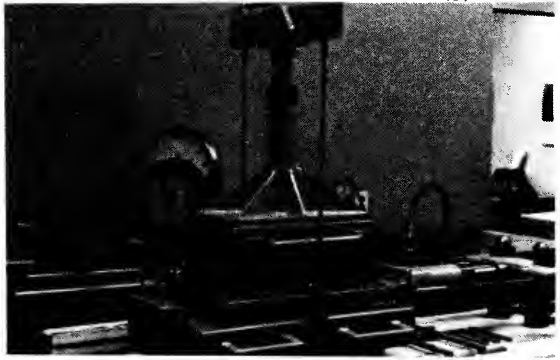


(a)

(b)



(c)



(d)

Figure 4 - Equipment used to determine structural geologic orientation and shear strength of rock for stability evaluation. Detailed stability studies are recommended where serious instability may occur.

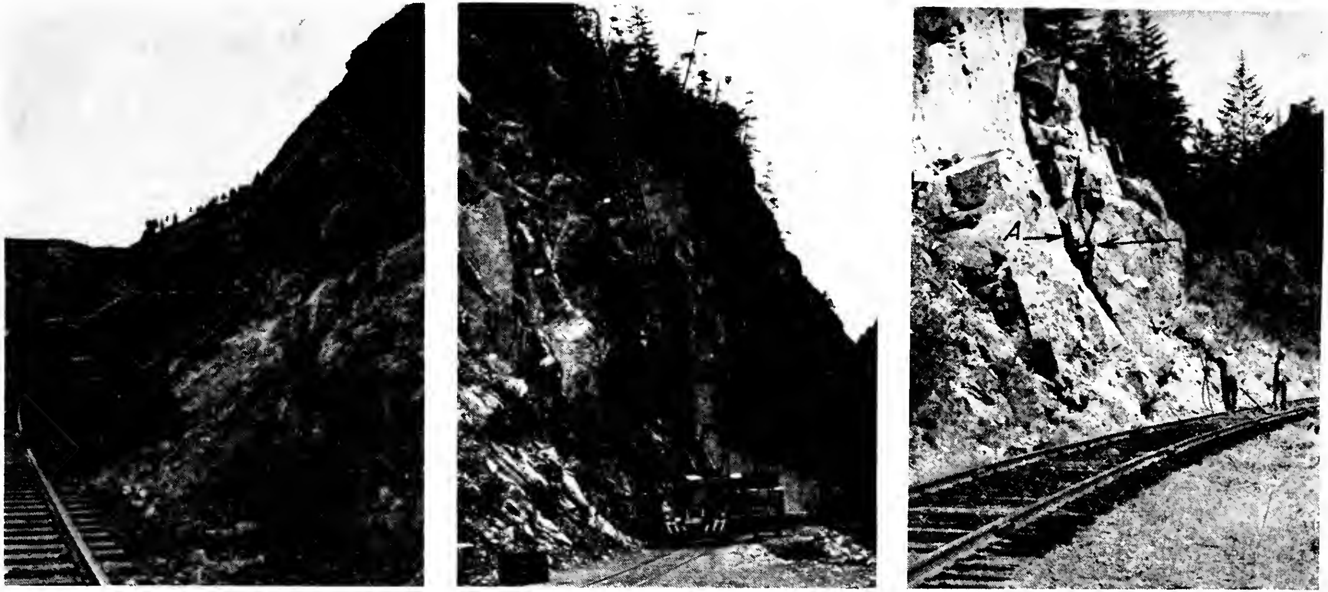
(a) Borehole camera.
(b) Borehole periscope.
(c) Large diameter triaxial cell.
(d) Large direct shear box.

METHOD	COMMENTS
(a) EXCAVATION	
(i) Scaling See Fig. 6(a) (b)	Most applicable to rock faces with infrequent random oriented geologic discontinuities. Generally required at least once every two years in areas of extreme climatic conditions (Rain, snow, numerous freeze-thaw cycles). A geologic appraisal can successfully locate most rocks that should be scaled. Normally not recommended where much of the rock joints dip out of the slope or where very blocky rock exists. Performed by hand from ropes or booms. Use explosives with care as vibration may loosen other rocks. Develop hydraulic scaling tools. A basic stabilization technique.
(ii) Trimming See Fig. 6(c)	Rock promontories or larger blocks may require removal. Usually by drilling and blasting. Use parallel drill holes wherever possible and drill parallel to required face line.
(iii) Slope Flattening	Where excessive rock falls occur or where the joints or bedding dips out of slope the slope can be flattened. A uniform slope may be used or the cut can be benched. The bench should be wide enough to clean out since falling rock from above may bounce from a debris filled bench onto the track. The same procedure can be used for gravel, till and boulder slopes.
(b) DRAINAGE	
(i) Runoff Diversion See Fig. 7(c)	Where water runs over the face of the slope attempts should be made to intercept and divert the water behind the crest. Ditches may require lining.
(ii) Slope Drainage See Fig. 7 (a) (b)	The most common method is to drill horizontal drain holes into the slope on 10 to 25 ft. centers to distances of at least 20 ft. and not more than 0.25 times the slope height. If the holes collapse perforated plastic pipe should be installed. If ice glaciers develop the drains must be insulated or heated with heating cables. A track mounted percussion unit could be designed for rapid installation. The drains are particularly effective in soft rock. A basic stabilization technique.
(iii) Ice Glacier Reduction	Some of the slope face seepage which freezes can usually be intercepted in the slope with horizontal drain holes. They may require a steep inclination or installation under the track. The concept is to lower the water level in the slope. At bad locations electric or propane radiant heaters installed on poles and directed at the glacier area could control the freezing.

Figure 5—Summary of stabilization procedures for rock slopes.

METHOD	COMMENTS
(c) SURFACE STABILIZATION	
(i) Shotcrete See Fig. 8	Sprayed on concrete to minimize further slope face deterioration and to seal exposed joints. Particularly applicable to blocky slopes. Surface must be cleaned and wetted prior to application. Thickness of 1½-2 inches normally adequate. Not necessary to cover massive faces - only 8-10 inches beyond joints. Frequent drain openings must be left so water pressure does not build up. Can use pipes or leave occasional joints unshotcreted. A basic stabilization technique.
(ii) Shotcrete plus wire mesh	Where the rock is very blocky and the blocks are small the shotcrete may require reinforcement. Wire mesh can be pegged to the face and shotcreted over. The wire mesh size depends on rock conditions and slope height.
(iii) Dry rock walls on slope.	Where shallow rock or soil slopes are ravelling a dry rock wall face can provide support and will be free draining. The base rocks must be on a firm foundation.
(d) SUPPORT SYSTEMS	
(i) Buttresses See Fig. 9 (a) (b)	Used to support large volumes of rock which would otherwise have to be excavated or where key rocks retain large volumes above. Ensure the buttress is designed to take the line of thrust. May require reinforcing or anchor grouting to the rock mass. Can be built up with shotcrete. For smaller volumes may consist of dry rock packing.
(ii) Rock Bolts and Cables See Fig. 9 (d)	Used to tie key rocks which if removed would undermine support for other rocks. For smaller blocks use bolts for large blocks, consider cables. To develop maximum stability they should be tensioned and then grouted full length. This increases shear strength of the joint, prevents stress relaxation, and minimizes corrosion. Rock bolt installations should be properly designed to develop a computed load. Special bolt head design may be necessary in soft rock. May be used in conjunction with shotcrete. A basic stabilization technique.
(iii) Rock Dowells	Dowells comprising reinforcing steel or scrap rail can be grouted into drill holes located at the toe of rock blocks to prevent them from sliding. The size, depth and spacing of the dowells depends on the rock block size and slope angle of the joint.
(iv) Anchor Beams and Walls	Anchored beams can be used to support larger areas of rock face. May be used in conjunction with shotcrete and wire mesh. Usually very expensive.
(v) Bolted Wire Mesh See Fig. 9 (c)	May be used where large areas of a rock face contains blocky jointed rock. Use corrosion-resistant mesh. Mesh size depends on rock size and bolt spacing.

Figure 5 (continued)

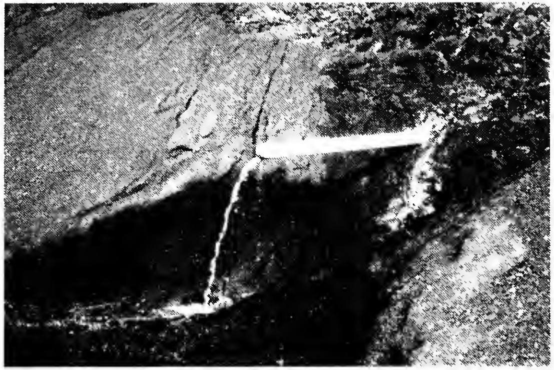


(a) Scaling a weathered rock slope from the bucket of a rubber tired loader. This unit can also clean and deepen the inner ditches.

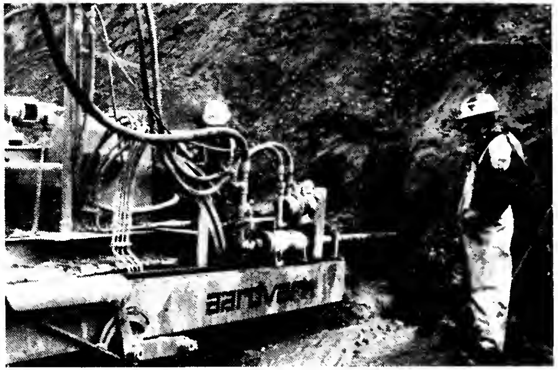
(b) Scaling a very high slope from a platform held by a long crane

(c) Preparing to trim an unstable rock block (A) which contains sufficient volume to cover the track. With the steeply dipping joint potential failure is obvious.

Figure 6 - Scaling and Trimming rock faces to improve stability.



(a)



(b)

(c)

Figure 7 - Drainage Control.

(a) Horizontal drain installation which is very effective in lowering water pressures in rock slopes to increase stability.

(b) Horizontal drain installation in progress.

(c) Control of surface runoff on slopes should be incorporated in all slope design. In this example, slope erosion and ditch plugging is excessive.

(a)

(b)

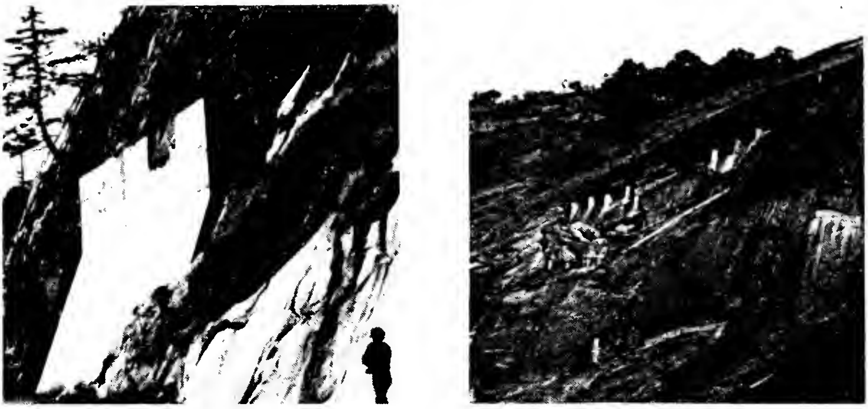
(c)

Figure 8 - Shotcrete surface treatment to stabilize blocky rock slopes.

(a) Shotcrete mixing machine.

(b) Shotcrete being applied to stabilize tunnel walls.

(c) Stabilized rock slope above a tunnel.



(a) Concrete buttress placed to support massive rock slab above the road bed.

(b) Anchored reinforced concrete buttresses placed to support foliated granite rock high up on a slope.

(c) Anchor bolts with wire mesh to positively control rockfall.

(d) Anchor bolt used to stabilize rock block. All bolts should be tensioned and grouted.

Figure 9 - Support Systems.

METHOD	COMMENTS
(a) SLIDE SHEDS See Fig. 11(a) (b)	Where slide runs or avalanche runs are well defined and slides occur frequently protection sheds can be constructed to carry the debris over the top of the track. Sheds may be timber or concrete. Steep roofs are recommended. Slide sheds may be required at tunnel portals if the rock face is high. Wing walls may be necessary.
(b) TUNNELS See Fig. 11 (b)	Where rock slopes are very irregular, steep and/or dangerous, tunnels offer safe conditions. Lining may be required in faulted or adversely jointed rock. Special drainage procedures may be required if wet conditions are encountered particularly during winter when freezing results in glaciers or large icicles. Special attention must be given to safety at the tunnel portal since accidents in tunnels would be extremely serious.
(c) RELOCATION	Where slide conditions are severe the alternative of moving the rail line should be considered. In particularly severe conditions relocating into a tunnel may be justified.
(d) BRIDGES	Where debris, slide or avalanche tracks cross the railway at an elevation near track level, it may be worth considering to excavate a slide channel well below track level and to bridge the channel.
(e) SLOPE TREATMENT	
(i) Catch Berms	Ditches or benches can be excavated along the base of rock cliffs or part way up talus, fill or soil slopes to intercept rolling rock.
(ii) Wire Mesh Blankets See Fig. 11(c)	Laying wire mesh over a slope which is ravelling will control surface movement. The mesh should be tied to trees or anchored above the slope and pegged periodically down the slope.
(f) DITCH TREATMENT	
(i) Deeper Ditches See Fig. 12	Wide, deep ditches will catch many rocks that roll or fall from above. Ditch design is surprisingly critical. (Ritchie, 1963). To be effective the ditch depth and width, where possible, should be determined by the slope angle and slope height above, the volume of potential rocks and whether the rocks will roll or bounce. Falls from irregular faced slopes are particularly dangerous since they may bounce in one of several directions. Ditch bottoms should be sand or gravel or soil covered
(ii) Catch Walls See Fig. 13 (b)(c)(d)(e)	Catch walls are effective when located on the inner side of the track on the track side of the ditch. They should have a vertical face so that rocks which hit the face will drop back into the ditch. Concrete walls are rigid and may be damaged by large rocks. Gabion walls are much less expensive and more flexible. Wire catch fences can be constructed on top of these walls to catch small rock.
(iii) Catch Fences See Fig. 13(a)	Catch fences can be installed along the inner ditch to catch rolling rock. The fence may be wire mesh or metal guard rail which are effective for small rock or scrap rail welded horizontally which is effective for larger rock. Fences can be expected to be costly to maintain.
(iv) Debris Fences	In creeks and gullies that periodically may carry debris, logs, brush, etc., debris fences or trash racks constructed with steel rails placed across the creek or gully are recommended Scrap railway railing can be used.
(g) Slide Track Diversion	At some locations where slide channels or avalanche channels exist and if room is available adjacent to the channel a deep diversion channel to direct the slide away from the track may be practical.

SUMMARY OF PROTECTION PROCEDURES - FIGURE 10

(a)

(b)

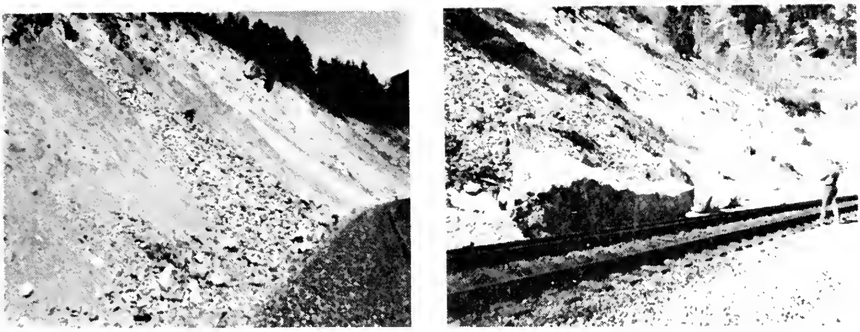
(c)

Figure 11 - Protection Systems.

(a) Wooden and concrete rock slide sheds utilized to carry frequent rockfalls over the track.

(b) Tunnel and rock shed construction to bypass unstable area.

(c) Wire mesh draped over ravelling rock slope .prevents rockfall into grade. Periodic ditch maintenance required.



(a) (b)

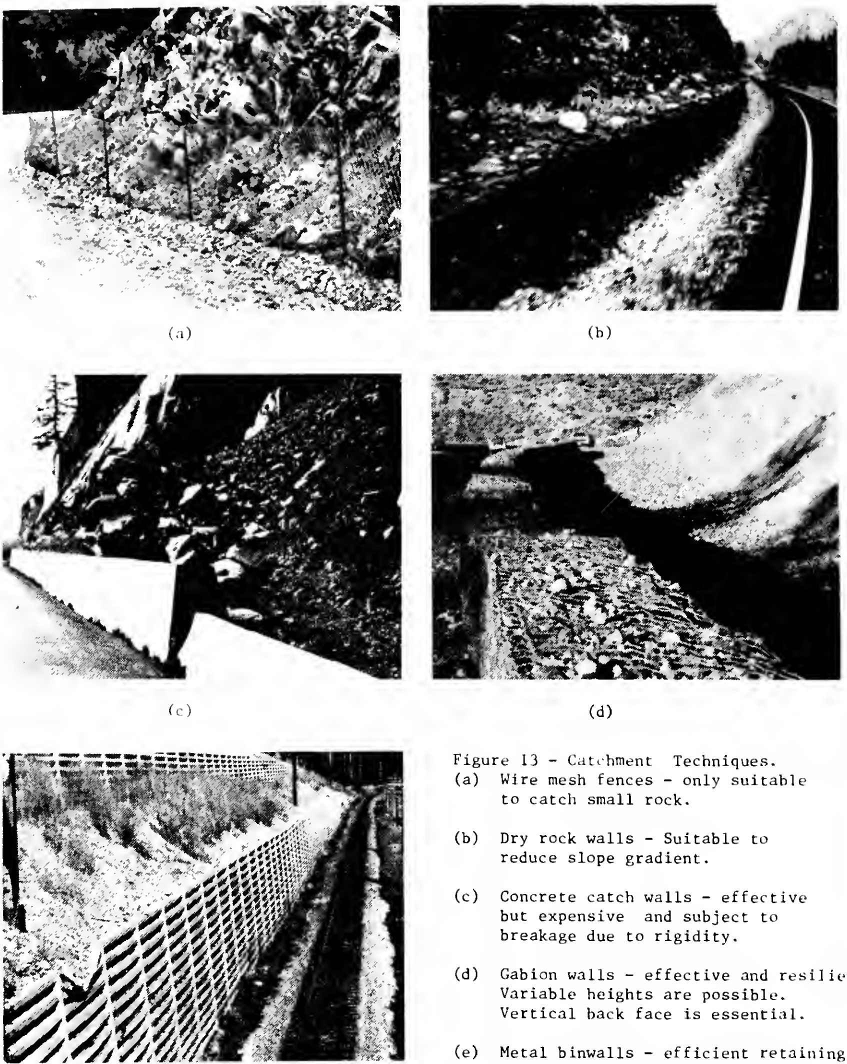
(c)

Figure 12 - Ditch Catchment Control. One of the most underated rockfall control techniques is the use of deep catchment ditches. Where possible ditches should be wide enough for equipment to clean out.

(a) Ravelling slope containing large boulders which can be caught with adequate ditch.

(b) Large rock (20 cu. yds.) caught by shallow ditch.

(c) Highway catch ditch developed to catch erosion wash and rockfall.



(a)

(b)

(c)

(d)

(e)

Figure 13 - Catchment Techniques.

(a) Wire mesh fences - only suitable to catch small rock.

(b) Dry rock walls - Suitable to reduce slope gradient.

(c) Concrete catch walls - effective but expensive and subject to breakage due to rigidity.

(d) Gabion walls - effective and resilient Variable heights are possible. Vertical back face is essential.

(e) Metal binwalls - efficient retaining structures, adjust to foundation conditions.

METHOD	COMMENTS
(a) Visual Inspection	Periodic inspection of rock faces and slopes will frequently indicate locations of potential slide conditions. The most important features are adversely dipping weaknesses in the rock on which falls will slip and the presence of water pressure often indicated by seepage.
(b) Air Photo Interpretation	Large scale features relating to slides and avalanches often indicate potentially unstable conditions developing. Air photographs are of limited use in rock fall assessment due to scale limitations.
(c) Review of Records	Records should be kept of all rock fall occurrences, slides and avalanches. Annual review of this data will pinpoint areas where more frequent falls, etc. occur.
(d) Track Patrols	In some hazardous areas, during very adverse climatic conditions or during spring melt periods track patrols prior to train movement have been used.
(e) Instrumentation	The major stability concern on the railway is the occurrence and potential of rock falls. Usually the volumes are less than 10 cu. yds. Warning instrumentation used on rock slope stability programs in mining are generally not applicable due to the high cost of the great number of installations that would be required. The most practical program is to observe movement across cracks. (a) Driving wooden plugs and observing plug behaviour. (b) Painting across cracks and observe paint. (c) Put plaster in cracks and observe plaster.
(f) Electric Warning Fences. See Fig. 15	The most common warning system used in Canada. Fences are of two general types - tension trip and broken wire trip. When rock or other falls or debris fall and hit the fence the block signals are automatically changed. For maximum statistical warning coverage, electric fences should be connected also to the dispatchers office. For consideration, suggest also that a radio signal be activated from the area of the fence to be picked up in all train cabs when they come within 3-5 miles. The greatest application for fences if for very high slopes where the cost of stabilization would be extreme. Slopes less than about 100 feet high can generally have the surface stabilized for less cost than installing and maintaining a fence. Snow and ice cause severe maintenance problems in winter. It is suggested for consideration that heating cable be tried as the fence wire. There are some areas where surface stabilization could be sufficiently successful to allow removal of the warning fence. It should be resolved whether this could psychologically be done.
(g) Vibration Meter Installations	Experimental at this stage. A test installation is being monitored.

FIGURE 14 - SUMMARY OF WARNING METHODS

Figure 15—Electric warning fence below high, steep rock slope which is connected into track signal system.

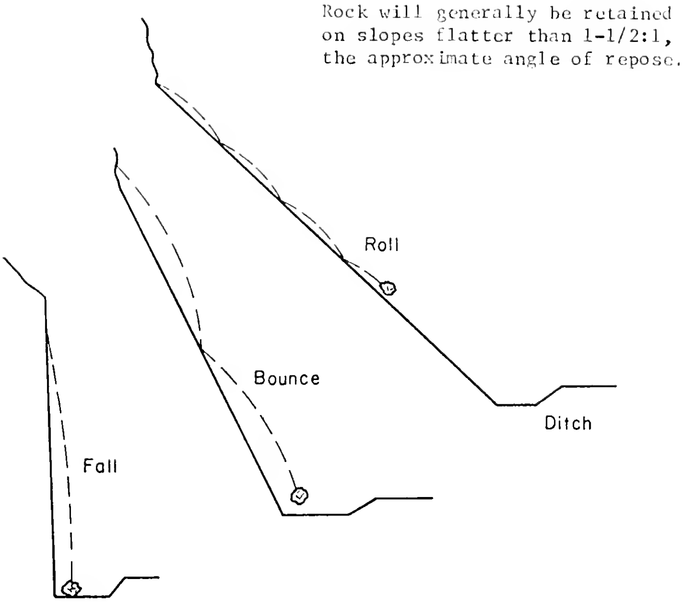
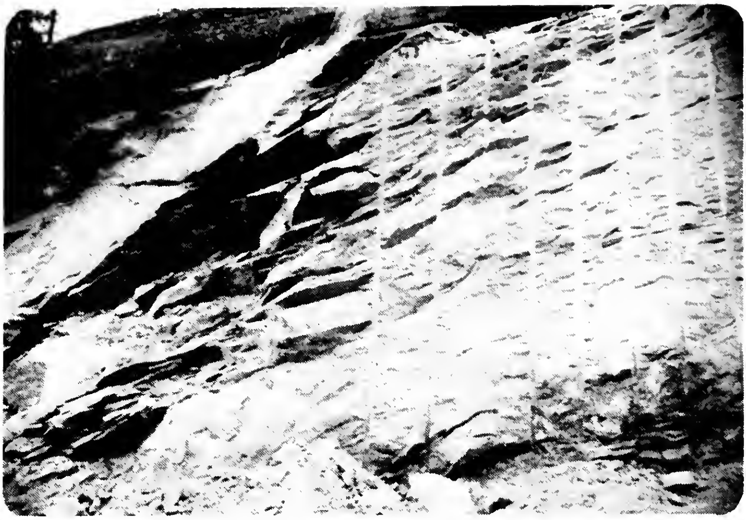
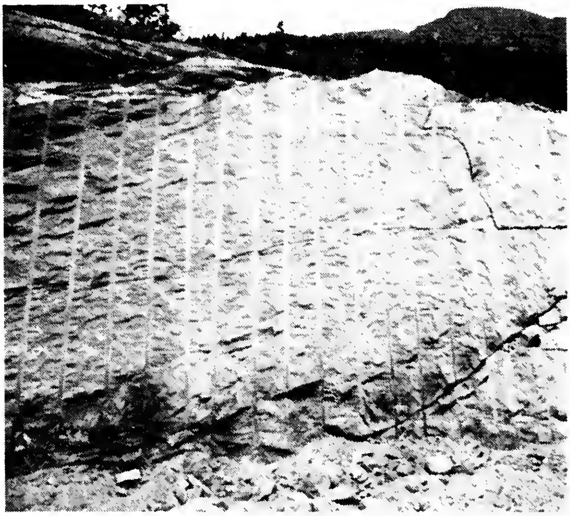


Figure 16 - Provided the rock strength and geologic structure is favourable and controlled blasting is used, vertical slopes should be considered. This will reduce quantities to allow a wider ditch and reduce maintenance. Ditches should be wide and deep enough to act as a catchment.



(a) Comparison of rock slope using uncontrolled and controlled blasting.



(b) Rock slope developed using preshear blasting. Close control over drill hole alignment is necessary.

Figure 17 - Controlled blasting to develop uniform slopes in competent granite.

Figure 18 - DETAILED APPRAISAL STABILITY ASSESSMENT

STABILITY ASSESSMENT

PRIORITY RATING A

Region Pacific Subdivision Cascade Date Apr. 10/75

Mileage 24.9 Train Traffic Very Heavy

Alignment slight curve Sight Visibility 400 ft. West; 800 ft. East

Average Climatic Conditions High winter snowfall, hot dry summers

Past Stability Record Several local blocks

DESCRIPTION OF SITE

NOTES

Cut ☒ Fill ☐ Other ☐

Height 50 ft. Length

Rock ☒ Soil ☐ Other ☐

Geologic Description Blocky faulted granite - 3 major faults. Random joints.

Evidence of Water Slight seepage

Work Space Available Limited

DESCRIPTION OF POTENTIAL INSTABILITY - (TYPE, MAGNITUDE, SERIOUSNESS)

Very large block could fail at east tunnel portal. Also - second block 60 ft. east of portal.

Tunnel has thin roof - some rockfalls will cause daylight

DETAILS OF RECOMMENDED STABILIZATION

Put in 8 - 1-1/4" dowels at lower edge of rock - shotcrete fault around dowels -
4 - 1-1/4" dowels at second block.
Shotcrete entire tunnel roof and side and tunnel portal

PHOTOGRAPH OF SITE

TABLE 1

TABLE OF PRIORITY RATINGS

A - Moderate probability of failure of sufficent volume to result in derailment if failure undetected.

B - Some probability of failure of sufficient volume to result in derailment if failure undetected.

C - Moderate probability of failure of small volumes which might reach the track.

D - Moderate probability of localized rocks or rockfalls occurring during extreme climatic conditions - Very heavy rainfall or runoff, extreme freeze-thaw cycles, etc.

E - Slight possibility of localized failures under extreme climatic conditions. Generally shallow cuts.

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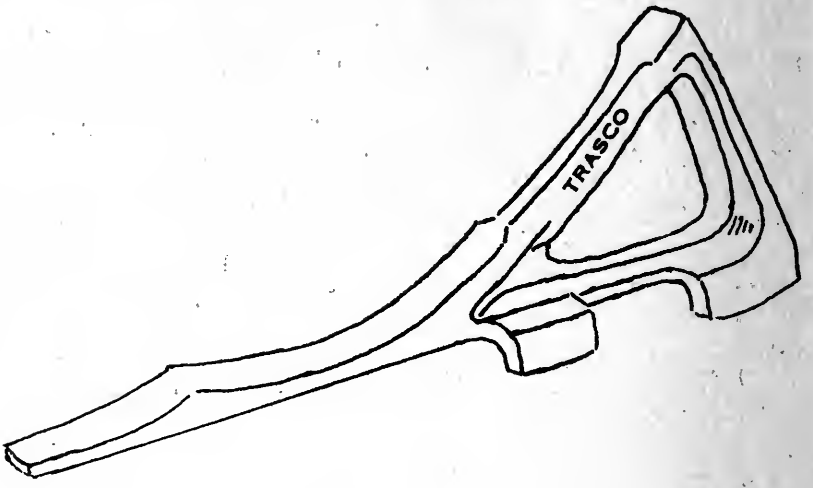
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TECHNICAL CONFERENCE REPORT ISSUE

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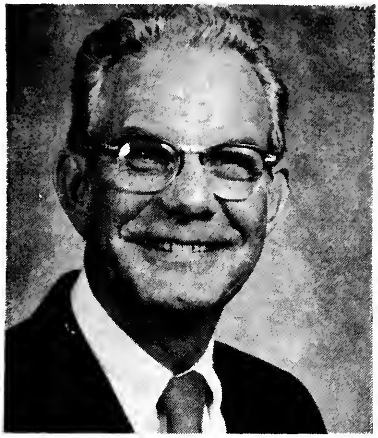

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MARCH 22–24, 1976
Palmer House, Chicago

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Invocation—Dr. Kenneth Hildebrand, Pastor Emeritus, Central Church of Chicago

Recognition of speakers table guests

Presidential Address—John T. Ward, Senior Assistant Chief Engineer, Seaboard Coast Line Railroad

Report of Treasurer—Arthur B. Hillman, Jr., Chief Engineer, Belt Railway of Chicago

Report of Executive Director—Earl W. Hodgkins, AREA

Greetings from Railway Engineering-Maintenance Suppliers Association—Harry D. Campbell, President

Description of Architectural Competition Sponsored by AREA Committee 6—Buildings (Illustrated) and Presentation of Award to Student Winner—D. A. Bessey, Architect, Chicago, Milwaukee, St. Paul & Pacific Railroad
Description of Winning Entry by Student Winner

Maintaining Track for High-Speed Trains—Harold Jenkins, Permanent Way Engineer, British Rail

Engineering Division Session—Red Lacquer Room—1:30 pm

Recognition of speakers table guests

Remarks by Chairman John T. Ward

Remarks by R. R. Manion, Vice President, Operations and Maintenance Department, AAR

Remarks by Dr. W. J. Harris, Jr., Vice President, Research and Test Department, AAR

Address by D. C. Hastings, Chairman, AAR Operating-Transportation Division; Executive Vice President, Seaboard Coast Line Railroad

Up Date on IFAST at Pueblo, Colorado (Illustrated)—Dr. G. C. Martin, Director of Dynamics Research, AAR, and Dr. R. M. McCafferty, Program Manager, Improved Track Performance Research, Federal Railroad Administration

Ballast and Foundation Materials Research Program (Illustrated) (Committee 1—Roadway and Ballast)—Dr. G. C. Martin, AAR, and Dr. M. R. Thompson, Professor of Civil Engineering, University of Illinois

Developments in Timber Ties (Illustrated) (Committee 3—Ties and Wood Preservation)—H. M. Williamson, Consulting Engineer; Retired Chief Engineer, System, Southern Pacific Transportation Company

REMSA RECEPTION—Grand Ballroom—6:30 pm–8:00 pm

TUESDAY, MARCH 23

Technical Session—Red Lacquer Room—8:30 am

Computer Analysis of Hot Box Detector Signals (Illustrated)—Walter Friesen, Senior Design Engineer—Signals, Canadian National Railways

The Quiet One—Noise Abatement Dealing with Retarders in the New Northtown Yard (Illustrated) (Committee 13—Environmental Engineering)—M. B. Walker, Assistant Director—Signal Engineering, Burlington Northern, Inc.

Fatigue Study of New Westminster Bridge (Illustrated) (Committee 15—Steel Structures)—Dr. J. W. Fisher, Professor of Civil Engineering, Fritz Engineering Laboratory, Lehigh University, and R. A. P. Sweeney, Structural Engineer, Canadian National Railways

Solving a Difficult Foundation Problem (Illustrated) (Committee 8—Concrete Structures and Foundations)—Dr. W. L. Gamble and Dr. M. T. Davisson, Professors of Civil Engineering, University of Illinois

ANNUAL LUNCHEON—GRAND BALLROOM—12:00 NOON

Presentation of guests at speakers table

Presentation of newly elected officers

Address by W. T. Rice, Chairman of the Board, Seaboard Coast Line Railroad

Technical Session—Red Lacquer Room—2:00 pm

Motion Picture on Northern Alberta Railways

Snow Control by Model Analysis (Illustrated)—F. H. Theakston, Partner, Morrison, Hershfield, Theakston and Rowan

Laminated Wood Materials for Bridge Decking (Illustrated) (Committee 7—Timber Structures)—T. E. Brassell, Director of Technical Services, American Institute of Timber Construction

Precast Concrete (Illustrated) (Committee 8—Concrete Structures and Foundations) —J. G. White, Vice President and General Manager, Con–Force Costain Concrete Tie Co. Ltd.

Data Bases: Help or Harassment for Engineering Management (Committee 32—Systems Engineering)—C. F. Wiza, Manager—Methods and Planning, Illinois Central Gulf Railroad

WEDNESDAY, MARCH 24

Technical Session—Red Lacquer Room—8:30 am

Rail Flow and Corrugation Studies (Illustrated) (Committee 4—Rail)—Dr. Joseph Kalousek, Research Engineer, Canadian Pacific Rail, and F. E. King, Senior Technical Advisor, Canadian National Railways

High-Strength Chrome Molybdenum Rail Steel (Illustrated)—Y. E. Smith, Research Supervisor, Climax Molybdenum Company of Michigan

Innovations in Frog and Switch Design (Illustrated) (Committee 5—Track)—E. H. Taylor, Supervisor of Track Development, Canadian Pacific Rail

C&NW's BUC (Ballast Undercutter Cleaner) (Illustrated) (Committee 27—Maintenance of Way Work Equipment)—R. W. Bailey, Director of Maintenance Planning, Chicago & North Western Transportation Company

Installation of Officers

Adjournment

Nominating Committee, 1976 Election

Past Presidents

E. Q. Johnson, *Chairman*
Senior Assistant Chief Engineer, Chessie System

A. L. Sams
Vice President, DeLeuw, Cather & Company

R. M. Brown
Chief Engineer, Union Pacific Railroad

D. V. Sartore
Chief Engineer—Design, Burlington Northern, Inc.

R. F. Bush
Chief Engineer—Special Projects, Consolidated Rail Corporation

Elected Members

J. E. Sunderland (East)
Director Engineering Programs, Chessie System

D. S. Bechly (South)
Engineer—Structures, Illinois Central Gulf Railroad

L. C. Collister (West)
Manager Tie & Timber Department, Atchison, Topeka & Santa Fe Railway

Bernard Fast (Canada)
Assistant Regional Engineer, Canadian Pacific Rail

C. L. Gatton (At Large)
Assistant Chief Engineer—Maintenance of Way, Louisville & Nashville Railroad

Committee of Tellers, 1976 Election

The following committee was appointed to canvass the ballots for Officers and Directors and for Members of the Nominating Committee, the count being made on February 20, 1976.

W. S. Stokely, *Chairman*
N. E. Whitney, Jr., *Vice Chairman*
L. R. Beattie
J. E. Beran
D. E. Buchko
J. Budzileni
W. F. Burt
J. L. Hodson
C. H. Hogue
R. W. Janssen
D. C. Knuth
C. R. Lund
G. W. Mahn, Jr.
W. B. Stanczyk
P. H. Swanson
R. Urbano
R. A. Vollrath
R. L. Williams
D. R. York

Successful Candidates in 1976 Election

FOR PRESIDENT

John Fox, Chief Engineer, Canadian Pacific Rail, Montreal, Que.

FOR SENIOR VICE PRESIDENT*

B. J. Worley, Vice President—Chief Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago

FOR JUNIOR VICE PRESIDENT

W. S. Autrey, Chief Engineer System, Atchison, Topeka & Santa Fe Railway, Chicago

FOR DIRECTORS

East:

J. W. Brent, Chief Engineer, Chessie System, Cleveland, Ohio

South:

L. F. Currier, Engineer—Structures, Louisville & Nashville Railroad, Louisville, Ky.

West:

T. L. Fuller, Engineer of Bridges, Southern Pacific Transportation Company, San Francisco, Calif.

J. A. Barnes, Assistant Vice President & Chief Engineer, Chicago & North Western Transportation Company, Chicago

FOR MEMBERS OF 1976 NOMINATING COMMITTEE

East:

J. J. Ridgeway, Director—Engineering Services, Bessemer & Lake Erie Railroad, Greenville, Pa.

South:

C. E. Webb, Assistant Vice President—Engineering & Research, Southern Railway, Washington, D. C.

West:

R. E. Frame, District Engineer, Southern Pacific Transportation Company, San Francisco, Calif.

Canada:

A. E. Speers, Regional Engineer Administration, Canadian National Railways, Toronto, Ont.

At Large:

R. E. Haacke, District Engineer, Union Pacific Railroad, Portland, Ore.

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* Under the provisions of the AREA Constitution, B. J. Worley advances automatically from Junior Vice President to Senior Vice President.

PRESIDENT'S ADDRESS

Address by President John T. Ward*

Welcome to the 75th Annual Technical Conference of the American Railway Engineering Association. This welcome is directed to all members and guests of the Association, but I wish to add a special or particular welcome to the ladies who are gathered near the front of the meeting room. It is always a pleasure to have you attend this opening session, and I trust you will remain for as much of the program as you desire.

Somewhere along the way, I heard the story of an elderly black preacher who expounded Sunday after Sunday on the "Status Quo." This went on for some time, when finally one of his parishioners got up nerve enough to ask him, "What is dis Status Quo?" The pastor's response was, "That's Latin for the mess we's in."

This is said to point up the fact that the rail industry, with which all of us are associated in one way or another, has been in somewhat of a mess during the year just ending. Possibly a better choice of words would be unstable or unsettled. Regardless of which descriptive word is used for the state of the industry, it has been a rather trying year for the group seated in this room today.

The year began with less rail traffic, resulting in reduced revenues. This caused a chain reaction towards lesser maintenance appropriations and restrictions on travel for most railroad employees, and particularly for maintenance employees, with the result that AREA has, likewise, felt the brunt of all of this in its activities.

Additionally, the Association's executive director, Earl W. Hodgkins, was away from the office for approximately four months as a result of bypass heart surgery. This slowed down somewhat the activities of AREA, although the yeoman job done by Don Fredley and Norris Engman, as well as others on the staff, plus the support of the Board of Direction, allowed the work to be accomplished as necessary. The special thanks of the Association are expressed to Don and Norry for their very able assistance while Earl was unavailable. It must be reported, however, that Earl continued to undertake considerable work of your Association at home while recuperating, including the many details of this Technical Conference which fall within his bailiwick.

What has been accomplished during the year? Your Association had a very excellent Technical Conference last March here at the Palmer House, headed up by immediate Past President Bob Bush. The program was excellent, as evidenced by the large attendance at each of the presentations. Very able assistance was offered by many members of AREA in suggesting track components and configurations which might be incorporated in the accelerated service testing loop under construction by the Federal Railroad Administration at Pueblo, Colo. This facility is scheduled to be in service by mid-year. In October, there was the annual Regional Meeting in Vancouver, B. C., attended by approximately 225 members and guests. The program for this latter meeting was developed by Vice President John Fox, and it was a good one. In between the Technical Conference and Regional Meeting, as well as before and after, the work of the 19 standing committees and one special committee of your Association was progressed—some quite actively, while certain other committees reacted in just a mediocre manner.

It is this latter phase of the work of AREA to which it is desirable that I address myself at the moment. The objectives of your Association are advanced

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* Senior Assistant Chief Engineer, Seaboard Coast Line Railroad, Jacksonville, Fla.

through the work of its committees in two ways, and these certainly are the heart and soul of the organization. First, the development of information pertinent to their assignments which may be presented to the membership as a whole "as information" and, secondly, the formulation of recommended practices to be submitted for adoption and publication in the Manual for Railway Engineering or Portfolio of Trackwork Plans.

It is, therefore, of the utmost importance that the work of AREA committees be pursued with vigor and dispatch in order that the aforementioned results will be completely fulfilled. There are many ways this may be accomplished. Membership attendance at all committee meetings is, of course, highly desirable, but in this day of suppressed travel, because of decline in revenues, may not be entirely possible. It is important, however, that the membership be selective in the meetings attended and certainly be cognizant of the ongoing activity of committee work by fully reading all correspondence, participating in same to the extent necessary to progress a given assignment, and, particularly, to respond to all questionnaires submitted by committees.

Additionally, all committee chairmen have been urged to recommend only those assignments which can be pursued to an early conclusion, to set completion schedules on authorized assignments and to check with subcommittee chairmen from time to time to insure that each assignment is being progressed accordingly. Only in this manner can the desired results of committee activity be accomplished.

The AREA Board of Direction and, particularly its Committee on Technical Activity, chairmanned by Director Mike Rougas, has urged each of the committees to progress their work accordingly. As stated above, I am happy to report that many have reacted favorably in this regard, but there are some whose work leaves something to be desired. It is in this latter area that improvement must be accomplished. This of course, is no different from any other organization, wherein it appears difficult always to obtain a full 100% participation.

Your Association's membership has continued to increase during the year under the leadership of the Committee on Membership, chairmanned by Director Doc Pember. AREA is also financially stable. Further detailed reports in this regard will follow from the Executive Director, Earl Hodgkins, and Treasurer Art Hillman. A number of the new members are consultants and others are from the supply industry. We need to concentrate our efforts in interesting some of our associates in the rail industry in membership in AREA, and particularly any new engineers who may be working with us. The expertise of these rail employees is very vitally needed in the work of your Association.

This year, there have been a number of requests for purchase of AREA Manuals for Railway Engineering and Portfolios of Trackwork Plans. These requests have come principally from consultants and foreign countries, but it bears out the fact your Association is well-thought-of worldwide. These sales have, of course, aided the financial condition of the organization. Additionally, in this day of rising costs, your Board of Direction found it necessary to increase the cost of registration at this Technical Conference to $10. Checking bills against receipts for these fine facilities at the Palmer House for the past couple of years, it was determined that your Association was running in the red in this item of the budget, and the increase in registration cost was, therefore, inevitable. These are just two areas of finance which I elected to lift up and comment on at this time. There are others, of course, and these are being watched very carefully on a continuing basis by the Committee on Finance, headed by Past President Bob Bush.

During this past year, a Manual chapter was assigned to the Committee on Electrical Energy Utilization. This group has been designated as Committee 33. This is particularly important in light of present-day activity in electrification.

This is just a thumb-nail sketch of some of the activities of your Association during the year just closing. My personal thanks are expressed to Earl Hodgkins, Don Fredley and Norry Engman for their able assistance in all phases of the work this year. A particular note of appreciation is directed to the entire Board of Direction who traveled many miles upon call for meetings, both regular and special, in order to participate in and further the ongoing work of AREA. Without such support, the desired results could certainly not have been obtained.

Certainly, the Conference Operating Committee, headed by Bruce Miller, and who was ably assisted by many, must be praised for the excellent arrangements in respect to these meetings. It must be realized there are many hours spent behind the scenes by this fine committee, and the smoothness of the operations simply does not come into being without such dedication.

The Association expresses appreciation for the cooperation during the year of its many friends in the supply industry and for their help in advancing the cause of the rail industry, as a whole, and AREA. It is through such associations that our jobs are made easier. Thank you, also, for your excellent attendance at this Technical Conference.

It would be an error in judgment to close without saluting the nation on its 200th birthday. I am particularly pleased to be a part of it and it is always thrilling to hear and/or see the action in respect to the bicentennial celebration on radio, television, the beautiful presentation at Disney World, and the like. These will continue throughout the year and will certainly add to the efforts of all in the celebration.

Business boomed during the mid-18th century war with France. American merchants traded freely with the enemy at the same time they supplied the British army. At the close of the war, however, there followed a traditional postwar letdown and this was America's first depression. This was a shock to Americans, and they really never got over it, even when prosperity returned.

There were many causes for the American Revolution 200 years ago. The most important, however, was the threat to the dream of an economically comfortable life which had brought most Americans to these shores initially, along with the desire to be independent and free from oppression.

Does this not strike a parallel with conditions as they exist today? As stated in my opening remarks, the year just closing has been a rather trying one. Possibly it was not a depression, as such, but it was bordering close thereon for whatever it may be called. The economy, however, is now on the way up and, hopefully, it will continue. This will make the job easier for all of us. As was noted in the January issue of *Railway Tracks and Structures,* "The next ten years are going to be the most exciting period ever experienced by maintenance of way men everywhere in the United States." Let's get going.

Thank you for the honor I have had this year in serving as President of AREA. It has been a pleasure, and certainly has been a high point in my career in the rail transportation field.

SPECIAL FEATURES

Description of Architectural Competition Sponsored by AREA Committee 6—Buildings

77–658–1

By D. A. BESSEY
Architect
Chicago, Milwaukee, St. Paul & Pacific Railroad

Article I, Sections 1 and 2, of the American Railway Engineering Association Constitution reads as follows:

> "The name of this Association shall be the American Railway Engineering Association. The objective of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of Railways."

I am assuming that the purpose of the Association, therefore, is to assist the engineers, architects and all other people involved in the engineering aspect ot our industry. So—it appears this is our purpose for being here. This very definitely justifies our existence.

Now, we of Committee 6, with a membership comprised of architects and engineers directly engaged in the design, construction and maintenance of our buildings, have, over a number of years, discussed a problem that not only seems unique to us, but possibly is unique to all engineering staffs on the American railroads. And that is in our particular case, in the staffing of architecture or building departments, we find it is definitely necessary to familiarize the architectural students throughout the U. S. and Canada with railroad architecture and to bring about an awareness of employment opportunity in the railroad industry. We feel that there has been a definite need to improve the communication between the railroad industry and the colleges and universities which offer an architectural program in their curriculum. During the process of attaining a degree in architecture, the architectural student has numerous design classes which involve the solution of problems, and in many cases, the architectural problems are obtained from corporations or associations, and the process of solving the problem is part of the class procedure.

It was with knowledge of this process that the AREA Committee 6 Architectural Competition idea came to life.

In December of 1971 the idea of an Architectural Competition sponsored by AREA was submitted to Committee 6 by W. C. Sturm who is presently chairman of the committee. The proposal was generally accepted by the committee and we pursued it further. We made inquiries of architectural schools throughout the country. We even contacted the American Institute of Architects to get a feel for the proposal. The reaction of universities that were contacted was favorable, so in 1974 a committee was appointed to further pursue the proposed Architectural Competition. At this time the special committee composed a preliminary draft of an Architectural Competition Problem. The Problem that was chosen was the design of a control tower and service building for a railroad classification yard. Committee 6 had just completed a report on elevated yardmasters towers which

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Note: Discussion open until October 15, 1976.

has been submitted for information and will eventually become a part of Chapter 6 and, it seemed like a logical type building to use for this Competition.

I would like to present a short pictorial story of the Architectural Competition project. [The slides presented are not reproduced herein.]

"What does a railroad architect do—design box cars?" I've heard that question for the last 25 years. But now I'm sure that there are hundreds of architectural students throughout the United States and Canada that have a much clearer understanding of railroad architecture.

On March 25, 1975, the Board of Direction of AREA approved the project and allocated the necessary funding to carry out the Architectural Design Competition.

A preliminary draft of the Architectural Competition Problem was sent to 79 colleges and universities in the U. S. and 10 in Canada, for a total of 89 schools of architecture. A total of 26 universities responded positively and indicated that they wished to consider participation in the Competition.

At the June meeting of Committee 6 the final draft of the Architectural Problem was completed by the membership at large. A representative from the membership of Committee 6 was appointed to each school taking part in the Competition. This representative kept in close contact with the college or university and assisted the school's Architectural staff in all matters dealing with the Competition. In many cases, the representative arranged for the students involved in the project to visit railroad installations. At this same meeting a panel of 7 judges, all members of Committee 6, were appointed. Included on the panel were 7 architects with excellent credentials holding registration in 13 States and 1 Province in Canada.

The Competition Problem was typed and copies of the Problem were printed, thanks to the EJ&E Print Shop. Approximately 900 copies of the Competition were mailed out to the 26 universities which indicated an interest in taking part in the Architectural Competition. We only worked with the university and did not work directly with the students in conducting the Competition.

[A list of the participating universities may be found in the report of Committee 6 as published in Bulletin 656, January–February 1976.]

The entries were mailed to my office and I received most of them by January 31. The Competition was judged in Chicago on February 9 and 10. A total of 96 entries was received from 14 schools.

All entries that were received were pre-judged prior to the 9th and 10th of February to determine if there were any great deviations from the rules of the Competition. All entries were numbered and the name of the architectural student was concealed.

The judging took place on February 9 and 10. On the first day of judging, the judges reviewed all the 96 entries and graded them on the basis of 1 to 9. At the close of the day, the judges had narrowed the 96 entries down to 23. As the judges finished grading the entries the tally clerks calculated the scores. On the second day of judging the remaining entries were reduced to 7. From the 7, the 1st place, 2nd place and 5 Honorable Mentions were chosen.

Now I would like to announce the winners of the AREA Committee 6 Architectural Competition. The 5 students receiving Honorable Mention and who will be awarded a $50 prize are as follows: Allen L. Brown—Oklahoma State University;

Glenn Philips—Oklahoma State University; Christopher M. Conley—University of Illinois; Gary Westfall—University of Illinois; and Dennis L. Norton, Georgia Institute of Technology.

The second place winner, who will receive a $250 prize, is Robert Mease—Texas Tech University. It now gives us great pleasure to introduce the architectural student winning 1st place—Don McGee of Texas Tech University.

REMARKS BY DON McGEE, TEXAS TECH UNIVERSITY

Mr. Bessey and members of the American Railway Engineering Association, thank you for the opportunity of representing my school and myself here in Chicago. I consider this award a great honor and asset not only for myself but also for Texas Tech University. The students and faculty are honored that your first and second place awards went to Texas Tech students.

Before I begin the explanation of my design, I thought you might enjoy hearing some general information concerning Texas Tech.

Texas Tech University is located in Lubbock on the South Plains of Texas. Approximately 22,000 students and 5,000 faculty members are accommodated on one of the largest campuses in America which is in excess of 1,800 acres. Students have their choice of studying in six colleges and three schools. There are currently in excess of 800 students enrolled in architecture which is a department of the College of Engineering. The department offers a Bachelor of Architecture degree with options in design, structures, history, and urban design. The department is housed in a modern 12-level facility which is connected with the art department by a sub-level courtyard.

Approximately 70 senior architecture students and four faculty members were involved with the AREA Architectural Competition. I would like to take this time to thank Professor Burran and the senior design faculty and fellow students for their assistance and constructive criticism in the development of my project.

Since I had never been exposed to railroad control towers, service buildings, and classification yards, I had to almost totally rely on the problem statement for all my information. The people responsible for writing the problem statement deserve some special recognition for providing such clear and concise design criteria. This excellent communication was definitely a controlling factor in the result of my work.

After reading and studying the problem statement, my major objectives were to solve the specific problems posed in the program: to design an economically feasible facility that could easily be implemented, and to design an aesthetically pleasing facility that would express its function. The major problems to be solved that I isolated out of the problem statement are:

1. The problem of controlling noise generated from yard operations and that noise generated from within the facility itself.
2. The problem of separating various work areas.
3. The problem of insufficient views from the facility.
4. The problem of coordinating the various functions of the facility in a logical order.
5. The problem of creating an aesthetically pleasing facility.
6. The problem of selecting mechanical and structural systems which could accommodate the various environmental demands of the facility.

The next step was to use the information made available to me and additional research to find the solutions to the isolated problems.

One of my major concerns is to protect employees and highly sensitive equipment from the intense sound generated by the retarders located in the hump yard. This problem is handled in several ways:

1. Lowering a portion of the building below grade.
2. Building berms around the facility to reflect sound waves.
3. By using as few windows as possible and locating only the windows in the control tower facing the tracks. All exterior windows are also double glazed.
4. No doors are allowed to open directly into the yard.
5. All skylights are double glazed.
6. The selections of building materials are chosen for their mass to restrict sound waves. These materials include concrete block, concrete panels, rigid insulation, and river rock.
7. Using spaces seldom used by employees as buffer zones adjacent to the tracks.

The solution to the problem of noise generated from within the facility is to simply concentrate and isolate these noise generators from the rest of the facility. As a result, the shop, mechanical equipment room, and compressor room are actually contained in a separate building and then located next to the locker rooms so that any escaping noise does not disturb sensitive equipment and employees.

It is very important to separate the various facilities and work areas with as few physical elements as possible.

Due to the nature of the surrounding areas, which contain railroad tracks, an interstate highway, and a nearby airport, I felt that there weren't any significant visual attractions to capitalize on. So without any available views, the facility is designed to look inward instead of outwards. An environment has to be created since an appropriate one is not available. As one enters the facility he must pass through some transitional areas. These transitional areas act as buffers between the harsh exterior environment and the "new" environment. The "new" environment is achieved through the use of a large space at a human scale. The space is given an indoor-outdoor relationship by:

1. Using the same materials that are used on the exterior.
2. Introducing vegetation through the use of planters.
3. Placing a large window wall adjacent to the enclosed landscaped courtyard.
4. Introducing natural light through the skylights and from the window wall.

The space not only accommodates many functions, but serves as an interior courtyard which is viewed from other spaces, such as the office area.

The diffierent functions of the facility are located so that they can operate efficiently. The electronic equipment room, electronic storage room, electronic equipment repair area all rely on each other, so they are located accordingly. The office, computer room, and communication room also have complementing functions and are located accordingly. This area is located near to the vertical access to control tower because of their electronic and communication relationship. The control tower location is a result of obtaining the best possible views in order to maintain control over yard operations. The control tower's form also expresses this.

The service corridor in the control tower is designed to keep the service functions (rest room and vertical transportation) to the control room from interfering with its function. All rest rooms and locker rooms are off the interior courtyard for convenience. This courtyard becomes the heart of the facility. It controls all of the traffic to and from the different spaces. The rest rooms and locker rooms are designed for efficiency in flow. The shop, mechanical equipment room, and compressor room are located near each other, not only to concentrate noise, but due to their interdependence on each other through their function and maintenance.

An attempt is made to improve the surrounding environment by creating an aesthetically pleasing facility. The equipment, such as the air reservoir tank and cooling tower, that must be outside are concentrated in one area and screened. This area becomes part of the overall architectural statement. The parking area is not located directly in front of the facility, but located to the side and bermed and landscaped to de-emphasize it. This also keeps the parking facilities from becoming just a sea of concrete and asphalt. All elevations were studied with composition and human scale considerations.

Due to the diverse activities that take place in the facility each activity requires a different environment, for instance, the computer equipment must remain at a constant temperature. This is achieved through the use of a zoned mechanical system. Each zone can be controlled independently of the other zones. Load-bearing walls and open-web steel joists are used to provide spaces with clear spans for flexibility.

Thank you again for this honor. This will certainly be an asset in my career. I hope that I have fulfilled my job of providing you with a functional, economically feasible, and implementable facility.

CONCLUDING REMARKS BY MR. BESSEY

At this time I would like to ask Mr. Ward if he would make the presentation of the 1st place award to Don McGee.

[President Ward presented to Don McGee a placque and a check for $500.]

Thank you, Mr. Ward. Once again I would like to congratulate you, Don McGee, for your first place award and assign you the responsibility of representing the some 800 to 850 students throughout the U. S. and Canada who were involved in this Architectural Competition.

In addition to the placque and certificate that was awarded to Mr. McGee, similar certificates were awarded to Mr. Mease, and the 5 Honorable Mention students. Certificates of Merit will be mailed to each of the 96 students who submitted an entry.

It is our hope to maintain correspondence with not only these universities that entered the Competition, but all universities throughout the U. S. and Canada. This has been an extremely rewarding undertaking and I am pleased to have been a part of it. On behalf of Committee 6 and all those people on the Committee that worked on the Competition and all the students who took part in it, I would certainly like to thank the Association for sponsoring and funding this Competition.

I guess at this point I could thank a lot of people.

I certainly must recognize Wally Sturm in the part he played in this Competition helping to write the program, printing and mailing the Competition to the Universities.

Dick Milbauer arranged for all the awards, placques and certificates.

The Judges—who not only put in a full two days, but spent considerable time preparing for the judging process.

The 15 representatives of Committee 6 who went to the universities, worked with the students and with the professors.

All the rest of the members of Committee 6 who have, for the past three or four years, worked on this project either by contacting universities initially, helping write the program, helping write the judging process and all the other numerous things that had to be done to make this project a great success.

All in all, of the 36 members of Committee 6, approximately 30 were involved in the Competition in one way or the other—as a judge, as a representative, writing the program and making the initial contacts with the universities.

As director of the Competition, I am a past chairman of Committee 6; Wally Sturm is the present chairman of Committee 6; and of the judges, Ken Hornung, past chairman of Committee 6; Bill Humphreys, past chairman of Committee 6; Stan Urban, past chairman of Committee 6, and the only other past chairman, John Hayes, retired architect, Burlington Northern, made some initial contacts with universities. So—past chairmen of Committee 6—don't fade away!

In my conversations with numerous universities over a period of the last year, and especially the last few weeks of the Competition, I received feedback from these schools that not only are they interested in remaining closely affiliated with the railroad industry in the school of Architecture, but other schools on the university campuses are considering re-installing railroad-oriented courses throughout their engineering school. So if this Competition has done anything, it has recreated an interest among the universities throughout the U. S. and Canada to develop and maintain a closer relationship between the civil and structural engineers, mechanical engineers, architectural and all other engineering-based schools with the railroad industry.

The first few lines of our Constitution describe our purpose. But, we cannot carry out the engineering functions of our railroad without the ability to staff our offices with the civil and structural engineers, mechanical and general engineering people and the architects from the campuses from the colleges and universities throughout the U. S. and Canada. I am pleased that this project has opened some doors and has created some interest among the students who will some day become a part of our industry and will some day be a part of this organization—and will help us live up to the first three or four lines of our Constitution.

I am very pleased to have been a part of this project. I am very proud to be a member of Committee 6 and I am very proud to be a member of American Railway Engineering Association.

I think we have taken a giant step forward.

Track Maintenance for High-Speed Trains

77–658–2

By HAROLD H. JENKINS, C.E., M.I.C.E.
Permanent Way Engineer
British Railways Board

In order to understand British Railways' readiness to accept on its main lines high-speed trains, it is necessary to explain very briefly changes that have already taken place in BR's track structure.

Immediately after the war, the railway system was in a relatively poor state of maintenance, with an overall speed limit of 75 mph, due to shortages of material and labor throughout the war period. The methods of maintenance were almost entirely manual. Labor, especially of the right quality, was difficult to obtain, and to hold. Railway track jobs offered heavy work, in all weathers, and relatively low wages, and compared with jobs on offer in the expanding motor trade were unattractive.

BR's track at this time was mainly bull-head rail, 95 lb/yd, on chaired, creosoted softwood sleepers. Its life in the main line was between 17 and 25 years. (Photograph 1) The standard sleeper spacing was 2 ft 6 in. and depth of ballast under sleeper 5 or 6 in. Ballast was mainly limestone. The day-to-day maintenance was carried out by small gangs (5, 6 or 8 men including the Ganger). The manning for daily maintenance was approximately 1 man per track mile. The track renewals were usually carried out in ½-mile or ¾-mile, occasionally 1-mile, lengths. This work was normally carried out on Sundays and preparation and finishing work on weekdays. The relaying gang (18 to 21 men) supplemented on the Sunday by maintenance men carried out this work. In addition there were extra gangs for drain and earth-work maintenance. This system was highly labor intensive.

The first priority was to restore the tracks for 90 mph running. Trials just prior to the war with flat-bottom rails 109 and 113 indicated economies especially in the displacement of the cast iron "chair" and its wooden or steel key.

The need for more ballast under the sleepers was apparent. BR then produced a desired standard of flat-bottom rails on baseplates with "Elastic" or "McBeth" spikes and increased required ballast depth below sleeper bottom to 8 in., with shoulders 12 in. wide from sleeper ends. (Also shown in Photograph 1)

The scarcity of timber during the war period encouraged the development of concrete sleepers. The earliest type, known as a "pot" sleeper, consisted of two concrete blocks, one under each rail, and connected by steel angle tie-bars to hold gauge. Cast iron chairs (baseplates) for bull-head rail were fixed by bolts set into the concrete. Although the concrete blocks did not crack or breakup under traffic, considerable difficulty was experienced in trying to maintain the track gauge. The blocks were apt to tilt either inwards or outwards and produced unacceptable gauge variations. After a year or so their use was restricted to sidings; those in running lines were removed and used as drainage channel block walls, and even small retaining walls. Finally the use even in sidings was banned.

Experiments with monoblock prestressed concrete sleepers continued and the E1 type using CI chairs and bull-head rail were proving successful. (Photograph 2)

Note: Discussion open until October 15, 1976.

Photograph 1—(Foreground) BS 95-lb bull-head rail, softwood sleepers, cast-iron chairs, steel keys. (Background) BS 109-lb flat-bottom rail, softwood sleepers, base plates, Elastic Spikes.

Photograph 2—Early "E1" type concrete sleepers for bull-head rail.

About this time, timber sleepers were increasing rapidly in price. The life of a wooden sleeper varied considerably, depending not only on differences in species, but also on differences in climatic conditions, and in resistance to decay. Differences in life were apparent even with sleepers cut from the same species in the same forest but from different trees.

Trials were made with specially selected hardwoods (Australian Jarrah). The results of the trials showed that the Jarrah sleeper had a significantly increased life compared with softwood and the behavior of the Jarrah was much more consistent. However even without the need to treat with creosote, the Jarrah sleeper was much more expensive.

Development of concrete sleepers proceeded fairly rapidly and it became obvious that it was feasible to design a concrete sleeper for any type of loading, any type of rail and any type of gauge. Furthermore the sleeper life could be extended well beyond that of any wooden sleeper.

The increasing costs of labor indicated the need for a track assembly with minimum maintenance. A concrete sleeper with long life was the obvious solution, but the rail fastenings then available required considerable maintenance attention. Developments and trials with all known and many new types of fastenings were tried; at one time BR had under trial in the running lines, over 30 different types of fastenings, including the best of those used in Europe.

It soon became apparent that the assembly requiring minimum maintenance was that which did *not* require:

(a) Any screw or nut.
(b) Any plug in the sleeper to take another metal insert of any kind.
(c) Any reliance of a cast concrete shoulder to hold gauge.

The reasons being:

Screws and nuts require regular attention; tightening as they work loose, and oiling to prevent rusting and seizing up.

Plugs (wood, rubber, plastic, etc.) in concrete sleepers eventually work loose and cause serious problems in correction, and on BR's main lines, within 10 years of installation, all such assemblies will have to be removed or provided with expensive temporary maintenance fastenings until complete replacement can be carried out.

Similarly, evidence indicates that concrete shoulders cannot alone be relied upon to keep gauge. In time the vibration and repetitive lateral loadings will almost certainly cause the concrete shoulder to deteriorate and crumble, well within the expected life of modern concrete sleepers of the F23, F27 types. (Photograph 3)

In these modern types, the problem has been overcome by casting hoops or metal inserts in the sleeper for use not only as part of the fastening fixing but also as the gauge stop. After the completion of many years of testing, BR has standardized on the F27 prestressed concrete sleeper with the Pandrol fastening. The rail is seated on a rail pad (rubber-bonded cork or similar) specially designed to provide in the assembly sufficient elasticity to cushion the effects of dynamic loadings—in particular to absorb the rail deflection due to the procession and recession waves caused by each axle, and at the same time to retain with the Pandrol fastening, adequate toe-load, resistance to rail creep and torsional movement of the rail.

Photograph 3—Latest concrete sleepers, F27.

The malleable-iron insert designed to hold the Pandrol fastening is fixed into the mold when casting the sleeper and provides a positive gauge stop which enables accurate gauge to be guaranteed. The Pandrol clip is driven into the insert and onto the rail foot (on BR an insulator, preferably with a metal cover plate, is used for track circuiting purposes).

The assembly has no nuts and no screws to work loose, nor to be tightened nor oiled; it has no baseplates with fastenings requiring additional tolerances so that it has an accurate initial and lasting gauge. In other words it is virtually a maintenance-free fastening assembly.

Meanwhile further developments in welding techniques enabled the changeover to continuous welded rail and the elimination of joints in the track. This meant that greater thermal forces had to be resisted by the sleepers, i.e., in the lateral direction to prevent buckling of the track in hot weather and in the longitudinal direction in all weathers to prevent sleepers moving forwards or backwards with the changing rail temperatures, and finally vertically to prevent upwards distortion. For all these purposes the heavy concrete sleeper was ideal—and although some lengths were installed on baseplated wooden sleepers, at least 25% more sleepers were necessary per mile than if concrete sleepers were used.

At this time BR were installing about 500 miles each year of continuous welded rail (CWR) with concrete sleepers, at 2-ft. 6-in. spacings and some lengths with hardwood sleepers at 2-ft spacings.

With the "Beeching" cuts in the total mileage of the BR system, some lines containing the bull-head rails and earlier concrete sleepers were taken up after 20 years or more in the track. The condition of these concrete sleepers was so good that it was decided to take off the bull-head chairs and replate them for use with flat-bottom rail. Several hundreds of thousands have been so modified and put back into the tracks for a further long life.

It should be noted that the prestressed concrete sleeper is designed to carry the specified dynamic loadings foreseen for the life of the sleeper. The design can be modified to suit any other type of dynamic loadings—heavier (or lighter axles). Prestressed sleepers (of the BR type) have been made suitable for the 33-ton axles on the Canadian National Railways and iron ore lines in Australia, whilst on BR special types have been made for use at heavily worked joints, for single- and double-checked curve, and shallower types for use in places with restricted headroom, e.g., in tunnels of small diameter, under overhead electric wires where it is not practicable to lower out, under bridges, etc.

So far BR have laid in nearly 20 million concrete sleepers (equivalent to approximately 8500 miles) and for the last eight years have averaged 1.2 million per annum, with a similar rate programmed for the next 5 years. The number of failures is exceedingly small, and when they have occurred have always been associated with poor track maintenance, epecially insufficient ballast on temporary jointed track—awaiting the installation of continuous welded rails.

Meanwhile labor was becoming more and more expensive and difficult to obtain, and it was essential that the existing labor force be used more efficiently, and the requirement for labor had to be reduced. This led to the need for mechanization, to the need for track requiring less attention and more planning of the work.

It was the introduction of Work Study (work measurement and method study) that for the first time provided accurate information of the actual work involved in each and every task; e.g., it indicated nearly 50% of all the labor used was spent on joint maintenance. The method study indicated better ways of doing the job. With the unions' cooperation, Work Study coupled with a bonus incentive scheme was introduced. It took approximately four years to introduce it all over BR and the results were outstanding—the labor requirement was reduced by about 30%. The output per man increased by 50%. Abortive and unnecessary work was eliminated and more essential work was carried out.

From the data and information obtained, the actual cost of any operation was available. These facts enabled financial justifications to be correctly assessed for continuous welded rail instead of jointed, for concrete sleepers instead of hardwood or softwood sleepers and last but by no means least for the purchase of heavy relaying and maintenance machines to reduce still further the labor requirements. So around about 1963–64 my then chief civil engineer, A. N. Butland, put all these developments together and formulated new plans for BR's future track maintenance and renewals.

With the BR Board's approval mechanization proceeded apace and purchases were made of automatic tamping machines, lining machines, ballast cleaners, etc, etc., all fully financially and technically justified. Standardization of the main-line track structure was introduced. FB 110A (later FB 113) rails (53 tons (short) sq. in. tensile steel) in continuous welded rail with F27 prestressed concrete sleepers, Pandrol clips, rubber-bonded cork rail pads, plastic insulators and minimum depth of ballast, minimum width of ballast shoulders. (Also shown in Photograph 3)

The "Butland" plan included "premature" renewals (instead of replacing only life-expired track) which enabled the 10 selected major routes of the system to be relayed to the new standard within approximately 5 years. It is on these routes that the high-speed trains are scheduled to run, and will commence this year.

During the same period of development, studies with freight vehicles at 28-ton (short) axles proceeded, and accepted for running at 60 mph (100 km/h), and experience since indicates no increase in rail failures, although the rate of track settlement has increased indicating a need for marginally earlier tamping.

The 28-ton axle is about the limit for the class of rail steel with tensile strength of 53 short tons/sq. in. (70 kg mm^2) which exists throughout BR. It should be noted that none of the continental railways, even with the steel 70 kg mm^2 and 90 kg mm^2 tensile strength has accepted 22 tonne (24½ short tons) axles.

The demand for higher speeds has been universal and with the Japanese commencing services at 200 km/h the demand in Europe increased.

Numerous studies were in hand on BR and on the Continent. In Europe high speed is usually regarded as 160 km/h (100 mph) up to 300 km/h (186 mph) and very high speed above 300 km/h (186 mph). Experts consider that 400 km/h (250 mph) is likely to be the maximum for the steel wheel on steel rail with present knowledge of adhesion, braking and acceleration.

The BR studies covered first the running of conventional type trains at speeds of 125 mph (200 km/h) on existing tracks with the possibilities of speeds up to 186 mph (300 km/h) on new tracks, and secondly the running of "tilting" trains—the APT (Advanced Passenger Train) on existing tracks with high cant deficiencies at speeds up to 155 mph (250 km/h).

The track problems arising from increasing the speeds of conventional trains on the main lines to 125 mph were easy to pin-point but more difficult to assess in work load. The increased speed would produce increased dynamic loadings, and increased lateral loadings, but no real data was available. Numerous tests were carried out with different locomotives running at speeds from 20 mph in steps of 10 mph to 130 mph and the vertical forces recorded at the axle-boxes and on load-measuring baseplates on the sleepers, including a preformed vertical irregularity ("dip"), and from all these tests it was possible to derive a formula linking the speed, axle-loading, unsprung mass, track irregularity, etc., to the vertical forces.

Although this formula does not provide the absolute forces it does provide an indication of relative vertical forces which would be experienced. It was decided to accept the vertical forces produced by the Deltic locomotive running at 100 mph as the maximum reference limit. This type of locomotive had been in regular service for many years and its effects on track maintenance fairly well established.

The vertical forces considered to be most important are those (known as the P2 forces) that are transmitted to the rail and through to the ballast and the impact forces (known as P1 forces) at the joint or irregularity which are experienced only by the rail. It was agreed to accept a "dip" of 0.2 radians (½ in. dip over 20-ft) as the "fixed" maximum irregularity for all future comparative measurements of vertical forces, and therefore the Deltic Locomotive running at 100 mph over such an irregularity would produce the maximum acceptable vertical forces, and these have been calculated and checked by measurements to be

P1 52 tons per wheel (58½ short tons)
P2 34 tons per wheel (38½ short tons)

The formulas are shown in Fig. 1.

It can be seen that the P1 force is related to speed and size of irregularity, and insignificantly relative to unsprung mass. It is the P1 force that causes rail batter but is of such short duration that whilst it contributes to forces in the rail, and at bolt holes it has practically no effect on the sleepers nor on the ballast.

The P2 force is the vertical force which contributes to the rail stresses including bolt holes and is then transmitted through the rail to the sleepers and to the ballast. It must be noted that the formulas are considered satisfactory for comparison of vehicles with modern suspension systems. They are not completely satisfactory for evaluating the forces produced by older type freight vehicles with single suspension systems as the "sprung mass" in these older vehicles does have an increasing effect with speed.

For all vehicles the "wheel flat" is a very important factor and on BR permissible maximum limits are laid down for each type of vehicle and speed band.

The high-speed conventional trains (HST's) for service running have axle loads of 18½ short tons (16½ Imperial tons) and unsprung mass of 2¾ short tons, and the relative P1 forces would be 67 short tons per wheel and the critical P2 force 35 short tons (33 Imperial tons). (Photograph 4)

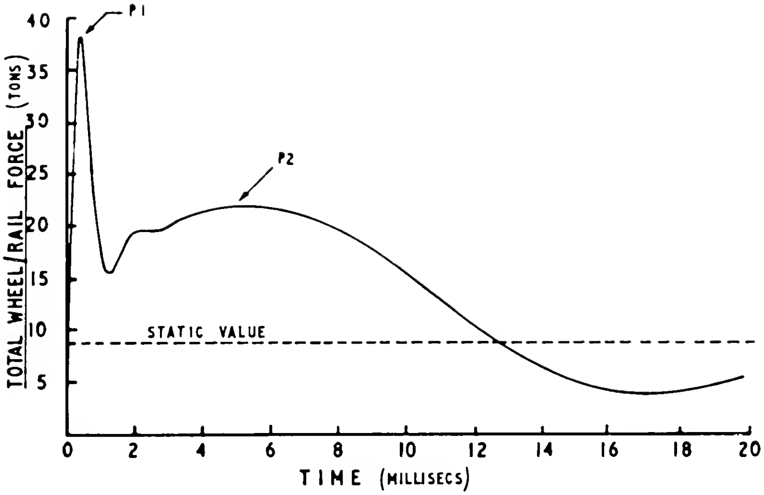
It is true that with continuous welded rail and main-line standards the irregularity used as a basis is most unlikely to be present in practice so that the P1 force excess has been accepted and the P2 force is actually less than that produced by the Deltic. This means that provided the lateral forces are no greater than those of the Deltic today then there is no increase in the rate of track deterioration.

The lateral forces are mainly comprised of guiding forces through curved track and centrifugal forces due to cant deficiency. Obviously, increasing the speed on existing cant and curves will increase the lateral forces. BR's standard formulas for cant and curvature are fairly well known and only recently a working party of UIC was set up to examine all the limits fixed by its members and set out recommended limits for every parameter. BR is the only member administration which at present meets every one of the recommendations.

The principle BR limits concerning high speed running are:

Maximum actual cant	6 in. (150mm)
Maximum deficiency	4¼ in. (110mm)
Desirable rate of change of cant or deficiency	1⅜ in. (35mm) per sec
Maximum permitted rate of change of cant or deficiency	2⅛ in. (55mm) per sec

(a) The maximum actual cant of 6 in. is very similar to that adopted by most major railway administrations with standard gauge. It is so limited



DYNAMIC INCREMENT OF P1 DEPENDS MAINLY UPON :		DYNAMIC INCREMENT OF P2 DEPENDS MAINLY UPON :	
SPEED	V	SPEED	V
JOINT ANGLE	α	JOINT ANGLE	α
CONTACT STIFFNESS	K_H	UNSPRUNG VEHICLE MASS	M_U
EFFECTIVE TRACK MASS	M_E	TRACK BALLAST STIFFNESS	K_S
UNSPRUNG VEHICLE MASS	M_U	TRACK BALLAST DAMPING	C_S
		EQUIVALENT TRACK MASS	M_T
		" " STIFFNESS	K_T
		" " DAMPING	C_T

$$P1 = P_0 + 2\alpha . V \sqrt{\frac{K_H . M_E}{1 + \frac{M_E}{M_U}}}$$

$$P2 = P_0 + 2\alpha V . \left[\frac{M_U}{M_U + M_T}\right]^{\frac{1}{2}} . \left[\frac{1 - C_T . \pi}{4 K_T . (M_U + M_T)}\right] \sqrt{K_T . M_U}$$

Fig. 1

BR's high-speed train (H.S.T.)

because of the possibility of overturning if a van is left standing on 6 in. canted track (1 in 10) in high winds or gales.

(b) After numerous trials the maximum deficiency and the rate of change of cant (or rate of change of deficiency) were all selected as the limits for reasonable passenger comfort (including walking in the train corridors or eating in the restaurant car). They are therefore arbitrary limits and not factors of safety—so that if means can be found to maintain passenger comfort then higher deficiences and rates of change of cant will be possible. This is the idea behind "tilting body" trains and BR's APT's. The limit will then have to be set by the track resistance to lateral forces arising from higher deficiencies and higher speeds.

In order that the existing tracks could be made suitable for higher speeds (125 mph) considerable re-canting, re-lining and more difficult re-transisioning has had to be carried out. There were many problems; in a few instances re-lining meant virtually re-routing, and in others the full requirement was virtually impracticable and some speed restrictions below 125 mph will remain. The increased speeds have necessitated the removal of all unmanned level crossings in the majority of cases.

Thus the problems of vertical forces and lateral forces were contained, but whilst the track tolerances at installation laid down for today's main-line speeds are acceptable for 125 mph, the minimum maintenance tolerances need tightening up. High-speed trains are much more susceptible to track irregularities, and therefore the rate of deterioration of line and level must be halted earlier than with present line speeds. This has meant laying down a more frequent cycle of maintenance attention.

TOLERANCES FOR HIGH-SPEED LINES

	100 mph (160 km/h) Lines				125 mph (200 km/h) Lines			
	Installation		Mtce		Installation		Mtce	
	(mm)	in.	mm	in.	(mm)	in.	mm	in.
Gauge	(—1)	1/16	(—1)	1/16	(—1)	1/16	(—1)	1/16
	(+4)	3/16	(+7)	5/16	(+3)	1/8	(+6)	1/4
Cant	(±2)	1/8	(±6)	1/4	(±2)	1/8	(±5)	3/16
Twist (over 3 metres)	I in 600		1 in 400		1 in 750		1 in 500	
Alignment over 20 metres overlapping chords	(±4)	3/16	(±5)	4/16	(±3)	1/8	(±4)	3/16

Gauge: (1432 mm) 4 ft 8-3/8 in.

It is true these tolerances are tight and difficult to obtain, but before they were fixed a detailed survey was made of the actual gauge and cant on many curves and it was found:

	GAUGE	CANT
100 mph lines:	Worst wide (+4mm) 3/16 in. Worst tight (—6mm) 1/4 in.	8mm over 10 metres 5/16 in. over 10 ft
90 mph lines:	Worst wide (+8mm) 3/8 in. Worst tight (0.) 0 in.	9mm over 3 metres 3/8 in. over 10 ft

Whilst by far the majority of readings fell within the specified tolerances.

The best results came from the F27/F23 type concrete sleepers.

The minimum radii for vertical curves are:

	(.01g) Recommended Radius	(.03g) Minimum permissible Radius
100 mph	12.6 miles	4.2 miles
125 mph	19.5 miles	6.5 miles
250 mph	78.2 miles	26.1 miles

Ballast

It is most important that tracks for high-speed lines have adequate depth of good ballast. The rate of deterioration of line and level depends to a large extent on the quality of ballasting. BR's new specification states that the ballast shall be good natural hard stone, angular in shape with all dimensions nearly equal, and meet the following requirements:

1. *Wet Attrition Value.* Not exceeding 6% for main- and high-speed lines (8% is permitted for secondary lines where 6% is not readily obtainable).
2. *Crushing Value.* Not to exceed 30%.
3. *Impact Value.* Not to exceed 25%.
4. *Flakiness Index.* Not to exceed 50%.
5. *Elongation Index.* Not to exceed 50%.

Ballast Size—Square Mesh Sieve.

50 mm (2 in.) all to pass.
28 mm (1-1/8 in.) Not less than 80% retained.
14 mm (9/16 in.) None to pass.

The 80% to be general graduation in sizes between 50 mm and 28 mm (2 in. to 1-1/8 in.).

Experience with available stone on BR indicates that the *wet attrition value* is critical, and that nearly all stone with low attrition values usually satisfied the other limits, and if not is seen easily. Basalts and granites usually have wet attrition values of 2% to 5%, although a few exceed 6% and are not used. Limestones, which are abundantly available, usually have wet attrition values exceeding 8%, and only a few sources are satisfactory.

It is found that stones with high wet attrition values form fine particles which combine with rain water to form a slurry which finds its way under the sleepers to start "pumping" of the sleeper. This creates voids under the sleeper and if not attended to, the "pumping" spreads to adjacent sleepers and line and level deteriorate rapidly. Briefly, the wet attrition value is obtained by taking a 30-lb sample, washing and drying (100°–110° C), cooling and weighing, and then placing in a cylinder to which is added equal weight of water. The cylinder is rotated 10,000 times at 30-33 revolutions per minute. The amount retained on a BSh 07 sieve, approximately 1/10 in. mesh, is washed and dried and the loss of weight as a percentage of the original is the wet attrition value.

Many of you will have seen BR's proposed 16 track categories (published in 1971). Experience and more reliable information of actual tonnages passing and actual maintenance work necessary have necessitated a change in the tonnage bands. Attention was drawn to this by the wide variation of work-load in Category (1) track 0 to 6 million, as compared with Category (2) 6 to 12 million. The new categories which are proposed for introduction this year are as follows:

Tonnage Band	Annual Tonnage per Year	(Millions Short Tons)	Old Annual Tonnages	(Millions Short Tons)
1	0– 2 million	(2¼)	0– 6 million	
2	2– 5 million	(2¼–5½)	6–12 million	(6¾–13½)
3	5–12 million	(5½–13½)	12–18 million	(13½–20¼)
4	12 and over	(over 13½)	18 and over	(over 20¼)

The speed bands remain unaltered:

A 100 mph to 125 mph
B 75 mph to 99 mph
C 50 mph to 74 mph
D Below 50 mph

It transpires that at present there are no New Category A lines carrying less than 5½ million short tons so the categories concerned with high-speed services are Categories A3 and A4 only.

The recommended maintenance cycles for these two high-speed category lines are:

1. Patrolling—3 times a week (safety union requirement).
2. Track geometry recording car runs—3 times a year.

3. Rail flaw detection car runs—twice a year (plain line).
4. Manual ultrasonic testing—3 times a year (switches and frogs).
5. Tamping/lining machines—Every 9 months (category A4) Every 12 months (category A3). Intermediate manual packing of adjustment switches and insulated joints, etc.
6. Kango, or machine or manual packing—3 times a year (switches and frogs).

The fixed manning on site (excluding machine workers) *per mile of track:*

	Cat. A4 man	Cat. A3 man
1. Allow for attention *to fastenings,* clips, pads, insulators, etc., etc	0.012	0.008
2. Allow for attention to adjustment switches	0.006	0.004
3. Allow for attention to ballast	0.090	0.063
4. Miscellaneous	0.003	0.002
	0.111	0.077
5. Patrolling (per mile of inspection)	0.079	0.075
6. Off-track work, grass-cutting, weeds, fences, drains, etc.	0.110	
(per *geographical mile*) (per mile if 2-track railway)	0.055	0.055
	0.134	0.130

The Tamping/Lining Service

Tamping machines have developed rapidly. BR issues its own specification (about 100 pages) for each machine. It may be of interest to follow some of the reasons for these changes.

If you assume you require a track maintenance machine to run on BR:

1. It must satisfy the signal engineers minimum requirements for safety of track circuit working which means it must have not less than 3 axles each with 9 short ton minimum loading.
2. It must satisfy Movement Departments "punctuality" requirement which means it must be able to run into/and out of Section at not less than 55 mph.
3. It must satisfy chief mechanical engineers anti-derailment requirement of a specified ride index (lateral and vertical forces).

These three conditions can only be met with a vehicle with bogies, and weighing at least 27 tons (short).

Agreements with Unions stipulate:

4. Operator must have direct visibility immediately in front of vehicle when travelling and working. This means either a tall central control position (impossible with BR's low headroom) or a cab at each end fully fitted with all running and operating controls.
5. Cabs must be waterproof, soundproof and air-conditioned. The noise levels have to be reduced to meet "Health and Safety at Work," a recent Parliamentary Act.

6. Because it may work under overhead electric wires, there is danger for a man standing on the vehicle floor, and raising a hammer/spanner within arcing distance of the live wires, so that the vehicle must be fully covered by a roof.
7. These conditions are essential for all machines required to move on or adjacent to any lines open to traffic. The "Union" requirements are enforceable for all such equipment, but the "ride index" and track circuiting requirements (which together eliminate the possibilities of 2-axle machines) do not apply to lines completely under engineer's occupation, if they can be conveyed to the site on a wagon or by road.

These basic requirements are fully satisfied by the latest types of track maintenance machines.

Recent investigations have proved that the accuracy of the finished level and finished line increases as the measuring base increases, and investigations continue into the use of low-powered laser beams as a means of extending the measuring bases, without creating any safety hazard for men working on or near the tracks.

Obviously in a complete on-track mechanization system adequate occupations of the line are essential. On some of the high-speed routes "reversible" (or two-way) signalling is being introduced. On others, "gaps" are being provided in the time tables; in some cases these will still only be available during the nights or Sundays. A computerized program is already in use for optimization of line occupations, maintenance and renewal items and available resources. Other noteworthy introductions are:

1. *Rail Flaw Detection Service* (Photograph 5)

BR, in conjunction with Wells Krautkramer developed a 2-car ultrasonic rail inspecting unit, which came into service in 1971. This 2-car set has basically one "instrument" car and one "staff amenity" car—including sleeping accommodation for the crew. The standard type ultrasonic probes are used, sliding on the rail surface.

Probes at 1, 30° and 70° to the vertical enable defects to be located through the whole of the head and web of the rail and in particular at and under bolt holes. The ultrasonic information is transformed and recorded on 35-mm film which at the end of a run (usually representing 100 miles of track per night) is dispatched for processing and returned to an evaluation center where it is manually inspected and interpreted. The evaluation is time-consuming, tedious and exacting. In conjunction with the Atomic Energy Authority at Harwell an Automatic Scanning Device coupled with computerized evaluation has now been installed at the evaluating center. It has completed its trials and as expected produces results even more accurate than the most expert of evaluators, and of course in a small fraction of the time.

The next development already being studied and found to be feasible is the elimination of the filming process, and to transform the ultrasonic information suitable for immediate scanning and evaluation either by a computerized system on the train itself, or by recording direct to a "floppy disc" which is then scanned and evaluated at the existing evaluation center.

When the divisional engineer receives the report of a run, he arranges for a manual ultrasonic inspection of each fault reported, and ensures the necessary action is taken and reports back accordingly to the center.

Photograph 5—Ultrasonic rail flaw detection car.

2. *Track Geometry Recording Car*

The difficulty of obtaining a passage on the main lines for slow-moving recording cars has become more and more difficult as speeds and densities of traffic increase. BR decided to construct its own car capable of running as part of the high-speed trains or with its own locomotive at 125 mph, or as part of any other train including existing 90 mph and 100 mph services.

The basic parameters are:

1. Vertical profile (left and right).
2. Horizontal profile (alignment).
3. Cross level.
4. Curvature.
5. Gauge.
6. Vertical slope.
7. Ride index.

and the following derivations:

8. Vertical slope.
9. Horizontal slope.
10. Equilibrium speed.
11. Dynamic cross level.
12. Twist (2 different wheel bases).

The measuring systems had to be all non-contact ones to enable accuracy of recordings at 125 mph. This has been achieved by the use of inertial sensors, accelerometers, transducers, gyroscopes and optical scanners. The data produced are then electronically processed to produce print-outs as required. The major faults are marked on the track by automatically fired "paint bullets." It is intended to obtain a true record of every section of BR track from which future maintenance standards will be set for each parameter.

Information of the traffic carried over each section will be fed into the computer and after successive runs the rate of actual deterioration will be calculated for each of the important parameters, and this will enable the next periods of maintenance attention to be forecast, reasonably accurately. Linking this information with possible line occupations, available machines and other resources will enable the maintenance requirements to be scheduled at least 12 months ahead using the computerized program already mentioned. The greatest task is feeding in accurate track component details, type, age, condition, etc., for the whole system, but this work is in hand.

There have been many other developments but due to the need to limit the length of this paper they can only be mentioned briefly, e.g.:

(a) *Track Circuits*

Glued insulated joints are in regular use on electrified lines. These are of 2 types, 1. The Edilon glued joint (polyester resin), and 2. The "BR" type (epoxy resin) with "Huck type" fastenings.

These joints are tested to 115 tons longitudinal force before acceptance. After 4 years, failures recorded are less than 2 per 1000 joints.

On non-electrified lines jointless track circuits (Aster type) are being installed as rapidly as possible. Recent developments indicate that possibilities now exist for a reasonably priced jointless track circuit suitable for electrified lines.

(b) *Welding*

Flashbutt welding is carried out at six depots spread throughout BR; each depot has only one main welding machine. Sixty-foot lengths are welded into lengths up to 1320 ft. Developments have taken place in the straightening and finishing of the welds. The equipment used is supplied by "A.I." Welders Ltd., of Inverness, Scotland. Failures of flashbutt welds in the track are rare.

Considerable effort has been made to improve the thermite welds. The main problems were lack of straightness, cupping at the weld, and lack of fusion. Every failed weld is sent to the laboratory for detailed investigation. The results have shown that in every case quality of workmanship has been the cause. This is understandable as the work has to be carried out in all weathers and usually during darkness and under pressure to restore the lines to traffic. Development has been, in conjunction with the Elecktro–Thermit Co., to produce a method less susceptible to workmanship and this has been achieved by using a system where the pre-heating time is far less critical.

(c) *Manual Packing*

It is important to ensure that local pumping of the sleepers is prevented, especially on high speed or heavily used lines. Instances occur at the introduction of a replacement rail, a replacement insulated joint or weld that the track bed is disturbed at that point, perhaps only one or two sleepers, but left unconsolidated. This creates bad spots which if left untreated develop rapidly and extend. It is generally impracticable to bring in the large tamping machines, and BR use portable equipment—Kango Generators and Kango Electric Hammers. Some of these are

2-man sets, others 4-man sets. The hammers are equipped with specially designed ballast tools. Their use enables the troublesome spots to be dealt with quickly and the track kept to the high standard and left until the next on-track machine scheduled tamping. The Kango equipment is used even more frequently for tamping regularly switches and frogs. BR has in regular use over 1000 sets of Kango Equipment.

(d) *Rail Drilling and Rail Sawing*

The problems associated with drilling holes in rails without creating starting points for a crack have been largely overcome by re-thinking the process of drilling. As a result the best combination of speed, pressure and angle of cutting edge of the drill has been found. These are incorporated in all new rail drilling equipment and BR has now standardized on the "Stumec" equipment for rail drilling and sawing. Since their introduction the number of bolt hole failures has fallen steadily.

(e) *Destressing and Restressing*

BR adopted several years ago the policy of stretching a rail to its required calculated "stress free" length. The equipment used has to be capable of pulling with a force of 100 tons (22,400 lb). Two makes of machine are in use: the "Greenside" equipment and the "Permaquip" machine; both give equally satisfactory results.

(f) *On-Track Maintenance Machines*

BR's detailed specifications already mentioned are regarded by manufacturers as the strictest and most demanding of all administrations—but these specifications have been compiled on actual service experience, actual safety requirements and the need for maximum utilization and minimum interruption to work on restricted availability of line occupations.

BR's present on track maintenance equipment is shown in Fig. 2. (Photographs 6 and 7 are examples)

(g) *On-Track Relaying Machines*

Two types are in regular use:

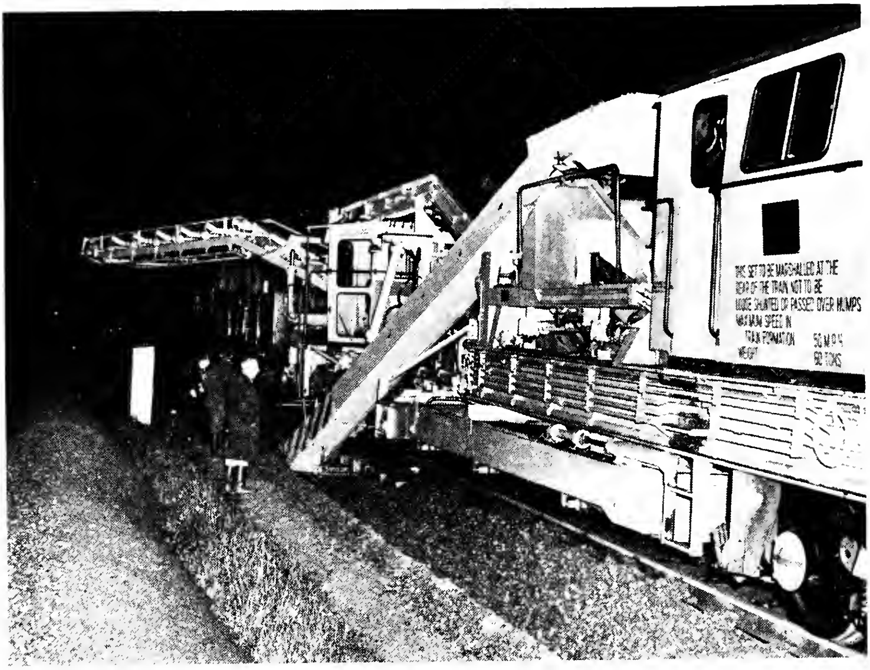
1. The Twin Jib Crane—this can only be used where two lines run alongside each other, as the equipment runs on one road and relays the other. As most of BR is double (or quadruple) track this is a very useful piece of equipment and can be used for "panel" laying (60-ft rails with sleepers attached) or direct sleeper laying (up to 60 concrete sleepers correctly spaced at each lift). (Photograph 8) The continuous welded rail is placed in both methods, after the panels of sleepers have been placed. BR has 47 such machines, some self-propelled, others requiring a locomotive. (Photograph 8) Rate of working averages 10 each 60-ft sections out and 10 new 60-ft stretches in per hour. In good circumstances 13 sections in and out are obtained.
2. Gantry Type Equipment—The difficulties of obtaining possession of two tracks simultaneously led to the development of single-line gantries of the Portal type. The new long welded rails are laid out alongside the outer ends of the sleepers of the track to be relayed. The Gantries running on the long welded rails (gauge 10 ft 6 in.) lift out the old track in panels and bring in the new sleepers—either on their own or with second-hand 60-ft rails. The rate of working is on average 10 sections in and out per

ON TRACK MACHINES

1976

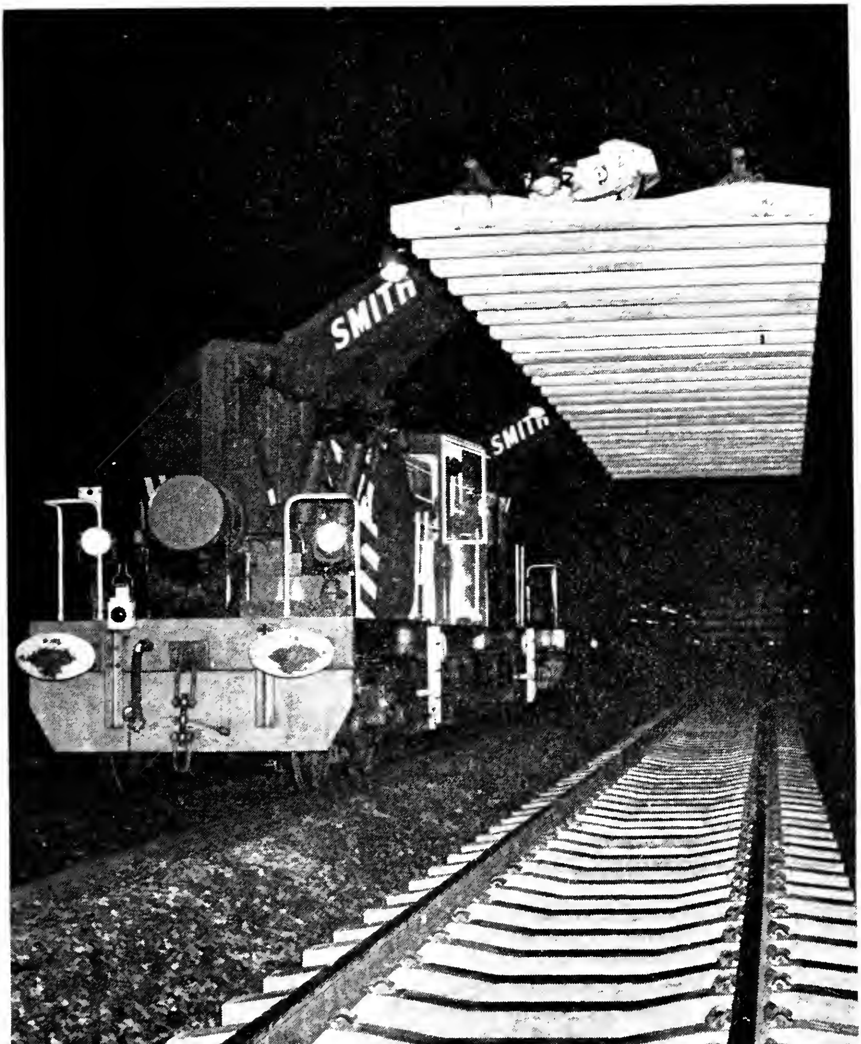
TAMPERS	PLASSER	05E	13
	..	06	50
	..	JOINT	1
TAMPER-LINERS	PLASSER	SLC	20
	..	07-16	38
TAMPER-LINER-CONSOLIDATORS	PLASSER	CTM	22
P & C TAMPERS	PLASSER	07-275	6
	..	07-16-275	3
LINING MACHINES	PLASSER	AL 203	35
	..	AL 250	13
BALLAST CONSOLIDATORS	ROBEL		5
	PLASSER	VDM 800	24
	MATISA	D 8	16
BALLAST REGULATORS	PLASSER	USP.3/4000	10
	..	.. 5000	12
	MATISA	R 7	10
BALLAST CLEANERS	PLASSER	RM 62	20
	MATISA	(OLD TYPES)	23
	..	C 311	2
TRACK RECORDERS	MATISA	PV 6	12
RELAYING MACHINES	BRITISH	TWIN JIB	47
	SECMAFER (SINGLE LINE)	(M6, M8, M9)	16
(ON ORDER;	GEISMAR	SINGLE LINE	3

Fig. 2

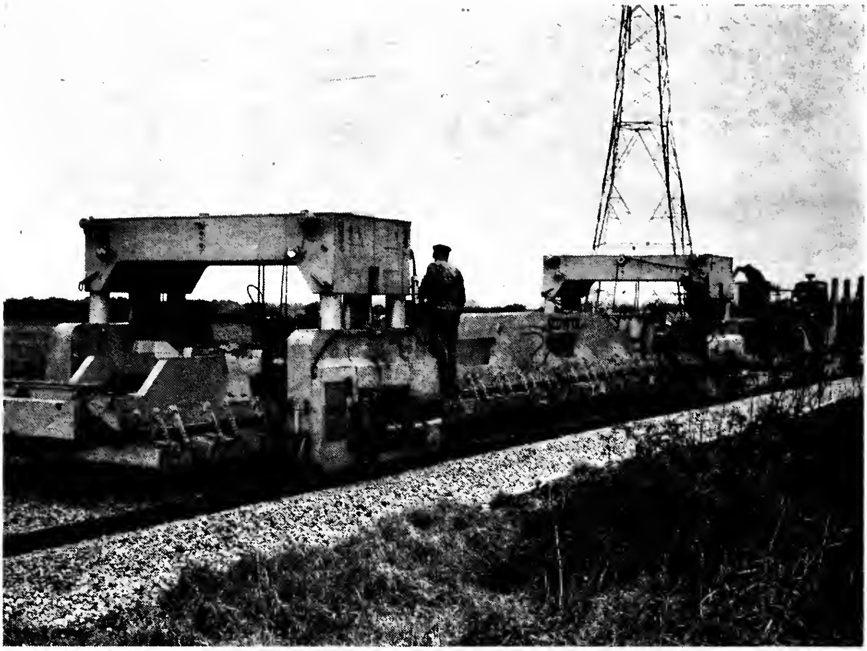


Photograph 6—Plasser ballast cleaner.

Photograph 7—Long-chord leveling, lining and tamping machine.



Photograph 8—BR's twin jib self-propelled track layer.



Photograph 9—Secmafer gantry track layer with sleeper beam.

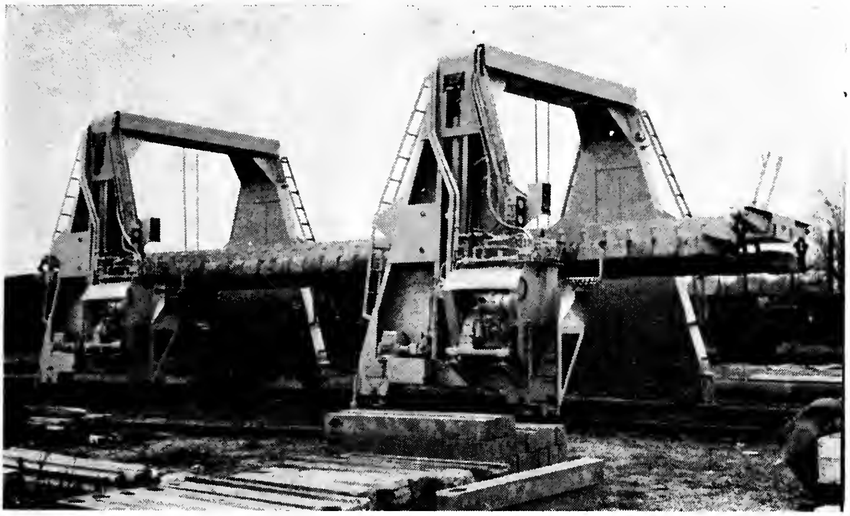
hour but frequently rates of 13 sections in and out are achieved for lengths of 50 chains (3300 ft) in one Sunday occupation.

BR has 12 Secmafer M6 and M8 Gantries capable of taking up and laying panels only, and 3 sets of M9 Gantries with an automatic pick-up sleeper beam. Those machines with the beam can carry up to 60 concrete sleepers, (2 rail lengths of sleepers correctly spaced and "interleaved"). The machines remove 4 lengths of old, then the ballast machine moves in and scarifies the old sleeper beds and reprofiles the ballast ready for the new sleepers. The beam then places its alternative sleepers and moves ahead to place the remainder so that two complete rail lengths of sleepers are laid. (Photograph 9)

BR takes delivery this month of three sets of Geismar "Pluto Mark III" gantries. These are built to BR's specification and can be used either for panel laying or with the automatic beam sleepers only. The specified rate of working is not less than 13 such 60-ft sections per hour. (Photograph 10)

Rail Changing Machine

In the early 1980's BR can expect to be required to re-rail about 200 miles of CWR a year increasing in the late 1980's to 500 miles. Experiments are being carried out to find the best equipment. One machine now on trial is a Plasser machine



Photograph 10—Geismar gantry track layer with sleeper beam.

(Photograph 11) which is expected to work at walking pace, i.e., 3 to 4 miles of changing both rails.

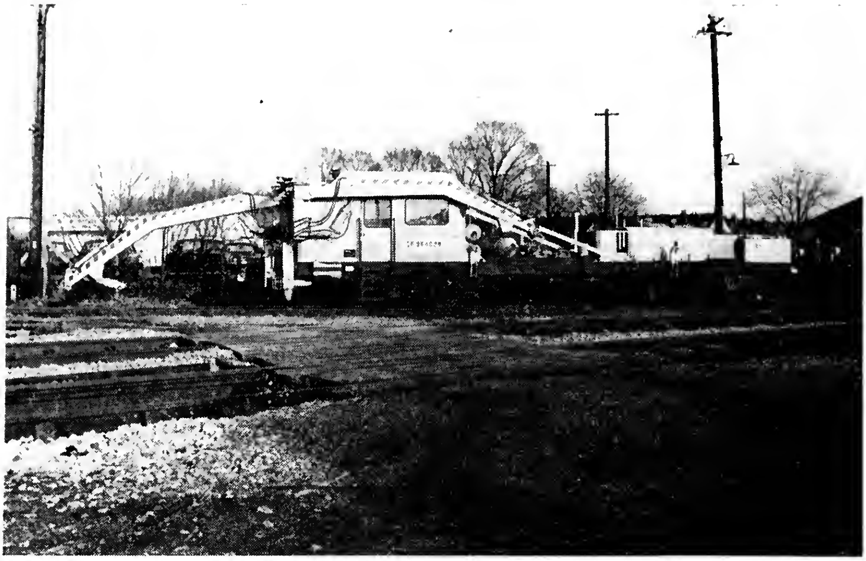
The changes in BR's track structure including the improved alignments, transition curves and canting as described, together with the maintenance procedures outlined explain BR's ability to introduce 125 mph services this year. Full evaluation of the effects of high-speed trains on the wear and safety of the track has been made and it can be seen that these high speeds can be obtained at only marginally increased costs of track maintenance.

The first of the conventional type high-speed trains (HST) from the batch production was delivered this month and is shown in Photograph 4.

Further work is still in hand concerning the effects of lateral forces by the APT tilting train running with cant deficiencies up to 12 in. The work is not complete but tests indicate that with deficiencies exceeding 8 in. that small lateral movement of the track (1/25 in.) can be expected after passage of each high-speed train on track with unconsolidated ballast (i.e., after tamping, or ballast cleaning, relaying etc.). Indications are that stability is not restored until some 200,000 tons of traffic have passed. (The APT train is shown in Photograph 12)

Load measuring wheels are used to measure lateral forces, and it seems that recent measurements indicate a correlation between the flange forces and the forces at the axle-box. The measurement of track resistance is even more difficult, and special on-track vehicles are being constructed to measure the forces required to shift the track laterally. It is hoped these experiments will be completed within the next 12 months. The lateral forces comprise (a + b) forces where (a) = Quasi-Static Forces arising from—

1. Cant deficiency.
2. The asymmetry between leading and trailing wheelsets of bogies.
3. Alignment of wheelsets in bogie frame.



Photograph 11—Plasser rail changing machine.

Photograph 12—BR's Advanced Passenger Train (APT).

and (b) = Dynamic Forces.

4. From body and primary sprung masses due to track irregularities.
5. From repose to the unsprung masses due to track irregularities.

With tests at 6°, 7°, 8°, 9°, 10° and 12°, measurements of peak lateral forces exceeding 10 tons (22,400 lb) at slight track irregularities have already been measured. Nevertheless present indications are that deficencies up to 9° will prove to be acceptable on concrete-sleepered track. It is unlikely that such deficiencies will be permissible on wooden-sleepered track.

The tests so far on lateral resistance of track indicate that over 90% of the resistance is provided by the friction between the base of the sleeper and the ballast. Heavy concrete sleepers therefore have a distinct advantage.

Hot Box Detector Data Analyzer System

77–658–3

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Synopsis

Infrared detectors are now being used to scan train wheel bearings for abnormal heat. In these hot box detector (H.B.D.) systems the most unpredictable factor in the production of consistent, reliable results has been the method of interpreting the data. At present, the detector readings are recorded on paper tape and the resulting train heat profile is manually analyzed. Unfortunately, however, this method of analysis is only accurate if the tape reader is intimately familiar with all the pulse patterns that the H.B.D. system may generate. An effort to provide consistent accurate analysis of the H.B.D. data is resulting in the development of a computerized analysis system. Fig. 1 is a map of the Canadian National's H.B.D. installations.

Fig. 2 shows both the physical plant layout and the data processing system block diagram for a typical hot box detector field installation. In this configuration, detectors 1 and 4 are used to initialize the system and to establish the direction of train movement; east or west, respectively. The infrared sensor itself produces a voltage related to the intensity of the heat radiation incident within its solid angle of sight. Normally off, this sensor is gated on with wheel detector 2 or 3, depending upon the established direction of train travel, to ensure the generation of heat information only when the bearing itself is over the scanner.

A train coming to the H.B.D. location from wheel detector 1 establishes direction of travel when detector 2 is activated. At that point the infrared sensor is gated on and, with the wheel now over its line of sight, scans the overhead wheel bearing. The moment the wheel arrives at wheel detector 3, the sensor is turned off to avoid scanning the rest of the train. This sequence of operation of wheel detectors 2 and 3 is repeated for every wheel on a train. The gating of senor 1 is only effective for the first wheel at the beginning of the train as direction needs to be established only once. Activation of any wheel sensor keeps the "Train Present" signal on.

Note: Discussion open until October 15, 1976.

After each heat pulse is generated, it is sent to the pulse processor where it is peak detected, then amplified and buffered to drive the carrier transmitter. The carrier transmitter relays the peak value to a central receiving office.

A typical H.B.D. Scanner is shown in Fig. 3.

The overall block diagram of the typical data handling system for a H.B.D. location is shown in Fig. 4. Each field location has two infrared detectors, one for each side of the train, and information coming from each is separately transmitted and received. Whenever a train enters a detector location, the output of the data control unit activates a relay which is used to key "ON" the two carrier transmitters for that location. At the central office, where all H.B.D. outputs are read, the heat data from each side of the train is received on separate channels and each channel is fed to one pen of a two-pen recorder. Each of the two receivers per location also has a carrier presence indication to provide location status. Train presence over the H.B.D. site is generated by AND'ing the two carrier presence outputs while, between trains, the two carrier channels are alternately gated on for the verification of each. The pen recorder, normally off, is started with the appearance of the train presence indication. An audible and visual alarm device is used to alert the tape reader of predefined heat alarm levels.

Fig. 5 shows a typical output and the interaction between train present and the recorder data output. Note the first car shows characteristically high pulses. This is because it is a roller-bearing car and *appears* to be hot, but in actual fact only more of the generated heat is visible.

In Fig. 6 we can see that on a car equipped with roller bearings there is no journal oil box to impede the line of sight of the infrared sensor. This causes the higher characteristic pulse seen on Fig. 5.

Reasons for Automated Analysis

Considering the type of system described it can be seen that there are several factors which influence the ability of the system to detect hot boxes. They are:

1. *Interpretation* of the data on the paper recordings depends on people and thus is not consistent.
2. Emotional state of mind of the tape reader greatly influences the system performance.
3. Employee mobility makes it difficult to maintain a good data evaluation standard.
4. It is a full stereo system and as such each rail could have a different system gain factor, thus generating false alarms on the fixed alarm system.
5. Noise generated by electrical storms sets off alarms and tends to make tape readers disgusted with the system, thereby reducing their ability to effectively read the tapes.

Fig. 7 shows how electrical interference can generate many false outputs in an unfiltered system and how (channel 2) filtering can greatly reduce this problem.

Benefits from Automated Data Evaluation

Fig. 8 lists the benefits of an automated evaluation system to the user of hot box detector data (Transportation Department).

Fig. 9 lists the benefits of an automated evaluation system to the hot box detector maintainers and technicians. Better maintenance is made possible by closer system observation using statistical evaluation made possible by the computerized system.

Configuration of automated systems can be as different as the people designing them. Shown in Fig. 10 is one possibility and the uses for the various in/output devices.

The CN Data Analysis System

On the block diagram shown in Fig. 11 it can be seen that the main element is Computer Automation LSI2/20, mini computer with 32K core and a 4.2M word DISC. This provides the ability (intelligence) to control the various interfaces and I/O devices as well as evaluate the data and detect hot boxes.

As can be seen on Fig. 12 the hardware (with complete spares) is mounted in three 19-in. racks. The I/O devices, shown beside the computers, may be mounted any reasonable distance away. This allows operators/dispatchers to have a cathode ray tube (C.R.T.) on their desks.

In Fig. 13 we can see the full complement of output devices used. One printer, C.R.T. and analogue recorder are actually located in the tape readers/dispatchers office. The tape reader may recall any train (presently programmed for close to 24 hours storage) for re-evaluation, viewing of the digitized data or output on the analogue recorder. Additionally an analogue recording is automatically produced if the computer is not able to evaluate the train. Control of the system is achieved with the maintainers C.R.T., where such things as: I/O device assignment, data evaluation parameters, noise filtering parameters, etc., may be changed. The maintainers devices also act as back up units (spares) in the event of a failure. In addition to the previously mentioned recordings the maintainers' recorder is automatically switched to the carrier output of any location not sending in good data, thus providing a direct analogue recording of the signals so that all symptoms can be seen. If this were not done only the filtered/digitized data would be available from the computer memory.

Training of personnel is greatly simplified by the use of a "HELP" command. This results in an output listing of all the system commands and shows the function of each one. The commands listed in Fig. 14 are only those available on that particular C.R.T. and are obviously different for the maintainer and the tape reader.

The alarm panel shown in Fig. 15 is used by the tape readers to call attention to the fact that an abnormality has occurred. The alarm must then be acknowledged on the C.R.T. before it is turned off. The computer fails and self check alarms are activated whenever there is a failure of the system hardware or software. The quality of this check system is quite high but only experience will indicate if it is adequate.

A listing of all the trains past a particular location can be obtained by keying in the appropriate command on the C.R.T. Shown in Fig. 16 is the list of messages from one location (Newtonsville North "NVN"). The one line messages show all the important data associated with the train.

An example of the command format used in the system to request stored data can be seen in Fig. 17. All data requests are based on train sequence number and location.

The list of numbers on Fig. 18 shows in hexadecimal code what data is in memory for the train. All data including pulses is stored so that re-evaluation with different parameters is made possible. (An explanation of the list is given.)

An overview of the system can be seen in the block diagram, Fig. 11. The data enters the computer through CN designed interfacing. Peak detection of the heat information is accomplished external to the computer because I/O speeds are not fast enough to collect accurate values from the 24 locations in the system.

An item of particular importance is the self checking system. This system outputs information from the computer which is routed back to the input for verification. If any channel or other part of the system becomes defective an alarm message is generated and the tape reader is alerted via the alarm panel.

System Outputs

The outputs shown in Figs. 19 through 23 are from the engineering model which was tested in 1974. These examples were selected because they exemplify the main points of interest very well and show the reasons for certain design parameters.

Fig. 19 shows a typical output for a train with no problem. The top portion shows the normal paper recording and the bottom shows the computer print-out. An important thing to note here is that on the average one side of the output (Rail 1) is 1.2 mm higher than the other. The effect of this difference is minimized by the use of ratios relating only to one side of the car. This can be seen in the fact that the maximum train side ratios (NMTSR and SMSTR) are almost the same even though the actual values are considerably different.

Figs. 20, 21 and 22 show how the use of ratios normalizes the data in spite of some rather large differences in absolute pulse values. These differences in value are due to different system gain settings in the scanners. In spite of variations between 8.3 mm and 11.3 mm on the analogue recording the car side ratios (CSR) varied by only 0.02 (1.96 to 1.98). This consistency in evaluation is made possible in spite of absolute values.

Fig. 23 is an actual hot box graph and computer printout. The order of magnitude of ratios (both car side ratio (CSR) and train side ratio TSR) can be seen when a single wheel is hot. If two wheels were hot the T.S.R. would be much the same but C.S.R. woud be smaller. (Maybe even in a non-alarm zone).

The train graph, Fig. 24, shows a string of pulses at the end of the train, which are actually pedestal pulses generated at the hot box detector field location. Use of this information allows data to be normalized so that heat evaluation is done only on heat information, not on heat plus pedestal as is being done in the manual systems. If normalized data is not used the weighting factor of high pedestals will result in small ratios and thus, potentially, a hot box may be missed.

Digital Transmission System

Analogue carrier systems, which are being used to transfer information from the field sites to the central office, are subject to many types of noise interference. This noise may be generated by lighting, line cross talk, carrier drop out, etc., and usually results in either spurious data or a loss of data, thus making it very difficult to correctly recognize and evaluate the heat information.

A digitizer/transmitter has been developed by the Canadian National Technical Research Department for use at the hot box detector field sites. The "digital transmission system" peak detects the information from the bolometer and converts it into an 8 bit digital "Word". These words, together with wheel spacing information, are stored in a 2,024 word (8 bits each) memory for later transmission. When the train present signal goes away the entire message is transmitted to the office using a standard FSK carrier system. To eliminate the problem of noise destroying the message it has both parity and block checks as well as being transmitted five times.

Self enhancement of the five transmission results in a very secure system which can reproduce a good message even though portions of the individual transmissions are destroyed.

Because the above-mentioned system is in the final development stages its actual performance record cannot be discussed, but it is fairly obvious that a much better quality of data will be made available to the tape readers or the computerized analysis system. Along with this improvement there should be considerable savings in maintenance since no calibration or adjustments of the carrier is required (aside from line level settings). This calibration (and linearity check) procedure should be done about twice a year in order to guarantee good performance on the analogue carrier.

Fig. 25 (not reproduced herein) is the field digitizer unit showing the front panel (test and display) and the shielded electronics cage. The unit is 5½-in. high and fits onto a 19-in. communications rack.

In Figs. 26 and 27 the cover of the electronics shield has been removed to expose the hardware which accomplishes peak detection, D/A conversion, memory and control logic. As can be seen in these pictures it is not a monumental task to build a system which will greatly enhance the performance of the data transmission system and as technology advances the digitizing system will become even simpler.

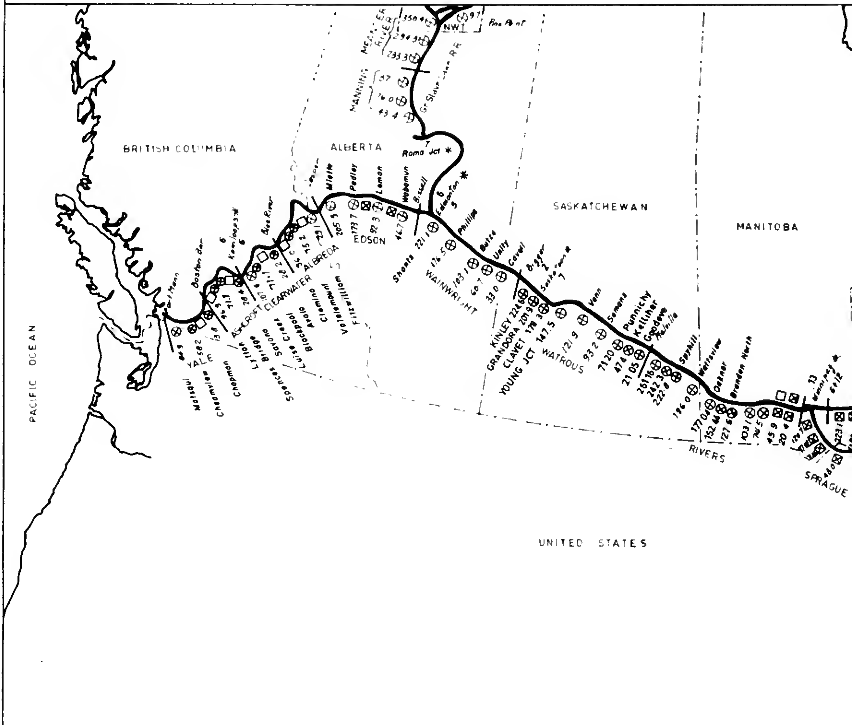
General

Some fringe benefits of the automated analysis system are such things as:

- train speed checks
- trains aren't lost due to out-of-ink or out-of-paper situations
- lightning generally will not set off the alarms and thus the tape reader is not annoyed
- statistical evaluation of data base allows trends and anomalies to be recognized and handled
- better overall system calibration and consistency of data input made possible by a common standard (data analyzer)
- no paper tape is required for system operation and therefore recorder maintenance is minimized.

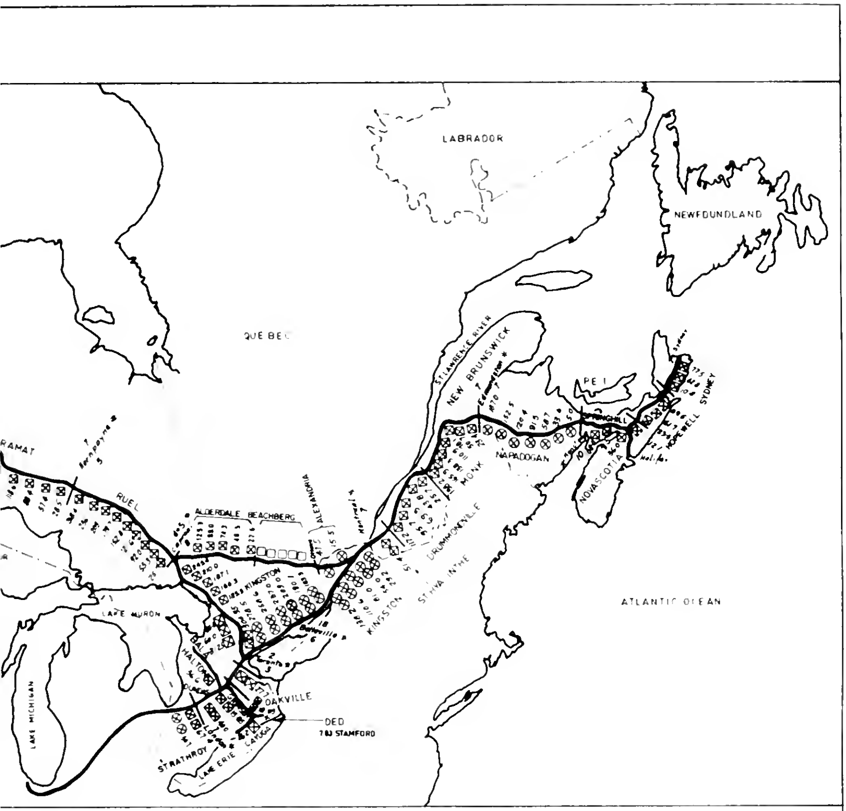
Figs. 28 to 34 show various views of the hardware used to implement the analyzer system in an office with up to 32 hot box detector systems reporting. These pictures show the system installed on the Canadian National at Belleville, Ontario, and operates 24 hot box detector locations. Although an engineering model of the system working with 4 hot box detectors was installed at Belleville in 1974, the present 24-location system has just been installed in February of this year.

Thank you for your attention. I hope that this brief description of our effort to improve the hot box detection system has been informative and interesting.



TOTALS		M	P	GL	SL	A		
	7707	28	18	22	4	7		
	8808	2	21	43	7	17		
		30	39	65	11	24	169	-1975
		6	1				7	-1976 (AFE'S)
							176	

Fig. 1



○ - HOT BOX DET. #7707
☐ = " " " #8808
X =IN SERVICE
✱ =READ OUT POINTS

DATE D M Y	REVISIONS	D	C
29 4 74	PLAN RENUMBERED (WAS C-DG-5)		
6-1-75	UPDATED TO END OF 1974		
6-1-76	UPDATED TO END OF 1975		

CANADIAN NATIONAL RAILWAYS

AREA SUB

SIGNAL ENGINEERING
MONTREAL

DES V S L
DR E B
CH

8 JANUARY, 1974

HOT BOX DETECTOR LOCATIONS
ENTIRE SYSTEM

S-DG-5

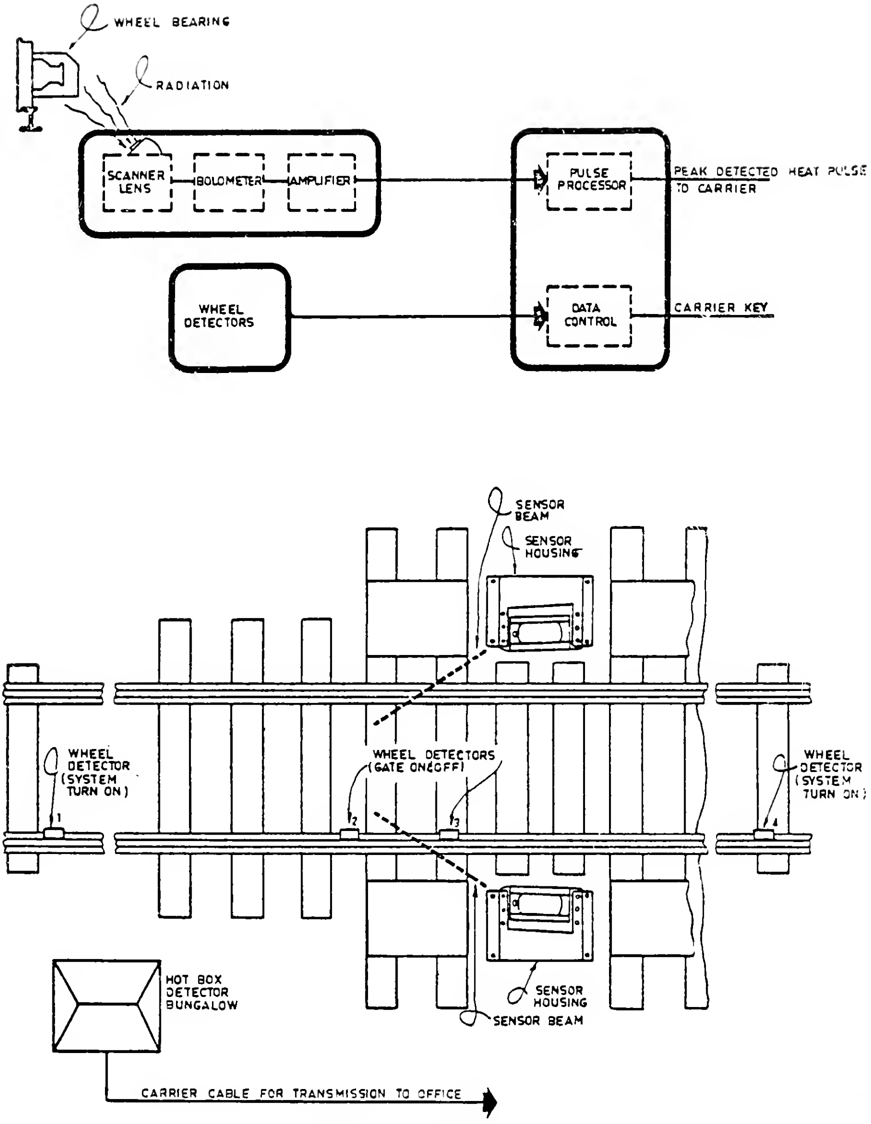


Fig. 2—Field equipment.

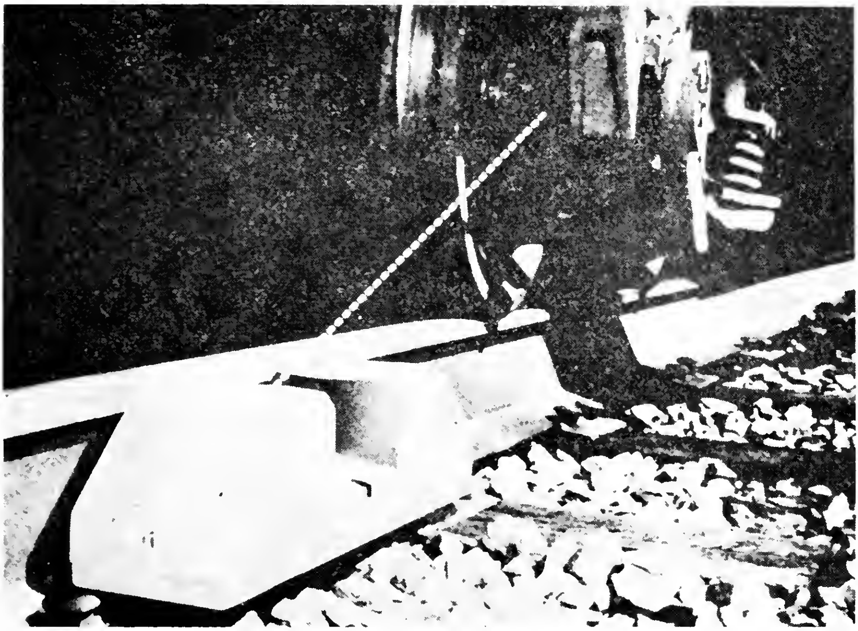
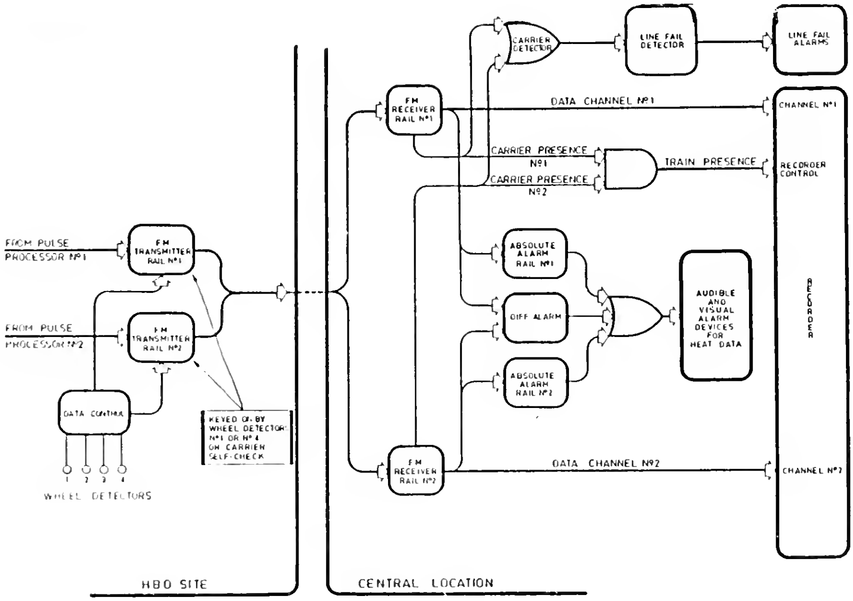


Fig. 3



HBD DATA PROCESSING SYSTEM PER LOCATION

Fig. 4

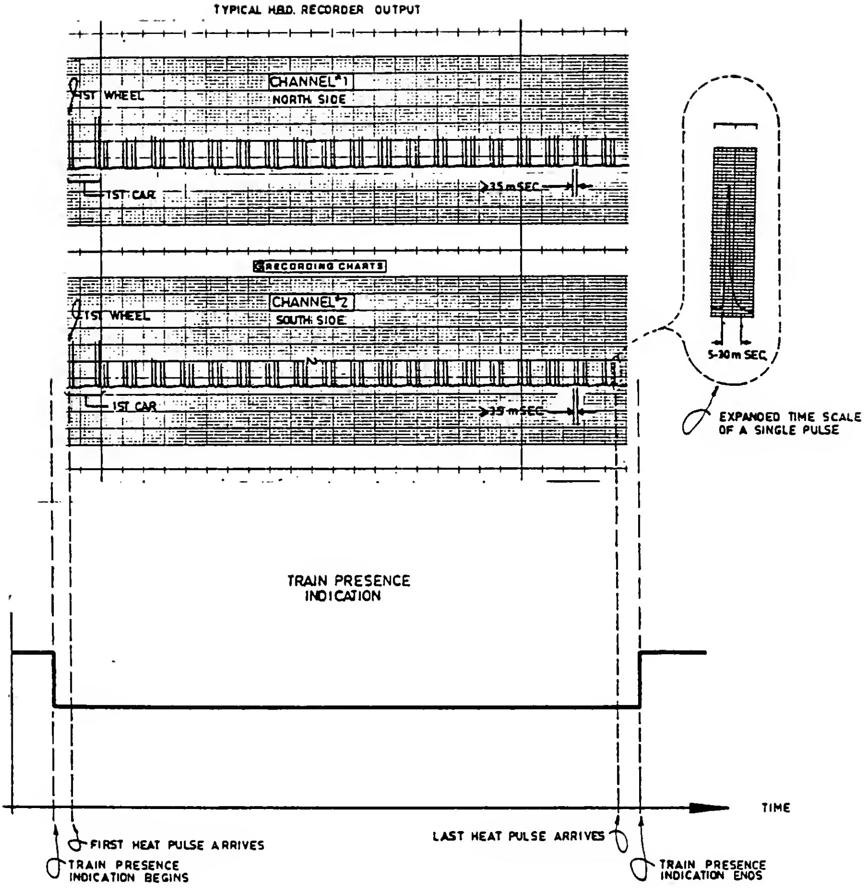


Fig. 5—H.B.D. receiver outputs, heat data and train presence.

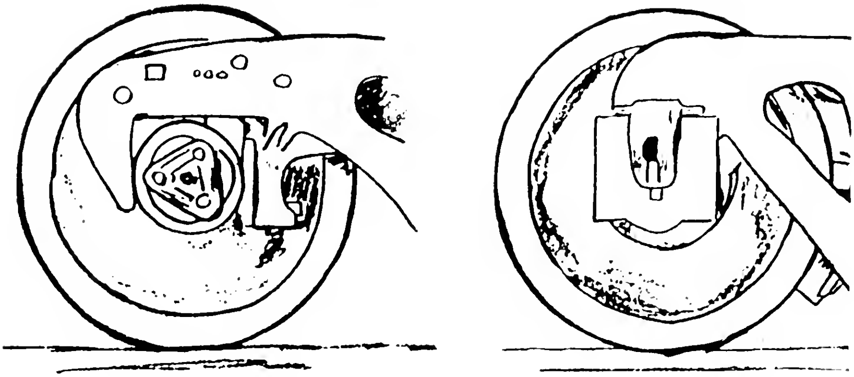


Fig. 6

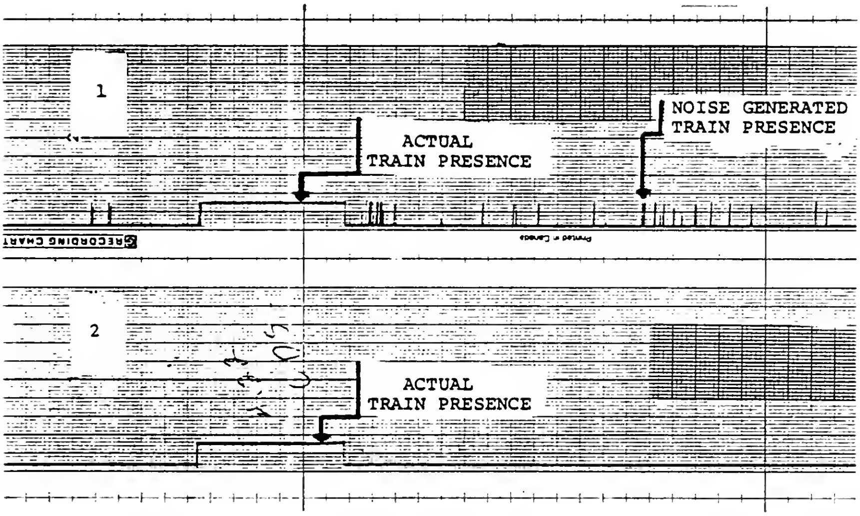
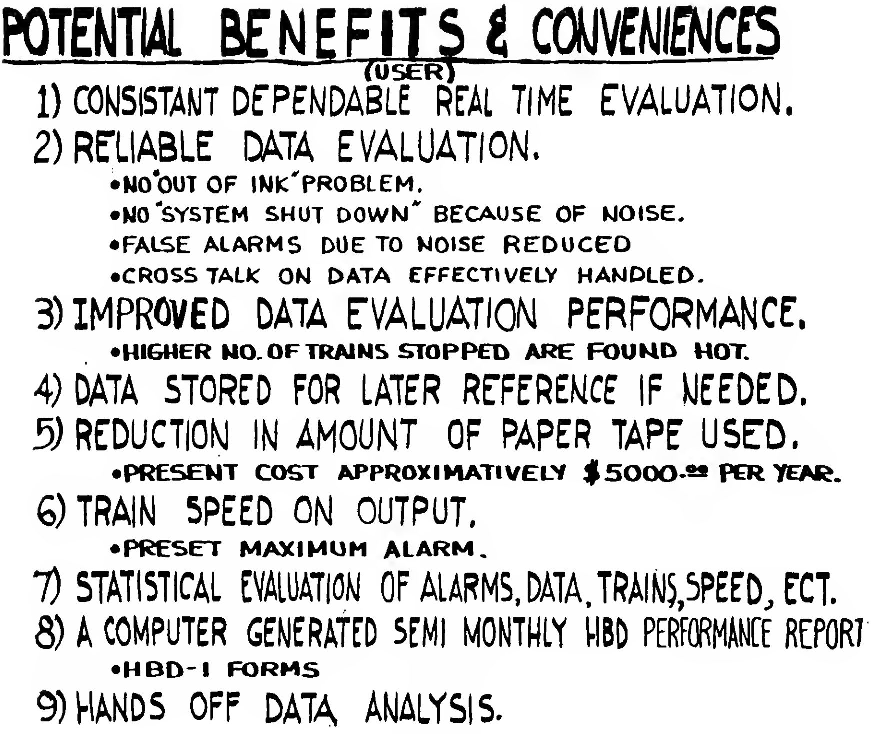


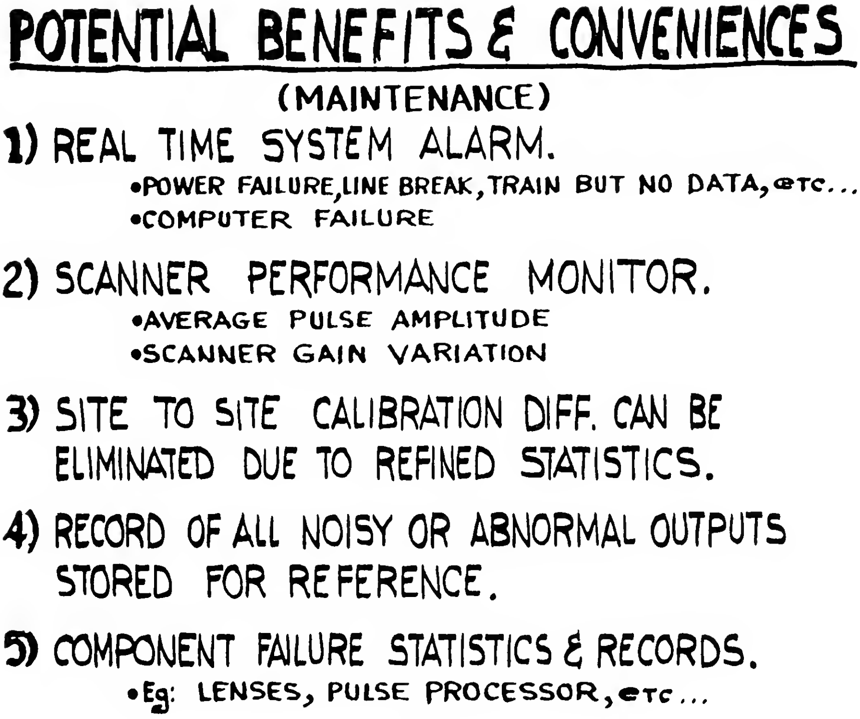
Fig. 7—Train presence detection on:
1. Servo (manual system),
2. H.B.D. analyzer.



POTENTIAL BENEFITS & CONVENIENCES
(USER)

1) CONSISTANT DEPENDABLE REAL TIME EVALUATION.
2) RELIABLE DATA EVALUATION.
    - NO "OUT OF INK" PROBLEM.
    - NO "SYSTEM SHUT DOWN" BECAUSE OF NOISE.
    - FALSE ALARMS DUE TO NOISE REDUCED
    - CROSS TALK ON DATA EFFECTIVELY HANDLED.
3) IMPROVED DATA EVALUATION PERFORMANCE.
    - HIGHER NO. OF TRAINS STOPPED ARE FOUND HOT.
4) DATA STORED FOR LATER REFERENCE IF NEEDED.
5) REDUCTION IN AMOUNT OF PAPER TAPE USED.
    - PRESENT COST APPROXIMATIVELY $5000.00 PER YEAR.
6) TRAIN SPEED ON OUTPUT.
    - PRESET MAXIMUM ALARM.
7) STATISTICAL EVALUATION OF ALARMS, DATA, TRAINS, SPEED, ECT.
8) A COMPUTER GENERATED SEMI MONTHLY HBD PERFORMANCE REPORT
    - HBD-1 FORMS
9) HANDS OFF DATA ANALYSIS.

Fig. 8



POTENTIAL BENEFITS & CONVENIENCES

(MAINTENANCE)

1) REAL TIME SYSTEM ALARM.
- POWER FAILURE, LINE BREAK, TRAIN BUT NO DATA, etc...
- COMPUTER FAILURE

2) SCANNER PERFORMANCE MONITOR.
- AVERAGE PULSE AMPLITUDE
- SCANNER GAIN VARIATION

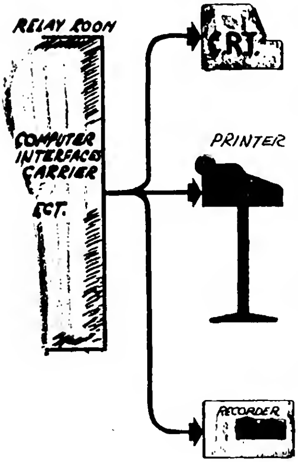
3) SITE TO SITE CALIBRATION DIFF. CAN BE ELIMINATED DUE TO REFINED STATISTICS.

4) RECORD OF ALL NOISY OR ABNORMAL OUTPUTS STORED FOR REFERENCE.

5) COMPONENT FAILURE STATISTICS & RECORDS.
- Eg: LENSES, PULSE PROCESSOR, etc...

Fig. 9

POSSIBLE (VISUALIZED) I/O DEVICES



- POSSIBLE TO HAVE MORE THAN ONE *
- USED FOR IMMEDIATE OUTPUT OF ALARMS, STATISTICAL DATA, ETC...
- USED FOR REQUESTING A TRAIN 'RECALL

- POSSIBLE TO HAVE MORE THAN ONE.
- USED FOR HARD COPY RECORD OF ALL TRAINS.
- WILL PRINT OPPERATORS RESPONSE TO ALARMS.
- PRINTS RECORD OF ALL RECALL ACTIVITY.

- PAPER TAPE (ANALOG) OUTPUT OF TRAIN.
- PRODUCED IF REQUESTED BY DISPATCHER
- REPRODUCTION OF TRAIN IN ORIGINAL PULSE PATTERN.

Fig. 10

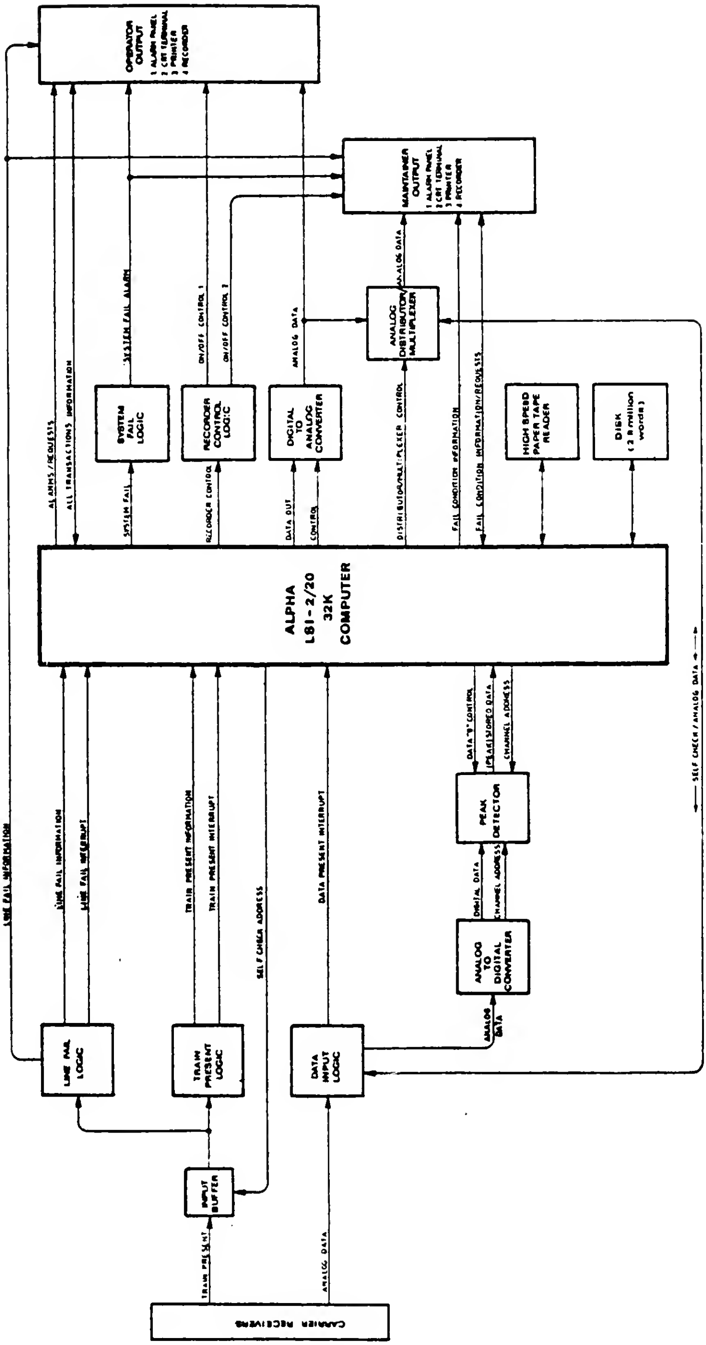

OPERATOR OUTPUT
1 ALARM PANEL
2 CRT TERMINAL
3 PRINTER
4 RECORDER
MAINTAINER OUTPUT
1 ALARM PANEL
2 CRT TERMINAL
3 PRINTER
4 RECORDER
SYSTEM FAIL ALARM
ON/OFF CONTROL 1
ON/OFF CONTROL 2
ANALOG DATA
ANALOG DATA
ANALOG DISTRIBUTOR/MULTIPLEXER
ALARMS/REQUESTS
ALL TRANSACTIONS INFORMATION
SYSTEM FAIL LOGIC
RECORDER CONTROL LOGIC
DIGITAL TO ANALOG CONVERTER
HIGH SPEED PAPER TAPE READER
DISK (2.8 million words)
SYSTEM FAIL
RECORDER CONTROL
DATA OUT
CONTROL
DISTRIBUTOR/MULTIPLEXER CONTROL
FAIL CONDITION INFORMATION
FAIL CONDITION INFORMATION/REQUESTS
ALPHA LSI-2/20 32K COMPUTER
DATA "B" CONTROL
PEAKS/STORED DATA
CHANNEL ADDRESS
PEAK DETECTOR
DIGITAL DATA
CHANNEL ADDRESS
ANALOG TO DIGITAL CONVERTER
ANALOG DATA
SELF CHECK / ANALOG DATA
LINE FAIL INFORMATION
LINE FAIL INFORMATION
LINE FAIL INTERRUPT
TRAIN PRESENT INFORMATION
TRAIN PRESENT INTERRUPT
SELF CHECK ADDRESS
DATA PRESENT INTERRUPT
LINE FAIL LOGIC
TRAIN PRESENT LOGIC
DATA INPUT LOGIC
INPUT BUFFER
TRAIN PRESENT
ANALOG DATA
CARRIER RECEIVERS

Fig. 11

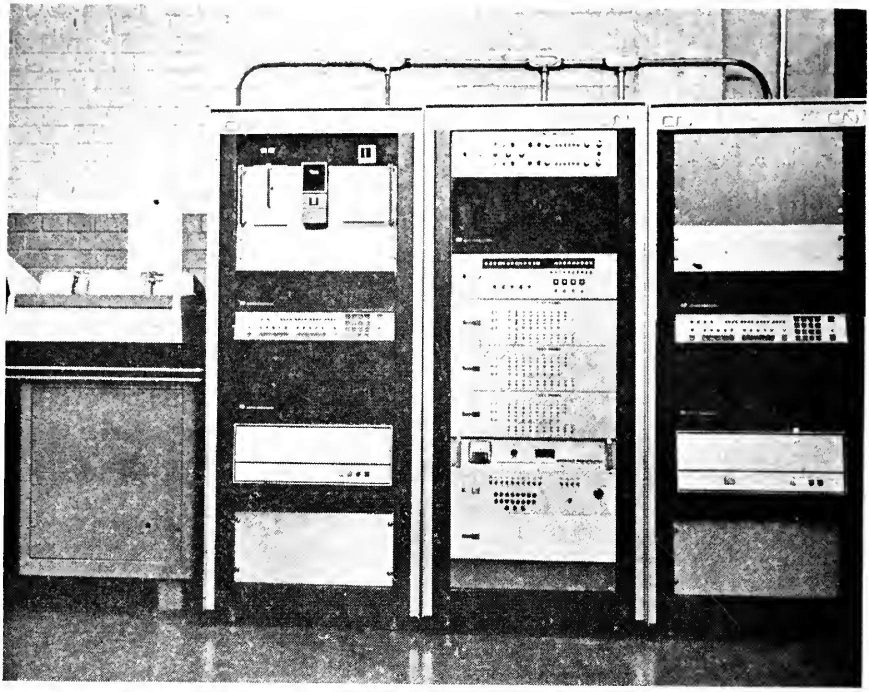


Fig. 12

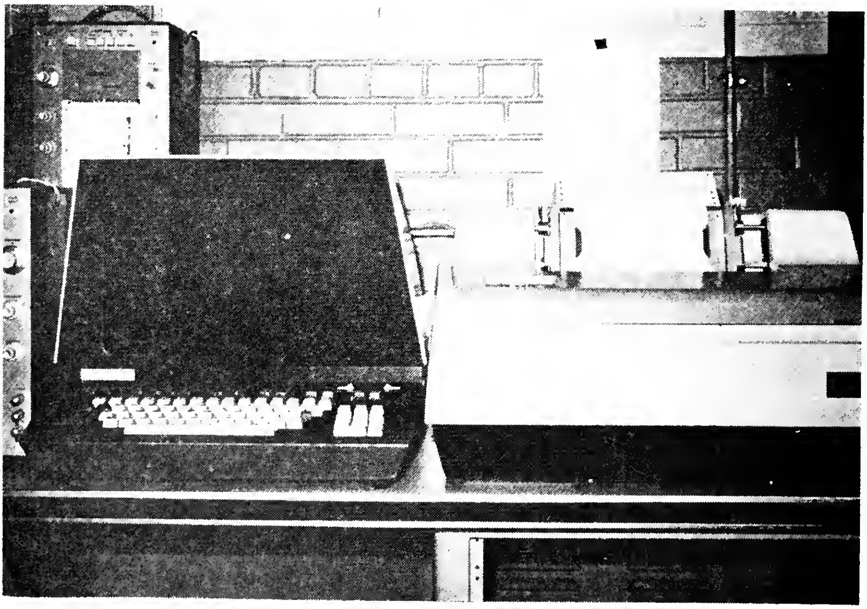
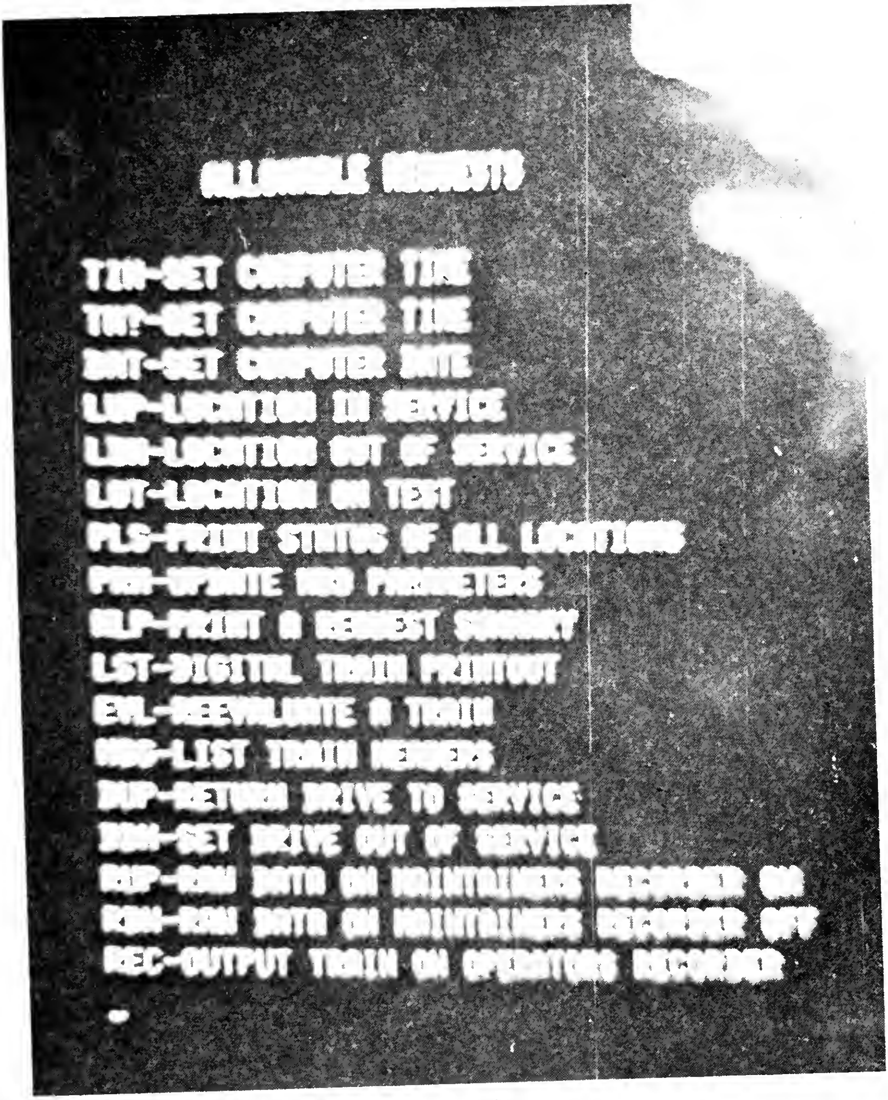


Fig. 13



```
       ALLOWABLE REQUESTS

TIN-SET COMPUTER TIME
TM?-SET COMPUTER TIME
DAT-SET COMPUTER DATE
LUP-LOCATION IN SERVICE
LDN-LOCATION OUT OF SERVICE
LOT-LOCATION ON TEST
PLS-PRINT STATUS OF ALL LOCATIONS
PRM-UPDATE HBD PARAMETERS
HLP-PRINT A REQUEST SUMMARY
LST-DIGITAL TRAIN PRINTOUT
EVL-REEVALUATE A TRAIN
NBR-LIST TRAIN NUMBERS
DUP-RETURN DRIVE TO SERVICE
DDN-SET DRIVE OUT OF SERVICE
MUP-RAW DATA ON MAINTAINERS RECORDER ON
MDN-RAW DATA ON MAINTAINERS RECORDER OFF
REC-OUTPUT TRAIN ON OPERATORS RECORDER

*
```

Fig. 14

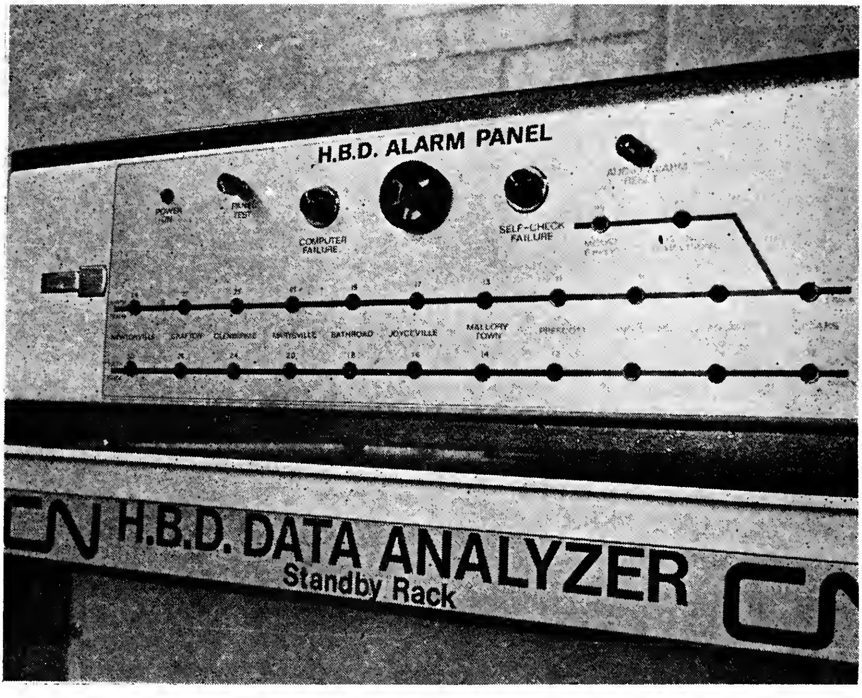
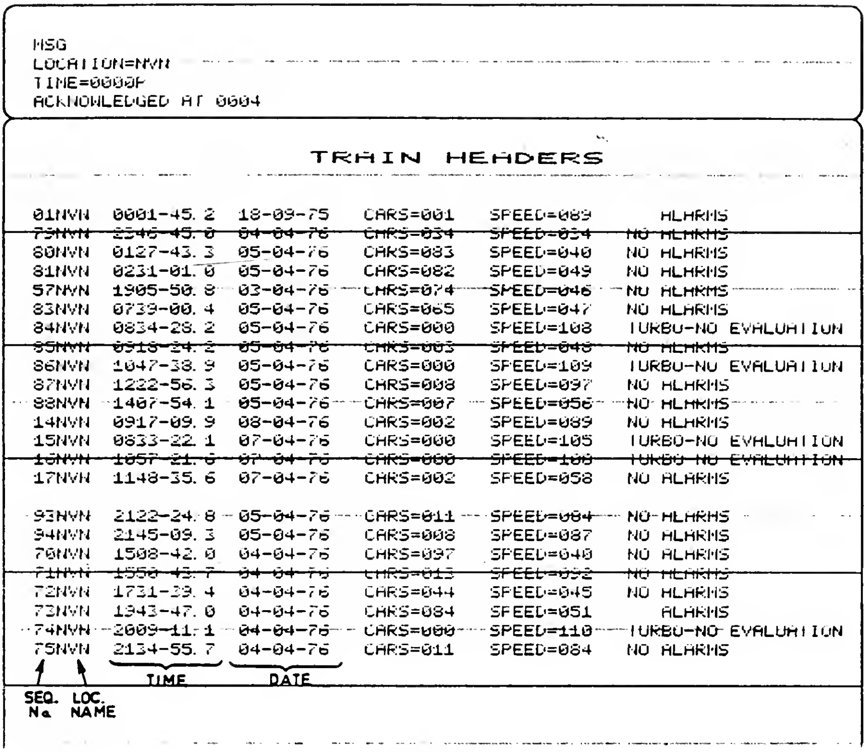

H.B.D. ALARM PANEL
POWER ON
PANEL TEST
COMPUTER FAILURE
SELF-CHECK FAILURE
JOYCEVILLE
MALLORY TOWN
H.B.D. DATA ANALYZER
Standby Rack

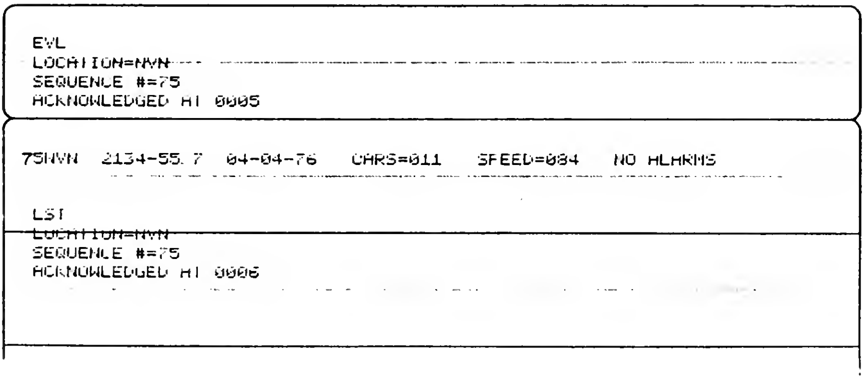
Fig. 15



```
MSG
LOCATION=NVN
TIME=0000F
ACKNOWLEDGED AT 0004
```

```
                         TRAIN  HEADERS

01NVN  0001-45.2  18-09-75  CARS=001  SPEED=089      ALARMS
79NVN  2346-45.0  04-04-76  CARS=034  SPEED=034  NO ALARMS
80NVN  0127-43.3  05-04-76  CARS=083  SPEED=040  NO ALARMS
81NVN  0231-01.0  05-04-76  CARS=082  SPEED=049  NO ALARMS
57NVN  1905-50.8  03-04-76  CARS=074  SPEED=046  NO ALARMS
83NVN  0739-00.4  05-04-76  CARS=065  SPEED=047  NO ALARMS
84NVN  0834-28.2  05-04-76  CARS=000  SPEED=108  TURBO-NO EVALUATION
85NVN  0918-24.2  05-04-76  CARS=003  SPEED=048  NO ALARMS
86NVN  1047-38.9  05-04-76  CARS=000  SPEED=109  TURBO-NO EVALUATION
87NVN  1222-56.3  05-04-76  CARS=008  SPEED=097  NO ALARMS
88NVN  1407-54.1  05-04-76  CARS=007  SPEED=056  NO ALARMS
14NVN  0917-09.9  08-04-76  CARS=002  SPEED=089  NO ALARMS
15NVN  0833-22.1  07-04-76  CARS=000  SPEED=105  TURBO-NO EVALUATION
16NVN  1057-21.6  07-04-76  CARS=000  SPEED=108  TURBO-NO EVALUATION
17NVN  1148-35.6  07-04-76  CARS=002  SPEED=058  NO ALARMS

93NVN  2122-24.8  05-04-76  CARS=011  SPEED=084  NO ALARMS
94NVN  2145-09.3  05-04-76  CARS=008  SPEED=087  NO ALARMS
70NVN  1508-42.0  04-04-76  CARS=097  SPEED=040  NO ALARMS
71NVN  1550-43.7  04-04-76  CARS=013  SPEED=052  NO ALARMS
72NVN  1731-39.4  04-04-76  CARS=044  SPEED=045  NO ALARMS
73NVN  1343-47.0  04-04-76  CARS=084  SPEED=051      ALARMS
74NVN  2009-11.1  04-04-76  CARS=000  SPEED=110  TURBO-NO EVALUATION
75NVN  2134-55.7  04-04-76  CARS=011  SPEED=084  NO ALARMS
```

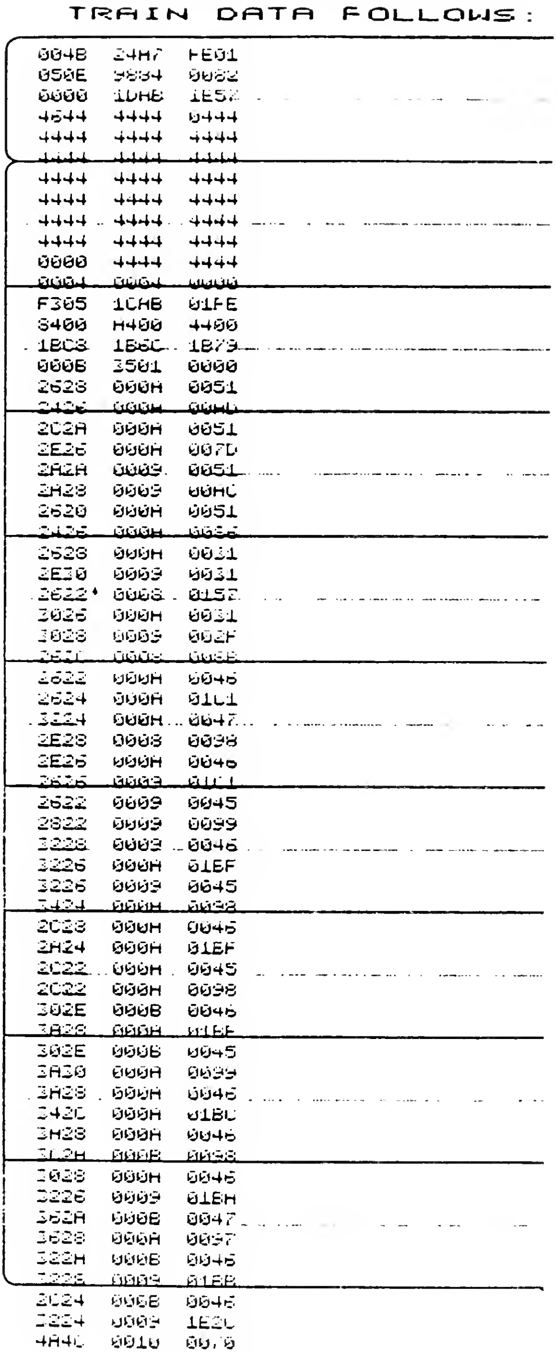
Fig. 16



```
EVL
LOCATION=NVN
SEQUENCE #=75
ACKNOWLEDGED AT 0005
```

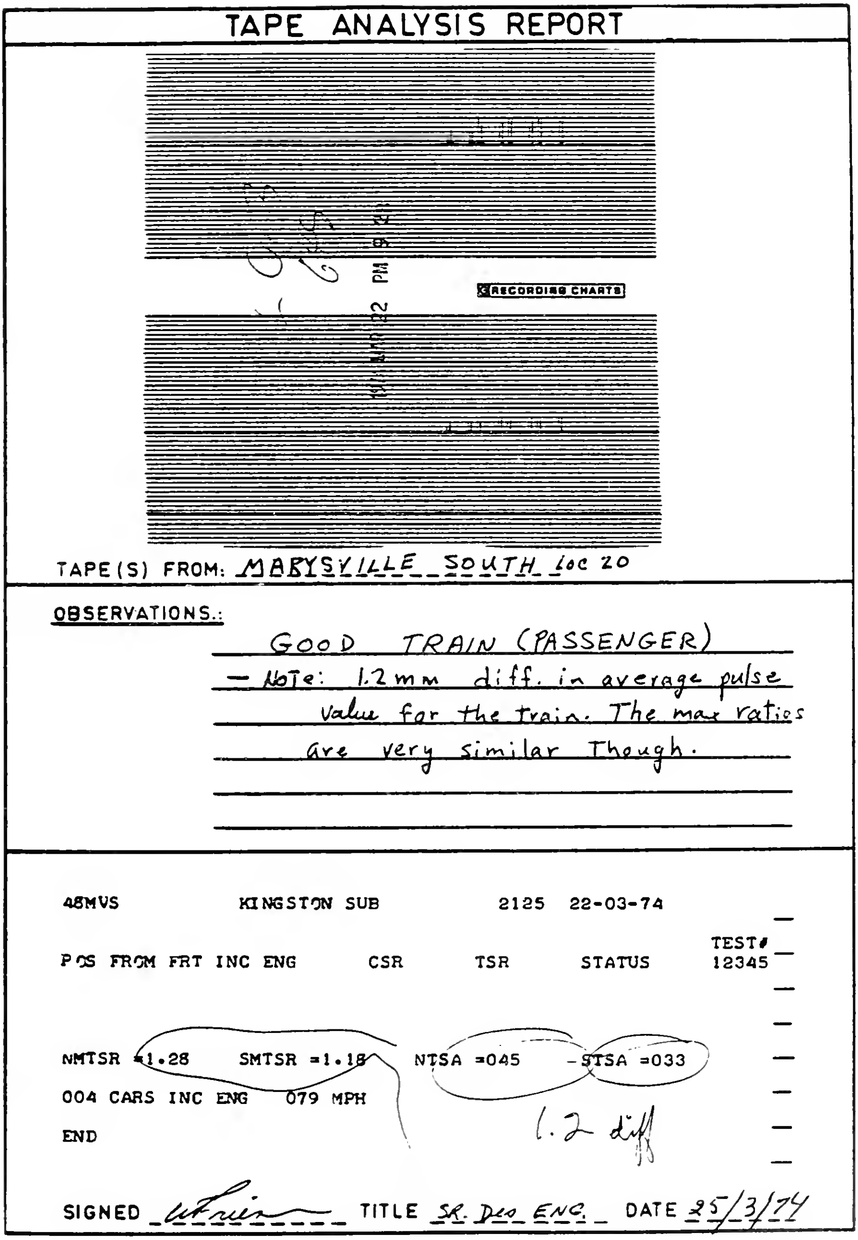
```
75NVN  2134-55.7  04-04-76  CARS=011  SPEED=084  NO ALARMS


LST
LOCATION=NVN
SEQUENCE #=75
ACKNOWLEDGED AT 0006
```

Fig. 17



```
TRAIN DATA FOLLOWS:

0048   24A7   FE01
050E   9834   0082
0000   1DAB   1E57
4644   4444   0444
4444   4444   4444
4444   4444   4444
4444   4444   4444
4444   4444   4444
4444   4444   4444
4444   4444   4444
0000   4444   4444
0004   0064   0000
F305   1CAB   01FE
8400   A400   4400
1BC8   1B6C   1B79
0006   3501   0000
2628   000A   0051
2426   000A   00AC
2C2A   000A   0051
2E26   000A   007D
2A2A   0009   0051
2A28   0009   00AC
2620   000A   0051
2426   000A   0036
2628   000A   0031
2E30   0009   0031
2622   0008   0152
3026   000A   0031
3028   0009   002F
2C2C   0009   0068
2622   000A   0046
2624   000A   01C1
3224   000A   0047
2E28   0008   0038
2E26   000A   0046
2626   0009   01C1
2622   0009   0045
2822   0009   0099
3228   0009   0046
3226   000A   01EF
3226   0009   0045
3424   000A   0098
2C28   000A   0046
2A24   000A   01EF
2C22   000A   0045
2C22   000A   0098
302E   000B   0046
3828   000A   01EF
302E   0006   0045
3A30   000A   0039
3A28   000A   0046
342C   000A   01BC
3A28   000A   0046
3C2A   000B   0098
3028   000A   0046
3226   0009   01EA
362A   0008   0047
3628   000A   0097
322A   0006   0046
3228   0009   01EB
2C24   0008   0046
3224   0009   1E2C
4A4C   0010   0076
```

Fig. 18



TAPE ANALYSIS REPORT

TAPE(S) FROM: MARYSVILLE SOUTH loc 20

OBSERVATIONS.:

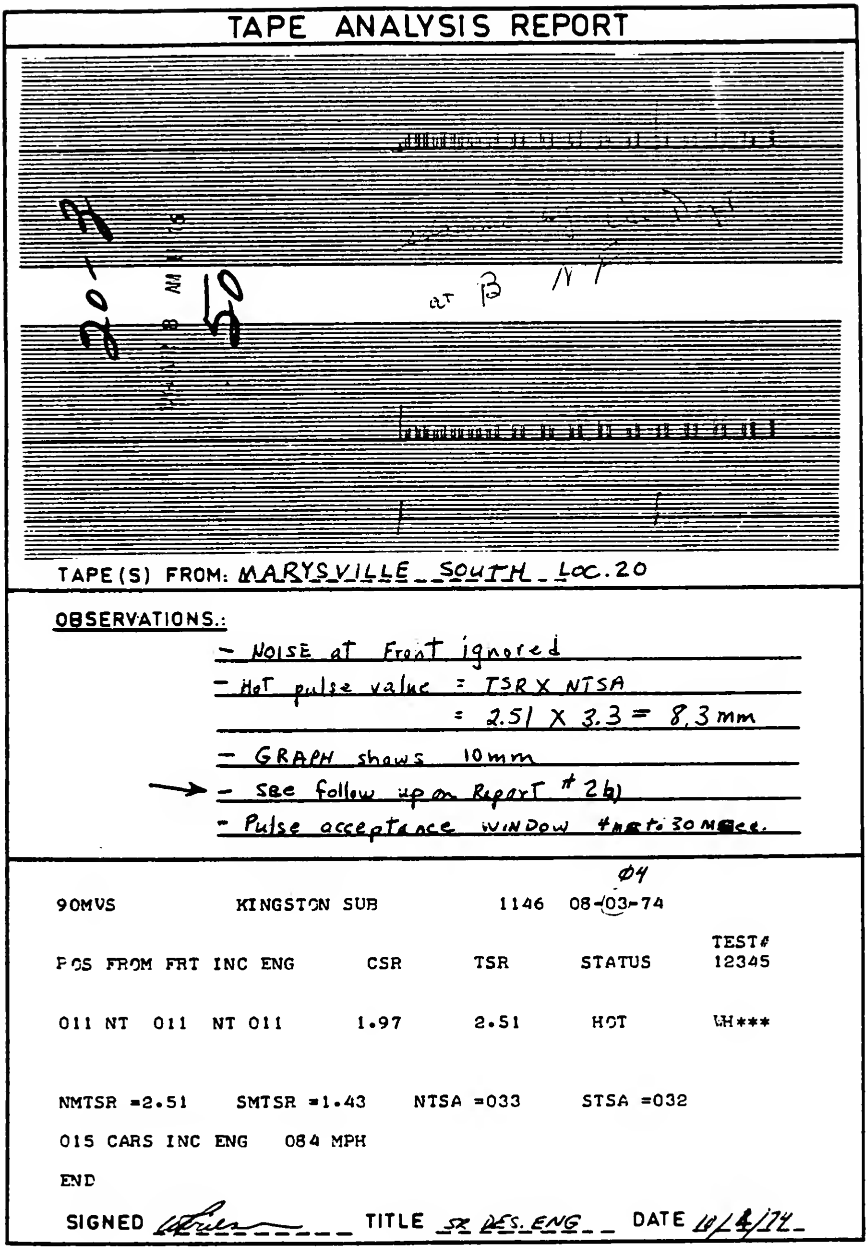
GOOD TRAIN (PASSENGER)
– Note: 1.2 mm diff. in average pulse value for the train. The max ratios are very similar though.

```
48MVS             KINGSTON SUB           2125   22-03-74

                                                          TEST#
POS FROM FRT INC ENG      CSR       TSR       STATUS      12345


NMTSR =1.28     SMTSR =1.18     NTSA =045     -STSA =033
004 CARS INC ENG    079 MPH
END
```

1.2 diff

SIGNED W Friesen TITLE SR. Des ENG. DATE 25/3/74

Fig. 19



TAPE ANALYSIS REPORT

TAPE(S) FROM: MARYSVILLE SOUTH Loc.20

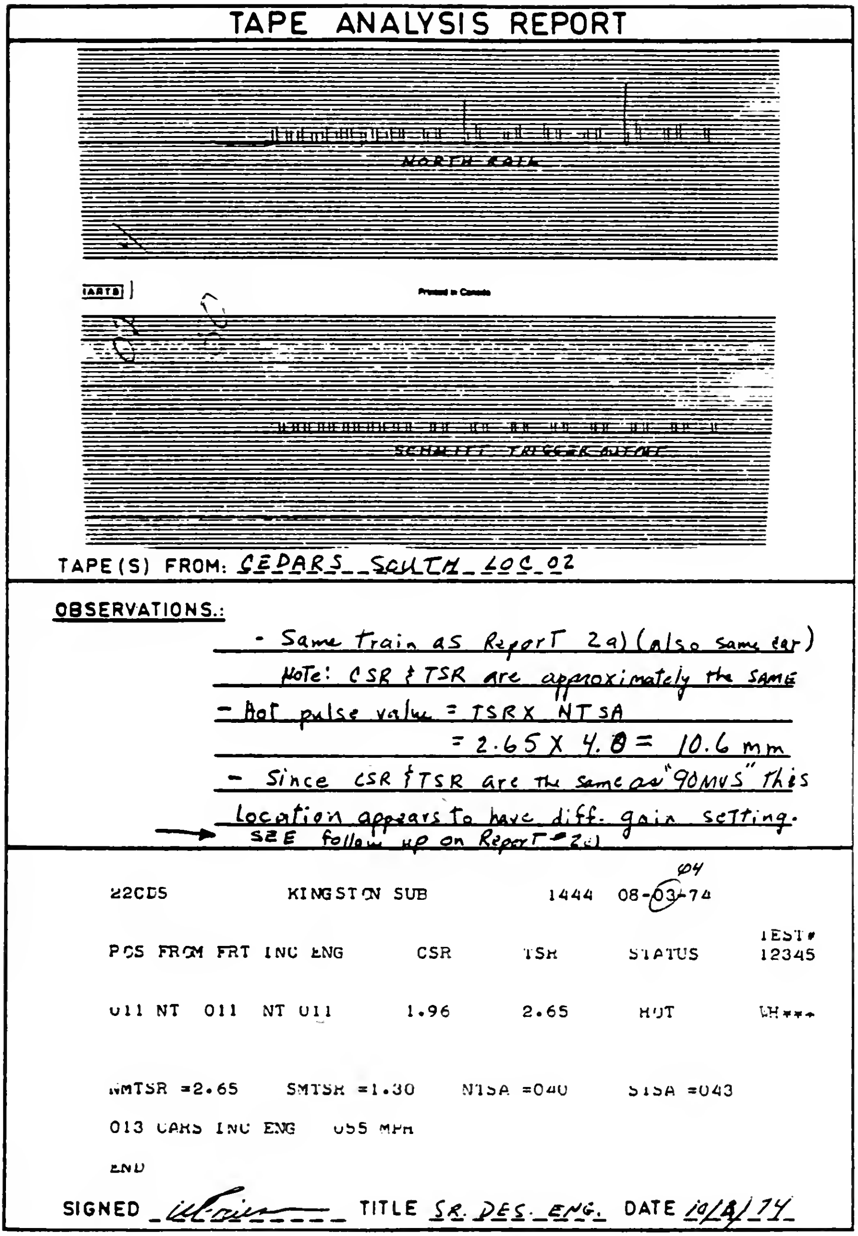
OBSERVATIONS.:

- NOISE at Front ignored
- HOT pulse value = TSR X NTSA
  = 2.51 X 3.3 = 8.3 mm
- GRAPH shows 10 mm
- → see follow up on Report # 2b)
- Pulse acceptance WINDOW 4 m to 30 msec.

```
                                          Ø4
9OMVS          KINGSTON SUB        1146   08-03-74

                                                         TEST#
POS FROM FRT INC ENG      CSR      TSR      STATUS      12345

011 NT  011  NT 011       1.97     2.51      HOT        WH***


NMTSR =2.51    SMTSR =1.43    NTSA =033    STSA =032
015 CARS INC ENG    084 MPH
END
```

SIGNED TITLE SR DES. ENG DATE 10/4/74

Fig. 20



TAPE ANALYSIS REPORT

TAPE(S) FROM: CEDARS SOUTH LOC 02

OBSERVATIONS.:

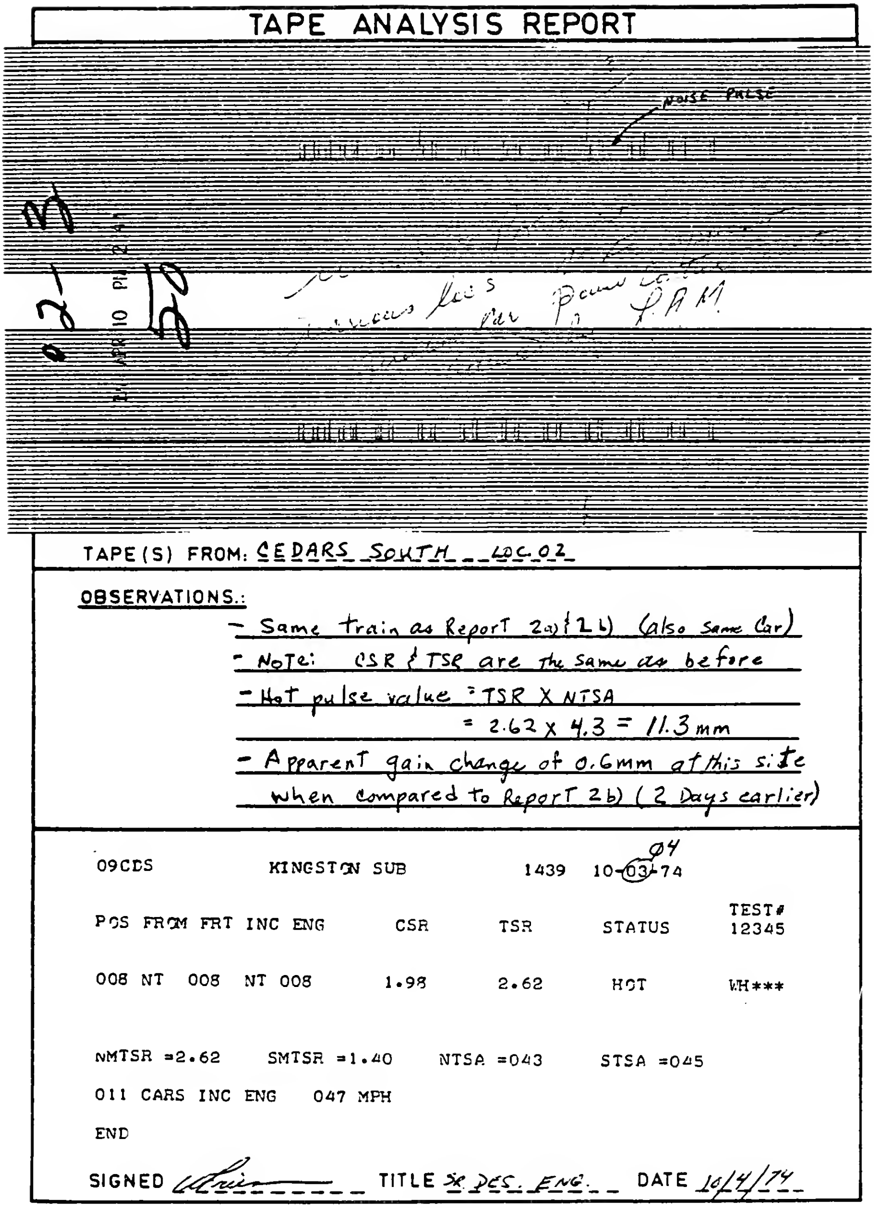
- Same Train as Report 2a) (also same car)
  NoTe: CSR & TSR are approximately the same
- Hot pulse value = TSR X NTSA
  = 2.65 X 4.0 = 10.6 mm
- Since CSR & TSR are the same as "90MVS" this location appears to have diff. gain setting.

SEE follow up on Report #2a)

```
22CDS          KINGSTON SUB          1444  08-03-74
                                              04

                                                     TEST#
POS FROM FRT INC ENG    CSR     TSR      STATUS      12345

011 NT  011  NT 011     1.96    2.65      HOT        WH***


NMTSR =2.65     SMTSR =1.30     NTSA =040     STSA =043
013 CARS INC ENG   055 MPH
END
```

SIGNED ________ TITLE SR. DES. ENG. DATE 10/8/74

Fig. 21



TAPE ANALYSIS REPORT

TAPE(S) FROM: CEDARS SOUTH LOC 02

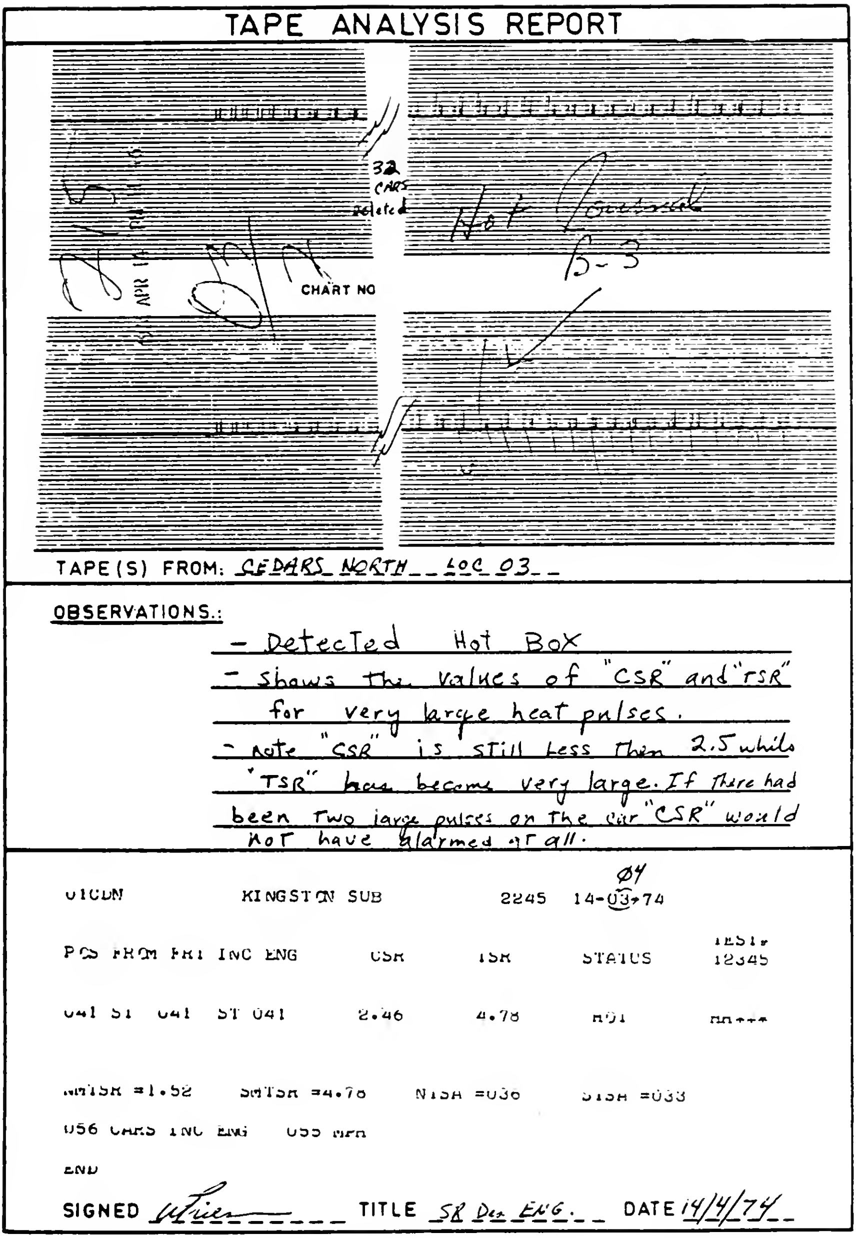
OBSERVATIONS.:

- Same train as Report 2a) & 2b) (also same Car)
- Note: CSR & TSR are the same as before
- Hot pulse value = TSR X NTSA
  = 2.62 X 4.3 = 11.3 mm
- Apparent gain change of 0.6mm at this site when compared to Report 2b) (2 Days earlier)

```
09CDS          KINGSTON SUB          1439   10-03-74
                                             04
                                                              TEST#
POS FROM FRT INC ENG     CSR      TSR      STATUS      12345

008 NT  008  NT 008      1.98     2.62      HOT        WH***


NMTSR =2.62    SMTSR =1.40    NTSA =043     STSA =045
011 CARS INC ENG   047 MPH
END
```

SIGNED ______ TITLE SR DES. ENG. DATE 10/4/74

Fig. 22



TAPE ANALYSIS REPORT

TAPE(S) FROM: CEDARS NORTH LOC 03

OBSERVATIONS.:

- Detected Hot Box
- Shows the values of "CSR" and "TSR" for very large heat pulses.
- note "CSR" is still less then 2.5 while "TSR" has become very large. If there had been two large pulses on the car "CSR" would not have alarmed at all.

```
                                                 Ø4
U1CDN            KINGSTON SUB           2245  14-03-74

                                                             IESI.
PCS FROM FRI INC ENG     CSR       ISR       STATUS     12345

U41 S1  U41  ST 041      2.46      4.78       HOT        nn+++


NNTSR =1.52    SNTSR =4.78    NISH =U36    SISH =U33
U56 CARS INC ENG    U55 MPH
END
```

SIGNED W. Friesen TITLE SR Des ENG. DATE 14/4/74

Fig. 23

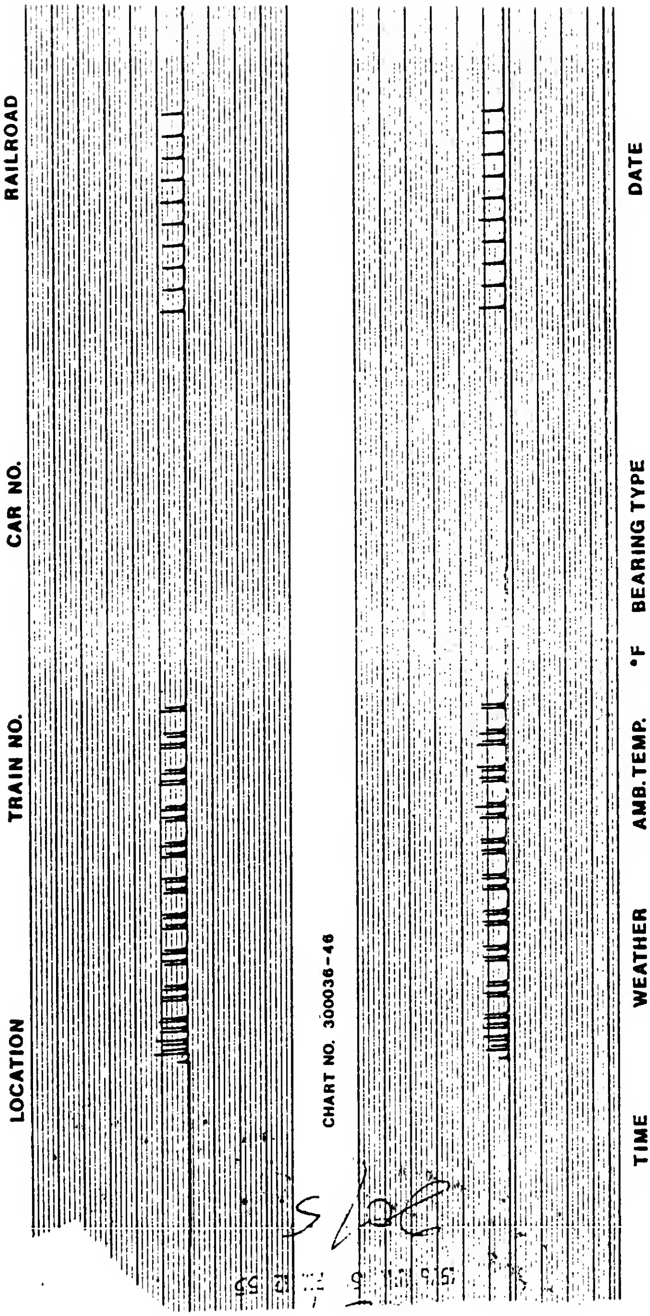

LOCATION
TRAIN NO.
CAR NO.
RAILROAD
CHART NO. 300036-46
TIME
WEATHER
AMB. TEMP. °F
BEARING TYPE
DATE

Fig. 24

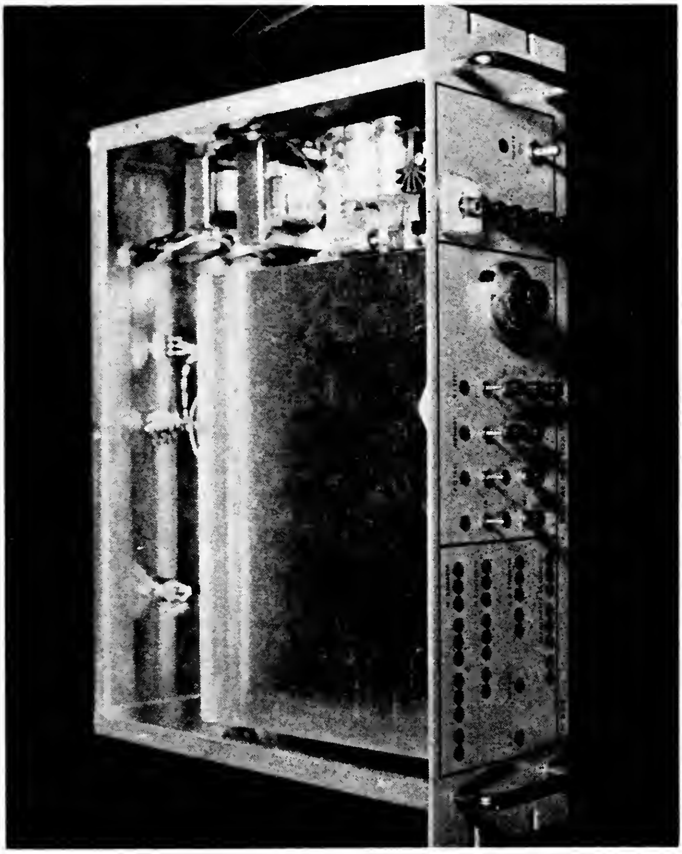


Fig. 26

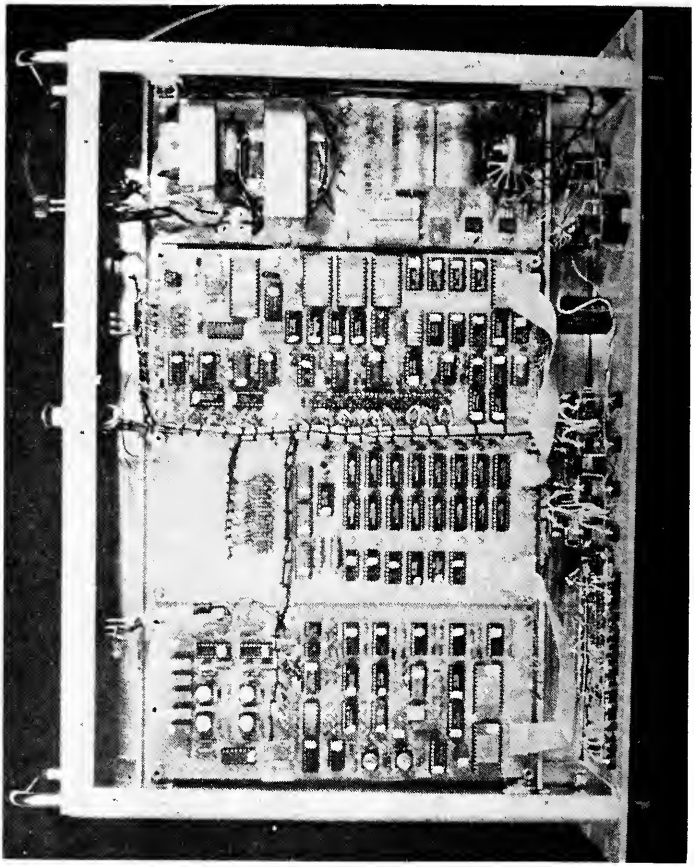


Fig. 27

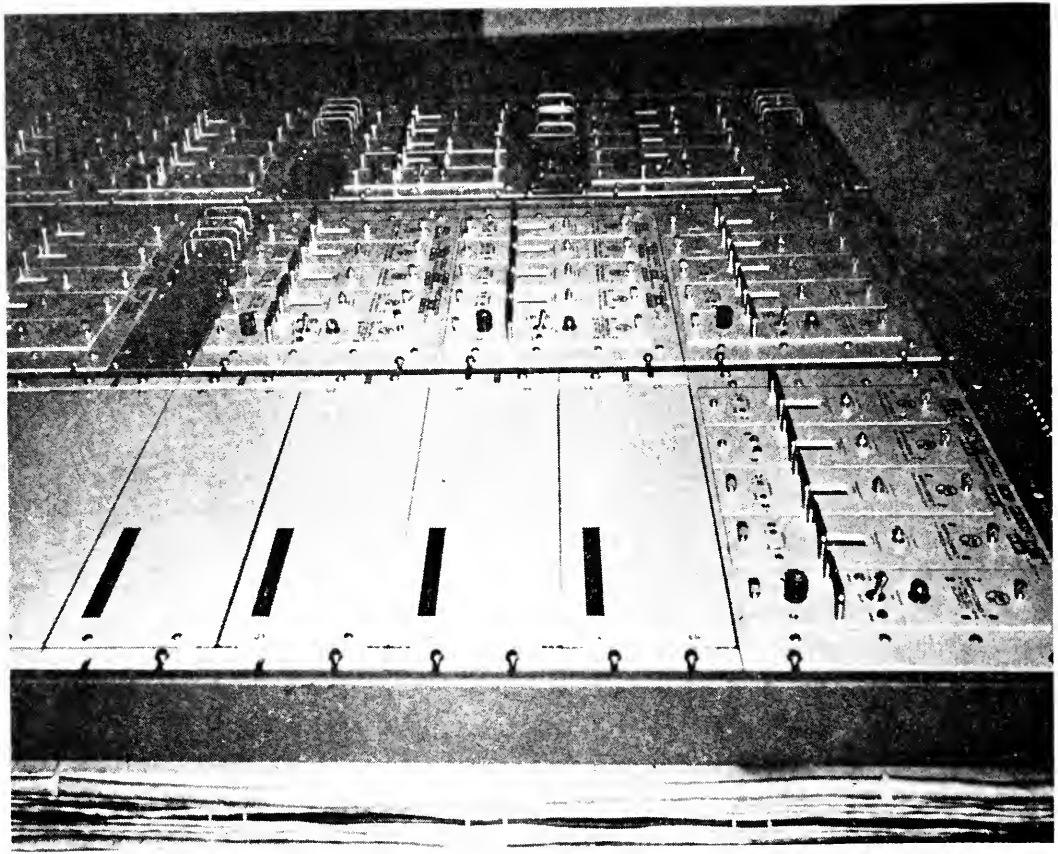


Fig. 28

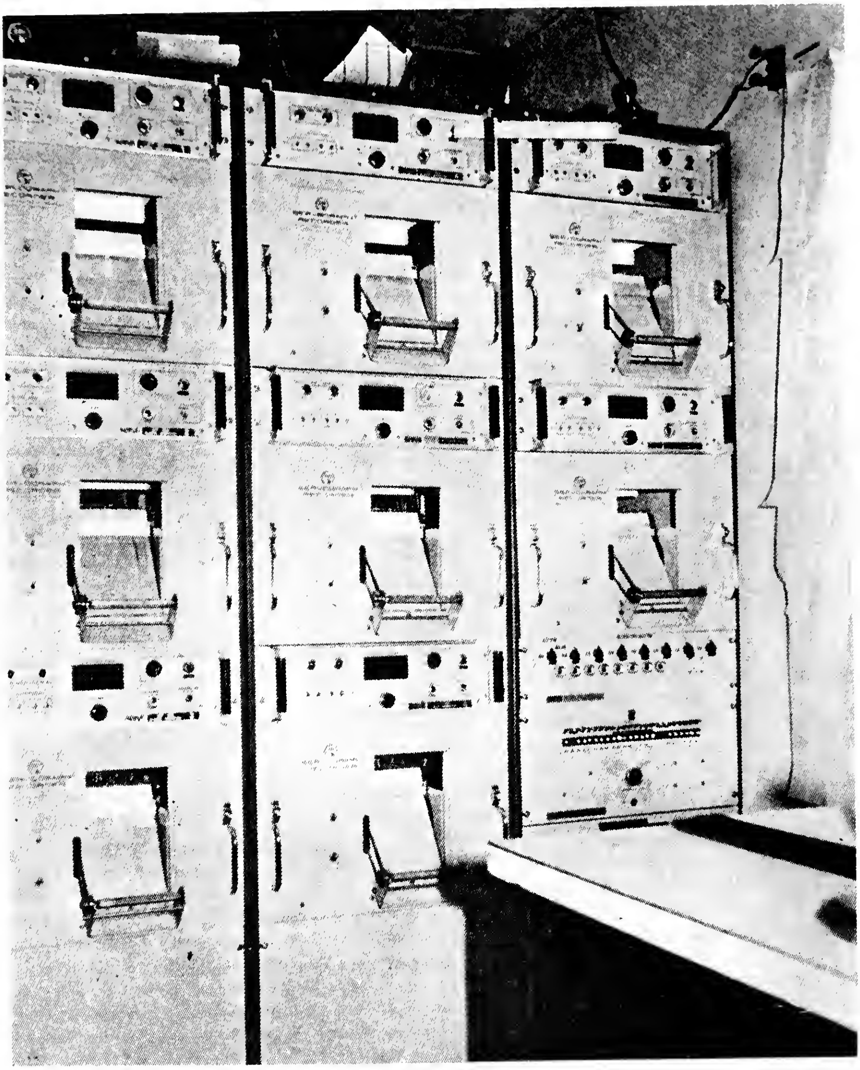


Fig. 29

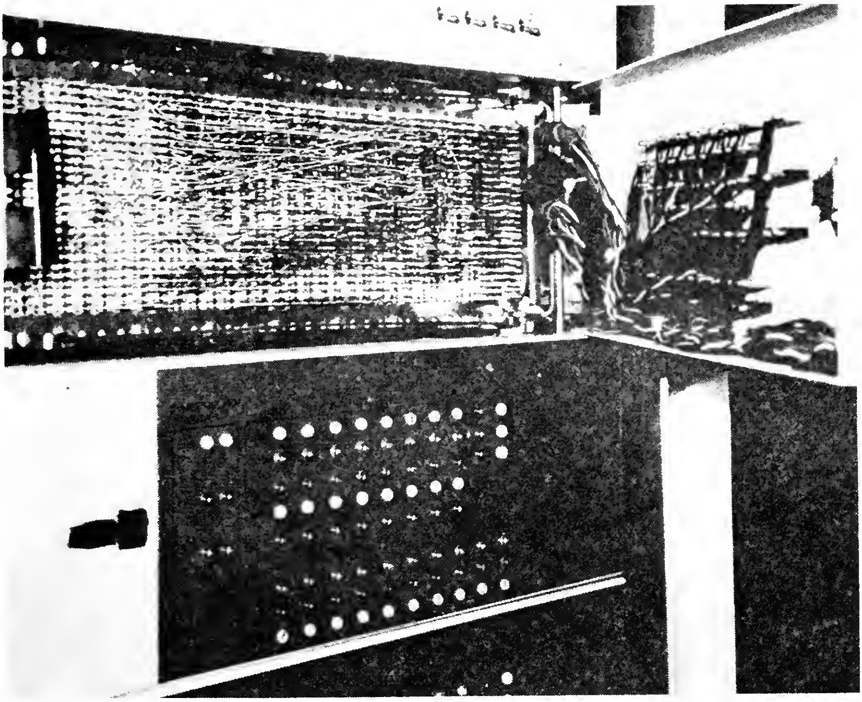


Fig. 30

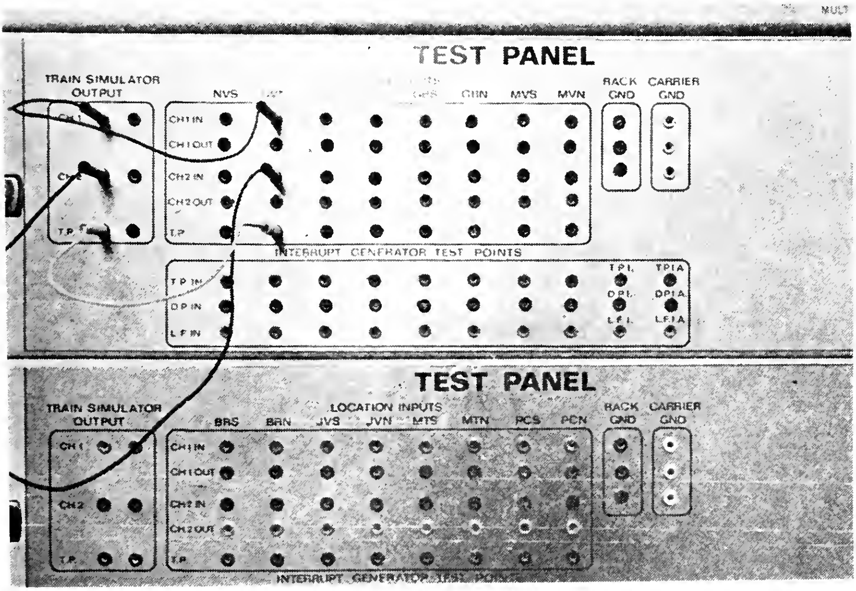

TEST PANEL
TRAIN SIMULATOR OUTPUT
NVS
GBS
GBN
MVS
MVN
RACK GND
CARRIER GND
CH 1
CH 2
T.P.
CH 1 IN
CH 1 OUT
CH 2 IN
CH 2 OUT
T.P.
INTERRUPT GENERATOR TEST POINTS
T P IN
D P IN
L F IN
TPI
DPI
LFI
TPIA
DPIA
LFIA
TEST PANEL
TRAIN SIMULATOR OUTPUT
LOCATION INPUTS
BRS
BRN
JVS
JVN
MTS
MTN
PCS
PCN
RACK GND
CARRIER GND
CH 1
CH 2
T.P.
CH 1 IN
CH 1 OUT
CH 2 IN
CH 2 OUT
T.P.
INTERRUPT GENERATOR TEST POINTS

Fig. 31

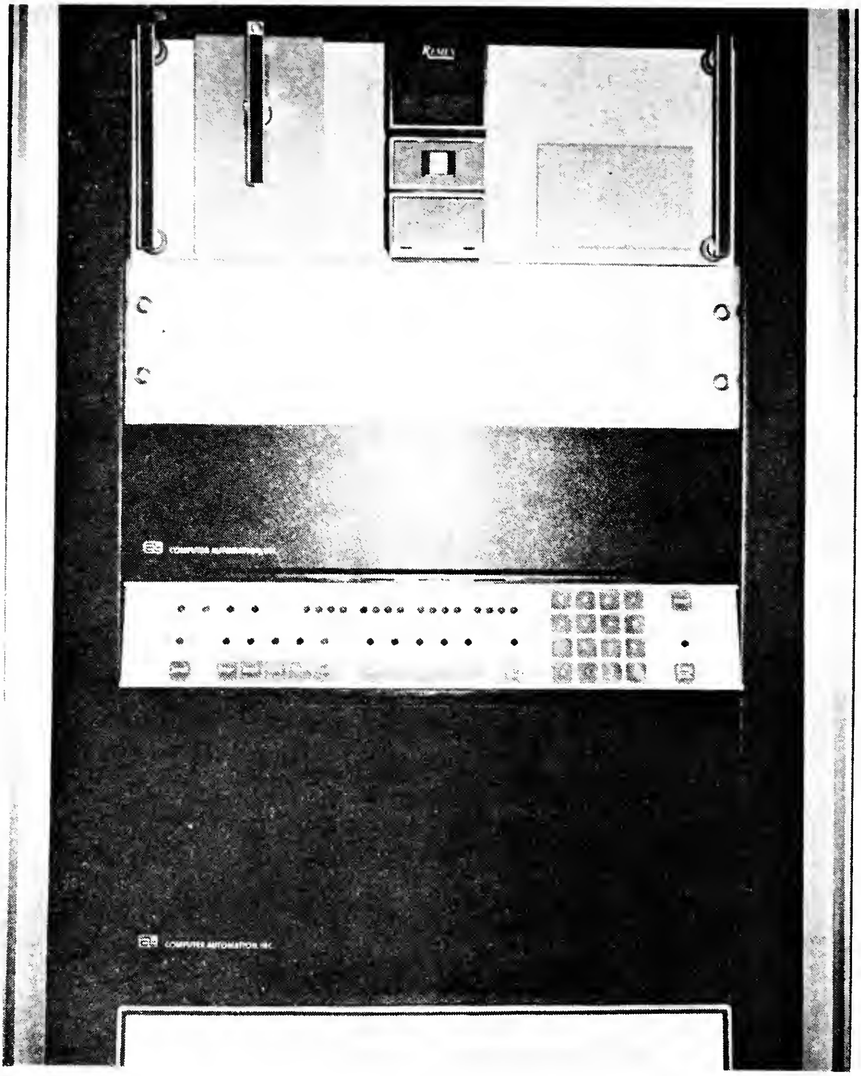


Fig. 32

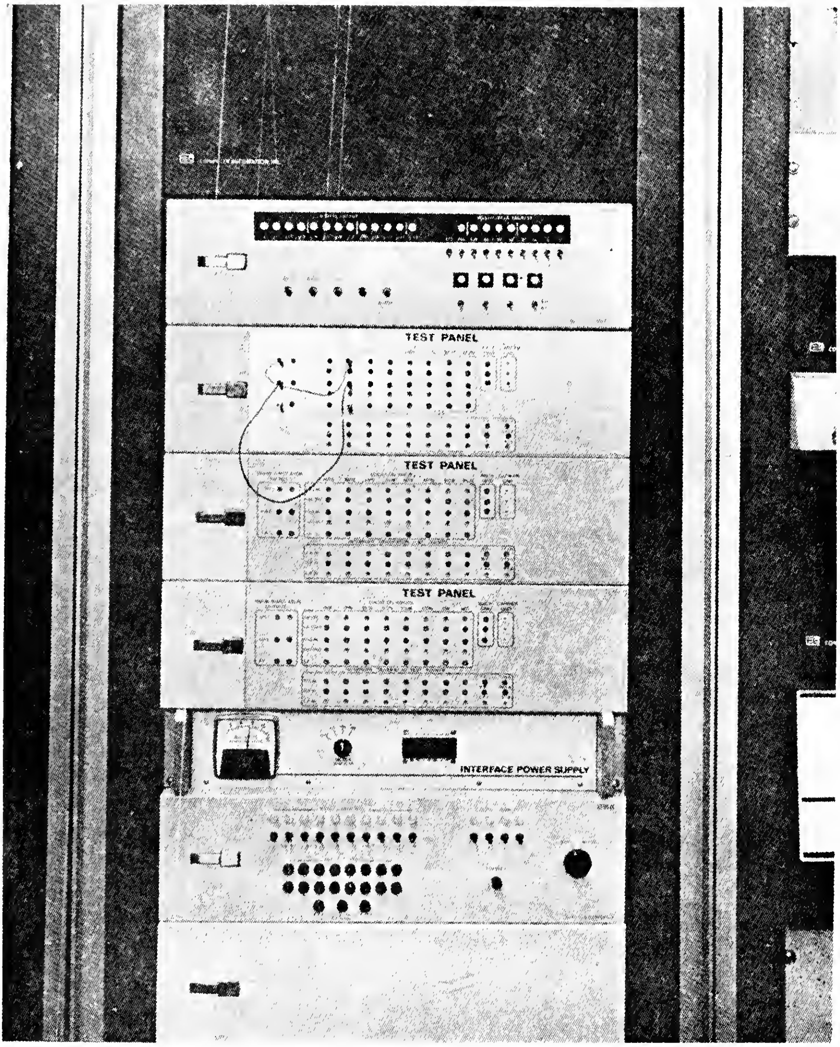


Fig. 33


.B.D. DATA ANALYZER
Data Acquisition Rack
CN TRAIN SIMULATOR
POWER
CAR TYPE
P.O. IND
TRAIN SPEED
PULSE WIDTH
SHORT
LONG
TRAIN PRESENCE
MODE
MANUAL STEP
SCOPE SYNC
AXLE MONITOR
NORTH RAIL
RANDOM PULSE

Fig. 34

"The Quiet One," Burlington Northern's Northtown Yard, Minneapolis, Minn.

77–658–4

By M. B. WALKER
Assistant Director–Signal Engineering
Burlington Northern, Inc.

Burlington Northern is justifiably proud of the results of efforts to quiet the noise of retardation of cars on the hump at Northtown Yard. Not all retarder screeching is gone and we still have the low-frequency rumbling created by retarder action on the cars, but what screeching now exists is very tolerable and occurs only occasionally with the heaviest cars.

This situation owes a debt to the efforts of many men who spent hours searching for an answer—to the signal supply companies, General Railway Signal Company (GRS), and Union Switch and Signal Division, WABCO—and to a number of railway companies which participated heavily in the research.

I wish also to acknowledge the source of some of the material presented here today:

> "Noise Problem Involving Retarders," September 25, 1972, by V. K. Southworth, Burlington Northern, Inc.
>
> "Retarder Noise Abatement," October 1, 1973, by D. E. Turner, General Railway Signal Company.
>
> "Noise Reduction in Classification Yards," October 1, 1973, by R. M. Karow, WABCO, Union Switch and Signal Division.

Before we look at what was actually done at Burlington Northern's Northtown Yard to abate the retarder noise, let's review very briefly what Northtown Yard is and where located. This yard—3.2 miles in length—was constructed on top of three existing yards, required extensive excavation, relocation of city utilities, erection of a four-lane overhead bridge to eliminate a busy grade crossing in the vicinity of the new hump, and is primarily for classification of eastward trains. Our Gavin Yard in Minot, North Dakota, classifies most westward trains. We expect to classify 3000 cars per day over the hump, terminate 16 trains, originate 19 trains, and handle 10 through trains together with 28 transfer trains within the Twin Cities area.

The yard is oriented in a north-south direction; the southern portion lies in northeast Minneapolis, the northern portion lies in Fridley, and immediately to the east of the hump and bowl tracks is the community of Columbia Heights. You see, then, we are contending with noise ordinances from three separate cities.

A brief history of efforts concerning retarder noise abatement is in order. Anyone who has ever been in the close proximity of a retarder in action knows that the emitted sound is deafening and many times crosses the threshold of pain. Because the human ear is most sensitive to frequencies in the range 500 to 5000 cycles and because a retarder in action creates extremely high sound levels in the 2000 to 4000 cycle range, all within hearing range of such retarders become very annoyed. It is the abatement of sounds in the 2000 to 4000 cycle range that concerns us today since the low frequency, grating, rattling, or rumbling noises do not carry far and give no particular trouble.

Note: Discussion open until October 15, 1976.

Some of the earliest attempts to suppress retarder screeching involved changing brake shoe hardness, composition or configuration. Softer shoes, that is shoes with a hardness of Brinell 200 instead of Brinell 290, were installed; however, no appreciable reduction in noise was obtained and shoe wear was considerably accelerated.

Next, ductile iron shoes were tested. Ductile iron is produced by a casting process and contains a fair amount of free graphite dispersed throughout the metal and has a hardness approximately equal to that of the original brake shoes. The incidence of screech was reduced about 30 percent over the standard steel shoe while shoe wear was four to five time that of standard shoes.

Another innovation was tested by WABCO engineers who machined a mitered slot lengthwise in the face of a retarder brake shoe into which was pressed Cobra brake shoe fibre. This shoe lasted for 86 cars under test, at which time the force caused by the wedging action of the wheel destroyed the lower edge of the shoe.

Abex Corporation fabricated cast shoes to fit its retarders and tests indicated good noise abatement properties if car speeds are held below 6 mph. WABCO tried Fabreka pads in its brake-shoe mounting to provide resiliency but couldn't keep the shoe bolts tight. Inert retarders have been sprayed with various coatings but they either didn't adhere well or did little to eliminate noise. Vertical grooves were cut in the brake rail, ¼-in. wide every 4 in. along the rail with no screech elimination. Diesel oil was sprayed on inert retarder rails as cars were pulled through with reduction in screech, but the continuous oil spray was objectionable due to ground contamination and reduction in retardation.

Brake shoes were prepared having ¾-in.-diameter holes drilled into the face of the shoe, as many as could be accommodated by the shoe face, and for the full length of the shoe. These holes were then plugged with lead. This did reduce the screech some but also reduced the retarding effort.

One of the more successful attempts to eliminate wheel screech was made in 1965 by Iron Ore Company of Canada on a WABCO inert retarder. The face of the shoe was slotted the entire length, ⅛-in. wide and 1-in. deep and packed with a lubricant. The last report stated screeching reduced approximately 75% with no extensive loss of shoe life.

Shoes with inserts of molydisulfide and with inserts of graphite were tried with little or no results. It is to be noted that in these tests involving shoe composition or inserts the shoe had a very high rate of wear, eliminated only a small percentage of screeching and when a car did screech it did so at the same sound pressure levels as before the test.

WABCO tried interrupting retarder beam and shoe arrangements since observations seemed to suggest a correlation between the shoe length and time taken to induce screeching. At one yard they tapered the ends of the shoes with a cutting torch all through the retarder while at other yards they installed entering and leaving beams every three cylinders. The results were negligible.

All the foregoing is a sort of prehistory. When Burlington Northern began planning Northtown Yard one of the obstacles that had to be overcome was restrictive sound pressure ordinances, that is, noise ordinances. For example, one community bordering the proposed yard passed an ordinance limiting pressure levels in the octave band 1200 to 2400 cycles to 33 db and in the octave band 2400 to 4800 cycles to 20 db.

Here are some typical decibel values encountered in daily life:

Rustling leaves—20 db (Note this is the maximum level we were allowed for the 2400–4800 cycle octave band.)

Soft whisper at 5 ft—34 db (Note this is the maximum level we were allowed for the 1200–2400 cycle octave band.)

Normal suburban residential area—43 db.

Typical office—70 db.

Car wheels in retarder at 15 ft—100 to 134 db.

It is interesting to note that the community which set the low noise levels of 20 and 30 db mentioned above is very likely in violation of its own ordinance. Certainly Burlington Northern was facing a potential problem with retarder noise.

In 1970 Burlington Northern engaged the consulting firm of Bolt, Beranek and Newman (BBN), sound specialists, to study the problem of retarder noise and invited General Railway Signal Company and WABCO to cooperate in a joint effort to find a solution. WABCO decided to work independently with its own consultant and GRS began work with Burlington Northern and BBN.

As a result of studies made by BBN it was concluded that the car wheel was the sound generator and was set into vibration by the slip-stick phenomena between wheels and brake shoes called spragging. As a wheel is squeezed in the retarder between the brake shoes it tends to be gripped and then to slip somewhat like a piece of chalk chattering on a black board. The screech is the audible evidence of the wheel vibration.

The race was on to find a way to abate the wheel screech of retarders so Northtown Yard could use its humping operation. At Pasco Yard, Burlington Northern, BBN and GRS conducted tests on:

1. Vertical sound barriers.
2. Sand damping of retarder members.
3. Wheel damping.
4. Water saturation of retarder shoes and car wheels.
5. Lubricants applied to retarder shoes and car wheels.

At North Kansas City Yard, Burlington Northern and WABCO conducted tests on:

1. Sound barriers.
2. Lubricants applied to retarder shoes and car wheels.
3. Pulsating air supply to retarders.

Theoretical calculations on sound barriers indicated we could expect a 20 to 30 db reduction in sound pressure levels along a line perpendicular to the center of the barrier wall. The Pasco barrier was of temporary construction, 96 ft long, of ¾-in. plywood faced with 6½ in. of fiberglass insulation. The main wall was 12 ft above ground level and approximately 9 ft above top of rail. At the top, a 2-ft hinged section of wall was arranged so it could be in the vertical position or any desired angle toward the track to form a deflecting baffle. The absorption coefficient of the fiberglass wool was 0.8, a relatively good factor. Measurements indicated the barrier provided between 20 and 23 db attenuation. No significant difference in attenuation was noted with the adjustable portion positioned at 45° above the horizontal.

The sound barrier at BN's North Kansas City Yard was designed by WABCO and is of a more permanent nature. The base and foundations are 10x10 in. timbers, the framework 2x6 in. fir and the panels are corrugated transite to which an acoustical lining was glued. All wood work is creosote treated and the panels are slanted about 30° from vertical toward the retarders. Sound level readings taken at a point 100 ft from and perpendicular to the center of the retarder indicated a 25 decibel reduction in noise level.

Sound damping of the retarder shoe beams was achieved by adapting frames to the inside and outside beams to hold sand bags. The arrangement was applied to the first section of a group retarder; however, limited clearance above the beams restricted the amount of sand that could be applied. Sand bags were placed in the frames and loose sand packed around the bags and over the top of the beams for a total weight of approximately 6000 lb. The beams were observed to be canted outward from the rail due to the outboard weight and there was apprehension that the retarder would respond too slowly; however, functioning was correct. Impact-excited vibrations were significantly reduced but there was very little effect on wheel screech.

Wheel damping tests were scheduled involving rubber-like pads cemented to both the inside and outside surfaces of car wheels. Due to the difficulty of applying damping pads to the wheels, to the inconclusive results and to the improbability that all cars could be so treated, these tests were never repeated. An alternate damping test was carried out at Pasco Yard by fitting six sections of a group retarder with wooden members consisting of 2x6 in. planks supported on steel frames bolted to the shoe beams. The damping bars were spring-loaded to provide about 50 lbs pressure against the side of the wheels. There was insufficient clearance between truck sides and damper frames which caused enough damage to prompt abandonment of this test.

A water test was conceived because it has been recognized that retarder squeal is often absent under certain moist conditions. In an attempt, and again at Pasco Yard, to simulate these conditions, we applied a water spray to a group retarder, completely drenching the shoes and the wheels of the test cars. The test result was negative.

The next logical test seemed to be lubrication of the retarder shoes. Mathematical calculations by BBN indicated the lubricant must have a stick-slip ratio of less than 1.0. The first lubricant tried had a ratio of 0.78 and was initially brushed on the faces of shoes in a group retarder. Extra-heavy cars were humped into this group as single car cuts and maximum retardation was applied in an attempt to produce screeching. None of the cars emitted screech.

The same cars were retrieved and again humped into the previously treated group, with no screech generated in either the master or group retarder. Enough residual oil remained on the wheels to cause loss of retardation in the master retarder. The same cars were again retrieved and were then humped into a different, untreated group. The cars were again difficult to control in the master; however, they were stopped easily in the untreated group retarder. Again, no screech was emitted by either the master nor untreated group retarder.

Direct lubrication of brake shoes eliminated screeching but is laborious of application and difficult to control, so the next stop was to carry the lubricant in a water solution which is the way Burlington Northern went at Northtown Yard. A test was conducted at Pasco Yard using a 55-gal drum for mixing and storage, and a small motor-driven irrigation pump was used to deliver the solution to lengths of perforated garden soaker hoses layed along the retarder shoe beams.

The arrangement produced a fine spray mist which enveloped the car wheel as it passed through the retarder. The dramatic results demonstrated clearly for the first time that screeching could be eliminated during passage of a car through a retarder. Continued experimentation with a variety of water-soluble oils produced a combination which virtually eliminated the screech from all cars with loss of retardation estimated at approximately 10%.

The oil used is Texaco No. 1609, soluble, heavy-duty, having a high extreme pressure property, which is formulated to mix readily with water and have a stable emulsion with good rust protection characteristics. The results of all experiments indicated that a 2% mixture of this oil with water either eliminated all screeching or, in worst cases, drastically reduced the sound pressure level of those cars that did screech. Since Northtown Yard lies adjacent to communities with very restrictive noise ordinances it was necessary to use a retarder noise abatement system that is 100% effective so the decision was made to use the spray concept together with sound barriers.

At Northtown the emulsified oil and water mixture is delivered to the retarder shoes and car wheels in a spray fog at 30 psi at the nozzles. A ¾-in.-diameter manifold runs the entire length of the retarder on the outside of each side with the manifolds controlled in two sections. The entering section extends for two-thirds the length of the retarder and the leaving section extends through the bottom 1/3 of the retarder. The spray nozzles are set into the manifolds on 3 ft 8 in. centers thus creating a very fine spray for the entire length of retardation. Each of these manifold sections is individually controlled either by the computer when in humping mode or manually by push button on the control console.

Cars are sprayed according to their weight so that every extra heavy and heavy car is sprayed, with medium and light cars having approximately every third or fourth car sprayed. The actual sequence of spraying is calculated by the computer on the basis of car weights and the mixture of cars.

The retarders are mounted on concrete foundations constructed so as to return the residual mixture to sumps located at the downhill end of the retarders from whence it is pumped to a reclaiming plant housed in a nearby building. The collecting sumps consist of a section of concrete pipe 4 ft in diameter with a poured concrete floor into which is placed a submersible pump controlled by a high-low limit switch. A cycle timer is provided to limit frequency of operation of the pump. This allows the sump to be pumped dry once after the start of a heavy rainfall after which the sump is allowed to overflow the relatively clear water into an industrial sewer. The amount of oil remaining in the collection system under these conditions is small and can easily be handled by the sewer with no problem. This insures at the same time that excess water does not get into the noise control system and dilute the mixture beyond a useful level.

In the reclaiming plant the incoming mixture is settled in a receiving tank, right, where large particulate and scum are removed. After this, the mixture is pumped through in-line filters, which remove small particulate, to a 2000-gal mixing tank, left, where metered oil and water is added to reconstitute as required. The supply of water is direct from commercial lines and the supply of oil is pumped from a 15,000-gal below-ground storage tank. In winter ethylene glycol is metered into the mixing tank in proper amounts to prevent freezing at the expected low temperatures for the next 24 hours. This antifreeze is stored in a below-ground 30,000-gal tank.

After agitation into a homogeneous solution the refreshened mixture is pumped into a 2000-gal supply tank from whence it is delivered at 90 psi back to the retarders for pressure reduction to the spray manifolds.

The receiving tank, mixing tank, and supply tank are located in the reclaim building for ease of operation and maintenance. Sizing of tanks was calculated to hold a 24 hour supply of material.

Eight-foot-high sound-absorbing barriers extending 6 ft above top of rail and overhanging both ends of the retarders by approximately 11 ft were installed on both sides of all retarders. These barriers are supported by the above-mentioned concrete retarder foundations and are made up of panels 4 ft high and 8 ft long held in vertical I-beam members so that sections may be removed to gain access to the retarder for maintenance. Doors are provided in front of each retarder operating mechanism for the same reason. A wind loading of 30 lb per sq ft was used in the design.

The effectiveness of the noise abatement effort related to the hump retarders may readily be judged by actual observation. With the spray system operating with the correct mixture of oil and water, car after car passes through the retarders without a screech. Occasionally, an extra-heavy car will just start to screech as the car reaches exit speed and will have the screech chopped off as the retarder opens. With the sound barriers doing their part, this brief and occasional screech goes unnoticed.

The sound barriers at Northtown are performing at a sound level attenuation of about 20 dbA in accordance with the manufacturer's published performance capabilities. One must keep in mind that these measurements are taken at a point 50 ft from and perpendicular to the center of the barrier and at rail height. The figure also represents the maximum capabilities, and as one moves away from this center line position of the barrier towards the ends of the barrier or travels vertically in relation to the barrier, the attenuation capabilities decrease.

Loss of oil and water mixture due to evaporation and carry down into the yard is much less than expected and what is tracked down into the bowl acts, together with rail surface lubricators, to reduce curve resistance.

Associated with the noise abatement efforts at the hump was the consideration given to the elimination of wheel screech associated with the skate retarders located at the pullout end of the bowl tracks. Traditionally, these skate retarders have been inert, and cars were simply pulled through giving rise to intolerable sound pressure levels. Since Burlington Northern was faced with such stringent restrictions concerning sound levels at Northtown, the decision was made to provide releasable skate retarders. Those installed at Northtown are GRS Model F-4 operable weight responsive, powered by Bellows–Valvair hydraulic units. Each hydraulic unit powers four skate retarders, thus there are 16 such units involved.

When the pullout yardmaster desires to pull a bowl track he requests the hump yardmaster to release the associated skate retarder. After necessary blocking is performed at the hump end of the track to prevent humping cars into tracks with released skate retarders, the computer sends a command to the field enabling the release circuit at the skate retarder where a trainman must operate a key switch before the retarder will open. After passage of the car movement the trainman removes his key from the key switch and the retarder will automatically reclose.

As previously pointed out, lying to the east, between the yard and residential areas, is a 65-ft bluff created by excavations for the yard. On top of this bluff was constructed a 10- to 15-ft mound so that the combination of the bluff and the mound would also act as a sound barrier shielding the concerned residents from yard noises. By eliminating retarder squeal at both ends of the yard, by use of sound barriers at the hump retarders, and by having a convenient bluff to the east where there are residential areas, Burlington Northern has been able to create an exceptionally quiet yard.

The Load Spectrum for the Fraser River Bridge at New Westminster, B.C.

77–658–5

By R. A. P. SWEENEY
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INTRODUCTION

"The thought of a steel member suddenly failing after years of service brings a chill to any engineer. This possibility turned to reality on December 15, 1967, with the collapse of the Point Pleasant Bridge connecting Point Pleasant, West Virginia and Kanauga, Ohio. Forty-six persons were carried to their deaths when an eyebar failed and the bridge suddenly collapsed into the Ohio River carrying 31 of the 37 vehicles on the bridge with it. This tragic event 'which occurred' during the evening rush hour has focused the attention of bridge engineers throughout the world on the safety of existing steel bridges." (1), (2), (3)[1]

In late 1971 the writer was asked to investigate the fatigue problem in a general way in order to determine what procedures should be used to evaluate Canadian National's over 3500 steel bridges. This study is still continuing.

In order to avoid a calamity of the magnitude of the Point Pleasant failure, the heavily travelled east-west main lines carrying more than 10 million gross tons annually were examined. Of the bridges evaluated, by far the weakest from the point of view of absolute strength and gross tonnage was the Fraser River Bridge at Mile 118.5 of CN's Yale Subdivision.

The Fraser River bridge is one of the largest rail-water crossings in Canada. It has a total length of about 2000 ft with additional extensive timber pile approaches. The bridge is owned by the Public Works Department of Canada and is used by three railways, namely: Canadian National, Burlington Northern and British Columbia Hydro. Canadian National Railways is the main user and has the responsibility for inspection.

Since the bridge was built in 1904 (see Figure 1), is of rather weak design (Cooper E40 at today's stresses) and carries all CN traffic to Vancouver, Canada's third largest city, with a heavy percentage of unit trains, Canadian National arranged for an investigation of its remaining useful life. (4), (5).

A firm maximum life could not be established without precise data on the loads to which the bridge has been and will be subjected. This paper describes the load spectrum used to analyze the bridge with particular reference to the useful life of the hangers of the main 380-ft span (Figure 2).

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[1] Numbers in parenthesis indicate references listed at the end of this report.

Note: Discussion open until October 15, 1976.

Figure 1

Figure 2

I. TRAFFIC DENSITIES AND PROJECTIONS

Figure 3 shows the actual and projected gross tonnages in million gross tons per mile for the period 1930 to 1980. The upsurge in traffic from 1970 is the result of the introduction of unit trains. During this study reasonably accurate carload data from 1967 to the present, and odd snapshot type studies before that year were available. The study showed that the fatigue analysis was not sensitive to relatively large errors in the predicted car cycles before 1967.

Annual tonnages (Figure 3) across the bridge did not exceed 10 million gross tons before 1963, but by 1970, 18 million gross tons were recorded. The marketing projection anticipates 60 million gross tons or full line capacity by 1980.

Sources of Data

The most reliable source of historical data is the conductor's train journals. These were not available for the full period and when available are extremely unwieldy. Two independent computerized data bases were available. The first is the CN car file which is made from the journals, and the second is the waybill file made from the waybills. These together with the bridge tender's annual car counts and a number of short-term studies done in the past based on conductor's journals were used to set up the historical data.

The projection used for future traffic was based on then current (1974) company forecasts by a special group set up to study traffic density problems in the Vancouver area. Two alternative forecasts were also investigated, but are not reported (4).

II. BASIC CAR CYCLE DATA

Past Traffic

As a sample the 1973 distribution based on the CN car file data base is as shown:

1973 Frequency Distribution

Range Tons	*Tons*	*Cars Per Annum*	*% of Total*	*% of Loaded*
0–20	10	20,445	4.9	N/A
20–40	30	234,117	55.9	N/A
40–60	50	23,876	5.7	N/A
60–80	70	33,582	8.0	23.9
80–100	90	32,878	7.8	23.5
100–120	110	9,418	2.2	6.7
120–131.5	125.75	64,152	15.3	45.8
131.5–140	135.75	329	0.1	
> 140		2	0.0	
Total Cars		418,799		

Gross Tonnage: 22,545,392

Average Gross Per Car: 54 tons

The AAR average for this same period was 56.9 tons.

Similar tables were made for all previous years (4).

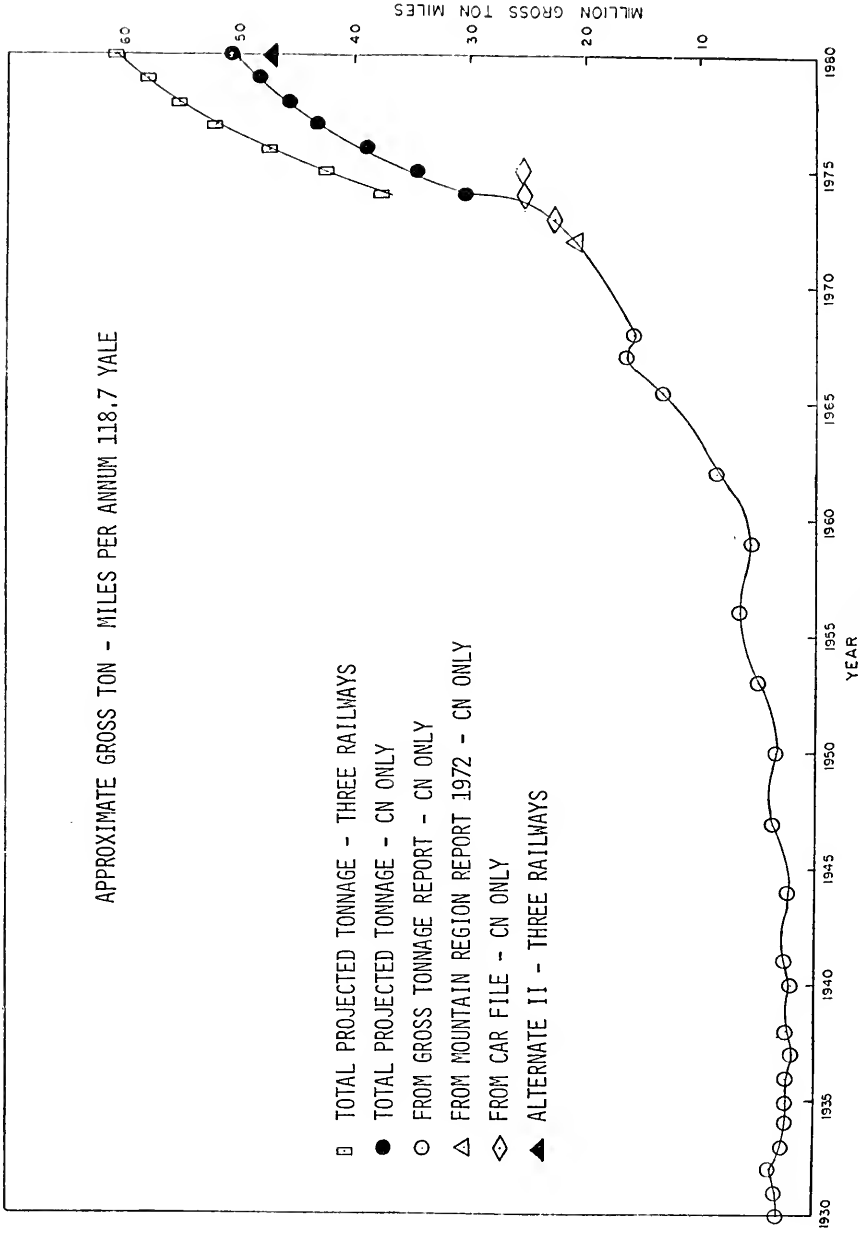
APPROXIMATE GROSS TON - MILES PER ANNUM 118.7 YALE
⊡ TOTAL PROJECTED TONNAGE - THREE RAILWAYS
● TOTAL PROJECTED TONNAGE - CN ONLY
○ FROM GROSS TONNAGE REPORT - CN ONLY
△ FROM MOUNTAIN REGION REPORT 1972 - CN ONLY
◇ FROM CAR FILE - CN ONLY
▲ ALTERNATE II - THREE RAILWAYS
MILLION GROSS TON MILES
60
50
40
30
20
10
YEAR
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980

Figure 3

In order to complete the picture an assumption had to be made with regard to locomotives, since except for unit trains the number of locomotives is not precisely known. It was assumed that on the average, except for unit trains, there was one locomotive for every 30 cars. The table below summarizes the relevant CN traffic to the end of 1973. Since car loads weighing less than 80 tons gross do not influence the fatigue life of this bridge, they are ignored in the following tabulation.

SUMMARY OF CAR CYCLES TO 1973

Range Tons	*1967 to 1973, inc.*	*1961 to 1966*	*1940 to 1960*	*1904 to 1940*	*Total CN*	*Total All Roads*
80–100	161,703	174,000	445,000	80,000	860,000	1,169,000
100–120	74,977	31,200	102,000	—	208,000	282,000
120–131.5	106,620*	780	—	—	107,000	145,000
131.5–140	329	20	—	—	300	407
> 140	2	—	—	—	2	3
Locomotives					370,000	503,000
Unit Trains	112,000	—	—	—	112,000	—
Their Locos.	4,200	—	—	—	4,200	—

---

* Unit trains excluded.

To obtain the total for all roads, i.e., CN, BN and BCH, CN traffic has been multiplied by 1.36. The figure 1.36 is the mean value over the last decade based on the bridge tender's car count (4). The assumption here is that the traffic pattern for these roads is the same as CN's for heavy traffic with the exception of unit trains.

Future Traffic

Using the figures supplied by the co-ordinator of the Vancouver Terminal Study (see Figure 4) and using average car types for each major commodity (4), the following table was derived:

1974–1980
INCLUDES CN, BN & BCH

Line	*Range G.T.*	*Cars*[1]	*% of Total*
1	100–120	447,600	7.9
2	120–131.5	925,600	16.3
3	Locos.	178,000	3.1
	Total	5,681,000	

Line 1 consists of predicted grain moves only.

Line 2 consists of predicted coal, sulphur, potash, phosroc and 5% of remaining loaded cars less express and passenger cars (6, p. 108).

Line 3 consists of three locomotives per unit train as per unit train specifications, two units per passenger train and one unit per each remaining 40 car group.

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[1] For the entire period.

Trains - actual - both ways
Cars 1,000 - both ways (Including Units)
M.G.T. - both ways

FRASER RIVER BRIDGE

YEAR	COAL			SULPHUR			POTASH			GRAIN			PHOSROC			EXPRESS			C.N. PASSENGER		
	Trains	Cars+U	M.G.T.	Trains	Cars+U	M.G.T.	Trains	Cars	M.G.T.	Trains	Cars	M.G.T.	Trains	Cars	M.G.T.	Trains	Cars	M.G.T.	Trains	Cars	M.S.T.
1974	776	68.3	5.86	327	30.4	2.39	424	37.3	2.84	1865	138.0	8.73	149	13.8	1.11	1086	57.9	2.93	910	15.5	1.35
1975	1141	100.4	8.62	374	34.8	2.73	464	40.8	3.11	1865	138.0	8.73	153	14.3	1.14	1248	64.9	3.29	910	15.5	1.35
1976	1506	132.5	11.37	421	39.2	3.07	501	44.1	3.36	1865	138.0	8.73	158	14.7	1.17	1248	73.6	3.68	910	15.5	1.35
1977	1868	164.4	14.11	468	43.5	3.41	541	47.6	3.63	1792	132.7	8.55	162	15.1	1.20	1470	81.6	4.11	910	15.5	1.35
1978	1969	173.3	14.87	501	46.6	3.65	598	52.6	4.01	1740	128.8	8.41	167	15.5	1.24	1646	91.3	4.60	910	15.5	1.35
1979	2070	182.2	15.63	536	49.8	3.90	656	57.7	4.40	1740	128.8	8.41	173	16.1	1.29	1846	102.4	5.16	910	15.5	1.35
1980	2172	191.1	16.40	568	52.8	4.14	713	62.7	4.78	1740	128.8	8.41	178	16.5	1.32	2065	114.6	5.77	910	15.5	1.35

YEAR	OTHER		
	Trains	Cars	M.G.T.
1974	3613	105.9	5.20
1975	3623	115.8	5.67
1976	3633	128.7	6.23
1977	3092	146.0	6.84
1978	3104	160.6	7.63
1979	3117	169.1	8.02
1980	3128	178.1	8.42

TOTAL CN		
Trains	Cars	M.G.T.
9150	467.1	30.40
9778	524.5	34.64
10242	576.3	38.96
10303	646.4	43.20
10635	684.2	45.76
11048	721.6	48.16
11474	760.1	50.59

TOTAL BN		
Trains	Cars	M.G.T.
2730	101.2	4.99
2730	106.1	5.21
2730	111.2	5.45
2730	116.6	5.69
2730	122.2	5.95
2730	128.1	6.22
2730	134.4	6.51

TOTAL BCR		
Trains	Cars	M.G.T.
1344	51.7	2.3
1344	56.9	2.6
1344	62.6	2.8
1376	68.8	3.1
1514	75.7	3.4
1604	80.2	3.6
1702	85.1	3.8

BRIDGE TOTAL		
Trains	Cars	M.G.T.
13244	620.0	37.7
13852	687.5	42.5
14316	750.1	47.2
14409	831.8	52.0
14879	882.1	55.1
15382	929.9	58.0
15906	979.6	60.9

Co-Ordinator -
Vancouver
Terminals
Study

29 March 1974

Figure 4

The above is referred to as the Full Market Analysis prediction. Two other market projections, not detailed here, were also carried out.

Summary, Car-Cycle Data

The most important traffic insofar as the life of this bridge is concerned is that occurring between 1970 and 1980. More tonnage will cross the structure in this decade than in its entire previous history. The annual gross million tons will go from roughly 18 in 1970 to 60 in 1980.

III. LOAD SPECTRUM FROM TRAINS

Analytical Study

The basic train and car crossing data outlined above were used to define the probable load spectrum that the Fraser River Bridge was subjected to from 1904 to 1973 and projected to 1980, at which time the traffic was assumed to have reached saturation. Each year after 1980 was assumed to carry the same traffic as that for the year 1980.

1. Cycles per Vehicle

Available field data show that the passage of trains over a bridge produces major stress cycles for axle and truck loaded members such as hangers and floor-beams, with superimposed vibrational cycles (6), (7), (12). For most structures the superimposed vibrational cycles are small enough to be neglected as the AASHO Road Test Studies confirmed (8).

Strain measurements on hanger, M_1 L_1 of the 380-ft through truss span of the Fraser River Bridge confirmed the theoretically calculated cyclic variation of stress range and showed that there is essentially one cycle per car with very little superimposed vibrational cycles. Figure 3.1 compares a portion of a record of a unit coal train with the theoretically calculated variation assuming space frame behavior. The comparison is within experimental error. Random samples of all other car types using the bridge compared as favorably with their theoretical force-time plots.

2. Probability Density in Each Weight Group

The field data from many previous studies of highway and railroad traffic also indicates that the frequency-of-occurrence data can often be idealized reasonably well by use of the Rayleigh curves, which defines a family of skewed probability-density curves. This approximation is currently being used to develop stress-cycle criteria for AREA Committee 15.

The nondimensional mathematical expression defining a truncated Rayleigh curve is given by (9).

$$p' = 1.011\ X\ e^{-1/2(X)^2} \qquad (3.1)$$

where

$$X = \frac{Pr - Prmin}{Prd} \backsim 3$$

Prmin is the minimum force in the spectrum

Prd is a parameter which is a measure of the dispersion of the data

The root-mean-square force range for the distribution is given by

$$PrRMS = Prmin + Prd \qquad (3.2)$$

A Rayleigh distribution was not used for the load spectrum since the actual spectrum was available. The use of the actual spectrum is preferable when it is

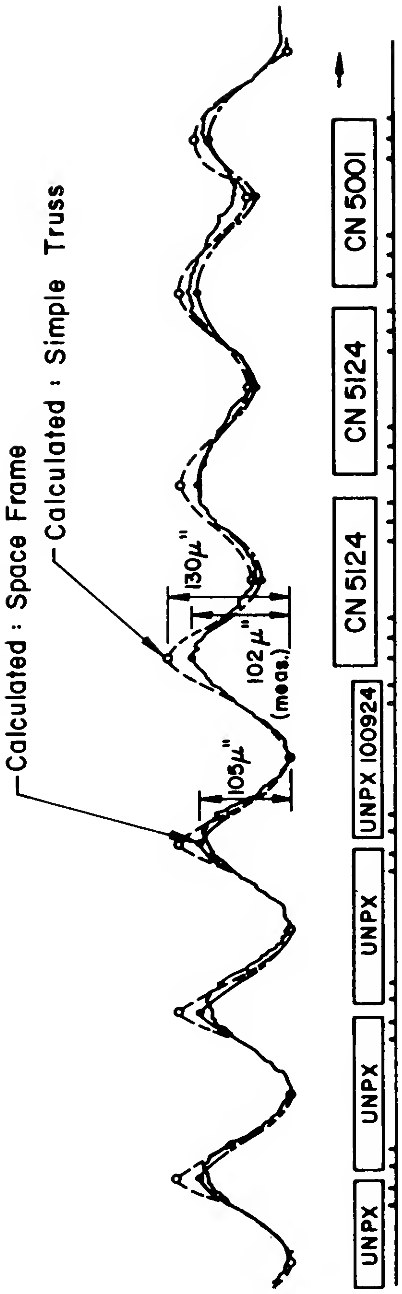

Figure 3.1—Comparison of unit train response with predicted strain.

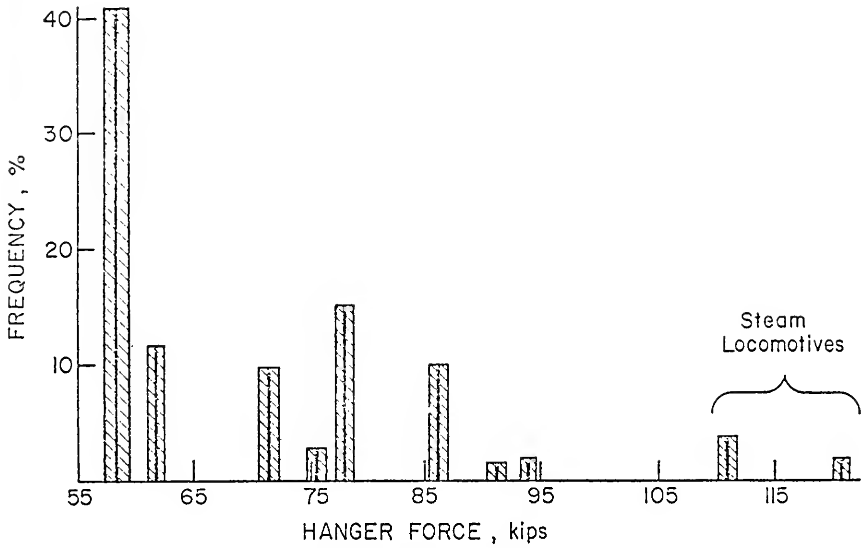

Figure 3.2—Load frequency (simple truss analysis) up to 1973.

available. The FHWA nationwide load spectrum used to derive the AASHTO fatigue provisions is bimodal (10). A similar traffic pattern exists over the Fraser River Bridge. The two peaks can be seen in Fig. 3.2. This reflects the effect of the heavy unit train traffic over the Fraser River Bridge (see Fig. 3.2). The obvious conclusion is that if any one commodity represents a substantial proportion of the traffic, it must be considered independently. A pure Rayleigh approximation with only one peak can be in substantial error.

Examining the distribution of loaded unit train vehicles from tests on the Fraser River Bridge and the far more exhaustive data on cars loaded over 110 tons on a line which feeds traffic to the bridge (11), it is quite evident that 100-ton-capacity cars used in bulk service are loaded close to their rated capacity.

Since most of the cars in the 120- to 131.5-ton range crossing the Fraser River Bridge are carrying bulk commodities, and since the 110- to 120-ton cars are put in the next lower class interval, these cars are assumed to be loaded to their rated capacity. Test measurements on the Fraser River Bridge made in June 1975 confirmed this assumption. Cars in lower weight ranges follow a Rayleigh distribution (5). Thus, except for the 120 to 131.5 group, each car or locomotive in an interval of car or locomotive loadings was assumed to result in a force range Rayleigh frequency distribution as shown in Fig. 3.3. As an example, this results in a RMS load for the load interval 80–100 tons of 89.2 tons as illustrated.

3. *Frequency Distribution up to 1973*

The force range P acting on a hanger was evaluated from force-time plots assuming plane truss behavior. The resulting value is adjusted to account for actual behavior. These provided the hanger force for several locomotive-car combinations.

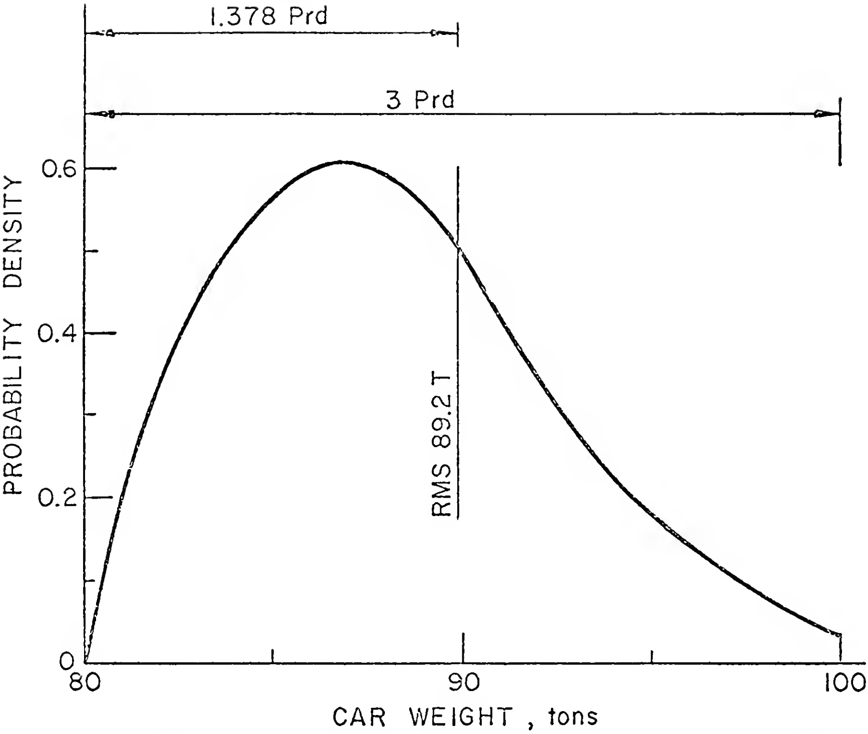

Figure 3.3—Assumed car weight distribution in 80–100 ton car load interval.

Of the 76,500 steam units, 80% were assumed to be transfer units as the bridge is in a terminal area. The balance was assumed to be Northern Class units. The remaining 293,500 diesel units were assumed to be composed of 235,000 single unit trains with the remaining units in trains with 2 or 3 units per train.

The cars in each weight class were assumed to be placed, in proportion to their frequency, after the diesel locomotive units. All stress cycles, except for unit trains, were increased by the factor 1.36 to account for other roads using the structure. These assumptions resulted in the following force range distribution for the cars and locomotives crossing the bridge (Tables 1 and 2) up through 1973.

The results in Tables 1 and 2 were used to evaluate the effective range of force under the random variable cycles of load that were applied to the hangers. Both the RMS and the Miner's equivalent force range were evaluated, as recent studies have shown that both provide reasonable estimates of the cumulative effects of variable cycle loading (9).

The root-mean-square force range corresponding to the 2,217,810 force cycles in Tables 1 and 2 was determined as:

$$\begin{aligned} \mathrm{PrRMS} &= \left[\Sigma\ (\alpha_i P_i^2)\right]^{1/2} \qquad (3.3) \\ &= 71.7 \text{ kips} \end{aligned}$$

TABLE 1—STRESS CYCLES UP TO 1973 FROM CARS

		Frequency		*RMS Force on*
Type (tons)	*PRMS (tons)*	*After Loco.*	*After Car*	*Hanger, kips*[*]
80 –100	89.2	262,970	—	61.8
		—	906,630	58.3
100 –120	109.2	63,602	—	75.6
		—	219,278	71.4
120 –131.5	131.5	32,717	—	91.0
		—	112,802	86.1
131.5–140	134.0	90	—	92.8
		—	321	87.7
Unit train 131.5	131.5	1,400	—	91.0
		—	110,600	86.1

---

[*] Assuming plane truss behavior.

TABLE 2—STRESS CYCLES UP TO 1973 FROM LOCOMOTIVES

Type	*Frequency*	*Frequency × 1.36*	*RMS Force on Hanger kips*[*]
Single Unit-Northern	15,300	20,808	121.0
Single Unit-Transfer	61,200	82,232	111.2
Single Unit Diesel	235,000	319,600	78.0
2 or 3 Unit Diesel	29,250	39,780	78.0
	29,250	39,780	94.0
Unit Trains	1,400	1,400	78.0
	2,800	2,800	94.0

---

[*] Assuming plane truss behavior.

The Miner's equivalent force range is defined by:

$$\mathrm{PrMINER} = \left[\Sigma\ \alpha_i P_i^3 \right]^{1/3} \qquad (3.4)$$

$$= 73.4 \text{ kips}$$

It is readily apparent that both methods yield about the same effective force range.

4. *Frequency Distribution Up to 1980*

For the period 1974–1980, the protection indicates that there will be 101,988 trains with 178,000 locomotives. Unit trains will number 19,534. Of the remaining 82,454 trains, 36,944 were assumed to have 2 locomotives and 45,510 trains were assumed to have a single locomotive.

Cars in each weight class were treated as in the 1904–1973 period. The following Table 3 summarizes the force cycles for this period.

TABLE 3—FORCE CYCLES FROM 1974–1980

Type	*PRMS (tons)*	*Frequency*	*Force, kips*[**]
Locomotives	—	101,988	78.0
	—	76,012	94.0
Cars (tons)			
80–100	89.2	93,215[*]	61.8
		321,374	58.3
100–120	109.2	16,624[*]	75.6
		430,976	71.4
120–131.5	131.5	34,376[*]	91
		891,224	86.1

---

[*] Adjacent to locomotive.
[**] Assuming plane truss behavior.

When the variable force cycles in Tables 1, 2 and 3 are combined, the effective force range for the 4,183,599 cycles becomes

PrRMS = 74.7 kips
PrMINER = 75.9 kips

5. *Frequency Distribution After 1980*

The traffic pattern for each year after 1980 was assumed to be at saturation which results in the following:

TABLE 4—FORCE CYCLES PER ANNUM AFTER 1980

Type	*PRMS (tons)*	*Frequency*	*Force, kips*[*]
Locomotives		16,330	87.9
		12,170	83.2
Cars			
80–110	89.2	16,100	61.8
		55,400	58.3
100–120	109.2	2,300	75.6
		59,500	71.4
120–131.5	131.5	6,290	87.9
		163,060	83.2
		331,150 cycles per annum	

---

[*] Assuming plane truss behavior.

6. *Summary of Field Test Results*

Three series of field measurement were taken; a series in June 1975 and two series in August referred to as the T and S series. The maximum amount of life used by cyclic variation was calculated for Hanger M_1 L_1 for the three series of tests. Figure 3.4 shows a plot with the measured cycles scaled by 10^4 indicating how this was done for the June series of tests.

A least life occurs when the root-mean-square stress range is nearest to the failure curve as derived from laboratory fatigue tests. The least life occurs in this case when all cars greater than 80 tons gross are included. Nevertheless, it is readily

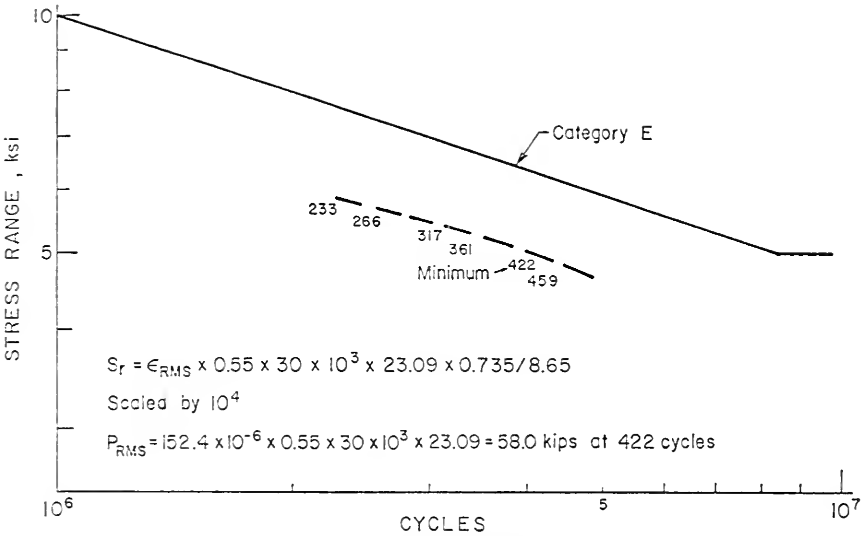

Figure 3.4—Frequency vs. effective stress range.

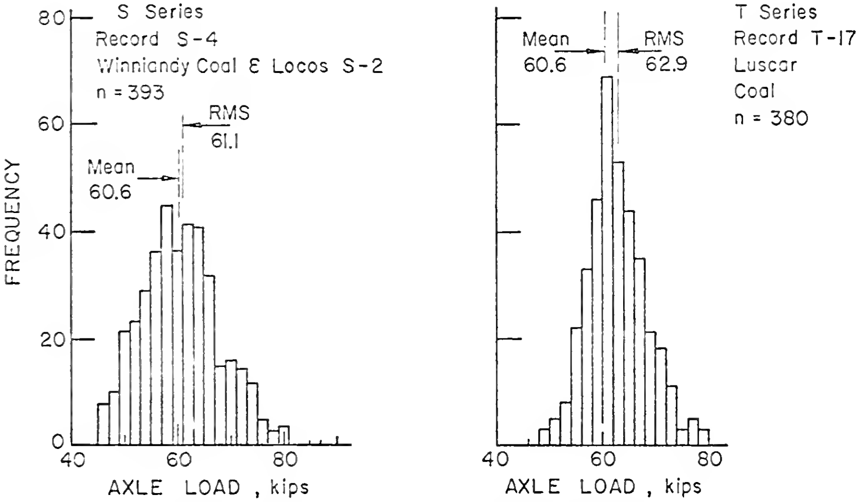

Figure 3.5—Unit train axle loads—August tests.

apparent from Fig. 3.4 that not much difference in life results by including all cars over 60 tons or only over 100 tons gross, as all points are about equi-distant from the failure curve. Hence, the use of cars weighing in excess of 80 tons provides a reasonable means of assessing the fatigue damage.

It is known that the unit train in test T and the one in test S were underloaded. Axle loads were recorded during the S and T test series. The results of these measurements are summarized in Fig. 3.5. The mean axle load is seen to equal 60.6 kips which is about 8% less than the anticipated mean of 64.8 kips. The theoretical value after correcting for this underloading is 64.3 kips for unit trains.

Table 5 shows the RMS force values and the number of cycles considered for the three test groups. Also shown is the 1975 RMS value corrected for space frame action. The data summarized in Table 5 show that unit trains result in stress cycles that are in very good agreement with the stress cycles estimated from 1975 traffic projections. The effective stress cycles for all train traffic was measured to be slightly less than predicted from the traffic projections. This difference varied from 7 to 10% on the conservative side. The frequency of occurrence of the measured stress cycles was in good agreement with the projected frequency for the 1974–80 time period (36.8% measured vs. 34.6% projected).

The experimental field measurements have confirmed the applicability of applying the traffic projections to evaluate the stress cycles in the members of the Fraser River Bridge. An accurate assessment of the member forces can be made using an appropriate analysis procedure. Hence, the equivalent static force range for the intervals 1904 to 1973, 1974 to 1980 and from 1980 onward can be used to determine the effective stress range for these intervals.

TABLE 5—MEASURED MEMBER FORCE

	All Trains		*Unit Trains*	
Test	*PRMS, kips*	*Effective Cycles Over Total Cycles*	*PRMS, kips*	*Effective Cycles*
June '75	58.1	422/984	70.6	182
T	56.1	178/568	64.1	95
T	56.3	172/568	63.9	95
S	55.2	183/605	61.7	95
Average		36.8%		51.8%
Predicted (1975 projected traffic)	62.6	34.6%	69.8[*]	51.7%

---

[*] For T & S series the estimated member force is 64.3 kips if underloading is considered for the 120–131.5 ton vehicles.

7. *Impact and Roll Effects*

Impact and roll effects increase the static force by an indeterminate dynamic interval. The influence of this variable on the stress cycle response is completely random and seldom if ever produces the full design stress range. In this study it was assumed that the dynamic increment was also distributed in a skewed manner. The assumed distribution is shown in Fig. 3.6. The maximum value was assumed to be the full 17.7% provided by the AREA specification for 10 mph. The minimum combined effect of impact and roll was taken as 0.95. This is reasonably compatible

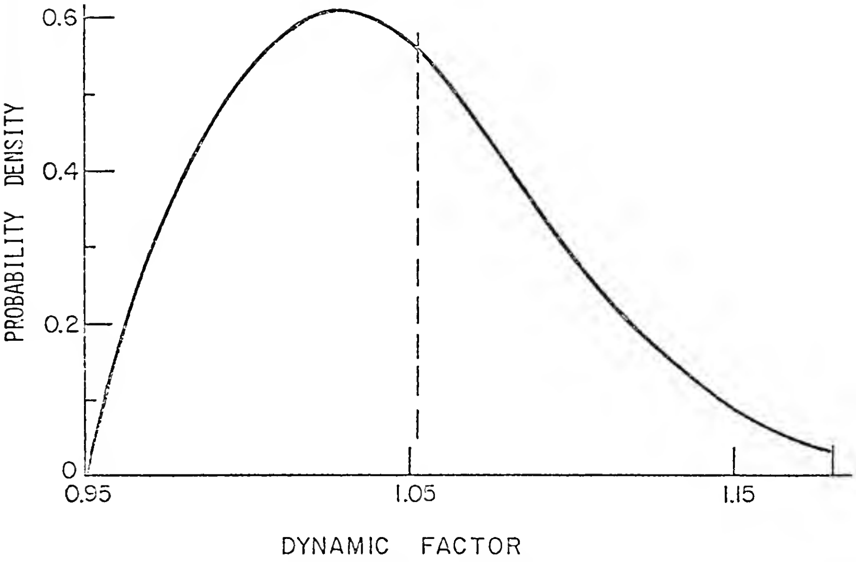

Figure 3.6—Assumed variation of dynamic increment.

with available studies which indicate that at times the member sees less than the static stress range. The root-mean-square of the skewed dynamic increment was determined to be 1.054.

A calculation of the static increment for an SD-40 locomotive produces an effective unsprung axle weight of roughly 15% × 65.75 = 9.86 kips which when compared to the static calclulated force in the hanger gives an impact of 1.054.

Field Tests on the Fraser River Bridge

All the field measurements except for a few of the S series were made with signal filters with roll-off frequencies from 10 to 14.2 Hertz (Hz). This did eliminate certain impact effects at 10 mph and upwards. For this reason a special series of impact tests were conducted using three locomotives.

Impacts increased with train speed as expected. The average impact at 20 mph in the loaded direction was 1.12. This is very close to the RMS value calculated as follows:

Vertical impact:	38.9%	
Rolling impact:	20.0	
	58.9%	
Speed correction:	0.6	20 mph
	35.4%	

The RMS value between 0.95 and 1.34 is 1.136 for 20 mph. The minimum measured impact coefficient was 0.956 which is very close to the assumed minimum of 0.95. The average measured impact at 10 mph in the loaded direction was 1.054.

In the pin plate the measured values were somewhat higher presumably due to a certain amount of ringing in the plate. At 20 mph the impact was 1.17 in the loaded direction with some evident ringing at 28 Hz. At 10 mph the impact in the pin plate was 1.071. Since the slow order on the bridge is set at 8 mph the average impact for the hanger was taken as 1.054.

Sensitivity of the Analysis

The calculations show that a 5% change in the predicted number of loaded 131.5 gross ton cars had a negligible effect on the calculated life, as the difference between the full market analysis prediction and alternate one is less than a year. Only a significant change would make a difference.

CONCLUSION

Historical data were scanned to produce a load spectrum for past traffic.

Future traffic was estimated based on marketing projections. The years 1974 and 1975 were used to check these projections and the comparison was favorable.

The effect of ignoring cars less than 80 tons was shown to be negligible. Strain measurements indicated that there was essentially one cycle per car, and confirmed the assumed impact percentage based on an RMS value of a Rayleigh distribution.

On this bridge bulk commodities in unit trains represent a substantial proportion of the traffic. Cars over 80 tons gross represented more than 25% of the traffic in 1975, with 16% of the total traffic in the 120 to 131.5 ton range.

Figures reported by Drew (6) in 1968 that no more than 5% of all loads are near the maximum appears to be valid only in cases where unit trains are not significant and furthermore appears only valid for the past decade. As time goes on and railroads become more efficient, this figure will creep upwards. On CN's main line through the Rockies a 25% figure for the 120–131.5 ton group is anticipated within the next decade. Further studies on other CN lines are being conducted to see if this increase can be expected elsewhere.

Finally, the experimental field measurements confirmed the applicability of applying the traffic projections to evaluate the stress cycles in the members of the Fraser River Bridge.

REFERENCES

1. W. J. Cain and C. Seim, "Carquinez West Bridge Eyebar Investigation—Phase I," May 1974, Toll Bridge Administration, Department of Transportation, State of California, San Francisco, Calif.
2. Charles F. Scheffey, "Point Pleasant Bridge Collapse—Conclusions of the Federal Study," Civil Engineering, ASCE, July 1971, pp. 41–45.
3. Daniel Dicker, "Point Pleasant Bridge Collapse Mechanism Analyzed," Civil Engineering, ASCE, July 1971, pp. 61–66.
4. R. A. P. Sweeney, "Investigation of the Remaining Useful Life of the Fraser River Bridge, New Westminster, B.C.," Phase I, Jan. 31, 1975, Canadian National Railways, Montreal, Quebec.
5. J. W. Fisher and J. Hartley Daniels, "Report on Investigation of the Estimated Fatigue Damage in Components of the Fraser River Bridge, New Westminster, B.C.," for Canadian National Railways, Montreal, Quebec, February 1976.
6. W. H. Munse, J. E. Stallmeyer and F. P. Drew, "Structural Fatigue and Steel Railroad Bridges," Proceedings of AREA Seminar, 1968, AREA Chicago.

7. Association of American Railroads, "Field Investigation of Two Truss Spans on the Southern Pacific Company," May 1968, Report ER-82, AAR Research Center, Chicago.
8. J. W. Fisher and I. M. Viest, "Fatigue Life of Bridge Beams Subjected to Controlled Truck Traffic," Proceedings, Seventh Congress, IABSE, 1964.
9. C. G. Schilling, K. H. Klippstein, J. M. Barsom and G. T. Blake, "Fatigue of Welded Steel Bridge Members under Variable-Amplitude Loadings," NCHRP Research Results Digest No. 60, April 1974.
10. J. W. Fisher, "Guide to 1974 AASHTO Fatigue Specifications," AISC, 1974, AISC, New York.
11. F. E. King, "Tests on B. C. South Line Clearwater Subdivision," CN Technical Research Center, Montreal, Quebec, February 28, 1975.
12. F. P. Drew, "Recorded Stress Histories in Railroad Bridges," Journal of the Structural Division, ASCE, Vol. 94, ST 12, Dec. 1968.

An Investigation of the Estimated Fatigue Damage in Members of the 380-ft Main Span, Fraser River Bridge

77–658–6

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INTRODUCTION

Older railroad bridges which have accumulated or are projected to accumulate large numbers of stress cycles may experience fatigue crack growth from their riveted connections or other structural details such as pin plates and weldments. This is particularly true of those structures built to carry loads that are not much greater than most of the traffic using the bridge.

The Fraser River Bridge at New Westminster, British Columbia, is typical of this type of structure, as it was built in 1904 to a weak design and presently carries most of Canadian National Railways' traffic to Vancouver. A large percentage of the current and projected traffic is of unit trains. Sweeney in a companion paper (1)* has examined the load spectrum for past traffic and for future traffic based on marketing projections.

In this paper the load spectrum defined in Ref. 1 is used to assess the actual stress spectrum developed in the members of the structure in the most highly stressed regions so that an evaluation of their fatigue life can be made.

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* Numbers in parenthesis indicate references listed at the end of this report.
Note: Discussion open until October 16, 1976.

Canadian National arranged for strain-gage measurements of certain bridge members to assist with the analytical determination of the stress resultants and to verify the applicability of applying traffic projections to evaluate stress cycles. Earlier tests had demonstrated, for example, that hangers could be expected to exhibit erratic behavior and unpredictable stresses adjacent to a floorbeam (2).

This paper summarizes the evaluation of the most critical hangers and the stringers of the main 380-ft fixed span.

STRESS RESULTANTS IN HANGER M_1L_1 AND PIN-PLATES AT M_1

Hanger M_1L_1 and the floorbeam and stringers are shown in Fig. 1 for the 380-ft fixed span. The hanger above the floorbeam connection consists of four angles 6 x 3½ x ⅜ plus two fill plates 3½ x ¼ riveted to a 17½ x 7/16 web plate as shown. Additional ⅜ fill and splice plates make up the cross-section near the floorbeam connection. The original hanger in 1904 consisted of four angles 6 x 3½ x ⅜ plus a system of 2½ x ⅜ lattice bars. The lattice bars were removed in 1923 and replaced with a solid web plate. As a result the web plate is discontinuous near the top of the connection between the hanger and floorbeam as shown by the dashed line in Fig. 1. The connection at M_1 consists of two 11/16 pin plates bearing on a 5.41-in.-diameter steel pin.

The riveted built-up floorbeam which is bent upwards and partly haunched between the stringers and the truss is attached to hanger M_1L_1 above L_1 using a pair of 6 x 4 x ⅜ connection angles. Between stringers the floorbeam consists of pairs of 6 x 6 x 9/16 angles top- and bottom-riveted to a 51 x ⅜ web plate.

Wheel loads are transmitted to the floorbeam and thus to hanger M_1L_1 through a rail and tie system bearing on a pair of built-up stringers placed symmetrically 48 in. either side of the bridge centerline. The stringers consists of pairs of 6 x 6 x 7/16 angles top- and bottom-riveted to a 42 x ⅜ web plate. The stringers are attached to the floorbeams using a pair of connection angles as shown in Fig. 1. The floorbeam reaction is theoretically carried by hanger M_1L_1 between the floorbeam connection and M_1.

Two different analytical models were used for the stress analyses of the main 380-ft span. The first was a plane simple truss model. This is the usual analytical model assumed in the linear stress analysis of a trussed bridge span as it normally provides an upper bound to overall member stress resultants. In this study, one 380-ft plane truss was isolated, in which all joints were assumed pin-connected.

The second was a three-dimensional model, developed specifically for this study to closely simulate the behavior of the entire 380-ft span including both trusses and all major load-carrying intermediate members. The model used in the computer solution is shown in Fig. 2. Due to symmetry about the bridge centerline, only one truss is shown. Since the analysis was concerned primarily with stress resultants in hanger M_1L_1 only major load-carrying members believed to have a significant influence on M_1L_1 stress resultants were retained in the vicinity of hanger M_1L_1. The influence of the structure beyond nodes 29, 30 and 31 was included by specifying displacement conditions obtained from a separate plane frame truss analysis. The stringer at node 29 was assumed continuous. Nodes midway between the trusses were constrained to displace only vertically and horizontally because of symmetry. Pin joints were assumed pinned in the analysis. Gussetted joints were assumed continuous.

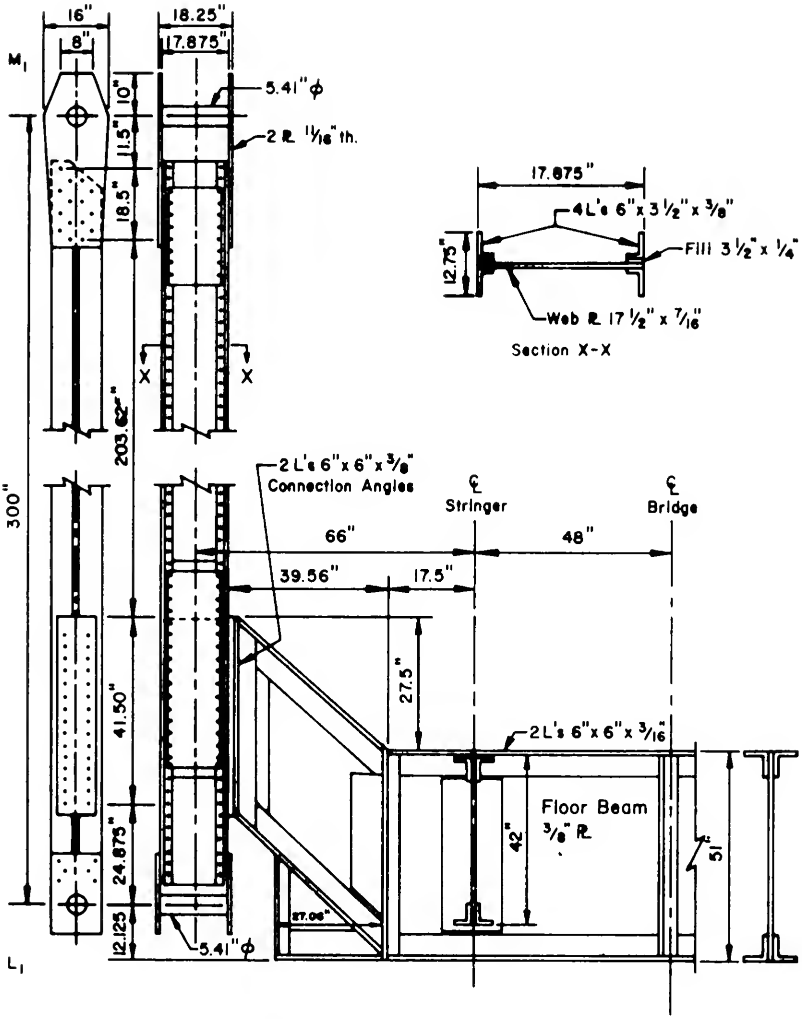

Fig. 1—Hanger M_1L_1, floorbeam at L_1 and pin-plates at M_1.

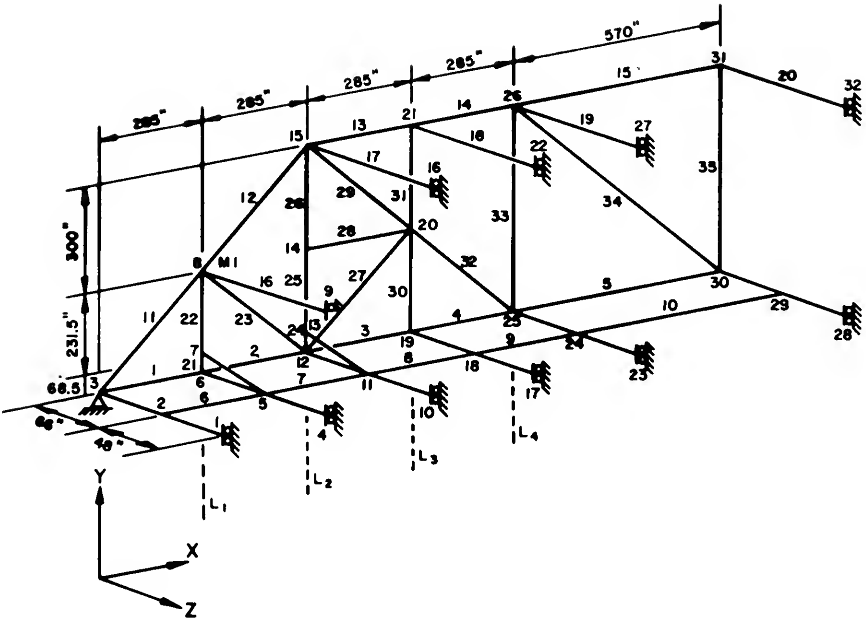

Fig. 2—Member and node numbering for three-dimensional framed truss model.

Stresses in the Hanger

(a) *Plane Simple Truss Model*

The plane simple truss model would imply that only axial force exists in hanger M_1L_1. This is a result of considering only a plane simple truss and assuming that the load is directly applied at panel point L_1. In reality, the load is applied through the floorbeam. The actual stress resultants in hanger M_1L_1 can be approximated by considering the hanger-floorbeam frame action.

Fig. 3 shows a simplified floorbeam-to-hanger frame model often used in conjunction with a plane simple truss analysis to obtain stress resultants in the hanger (3).

By superposition, the combined axial and flexural stress, σ (ksi), at a cross section of the hanger between M_1 and the top of the connection to the floorbeam can be computed as:

$$\sigma = \frac{P}{A} \pm \frac{0.0178Phy}{I_x} \text{(tension positive)} \qquad (1)$$

where A = gross or net section area (in.^{2})

I_x = gross or net section moment of inertia about the major axis (in.^{4})

h = distance from M_1 to cross section under consideration (in.)

y = distance from hanger centroid to point in the cross section (in.)

P = hanger axial force in kips

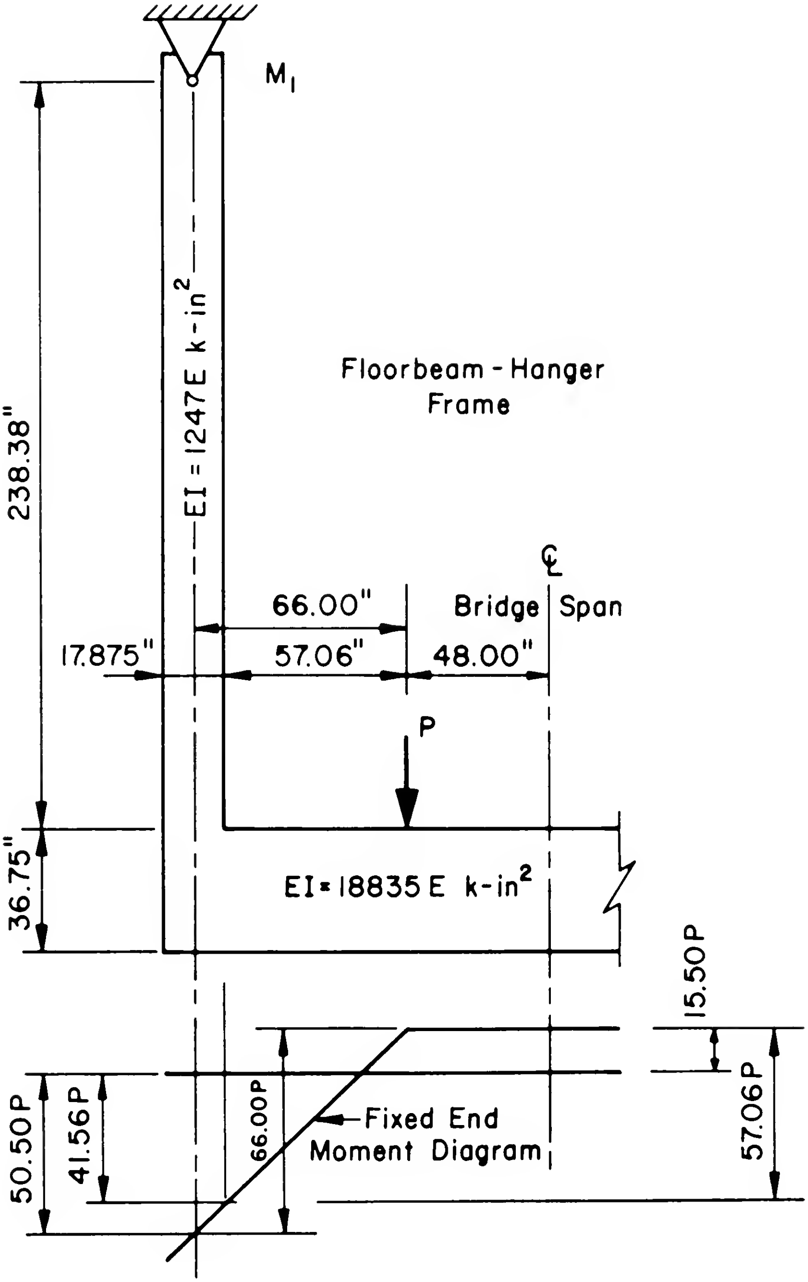

Fig. 3—Floorbeam-hanger frame model.

(b) *Three-Dimensional Model*

The three-dimensional model reasonably approximates the continuity conditions in the actual bridge span. In terms of a load P at the stringer-floorbeam connection, the combined axial and flexural stress, σ (ksi), in the hanger between M_1 and the top of the hanger to floorbeam connection is computed as follows:

$$\sigma = \frac{0.8194P}{A} \pm \frac{(0.0169h-0.0086)Py}{I_x} \pm \frac{(0.0007h-0.1221)Px}{I_y} \text{(tension pos.)} \quad (2)$$

where A, I_x, L and y are as defined above, P is the concentrated load in kips at node 5 (Fig. 2), and

I_y = gross or net section moment of inertia about the minor axis (in.^{4})

x = distance from hanger centroid to point in the cross section (in.)

The coefficient 0.8194 is the axial force in the hanger which results from a unit load at the stringer-floorbeam connection.

For normal downward loading P, the first term produces axial tension; the second term produces axial tension on the face of the hanger towards node 5 except near M; the third term produces tension in the lower part of the hanger on the side of the hanger towards node 3 (Fig. 2) and on the opposite side in the upper part of the hanger.

Analysis of Stress Resultants in Pin-Plates at M_1

The plane simple truss model assumed a pin connection at M_1. The three-dimensional model assumed continuity at M_1. The boundary conditions at M_1 will have negligible influence on the calculation of stress resultants near the hanger to floorbeam connection because of the flexibility of the hanger relative to the floorbeam. However, the boundary condition assumed at M_1 will have a pronounced effect on the distribution of hanger stress resultants to each of the two pin-plates at M_1.

If only axial force exists in the hanger, and both pin-plates share the force equally, then the change in pin-plate forces due to frame action of the hanger-floorbeam can be calculated in both the simple truss or three-dimensional models.

For the plane simple truss model, the results of the frame analysis (Fig. 3) can be used to estimate the pin-plate forces. Assuming that both plates are in bearing under the hanger stress resultants, the rotation of the hanger at M_1 will be essentially zero. The moment at M_1 is resisted by the couple 17.875 δF where δF is the increment of pin-plate force in kips and the distance between pin-plates is 17.875 in. Superimposing this result with the hanger axial force P the individual pin-plate forces F can be calculated from,

$$F = \frac{P}{2} \pm 0.12P \text{ kips} \quad (3)$$

where the trackside pin-plate will carry the smaller force.

The three-dimensional model yields individual pin-plate forces equal to:

$$F = \frac{0.819P}{2} \pm 0.00048P \text{ kips} \quad (4)$$

Finite Element Analysis of Pin-Plate

To assist in evaluating the fatigue strength of the pin-plates, a finite element analysis was carried out. Since the pin-plate was essentially symmetric, only one-half of the pin-plate was modeled and used for the finite element analysis. The finite element model is shown in Figure 4. The loads shown at the end of the plate provided an average net section stress of 10 ksi. The finite element program SAP IV was used to perform the finite element analyses. (4)

The bearing of the pin-plate on the pin was modeled by connecting radial and tangential elastic supports to nodes at the pin interface. The radial and tangential support stiffness was taken as:

$$K_r = AE/D$$
$$K_T = 0.3\ K_r \tag{5}$$

where K_r = radial stiffness, K_T = tangential stiffness, A = bearing area, D = pin diameter and E = modulus of elasticity.

Fig. 5 shows the principal tensile stress contour plot that results when the average net section stress is 10 ksi. Only the region near the pin hole is shown.

Since strain measurements were obtained on the inside pin-plate of the west hanger M_1L_1, these measurements were compared with the predicted strains. The force going into the pin-plate was measured to be about 43 kips. This would result in an average net section stress of 5 ksi. Fig. 6 shows the predicted stress gradient across the net section and compares it with the measured stresses. The results are in good agreement.

Correlation of Predicted Stresses with Field Measurements

The results of static load tests conducted by the CNR were compared to the predicted stresses using the results of the three-dimensional model.

Table 1 shows the correlation in the west hanger between predicted stress, σ_p, and measured stress, σ_m, (ksi). The predicted stresses are computed separately from each of the three terms of Eq. 2. The gages on the west hanger were located so that the gross cross section is effective.

Table 1 Correlation of Predicted and Measured Stresses: West Hanger (ksi)

Gages	Section	Axial Stress			Major Axis Bending Stress			Minor Axis Bending Stress		
		σ_p	σ_m	$\frac{\sigma_m}{\sigma_p}$	σ_p	σ_m	$\frac{\sigma_m}{\sigma_p}$	σ_p	σ_m	$\frac{\sigma_m}{\sigma_p}$
2-6	Gross	3.25	3.11	0.96	2.08	2.55	1.22	0.02	0.22	11.0
7-11	Gross	3.25	3.15	0.97	0.94	2.55	2.71	-0.27	0.22	-0.81

The correlation between predicted and measured axial stresses at both cross sections is quite good. Fig. 7 shows the measured and predicted axial force response for a portion of a unit train which confirms the applicability of the space frame analysis.

Table 1 shows that the correlation between predicted and measured major and minor axis bending stresses at both cross sections of the west hanger is poor.

Observations of strains in the pin-plates near M_1 of the west hanger during passage of trains over the bridge indicated that the pin-plates are not both initially in contact with the pin at M_1. It was observed that when the bridge was unloaded

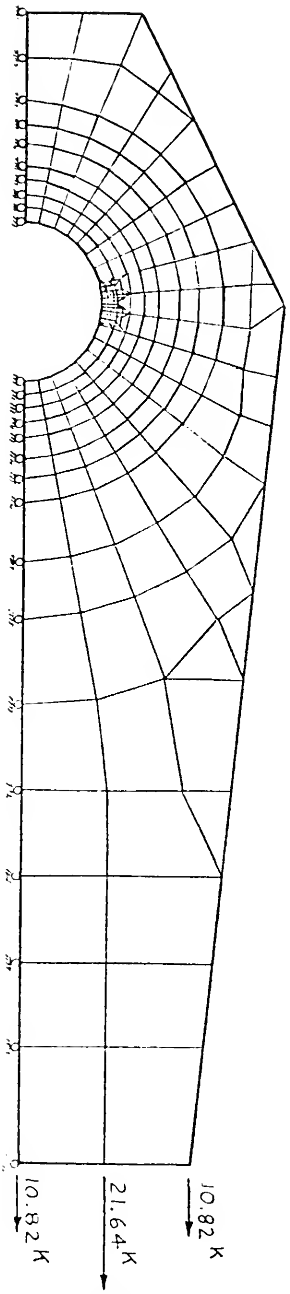

Fig. 4—Finite element model of pin-plate.

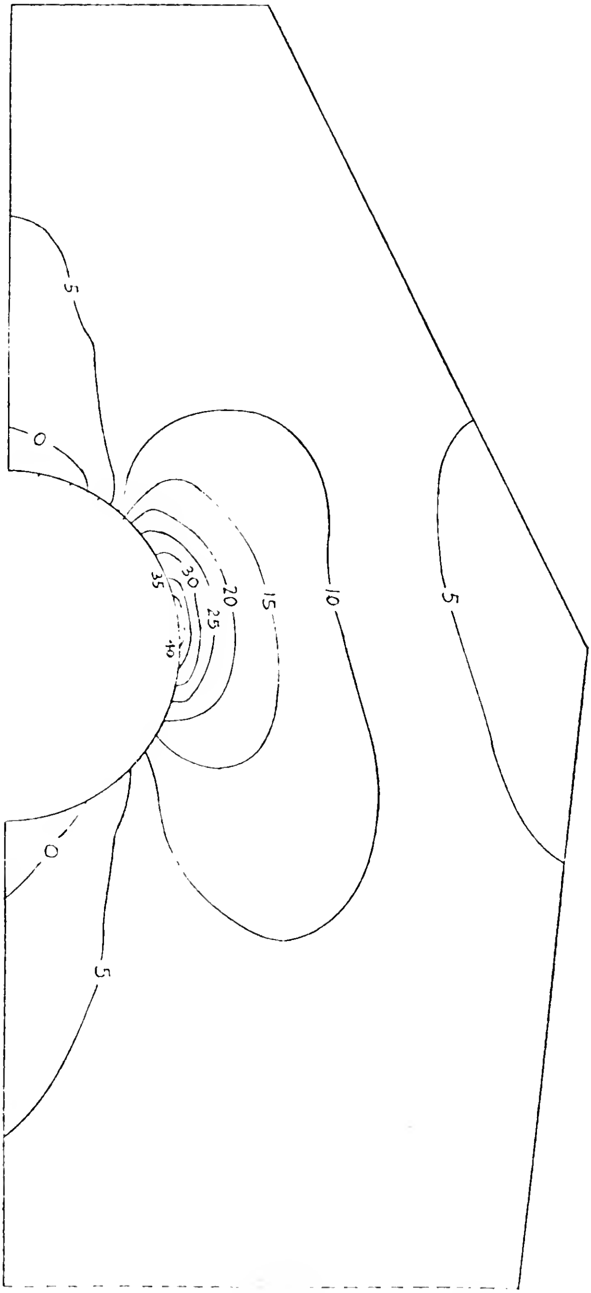

Fig. 5—Principal tensile stress contour plot for pin-plate.

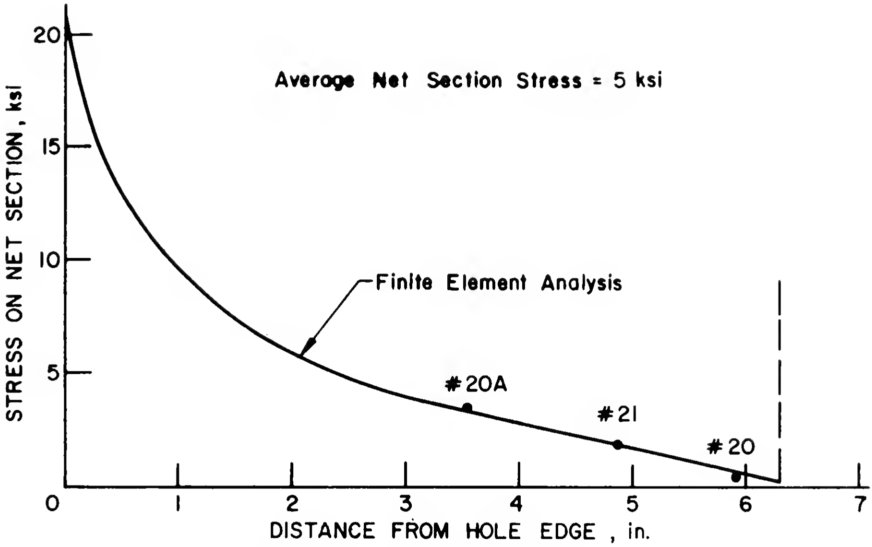

Fig. 6—Comparison of predicted and measured stresses on net section of pin-plate.

the waterside pin-plate did not bear on the pin. As loading increased the trackside pin-plate initially carried the hanger force as shown in Fig. 8. The exterior pin-plate did not bear until the hanger was subjected to high loads. An analysis showed that if the correlation at both gaged cross sections is assumed to be unity in Table 1, this implies that the axial force in the west hanger is shared between the trackside and waterside pin-plates in the ratio 70 to 30 percent, respectively.

Table 2 shows the correlation in the east hanger between predicted stress, σ_p, and measured stress, σ_m, in ksi, for the same loading.

Table 2 Correlation of Predicted and Measured Stresses: East Hanger (ksi)

Gages	Section	Axial Stress			Major Axis Bending Stress			Minor Axis Bending Stress		
		σ_p	σ_m	$\frac{\sigma_m}{\sigma_p}$	σ_p	σ_m	$\frac{\sigma_m}{\sigma_p}$	σ_p	σ_m	$\frac{\sigma_m}{\sigma_p}$
22-26	Gross	3.25	3.33	1.02	2.08	2.02	0.97	0.02	0.24	12.0
27-31	Gross	3.25	3.26	1.00	0.94	1.01	1.07	-0.27	0.22	0.81

Except for the minor-axis bending stresses, the correlation of axial stresses and major-axis bending stresses is quite good for the east hanger. The latter indicates that both pin-plates at M_1 are in nearly equal bearing. This condition was also observed during passage of trains over the bridge. Since the minor axis bending stresses are low, correlation was not expected to be good.

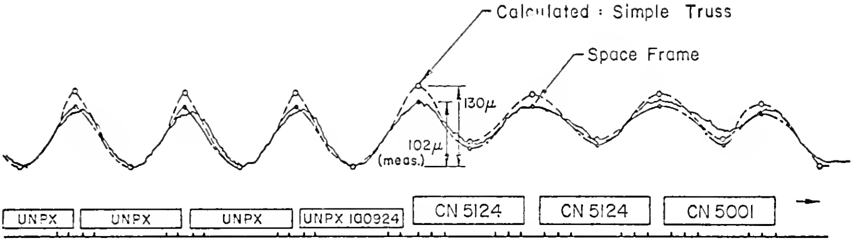

Fig. 7—Comparison of unit train response with predicted axial strain.

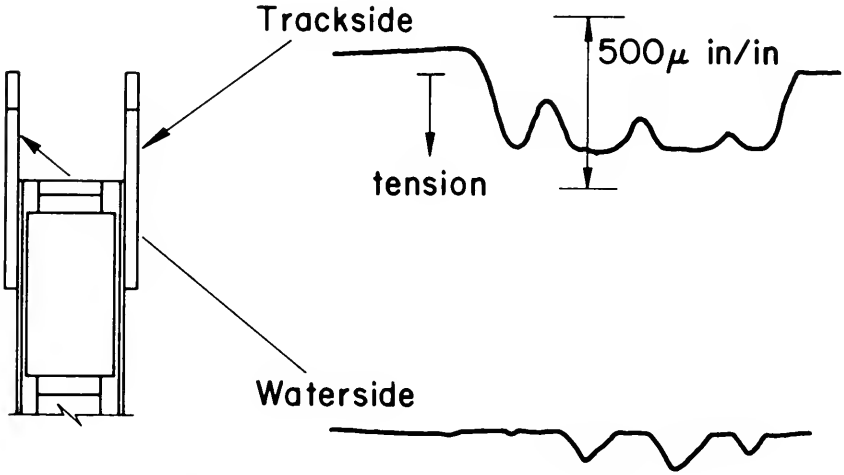

Fig. 8—Strain in pin-plates of west hanger.

ESTIMATED FATIGUE STRENGTH OF RIVETED MEMBERS AND PIN-PLATES

Fatigue Strength of Riveted Members

Tests of riveted joints have demonstrated that crack growth usually originates at the rivet hole in a region of high stress concentration (5). Almost all fatigue data on riveted joints has been acquired on small butt joints (5), (6), (7), (8), (9). This work was performed at the University of Illinois, Northwestern University, Purdue University and in Germany. Investigators examined the influence of the bearing ratio, the effect of rivet clamping force, the rivet pattern and other variables. Most of the data was obtained from tests on A 7 steel joints.

The test results from all of the available sources are plotted in Fig. 9. The stress range on the net area is plotted as a function of cycle life. There is substantial scatter in the test data which mainly reflects the influence of clamping force and probable variation in the initial flaw condition. When extreme bearing ratios are ignored, especially with reduced clamping force, the effect of bearing does not appear as

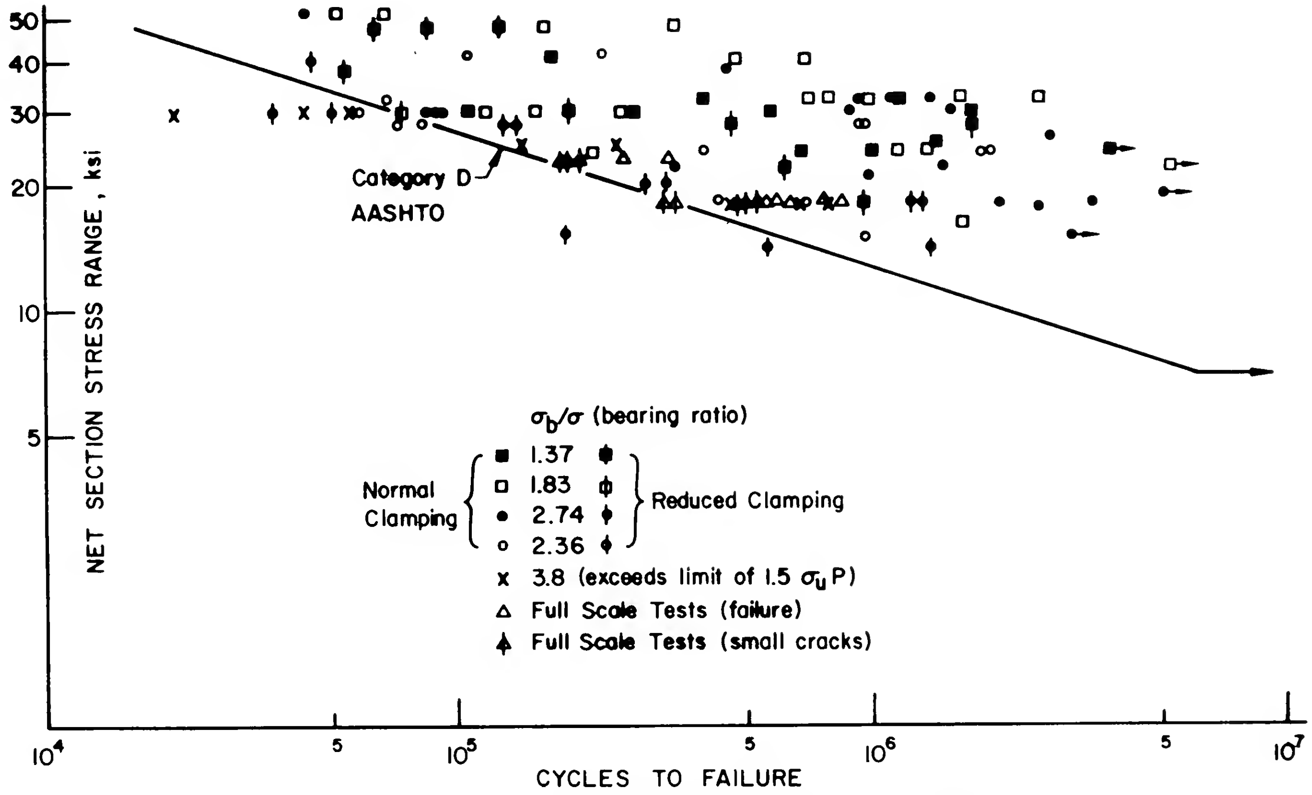

Fig. 9—Stress range on net section vs. cycle life for riveted joint tests.

critical a variable. The bearing ratios of 2.74 and 3.8 far exceed permissible and recommended levels. No tests were included in Fig. 9 when the specimens were subjected to stresses which far exceeded the yield point on the net section. In many of these tests when the R ratio was taken as ½, the stress approached the tensile strength. As was noted in Ref. 10, the data from specimens that exceed the yield point are not representative of the conditions that occur in actual structures. Also shown in Fig. 9 are recent tests on large scale specimens which simulated joints in an ore bridge (11). The points that are indicated as small cracks were subsequently fitted with high-strength bolts and showed substantial improvements in fatigue strength.

For design purposes the data on riveted joints are compared with the fatigue relationship defined by Category D of the AASHTO specification (12). This category has been used to define the strength of riveted joints in the design recommendations now being developed by Subcommittee 4, AREA Committee 15—Steel Structures. It is visually evident that Category D provides a lower confidence limit to the available test data on riveted joints. Category D will be used in this report to define the fatigue behavior of the riveted members of the Fraser River Bridge.

Fatigue Strength of Pin-Plates

Since test data are not available on pin-plates, it is necessary to estimate their fatigue strength. The fracture mechanics approach to crack propagation is the most rational method currently available for predicting the fatigue life. It has been used to provide an explanation of the fatigue crack growth of a number of welded steel details (13), (14), (15). These studies have shown that the crack growth rate of structural steels can be taken as:

$$\frac{da}{dN} = 2 \times 10^{-10} \Delta K^3 \tag{6}$$

for all details, where ΔK is the range of the stress-intensity factor K. Basic crack growth studies have provided similar results.

To permit evaluation of the stress intensity factor on the axis of the pin-plate holes, the finite element analysis was made to define the state of stress. The pin-plate stress results showed that the highest stress location is at the surface of the pin-plate hole (see Fig. 6). The stress gradient on the net section of the pin-plate is produced by the geometric condition of the detail and its loading configuration.

Closed form analytical solutions for K do not exist for the pin-plate geometry shown. The finite element solution showed the stress concentration effect was 4.16 at the hole edge and decayed rapidly away from the hole edge.

The stress field in the plate near the hole was observed to be defined by the stress concentration decay function defined in Ref. 13 for crack sizes less than the plate thickness in length.

If the stress distribution is given in function form, the geometric correction factor for the stress intensity factor can be determined from the relationship (16)

$$K = \sqrt{\pi a}\,\frac{2}{\pi} \int_0^a \frac{\sigma_b \, db}{\sqrt{a^2 - b^2}} \tag{7}$$

This is similar to the influence function method used in Ref. 17. The redistribution of the non-uniform stress field is accounted for as a crack grows. This yields a relationship F_G equal to

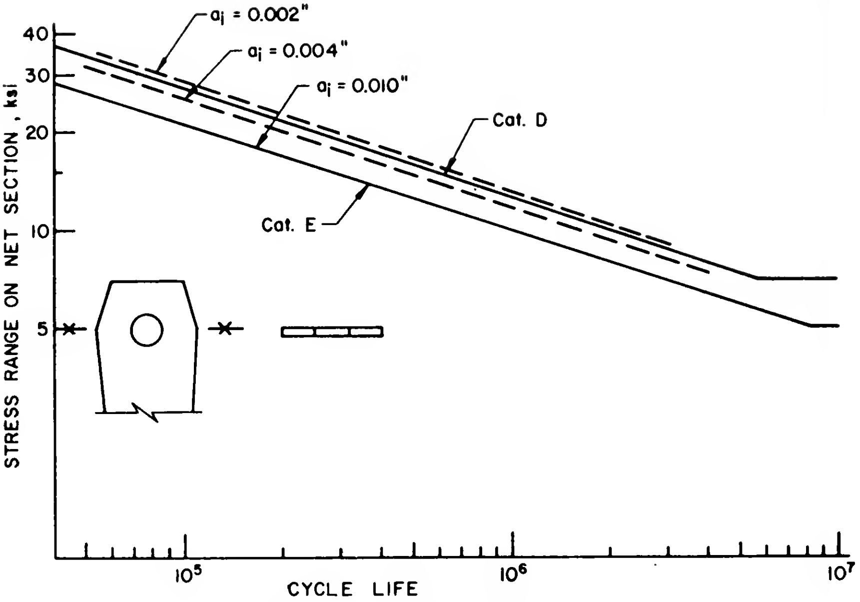

Fig. 10—Predicted fatigue strength of pin-plates.

$$F_G = 4.16 \left\{ 1 - 3.215 \left(\frac{2}{\pi}\right)\frac{a}{R} + \frac{1}{2}(7.897)\left(\frac{a}{R}\right)^2 - 9.288\left(\frac{4}{3\pi}\right)\left(\frac{a}{R}\right)^3 + 4.086\left(\frac{3}{8}\right)\left(\frac{a}{R}\right)^4 \right\} \qquad (8)$$

Hence, the stress intensity factor for the pin-plate is given by

$$K = F_G \, q \, \sigma \sqrt{\pi a} \qquad (9)$$

where q is a crack shape factor that varies from $2/\pi$ to 1. For the pin-plates being examined, the holes were drilled and hence the initial flaw condition expected at such a hole should not exceed the small discontinuities expected at such edges (i.e., 0.001 to 0.004 in.).

The stress range-cycle life relationship for the pin-plates was estimated from Eqs. 5 and 8. The results of this evaluation are plotted in Fig. 10 and compared with fatigue strength Categories D and E (12). Fig. 10 shows that for the expected corner crack at the hole edge ($q \backsim 2/\pi$), the fatigue strength of the pin-plate is between Category D and E. Since the crack shape factor q may be slightly greater than $2/\pi$, it appears reasonable to use Category E to define the fatigue strength of the pin-plates. This would also allow for an above-average-size initial discontinuity at the hole edge (up to 0.010 in.).

EVALUATION OF FATIGUE DAMAGE

The predicted nominal forces in the hanger for the random load spectrum defined by Sweeney in Ref. 1 was used to estimate the cumulative damage in the hanger and pin-plates of the 380-ft fixed span. The experimental studies carried out by CN Research showed that the structure was acting more nearly like a space frame than a pin-ended truss structure (see Fig. 7). However, measurements under static loading indicated some variability depending on the location of the test load. It appeared that the full stringer continuity was not always available. The analysis indicated that the predicted nominal axial forces assuming plane simple truss behavior should be adjusted by a factor of 0.82 to reflect the joint fixity of the truss and the continuity of the stringers.

An impact factor of 1.054 was applied to the predicted hanger forces to account for uncertainties in the analysis, provide a margin for unaccounted variables, and because impact effects were filtered out above 10 to 14 Hz.

Estimated Damage in Hanger M_1L_1

Since the floorbeam hanger connections had been strengthened in 1923 by the removal of the hanger lacing and the addition of a solid web plate and splice plates, it was necessary to examine the hanger at two locations. At the hanger-floorbeam connection, the gross section was provided by four angles 6 x 3½ x ⅝, two plates 16½ x ⅝, one plate 10⅝ x ⅝ and one plate 10⅝ x 11/16 in. This provided much higher cross-section area and moments of inertia Ixx and Iyy at the hanger section subjected to the largest moments from floorbeam end rotation and twist.

The space frame analysis indicated that the highest stressed cross-section in the hanger M_1L_1 at the floorbeam-hanger connection is located just at the hanger web splice where five rivet holes occur. Using net section properties, the critical stress range at the most highly stressed rivet hole was derived from Eq. 2. The coefficient for weak axis bending was increased to reflect the actual measured response at the hanger connection. Variability in stringer continuity is believed to be the cause for the variation in strain across the inside face of the hanger.

$$\sigma = \frac{0.82\ P}{29.42} + \frac{35.00\ P}{1099} + \frac{0.80\ P}{143} = 0.06536\ P \qquad (10)$$

where P is the force assuming plane truss behavior defined in Chapter III of Ref. 1. Both the RMS and Miners equivalent force range were evaluated and found to be less than 2% different. These values are summarized in Table 3.

Table 3 Nominal Hanger Force*

Time Interval	No. of Cycles	P_{RMS}	P_{MINER}
up to 1973	2,217,810	71.7 kips	73.4 kips
up to 1980	4,183,600	74.7	75.9
up to 1985	5,839,350	75.3	76.3
up to 1990	7,495,100	75.6	76.6

*Assuming plane simple truss behavior; see Reference 1 for detailed description of load spectrum

The coefficients in Eq. 10 have been adjusted to account for space frame behavior. The resulting effective stress ranges at the hanger-floorbeam connection, including the impact factor 1.054, are shown in Fig. 11 and compared with Cate-

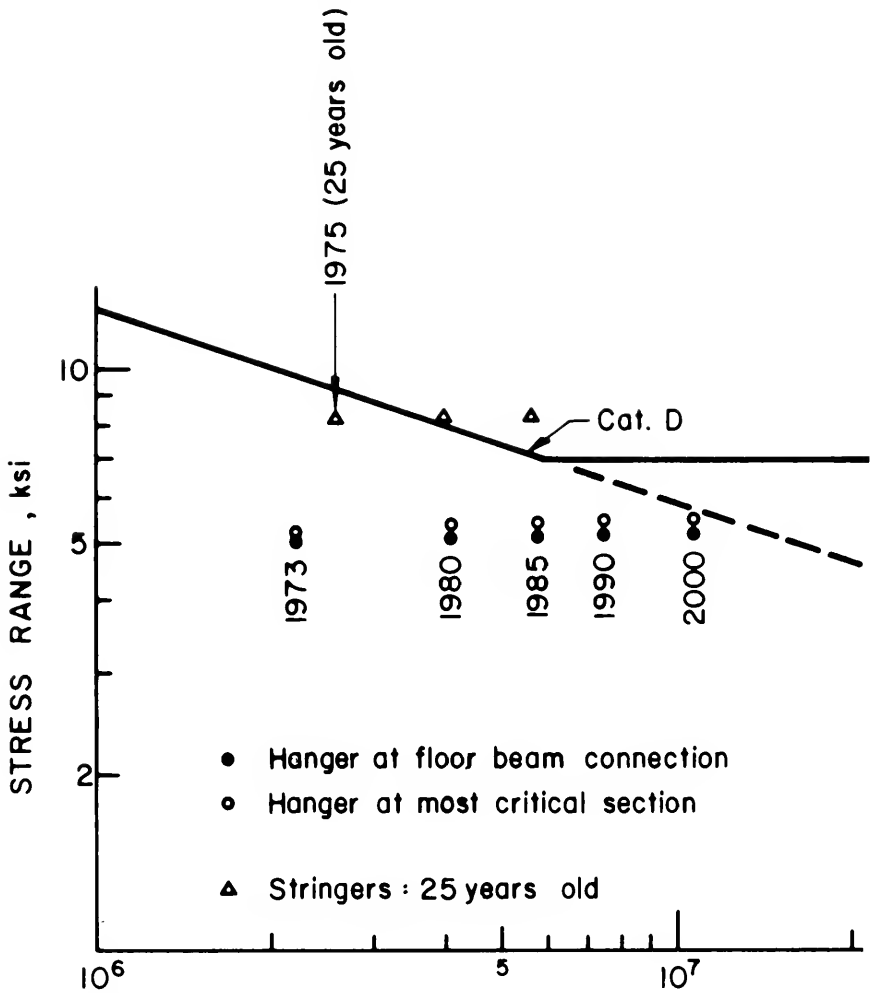

Fig. 11—Comparison of effective stress range in hanger and stringers of 380-ft fixed span with fatigue strength of riveted joints. (See Fig. 12 for pin-plates.)

gory D. It is readily apparent that no difficulty should be encountered with the hanger near the floorbeam until after 2000.

Under normal circumstances the moment along the hanger length would be expected to vary from a maximum at the hanger-floorbeam connection to a minimum at the pin-plate end. This was observed for the east hanger but was not the case at the west hanger. The field measurements showed that the west hanger pin-plates were not carrying the same load. Initially only the inside pin-plate was in bearing. The outside pin-plate picked up load only after it seated and came into bearing (see Fig. 8). This end eccentricity meant that the moment along the west hanger length was nearly constant. The moment about the hanger weak axis was very small away from the hanger-floorbeam connection and was ignored.

The most highly stressed rivet hole was at the angle-web connection. The stress at this location is given by

$$\sigma = \frac{0.82\ P}{20.39} + \frac{3.916 \times 8.148\ P}{1073} = 0.070\ P \qquad (11)$$

The effective stress ranges adjusted for an impact factor of 1.054 are also plotted in Fig. 11. The results demonstrate that hanger M_1L_1 is not in danger of failure before the year 2000. Since the unequal distribution of load in the pin-plates was most severe in the west hanger, it represents the worst condition.

Estimated Damage in Pin-Plates (M_1L_1)

The maximum expected force to be carried by the most highly stressed pin-plate was 40 to 50% of the nominal hanger force. However, field measurements demonstrated clearly that the pin-plates of the west hanger were not sharing the load as expected (see Fig. 8). As a result, the inside pin-plate was observed to carry 73.5% of the load. Hence for purposes of evaluation, the effective force acting on the most highly loaded pin was

$$\overline{P} = 0.735 \times 1.054 \times 0.82\ P = 0.635\ P \qquad (12)$$

where P is defined in Table 3. Since the net section area was used to define the details fatigue strength (see Fig. 10) the resulting nominal net section stress on the pin-plate is $\overline{P}/8.656$.

These results are plotted in Fig. 12 and compared with Category E. This shows that a critical condition develops as 1985 is approached. The probability for failure of this highly stressed pin-plate is great thereafter. Since the design line is based on the lower bound fatigue strength, failure will depend greatly on the condition of the pin-plate. When the pin plates are sharing the load about equally as was the case for the east hanger, the effective force is $\overline{P} \simeq 0.44P$. This results in effective stress ranges between 3.7 and 4 ksi as shown in Fig. 12. This shows that the fatigue strength of the east hanger pin-plates are adequate well beyond the year 2000.

Estimated Damage in Stringers

Strain measurements were made near midspan on a bottom flange angle of the west stringer between L_1L_2. These measurements confirmed that the stringer was subjected to some strain reversal and acted with some degree of continuity. An examination of the strain response indicated that the stringer was subjected to about the same number of stress cycles as was experienced by the hanger M_1L_1. Fig. 13 shows the measured stress spectrum which was used to assess the fatigue resistance of the stringers. This results in measured effective stress ranges of $S_{rRMS} = 7.43$ ksi and $S_{rMINER} = 7.54$ ksi.

These measured values of effective stress range were made on the top surface of the bottom flange angle. When adjusted to the bottom edge of the rivet holes at the web-angle connection, which is the critical location, these stress ranges are reduced by about 8%. However, the stress range should be increased by several other factors when estimating damage over the full life of the structure. Since the records were filtered for roll-off frequencies above 10 to 14 Hz, the full effect of impact was not taken into account. Records were acquired with the filters removed

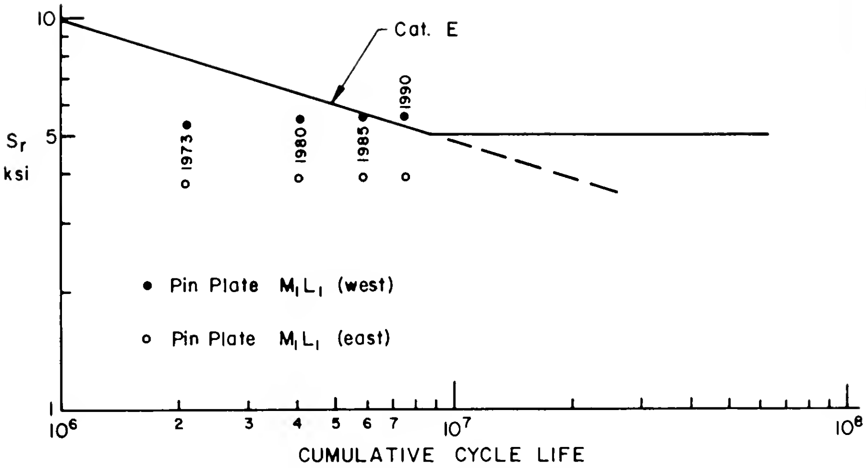

Fig. 12—Comparison of effective stress range in pin-plates with their predicted fatigue strength.

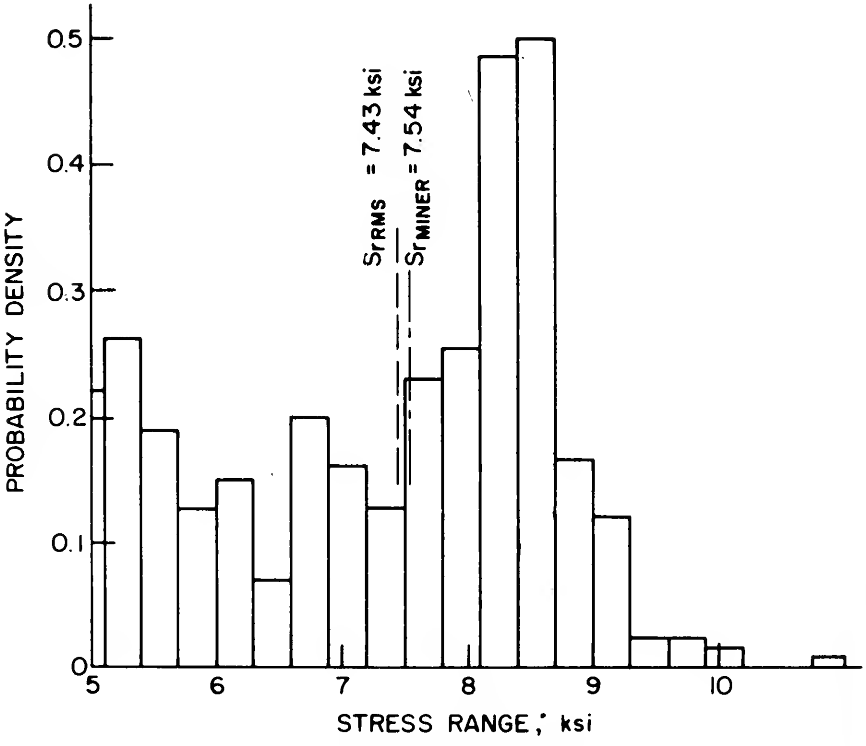

Fig. 13—Measured stress distribution in the stringers.

and suggest that higher peak stresses were probable. Based on the relative difference between the response, a factor of 1.04 appears appropriate. The second factor is the underloading that was observed for the unit trains of the T and S series. These suggested a correction of 1.085 should be applied to the strain cycles of unit-train car loading. The other trains crossing the bridge were not affected. This was found to increase the effective stress range by a factor of 1.035.

One other factor should be considered when estimating fatigue damage in the stringers. The measured strains were obtained for the gross section. To adjust to the net section stress, an additional increase of 10% is necessary.

As a result of the adjustments for the point of crack initiation, maximum moment, greater impact and heavier axle loads, the adjusted values of effective stress range are increased by $1.04 \times 1.035 \times 1.10 \div 1.08 \simeq 1.10$. Hence the effective stress range becomes: $S_{rRMS} = 8.17$ ksi and $S_{rMINER} = 8.29$ ksi. These values are also plotted in Fig. 11. This shows that fatigue cracking could be expected in the stringers about 1979.

Since the stringers are predicted to reach their lower bound fatigue strength in 1979 it is appropriate to discuss the significance of this observation. This does not mean that large numbers of stringers will immediately crack. The lower bound fatigue strength defines the worst condition. As the fatigue test data plotted in Fig. 9 shows, large variation in life can be expected. Also, since the riveted stringers have two tension flange angles and a web plate, failure of one element will not result in immediate collapse of the member. It should be possible to detect a failed component before a severe collapse occurs.

SUMMARY AND CONCLUSIONS

An analysis of the most highly stressed hangers and the stringers of the main 380-ft fixed span of the Fraser River Bridge has indicated that fatigue cracking can be expected. The stringers were predicted to reach their lower bound fatigue strength in 1979 based on the traffic defined by Sweeney in Ref. 1. The hanger pin-plates which had unequal distribution of load were predicted to reach their lower bound fatigue strength in 1985. The RMS and Miners rule assessment of fatigue damage provided comparable results.

The method used to assess the fatigue damage in the hangers and stringers of the Fraser River Bridge can be used on other bridge structures as well. The frequency and magnitude of force or moment can be estimated from traffic using the structure. Only cars 80 tons or heavier and locomotives will normally need to be considered on comparable structures. The effect of lighter cars should be examined on weaker structures.

In order to accurately assess the significance of the applied loads, a space frame analysis will normally be required for all structures. The behavior of truss spans can range from plane truss to space frame behavior with full continuity. Hence only field measurements of the stress in critical components can determine the actual behavior and the applicable analysis. In the case of the hangers of the Fraser River Bridge this was found to make a 15 to 20% difference in the actual stress range. In fatigue life evaluation, a 10% variation in stress range can mean a 36% variation in permissible stress range cycles. For the Fraser River Bridge this means a difference in life of about six years at the current rate of loading.

Care should be exercised in evaluating the fatigue damage of hanger connections at floorbeams. Here the high bending stresses from the end rotation and twist of the floorbeam must be properly assessed. These stresses are particularly sensitive to stiffness and geometry of the connection. Care should also be taken when interpreting field measurements. The possibility for unequal distribution of force to various components as was the case with the pin-plates on the west hanger M_1L_1, should be carefully examined.

ACKNOWLEDGEMENTS

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REFERENCES

1. R. A. P. Sweeney, "Load Spectrum for Fraser River Bridge at New Westminster, B.C.," Proceedings AREA, Vol. 77, 1976.
2. Association of American Railroads, "Field Investigation of Two Truss Spans on the Southern Pacific Company," May 1968, Report ER-82, AAR Research Center, Chicago.
3. James Michalos and J. M. Louw, "Properties for Numerical Analyses of Gusseted Frameworks," Proceedings, AREA, Vol. 58, p. 7.
4. K. J. Bathe, E. L. Wilson and F. E. Peterson, "SAP IV—A Structural Analysis Program for Static and Dynamic Response of Linear Systems," Report EERC 73–11, Earthquake Engineering Research Center, University of California at Berkeley, June 1973, Rev. April 1974.
5. J. F. Parola, E. Chesson, Jr. and W. H. Munse, "Effect of Bearing Pressure on Fatigue Strength of Riveted Connections," Bulletin 481, Engr. Exp. Station, Univ. of Illinois, Vol. 63, No. 27, Oct. 1965.
6. K. H. Lenzen, "The Effect of Various Fasteners on the Fatigue Strength of a Structural Joint," AREA Bulletin 481, Vol. 51, June–July 1949.
7. W. M. Wilson and F. P. Thomas, "Fatigue Tests of Riveted Joints," Bulletin 302, Univ. of Ill., 1938.
8. F. Baron and E. W. Larson, Jr., "The Effect of Grip upon Fatigue Strength of Riveted and Bolted Joints," 2nd Progress Report, Proj. 5, Northwestern Univ., 1951.
9. F. Baron, E. W. Larson, Jr., and K. J. Kenworthy, "The Effect of Rivet Pattern on the Fatigue Strength of Structural Joints," Prog. Report Proj. 6 and 7, Northwestern Univ., 1953.
10. J. W. Fisher and J. H. A. Struik, "Guide to Design Criteria for Bolted and Riveted Joints," Wiley Interscience, 1974.
11. H. S. Reemsnyder, "Fatigue Life Extension of Riveted Structural Connections," Journal of the Structural Division, Vol. 101, ST 12, Dec. 1975.

12. AASHTO, 1974 Interim AASHTO Specifications, Art. 1.7.3.
13. J. W. Fisher, P. A. Albrecht, B. T. Yen, D. J. Klingerman and B. M. McNamee, "Fatigue Strength of Steel Beams with Transverse Stiffeners and Attachments," NCHRP Report 147, Transportation Research Board, 1974.
14. M. A. Hirt and J. W. Fisher, "Fatigue Crack Growth in Welded Beams," Engineering Fracture Mechanics, Vol. 5, 1973.
15. S. J. Maddox, "Assessing the Significance of Flaws in Welds Subject to Fatigue," Welding Research Supplement, September 1974, Vol. 53, No. 9.
16. P. Albrecht and K. Yamada, "Rapid Calculation of Stress Intensity Factors," paper submitted for publication in the Journal of the Structural Division, ASCE, 1975.
17. T. A. Cruse and P. M. Besumer, "Residual Life Prediction for Surface Cracks in Complex Structural Details," Journal of Aircraft, Vol. 12, No. 4, pp. 369–375, April 1975.

Data Bases: Help or Harassment for Engineering Management

77–658–7

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What would happen if upon your return to your respective offices you would find a Federal Railroad Administration official, and he said that by tomorrow he needs to know: How many ties did you install on line segment A in the last five years?

Your responses would probably fall into three basic categories. First, total chaos—having very little ability to recount tie installation information. Second, controlled chaos—sending a task force pouring through manual records to find the tie installation information. And third—a relaxed attitude for sure—we'll punch that request right into our black box known as a computer, watch the lights blink awhile, and have the results first thing in the morning.

This last response is the one I am here to discuss today—Data Bases: Help, or Harassment for Engineering Management. Hopefully, you will see that they are a help and will be using this concept in the future.

First, what is a data base? Simply put, it is an inventory of information. This information can be stored as simply as on index cards, more sophisticatedly on punched cards for mechanical sorting, or in computers for electronic data processing.

Although the term "data base" may be new, the concept certainly is not. Bridge lists and track profiles have been in existence as long as railroads. Mechanized data bases arrived in the early 1960's when several roads computerized their work equipment inventories. Presentations at previous Technical Conferences have dealt with individual data bases, specifically structures inventories.

Why the big push for data bases now? There are two big reasons: First, the needs of railroads, and of engineering departments have changed. No longer are vast sums of money available for maintenance and improvements. Today's economic

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Note: Discussion open until October 15, 1976.

conditions dictate that the greatest possible rate of return be attained for the maintenance dollar. The information in data bases can provide quantifiable answers for maintenance planning, increase productivity, and optimize equipment utilization.

Second, as far as data bases are concerned, the wheel has been invented. Much like pocket calculators, their availability has increased while costs have decreased. Each road need not go off independently trying to blaze a new trail. Some railroads, as well as commercial concerns, have already swept a fairly wide path in the concepts, designs and implementation of data bases. With the advent of this technology more and more people in all levels of management are realizing the need for fast, accurate data retrieval and manipulation.

What then is the state of the art of data bases with respect to maintenance of way, and more important, what are the benefits of such data bases?

One road maintains a partial rail inventory of its traditional new rail territory —those tracks having the highest traffic densities, carrying the most profitable commodities, and being located in the most severe curvature/gradient terrain. This inventory is used to determine the priority of rail replacement and to select the most economical rail type.

An extension of this limited rail inventory is exhibited by another road which inventories all rail and turnouts, including main line, branch line, industry spurs, and yard tracks. In addition to the rail data, information regarding surfacing, tie installation, rail testing, and weed spraying is being collected. When completed, this data base will provide a basic track characteristics file which will greatly aid in developing all renewel and maintenance programs.

These two cases are examples of independent data bases which are very fine for particular data recall. They fit in very well for line segment analysis where the question to be answered is "What do we have out there?" Instead of paging through rail charts and condensed profiles to manually retrieve the desired information, the data could be obtained much quicker and more accurately if a computerized data base were available.

Now suppose upon returning to your office, you find that your budget for the remainder of the year was being reduced by 20 percent. The question now is not only one of data recall—what do I have that needs to be replaced, but what are the benefits—which lines have the greatest traffic density and must be maintained, and where can money be saved by reducing derailments?

What you need now is an integrated data base system; that is, for each segment not only is engineering information needed, but operating and traffic data as well. One road has taken a step forward in data base development and installed such a system. For each milepost, six independent inventories or files, dealing with track characteristics, derailments, track defects, bridges, track profiles and traffic densities are kept up. By being able to concurrently search each file for certain characteristics or milepost information, much more data are available at a single time and much "cross-indexing" can be done.

The benefits of such an integrated system are very great. The previous question can be quantifiably answered. Quickly and accurately, the exact location of substandard track sections can be pinpointed on the most economically justifiable line segments. From this listing, repair priorities can be set.

Such an integrated data base system also embraces research for behavioral patterns. Example, rail wear can be pinpointed as to curve, grade, traffic density, and tie and surface conditions.

The track characteristic file points out another new tool in information processing—that of the track geometry car. Such cars, now in use on several different roads, provide information on such things as cross level, surface, gauge and alignment, thus providing an excellent condition inventory of the property. This condition inventory is a must, since it is of little use to know exactly what is sitting out there without knowing what condition it is in.

One further extension of the integrated data base concept is currently being developed. Under this system, a mile-by-mile record of physical characteristics and descriptions will be built plus a similar record of dollar accounting information. This system will be driven by a single, all-purpose reporting form which will provide all the necessary engineering and expense data.

Existing data bases are exclusively by and for maintenance of way departments. They are maintained through separate engineering department forms with other paperwork being necessary to maintain accounting department needs.

There are many testimonials and bouquets for data bases and data processing in general, some of which already have been alluded to. More and more are forthcoming every day, especially from the Northeast Corridor. Existing data bases are providing information and answers to questions which would take many man-months to otherwise research. If these data were not readily accessible, I shudder to think where that problem would be now.

So far I have shown what data bases are and can do. They are and can be a tremendous help, only if properly designed, implemented, and maintained. If not so, they can indeed be a harassment.

There are several ground rules which must be laid down before any system can be designed. First, there must be a definite commitment from management for such a system. This means you. You must want the system, use it and ensure that it is properly maintained. If you are not enthusiastic about it and do not instill this feeling to your subordinates, then regardless of how technically sound the system is, it will falter and become another white elephant.

The second ground rule is to make sure of a definite purpose or intent in the design of the system. Information must be provided to meet specific ends such as to prevent derailments, minimize slow orders, or provide a satisfactory quality of ride.

With these ground rules met, what next? There are three things to consider: what type of data is needed, how to obtain it, and how to design and maintain the data base to ensure current, accurate data at minimum cost.

Decisions as to the types of data to be contained in the data base must be made by you, those directly concerned. There is no golden rule, nor necessarily rule of thumb for the data base contents. Each one can be custom-made to the user's purposes.

There are several schemes available for obtaining the necessary physical information. The most precise, but most costly and time consuming way would be to physically inventory the property. The most practical and economical way is to transcribe as much existing data as possible. It is amazing how much information will already be available from condensed profiles, bridge lists, signal lists and the like. Once the transcription is complete, it can be field verified, and any incorrect or missing information compiled. Another approach is to establish a bench mark work date, start from zero, and proceed to build the data base as material is installed.

Besides defining and initializing the data base, some consideration must be given to the retrieval and manipulation routines necessary to fully utilize the systems. These routines can be custom-built, as has been the case in most instances, or a "canned" report generating system could be installed to produce the desired outputs.

Maintaining the system is a must. The railroad is a dynamic entity and the data base must reflect these changes. After all, how good is a month-old newspaper. The key to the maintenance of the data base is the source document, ideally one all-purpose form to provide engineering and accounting data. Regardless if multiple forms are used, they should be simple, straightforward, with as much pre-printed data as possible. Such forms reduce paperwork and provide one set of figures for purposes of maintenance planning and expense monitoring. It must be remembered that these source documents are not meant to be harassments, rather means to obtaining the required answers for management questions.

Today I have attempted to whet your whistle so-to-speak for data bases and tried to show that the information explosion should be a help, not a harassment to engineering management. I have been fortunate in that I have been able to visit some of the various railroads throughout this continent and observe what they are doing with regard to information processing. When I graduated from college a handful of years ago, I thought that I had a prety good appreciation for what a computer could do in terms of pure "number crunching." Here, I hope I have conveyed the added appreciation I have recently learned for data base processing.

I am by no means an expert in the field of data bases nor maintenance of way. The Board of Direction of the AREA has charged Committee 32—Systems Engineering, with presenting a symposium on data bases for maintenance of way. This symposium tentatively scheduled to be held along with the Regional Meeting in Pittsburgh this fall, will be given by the experts in railroad engineering data bases. Within the next few days, each chief engineer will receive a letter informing him of Committee 32's intentions for the symposium, and requesting comments. I hope you will support the idea, and that you will attend the symposium. See you there.

Rail Wear and Corrugation Studies

77–658–8

By

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and

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These are case studies of rail wear problems occurring on two Canadian railways' main lines in the Rocky Mountains. The problem arose about 1969 with the introduction of unit trains for hauling coal, potash and sulfur. These unit trains consisted of identical, fully loaded 100-ton-capacity vehicles having a gross weight on rail of 263,000 lb.

Table I shows for the Canadian National Railways' line a traffic split by vehicle type, excluding tonnage generated by empty cars, passenger trains, and locomotives. Note that on the average 100-ton cars are loaded to 94% of their rated capacity, while 50- and 70-ton cars are loaded to 74% of their rated capacity.

Fig. 1 shows a frequency histogram of gross car weights through a section of Canadian Pacific Rail line. Note that the heavy loaded movement is in the westward direction and is in the 130–140 ton range. The column in the 20–30 ton range shows that empty car return movement is in the eastbound direction. The intermediate columns represent mixed freight.

In the mountainous territory sharp curves are frequently encountered. The combination of heavy vehicles, large annual tonnages and curved track resulted in greatly accelerated rail wear in curves. The rail wear was much greater than would be anticipated based only on increased annual tonnage.

Examination of the train consists confirmed that nearly all of the 100-ton cars moved in unit trains. Since the basic design of all capacities of freight car trucks is the same, the rail wear problems are more accurately attributable to 100-ton carloadings. It is apparent that in going to 100-ton carloadings we have unwittingly stepped over a threshold and are now suffering punitive rail damages on lines where sharp curves are frequently encountered. The role of the unit train has been to bring this problem into sharper focus. The need for a program of remedial action to improve existing services and for the exercise of caution in designing new services is now apparent.

UNDERSTANDING THE PROBLEM

For any remedial action to be effective, the causes of the problem and the nature of the remedial action must be understood. We will, therefore, attempt to deal with the subject by posing the following questions, and then attempting to answer them in a manner that can be understood by people of varying educational backgrounds and work experience:

How Severe Is the Problem?
What Are the Causes of Accelerated Rail Wear?
What Remedial Action Is Required and by Whom?

Note: Discussion open until October 16, 1976.

TABLE I

1972 Traffic Carried by Vehicles of 50, 70 and 100 Ton Capacity

Car Capacity (Nominal)	Number of Cars	Gross Tonnage	Gross Tons/Car		% Car Capaci
			Actual	Gross Limit	
40-50 tons	126,487	8,257,315	65.3	88.5	74
70 tons	41,595	3,374,630	81.1	110.0	74
100 tons	59,261	7,306,415	123.3	131.5	94
TOTAL	227,343	18,938,360			

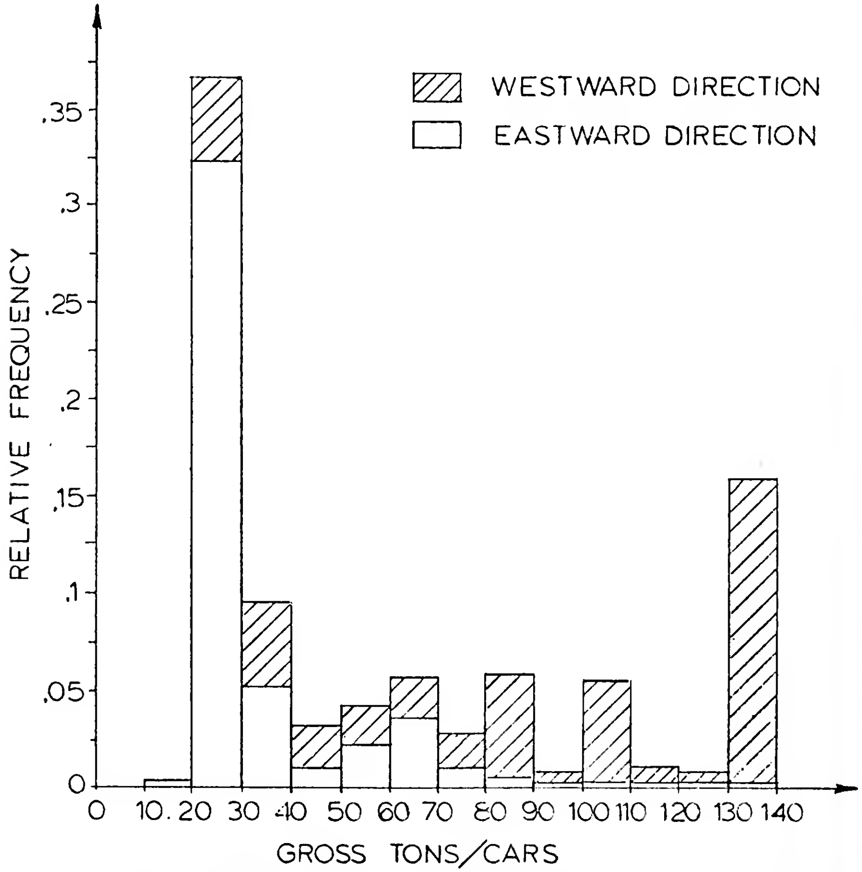


Fig. 1—Frequency histogram of gross car weight through Shuswap Subdivision.

HOW SEVERE IS THE PROBLEM?

The problem occurs to some extent on all curves but seems to be more troublesome on the sharper curves of 4° and up. CN has made rather extensive analyses deriving data from traffic splits by gross carloadings from 1967 to 1974, from rail replacement data from 1964 to 1974, and from annual gross tonnages back to 1960. There is a clearly discernible trend of severely escalating replacement rates as the percentage of fully loaded 100-ton cars increases. It appears that we can anticipate replacing about one-third of track in these curves annually if the present traffic patterns and replacement rates are sustained.

On Canadian Pacific trackage, these problems coincided with the dramatic increase in freight traffic which nearly doubled in the period between 1964 and 1969. On CP Rail, the gross tonnages are higher and the curvatures are sharper, therefore the problem is even more serious. This problem also occurs in other locations where substantial numbers of heavy vehicles operate on curved track.

Curve wear, head flow and rail corrugations also occur on other railways in Canada and elsewhere in the world. In planning new unit-train movements, it is important to consider the percentage of curved trackage over which the trains will operate. Otherwise, greatly accelerated rail wear may occur and the rates charged by the railroad may not be fully compensatory.

WHAT ARE THE CAUSES OF ACCELERATED RAIL WEAR?

The accelerated rail wear, although closely linked with unit-train operation is, in fact, a direct consequence of overloading of the rail by the fully loaded 100-ton cars used in these trains. The rail wear takes three forms:

(a) Gauge face wear on the high rail.

(b) Head flow on the low rail.

(c) Corrugations of wavelengths of 8 to 30 in.

Each of these is caused by a different mechanism or mechanisms and will be treated separately, although head flow and corrugation often occur on the same rail. Before discussing these causes, I would like to point out again that this accelerated wear is much greater than would be expected due to tonnage increases alone. Neither is overspeeding or underspeeding in curves a necessary condition, since this wear will take place when the vehicles are passing through the curve at the designed speed. However, overspeeding or underspeeding does aggravate the condition and should not be permitted.

Gauge Face Wear

The rate of gauge face wear on the rail is obviously affected by the rail properties, for example, the harder the rail, the lower the expected rate of wear. However, for any given rail steel, gauge face wear on the side of the high rail in curved track is caused by vehicle tracking problems. Existing vehicles, both locomotives and cars, do not track very well in curves. A brief exposition of this tracking problem is given here.

Gauge face wear is a function of the four parameters listed below:

μ_f = The coefficient of friction between the flange and the gauge face of the rail at the point B as shown in Fig. 2.

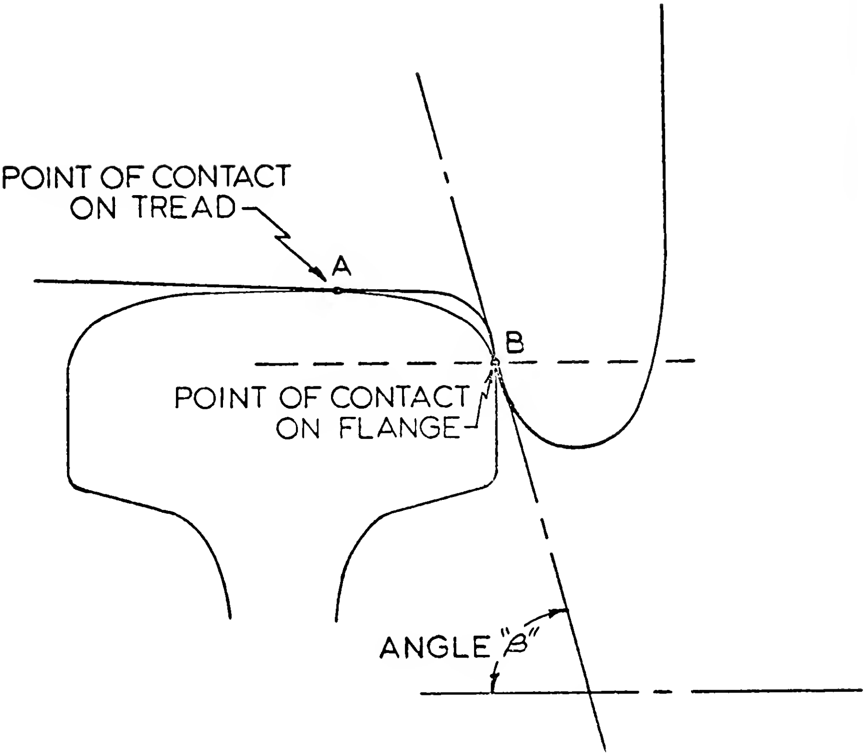


Fig. 2—Wheel-rail contact.

β = The angle of the tangent to the flange at the contact point between the wheel and the rail, measured from the horizontal position also as shown in Fig. 2.

α = The angle of attack between the flange of the wheel and the gauge face of the rail as shown in Fig. 3.

F_f = Flange force which is equal to the sum of two components as given in the equation:

$$F_f = 2\ \mu_e\ N + H$$

The term "$2\ \mu_e\ N$" is the lateral component of the tread creep force required to slide the wheels laterally in the curve. The term "H" is the lateral thrust due to unbalanced centrifugal forces, alignment irregularities, dynamic effects such as vehicle rocking and the interaxle forces on the truck. The forces are illustrated in Fig. 4.

It is apparent that reduction in gauge face wear as well as wheel flange wear can be effected by reducing the magnitude of these four parameters μ_f, β, α and F_f. Increasing the hardness of the rail will also decrease the rate of rail wear. There-

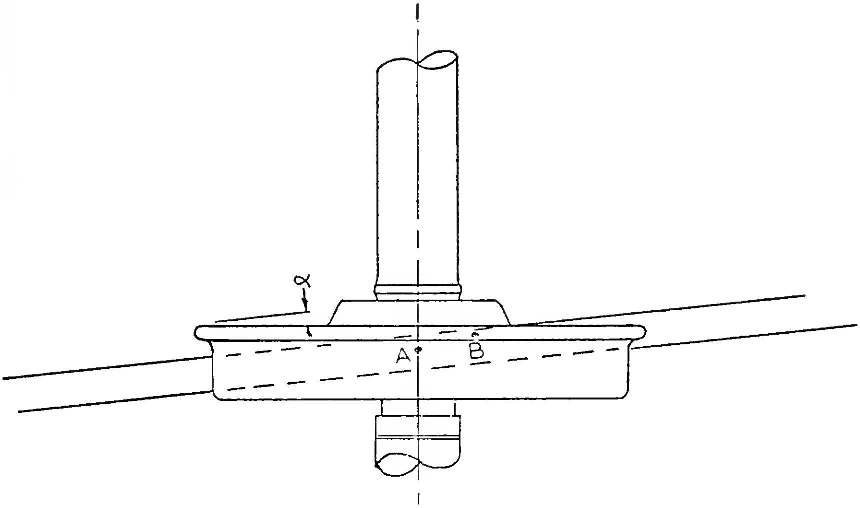


Fig. 3—Angle of attack between wheel flange and rail.

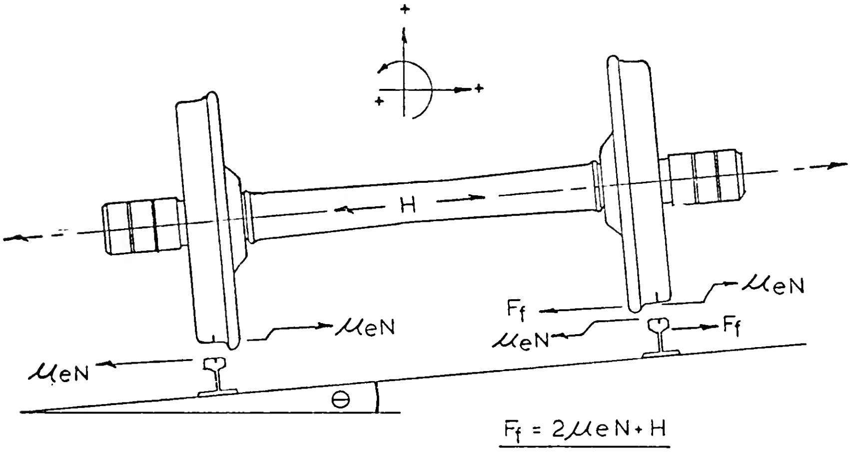


Fig. 4—Lateral forces on curves.

fore, the maximum benefits will be achieved if the use of harder rail steel in curves is accompanied by measures designed to reduce the four parameters listed above.

The value of the coefficient of friction μ_f, can be reduced by judicious use of track-mounted wheel flange oilers. The angle β cannot readily be changed since this angle should not be appreciably less than 70° because of the danger of the wheel flange climbing the rail. Also, it should not be greater than about 80° because of the danger of derailment at switch points. The angle of attack α and the flange force

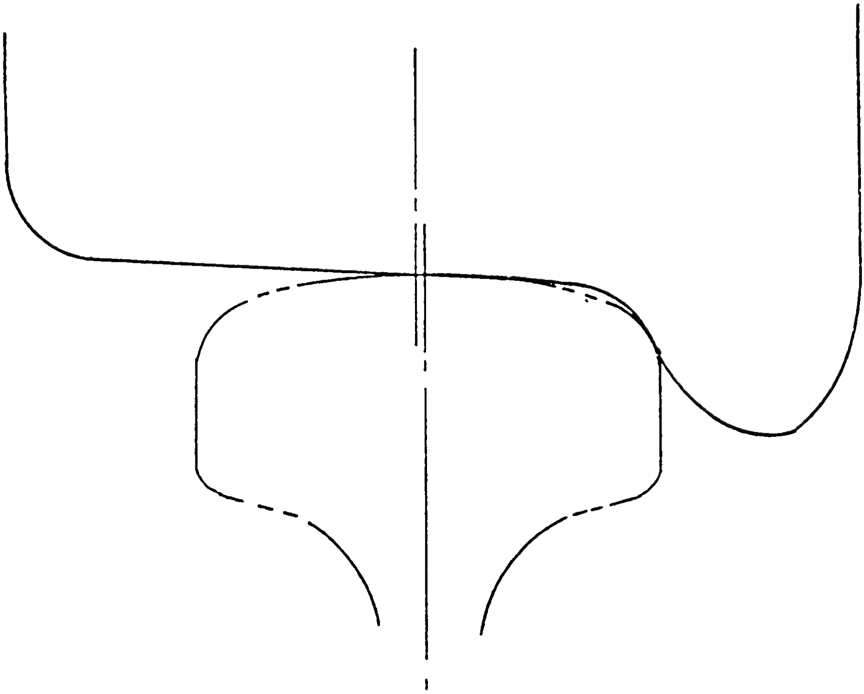


Fig. 5—New AAR wheel profile.

can be reduced by proper combination of sufficient wheel tread conicity and flangeway clearance to help the wheelset to steer itself around the curve. The interaction of these two parameters is quite complex and requires further explanation.

The standard Association of American Railroads (AAR) new wheel profile has two major defects in its curving capability. These are insufficient conicity and two-point contact in curves. The conicity of 1 in 20 or 0.05 limits the ability of a single wheelset to negotiate curves without flanging to those curves which are less than 2.4°. The two-point contact allows the flange of the wheel to scrub the side of the rail in curves. Both the defects can be minimized by special profiles having conicities 3 to 5 times greater than the new AAR profile and shaped to avoid two-point contact. Fig. 5 shows a new AAR wheel profile with contact at both the flange and crown of a new 132-lb rail. Fig. 6 shows a special experimental profile designed to give sufficient conicity to allow a single wheelset to pass through most main line curves without flanging and two point contact.

Special wheel profiles alone on standard freight car trucks will not make the wheelsets negotiate curves in a flange-free condition because this truck does not have the ability to align the wheelsets radially in the curve. The special profile will, however, reduce wheel flange and rail gauge face wear. Canadian National is presently testing and evaluating the comparative wear characteristics of new AAR profiles against the experimental profile shown in Fig. 6.

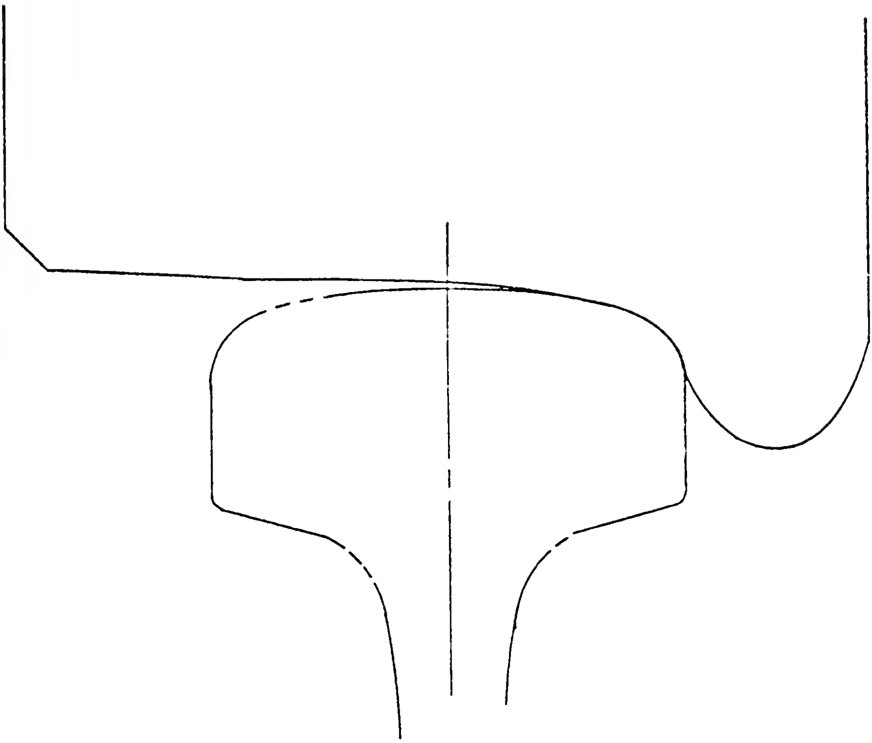


Fig. 6—Experimental wheel profile.

Since the flange force $F_f = 2\mu_e N + H$, as shown in Fig. 4, it can be reduced by diminishing either or both these components. The term $2\ \mu_e N$ is the lateral component of the tread creep forces required to slide the wheels laterally in a curve, where μ_e is the effective lateral tread coefficient of adhesion and N is the wheel load normal to the rail. The coefficient μ_e depends on the angle of attack α; and can vary from zero at zero angle of attack to μ the limit of wheel rail adhesion at an angle of attack of about 1° as shown in Fig. 7. Thus, if the wheelset has sufficient tread conicity and the ability to align itself radially in the curve, this term $\mu_e N$, will become zero. With existing AAR profiles and standard three-piece trucks, the angle of attack α often exceeds 1° and the value μ_e approaches μ, the limit of wheel-rail adhesion. This gives rise to very high values of tread creep force which can range from 9,800 to 23,000 lb for typical values of μ between 0.15 and 0.35 and a wheel-load of 32,875 lb (100-ton vehicle). This can be considered to be a major component of flange force and the importance of achieving a minimized angle of attack α through the combined use of profiled wheels and improved truck design with radial curving ability can hardly be overemphasized.

The other component of flange force H, the lateral thrust, is due to unbalanced centrifugal forces, alignment and cross level irregularities, dynamic effects such as car rocking and interaxle forces on the trucks. This component can be reduced by

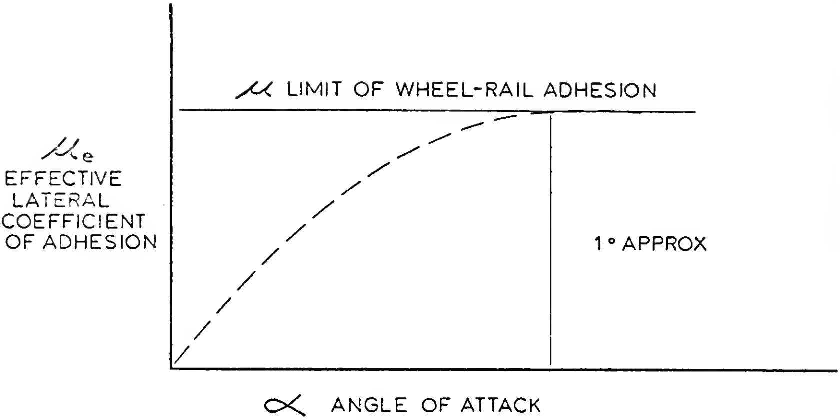


Fig. 7—Effective lateral coefficient of adhesion versus angle of attack.

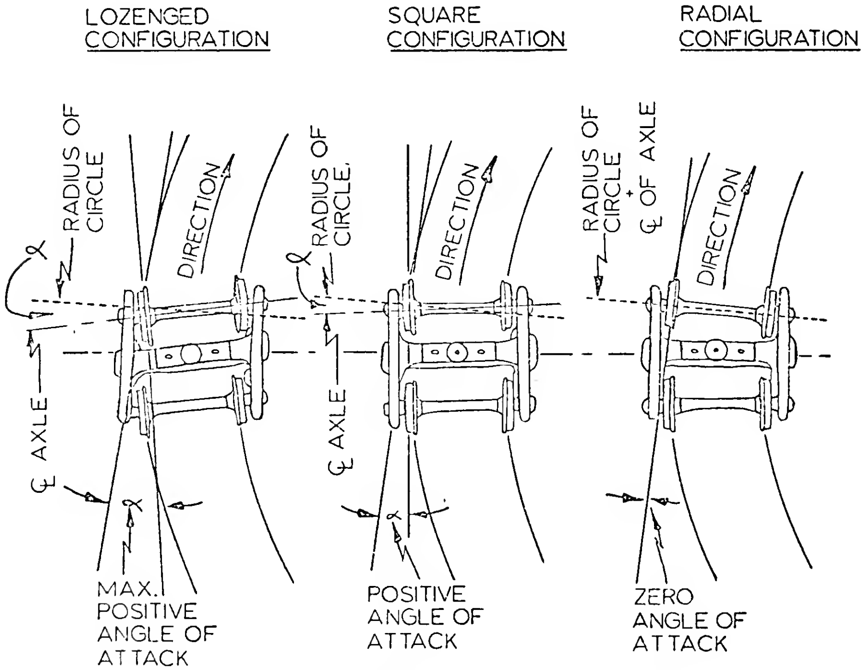


Fig. 8—Angle of attack of leading wheel in curves.

diminishing or eliminating these conditions. Interaxle forces arise because the existing freight car truck does not permit the axles to align themselves radially in a curve, preventing the wheel flange from assuming a zero angle of attack. In addition, the clearances between the major components of the truck permit the truck side frames to lozenge further increasing the angle of attack. Fig. 8 shows the angle of attack of the leading wheel in curves for the three configurations, lozenged, square and radial.

From the above discussion, it can be seen that there will be minimal lateral force in curves if four conditions are met simultaneously:

1. The vehicles pass through the curve at the exact speed for which the curve is banked.
2. The curve has no alignment and cross-level irregularities.
3. The wheel treads have sufficient conicity and flangeway clearance to steer the wheelsets in the curve without flanging.
4. Vehicle trucks allow the axles to align radially under the action of tread creep forces.

Since the force on the flange increases with increasing angle of attack and since flange wear on the wheel, gauge face wear on the rail, and curving resistance all increase directly with the angle of attack, the benefits to be derived from a truck design which permits radial action are obvious. A prototype truck with radial curving capability is currently under test at the Canadian National Technical Research Center.

Rail Head Flow

Rail head flow is found on the low rail in curves in British Columbia and is caused by excessive pressure at the point of contact between the wheel and the rail. The mechanism which is believed responsible for this excessive contact pressure is described in this section.

Both the wheel and the rail have curved surfaces at their point of contact. The first satisfactory solution for contact stresses occurring between two elastic bodies having curved surfaces was provided by Hertz in 1881.

For a steel wheel on a steel rail, the maximum compressive stress q_o can be approximated using the following formula:

$$q_o = 2.36 \times 10^4 \Sigma \left(\frac{1}{R}\right)^{2/3} (P)^{1/3}$$

where q_o = the maximum compressive stress in pounds per square inch.

P = the imposed wheel load in pounds.

$$\Sigma \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R'_1} + \frac{1}{R_2} + \frac{1}{R'_2}$$

R_1 = the radius transverse to the tread in inches.

R'_1 = the radius of the wheel in inches.

R_2 = the crown radius of the rail head in inches.

R'_2 = the track curvature in the vertical direction.

Since there is virtually no vertical curvature, R'_2 approaches ∞. Therefore, $\frac{1}{R'_2}$ can be assessed to be always equal to zero and this term can be eliminated from the calculation of maximum contact stress.

TABLE 2

Effect of Design Parameters on q_o

$$q_o = 2.36 \times 10^4 \; \Sigma \left(\frac{1}{R}\right)^{2/3} (P)^{1/3}$$

Change No.	Design Parameters				$P^{1/3}$	$\Sigma \left(\frac{1}{R}\right)^{2/3}$	q_o	Change in q_o	Parameters Varied
	P	R_1	R_1'	R_2					
	Pounds	INS.	INS.	INS.			PSIx1000	%	
0	32875	∞	18.0	10	32.03	0.29	219	0	None
1	27500				30.18	0.29	206	- 6	P
2			16.5		32.03	0.30	227	+ 4	R_1'
3	27500		16.5		30.18	0.30	210	- 4	P and R_1'
4				+ 14	32.03	0.25	190	-13	R_2
5		-15.0			32.03	0.20	151	-31	R_1
6		+ 6.0			32.03	0.47	355	+62	R_1
7		+ 2.0			32.03	0.75	570	+160	R_1
8		-15.0		+15.0	32.03	0.15	110	-50	R_1 and R_2

N.B. (1) Blank spaces in design parameters columns P, R_1, R_1' & R_2 have same values as in Change #0.

(2) Values of q_o shown for changes #6 and #7 exceed the elastic limit of rail steel. The material will yield and flow at some lower value.

The above formula can be used to assess the relative importance of these variables in generating the maximum contact stress, q_o. Table 2 shows the effect of varying the design parameters, P, R_1, R'_1 and R_2. In this table, the standard for comparison (change number 0) is a fully loaded, 100-ton-capacity vehicle mounted on new AAR profile wheels of 36-in. diameter. The wheels run on a new 132-lb rail section with a head radius of 10 in. Under these conditions, the maximum contact stress is estimated to be 219,000 psi.

Table 2 shows that changes in the radius transverse to the wheel tread are responsible for the head flow conditions found on the low rail in curves.

Figure 9 shows the value R_1, the radius across the tread, may be infinitely large, negative or positive, depending on the wear condition of the wheel. When the wheel is new, the coned surface is a straight line in the contact plane and R_1 becomes infinite and $\frac{1}{R_1}$ becomes zero. This is the comparison case: change No.

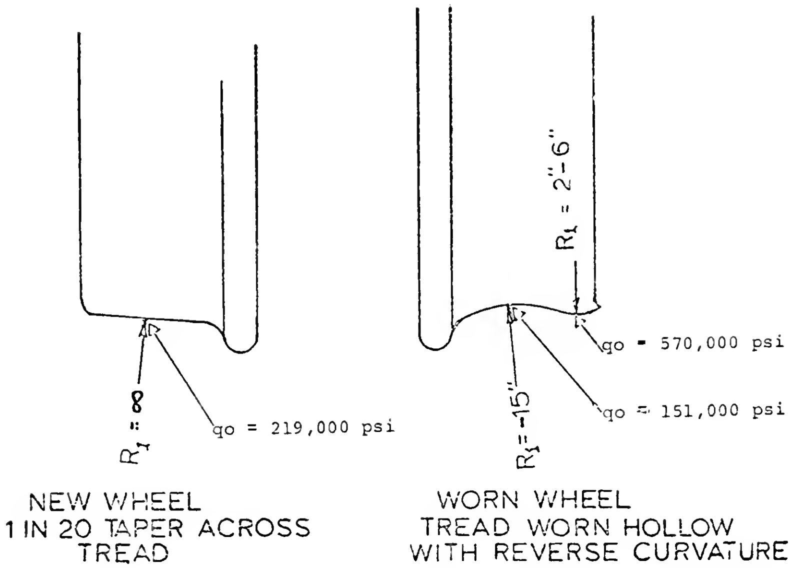


Fig. 9—Transverse tread radius, R_1.

zero and q_o equals 219,000 psi as shown in the table. When the wheel is worn, the central portion of the tread hollows out to approximately 15 in. radius. By convention, this radius is considered negative for purposes of calculation. This condition is shown as change No. 5, giving a value of q_o equal to 151,000 psi, or a reduction of 31% over the standard for comparison.

At the edge of the worn tread, a reverse curvature of 2 in. to 6 in. may develop as shown in Fig. 9. With reverse curvatures of 6.0 in. and 2.0 in. values of q_o of 355,000 and 570,000 psi, respectively, would be developed if the material did not yield, giving increases of 62 and 160%. These are shown in the table as change Nos. 6 and 7. These values of maximum compressive stress exceed the elastic limit of steel and the material will yield and flow at some lower value. It is this reverse curvature on the edge of the wheel tread which is responsible for the head flow problems encountered on our lines.

Fig. 10 shows that, provided sufficient flangeway clearance exists between the wheels and the rails, the outer convex portion of the wheel tread can ride up on the rail head. It can be shown that under conditions which are not considered condemnable the outside edge of the wheel can be 0.6 in. inside the field side of the rail and the center of the reverse curvature may therefore contact the rail 1 in. or more from the field side. This condition is essentially point loading and generates maximum contact stresses several times that developed for a new coned wheel. This point loading is illustrated in Fig. 10 for actual sections of worn wheel and rail.

Fig. 11 shows graphically the effect of transverse tread radius on maximum wheel rail contact stresses for a fully loaded 100-ton car on 36-in.-diameter wheels and a fully loaded 70-ton car on 33-in.-diameter wheels. Note that the effect of reduction of gross rail load on the maximum contact stress is rather small, being

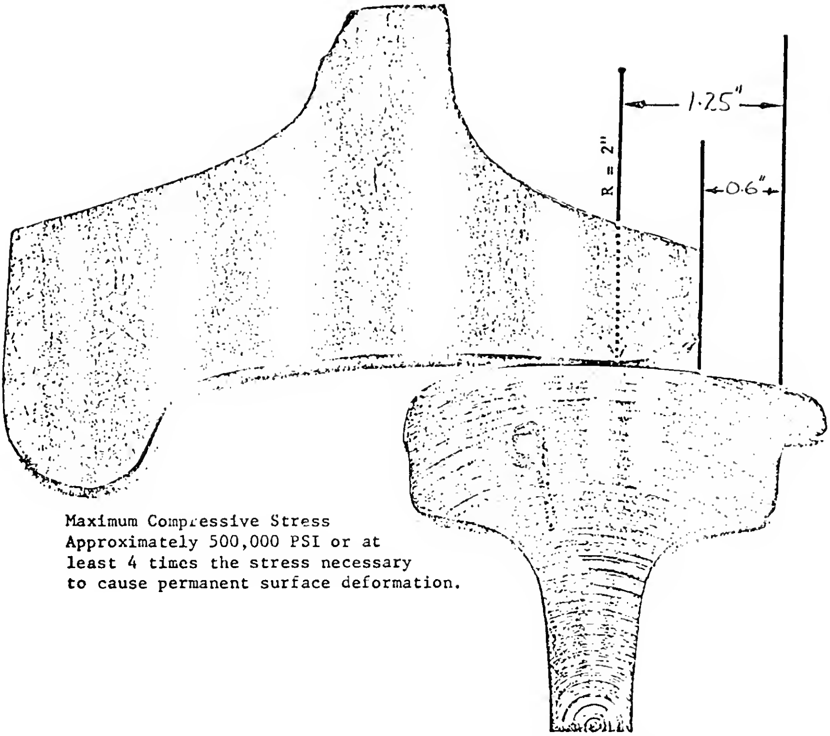


Fig. 10—Contact between wheel and rail in curves.

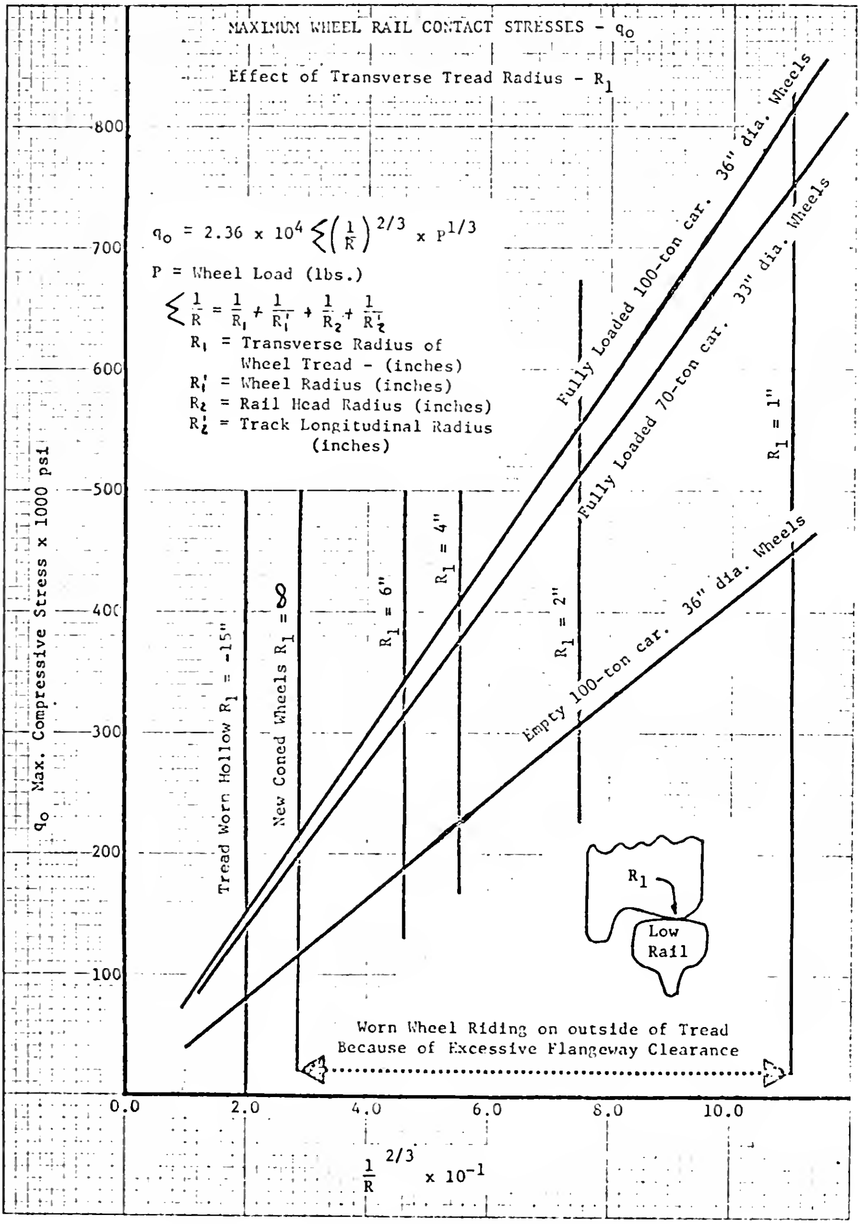


Fig. 11—Maximum wheel rail contact stresses.

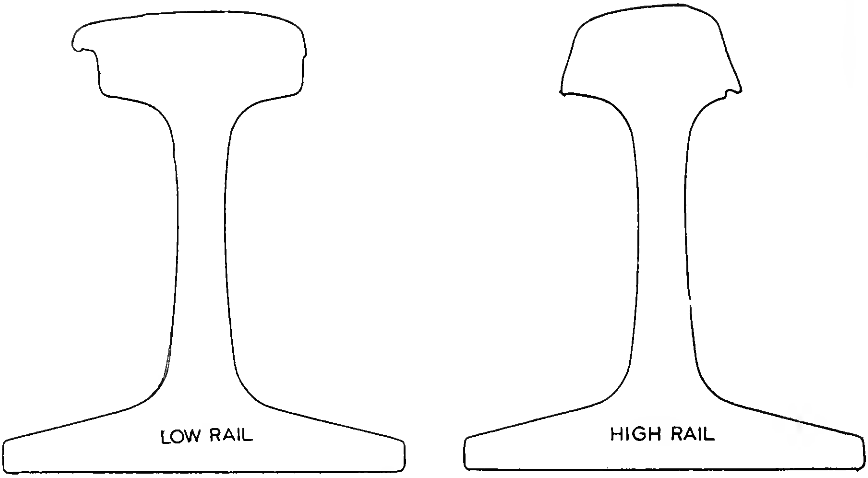


Fig. 12—Rail wear examples.

about 3%. Even if the 70-ton car were fitted with 36-in.-diameter wheels, the reduction would not exceed 6%. Thus, the remedial action to eliminate head flow must involve the elimination of this reverse curvature condition on the worn wheel tread.

RAIL CORRUGATIONS

Rail corrugations present one of the most challenging problems of our day to the railway engineer. The problem is rather complex and has been experienced for a considerable length of time. Perhaps, the first difficulty in coming to grips with the problem lies in the fact that the term corrugation in North American railroad terminology is used to describe a short wavelength form, 1 in. to 3 in., as well as a long wavelength form 8 in. to 24 in.

Short wavelength corrugations, often referred to as "washboard rail" or "roaring rail," occur most frequently on mass transit lines. These corrugations are primarily a source of noise pollution, disturbing both passengers and residents living near the track. This "roaring rail" results in accelerated deterioration of rolling stock and track components, but does not constitute a serious operating hazard.

Long wavelength corrugations appear most often on routes with large annual tonnages (20 MGT or more) and high axle loadings (30 tons typically). Unlike the short wavelength form, long wavelength corrugations present an operating hazard. If these corrugations are allowed to grow deeper with time, derailments may occur either as a result of wheel lift or rail failure due to an increased level of dynamic loadings. To avoid this failure risk, the growth of corrugations must be controlled by periodic grinding. Apart from the potential derailment hazard, rail corrugations create substantial operating difficulties for railroads due to temporary slow orders which have to be imposed from time to time and because of the track occupancy time required for rail grinding and rail replacement. The total costs incurred by a railroad due to rail corrugations have never been accurately quantified. The annual rental cost of the specialized grinding equipment and operators can easily amount to $0.75 million. Costs incurred as a result of rail replacements, additional wear and tear on rolling stock, and lading damage are appreciable, but are difficult to quantify. A fundamental understanding of the factors which contribute to the formation and propagation of long wavelength corrugations is necessary to formulate proper remedial action and thereby achieve appreciable savings to the railroad.

Where Do Rail Corrugations Occur?

In general, rail corrugations appear on the running surface of low and high rails in curves, on tangent track, and on frogs.

The occurrence of rail corrugations on tangent track is very infrequent and we will, therefore, devote our attention only to rail corrugations on curves. CP and CN experience corrugations on the low rail, where they are usually most prevalent, before they appear on the high rail.

In contrast, on railways exclusively hauling mineral traffic, rail corrugations appear first and are predominant on the high rail. In both cases, corrugations are usually deeper on the inner side of the curved rail, that is, on the field side of the low rail and on the gauge side of the high rail.

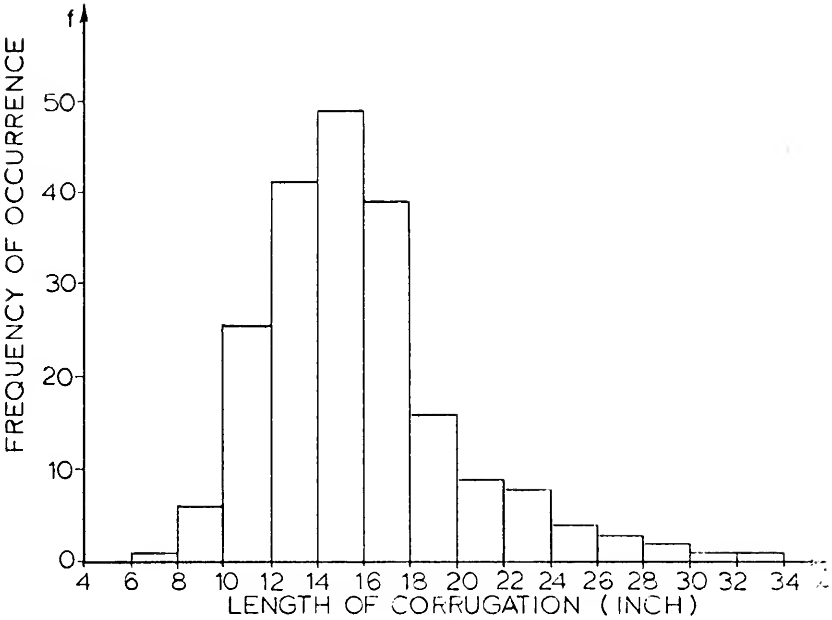
To determine the longitudinal characteristics of rail corrugations, we have measured corrugation profiles on a point by point basis along the centerline of the railhead. These profiles were completely random in shape, depth and length. Subsequently, we measured the depth, and length of the corrugations on a low rail throughout the entire curve. Fig. 13 shows the resulting frequency histogram of corrugation wavelength or pitch. The mean length was calculated as approximately 15½ in. and the mode at 12 in.

What Are the Possible Causes of Rail Corrugations?

The periodicity of the corrugation pitch correlates reasonably well with some of the reasonant frequencies of the track-train system, but no distinct correlation peak could be found between track-train harmonics, operational speeds, and corrugation pitch. The variables in car design, loadings, and track substructure make it quite unlikely that dynamical peaks repeat exactly at the same locations on uncorrugated rail. These two aspects of dynamical loadings reinforce the opinion that the presence of dynamical loadings alone is not sufficient to initiate formation of corrugations.

If corrugations are not "initiated" by dynamical loads, what other mechanisms are involved? Several other mechanisms have been suggested to explain the initiation of rail corrugations. One school of thought believes corrugations are related to contact vibrations. Contact vibration theory states that a small volume of wheel/rail material in the zone of contact can be excited by the roughness of the wheel and rail surfaces to vibrate at its natural frequency. The compressive dynamical contact vibration peaks accelerate wear and contribute to plastic deformation of rail metal which may initiate formation of corrugations. Whilst this theory correlates well with formation of "roaring rail," there is no experimental data as yet available which may be used to test this theory and its applicability to long wavelength corrugation formation.

Many railroaders and researchers have suggested that corrugations are initiated by a "stick-slip" effect of the wheelset during curve negotiation. The stick-slip effect results from the fact that the wheelset acts as one piece and the wheel on the high rail must travel further than the one on the low rail during curve negotiation. Assuming that the effective radius is the same for both wheels, the wheel on the



MEAN:	15.4 in.	STANDARD DEVIATION:	4.6
MODE:	12.0 in.	SKEWNESS:	1.4
MEDIAN:	14.4 in.	CURTOSIS:	3.25

Fig. 13—Frequency histogram of corrugation length.

high rail would be forced to rotate more than the wheel on the low rail. This differential in wheel revolutions places the axle in torque until the adhesion forces at the wheel/rail interface become insufficient on either the high or low rail resulting in a "slip" effect. Once slip occurs, the adhesion forces are restored, and the wheels "stick." The entire process occurs in a very short period of time and is repeated over and over again. If the "stick-slip" occurs on uncorrugated rails, it may initiate formation of corrugations.

Experimental data are needed to understand the role which any "stick-slip" effect might have in corrugation formation. Canadian Pacific and the National Research Council of Canada will, at the request of the AAR, carry out field testing later this year to record the behavior of wheelsets during curve negotiation.

Other theories and suggestions have been proposed to account for initiation of rail corrugations. We have limited our discussion only to those which are most frequently mentioned in connection with corrugation formation. It is quite possible that any one or combination of all three mechanisms mentioned above may be a contributing factor in corrugation formation. We believe, however, that plastic flow and surface fatigue in the top layer of rail head material are the most significant factors contributing to formation of long wavelength corrugations.

Surface Fatigue and Plastic Flow

In the first portion of this presentation, the presence of high contact stresses was demonstrated, namely, in the case of wheels with a reverse curvature running on top of the low rail. The yield stress of the rail material is exceeded and metal flow results. During the first few loading cycles by passing wheels, the surface layer of rail material is plastically compressed and a residual stress acting parallel to the surface is introduced. During subsequent passages of wheels, the rail material is subjected to the combined action of residual and contact stresses and further yielding becomes less likely. This process is referred to by metallurgists as cold-working of material and when it is confined to rolling contact, it is referred to as "shakedown." The maximum load for which the rail material can still be cold-worked is called shakedown limit or plasticity limit. In other words, if the magnitude of contact stresses falls between the elastic and plastic limits, the rail material cold-works and the system "shakes down" to the elastic cycle of stress. Overstressing of rail material above the plastic limit results in continuous and cumulative plastic deformation of rail material.

Under the conditions of pure rolling such as in the case of rolling wheelsets on tangent track without braking or traction, the plasticity limit is proportional to hardness of rail metal:

$$q_{pl} \approx \frac{2}{3}\text{DPH} \quad \text{(after K. L. Johnson)}$$

where DPH is the Vickers diamond pyramid hardness. Under the presence of tractive forces in the zone of contact, caused by traction, braking or lateral curving forces, the plasticity limit decreases with increasing effective coefficient of friction as shown in Fig. 14. In this figure, the effective coefficient of friction is presented as the ratio of tractive force to normal load F_f/P. In reality, this means that the beneficial effects of cold-working of rail materials in curves is lost when the effective coefficient of friction reaches a value of 0.26.

Table 3 indicates the plasticity limits q_{pl} for various rail materials in terms of maximum Hertzian contact pressure. In calculating the plasticity limits, a value of 0.16 was considered as typical for wheel/rail adhesion in lubricated curves. These values are approximate and may vary somewhat with metallurgical properties of rail material. The rail head hardness range of 250–270 BHN corresponds to plain carbon rail, 310–330 BHN to manganese-vanadium or chromium rails and 360–380 BHN to fully heat-treated or curvemaster rails. The increase in plasticity limit and resulting reduction in head flow with increasing rail head hardness is self-evident in this table. The table also indicates that installation of premium rails in curves is advantageous on lines where 100-ton-capacity cars are used extensively.

During initial cold-working and homogeneous plastic flow, conditions are being formed within the rail material which will lead to localized failure. Cracks may develop at, or very near, the rail surface or a short distance below it. The large variation in possible wheel/rail contact geometries and the effect of frictional forces and other parameters on the distribution of contact stresses, may cause the railhead material to fail due to flaking, pitting, spalling or subsurface shelling. These failures fall under the common category of surface fatigue or contact fatigue. Each of these contact fatigue manifestations develops in two stages. The first stage is crack initiation and the second is crack propagation. The cracks which initiate at the surface give rise to flaking on the low rail or spalling on the high rail and contribute significantly to the initiation of corrugations.

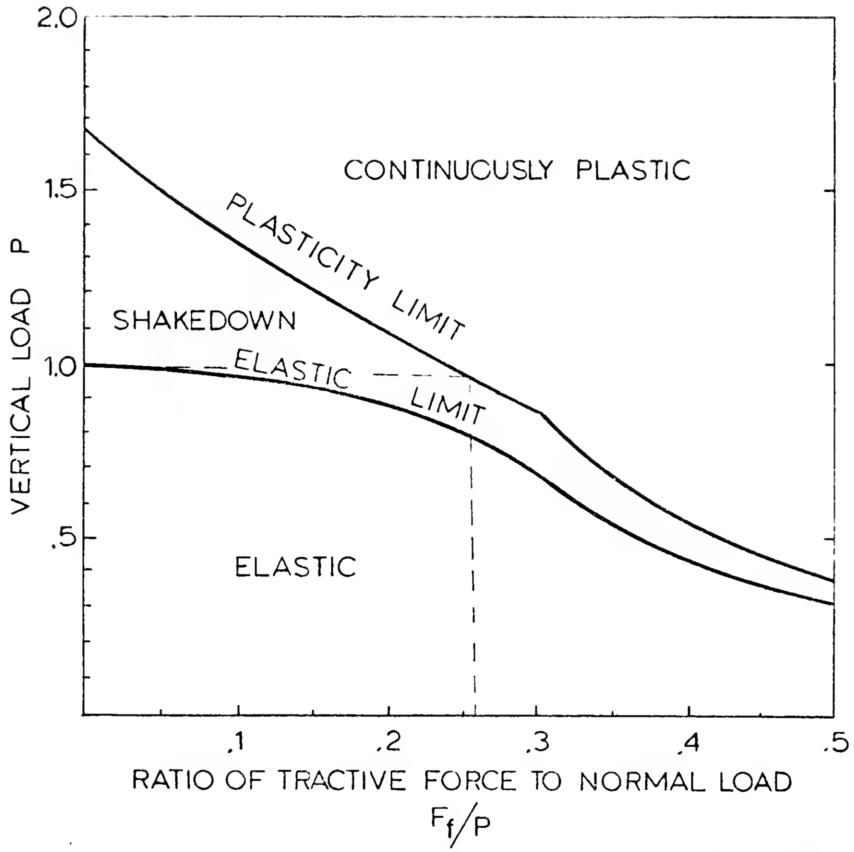


Fig. 14—The effect of tangential force on the elastic and plasticity limits.

The mechanics of surface crack initiation and growth have been dealt with in detail at the AREA Regional Meeting held in Vancouver in 1975 and are published in AREA Bulletin No. 656. To avoid repetition, only the main points concerning the role which cracks play in corrugation formation will be summarized here. Once the cracks form:

(a) they disrupt the homogenity of the surface layer of rail metal and significantly redistribute contact stresses, which results in a reduction of rail metal resistance to plastic flow;

(b) in combination with lateral tractive force, cracks enhance the depletion of metal from the surface layer through flaking or gauge corner spalling;

(c) inside the cracks, a significant amount of wear debris may form which can lead to accelerated depletion of metal from within the crack.

In locations where cracks are more numerous or where they grow at an accelerated pace, head flow is more rapid, depletion of metal from the head is greater than in the neighboring locations and corrugation valleys are thus formed.

TABLE III

Plasticity Limits for Various Rail
Materials and Rolling Conditions

	Plasticity limits q_{pl} (psi) for rail hardness ranges of:		
	250-270 BHN	310-330 BHN	360-380 BHN
Case of pure rolling (tangent track)	250,000	305,000	365,000
Case of rolling with lateral tractive forces (curves)	185,000	225,000	275,000

Remedial Action

Remedial action required to correct both gauge face wear and corrugations must be optimized in such a way that the maximum service life of rails and wheels is realized.

Gauge face wear may be best alleviated by correcting vehicle tracking deficiencies. The first deficiency arises from the fact that wheel profiles do not have sufficient conicity to steer the wheelset around most curves without flanging. The second tracking deficiency is that vehicle trucks are not designed to allow the axles to align themselves radially in curves. To correct for head flow and corrugations, it is necessary to prevent reverse curvature on the outside of the wheel tread from running on the top of the rail. This can be done by reducing or eliminating the reverse curvature on the tread of the wheel and by close control of excessive flangeway clearance whether due to gauge face wear, wide gauge or wheel flange wear.

The experience of the two major Canadian railways indicates that the following remedial measures also have considerable merit and should be incorporated into the remedial action program. These are:

(a) Judicious use of flange oilers to reduce wear. Under- and over-lubrication of track has a negative effect on rail life. Under-lubrication leads to excessive gauge face wear and over-lubrication leads to early occurrence of rail corrugations.

(b) The use of rail steel with higher yield point to reduce gauge face wear, head flow and effects of surface fatigue. The wear rate of steel is indirectly proportional to hardness, the load required to produce yield is proportional to the cube of rail yield strength and the resistance to surface fatigue is approximately proportional to second power of rail hardness.

(c) Timely grinding of the rail head to remove existing corrugations before these become so deep that grinding becomes ineffective.

(d) Avoidance of overspeed or underspeed in curves as this aggravates all wear conditions.

For convenience, recommended remedial actions are given in the accompanying tabulation.

Remedial Action	*Purpose of Action*	*Function Responsible For Applying Action*
1. Buy and maintain all wheels to a special profile with increased conicity.	To reduce gauge face wear on high rail in curves. Also increases wheel life and reduces head flow and corrugations on low rail.	Equipment
2. Eliminate reverse curvature on outside of wheel tread.	To reduce or eliminate head flow and corrugation on the low rail in curves.	Equipment
3. Develop and use a truck with improved curving properties.	Eliminate or reduce gauge face wear. Also reduces head flow and corrugation.	Equipment (with technical research)
4. Maintain close control of wide gauge in curves.	Eliminate or reduce head flow and corrugation.	Engineering
5. Maintain and optimize the use of existing flange oilers.	Reduce gauge face wear.	Engineering
6. Use rail steel with higher yield point and hardness.	Reduces gauge face wear, head flow and effects of surface fatigue.	Engineering
7. Grind rail corrugations.	Remove existing corrugations.	Engineering
8. Avoid overspeed or underspeed in curves.	Aggravates all conditions.	Transportation

CONCLUSION

The mechanisms causing rail wear and tear have been described. Effective remedial action is possible but requires a concerted effort by the engineering, equipment and transportation functions. There is no "quick fix" that can be bought and applied. Moreover, it must be realized that although effective action can be initiated almost immediately, it may be some time before the full benefits can be assessed. However, if no action is taken, the situation will not improve or go away, it can only deteriorate. If we wish to move bulk commodities economically in unit trains, we must attack the problem in an organized manner.

High-Strength Chromium-Molybdenum Rails

77–658–9

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ABSTRACT

A laboratory study was conducted with the aim of developing an as-rolled rail of over 100 ksi (689 N/mm^2) yield strength. A series of compositions providing both pearlitic and bainitic microstructures was evaluated. A fine pearlitic structure was developed in a 0.73% C — 0.83% Mn — 0.16% Si — 0.75% Cr — 0.21% Mo steel by simulating the mill cooling rate of 132-lb/yd (65.5-kg/m) rail.

Two 100-ton commercial heats were made of this approximate composition and processed into 132-lb/yd (65.5-kg/m) rail. Samples tested in the laboratory ranged from 109 to 125 ksi (750 to 860 N/mm^2) in yield strength. The chromium-molybdenum rails also exhibited excellent fracture toughness and fatigue properties. Sections of the rail were joined by both flash-butt welding and thermite welding. The hardness peaks produced in the flash-butt welds could be reduced by applying either a postweld current or an induction heating cycle. The high-strength chromium-molybdenum rails have been in service for over eight months in curved sections of an ore railway that carries over 55 million gross long tons per year.

INTRODUCTION

One of the outstanding problems for heavily traveled railroads throughout the world is an excessively high rate of rail deterioration, especially in curved sections of track. The problem is particularly acute on ore railroads, where every car is heavily loaded, and on main lines, which are also subjected to high gross annual tonnages. Axle loadings now often exceed 30 tons, and a high traffic volume at high axle loadings can result in the annual tonnage being in the range of 30 to 55 million gross tons. At lower levels of loading, rails deteriorate by the classical mechanism of surface wear and abrasion. However, with a combination of high loading and high gross tonnage, rails deteriorate at a much faster rate by undergoing plastic flow and surface fatigue.[1] In general, these two modes of failure are best resisted by increases in rail yield strength and tensile strength, respectively.[2]

As this study was initiated, most of the commercially available alloy rails were below 100 ksi (689 N/mm^2) yield strength.[3] It was the objective of this work to develop an alloy rail steel over 100 ksi (689 N/mm^2) yield strength and around 160 ksi (100 N/mm^2) tensile strength. These improved properties were to be achieved by balancing the alloy composition to obtain transformation to a fine microstructure, with the strength possibly being supplemented by carbide precipitation.

An additional objective of this work was to develop commercially feasible welding procedures for joining the high-strength rails.

LABORATORY DEVELOPMENT OF RAIL STEEL

It was recognized at the beginning of this effort that processing a steel on the very small scale that is available in the laboratory would have serious scale-up problems when the results were ultimately applied to the production of a commercial

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Note: Discussion open until October 16, 1976.

heat of 132-lb/yd (65.5-kg/m) rail. Much consideration was given to taking these scale-up problems into account and making the appropriate adjustments in the experimental techniques.

Experimental Procedures

Laboratory steels were made from high-purity charge materials. Most of the heats (those with a "P" in the heat number) were argon-melted to prevent excessively high nitrogen contents that occur as a result of melting in a small induction furnace. It was later decided that this precaution was not necessary. The heats ranged in size from 55 to 75 lb (25 to 34 kg). They were poured into copper chilled tubular steel molds. The compositions are presented in Table 1. The ingots were forged and rolled in order to produce bar stock for tensile specimen blanks. The specimen blanks were reheated to 1850 F (1010 C) and cooled at rates to simulate the cooling of 132-lb/yd (65.5 kg/m) rail on a mill cooling bed. The cooling rate was controlled by making bundles of bars to increase the thermal inertia accordingly. The specific cooling schedules employed are described in Table 2. The cooling schedules included relatively slow cooling at lower temperatures to simulate the box-cooling treatment normally given to rails to avoid hydrogen-induced cracking. The tensile specimen had a ½-in. (13-mm) diameter reduced section with a 2-in. (51-mm) gauge length. The strain rates were 18 and 120%/hour in the elastic and plastic ranges, respectively. Hardness tests and microstructual examinations were made on the broken halves of tensile specimens.

Laboratory Results and Discussion

The tensile testing and hardness results that were obtained on the control-cooled specimens are presented in Table 2. The microstrucures are presented in Figures 1 through 6. Steel A was included as a base composition, representative of commercial carbon steel rail. The 62 ksi (427 N/mm^2) yield strength shown in Table 2 is typical for such a product. The pearlitic microstructure of Figure 1(a) is also typical for rails of this composition in the as-rolled condition.

The first experimental steels that were made were designed to increase yield strength by developing a bainitic microstructure. Steels C and E represent different approaches in developing this microstructure by using silicon-molybdenum and chromium-molybdenum combinations, respectively. Vanadium was included in the former, with the aim of obtaining some precipitation strengthening. Upon employing the conventional rail cooling cycle for 132-lb/yd (65.5-kg/m) rails, which involved slowing the cooling rate at 1000 F (535 C), yield strengths of 106 to 119 ksi (731 to 820 N/mm^2) were produced. The microstructure of Steel C, in Figure 1(b), is completely bainitic, while that of Steel E, in Figure 2(a), is largely bainite with some fine pearlite. An attempt was made to adjust the cooling schedule of Steel C to increase the probability of attaining precipitation strengthening. A pair of specimens were subjected to the same initial cooling rate, but the slower cooling rate (to simulate box cooling) was begun at 1100 F (595 C). The resulting yield strength of 140 ksi (965 N/mm^2) suggests that some precipitation strengthening may have been developed. The microstructure, shown in Figures 2(b) and 5(a), is a mixture of fine pearlite and bainite.

In general, the bainitic compositions offer promising yield strengths, but there was much concern regarding the relatively low transformation temperatures involved. Since rails are normally transferred to the cooling box by a magnetic crane, transformation must be substantially complete around 1000 F (535 C). As a result of this requirement, further efforts were directed toward developing pearlitic microstructures that would form at higher temperatures.

A pearlitic microstructure was attained by reducing the molybdenum content of Steel E. It may be recalled [Figure 2(a)] that Steel E exhibited a partially pearlitic microstructure. In general, of the alloying elements in Steel E, molybdenum is the strongest in its influence on shifting the pearlite nose to the right in the continuous-cooling transformation diagram. Reducing the molybdenum to 0.31%, and cooling according to the established schedule, produced the very fine pearlitic microstructure of Steel J shown in Figures 3(a) and 5(b). It is unresolvable at a magnification of X1000, but clearly defined by the carbon replica at X5000. The steel has a yield strength of 126 ksi (869 N/mm^2) and a hardness of 388 HB.

As this study was being performed, there was conflicting information from various sources as to the actual cooling rate of 132-lb/yd (65.5 kg/m) rail, in the high temperature range prior to box cooling. At one point, the availability of new information resulted in a change from cooling schedule 1, in Table 2, to cooling schedule 2. One group of experimental steels was processed using this slower cooling rate. It was subsequently determined that cooling schedule 1 was closer to the actual mill cooling rate.

The investigation of the sensitivity of Steel J to variations in molybdenum content involved several compositions, including Steel M. The lower molybdenum content of Steel M, combined with the slower cooling rate of cooling schedule 2, resulted in the coarser pearlite of Figures 3(b) and 5(c). The yield strength of 87 ksi (600 N/mm^2) is consistent with the coarser pearlite spacing. It was ultimately concluded that as molybdenum is reduced in this C-Mn-Cr-Mo rail steel, at a fixed cooling rate, bainite disappears leaving a very fine pearlite. As molybdenum is reduced further, the pearlite becomes more coarse. Therefore, the finest and highest-strength pearlite is obtained by employing the amount of molybdenum that is just less than that required to produce bainite. This effect is demonstrated by the specimen of Steel M that was cooled according to cooling schedule 1B in Table 2. The hardness is 415 HB, while the microstructure (not shown) is almost completely fine pearlite, with a small amount of bainite. The fact that this specimen was not slow-cooled in the low temperature range is not considered important, because most of the microstructure was transformed by the time the specimen reached 1000 F (535 C).

Steels Q and R were made at 0.28% Mo to allow sufficient hardenability to obtain the finest pearlite at the slower cooling rate involved. Vanadium was included in Steel R in an attempt to precipitation strengthen the pearlite. The optical microstructures of the two steels were identical. That of Steel R is shown in Figure 4(a). The replica electron micrographs of Steels Q and R are presented in Figures 6(a) and 6(b), respectively. The hardness of the steels was similar at 418 to 430 HB; however, there was a notable difference in yield strength. The higher yield strength of Steel R (Table 2) is apparently attributable to the vanadium, possibly due to some precipitation strengthening.

In the course of planning for the melting of a commercial heat, it was reaffirmed that the faster cooling rate of cooling schedule 1 in Table 2 was more realistic for 132-lb/yd (65.5 kg/m) rail. Steels S and T were prepared with the goal of finalizing the molybdenum content for the commercial heat, aiming for a minimum yield strength of 100 ksi (758 N/mm^2) in an as-rolled rail. Steels S and T, with 0.21

and 0.24% Mo, respectively, satisfied the yield strength requirement. The fine pearlitic microstructure of Steel S is shown in Figures 4(b) and 6(c). On the basis of these results, it was decided to proceed with a commercial mill trial.

COMMERCIALLY PRODUCED CHROMIUM-MOLYBDENUM RAIL

Production and Evaluation Procedures

The first trial production heat of the newly designed composition of chromium-molybdenum rail was made at CF&I Steel Corporation. The 100-ton BOF heat (Heat 11406) was aluminum-killed and poured into twenty-one 5-ton ingot molds with hot tops. Six of the ingots, Numbers 3, 5, 7, 13, 15, and 17, were treated with Hypercal, a Ca-Si-Al deoxidation agent, added in the amount of 6 lb/ton (2.7 kg/ton) in an effort to improve fracture toughness by affecting the type, amount, and distribution of nonmetallic inclusions. The ingots were soaked and then directly rolled into 132-lb/yd (65.5-kg/m) rail in 31 passes. Five rails, designated A through E in sequence from the top to the bottom of the ingot, were obtained from each ingot. The hot-rolled rails were hot-sawed and deposited on the cooling bed until they were placed in a cooling box in the usual manner to prevent flake cracking.

Samples of the chromium-molybdenum rail were subjected to a thorough laboratory evaluation, including metallography, tensile testing, hardness, and fracture toughness testing. The laboratory techniques were the same as those employed in the above-described evaluation of laboratory steels. The fracture toughness test specimens were taken from the web section of the rails. Compact tensile specimens were prepared so that the direction of crack propagation was perpendicular to the rolling direction.

On the basis of the satisfactory properties of the first heat, a second heat of similar size was melted. The second heat (Heat 12547) was the same as the first in both composition and melting practice. However, no Hypercal treatment was used, as it was not considered necessary for obtaining satisfactory properties.

Commercial Product Results and Discussion

The composition of two commercial heats of chromium-molybdenum rail is shown in Table 1. The mechanical property results presented in Table 3 confirm that the desired level of strength was attained. The rail head hardness is about 340 to 360 HB, and the yield strength is in the range of 109 to 125 ksi (751 to 865 N/mm^2). It was initially suspected that a difference in prior austenite grain size was the reason for a lower molybdenum level being sufficient for producing the desired properties in the commercial heat. If the commercial heat had a larger austenite grain size than the laboratory heats, this would account for an increment of hardenability. Most of the laboratory steels had austenite grain sizes of ASTM 6 or 7, with the average being ASTM 6.5, as determined by the fracture grain size technique. A specimen from Heat 11406 was tested the same way and found to be ASTM 6. This grain size is consistent with the fact that the heat was aluminum deoxidized, but it leaves unexplained the apparent difference in hardenability between the laboratory and commercial steels. Another possible explanation for the difference is that the laboratory specimens are cooled from a reheat, while the commercial rails are cooled directly from hot-rolling.

A Hypercal inoculation treatment was given to several ingots of the first commercial heat. This calcium-silicon-aluminum deoxidation agent, which was added in the amount of 6 lb (2.7 kg) per ton, had a significant effect on the shape of sulfide inclusions, as shown in Figure 7. However, the fracture toughness results for Rails 4B and 5C in Table 3 show that the fracture toughness was not affected by the change in inclusion shape. This is presumably because the fracture direction was perpendicular to the elongated inclusions. Tests were conducted in this direction because it is the direction of crack propagation for rail failure.

It should be noted that the fracture toughness of Rail 10C of Heat 12547 is notably higher than the fracture toughness measured on the rails from Heat 11406. This K_{Ic} value of 43.5 ksi$\sqrt{\text{in.}}$ (47.8 MN/m$^{3/2}$) for Rail 10C is at the level of fracture toughness normally found in lower strength carbon-manganese rails that are vacuum degassed. Rail 10C also has higher elongation and reduction in area values than were observed on the first heat. It may be observed that the elongation and reduction in area values obtained for the first commercial heat, Heat 11406, are low relative to the test results on the laboratory steels. On the basis of the laboratory results, it is suggested that the higher ductility and fracture toughness values exhibited by Rail 10C from Heat 12547 are more representative of what should be expected of the chromium-molybdenum rail. Additional commercial product that was produced as this paper was being reviewed confirmed this conclusion.

Representative microstructures of the chromium-molybdenum rail are presented in Figures 8 and 9. The rail head is very fine pearlite, as were the laboratory steels. The web and flange (not shown) are both predominantly fine pearlite, with some bainite. Also, near the center of the web, occasional thin, light streaks may be observed in the microstructure, as marked in Figure 10. These streaks were found to be cross sections of very thin martensitic regions that lie in the plane of the web. It was established by electron probe microanalysis that these martensitic regions are rich in chromium and manganese. They are apparently regions of interdendritic segregation in the ingot. It should be noted that the compact tensile specimens that were employed for the fracture toughness determination were taken from the web of Rail 10C, from which the sample shown in Figure 10 was cut. The martensite probably did not affect the K_{Ic} value because of the small amount present and its anisotropic distribution in the plane of the web. For the same reasons, these thin regions of martensite are believed to have a negligible influence on the other mechanical properties of the rail.

The distribution of the hardness over a rail cross section is shown in Figure 11.

A short section of chromium-molybdenum rail was subjected to a rolling contact fatigue (cradle rolling load) test at the AAR Technical Center. The test employs a single, full-size wheel under a 50,000-lb (22,400-kg) load that is intended to simulate a 50% overload condition. The test normally produces shelling in standard carbon-manganese rails in 3-million cycles. The test on the chromium-molybdenum rail was discontinued after 5-million cycles, with no significant deterioration of the rail, as determined by ultrasonically testing each week during the test.

The abrasive wear resistance of the head of a chromium-molybdenum rail was evaluated by a pin abrasion test.[4] The weight loss was 0.095 gram, which was 88% of the weight loss sustained by the head of a standard AREA carbon steel rail.

WELDING OF CHROMIUM-MOLYBDENUM RAILS

Flash-Butt Welding

To evaluate the weldability of the chromium-molybdenum rail, several 132-lb/yd (65.5 kg/m) sections were flash-butt welded by Chemetron Corporation. One weld was subjected to a postweld current that slowed the cooling rate after flashing, in order to promote the formation of higher temperature transformation products and thereby limit the presence of martensite. As an additional effort to improve weld-zone properties, one of the welds that was made according to the standard flash cycle was sent to Teleweld, Inc., for an induction tempering treatment. Preliminary laboratory tests defined the time-temperature parameters required for tempering. The welds that were produced by the above three procedures were sectioned and evaluated by hardness traverses, metallographic methods, and bend testing.

Tempering would normally be performed after the weld had cooled to temperatures near ambient, but induction heating could be used earlier in the operation to interrupt cooling. This procedure was evaluated by laboratory simulations.

A Schlatter flash-welding unit with an NCC Sciaky control was employed in performing the flash-butt welding operations at Chemetron. Preheating was accomplished by 10 current impulses of about 95,000 amperes and 3 to 3.5 seconds duration, separated by 0.5 second. Flashing took place in 24 to 37 seconds followed by application of the upset force that produced the weld. A current of 95,000 amperes was held for 2.5 to 3.0 seconds after the initiation of upset, with the upset force being held for 9 seconds. Up to this point, the procedure was typical of that normally used to weld 132-lb/yd (65.5 kg/m) rail. After shearing off the flash, the electrodes were put back in place, in the case of the weld that was to receive the postweld current. A current of 95,000 amperes was applied for a 5-second duration exactly 60 seconds after the beginning of upset.

To define an appropriate tempering heat treatment, sections were cut from the head of a flash-butt weld performed by the normal procedure, and short-time tempering treatments were performed on the sections in a lead bath. It was determined from a Larson–Miller plot that, for a 15-second hold time, a tempering temperature of 1230 F (665 C) would be required to reduce the maximum weld hardness to 41 HRC and a tempering temperature of 1280 F (690 C) would be required to reduce the maximum hardness to 40 HRC.

Having defined the desirable tempering temperature, another flash-butt weld that was performed by the standard procedure was sent to Teleweld for a full-scale tempering experiment. Two induction heating coils were constructed and connected in series, at Teleweld, to simulate induction tempering at two adjacent stations in a flash-welding operation. The 16-turn coils were wrapped around the entire rail cross section, separated by ½ in. (13 mm) from the head and edges of the flange. One coil was centered on the weld. The 35-kva power supply was capable of delivering an AC current of 300 amperes at 120 volts and 1000 Hertz. The first application of power, for 2.5 minutes, heated the rail to 780 F (415 C), as measured by a thermocouple on top of the head. The power was then turned off for 1 minute to simulate cooling of the rail as it was moved to the second induction heating station. The power was then applied for 2.5 minutes more to develop a peak temperature of 1260 F (680 C). The weld was then air-cooled to room temperature.

Evaluation of Flash-Butt Welds

A weld hardness profile that was obtained by making a traverse across a flash-butt weld on a cross section of the rail head is presented in Figure 12. This hardness profile is for the standard welding procedure, which is shown to produce a hardness peak of about 8 to 10 HRC points above the base-metal hardness and a hardness trough of about 6 to 7 HRC points in the heat-affected zone (HAZ) of the weld.

The variation in carbon content near the fusion line was determined from slices approximately 0.02 in. (0.5 mm) thick that were sectioned from near the weld line of the head. These results are also presented in Figure 12 and show that decarburization occurs during flashing. The lower carbon content of this center region prevents the formation of martensite, allowing the hardness at the center of the weld to be about equal to the original rail hardness. Within less than an inch from the weld centerline, the hardness is unaffected by the welding operation. The hardness peak just outside the weld line is caused by partial transformation to martensite. The adjoining hardness trough is a manifestation of the spheroidization of pearlite in the region that was heated to a peak temperature just short of austenitization. The full cross section of the web of the weld made by the standard procedure is shown in Figure 13(a). The white streaks highlight the martensite that forms upon cooling from welding. One of the martensite streaks is shown at higher magnification in Figure 14(a). The effects of a postweld current on the hardness profiles through the weld in various parts of the rail are shown in Table 4. The maximum hardness is somewhat reduced by this treatment. The cross section of the web of the weld subjected to the postweld current is shown in Figure 13(b). The cooling delay introduced by this additional heating step reduced the martensite at the hardness peak to about 5%.

The weld hardness profile that results from postweld tempering is presented in Figure 15. The corresponding profile for the untempered weld is also shown in this figure for reference. The induction tempering treatment was successful in lowering the hardness peaks. The structure of the weld was similar to that of the standard flash-butt weld [Figure 13(a)] except that the streaks which had appeared white in the untempered weld [Figure 14(a)] were gray in the tempered weld [Figure 14(b)].

Brinell tests were performed in the above three welds on top of the head where the Rockwell traverses had indicated that the hardness was at a maximum. The flash-butt welds that received standard, postweld current, and tempering treatments exhibited maximum Brinell hardness values of 415, 371, and 368 HB at distances from the weld line of 0.35, 0.25, and 0.38 in. (9, 6, and 10 mm), respectively. Thus, Brinell tests performed on top of the head could be used as a check on the welding operation.

Bend specimens, of rectangular cross section, were cut from the rails at the junction of the web and the flange, with each of the three types of welds, (a) standard weld, (b) postweld current, and (c) tempered weld. The specimens were cut longitudinal to the rails, with the weld lines at the centers of the specimens. The specimens were tested in three-point bending at slow strain rates, with the maximum load being used to calculate the fracture stress, by the formula that describes the bending of a simple rectangular beam. The fracture stresses are presented in Table 5.

Laboratory Simulation of Interrupted Cooling by Induction Heating

Induction tempering would be performed on welds that had cooled below the martensite transformation temperature. This temperature is normally not reached until at least 20 minutes after upset. If induction heating is used earlier in the flash-butt welding operation, martensite will not form because cooling can be interrupted to force nearly complete transformation to fine pearlite. In a laboratory experiment to evaluate the feasibility of this approach, chromium-molybdenum rail sections were heat-treated using programs that approximated the thermal cycle of the high-temperature region of a flash-butt weld, plus several heating cycles obtainable with postweld induction heating equipment. Examples of the thermal cycles used are shown in Figure 16 and listed in Table 6. Since flash-butt welds are normally performed at a rate of about 2.5 to 6 minutes per weld, these heat treatments cover the range of anticipated production conditions if induction heating is applied at the fourth station (flash welding being the first station). The results shown in Table 6 show that all specimens heated above 1100 F (595 C), regardless of the time at which heating was initiated, exhibited a hardness of less than 37 HRC or 370 HB. The levels of hardness and martensite content measured in the normal weld thermal cycle (No. 1) are higher than the maximum levels measured in the actual flash-butt welding of chromium-molybdenum rail because, during simulation, plastic deformation and decarburization were not operative; thus, the hardness and martensite levels presented in Table 6 are probably higher than the levels anticipated in actual flash-butt welds that are induction heated at the fourth station. The results of Table 6 also show that there is a wide range of times (between 5 and 15 minutes after upset) at which induction heating could be initiated to significantly reduce the hardness and amount of martensite in a flash-butt weld. Of course, if induction heating is applied later in the operation, any martensite that formed would be tempered, as discussed previously.

In general, the postweld current and induction heating treatments, used either to interrupt cooling or temper the weld, appear to be technically feasible means of lowering the hardness peaks in chormium-molybdenum rail flash-butt welds. The postweld current treatment could be performed on existing welding units without modification. However, this treatment lengthens the welding cycle by as much as 3 minutes, depending upon the specific procedure used, and would therefore reduce flash-butt welding productivity accordingly. On the other hand, induction heating would require the addition of heating coils at other stations downstream from the flash-welding operation, but would allow maintaining welding productivity.

THERMITE WELDING

Welding Procedure

Several chromium-molybdenum rails of Heat 12547 were welded by the Penn Central Transportation Company using the Boutet thermite welding process. The ends to be welded were aligned with a 1-in. (25-mm) gap between them. Ceramic mold sections were placed on both sides of the rail ends, and a third base section covered the bottom of the gap. Clamps held the mold together, and a sealant was applied to eliminate the possibility of hot metal flow between mold sections or between the mold and the rail. The rail ends were then preheated for 20 to 25 minutes by directing a flame down through the top of the mold. A crucible containing the thermite mix was put in place over the mold after the torch was removed. The thermite mix was ignited, and, after a reaction time of about 22 to 28 seconds, the metal ran into the mold through self-tapping plugs. After a period to allow solidification of the weld metal, the mold was removed and the risers knocked off.

Evaluation of Thermite Weld

The thermite welds were evaluated by hardness traverses and metallographic inspection, as were the flash-butt welds. In addition, the fusion zone was analyzed for carbon, and spectrographic analyses were conducted for alloying elements. A sample of the ferrous portion of the thermite mix was also analyzed to detect the presence of alloying elements.

The hardness profile of one of the thermite welds is shown in Figure 17. The relatively flat hardness peaks in the HAZ adjacent to the fusion zone are only about 40 HRC, somewhat lower than those developed by flash-butt welding. The lower peak hardness and larger heat-affected zones are indicative of the higher heat input and, thus, slower cooling rate of the thermite weld. The soft region in the fusion zone is about 1¼ in. (31 mm) wide, notably larger than the soft spots developed in the HAZ regions of flash-butt welds.

Replica electron micrographs of four representative points on the hardness traverse are presented in Figure 18. These four locations are marked on the hardness profile of Figure 17 by the letters a, b, c, and d. The fine pearlite of the unaffected base metal is shown in Figure 18(a). The spheroidized, softened region of minimum hardness in the HAZ is shown in Figure 18(b). The reaustenitized region of the HAZ that transformed back into fine pearlite is shown in Figure 18(c). Figure 18(d) shows the coarse pearlite of the fusion zone that is of somewhat lower hardness.

The fusion zone of the thermite weld is softer primarily because of the lower carbon and alloy contents, as shown in Table 7. This region is intermediate in alloy composition between the base metal and the thermite mixture, which contained no alloy except for a small amount of manganese. The hardness of this region could be brought up to the level of the base metal by using a similarly alloyed thermite mixture.

INSTALLATION OF CHROMIUM-MOLYBDENUM RAIL

The chromium-molybdenum rails from the two CF&I heats have been placed in service as part of a high-strength rail test program by the Mt. Newman Mining Company in Australia. The rails were installed, along with other types of high-strength rail, in specifically selected curved sections of track. This 265-mile (490-km) long rail line is regularly traversed by 130-car trains of iron ore cars, with a gross weight of 120 long tons each, divided among four axles. Ten trains per day provide an annual loading of about 55 million gross long tons. The chromium-molybdenum rails have thus far experienced eight months of trouble-free service.

SUMMARY

A series of steels was prepared in the laboratory, processed to simulate rail cooling, and evaluated for mechanical properties. Yield strengths of up to 162 ksi (1117 N/mm^2) were obtained, with both pearlitic and bainitic steels being investigated. A 0.73% C — 0.83% Mn — 0.16% Si — 0.75% Cr — 0.21% Mo steel, with a fine pearlitic microstructure, exhibited a 100 ksi (689 N/mm^2) yield strength.

Two 100-ton commercial heats were made of this approximate composition and processed into 132-lb/yd (65.5 kg/m) rail. The yield strengths ranged from 109 to 125 ksi (750 to 860 N/mm^2), and the fracture toughness (K_{Ic} value) ranged from 36 to 44 ksi$\sqrt{\text{in.}}$ (40 to 48 MN/n$^{3/2}$). The microstructure of this product was predominantly fine pearlite, with small amounts of bainite in the web and flange. An accelerated (high load) rolling contact fatigue test showed no significant deterioration after 5-million cycles.

Test welds were made in commercial rail in both flash-butt welding and thermite welding processes, and laboratory simulations demonstrated the effectiveness of induction heating the chromium-molybdenum flash-butt welds to control the microstructure. Standard flash-butt welding produced weld hardness peaks of about 10 HRC above the 35 HRC rail head hardness and martensite bands near the weld line. Either a postweld current in the flash-welding machine or heating at another station could be used to significantly reduce the maximum hardness and practically eliminate the martensite bands. Induction tempering of a weld that was flash-butt welded using normal procedures also reduced the maximum weld hardness. Somewhat lower hardness peaks resulted from welding by the Boutet thermite process, and the fusion zone was relatively soft. The weld-metal hardness could be increased by alloying the thermite mixture. The high-strength chromium-molybdenum rails have been welded into curved sections of a high gross tonnage ore railroad.

ACKNOWLEDGMENTS

The authors would like to recognize the efforts of several other organizations that contributed to this work, including CF&I Steel Corporation, which produced the commercial rail, Chemetron Corporation, Teleweld, Inc., and Penn Central Transportation Company, which performed the various welding operations, and the Technical Center of the Association of American Railroads, which conducted a rolling contact fatigue test.

Within the Climax Research Laboratory, the authors appreciate the efforts of Dr. D. E. Diesburg for providing the fracture toughness measurements and V. Biss for electron microscopy.

REFERENCES

1. R. G. Read, "Rail for High Intensity Mineral Traffic," Rail Track Materials Seminar, B.H.P. Melbourne Research Laboratories, Clayton, Victoria, Australia, October 1971.
2. I. Mair, "Material Aspects of Rail Design," Rail Track Materials Seminar, B.H.P. Melbourne Research Laboratories, Clayton, Victoria, Australia, October 1971.
3. S. Marich, "Overseas and Future Developments of Rail Steels," Rail Track Materials Seminar, B.H.P. Melbourne Research Laboratories, Clayton, Victoria, Australia, October 1971.
4. J. Muscara and M. J. Sinnott, "Construction and Evaluation of a Versatile Abrasive Wear Testing Apparatus," Metals Engineering Quarterly, May 1972.

Table 1

Compositions of Experimental and Commercial Rail Steels

Steel	Heat or Ingot	Element, %									
		C	Mn	Si	Cr	Mo	V	Al	N	P	S
A	P924	0.75	0.81	0.15	--	--	--	0.05	0.007	(0.015)[a]	(0.015)
C	P928B	0.74	0.80	1.04	--	0.40	0.09	0.04	0.006	(0.015)	(0.015)
E	P925	0.75	0.81	0.17	0.73	0.40	--	0.04	0.007	(0.015)	(0.015)
J	P974	0.78	0.82	0.14	0.75	0.31	--	(0.04)	(0.007)	(0.015)	(0.015)
M	P994B	0.76	0.81	0.14	0.74	0.23	--	(0.04)	(0.007)	(0.015)	(0.015)
Q	P995C	0.76	0.92	0.14	0.81	0.28	--	(0.04)	(0.007)	(0.015)	(0.015)
R	P995D	0.76	0.92	0.13	0.80	0.28	0.056	(0.04)	(0.007)	(0.015)	(0.015)
S	1095A	0.78	0.88	0.17	0.79	0.24	--	(0.04)	(0.007)	(0.015)	(0.015)
T	1096A	0.73	0.83	0.16	0.75	0.21	--	(0.04)	(0.007)	(0.015)	(0.015)
Commercial	11406	0.78	0.84	0.22	0.72	0.18	--	ND[b]	ND	0.026	0.022
Commercial	12547	0.77	0.89	0.20	0.76	0.16	--	ND	ND	0.014	0.034

[a] Numbers in parentheses are aim compositions, not analyzed.
[b] ND = not determined.

Table 2

Mechanical Properties of Experimental Steels Subjected to Simulated Rail Cooling for 132-lb/yd (65.5-kg/m) Rails

Steel	Cooling Schedule[a]	Hardness, HB	0.2% Offset Yield Strength, ksi (N/mm²)	Tensile Strength, ksi (N/mm²)	Elongation, %	Reduction in Area, %
A	1	--	62 (427)	129 (889)	12.2	22
C	1	--	106 (731)	153 (1055)	10.6	29
C	1A	--	140 (965)	184 (1269)	10.8	25
E	1	--	119 (820)	165 (1138)	11.6	31
J	1	388	126 (869)	181 (1248)	13.5	42
M	2	325	87 (600)	152 (1048)	12.8	33
M	1B	415	--	--	--	--
Q	2	418	136 (938)	190 (1310)	12.6	41
R	2	430	162 (1117)	211 (1455)	11.5	37
S	1	361	120 (827)	190 (1310)	12.5	37
T	1	330	100 (689)	163 (1124)	13.0	39

[a] Cooling Schedules:

1	Cooled from 1600 F (870 C) to 1000 F (535 C) in 18 minutes, followed by furnace cooling from 1000 F (535 C).
1A	Same cooling curve as above, with furnace cooling from 1100 F (595 C).
1B	Same cooling curve as (1) continued to room temperature.
2	Cooled from 1600 F (870 C) to 1000 F (535 C) in 22 minutes, followed by furnace cooling from 1000 F (535 C).

Table 3

Mechanical Properties of Commercially Produced 132-lb/yd (65.5-kg/m) Chromium-Molybdenum Rail

Designation		Ingot Treatment	Specimen Location	Mechanical Properties					
Heat	Rail			0.2% Offset Yield Strength, ksi (N/mm^2)	Ultimate Tensile Strength, ksi (N/mm^2)	Elongation, %	Reduction in Area, %	Fracture Toughness, K_{Ic}, ksi$\sqrt{\text{in.}}$ (MN/m$^{3/2}$)	Hardness, HB
11406	4B	None	Head	108.7 (749)	172.4 (1189)	8.0	13.0	--	343
				109.0 (751)	172.6 (1190)	8.0	15.3		
			Web	--	--	--	--	35.8 (39.3)	--
	5C	Hypercal	Head	125.6 (866)	184.3 (1271)	5.5	8.2	--	358
				125.3 (864)	184.3 (1271)	5.5	8.6		
			Web	--	--	--	--	40.0 (40.6)	--
	13A	Hypercal	Head	109.0 (751)	172.0 (1186)	9.0	12.3	--	342
				110.9 (765)	174.5 (1203)	9.2	14.7		
12547	10C	None	Head	119.0 (820)	178.2 (1229)	11.5	24.5	--	352
				114.0 (786)	175.0 (1206)	11.3	25.2		
			Web	--	--	--	--	43.5 (47.8)	--

Table 4

Maximum and Minimum Hardness Measured in the Region of the Flash-Butt Weld

Location of Traverse	Maximum/Minimum Hardness, HRC	
	Welded with Standard Method	Welded with Postweld Current
Top of Head	43.6/31.8	42.4/26.5
Center of Head	46.5/29.6[a]	44.0/25.7
Web	48.3/29.9	45.0/29.9
Flange	46.3/29.8	40.2/28.5

[a] Average of four traverses.

Table 5

Bend Test Results for Chromium-Molybdenum Flash-Butt Welds

Type Weld	Average Fracture Stress, ksi (N/mm^2)
Standard Method	216 (1490)
Current Applied after Upset	237 (1630)
Induction Tempered	228 (1571)

Table 6

Results of Hardness Tests Performed on Chromium-Molybdenum Rail Specimens Heat Treated to Simulate a Flash-Weld Thermal Cycle and Different Heating Cycles Used to Interrupt Cooling

Specimen	Cooling Time between Upset and Interruption of Cooling, min	Temperature at Initiation of Second Heating Cycle, F (C)	Peak Temperature during Second Heating Cycle, F (C)	Average Hardness		Martensite, %
				HRC	HB (3000 kg)	
1	Simulation of Weld Thermal Cycle			55.9	578	65
2	15	390 (200)	1250 (675)	34.7	341	10
3	10	535 (280)	1280 (695)	34.1	326	10
4	10	535 (280)	1150 (620)	37.6	366	5
5	10	525 (275)	1100 (595)	39.4	363	5
6[a]	5	885 (475)	1255 (680)	35.8	331	5
7[a]	5	880 (470)	1255 (680)	35.2	331	5
8	5	890 (475)	1035 (555)	40.7	409	15

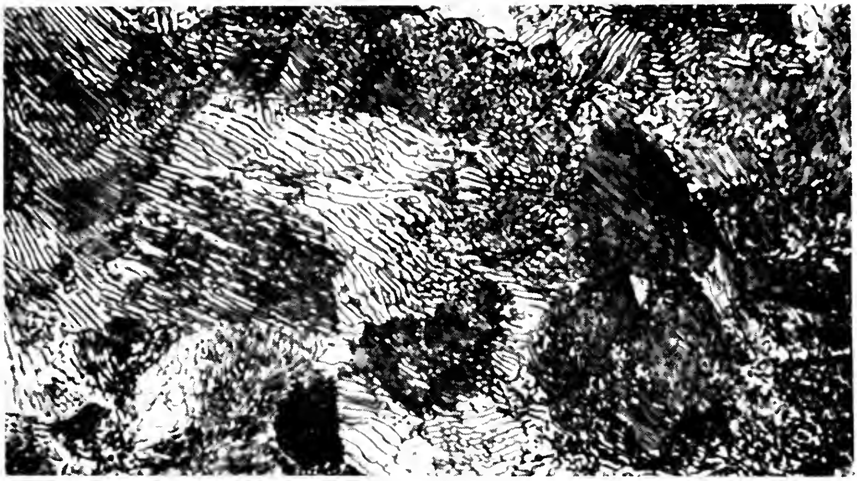
[a] Specimens 6 and 7 were given approximately the same heat treatment.

Table 7

Chemical Compositions of Chromium-Molybdenum Rail, Thermite Mixture, and Weld Zone of Thermite Weld

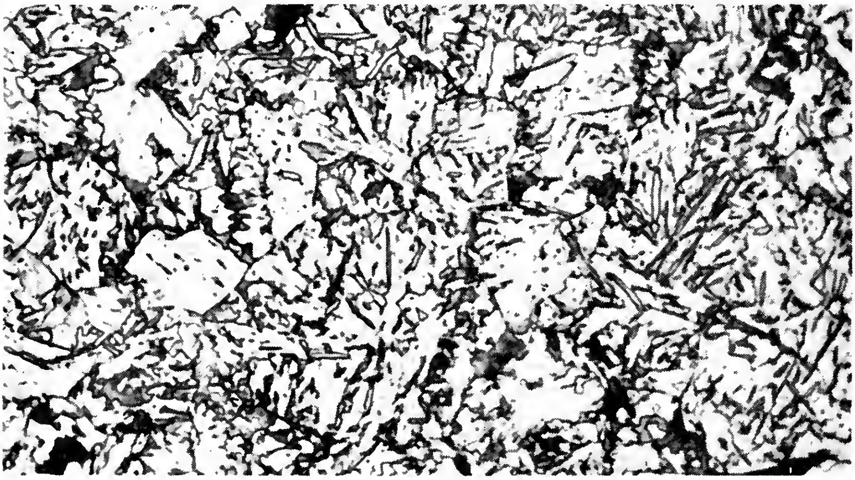
Sample	Element, %							
	C	Mn	Si	P	S	Cr	Mo	Ni
Rail	0.77	0.89	0.20	0.014	0.034	0.76	0.16	NA[a]
Thermite Mixture	NA	0.35	NA	NA	NA	Nil	Nil	0.029
Weld Zone	0.59	0.87	0.32	NA	NA	0.17	0.09	NA

[a] NA = not analyzed



2% Nital X1000

(a) Steel A--0.75C-0.81Mn-0.15Si (Base Composition)



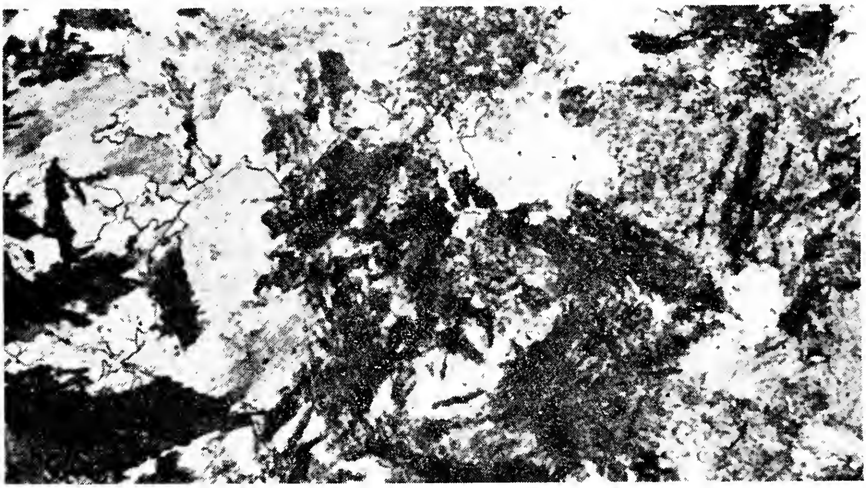
2% Nital X1000

(b) Steel C--0.74C-0.80Mn-1.04Si-0.40Mo-0.09V
Cooling Schedule 1

Figure 1 Experimental Alloy Rail Steels--I

2% Nital X1000

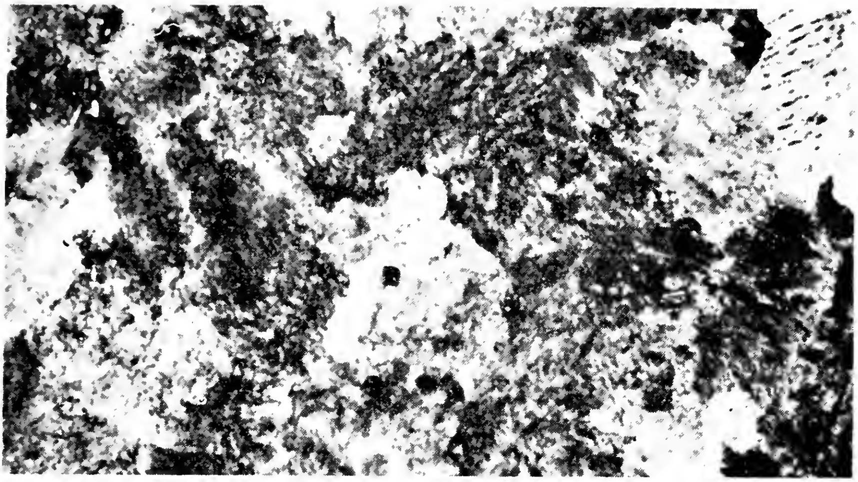
(a) Steel E--0.75C-0.81Mn-0.17Si-0.73Cr-0.40Mo



2% Nital X1000

(b) Steel C--0.74C-0.80Mn-1.04Si-0.40Mo-0.09V
Cooling Schedule 1A

Figure 2 Experimental Alloy Rail Steels--II

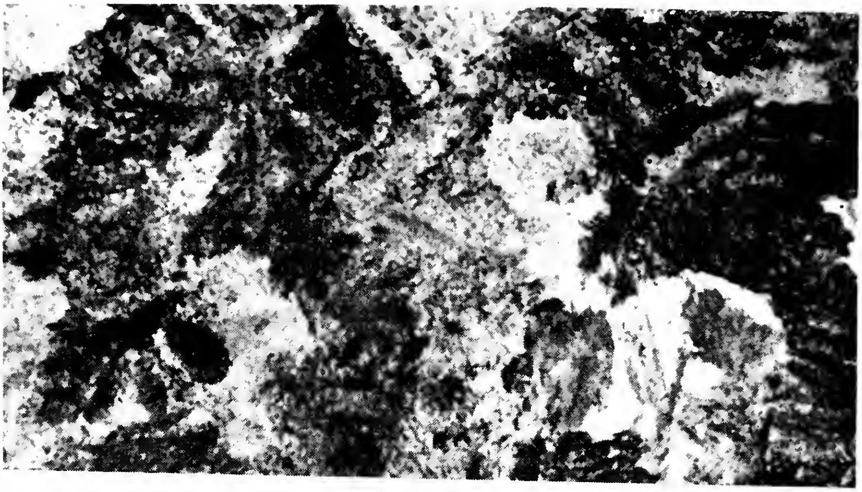


2% Nital X1000

(a) Steel J--0.78C-0.82Mn-0.14Si-0.75Cr-0.31Mo

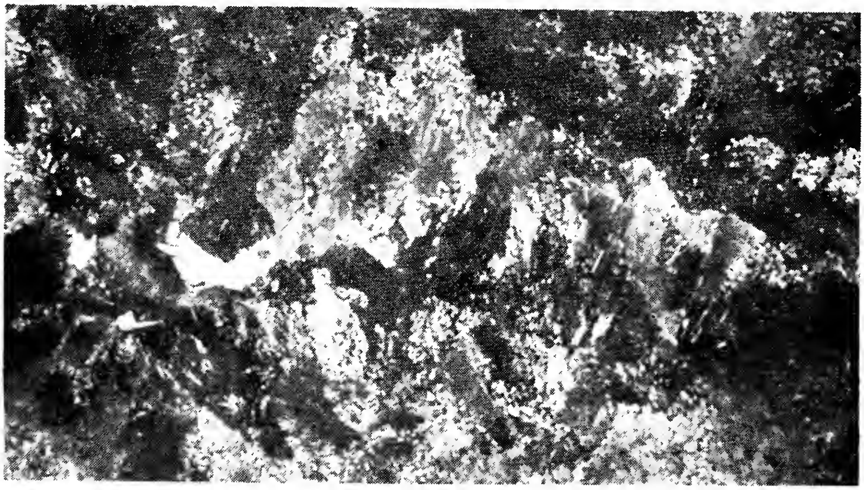
(b) Steel M--0.76C-0.81Mn-0.14Si-0.74Cr-0.23Mo

Figure 3 Experimental Alloy Rail Steels--III



2% Nital X1000

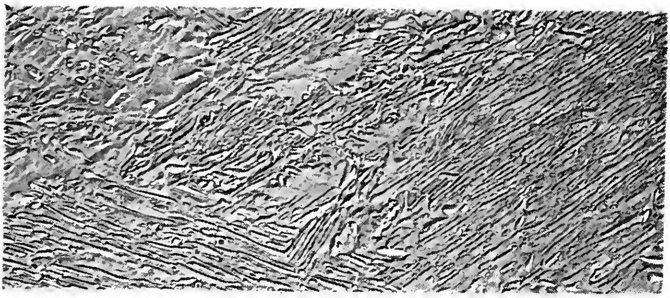
(a) Steel R--0.76C-0.92Mn-0.13Si-0.80Cr-0.28Mo-0.056V



2% Nital X1000

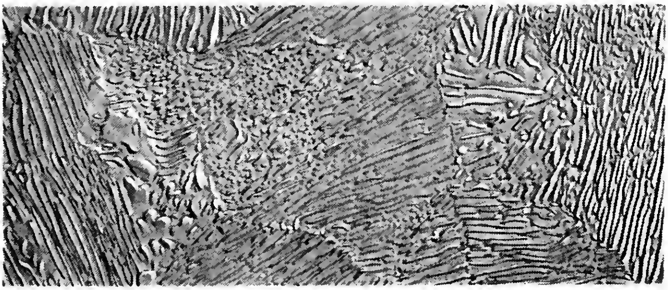
(b) Steel S--0.78C-0.88Mn-0.17Si-0.79Cr-0.24Mo

Figure 4 Experimental Alloy Rail Steels--IV



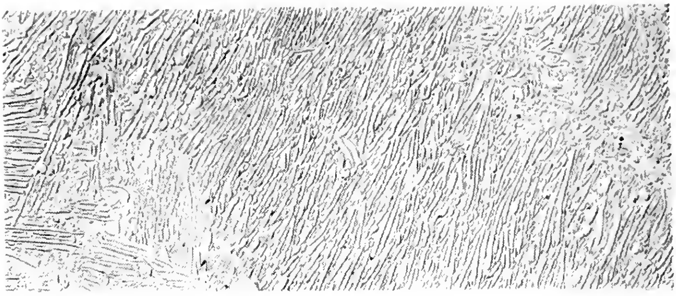
(a) Steel C--0.74C-0.80Mn-1.04Si-
0.40Mo-0.09V
Cooling Schedule 1A

(b) Steel J--0.78C-0.82Mn-0.14Si-
0.74Cr-0.31Mo

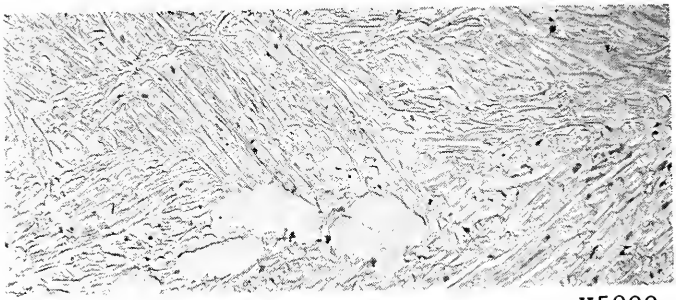


(c) Steel M--0.76C-0.81Mn-0.14Si-
0.74Cr-0.23Mo

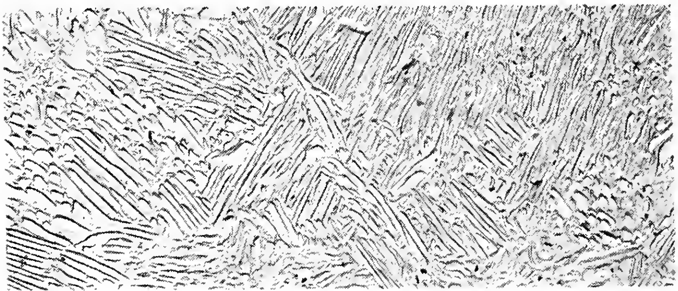
Figure 5 Replica Electron Micrographs of Experimental Alloy Rail Steels--I



(a) Steel Q--0.76C-0.92Mn-0.14Si-0.81Cr-0.28Mo



(b) Steel R--0.76C-0.92Mn-0.13Si-0.80Cr-0.28Mo-0.056V



(c) Steel S--0.78C-0.88Mn-0.17Si-0.79Cr-0.24Mo

Figure 6 Replica Electron Micrographs of Experimental Alloy Rail Steels--II

X1000

(a) Rail 4B

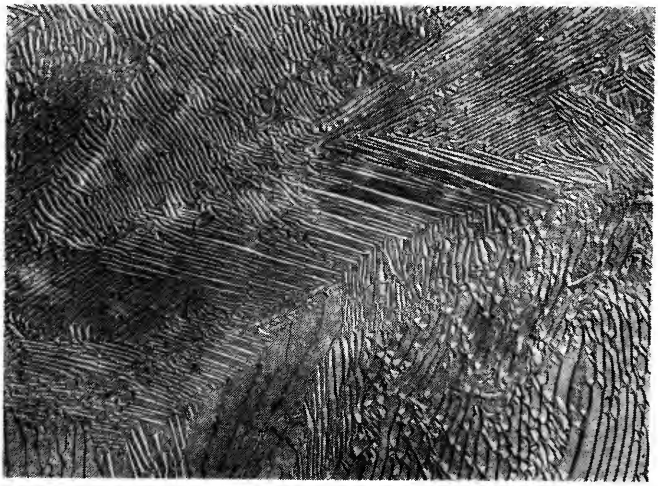
X1000

(b) Hypercal-Treated Rail 13A

Figure 7 Typical Nonmetallic Inclusions in the Longitudinal Web Sections of Chromium-Molybdenum Rails from Heat 11406

4% Picral X500

(a)



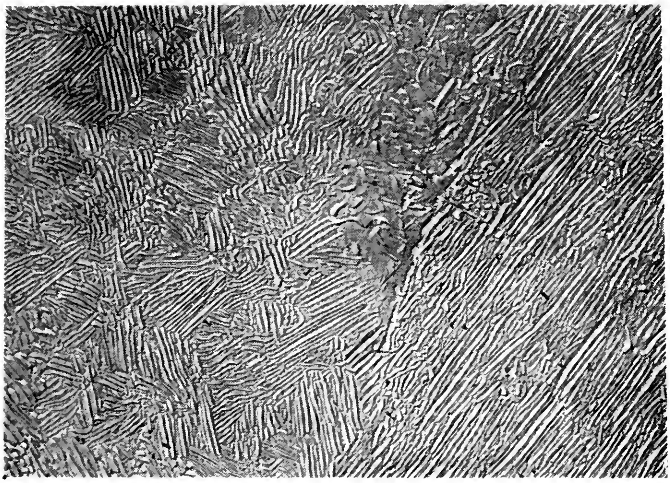
4% Picral X5000

(b)

Figure 8 Optical and Replica Electron Micrographs of the Longitudinal Head Section of Chromium-Molybdenum Rail 4B from Heat 11406

4% Picral X500

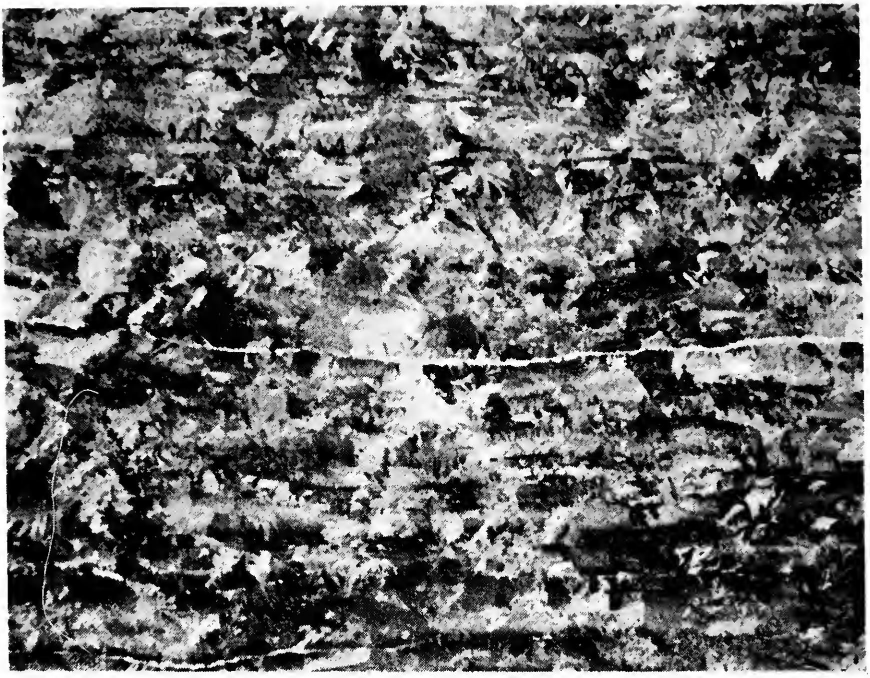
(a)



X5000

(b)

Figure 9 Optical and Replica Electron Micrographs the Longitudinal Web Section of Chromium-Molybdenum Rail 4B from Heat 11406



4% Picral X500

Figure 10 Optical Micrograph of Longitudinal Web Section of Chromium-Molybdenum Rail 10C from Heat 12547 Showing Isolated Martensite Streaks

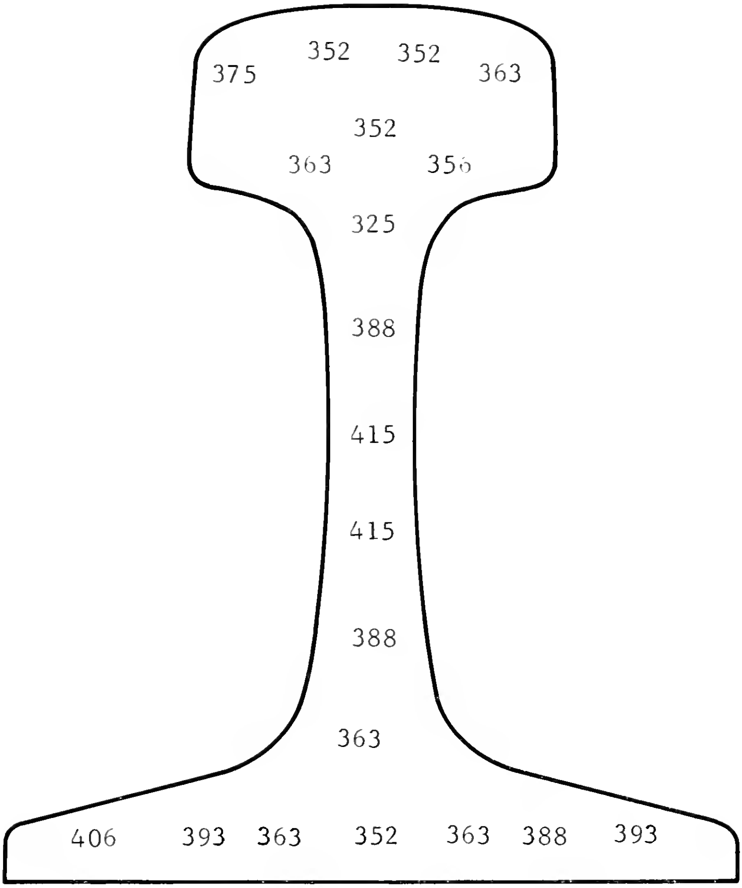


Figure 11 Brinell Hardness Survey of the Cross Section
of Chromium-Molybdenum Rail 10C
of Heat 12547

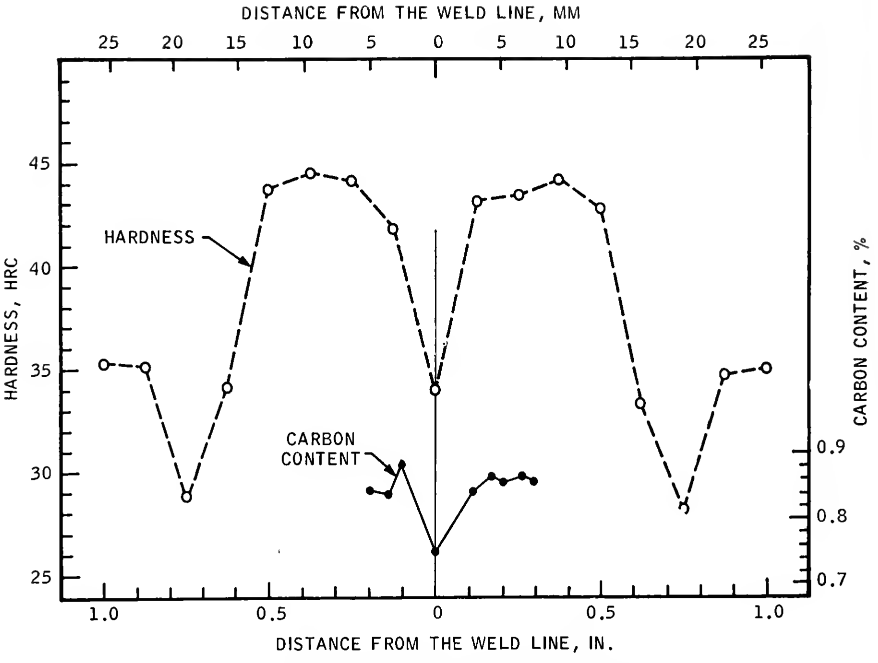
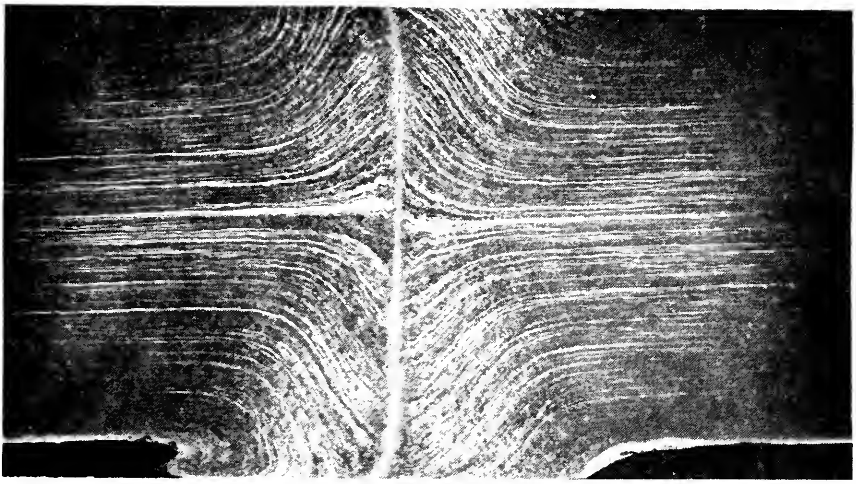
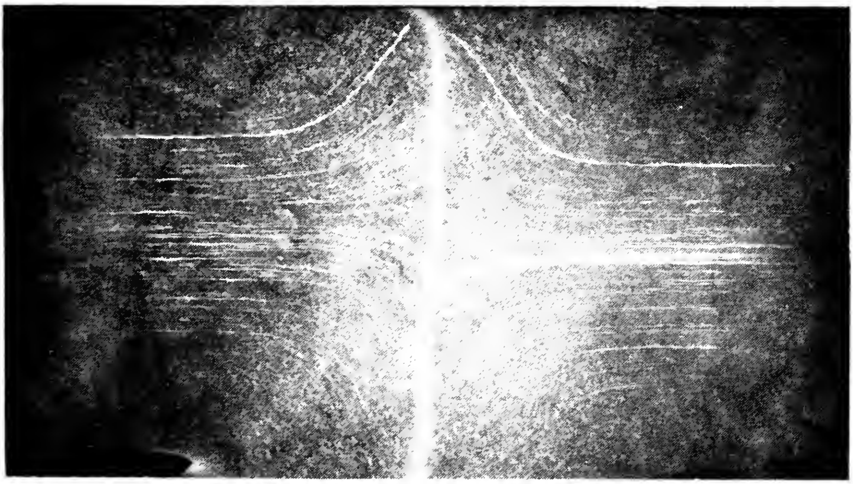


Figure 12 Hardness Traverse on Sections Cut from the Head of Flash-Butt Welded Chromium-Molybdenum Rail 5C from Heat 11406



4% Nital X3.3

(a) Welded Using Standard Procedure



4% Nital X3.3

(b) Welded Using Postweld Current

Figure 13 Macrographs of the Web Section in Flash-Butt Welds Performed in Chromium-Molybdenum Rail

10% Potassium meta-Bisulfite X500

(a) Welded Using Standard Procedure

10% Potassium meta-Bisulfite X500

(b) Welded Using Standard Procedure
and Induction Tempering

Figure 14 Micrographs of Martensite Bands in The Web Section of Flash-Butt Welds Performed in Chromium-Molybdenum Rail

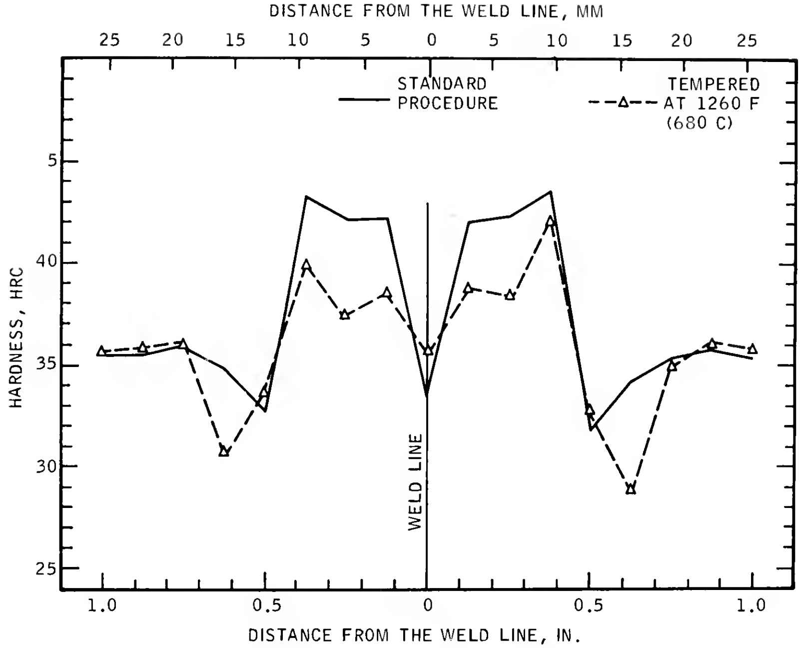


Figure 15 Hardness Traverses Located 0.2 Inch (5 mm) from the Top of the Head in Both As-Welded and Tempered Flash-Butt Welds in Chromium-Molybdenum Rail 4B of Heat 11406

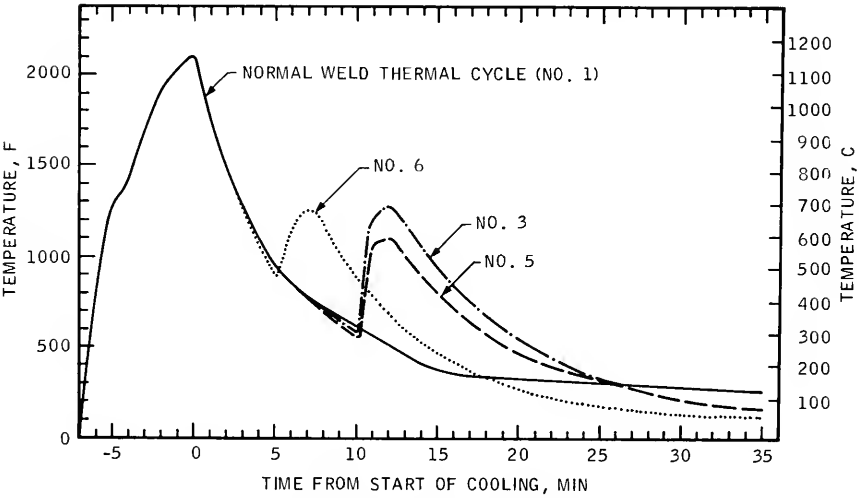


Figure 16 Thermal Cycles of Specimens Heat Treated to Simulate a Flash-Butt Weld (No. 1) and a Flash-Butt Weld plus Different Postweld Heat Treatments (Nos. 3, 5, and 6)

The numbers refer to the specimens listed in Table 6.

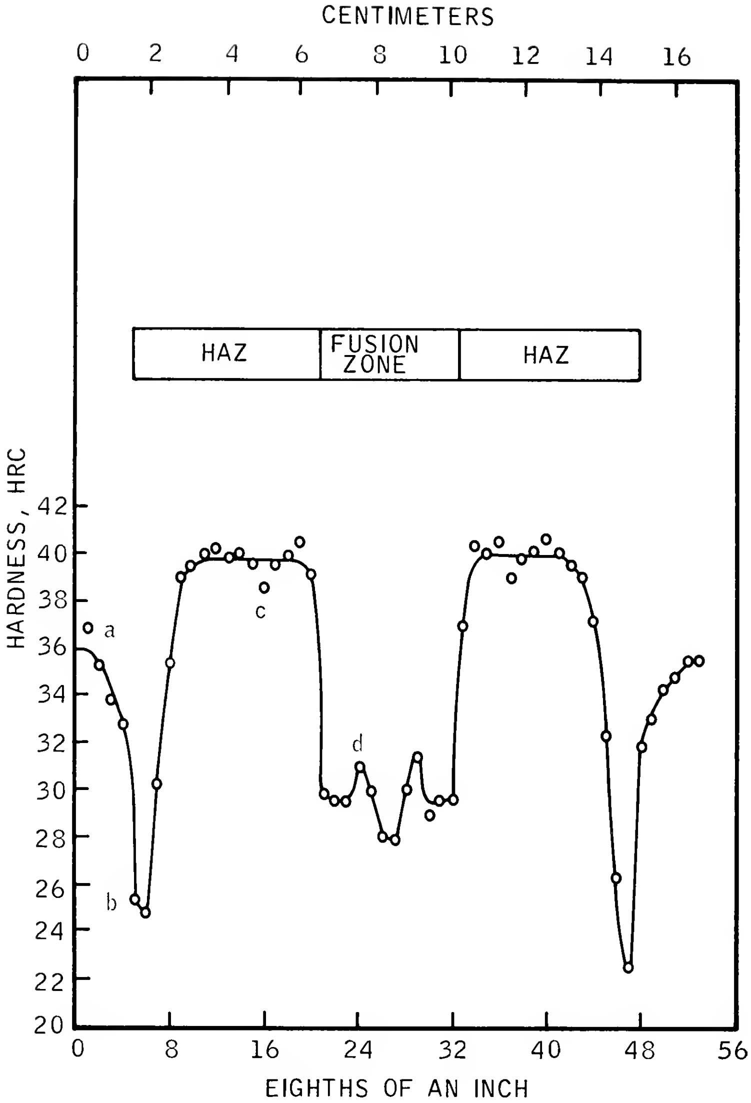


Figure 17 Hardness Profile of Thermite Weld in Chromium-Molybdenum Rail

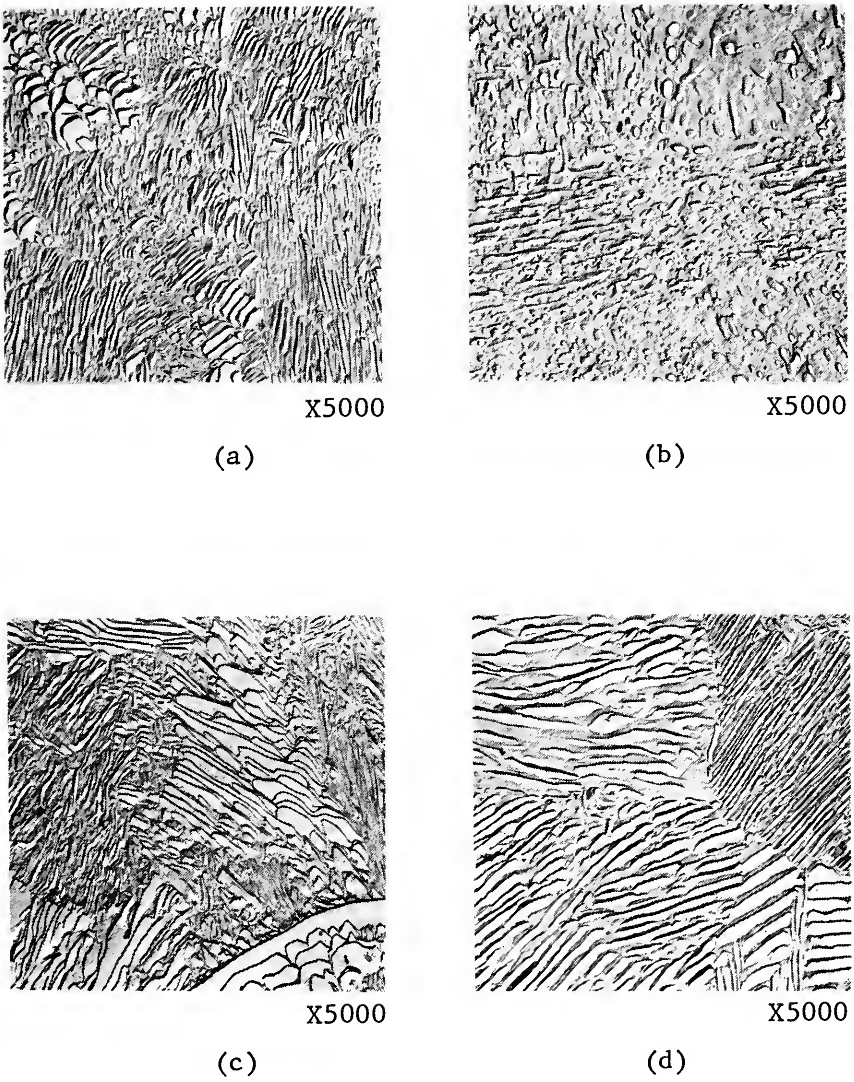


Figure 18 Replica Electron Micrographs of Selected Areas along Hardness Profile (Figure 17) of Thermite Weld in Chromium-Molybdenum Rail

Innovations in Frog and Switch Design

77–658–10

By E. H. TAYLOR
Supervisor Track Design and Development
Canadian Pacific Rail

Acknowledgment

The author wishes to express his sincere thanks to the following men for their cooperation and assistance in the development and design of many aspects of the special trackwork discussed herein: J. Fox, chief engineer, CP Rail; G. Sinclair, engineer of tests, CP Rail; C. N. King, retired senior engineer, CP Rail; and E. Frank, chief engineer, Abex Corp., Trackwork Products.

I wish to express my appreciation for the invitation to speak on behalf of CP Rail and to elaborate on this progressive project—"Innovations in Frog and Switch Design."

The purpose of this paper is to outline the continuing development of CP Rail in frog and switch design. This development is dictated by our requirement to handle single-track traffic in CTC territory of approximately 50 million gross tons, per mile, per annum on our main line west of Golden to Vancouver which traverses the Rocky Mountains, Selkirk and Cascade mountain ranges with grades up to 2.2% and curvature up to 12°. In addition to the usual type freight trains, this route also handles our unit coal trains.

At present there are a number of frog designs constructed in a variety of manufacturing methods and materials with a preference by many railroads for a certain type design. However, it is generally accepted that either rigid or spring railbound manganese steel frogs are the most desirable frog type for use in single-track, heavy-tonnage main lines.

CP Rail's investigation commenced in 1968 and was prefaced with the following criteria: frog design, material, and construction. Our existing frog design was to a modified AREA heavy-wall insert casting with the 7-in. heel spread. This design had been in service for some 10 years superseding the AREA light-wall design with 4¾-in. heel spread. This heavy wall designed frog in 115-lb and 132-lb rail sections had proven to be adequate in most locations. However, with the increased wheel loads and higher speeds, serious casting problems were becoming more apparent. This initially was considered a material problem.

It is acknowledged that the use of high manganese steel will provide the best wearing surface and resistance to abrasion and deformation from heavy impact than any other type materials for frog insert castings. In addition it has been substantiated that some form of depth hardening in a manganese steel casting will substantially increase its initial life. Initial life is defined as from the first installation until sufficient wear occurs to require rebuilding by welding. Laboratory tests conducted by the AAR Technical Center on manganese track work castings, hardened by the explosive process, have shown that hardened castings will resist wear and batter in a superior manner to unhardened castings.

The two graphs on Fig. 1 show the progressive wear results throughout the test in the critcial areas on the point and wing opposite the point area. Average values for three castings were plotted in each category. It will be noted that the rate of

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Note: Discussion open until October 15, 1976.

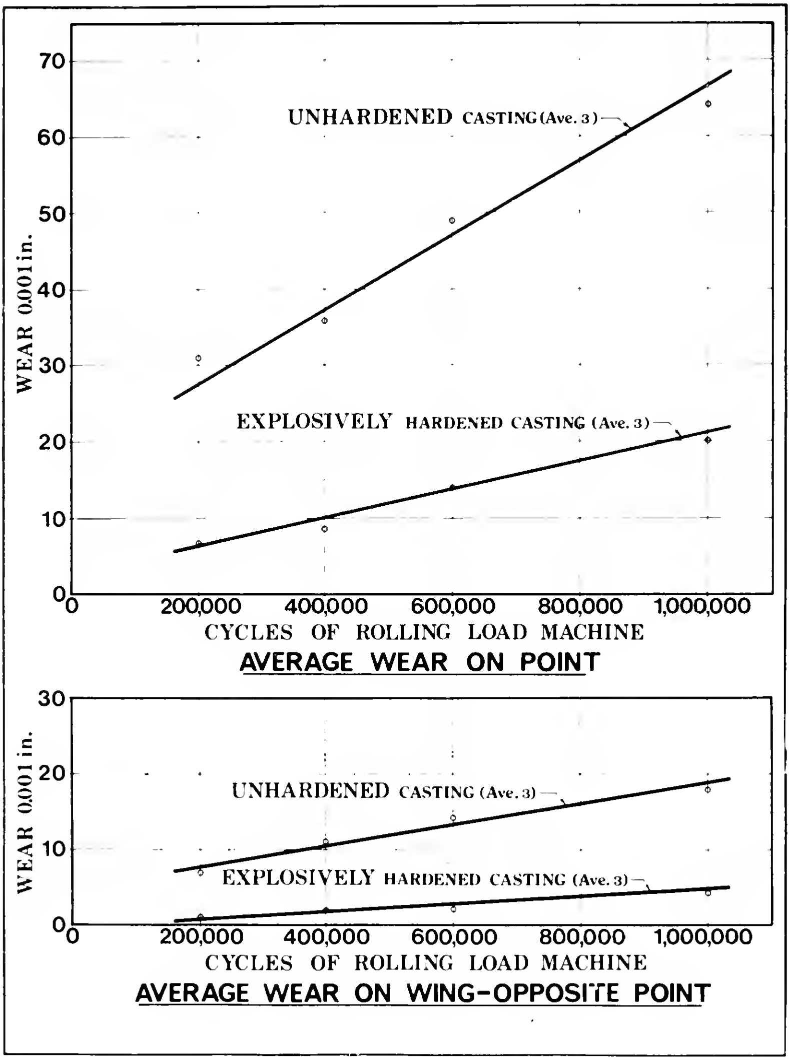


Fig. 1—Rolling-load wear results on manganese insert castings.

wear increased in a manner approaching a straight line between 200,000 and 1,000,000 cycles.

These test results were produced on a rolling-load machine which operated with a 30,000-lb wheel load for 1,000,000 cycles. This produced 30,000,000 tons of rolling load on each specimen, divided equally as to direction, which is equivalent to a frog insert casting having 60,000,000 gross tons of traffic. These results represent an expected initial frog insert service life of approximately 3 to 1—hardened versus unhardened manganese insert castings.

On CP Rail all aspects of frog manufacture were thoroughly investigated and the initial change was in the adoption of the elastic stop nuts in place of the conventional spring washer and square nut with heavier designed rail headlock and rail washers. Laboratory and in-track tests were conducted and it was substantiated that this lock nut under all track conditions provides the best type locking device to resist back-off and reduce maintenance. All special trackwork components, i.e. frogs, diamond crossings, switches, etc., are now equipped with the heavy series elastic stop nuts.

Based on the results obtained from these investigations a series of in-track frog tests were made using standard No. 13, 132-lb RE railbound manganese frogs. Our first test frogs were installed on the Mountain and Shuswap Subdivisions in April 1970. These frogs were equipped with explosive-hardened and unhardened manganese inserts with standard carbon rail. Regular field inspections were carried out and profilometer readings were taken. After approximately 18 months of service and 60 million gross tons of traffic, the standard frogs with unhardened inserts at certain locations were removed from track due to excessive wear, primarily in the point area of wheel transfer.

I would like to draw your attention to sections in B-B and C-C on Fig. 2. These two areas of wheel transfer are invariably subjected to excessive wear. Please note in section C-C the collapse in the casting in the point area—standard unhardened insert right-hand side. In general the explosive-hardened frogs provided approximately 40 months of service and 115 million gross tons of traffic. A number of explosive-hardened frogs were removed from track due to manganese batter and flow—specifically in the area of wheel transition from the wing to the point approximately 20 in. to 22 in. from the ½-in. point. This depression is the result of the wheels with a false flange running on the wing of the casting, and on cross over dropping into the flangeway resulting in heavy impact in a very localized area. Excessive rail flow developed in areas of wheel run-off from the manganese insert, point rail junction and heel extension easer.

Conclusive results obtained from the first series of frog test installations indicated that standard railbound manganese frogs with explosive-hardened inserts had twice the initial service life expectancy over frogs with unhardened manganese inserts.

The magnitude of the possible savings involved provided the incentive to continue this investigation. Sample test frogs that were removed from track due to service failures were completely examined. Rail flow on point rails and wing rails, also rail end batter, indicated that improved rail steel properties were positively required. Investigation into the availability of improved rail steel that would suffice for special trackwork manufacture indicated that two alternatives existed—fully heat-treated or chromium alloy rails.

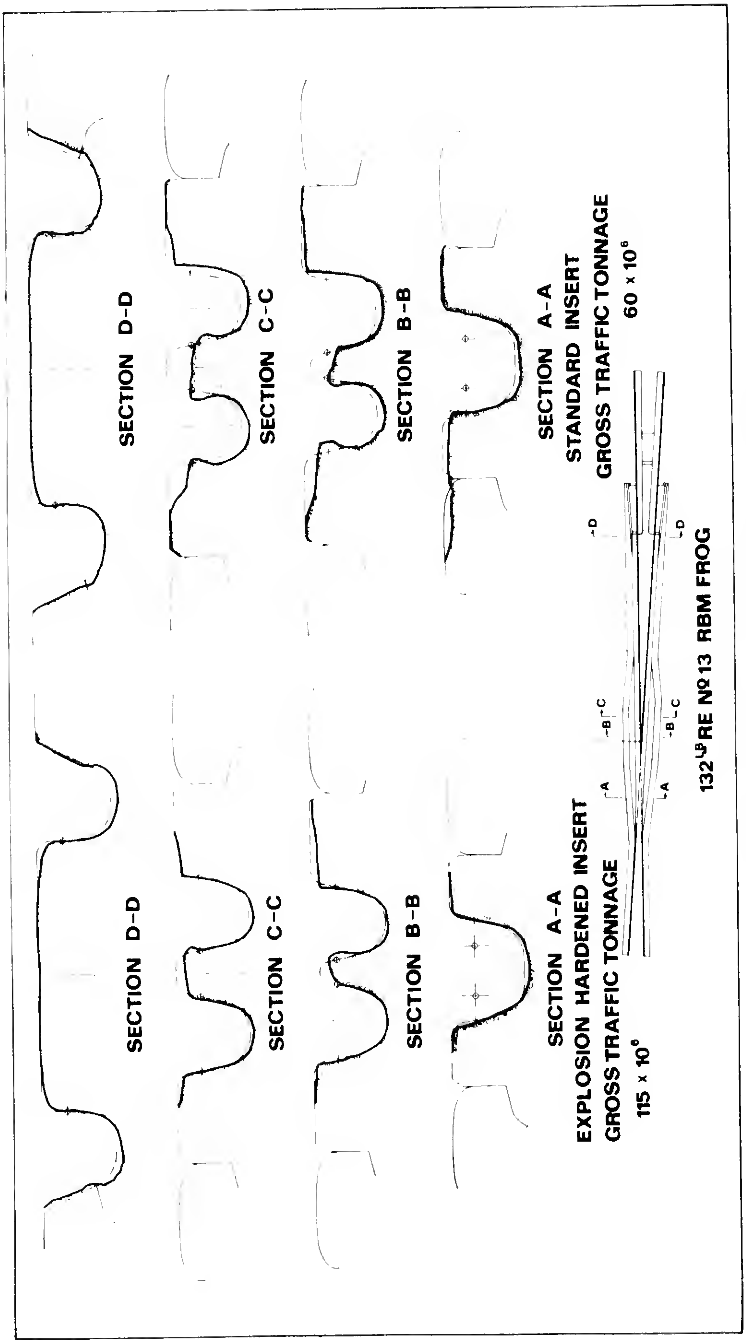


Fig. 2—Profilometer reading on manganese insert castings.

MECHANICAL PROPERTIES	AREA CONTROL COOLED CARBON	CHROMIUM (ALGOMA CANADA)	FULLY HEAT-TREATED (BETHLEHEM STEEL)
YIELD STRENGTH (KSI)	66-88	100	114
ULTIMATE TENSILE STRENGTH (KSI)	100-138	160	172
ELONGATION %	9-20	12	13
REDUCTION AREA %	15	15	35
HARDNESS BHN	235-260	295-325	315-370

Fig. 3—Mechanical properties of commercial rail steels.

Fig. 3 shows the comparison of mechanical properties for standard carbon, fully heat-treated and chrome rails. The mechanical properties for chrome rail are not quite as good as fully heat-treated rail. However, chrome rail is available from the steel mill in Canada whereas fully heat-treated rail is not available at present. Subsequent tests with frogs and switches fabricated with fully heat-treated and chrome rails substantiated the research recommendations. Rail flow characteristics in all areas were greatly reduced. At present, on CP Rail, all special trackwork, i.e., switch points, stock rails, guard rails, frogs, etc., are manufactured exclusively with chrome rail.

A number of defective unhardened frog inserts were sectioned and shape-measured with confirming results that the center point section of the casting in the wheel transition area had partially collapsed. This was due to the previously mentioned localized repeated wheel impacts. Wheel jump produced by casting wear and longitudinal flexing in the point area of the insert produced wheel bounce with related high impact and repeated localized spot failures.

Defective explosive-hardened frog inserts were also sectioned and found to have a number of crack propagations developing in the underside of the castings in the point area. These were considered tensile failures due to excessive stresses.

Research has shown that merely increasing the thickness of casting sections where weaknesses develop is not necessarily the answer. Mass does not always ensure added strength. In fact, heavy mass will reduce the strength of manganese castings because of internal defects inherent in the manufacturing process usually employed—for example, limited amount of feeders, etc.

An example of one type of defect resulting from improper design is the shrink cavity resulting from too great a mass. The thinner sections and outer walls chill and set quickly after pouring, while the heavy mass in the interior is still molten. As the outer surface solidifies, it draws on the molten mass to fill the shrinkage and the result is a cavity in the interior of the large mass.

In addition to the danger of shrink cavities in the regions of unequal sections, it has been found that thick sections, even though made uniform, may develop internal defects during the heat-treatment of the casting. During the quench, the chill from the water on the outer surfaces will produce total shrinkage while the interior of the casting is still at a high temperature. Subsequent cooling and shrinking of the interior is likely to produce a concealed inner crack, or what is known as "inner check." In service, due to repeated alternating stresses from wheels loads, this check develops until it progresses to the surface of the casting.

The conclusions resulting from many aspects of research in frog casting design indicated that an improved type of manganese insert was a prime requirement. The frog insert was redesigned and is shown on Fig. 4.

Fig. 4 shows two types of manganese insert cross sections. The original test frog inserts were constructed to the CP Rail modified AREA heavy-wall design, shown on the left-hand side. The cross section shown on the right hand side is a modified integral-base design with a structure of near-uniform thickness. The vertical rib in the point area reduces casting flexing and assists in transmitting the wheel load to the base. Greater structural strength is desirable for explosive depth hardening, and inserts to this design will offer longer life in the rebuilt condition.

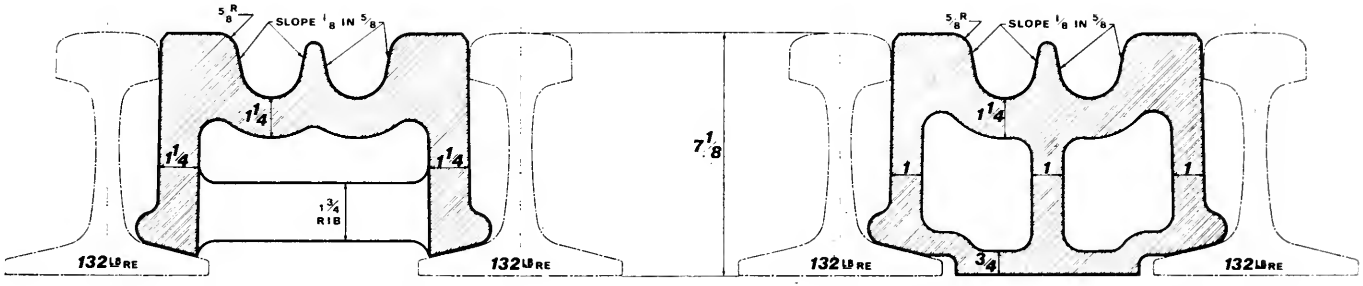
Diamond crossings with this general casting design configuration and depth hardening have provided substantially increased service life over the current AREA open-type design and are presently used by many American railroads. CP Rail has used this diamond crossing design for some 15 years and acquired extremely good crossing life.

Fig. 5 depicts the new design of depressed and shortened heel tail section for the insert casting. Numerous problems have occurred in this area, especially with the 4¾-in. heel design. Investigation and subsequent design has produced the following:

- The depressed tail is ideally suited for the casting design with a 7-in. heel spread only, and the false flange easer is relocated into the insert body with the vertical rib located under the easer slope.
- Top of casting tail is reduced in height by approximately ½-in. below top of rail and eliminates false flange contact.

The merits of this design are as follows:

- Insert casting tail fracture at heel junction is practically eliminated.
- Castings are shortened with reduced costs for insert and shop fitting.
- Reclamation by welding and maintenance by slotting in the tail section are eliminated.
- Wheel easer transitions occur on manganese insert surfaces and this further reduces wear and maintenance on the point rails etc.



SECTION 5/8 ACTUAL POINT

MODIFIED AREA HEAVY WALL DESIGN

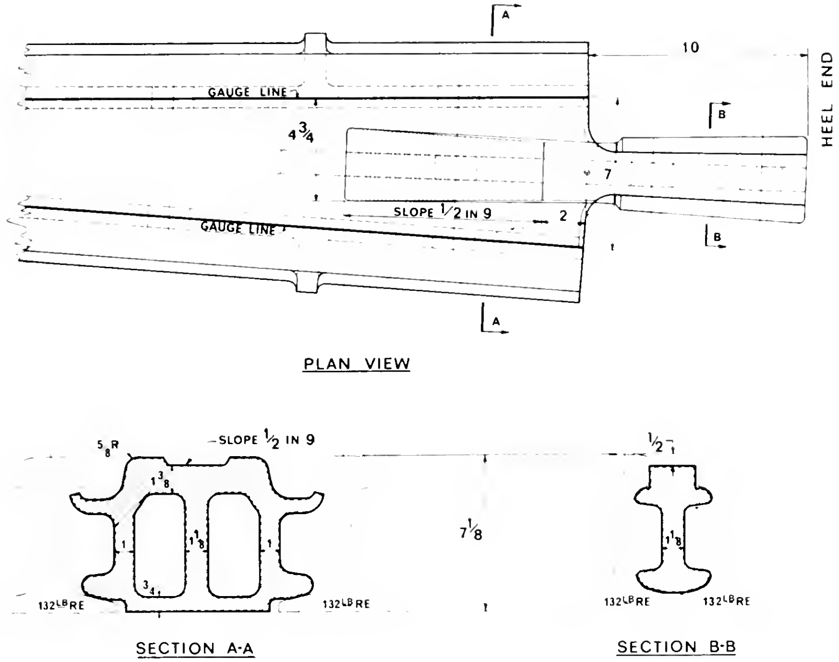
SECTION 5/8 ACTUAL POINT

MODIFIED INTEGRAL BASE DESIGN

MANGANESE STEEL INSERT SECTIONS

CP Rail DESIGN

Fig. 4



DEPRESSED TAIL No 13-132LB RE R.B.M. FROG

C P Rail DESIGN

Fig. 5

Figs. 6 and 7 are photos of frogs in service with depressed tails showing the false flange contact on the easer. To date, excellent results have been obtained with this design.

Fig. 8 is a typical cross section of a manganese insert that was explosive depth-hardened showing the hardness transitions and contour pattern. Extensive explosive depth-hardening tests were conducted with the following results.

1. Depth of hardening increases with the number of explosions, at least up to a number of three.
2. The depth of hardness raised above Rc 20, doubled between the first and second explosions.
3. The depth of hardening is not the same for differently shaped portion of the insert because of reflection of shock waves.
4. The maximum surface hardness was found to be slightly in excess of 400 BHN with the three-shot application using Du Pont Detasheet "C" Flexible Explosive, weight 2 gm/in.^{2}
5. Hardness values in excess of 400 BHN are not considered to be any more effective at increasing frog insert life.

Fig. 6—Photo of depressed tail.

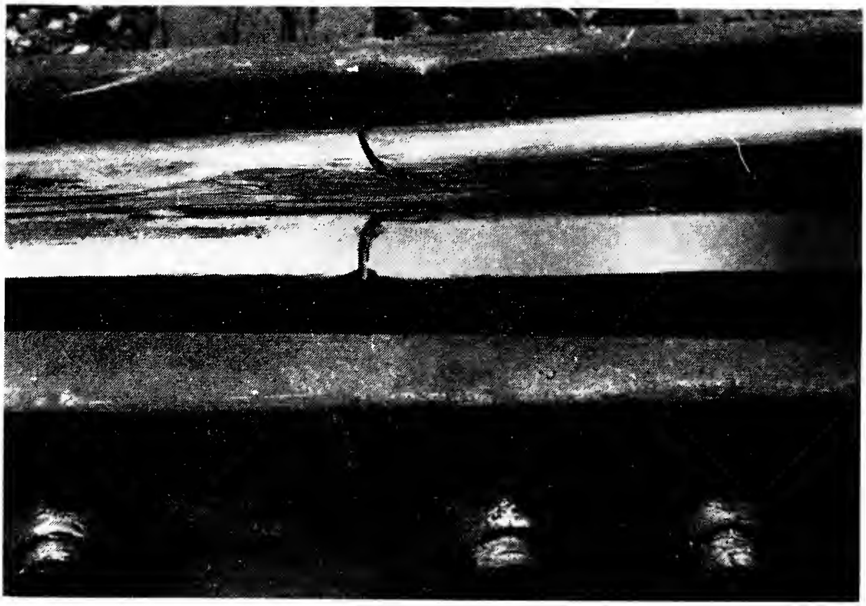
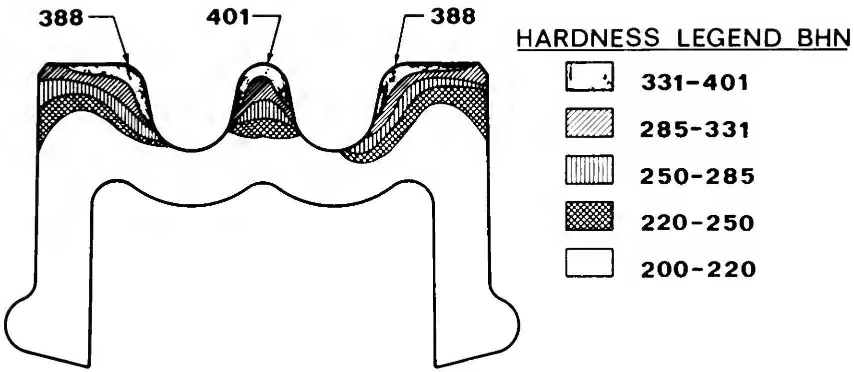


Fig. 7—Photo of depressed tail.



TYPICAL INSERT SECTION
EXPLOSIVE DEPTH HARDENED
FLEXIBLE SHEET EXPLOSIVE
3 SHOT APPLICATION
2 gm/in²

Fig. 8

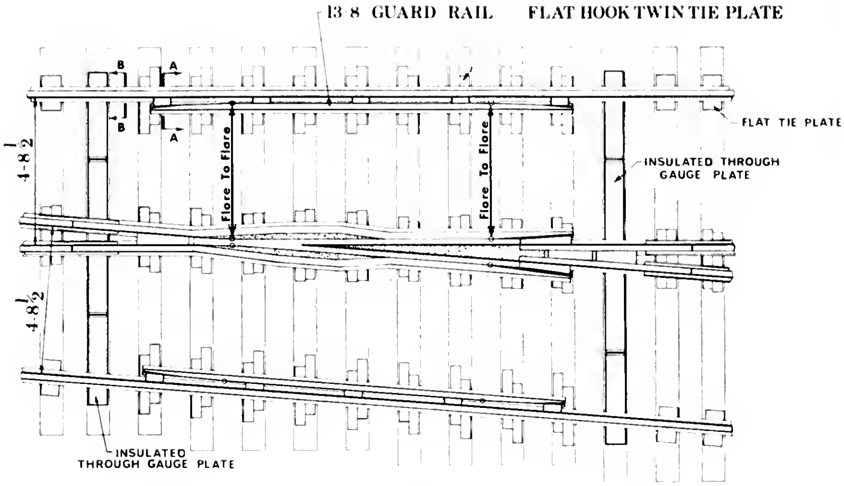
6. As the major weakness of a manganese steel insert is the softer metal beneath the work-hardened surface, a good depth of hardening is considered the prime factor.

Conclusive results have shown that light wheel loads tend to produce the surface hardening while heavy loads cause deeper hardening and more extensive flow.

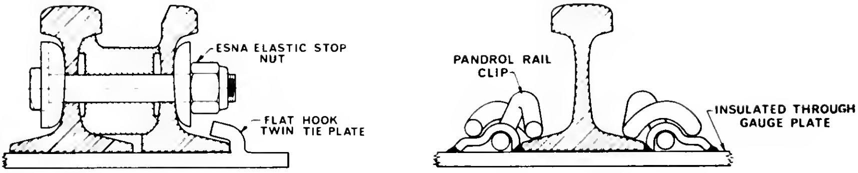
The complete explosive depth-hardening process has been instituted in conjunction with our frog shop manufacturing and all manganese steel castings used in CP Rail system are explosive depth-hardened.

A complete study has been conducted on the wheel action through frogs and guard rails also the effects of truck skewing. Numerous field conditions of fractured bolts in bolted guard rails, hooks or kinks in main line stock rails, lateral movement of frogs, excessive wear in the frog throat and many more problems have all been experienced. A number of methods have been devised and a summary of recommendations is as follows:

Rigid Frog—For a facing-point movement, a guard rail should be so located that the guard rail flare is directly adjacent to the frog throat so that both throat flare and guard rail flare exert almost simultaneous wheel flange pickup. Conversely, during the trailing point movement guard rail flare and frog wing rail flare should be directly opposite. The combination of wide gauge or tight guard rail flangeway in conjunction with incorrect lateral guard rail settings are generally responsible for lateral motion in both the frog and stock rails, also excessive wear on the frog point, throat and guard rail. Special through insulated gauge plates are recommended to reduce or eliminate these conditions.



Nº 13-132LB RE INSTALLATION



SECTION A-A

SECTION B-B

TYPICAL INSTALLATION

GUARD RAILS AND GAUGE PLATES

Fig. 9

Fig. 9 shows the recommended guard rail location relative to the frog previously described; also shows the installation of the through insulated gauge plates in the toe and heel areas of the frog. Note in section view the use of the Pandrol Clip which is an ideal fastener for rail and plate in special applications. At present all guard rail lengths are designed to suit the specific frog parameters described above.

In Fig. 10—Guard rail flare at toe of frog, and Fig. 11—Guard rail flare at heel of frog, note wheel flange pick-up. In-track installations with through insulated gauge plates have substantiated this approach. After approximately one year of service both main and turnout tracks have been maintained within 1/16-in. of gauge and related wear conditions have been greatly reduced.

CP Rail switch design parallels AREA design recommendations in many aspects. Straight and curved switches with uniform risers in 39-ft and 13-ft curved; 22-ft, 16-ft 6-in. and 11-ft straight, are used with switch point planing to AREA design detail 4,000 and 5,100. All power switches are equipped with vertical switch rods, offset fixed heel blocks to AREA design 2125 and adjustable rail braces.

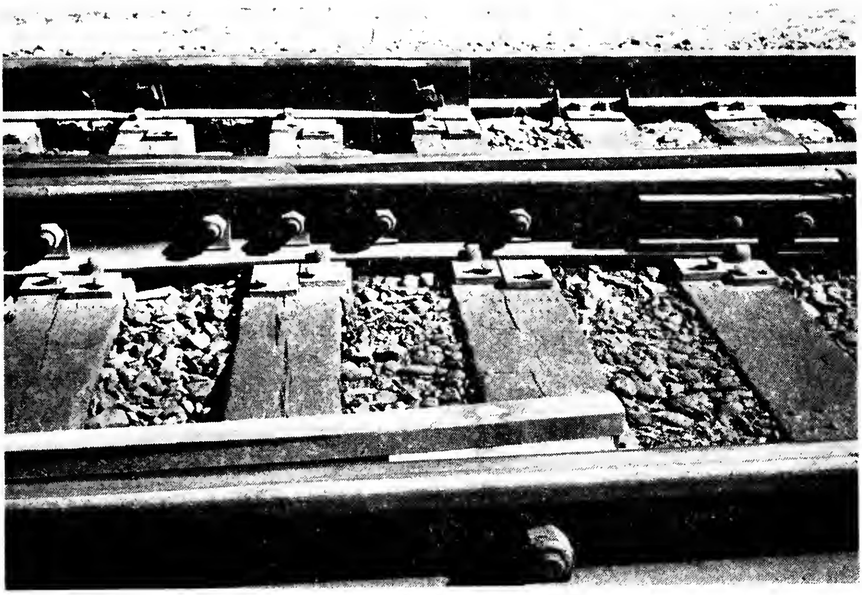


Fig. 10—Photo of toe end of guard rail.

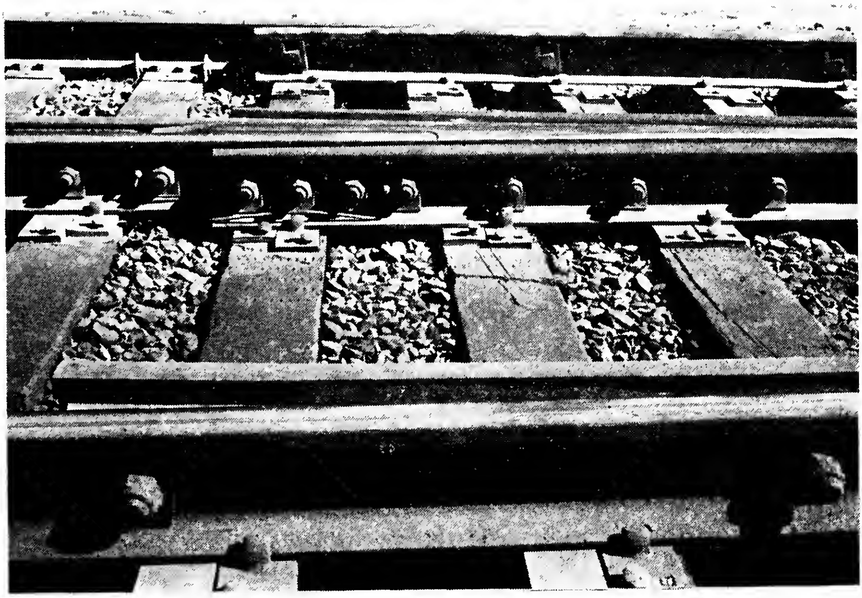


Fig. 11—Photo of heel end of guard rail.

Areas of variation are as follows: all switch point top cut planing is contoured to the original rail head shape rather than the conventional flat cut with a ⅝-in. radius. This design has reduced the gauge line rail flow and required maintenance grinding. All reinforcing straps and rail stops are bolted to the switch points with hexagonal head cap screws and elastic stop nuts. This provides for adjustment when fretting of mating parts has stabilized. During reclamation the removal of straps, bolts, etc., which represent approximately 40% of the cost of a new switch point, is greatly facilitated.

Field investigation of chipped or scalloped switch points has indicated that in the straight through position the stock rail bending has not been sufficient and the normally protected point has been exposed to wheel contact. All stock rails are now shop bent where the vertex location and bend is more precise and switch point tip is protected. In addition, the complete assembly consisting of the bent stock rail, switch point and heel block assembly is considered the ideal method of shop manufacture and this greatly facilitates field installation. This practice is presently being carried out on CP Rail.

Field investigation of gauge throughout the switch area has generally indicated that the point of switch is held to gauge with the insulated gauge plates, but wide variations in gauge have been experienced from the third rod through the heel turnout area. To rectify this gauge problem, which is detrimental to switch point alignment and adjustment, resulting in increased wear and maintenance, all mainline power switches are being equipped with insulated gauge plates at the third rod and heel locations. These plates also assist during the installation of new switches.

Special flat seat double shoulder tie plates are used throughout the turnout in order to eliminate the gauge alignment transitions at the heel of switch and toe and heel of frog. Specially developed track bolts with extruded shank, cold-rolled threads, are used with elastic stop nuts in standard rail joints within the turnout area. Chrome rails are used throughout the turnout area and this has resulted in reduced rail end batter and flow at new rail cuts; also reduced flow over standard carbon rails when used in the vertical position.

The cumulative effect of many aspects of design have produced a main line turnout that has provided a significant improvement in service life with reduced maintenance and corresponding costs.

Conclusion

I have attempted to illustrate some of the more interesting innovations in special trackwork design and development which are presently ongoing in CP Rail. We are currently involved in the evaluation and development of special switch designs, new designs of railbound manganese spring frogs and investigation into the design and use of swing-nose frogs. These are a few of the challenging problems which railroads must cope with in the ever-increasing demands for low-cost and reliable transportation service

C&NW's "BUC" (Ballast Undercutter-Cleaner)

77–658–11

By R. W. BAILEY

Director of Maintenance Planning
Chicago & North Western Transportation Company

The Chicago & North Western Transportation Company began using a quartzite ballast 20 years ago on our 3900 track miles of primary main line. This ballast is classified in between No. 4 and No. 5 in the AREA Ballast Specifications in sizes from 1¾-in. to ½-in. During this period ballast rehabilitation consisted of plowing out the fouled slag, limestone or gravel ballast to build up the shoulder and then to surface with 30 to 40 cars of new ballast per mile. After an initial life of 5 to 10 years with spot surfacing only, the track was maintained by dumping 10 to 12 cars of ballast per mile and raising approximately 1-in. to give a new surface. This process had a short life, often only a year or two in muddy areas, and had to be repeated to maintain an acceptable operating speed.

We reasoned that the original material, a hard quartzite, was still under the tie and could be salvaged if the contamination could be removed. We therefore began a study on what we felt was taking place and the following movie illustrates our findings.

(Movie was shown.)

The process just illustrated had to be justified financially to our management for them to provide funds for its purchase and operation.

To cite some general considerations, we calculated that raising the track 3-in. and undercutting 12-in. would result in the cleaning of 55 cars of compacted material per mile. If our recovery of this material was to be 70%, we would salvage 38 cars per mile. Based on today's ballast cost from our own pit of $140 per car, the undercutting-cleaning would save an "out of pocket" ballast cost of $5300 per mile. However, it must be recognized that the ballast in place has a value two times the pit cost when the transportation charges and equipment costs are included. On our railroad if the average ballast mileage is 250 miles, the value of ballast per mile in place is 1.7 times the pit cost or $9100.

To salvage this material we must have machine and labor costs. Annual charges for depreciation of the equipment, interest on investment, maintenance at 16% of investment, fuel, lubricants, salaries and additions for four men, their expenses, insurance and miscellaneous contingencies, indicated that to salvage $5300 of ballast would cost 55 to 60% of the material cost. The net savings would be approximately $6000 in ballast per mile.

In 1975 our program work was sharply reduced to conform with economic conditions and it was decided to lease "BUC" to other railroads.

In the 4th quarter, the economic picture changed and on November 4th we began operating the equipment in a problem area in Iowa for 13 days before we froze up. We averaged 5 hours undercutting daily, due to train operations, and 584 track feet per hour.

These limited operating statistics neither confirm nor deny our assumptions on savings but do indicate the machine's productive capabilities to clean ballast at a rapid rate.

INSTALLATION OF OFFICERS

Installation of Officers

President Ward: I would like to install the newly elected officers of the Association at this time. This is a short but important and impressive ceremony and will let each of you become more acquainted with the officers you have elected. So, with your permission, I will proceed with the installation ceremony.

To make room for new officers and directors a certain number of them complete their service on the Board of Direction each year. It is with mixed feelings that we see these changes take place.

I want to thank each member of the Board for his counsel, advice and support, and especially those members who, having completed their term of office, are retiring from the governing body of the Association. The close of this technical conference completes the services on the Board of Past President D. V. Sartore, chief engineer—design, Burlington Northern. The AREA Constitution provides that past presidents will remain on the Board for two years after completion of their term as president. We are deeply indebted to Mr. Sartore for his long and outstanding service to our Association—both in an official and an unofficial capacity—and, although he will be off the Board, I am sure he still will be called upon for counsel and advice as important matters come up.

Don, will you please stand so we may give you the applause you so richly deserve.

(Applause)

President Ward (continuing): Other members of the AREA Board of Direction completing their term of service are these directors: R. W. Pember, chief engineer, design and construction, Louisville and Nashville Railroad; E. Q. Johnson, senior assistant chief engineer, Chessie System; W. E. Fuhr, assistant chief engineer—staff, Chicago, Milwaukee, St. Paul and Pacific Railroad; and B. E. Pearson, chief engineer, Soo Line Railroad.

These men have served our Association well in their official capacity on the Board and I want to express our deep appreciation to each of them.

Will Messrs. Pember, Johnson, Fuhr, and Pearson please stand and permit us to show our appreciation for their service.

(Applause)

President Ward (continuing): It is now my privilege and pleasure to install the new directors you have elected for the ensuing year. As I read your name, please come to the speaker's table through the walkway adjacent to the podium, and take a place at my right.

J. W. Brent, chief engineer, Chessie System—from the East District.

L. F. Currier, engineer-structures, Louisville & Nashville Railroad—from the South District.

T. L. Fuller, engineer of bridges, Southern Pacific Transportation Company—from the West District.

J. A. Barnes, assistant vice president and chief engineer, Chicago & North Western Transportation Company—from the West District.

Gentlemen, I welcome you as directors of the American Railway Engineering Association. These are offices of high honor and responsibility you are assuming. I hope you will enjoy your service on the Board of Direction and will bring much value to its deliberations. Congratulations. You may be seated.

Our newly elected junior vice president is W. S. Autrey, chief engineer system, Atchison, Topeka & Santa Fe Railway.

Mr. Autrey, will you please come to the platform.

Mr. Autrey, I congratulate you upon your election as junior vice president and return to our Board of Direction.

The new senior vice president is B. J. Worley, vice president and chief engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad.

Mr. Worley, will you please come to the platform.

Mr. Worley, I congratulate you on your advancement to senior vice president and continued service on the governing body of our Association. I know that you will discharge this greater responsibility with distinction.

You and Mr. Autrey will make a splendid team of vice presidents. Please be seated.

Our new president is John Fox, chief engineer, Canadian Pacific Rail.

Mr. Fox, I congratulate you upon your election to the highest position of honor in the American Railway Engineering Association. I share the confidence which has been placed in you by our membership and it is with pleasure and satisfaction that I turn over the responsibility of AREA President to you at the end of this meeting.

President Ward: We have now completed the scheduled program for the 75th Annual Technical Conference of the American Railway Engineering Association and the 1976 Annual Meeting of the Engineering Division, Association of American Railroads.

You will be interested to know that the registration for our 1976 meetings is: railroad men 470; non-railroad men 510; total registration 980.

It is now time to turn over the Association to our new president and to adjourn these meetings. Before doing so, however, I want to take this opportunity to thank all who contributed to the work of our Association during the past year and to the success of this Conference. The AREA has had a successful and productive year in spite of difficult conditions. This has happened because so many of you gave so generously of your time and effort, which I assure you, has been greatly appreciated.

There are so many to whom I am personally indebted that I cannot possibly name them all here, but I do want to express my personal appreciation for the splendid cooperation of our officers and directors, our committee chairmen and the active committee members, and all others who contributed in any way to the success of the 1975–1976 Association year. I especially want to express my sincere appreciation, and the appreciation of the Association, to our headquarters staff for the manner in which they have conducted the affairs of the AREA during the past year. Their attention to the multitude of details in the planning and execution of the many Association activities and programs, and their efforts in connection with the important, world-wide-used AREA publications, many times under most difficult circumstances, has been invaluable to the Association, the Board of Direction, and to me. They deserve the maximum extent of our support, patience and understanding.

The Conference Operating Committee, under the direction of its manager, Bruce Miller, Penn Central, did its usual outstanding job in connection with operating this conference in accordance with the plans and arrangements made by the Association's staff. These well-planned and well-operated conferences do not just happen.

Other than our past presidents, few members are in a position to know the multitude of details handled by this committee during our conferences and how easily things could go awry if it were not for their diligence.

I join Mrs. Ward in thanking all of those ladies who, with Mrs. Fox, Mrs. Worley and Mrs. Hodgkins, gave so generously of their time in assisting with the functions of our conference planned expressly for our wives. You have our grateful appreciation.

Is there any further business to come before this meeting?

(At this point, Past President T. B. Hutcheson asked for the privilege of the floor and presented President Ward with the AREA plaque.)

President Ward (continuing): It now gives me great pleasure to formally install our new president, and I request him to join me at this podium.

Mr. Fox, I congratulate you upon your election to the highest position of honor in the American Railway Engineering Association, and I now proclaim you President. In taking this action, I also proclaim Mrs. Fox as the unofficial "First Lady" of the Association.

I share the confidence which has been placed in you by our membership and it is with pleasure and satisfaction that I turn over the responsibility of President to you.

In doing this, I want to present you with this gold pin, which bears the words engraved on the back:

JOHN FOX
PRESIDENT
1976–1977

This is the official emblem of the AREA and I am sure you will wear it with equal pleasure to yourself and honor to the Association.

(President Fox responded and then continued as follows):

President Fox: Before I adjourn this conference, I would like to remind all members of the Board of Direction, including the former members and new members, and all the members of the Conference Operating Committee, that we will have a joint luncheon together in the Wabash Parlor on the third floor of this hotel immediately following the adjournment of this meeting.

The luncheon will be followed by the post-conference meeting of the AREA Board of Direction in Private Dining Room 9.

Before closing this Technical Conference of AREA, is there any further business to come before the meeting?

(At this point A. F. Joplin, vice president, operation and maintenance, Canadian Pacific Rail, asked for the privilege of the floor and spoke as follows):

A. F. Joplin: It is my pleasure to express to John Fox on behalf of his colleagues in Canadian Pacific our great pride and admiration in the high honor he has attained. I am sure that this feeling is shared by all Canadians. Many Canadians from CP Rail serve in this Association, and we feel that his elevation to this office reflects the great hand of friendship and cooperation that exists between our two countries.

Mr. Fox, as you may know, has worked his way through each level of our railway and on February 1 of this year was appointed chief engineer of Canadian Pacific. Similarly he has *worked*—you notice my emphasis on work, because that is what it takes—he has worked his way through the various committees and service offices of this Association, and is signally honored this day.

Mr. President, on behalf of your associates in Canadian Pacific may I present to you this gavel to wield during your term of office in this Association. It is made from a tie from our, your, railway from the Newport subdivision at M4.1 Quebec Central Railway installed in 1956. This tie has served us well in its first life—may it serve you well in your term of office—and later serve as a happy memento of this occasion and an expression of our confidence in your ability to discharge the duties of this high office so as to reflect greatly to the credit of yourself and this Association.

PRESIDENT FOX: Thank you very much Mr. Joplin. It is my pleasure to accept this gavel in the friendly spirit in which it has been presented. I appreciate this gift, coming as it does from my friends and associates in CP Rail Engineering Department. This gavel will greatly assist me in carrying out my duties as presiding officer at meetings of this Association during the next year.

I should like to thank Mr. Ward for his kind remarks and would like to take this opportunity to say to John, congratulations on a job well done during his tenure as President.

Members of the American Railway Engineering Association, it is indeed an honor to be chosen by you to be president of this fine and progressive Association. I greatly appreciate the confidence that you have shown in me and consider that the election of a Canadian railway engineer to head this Association during this, your Bi-Centennial year, to be a signal honor for Canadians. With the help of all the officers, directors, committees, members and staff which has always been fully given, I know that the coming year will be a successful one for the Association and myself.

I should now like to introduce to you my devoted life partner who will be the Association's First Lady for the next year—my wife Janet; with Janet is my eldest son, John.

If there is no further business, the 75th Annual Technical Conference of the American Railway Engineering Association will adjourn sine die.

AAR ENGINEERING DIVISION SESSION

Remarks by Division Chairman John T. Ward*

This morning, most of you were present when I welcomed you to the opening session of the AREA Technical Conference. Now it gives me great pleasure to welcome you to the 1976 Annual Meeting of the Association of American Railroads, Engineering Division of its Operations and Maintenance Department.

What is the relationship between the AAR Engineering Division and the AREA? The governing body of AREA consists of a Board of Direction totaling 17 elected by the membership. The governing body of the Engineering Division is a General Committee appointed by the vice president of the Operations and Maintenance Department, and consists of the same 17 members forming the AREA Board of Direction, plus an additional group, making the total on the ED General Committee a maximum of 21. In the latter instance, there is only one member from any family of lines, making it necessary on occasions to substitute for one or more of the Board of Direction, thereby distributing the membership among as many member lines as possible.

The AREA is a private organization, and while it has considerable technical expertise among its membership, permitting the furthering of its objectives in the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways, there is no opportunity for any action which would be binding upon a particular carrier. On the other hand, the AAR Engineering Division, through its General Committee, as described previously, may do so with proper approvals.

A few remarks are now in order to acquaint you with the work of the Engineering Division for the year just closing. The Division has been an aid to the rail industry and will continue to be so in the future as engineering problems arise requiring consideration or recommendations for possible solutions.

The ED General Committee met four times during the year to discuss and progress various matters relating to the work of the committee. The first such meeting was held following the 1975 annual meeting of the Engineering Division held at the Palmer House in Chicago last March.

During the year, a liaison committee was appointed from the membership of the ED General Committee to provide direction and close relations with the Federal Railroad Administration on problems and other matters of mutual interest. This committee has reviewed many suggested changes in the FRA Track Safety Standards and is, at the moment, handling for possible revisions.

This same liaison committee formed the nucleus of a new task force charged with the responsibility of developing the costs to the rail industry of government regulations associated with fixed property engineering and maintenance of way. Hopefully, this will result in the industry recovering all, or certainly a part, of such costs. This is particularly in regard to costs associated with inspections, etc., related to the FRA Track Safety Standards, with which we are all familiar.

Still another task force of the Engineering Division reviewed in detail the Occupational Safety and Health Standards, following which recommendations were made to the AAR on certain changes that might be considered should the standards be adopted by the FRA.

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* Senior Assistant Chief Engineer, Seaboard Coast Line Railroad.

The General Committee reviewed the FRA's plans to install a test loop track at Pueblo, Colo., and made recommendations to the AAR Research and Test Department relative to general layout, specific track geometry and certain support facilities.

In response to a request from the Federal Highway Administration to the AAR for a recommendation for appropriate clearances for highway grade separation structures over railroads either electrified or expected to be electrified, the Engineering Division's Committee on Electrical Facilities (Fixed Properties) submitted a report and drawing recommending clearances. The ED General Committee approved the report and drawing, with some modifications, with same subsequently having been approved by the ED voting representatives of the AAR member roads.

The above is just a brief outline of what has taken place this year in the Engineering Division, and I sincerely trust it has aided in clearing any question in your minds of what may have been accomplished.

A Time for Challenge

By D. C. HASTINGS

Executive Vice President, Seaboard Coast Line Railroad;
Chairman, AAR Operating–Transportation Division

Almost 200 years ago when the United States of America had its beginning as a new government, a new concept of government—a government which had as its foundation the highest Christian principles—one of its founders or authors, Benjamin Franklin, said, "He who would incorporate in public affairs the principles of Christianity would revolutionize the world." That's exactly what they did! Basically they provided for the freedom of man. They provided for the preservation of the dignity and the worth of every single individual. And predicated on this they brought hope to the world. And this system of government still brings hope to the world.

This hope though is based on the concept that man can be free and live free. And that concept has been the basis of what we call today our free enterprise system. With such a system our nation has grown into one that has been the envy of the world. But our nation and its system is under attack. It is under attack both directly and indirectly, even by those who don't realize they are attacking it. Our free enterprise system is facing its greatest test in its entire history, and when people say this is a young, new country, don't be fooled by that statement. Our country as now constituted is one of the oldest forms of government now in existence.

There are practically no countries in the world today that have the same form of government they had 200 years ago—but we still have ours—and when people seek to attack the free enterprise system I think we ought to remember three characteristics of our American way of life.

One of them is our great resources. I refer to, in addition to our natural resources—our people. The people of America are the greatest. They rise to the occasion. They have always risen to the occasion. They, as a people, sometimes do some stupid things, but when the real crisis comes you can count on the people of America to come up with the solutions.

The second is our capacity to do anything that is required when the time comes. America has great capacity. With only 6% of the world's population, we produce over 37% of the world's goods.

The third is that the America we know has heart. We feed more people, take care of more hungry people and more disabled people than any other country in the world. We have compassion and have demonstrated it over the years. What other country in the history of the world has ever been brutally attacked by another and after a bloody war has beaten it and then turned right around and spent hundreds of millions of dollars in its rehabilitation?

This is the American way and regardless of what people in the world might say about it—accusing us of decadence, with inability to meet the test of the times and anything else you can think of—most of them would give their right arm to live here.

Yes, we are under attack and there is no question about it. One of the most vicious attacks on our free enterprise system is posed by the situation confronting the railroads today. In order to look at that problem properly and in the right perspective, we need to look at transportation in general.

Transportation, as we all know, is a vital part of our free enterprise system. You remember in your courses in economics in college you were taught that if you had a raw material, plenty of capital and adequate labor you could start up a commercial or industrial enterprise. One big factor, however, was left out and that is transportation.

No raw material is worth anything until it has transportation applied to it to get it where it is needed—and no refined or manufactured product has any appreciable value until it is transported to the point of consumption. So transportation is the fourth ingredient—raw material, capital, labor and transportation—and when any one of these four things loses its characteristic of freedom it becomes nationalized—then the whole ball begins to unravel.

Now when we consider the transportation system in America today the railroads become the major factor. They are, first of all, the only true or real common carrier. They take—in fact they have to take—anything everywhere. They are the principal carrier in our transportation system and as such they are a vital part of our free enterprise system.

If the railroads are unable to continue as a free enterprise the whole transportation business falls apart and it is high time that everyone in America understands this. Every report to the Congress, of which the have been six, beginning in 1934 and ending with the Smathers' Report in 1959, has concluded with the fact that if the railroads are nationalized the whole agricultural, industrial and commercial life of America would be at the mercy of the Government. And if that happens, down the drain would go the whole free enterprise system. So we should accept the fact that unless the railroads can make it, our very way of life is in jeopardy.

Now as we all know, our nation's railroads are in trouble. The year 1975 was one of the worst in the history of the nation when the industry is looked at on a national basis. Earnings were down, maintenance was deferred, capital was getting harder to acquire and in general the situation was not good. The recently passed Railroad Revitalization and Regulatory Reform Act of 1976 may be of some benefit—but it is *not* the answer to the maiden's dream!

While things may look bad, there are three things about the railroad industry that we should always remember:

First of all they have to have us! America cannot survive without the railroad industry. We are essential to the American way of life.

Secondly, if the energy crisis is ever to be solved, the answer lies in the transportation of materials by rail, since we are not only the most efficient mode of transportation in energy consumption, but also we are the only mode that can move coal in the quantities and to all the places that will be required. Barges and pipelines may be talked about but they can never do the total job.

Thirdly, if the railroads were nationalized the problems would still exist. None of our present problems would be solved. Therefore, what we need is to solve the problems and if we do—we then have a viable segment of the free enterprise system.

Our problems are many and are as well known to each of you as they are to me. The RR & RR Act of 1976 is only a "Birdie Hop" in the game of "'May I' be an equally treated industry." I will not attempt to enumerate all the things that confront us except to say that added to all the regulations and restrictions that began with the Interstate Commerce Act in 1886, we have the new regulations that have come along in the late 60's and early 70's: (1) Mechanical Safety Standards, (2) Track Safety Standards, (3) Hours of Service Act Revisions, (4) Pollution control regulations (noise included), (5) E.E.O.C. requirements, (6) Invasion of OSHA into the railroad world, (7) The myriad of FRA regulations running from how we switch, etc., to how we word and even apply our transportation operating rules, and (8) the dozens of recommendations that emanate from the National Transportation Safety Board—which agency seems to think that every railroad accident could have been avoided if management had just done something that to those of us who have been in this racket a few years know borders on being absurd.

While we need freedom from many of these shackles, we must also take a look at ourselves too and see what we can do from within to improve our position. We may think that the diesel locomotive, the mechanization of track maintenance, CTC, the computer, etc., have exhausted our efforts to be more efficient; however, the fact remains that we *must* find ways of being more efficient, and I know of no better group to do something in this area than you! We all have management objectives and they vary from railroad to railroad, but I think that today's managements have one common objective and that is *SURVIVAL!* I don't mean to sound discouraged—for I am not! I mean that we all should be challenged to preserve our great industry as a free enterprise, because in so doing we will preserve the free enterprise system in America, we will preserve our way of life—and I know that you, along with all other railroaders, are equal to this task.

Reflect for a moment on our history—the problems that faced our forefathers and how they came out when times were so tough as to seem unsolvable.

Remember in 1776 when the entire military might of America was gathered at Valley Forge—they were ill-housed, ill-clothed, ill-fed—but they were never discouraged. They were challenged by their great leader and they had the spirit to win! They did.

In 1812 this little nation of ours with such great ideals was attacked by the greatest power in the world and our Capitol was burned to the ground. But we came out of that because we were challenged by our leader and we won.

In 1865 we were faced with rebuilding a country torn apart by the worst Civil War any nation had ever endured and we came out of that crisis.

In 1917, after desperately trying to stay out of a war, we found ourselves again plunged into a conflict that we were ill-prepared to fight, but we rose to the occasion and we won.

In the 1930's we found a situation only a little worse than the depression of 1975 and we came out of that.

In 1941 we again engaged in a World Conflict that we were hardly prepared to fight, but we rose to the occasion and we won that one!

I think we will come out of this too—because we are challenged to preserve that which we love—our country, our way of life, and our industry—and it is the very least we can do to improve it and pass it on as a viable free enterprise to those who come after us. I close with a poem that expresses this quite well:

An old man, traveling a lone highway,
Came at the evening cold and gray,
To a chasm vast and deep and wide,
Through which was flung a sullen tide.

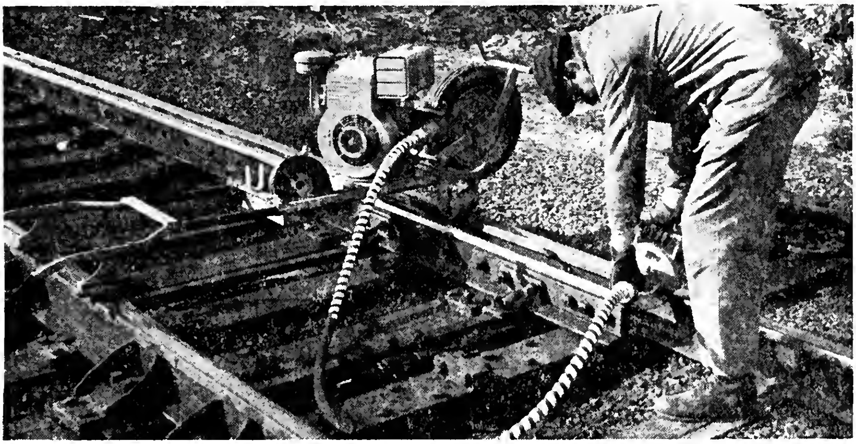
The old man crossed in the twilight dim,
The sullen stream held no fears for him.
But he turned when safe on the other side,
And built a bridge to span the tide.

"Old man," cried a fellow pilgrim near;
"You're wasting your time in building here;
Your journey will end the closing day.
You never again will pass this way.

"You've crossed the chasm deep and wide.
Why build you this bridge at eventide?"
The builder lifted his old gray head:
"Good friend, on the path I've come," he said,
"There followeth after me this day
A youth whose feet must pass this way.

"This stream, which has been as naught to me,
To that fair-haired youth may a pitfall be;
He, too, must cross in the twilight dim—
Good friend, I'm building this bridge for him."

RTW PORTABLE RAIL GRINDERS...



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- P-16 D.S.P., a heavy duty unit designed for removing overflow metal from all types stock rails and switch points.
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- Hydraulic-16
- Multi-Purpose 8
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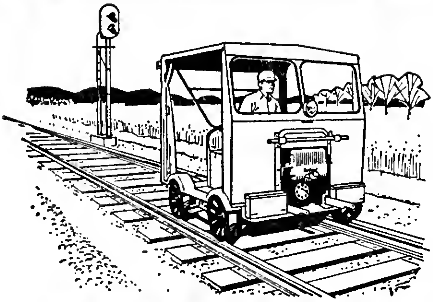

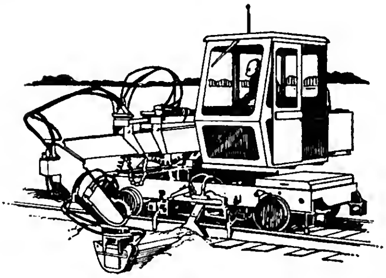

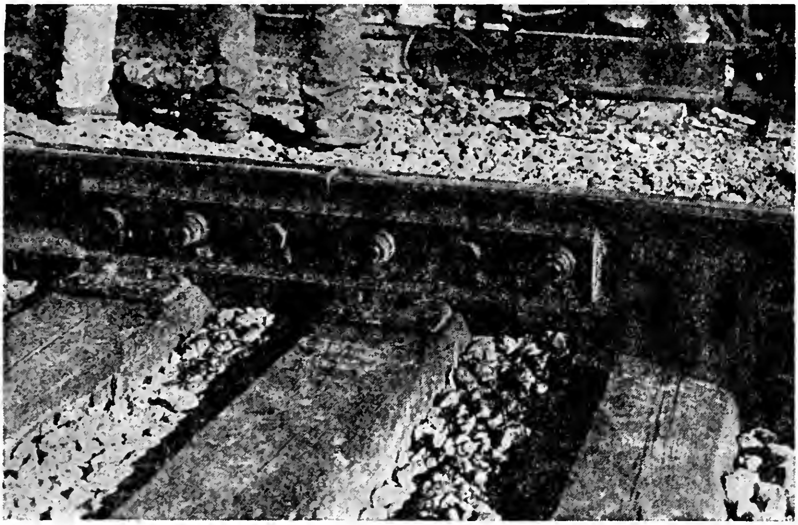

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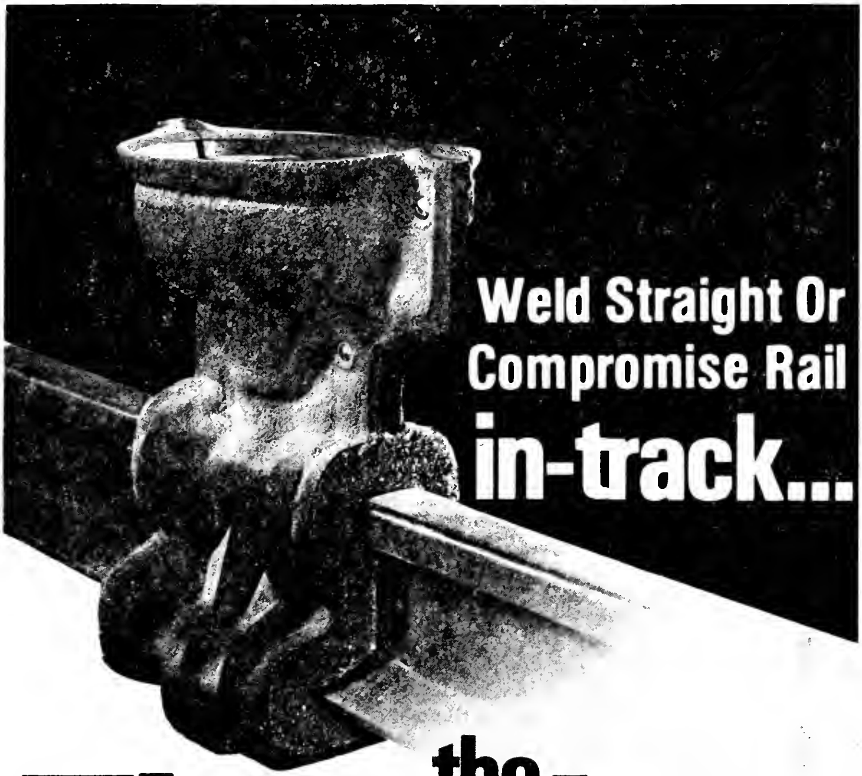
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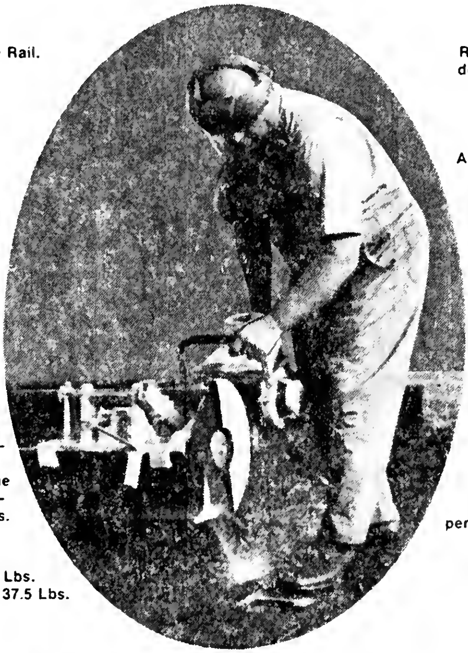

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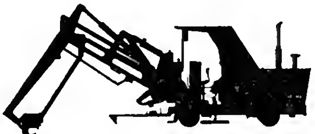

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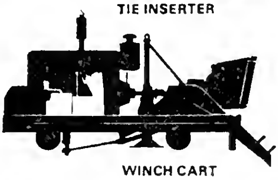

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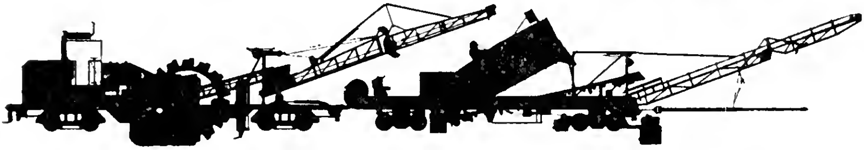

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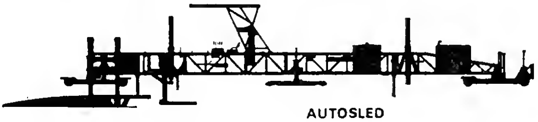

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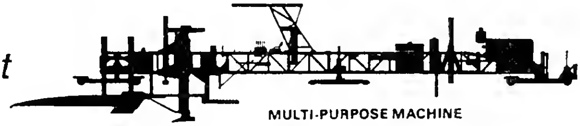

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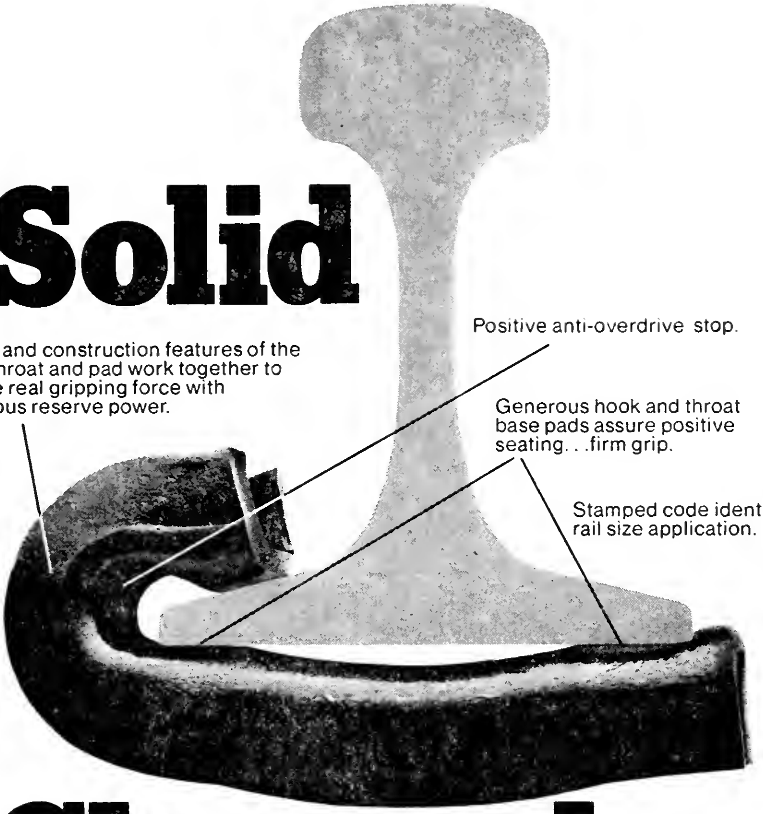

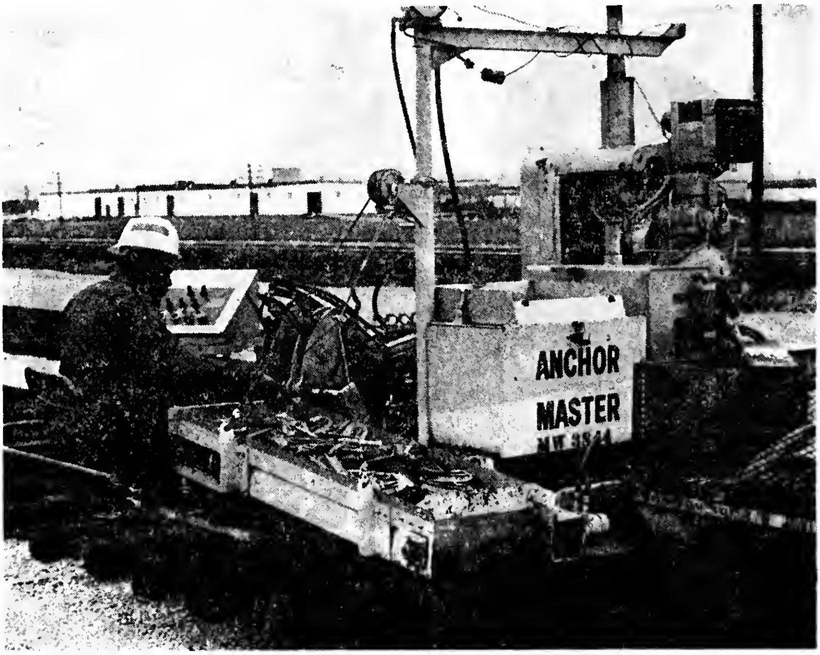
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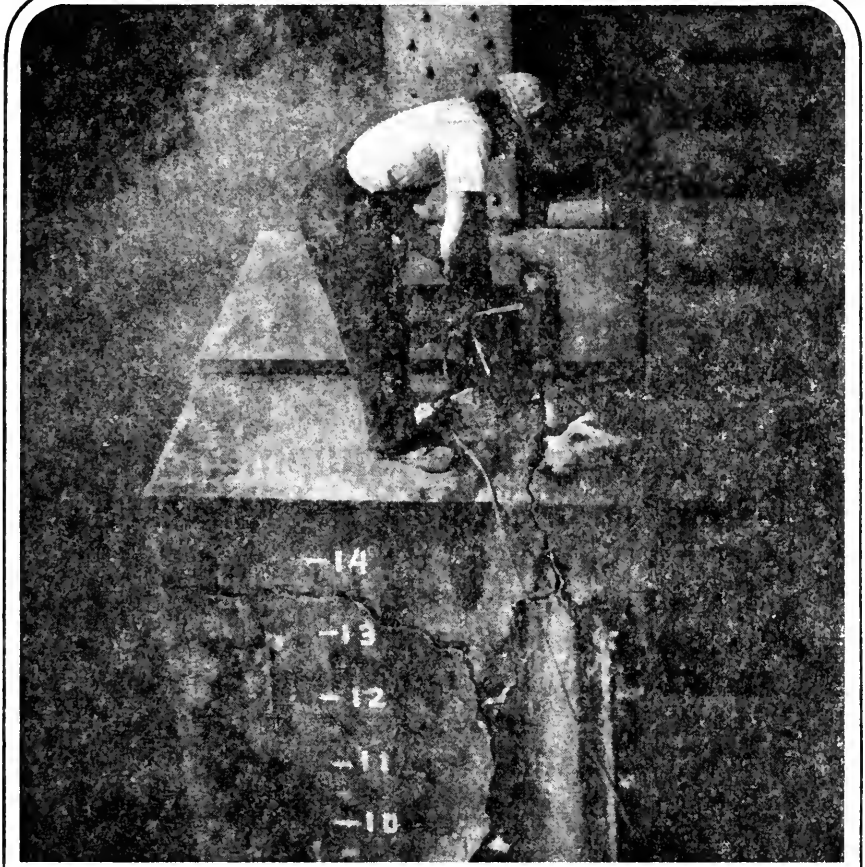
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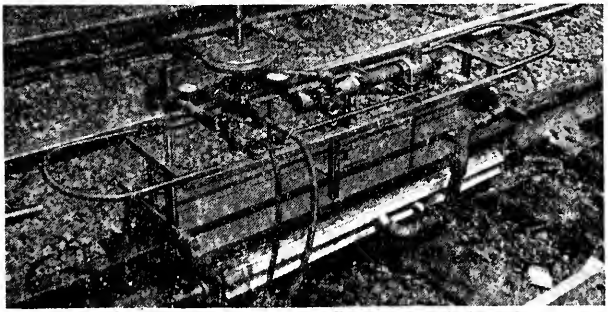

REPORT OF EXECUTIVE DIRECTOR

Report of the Executive Director

March 24, 1976

To the Members:

The 1975 Association year was a success from most aspects. Membership remains high, with a loss of only five members during the year, a good showing in view of the economic difficulties experienced by the railroads. Financially, the AREA had an adequate year. While our financial statement for the year shows a deficit of $9814, this was due to the necessity of replacing our stock of Manual binders and will be recaptured over a two- to three-year period from the sale of Manuals. Otherwise, actual receipts closely matched actual expenditures. To maintain receipts at the highest possible level, the Board of Direction and staff of the Association solicit the active cooperation and support of AREA members by interesting others in becoming members, by paying their annual dues early in the year, and by bringing the AREA Bulletin to the attention of supply companies, contractors and consulting engineers as a prime advertising medium.

Major Meetings During 1975 Association Year

The 11th Regional Meeting of the Association was held at the Hotel Vancouver, Vancouver, B. C., Canada, on October 30, 1975. It was attended by 221 AREA members and guests. The meeting was organized and directed by John Fox, then assistant chief engineer, now chief engineer, Canadian Pacific Rail, and chairman of the AREA Board Committee on Regional Meetings. It was presided over by AREA President John T. Ward, senior assistant chief engineer, Seaboard Coast Line Railroad.

The 75th Technical Conference of the AREA and the 1975 Annual Meeting of the Engineering Division, Association of American Railroads, was held at the Palmer House, Chicago, on March 22–24, 1976. Total registration was 980, comprised of 470 railroad men and 510 non-railroad men, and, in addition, 156 ladies. The program of the Conference consisted entirely of features—some general, others sponsored by our technical committees. No committee reports were given since all of them had been published in the various issues of the Bulletin prior to the Conference. The Engineering Division Session was held on Monday afternoon, March 24, and consisted of reports on the activities of the Division during 1975 and a number of timely and informative addresses and illustrated presentations.

The 1976 meetings were presided over by John T. Ward, senior assistant chief engineer, Seaboard Coast Line Railroad, president of the AREA and chairman of the AAR Engineering Division. The address at the Annual Luncheon was given by W. T. Rice, chairman of the Board, Seaboard Coast Line Railroad.

MEMBERSHIP

As mentioned above, the membership statistics show a loss of five members during the year, a warning to AREA members not to relax their efforts to interest their friends and associates both inside and outside the railroad industry, and allied to it, in AREA membership. Approximately 250 new members are needed each year simply to overcome normal attrition. A wide range of people are qualified for AREA membership, and would benefit by it, as would the Association. These qualifications are given in Article II, Sections A, B, E and F, of the AREA Constitution (see pages 699 to 701 in this Bulletin.) Your help is earnestly solicited in this vital area of Association efforts.

MEMBERSHIP

	Membership Years			
	1974		*1975*	*(Corrected)*
Membership as of January 1		3391		3328
New Members during year	210		175	
Reinstatements during year	12		5	
Gain or Loss in Junior Members	+ 24		— 14	
		246		166
Deceased during year	30		43	
Resigned during year	48		32	
Dropped during year	90		96	
		168		171
Net Gain or Loss	+ 78		— 5	
		3469		3323

MEMBERSHIP CLASSIFICATION BY YEARS

The year 1968 begins on February 1 and ends on December 31. Each succeeding year begins on January 1 and ends on December 31.

	1968	*1969*	*1970*	*1971*	*1972*	*1973*	*1974*	*1975*
Life	433	437	443	451	560	562	472	474
Member ...	2659	2577	2579	2502	2549	2492	2500	2509
Associate ...	258	264	257	244	247	232	238	241
Junior	56	55	62	67	96	105	111	93
Honorary ..							6	6
Totals	3406	3333	3341	3264	3352	3391*	3328**	3328

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* Adjusted from 3310 to match carryover numbers with existing records.

** Corrected from 3469 by actual count of membership cards on 12–31–74.

Deaths During 1975 Association Year

From May 1, 1975 to March 24, 1976, notice was received at Association Headquarters of the deaths of 36 members, 4 more than the previous year and 6 fewer than 2 years ago.

One of the deceased was a past president (1966–1967) of the Association—J. M. Trissal (M '33, L '70), retired vice president—real estate, Illinois Central Railroad. He was also a member of Committee 9—Highways, 1942 to 1969, serving as chairman, 1959–1961; and a member of former Committee 18—Electricity, for some 10 years. Another was a past director (1941–1943)—C. E. Smith (M '09, L '45), retired vice president, New York, New Haven & Hartford Railroad. Mr. Smith was a member of Committee 15—Steel Structures, 1911–1921; Committee 14—Yards and Terminals, 1922–1926; and Committee 21—Economics of Railway Location, 1930–1938.

COMMITTEES OF 1975 BOARD OF DIRECTION

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John Fox
B. J. Worley
D. V. Sartore
R. F. Bush

Membership

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B. E. Pearson
P. L. Montgomery
Mike Rougas
R. L. Gray

Finance

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B. H. Worley
E. Q. Johnson
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R. M. Brown, *Chairman*
D. V. Sartore
E. Q. Johnson
Mike Rougas
R. L. Gray
G. H. Maxwell

Technical Activity

Mike Rougas, *Chairman*
R. W. Pember
W. E. Fuhr
J. W. DeValle
E. H. Waring

Publications

John Fox, *Chairman*
D. V. Sartore
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E. C. Honath
J. W. DeValle

Regional Meetings

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William Glavin
G. H. Maxwell

Conference Programs

R. L. Gray, *Chairman*
B. J. Worley
B. E. Pearson
P. L. Montgomery
William Glavin

Advertising (Special)

E. C. Honath, *Chairman*
R. F. Bush
W. E. Fuhr
E. H. Waring
G. H. Maxwell

A number of other deceased members are worthy of note, either for the prominent positions they had attained or for the many years they had devoted to committee service. They are: **N. V. Back** (M '51), retired chief engineer, Toronto, Hamilton & Buffalo Railway; **Edgar Bennett** (M '20, L '55), retired assistant chief engineer, Southern Railway, member of Committee 27—Maintenance of Way Work Equipment, 1940–1956, serving as chairman 1946–1948; **O. C. Benson** (M '28, L '66), retired director of budgets, Boston & Maine Corporation, member of Committees 9—Highways, 1948–1953, 5—Track, 1956–1958, 27—Maintenance of Way Work Equipment, 1958–1961, and 22—Economics of Railway Construction and Maintenance, 1961–1968; **H. M. Booth** (M '24, L '60), retired division engineer, St. Louis–San Francisco Railway, member of Committees 6—Buildings, 1949–1961, and

14—Yards and Terminals, 1961–1965; **L. B. Cann** (M '48), chief engineer, Richmond, Fredericksburg & Potomac Railroad, member of Committees 27—Maintenance of Way Work Equipment, 1951–1963, and 22—Economics of Railway Construction and Maintenance, 1964 until time of his death; **R. P. Davis** (M '14, L '49), dean emeritus, College of Engineering, West Virginia University, member of Committees 15—Steel Structures, 1923 until the time of his death, having been elected Member Emeritus in 1955, and 24—Engineering Education, 1942 until the time of his death, having been elected Member Emeritus in 1959; **R. P. Hughes** (M '22, L '57), member of former Committee 17—Wood Preservation, 1934–1960, and of Committee 3—Ties and Wood Preservation, 1953 until the time of his death, having been elected Member Emeritus in 1963; **L. S. Jeffords** (M '20, L '63), retired vice president operations, Atlantic Coast Line; **A. S. Krefting** (M '35, L '70), retired chief engineer, Soo Line Railroad, member of Committee 14—Yards and Terminals, 1945 until the time of his death, having served as chairman, 1956–1958, and having been elected Member Emeritus in 1974; **W. B. Leaf** (M '39, L '64), retired research physicist, Denver & Rio Grande Western Railroad, member of Committees 13—Environmental Engineering, 1943–1949, and 4—Rail, 1949–1959; **J. P. Morrissey** (M '44, L '69), retired engineer—staff, Erie Lackawanna Railway, member of Committees 22—Economics of Railway Construction and Maintenance, 1951–1959, and 31—Continuous Welded Rail, 1966–1973; **R. A. Shier** (M '49), director of engineering, Canadian Transport Commission; **M. M. Stansbury** (M '47, L '72), retired engineer roadway equipment, Norfolk & Western Railway, 1948–1973; **L. J. Sverdrup** (M '39, L '75), chairman of the board and chief executive officer, Sverdrup & Parcel and Associates, Inc.

ACTIVITIES OF TECHNICAL COMMITTEES

Assignments

During 1975 the 20 technical committees of the Association, including the Special Committee on Scales, worked on 165 assignments, 10 of which were new. The work of the Special Committee on Concrete Ties involved the revamping of the preliminary Specification for Concrete Ties and Fastenings it had developed and published in Bulletin 644, September–October 1973; and publishing the revised version in Part 1 of Bulletin 655, November–December 1975, with the recommendation that it be adopted and published in the Manual as Part 10, Chaper 3. During the year the Board of Direction assigned a number to the Committee on Electrical Energy Utilization—No. 33.

AREA committee work is directed toward the preparation of reports for information, toward revising material appearing in the AREA Manual for Railway Engineering and the Portfolio of Trackwork Plans, and toward carrying out special projects related to their assignments.

The 1975 statistics show that our 20 standing committees produced one or more information reports on 40 of their 165 assignments (not including Assignment A). In addition, the standing committees submitted 8 reports containing Manual recommendations, and the Special Committee on Concrete Ties one such report, all of which were published in Part 1 of the November–December Bulletin, separate from the committee reports. Furthermore, most committees presented brief status statements with respect to assignments on which they made no formal report.

During 1976 the technical committees as a whole will work on 155 assignments, 12 of them new.

Classification of Material

The work of AREA committees during 1975 was so diversified that, as in other years, it is impossible to do other than refer to it in general terms in a report such as this. However, the following is a general categorical classification of the results of this work as published in the technical Bulletins of the Association.

Recommendations pertaining to the development, revision or deletion of 19 different specifications and recommended practices for inclusion in the AREA Manual; 30 reports on current developments in engineering practice and design; 1 report on current developments in systems engineering, data processing and the use of computers to solve problems in railway construction, operation and maintenance; 1 report dealing with pollution control; 2 reports dealing with the training and recruitment of employees; 3 economic and analytical studies; 4 reports on relations with public authorities; 4 reports dealing with statistics; and 1 bibliography.

Committee work affecting the AREA Manual included the presentation of 1 specification for adoption; the revision of 1 specification; the presentation of 2 tentative specifications; the presentation of 5 recommended practices for adoption; and the revision or rewriting of 10 recommended practices.

Discussion Section

During the 1975 Association year, subcommittee reports, papers and addresses published in the technical issues of the Bulletin were again advertised as open for discussion.

Personnel of Committees

At the beginning of the 1975 Association year 1072 members were assigned to 1166 places on the Association's 20 technical committees. This compares with 1090 members assigned to 1186 places at the beginning of the previous year. In addition, 11 members were assigned to the Special Committee on Concrete Ties.

AREA committees again were limited to a maximum membership of 70 and to the number from each railroad depending on the total number of AREA members on the railroad.

In the 1975 Handbook of Committee Activity the names of committee chairmen, vice chairmen, secretaries and subcommittee chairmen were again shown in boldface type at the head of each committee roster.

The number of members so far assigned to committees for 1976 (as of April 1) is somewhat higher than a year ago; specifically 1080 members assigned to 1178 places.

Committee Meetings

To progress work on their assignments the 20 standing AREA technical committees held a total of 42 meetings during the 1975 Association year, 4 fewer than during the previous year. In addition, the Special Committee on Concrete Ties held 1 meeting in 1975. As is usually the case, the majority of these meetings were held at Chicago or at points central to the largest number of committee members. The exceptions were scheduled to permit inspections of facilities, operations or projects which could be seen only by going to those points.

Of the 42 meetings held during the 1975 Association year, 18 were held at Chicago; 2 each were held at Memphis, Tenn., St. Louis, Mo., and St. Paul, Minn., and 18 were held at as many other cities.

The number of meetings held during the year by each committee was dictated by the scope of their work and other considerations. Accordingly, 1 committee held 4 meetings, 5 committees each held 3 meetings, 10 committees each held 2 meetings, 2 committees each held 1 meeting, and 1 committee held no meeting.

ASSOCIATION PUBLICATIONS

In 1975 the AREA Bulletin was again published on the scheduled five-time basis. The Bulletin Issues in Proceedings Volume 77, 1976, are Nos. 654, September–October 1975; 655, November–December 1975; 656, January–February 1976; and 658, June–July 1976. Bulletin 657 is the blue-covered April–May Directory Issue, which is not a part of the Annual Proceedings of the Association.

The 1975 Handbook of Committee Activity was published in April and distributed to all committee members at that time.

The Manual recommendations of committees as published in Part 1 of Bulletin 645, November–December 1973, and Part 1 of Bulletin 650, November–December 1974, were approved, with certain exceptions, by the Board of Direction at its meeting on August 13, 1975. The approved material in both Bulletins was combined and issued in a single Supplement, known as the 1974–1975 Supplement. The Supplement consists of 349 sheets (698 pages) and includes three complete Manual chapters: 3—Ties and Wood Preservation, 22—Economics of Railway Construction and Maintenance, and 28—Clearances. The revised sheets for Chapter 15 include a completely rewritten Specification for Movable Railway Bridges.

No Supplement to the AREA Portfolio of Trackwork Plans was issued in 1974 or 1975.

A letter dated January 9, 1976, was sent to AREA members in regard to the availability of the Volume 76 (1975) Bulletin Binder. Attached to this letter was a simple order form for the use of members desiring to purchase one or more copies of these binders. The member price of the Volume 76 binder was established at $5.00 each, including handling and shipping ($5.50 each, including shipping and handling, for members in Central and South America and overseas countries). Each of these hard-cover book-type binders is designed to house all the Bulletins in a publication year, which starts with the September–October issue and ends with the June–July issue, with the exception of the blue-covered April–May Directory issue which is not punched for binding.

The June–July 1975 Bulletin contained all material presented at the March 1975 Technical Conference having technical and historic interest—the president's address, reports of the executive director and treasurer, features and committee reports not previously published in the committee report Bulletins.

The January–February 1976 Bulletin contained, in addition to committee reports, five of the addresses presented at the Regional Meeting held at Vancouver, B. C., on October 30, 1975.

LOOKING AHEAD

The next Annual Technical Conference of the AREA will be held at the Palmer House, Chicago, on March 29–31, 1977. In conjunction therewith, Railway Engineering-Maintenance Suppliers Association, Inc. (REMSA) will stage, at McCormick Place, Chicago, an exhibit by more than 100 companies showing their latest developments in machines, equipment and materials used in railway engineering and maintenance operations.

The next Regional Meeting will be held at Pittsburgh, Pa., on October 21, 1976. Arrangements and planning for the meeting are under the direction of AREA Director Mike Rougas, chief engineer, Bessemer & Lake Erie Railroad. In 1977 the Regional Meeting will be held at New Orleans, La.

As reported, our membership level remains high, considering the reduction of engineering employees on the railroads, the unfavorable economic situation that has prevailed, and other factors which prevented participation in Association activities, and our financial situation remains sound—the Association is still going strong. Keeping it strong will require that the Association accomplish its professional responsibilities in behalf of the engineering profession and the railroad industry expeditiously and efficiently, and this it can do with the active support of its officers, directors and members, and all railroad engineering and maintenance officers.

Respectfully submitted,

EARL W. HODGKINS,
Executive Director and Secretary

Deceased Members

N. V. BACK (M '51)
Retired Chief Engineer, Toronto, Hamilton & Buffalo Railway, Hamilton, Ont.

A. L. BARTLETT (M '20, L '49)
Laguna Hills, Calif.

B. A. BATES (M '28, L '63)
Retired Industrial Engineer, Southern Railway System, McAdenville, N. C.

EDGAR BENNETT (M '20, L '55)
Retired Assistant Chief Engineer, Southern Railway System, Knoxville, Tenn.

O. C. BENSON (M '28, L '66)
Retired Director of Budgets, Boston & Maine Corporation, Concord, N. H.

H. M. BOOTH (M '24, L '60)
Retired Division Engineer, St. Louis–San Francisco Railway, Greenville, N. C.

D. C. BOWMAN (M '28, L '60)
Retired Engineer and Contractor, St. Louis, Mo.

L. B. CANN, JR. (M '48)
Chief Engineer, Richmond, Fredericksburg & Potomac Railroad, Richmond, Va.

R. P. DAVIS (M '14, L '49)
Dean Emeritus, College of Engineering, West Virginia University, Morgantown, W. Va.

J. M. FARRIS (M '64)
Assistant Engineer, Southern Railway System, Atlanta, Ga.

T. W. FATHERSON (M '10, L '40)
Retired General Superintendent, Tremont & Gulf Railway, Denver, Colo.

F. P. FUNDA (M '20, L '55)
Retired Division Engineer, Chicago, Rock Island & Pacific Railroad, Peoria, Ill.

C. D. HORTON (M '27, L '52)
Retired Clearance Engineer, Erie Railroad, St. Petersburg, Fla.

R. P. HUGHES (M '22, L '57)
Retired Inspector, Tie and Timber Treating Department, Atchison, Topeka & Santa Fe Railway, San Jose, Calif.

A. C. JACK (A '27, L '65)
Consultant, Lock Spikes, Pittsburgh, Pa.

L. S. Jeffords (M '20, L '63)
Retired Vice President Operations, Atlantic Coast Line Railroad, Jacksonville, Fla.

A. S. Krefting (M '35, L '70)
Retired Chief Engineer, Soo Line Railroad, Minneapolis, Minn.

B. J. Lampert (M '73)
Resident Engineer, Bechtel Associates, Iowa City, Iowa

W. B. Leaf (M '39, L '64)
Retired Research Physicist, Denver & Rio Grande Western Railroad, Denver, Colo.

C. W. Meyer (M '58)
Retired Assistant to Valuation Engineer, System, Atchison, Topeka & Santa Fe Railway, Topeka, Kans.

J. P. Morrissey, Jr. (M '44, L '69)
Retired Engineer—Staff, Erie Lackawanna Railway, Bay Village, Ohio

C. W. Murdaugh (A '43, L '74)
Portsmouth, Va.

C. W. Murphy (M '56)
Assistant Supervisor of Track, Patapsco & Back Rivers Railroad, Sparrows Point, Md.

T. H. Patrick (M '57)
Retired Supervisor Tie Bureau, Chicago, Milwaukee, St. Paul & Pacific Railroad, Modesto, Calif.

C. B. Patterson (A '11, L '46)
Retired Assistant Engineer, Ohio State Department of Highways, Toledo, Ohio

R. H. Peterson (M '62)
Railroad Safety Specialist, National Transportation Safety Board, Washington, D. C.

R. B. Shepard, Jr. (M '15, L '50)
Retired, Southern Services, Inc., Birmingham, Ala.

R. A. Shier (M '49)
Director of Engineering, Canadian Transport Commission, Ottawa, Ont.

C. E. Smith (M '09, L '45)
Retired Vice President, New York, New Haven & Hartford Railroad, New Haven, Conn.

M. M. Stansbury (M '47, L '72)
Retired Engineer Roadway Equipment, Norfolk & Western Railway, Bellevue, Ohio

J. H. Stinebaugh (M '59)
Supervisor Water Service and Roadway Machines, Illinois Central Gulf Railroad, Carbondale, Ill.

L. J. Sverdrup (M '39, L '75)
Chairman of the Board and Chief Executive Officer, Sverdrup & Parcel and Associates, Inc., St. Louis, Mo.

J. M. Trissal (M '33, L '70)
Retired Vice President—Real Estate, Illinois Central Railroad, Flossmoor, Ill.

R. W. Webb (M '50)
Division Engineer, Canadian Pacific Limited, Montreal, Que.

D. W. Wessells (A '66)
Streeter-Amet, Grayslake, Ill.

J. W. Westwood (M '44, L '69)
Retired Division Engineer, New York Central System, Kansas City, Mo.

REPORT OF TREASURER

Report of the Treasurer

December 31, 1975

To the Members:

The year 1975 was a good year financially for your Association in that our actual receipts very closely matched our actual expenditures, which were under our budgeted expenditures.

Last year I reported that our approved budget for 1975 anticipated that expenditures would exceed receipts by more than $11,000. This was due to replacing the inventory of Manual binders and is to be recaptured over a 2- to 3-year period from the sale of Manuals.

We estimated receipts of $138,350 compared with actual receipts of $138,432. Total expenditures amounted to $148,246 compared with our budget of $150,000. The net result is a deficit of $9,814 instead of the $11,000 that was estimated by Executive Director Earl Hodgkins. Earl and his able assistants, Norrie Engman and Don Fredley, are to be congratulated for keeping such a tight rein on expenditures.

In past years I have talked about the high esteem our publications receive in and about the industry. This was especially evident in 1975 when publication sales amounted to $56,830 as compared with $30,429 in 1974.

We can maintain our healthy financial situation if our members and associates will promote use of the Manual and Portfolio of Trackwork Plans as well as use of the Bulletin as an advertising medium.

Following is the General Balance Sheet for December 31, 1975; the Statement of Receipts and Expenditures for Calendar Year 1975; the Comparative Statement of Receipts and Expenditures for the Last 20 Years; and the Comparative Statement of Association Equity as of December 31, 1974 and 1975.

A. B. Hillman, Jr., *Treasurer*

GENERAL BALANCE SHEET

DECEMBER 31, 1975

Assets:			
Cash:			
Checking Account	$ 2,611.48		
Special Deposit	75,324.07		
Petty Cash	50.00		
Total Cash		$77,985.55	
Accounts Receivable		221.13	
Inventory of Publications:			
Manual For Railway Engineering	$ 10,997.05		
Portfolio of Trackwork Plans	450.00		
Bulletins	300.00		
Proceedings	100.00		
Newsletter	......		
Other Publications	120.00		
Total Inventory of Publications		$11,967.05	
Other Assets:			
*Prepaid Postage	$ 833.57		
Furniture and Fixtures	1,000.00		
Investments	42,000.00		
Total Other Assets		43,833.57	
Total Assets			$134,007.30
Liabilities and Association Equity:			
Member Dues Paid in Advance	$		
Association Equity	134,007.30		
Total Liabilities and Association Equity			$134,007.30

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* Prepaid Postage:	
Second Class deposit—Madison	$ 150.00
Postage Meter	613.57
Postal Stamps	70.00
Total Prepaid Postage	$ 833.57

STATEMENT OF RECEIPTS AND EXPENDITURES
CALENDAR YEAR 1975

RECEIPTS

Current Receipts:		
Membership Accounts:		
Member and Associate Dues	$55,498.27	
Student Affiliate Dues	155.00	
Entrance Fees	1,960.00	
Total Membership Accounts	$57,613.27	
Publications:		
Manual For Railway Engineering	$34,586.75	
Portfolio of Trackwork Plans	11,300.10	
Bulletins	4,375.75	
Proceedings	1,894.50	
Specifications	4,673.15	
Handling and Shipping	4,768.41	
Total from Publications	$61,598.66	
Other Sources:		
Advertising in Publications	$ 8,204.99	
Annual Conference Registration Fees	6,637.06	
Interest on Investments	2,599.65	
Miscellaneous	1,778.03	
Total Other Sources	$19,219.73	
Total Receipts		$138,431.66

EXPENDITURES

Current Expenses:		
Salaries and Wages	$42,109.64	
Soc. Security, Ins., and Unempl. Tax	3,396.21	
Retirement Benefit	3,152.28	
Manual For Railway Engineering	26,581.39	
Portfolio of Trackwork Plans	276.10	
Bulletins and Proceedings	43,237.22	
Newsletter	1,296.36	
Shipping Charges	5,594.51	
Stationery and Printing	3,378.91	
Supplies	412.09	
Refunds and Miscellaneous	1,683.31	
Rent	1,045.00	
Telephone	374.25	
Committee and Traveling Expenses	2,232.12	
Professors Expenses	5,256.47	
Annual Conference	8,220.20	
Extraordinary	......	
Total Expenditures		$148,246.06
Excess of Receipts over Expenditures		$ (9,814.40)

COMPARATIVE STATEMENT OF RECEIPTS AND EXPENDITURES FOR THE LAST 20 YEARS

	Receipts	*Expenditures*	*Increase or (Decrease)*
1956	$ 79,351.11	$ 70,336.17	$ 9,014.94
1957	85,429.31	89,830.57	(4,401.26)
1958	81,454.56	77,348.92	4,105.64
1959	80,407.16	80,297.48	109.68
1960	81,138.79	83,978.29	(2,839.50)
1961	83,461.73	73,410.20	10,051.53
1962	76,097.28	87,344.12	(11,246.84)
1963	73,653.48	66,156.99	7,496.49
1964	74,834.81	78,118.66	(3,283.85)
1965	81,336.73	73,895.90	7,440.83
1966	84,590.91	80,454.00	4,136.91
1967	78,724.17	101,087.51	(22,363.34)
1968	97,639.94	111,054.20	(13,414.26)
1969	109,893.16	112,741.62	(2,848.46)
1970	113,245.85	108,305.33	4,940.52
1971	113,756.51	116,003.93	(2,247.42)
1972	128,208.01	125,534.70	2,673.31
1973	110,193.20	108,148.33	2,044.87
1974	112,549.90	112,153.50	396.40
1975	138,431.66	148,246.06	(9,814.40)

COMPARATIVE STATEMENT OF ASSOCIATION EQUITY AS OF DECEMBER 31, 1974 AND 1975

	1975	*1974*	*Increase or (Decrease)*
Assets:			
Cash	$ 77,985.55	$ 84,385.33	(6,399.78)
Accounts Receivable	221.13	974.65	(753.52)
Inventory of Publications	11,967.75	13,910.00	(1,942.25)
Other Assets	43,832.87	44,551.72	(718.85)
Total Assets	$134,007.30	$143,281.70	(9,814.40)
Liabilities and Association Equity:			
Member Dues Paid in Advance	$	$	......
Association Equity	134,007.30	143,821.70	(9,814.40)
Total Liabilities and Association Equity	$134,007.30	$143,821.70	(9,814.40)

CONSTITUTION

American Railway Engineering Association

CONSTITUTION

Revised to February 8, 1974

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 Study and Research 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 thereof, 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) A railway engineer or officer who has had not less than five years' experience in the location, construction, operation or maintenance of railways and who is employed by a common-carrier railway corporation, by an approved association of railroads or railway engineers or officers, or by a non-common-carrier railway if primary duties consist entirely or primarily of the location, construction, operation or maintenance of a railway plant and facilities.

(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 regular duties, deals with railway problems.

(d) An editor of a trade or technical magazine who, in the discharge of regular duties, deals with railway problems, and who has had the equivalent of five years' engineering or railway experience.

(e) A consulting engineer or contractor, or an engineer in their employ, engaged in the engineering, construction and maintenance of railroad-related facilities or an engineer employed by a technical service or research and development organization who has had the equivalent of five years' engineering experience.

(f) An officer or engineer of an engineering or scientific society or association whose aims and objectives are compatible with the aims and objectives of this association.

C. LIFE MEMBER

A Life Member shall be a Past President of the Association who has been retired under a recognized retirement plan, or 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 railways engineering or management.

(b) The number of Honorary Members shall be limited to ten.

E. ASSOCIATE

An Associate shall be:

(a) A member of a railway supply company or association who meets the qualifications of Section 2, Paragraph A (a) and (b).

(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, shall have had not less than three years' experience in the location, construction, operation or maintenance of railways, and shall be an employee of a railway corporation, or one of the organizations or institutions listed under Section B of this Article, or a railway supply company if qualified under Section 2, Paragraph A (b) of this Article.

(b) Membership in this classification in the Association shall terminate at the end of the calendar year in which individual becomes 30 years of age.

(c) A Junior Member may make application for membership in another grade at any time when 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 consisted 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 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 the applicant is personally known shall be substituted, as necessary, to provide a total of at least three references. Each of these persons shall be requested 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 provision of Section 2, Paragraphs (a) and (c) of the 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 willingness to abide by the Constitution of the Association in the 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) An entrance fee of $5 shall be payable to the Association with each application for Junior Member, which sum shall be returned to an applicant not elected. When a Junior Member transfers to the Member or Associate Member class the previously paid $5 entrance fee shall be credited towards the entrance fee for the class to which transferring. However, the Junior Member entrance fee shall not be returnable should the individual resign from the Association or allow membership to lapse. Neither shall it be applicable to the dues for any year.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be $20.

(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 Executive Officer-Secretary. If the dues are still unpaid on July 1, further notice shall be given, informing the person that he or she is not in good standing in the Association. If the dues remain unpaid by October 1, the person shall be notified that he or she 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, two Past Presidents, twelve Directors, an Executive Officer-Secretary, and a Treasurer.

(b) The President, the Vice Presidents, the Directors and the two Past Presidents on the Board of Direction shall be Members and shall act as the trustees and have the custody of all property belonging to the Association.

(c) The Executive Officer-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 technical conference 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 Annually

(a) There shall be elected prior to or at each annual technical conference 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 resignation from office, or if the officer 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.

(d) If one or more Past Presidents are unable to act as members of the committee through disability, the President shall have the authority to appoint an equivalent number of eligible next senior Past Presidents to the committee as ordinary members.

(e) If one or more elected members of the committee are unable to act, through death or disability, the President shall have the authority to appoint as replacements an equivalent number of the senior unsuccessful candidates for election to the committee.

2. Method of Nominating

(a) At least three months prior to the annual technical conference, the Chairman shall call a meeting of the committee at a convenient place, at which nominees for the several elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee*	*Number of Candidates to be elected at the Annual Election of Officers*
President	1	1
Vice President	1	1
Directors	8	4
Nominating Committee	10	5

(b) The nominations for Director shall maintain the territorial balance prescribed in Article VII, Section 1, Paragraph (b), to the maximum extent practicable. In this connection, the nominations for Director shall be predicated, insofar as practicable, on the following three-year repeating pattern of Director positions to ensure adequate territorial distribution:

First Year	Second Year	Third Year
East—2	East—1	East—1
South—1	West—2	South—1
West—1	Canada—1	West—2

Nominations in any one year shall be double the number of positions available for each district that year, with the nominations listed separately by districts.

(c) The elected members of the Nominating Committee each year shall include one from each district represented on the Board of Direction and one at-large member. Nominations in any year shall be double the number of positions available for each district, with the nominations listed separately by districts.

(d) The Chairman of the Nominating Committee shall send the names of the nominees to the President and Executive Officer-Secretary within 15 days after the meeting of the Nominating Committee, and the Executive Officer-Secretary shall report the names of these nominees to the members of the Association not less than 60 days prior to the annual technical conference.

(e) At any time prior to 30 days before the annual meeting of the Nominating Committee, any ten or more Members may send to the Executive Officer-Secretary nominations for any elective office for the ensuing year for consideration by the Nominating Committee, signed by such Members.

(f) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, the name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than 60 days prior to each annual technical conference, the Executive Officer-Secretary shall issue a ballot to each voting Member of record who has paid dues to or beyond December 31 of the previous year, listing by districts 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 within each district that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate his or her record of membership and activities in the 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 Executive Officer-Secretary at any time previous to the closure of the polls.

(b) A voter may have the privilege of withdrawing his ballot, for the purposes of casting another, or otherwise, at any time up to ten working days prior to the closure of the polls. After that date, no ballot shall be subject to withdrawal or revision.

(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 at least 30 days, but not more than 45 days, prior to the first day of the annual technical conference. The ballots shall be counted soon thereafter by tellers appointed by the President of the Association.

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 technical conference shall elect the officer by ballot from the candidates so tied.

(c) The presiding officer shall announce at the annual technical conference the names of the officers elected in accordance with this Article.

Article VII

MANAGEMENT

1. Board of Direction

(a) The Board of Direction shall be the governing body of the Association and shall manage the affairs of the Association in accordance with the Constitution of the Association, and shall have full power to control and regulate all matters not otherwise provided for in the Constitution. It shall be composed of seventeen Members of the Association, and shall include the President and two Vice Presidents of the Association, the two living junior Past Presidents, and twelve elected Directors. The nomination and election of the Officers and Directors shall be in accordance with the procedures set forth in Article VI herein.

(b) Furthermore, the membership shall, insofar as possible, include proportional representation from the territorial divisions contained in the "List of Principal Railroads Showing Allocation to Geographical Groups" (published in the current issue of The Official Railway Equipment Register).

Accordingly, the twelve Directors shall be elected in accordance with Article VI, Section 2, to fit, insofar as possible, the following general plan for territorial representation:

Four from the Eastern District; two from the Southern District; five from the Western District, including the Northwestern, Central Western and Southwestern Districts; and one from Canada.

(c) The President and two Vice Presidents of the Association and the two Past Presidents on the Board of Direction shall be at-large members of the Board.

(d) Vacancies occurring in Director positions prior to normal expiration of term of office shall be filled by the Board, insofar as possible, from the district represented by the previous incumbent.

(e) The Board of Direction shall meet within thirty days after each annual technical conference, 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.

(f) Seven members of the Board of Direction shall constitute a quorum.

2. Executive Committee

(a) An Executive Committee of the Board of Direction shall be constituted annually and shall consist of the President and two Vice Presidents of the Association and the two Past Presidents on the Board of Direction. The Executive Committee shall be subject to confirmation of the Board of Direction each year at the first meeting of the Board following the Convention. The President of the Association shall be the chairman of the Executive Committee.

(b) The Executive Committee shall possess and may exercise during intervals between meetings of the Board, all of the powers of the Board on matters which in the judgment of a majority of the Executive Committee cannot properly be delayed until the next meeting of the Board. Actions of the Executive Committee shall be authorized by a concurring majority of its full membership and shall be reported to the Board of Direction at its next meeting.

(c) The Executive Committee may be dissolved at any time by action of a majority of the full membership of the Board of Direction. Following such dissolution, the Executive Committee may be re-created with personnel different than prescribed in Paragraph (a) herein at any time prior to the annual technical conference by action of a majority of the full membership of the Board. However, if the Executive Committee is not re-created prior to the next annual technical conference it automatically shall come under the provision of Paragraph (a) herein unless the Board of Direction decrees otherwise.

3. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association, the Board of Direction and the Executive Committee of the Board of Direction, and, by virtue of his office, shall be a member of all committees, except the Nominating Committee.

4. Vice Presidents

The Vice Presidents, in order of seniority, shall preside at meetings in the absence of the President.

5. Treasurer

The Treasurer shall pay all bills of the Association when properly certified by the Executive Officer-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.

6. Executive Officer-Secretary

The Executive Officer-Secretary of the Association shall be appointed by the Board of Direction to manage the affairs of the Association under the direction of the President and the Board of Direction. This officer shall use the title "Executive Director," or such other title as the Board of Direction may direct, except that on legal papers or on other documents, at his or her discretion, the title "Secretary" shall be used. This officer shall serve as secretary of the Board of Direction and of the Executive Committee of the Board of Direction.

The Executive Officer-Secretary shall attend the meetings of the Association, the Board of Direction, and the Executive Committee of the Board of Direction, prepare the business therefor, and record the proceedings thereof. Furthermore, this officer 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. This officer shall personally certify to the accuracy of all bills and vouchers on which money is to be paid. In addition, shall invest all funds of the Association not needed for current disbursements, as shall be recommended by the Finance Committee of the Board of Direction and approved by the Board of Direction, with notification to the Treasurer of such investments.

The Executive Officer-Secretary shall be responsible for the handling of the correspondence of the Association, shall make an annual report to the Association, shall have direct charge of the property and quarters of the Association, shall direct the work of the secretaries, assistant secretaries and other employees of the Association, and shall perform such other duties as the Board of Direction may prescribe.

7. 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.

8. Administrative Committees

At the first meeting of the Board of Direction after the annual technical conference, the following Administrative Committees, each consisting of not less than three members, shall be appointed by the President. The personnel of these committees shall be subject to approval by the Board of Direction.

Finance
Membership
Publications
Research
Technical Activity
Conference Program

Other special Administrative Committees may be appointed by the President at any time, and reappointed annually, if necessary, their personnel being subject to approval by the Board of Direction.

Membership on Administrative Committees shall be restricted to members of the Board of Direction, except that one or two members of the Administrative Committee on Research may be past members of the Board of Direction.

9. Study and Research Committees

The Board of Direction may establish continuing or special Study and Research Committees to investigate, consider, and report upon subjects appropriate to the object of the Association, as set forth in Art. I.

10. Duties of Administrative Committees

(a) Finance

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) Membership

The Membership Committee shall investigate applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(c) Publications

The Publications Committee shall have general supervision over the publications of the Association, including the Manual and the Portfolio. The Publications 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.

(d) Research

The Research Committee shall encourage and coordinate the research activities of the Association, in the course of accomplishment of which it shall review and pass upon the recommendations of Study and Research Committees for research projects and shall report thereon to the Board of Direction, recommending for approval specific projects initiated by these committees or by the Research Committee and recommending allotments of funds for these projects in the research budget of the Association of American Railroads or from other sources compatible therewith; shall collaborate closely with the research staff of the Association of American Railroads and other organizations; and when called upon by the Vice President—Research or the Vice President—Operations and Maintenance of that association, members of the Research Committee shall engage in the activities of advisory committees or groups of that organization and shall report from time to time to the Board of Direction on those activities.

(e) Technical Activity

The Technical Activity Committee shall monitor and give direction to the activities of Association Study and Research Committees, and review the activity of the personnel assigned thereto. It shall review and pass upon the recommendations of those committees for subjects to be investigated, considered, and reported on by those committees during the ensuing Association year, and shall report thereon to the Board of Direction for its approval. The Technical Activity Committee shall have authority to assign additional subjects or change the scope of any existing subjects at any time during the year, reporting its action thereon to the Board at its next regular meeting.

This Committee also shall review and pass upon applications of members for appointment to Study and Research Committees, and shall appoint the chairman and vice chairman of each such committee and make a report thereon to the Board of Direction for its approval. Should an unexpected vacancy in the chairmanship or vice chairmanship of any such committee occur, the Technical Activity Committee shall have authority to fill such vacancy immediately, reporting its action thereon to the Board at its next regular meeting.

(f) Conference Program

The Conference Program Committee shall develop the program of the annual technical conference with the assistance of the Study and Research Committees, the Board of Direction, the Executive Officer-Secretary, and others.

11. 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.

12. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

13. 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 technical conference of the Association shall be deemed to be the act of the Association.

Article VIII

MEETINGS

1. Annual Technical Conference

(a) The Annual Technical Conference 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 technical conference in any year shall be held on dates determined by the affirmative vote of two-thirds of the entire membership of the Board of Direction.

(b) The Executive Officer-Secretary shall notify all members of the Association of the time and place of the annual technical conference at least 30 days in advance thereof.

(c) The order of business at the annual technical conference of the Association shall be:

Address of the President
Reports of the Executive Officer-Secretary and the Treasurer
Committee and other presentations
Unfinished business
New business
Installation of officers
Adjournment

(d) This order of business may be changed by the presiding officer.

(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

Amendment of this Constitution may be proposed by written petition signed by not less than ten Members of the Association, and shall be acted upon in the following manner:

The proposed amendment shall be presented to the Executive Officer-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 voting members of the Association by letter ballot.

Amendment to the Constitution also may be proposed by majority affirmative vote of the entire Board of Direction, and the proposed amendment then submitted to the voting members of 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.

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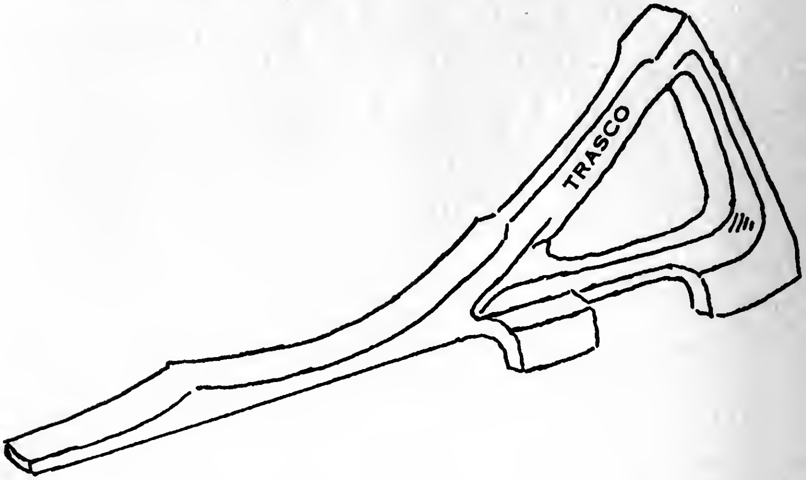
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