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LABORATORY INVESTIGATION OF TRACK GAUGE WIDENING CHARACTERISTICS

INTERIM REPORT

AUGUST 1980

Prepared for

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NOTICE

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16. Abstract

This report describes test procedures and results of the AAR track gauge widening tests. The tests included static and dynamic lateral rail loadings under various vertical and longitudinal loads, relative effects of single and double axle gauge widening and single axle dynamic gauge widening under a range of applied vertical loads.

These tests were conducted to study the effects of progressive track damage, due to gauge widening, to determine if non-destructive gauge widening field tests are feasible and if so, the best vertical and lateral loads to be used for testing purposes.

The results of these tests indicate that non-destructive gauge widening testing is possible, and that the predamaged condition of the track can be measured and evaluated.

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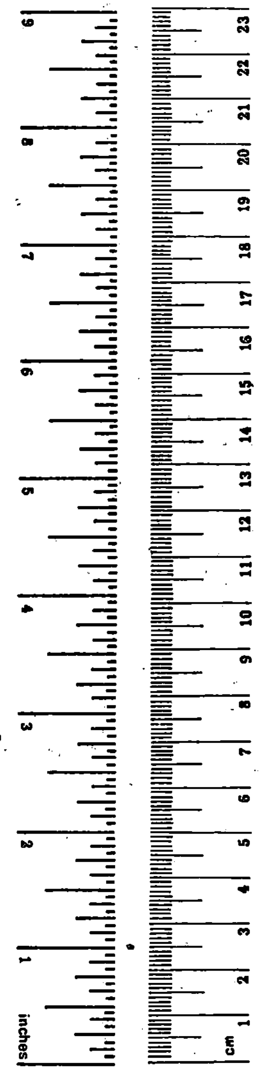
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

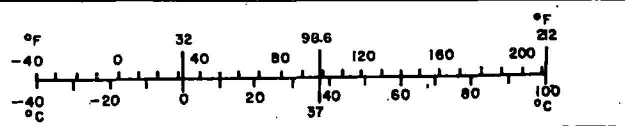
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

These tests were conducted under Task Three, Laboratory Testing, of Contract DOT-FR-30038, sponsored by the Federal Railroad Administration, Office of Research and Development, Improved Track Structures Research Division.

The principal objective of these laboratory tests was to investigate the gauge widening and rail overturning behavior of track subjected to varying combinations of lateral, vertical and longitudinal loadings.

The valuable suggestions of Mr. Howard Moody, Contracting Officer's Technical Representative, Federal Railroad Administration and Mr. Donald P. McConnell, Transportation System Center, Dept. of Transportation, are gratefully acknowledged.

Special thanks also go to members of Subcommittee Two of the Track Strength Characterization Program, Messrs: J. F. Scott and A. Worth of CN Rail, and Mr. K. Jansens of CP Rail, for their valuable assistance in the evaluation and interpretation of the test results.

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1. INTRODUCTION

Gauge widening and rail overturning from lateral forces has been a continual problem on the railroads, particularly in the modern era of high speed, heavy freight trains. Large lateral forces applied to track with damaged or deteriorated ties and/or fasteners can result in excessive gauge widening and possible rail overturning which can cause a derailment.

The ability to hold gauge and prevent rail overturning is not limited to deteriorated or damaged track, but can be experienced even in new track that was not properly designed to handle high applied lateral loads.

In order to prevent derailments from this cause, and to maintain a suitable track integrity, the track engineer must be able to determine to what extent his track has deteriorated from a safe operating condition. A correlation with some known base parameters must be made, either by visual inspection, or some type of measurement, in order to determine the condition of the track. The present study was initiated in order to determine if track damage, resulting from lateral forces, can be detected without further damage to the track, and to see if measurements in the field could be correlated with those in the track laboratory.

The historical background of track gauge widening is well documented (1). Many other well-known investigators have studied gauge widening, of one type or another. A. N. Talbot studied bending stresses in rails due to lateral forces (2), and railhead deflections and rail rotation in tangent track (3). S. Timoshenko and B. F. Langer looked at the torsional resistance of rail, and various methods for measuring lateral forces applied to rail (4). Numerous other investigators (1) have studied gauge widening under static and dynamic loading conditions, in order to determine safe wheel loads and track speeds.

In order to answer some of the outstanding questions on the phenomenon of gauge widening, to determine if nondestuctive gauge widening tests can be done in the field, and to generate a data base for field data correlations, a series of tests were conducted at the Association of American Railroad's Track Structure Dynamic Test Facility located in Chicago, Illinois.

This report describes specific test set-ups and procedures, presents the results of the various gauge widening tests and discusses the test conclusions, and recommendations.

2. PURPOSE

The purpose of this series of tests was to determine if non-destructive gauge widening tests can be used to detect damaged or weakened track, to quantify the lateral resistance characteristics of track and to investigate the ultimate strength and failure modes of track, due to high lateral loads on the rail. To accomplish this goal, the gauge widening tests were designed and conducted, using the following guidelines (5):

1. Conduct a sequence of single-point lateral rail loadings, whereby the track gauge is progressively damaged in order to determine if "nondestructive" loadings and measurements can be used to determine deteriorated track conditions.
2. Continue these tests until the track's resistance to gauge widening is "seriously weakened," and determine what nondestructive loading levels are required to detect this weakened condition.
3. Further reduce the resistance to gauge widening by sequentially removing first the gauge spikes, and then the field spikes to determine what effects the missing spikes have on gauge widening resistance.
4. Determine the effects of vertical and lateral loads from a simulated adjacent axle on gauge widening.

5. Determine the effects of dynamic loads on gauge widening.

6. Determine the effects of longitudinal rail loadings on gauge widening.

Using the data from these tests, a data base can then be established, from which the vertical and lateral load values for use in field tests, can be determined. This data can also be used to determine correlation factors for comparison with field data, to aid in identifying gauge-restraint damage that a specific section of track has experienced.

3. BASIC GAUGE WIDENING TESTS

This series of 84 basic gauge widening tests was designed to progressively damage the test track (Figure 1) by the application of combined lateral and vertical loads, using predetermined gauge widening limits, e.g. maximum allowable railhead lateral deflections of 0.25, 0.50, 1.0, and 2.0 inches. With the track now in a damaged condition, two additional series of tests were conducted, in which nine gauge spikes, and then nine field spikes, were sequentially removed. Table 1 defines the vertical loading sequence and gauge widening limits for the various test categories.

3.1 Test Procedure

The test track used for the basic gauge widening test series (Figure 1) was constructed with:

136 RE Rail

#5 AREA cross ties, 7 inches by 9 inches by 8.5 feet, spaced on 19.5 inch centers.

#12 AREA tie plates, with two cut spikes per plate (spikes were fully driven).

#4 AREA limestone ballast, 12 inches deep, with 12 inch shoulders.

CA-8 Illinois Specification limestone subballast, 6 inches deep.

The AREA Manual of Recommended Practices was used as a guide throughout the construction of the track.

Track loading was accomplished using four 50-ton capacity hydraulic jacks for vertical loads, and two 25-ton capacity hydraulic jacks for lateral loads, as shown in Figures 2 and 3.

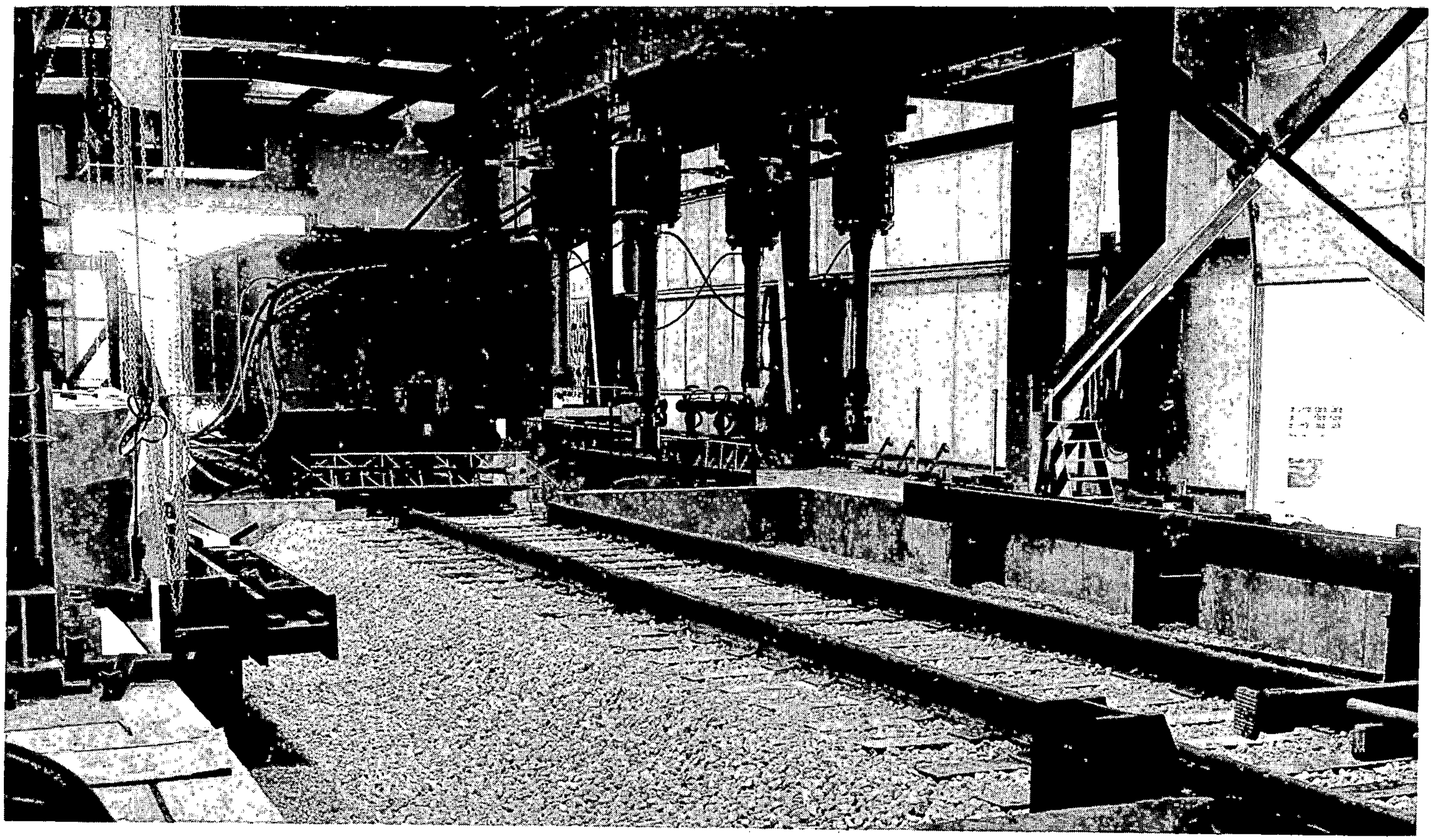


Figure 1. Test Track Used for Gauge Widening Tests.

TABLE 1. VERTICAL LOADING SEQUENCE FOR

BASIC GAUGE WIDENING TESTS

Test Series	Vertical Load Sequence	Gauge Widening (Inches for one rail)	Total Number of Tests
A. New Track Construction	I	0.25	9
	I	0.50	9
	I	1.0	9
	I	2.0	9
B. Number of Gauge Line Spikes Pulled 1	II	3	4
2	II	3	4
3	II	3	4
5	II	3	4
7	II	3	4
9	II	3	4
C. Number of Field Line Spikes Pulled 1	II	3	4
2	II	3	4
3	II	3	4
5	II	3	4
7	II	3	4
9	II	3	4

Vertical Load Sequence

I: 0, 0, 0, 5, 10, 15, 20, 30, 40, Kips

II: 0, 10, 20, 40 Kips

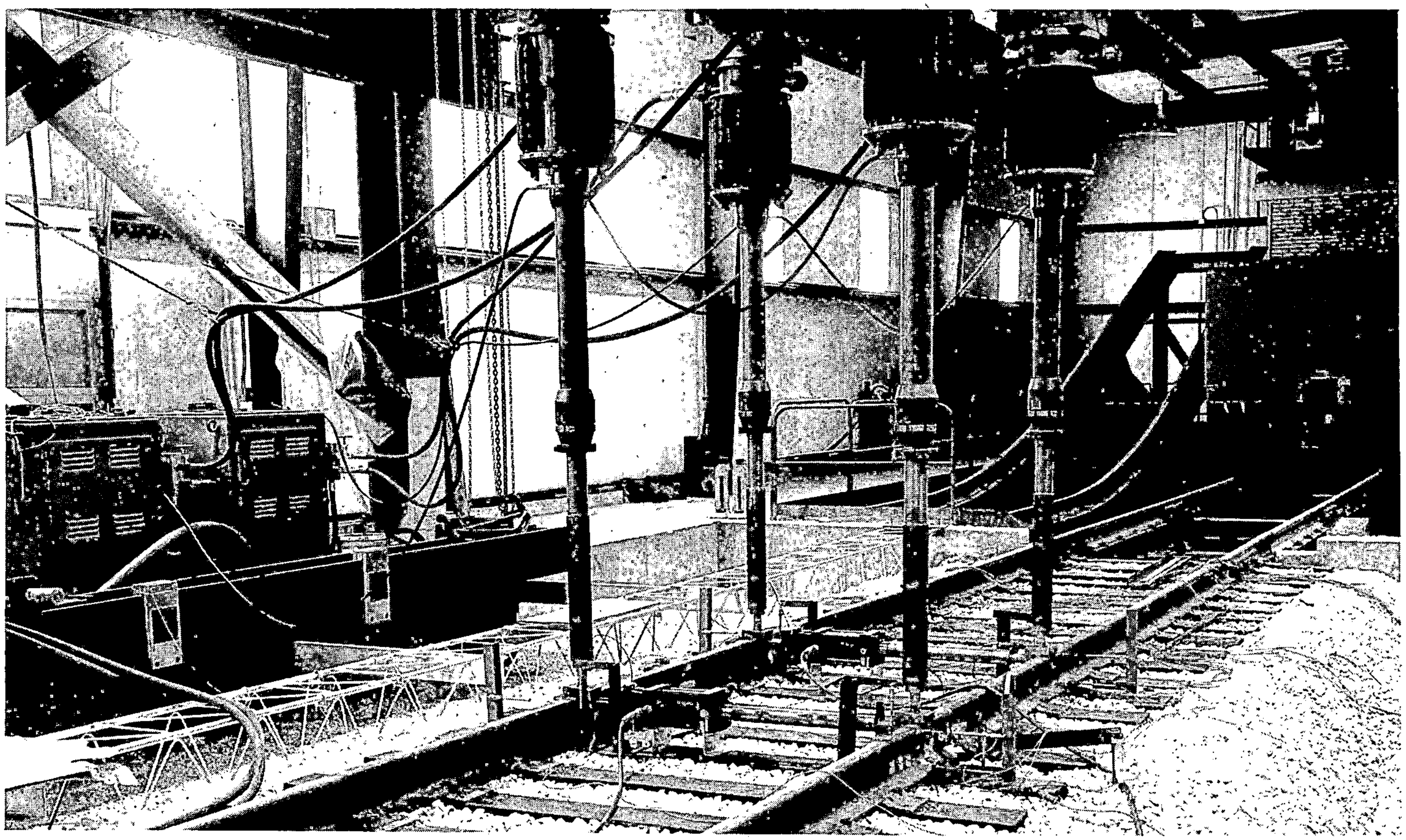


Figure 2. Basic Gauge Widening Tests- Hydraulic Equipment for Vertical and Lateral Load Applications During Simulated Dual-Axle (Truck) Loadings.

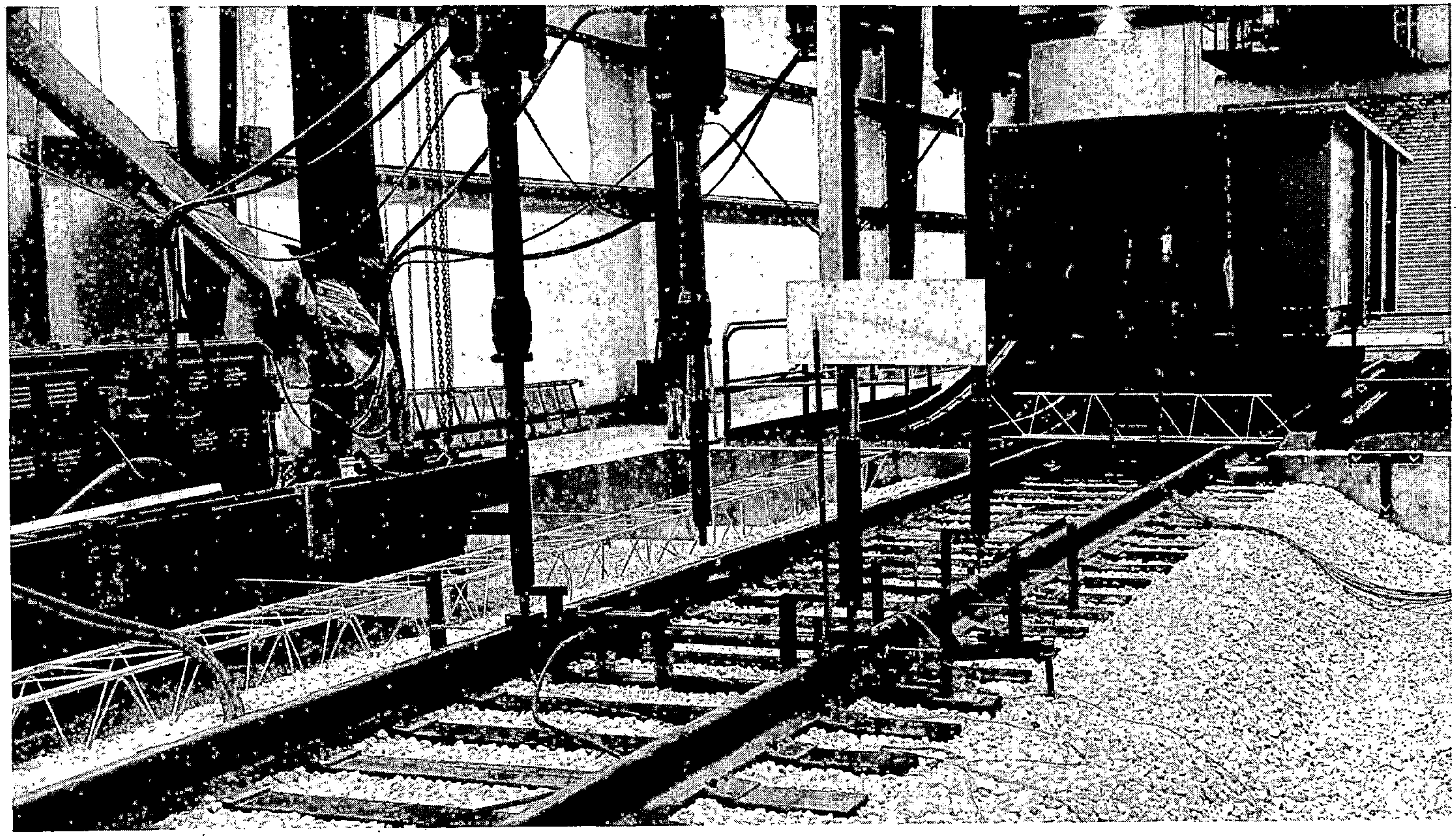


Figure 3. Basic Gauge Widening Tests - Hydraulic Equipment for Vertical and Lateral Load Applications During Simulated Single Axle Loadings.

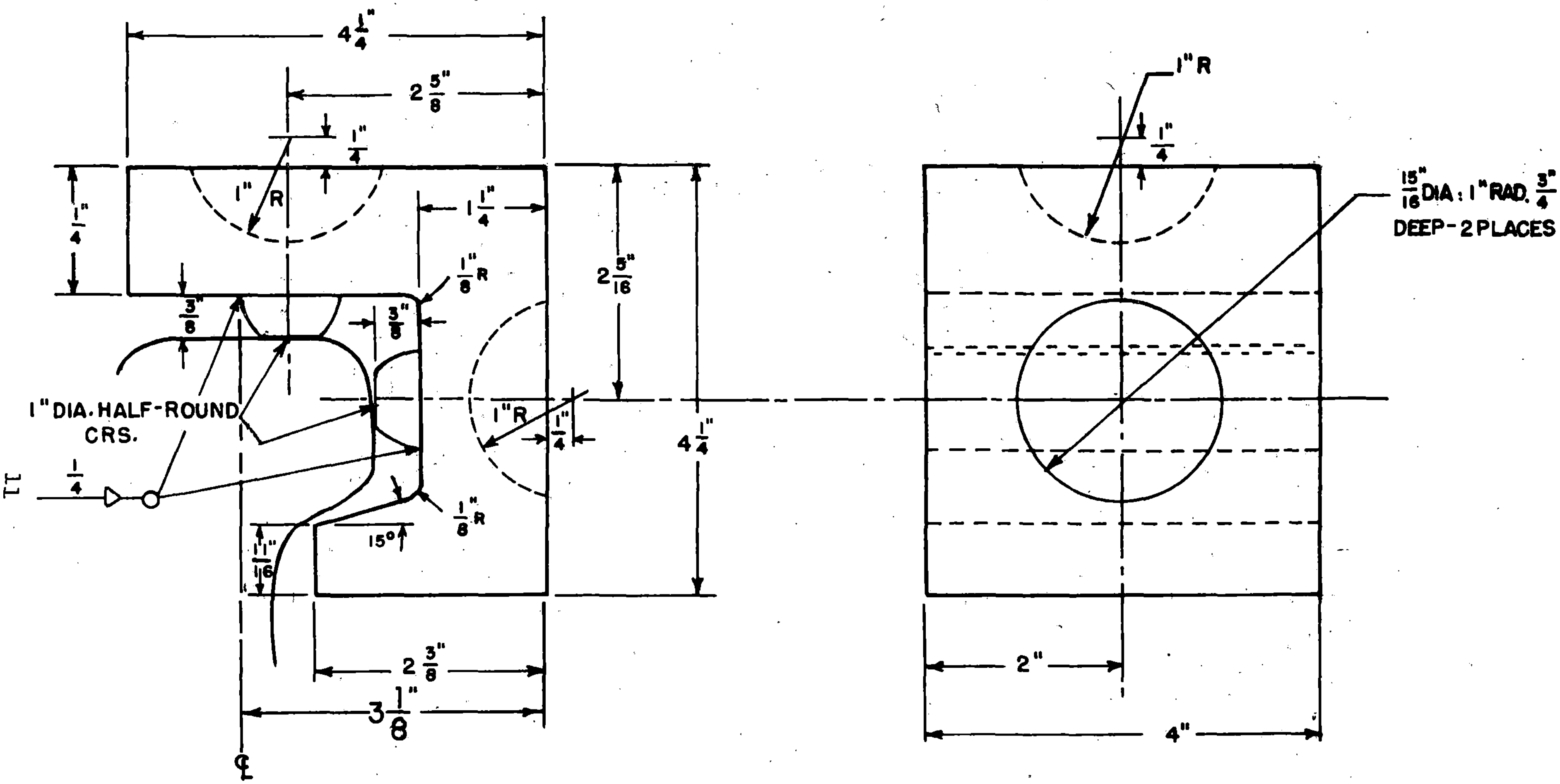
Figure 2 shows the simulated dual-axle loading, and Figure 3 shows the simulated single axle loading arrangements used for this basic gauge widening test series.

Vertical and lateral wheel loads were applied to both rail heads by means of a specially-designed loading fixture, shown in Figure 4. Use of this fixture resulted in vertical load application 0.50 inch from the 136 RE rail head center line, and lateral load application 0.69 inch below the top of the rail. During the tests, any vertical or lateral loadings were applied equally to both rails. All applied loads were measured by strain gauge load cells inserted between the loading fixture and the jack stilts. Figure 5 shows a typical load cell installation for lateral load measurements.

3.2 Test Instrumentation

Rail deflections were measured at specific locations on both rails, e.g. 0, 39, and 78 inches from the east rail loading point, and at the west rail loading point. Three sets of deflections were measured at each location: rail head and rail base lateral, and rail base vertical, i.e. gauge side vertical displacement. Figure 6 shows a typical measurement location. All were measured relative to the tie; rail base lateral deflections were measured from the tie plate. During the tests, a thirteenth data channel was added for measuring absolute track vertical deflection, measured relative to a reference framework.

Bending mode rail strain measurements at the east



Material: Hot or Cold Rolled Steel

FIGURE 4. TEST FIXTURE USED TO APPLY VERTICAL AND LATERAL RAIL HEAD LOADS.

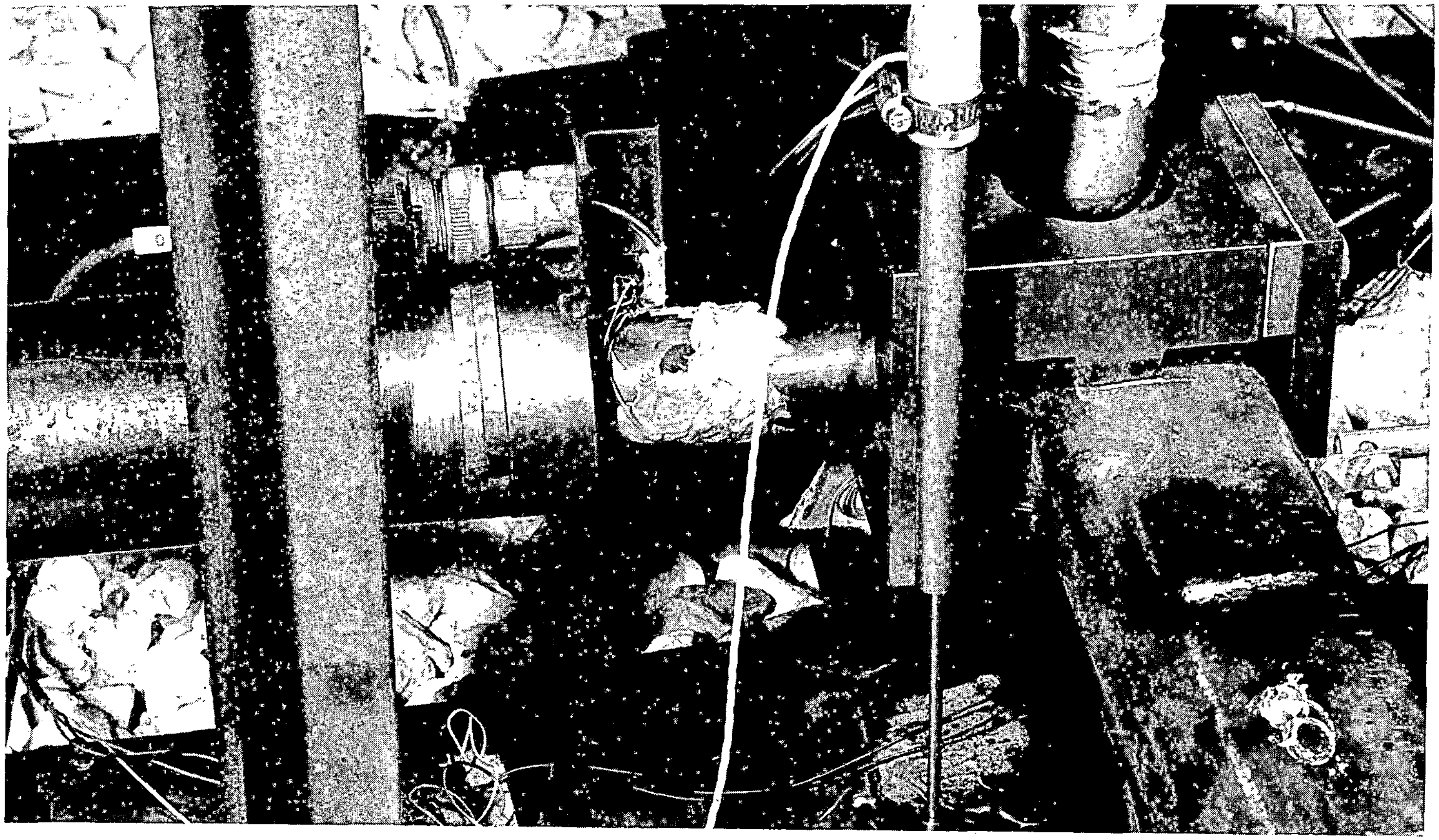


Figure 5. Load Cell Installation For Measuring Lateral Rail Loads.

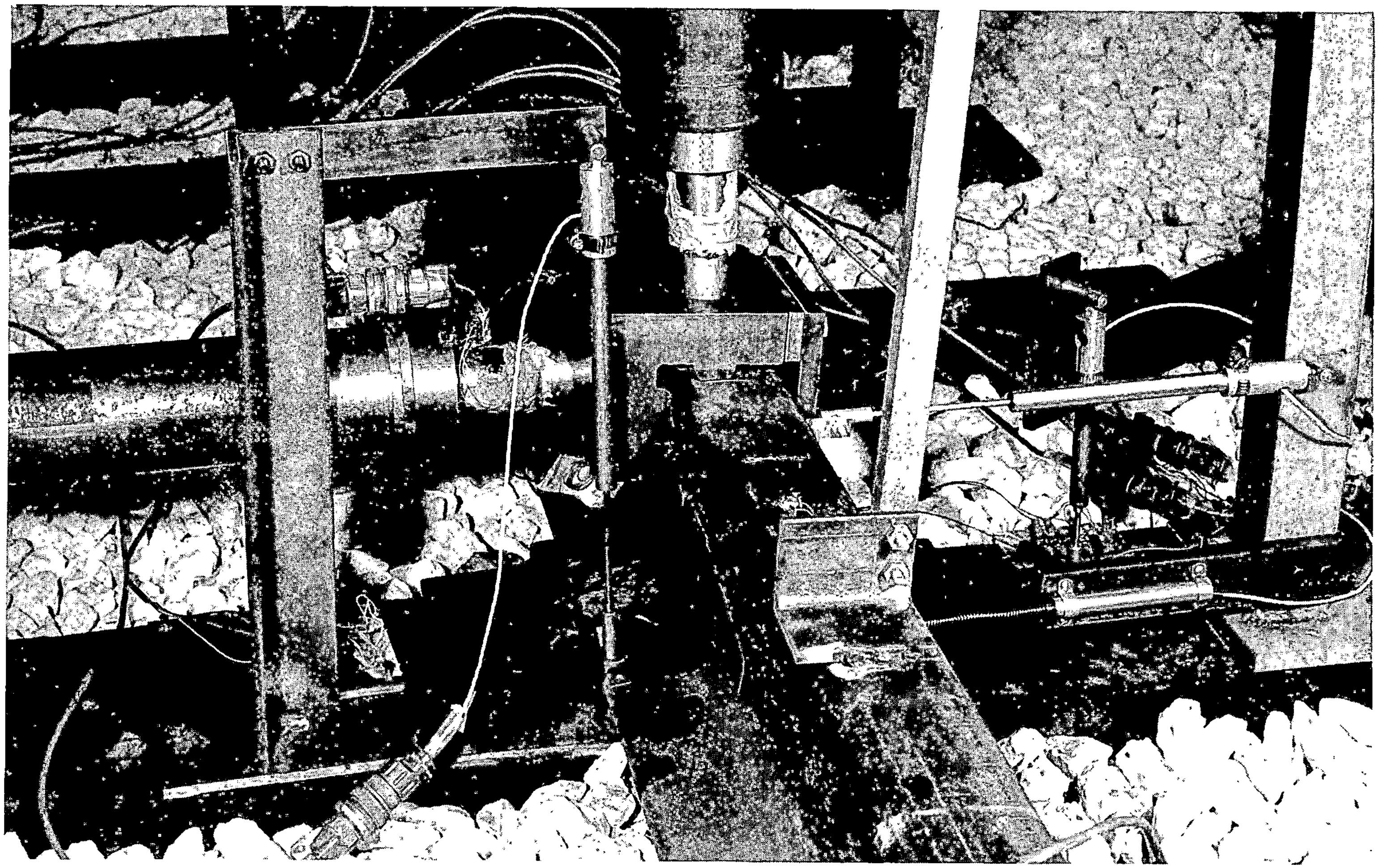


Figure 6. Typical Measurement Location for Rail Deflections: Railhead Lateral and Rail Base Lateral/Vertical.

rail loading point were also taken. Three strain gauges were installed at appropriate locations on the rail to measure the following strains: rail base compression (gauge side) and tension (field side), and rail head tension (field side). Figure 7 is a schematic showing the rail-mounted strain gauge orientations and electrical bridge measurement circuitry.

After instrumentation installation and check-out, the series of basic gauge widening tests was started. Prior to any load application, zero reference readings (for all data channels) were recorded. During the actual loading sequences, the vertical load was applied first and a set of readings taken. The lateral load was then applied and increased until a predetermined deflection of the railhead was reached, at which time the load was held constant and another set of instrument readings taken. Figure 8 shows the test area during a typical basic gauge widening test, with the operator's indicator showing a two inch east railhead deflection. The lateral load was then increased to the next desired deflection value and another set of readings taken. This procedure was continued until the gauge widening limit shown in Table 1 was reached. The lateral load was decreased to zero, the vertical load was then decreased to zero, and the procedure repeated until the first test series (series A shown in Table 1) was completed.

It is important to note that, during the entire test series shown in Table 1, no attempt was made to rearrange or repair the track. The position of each rail after each

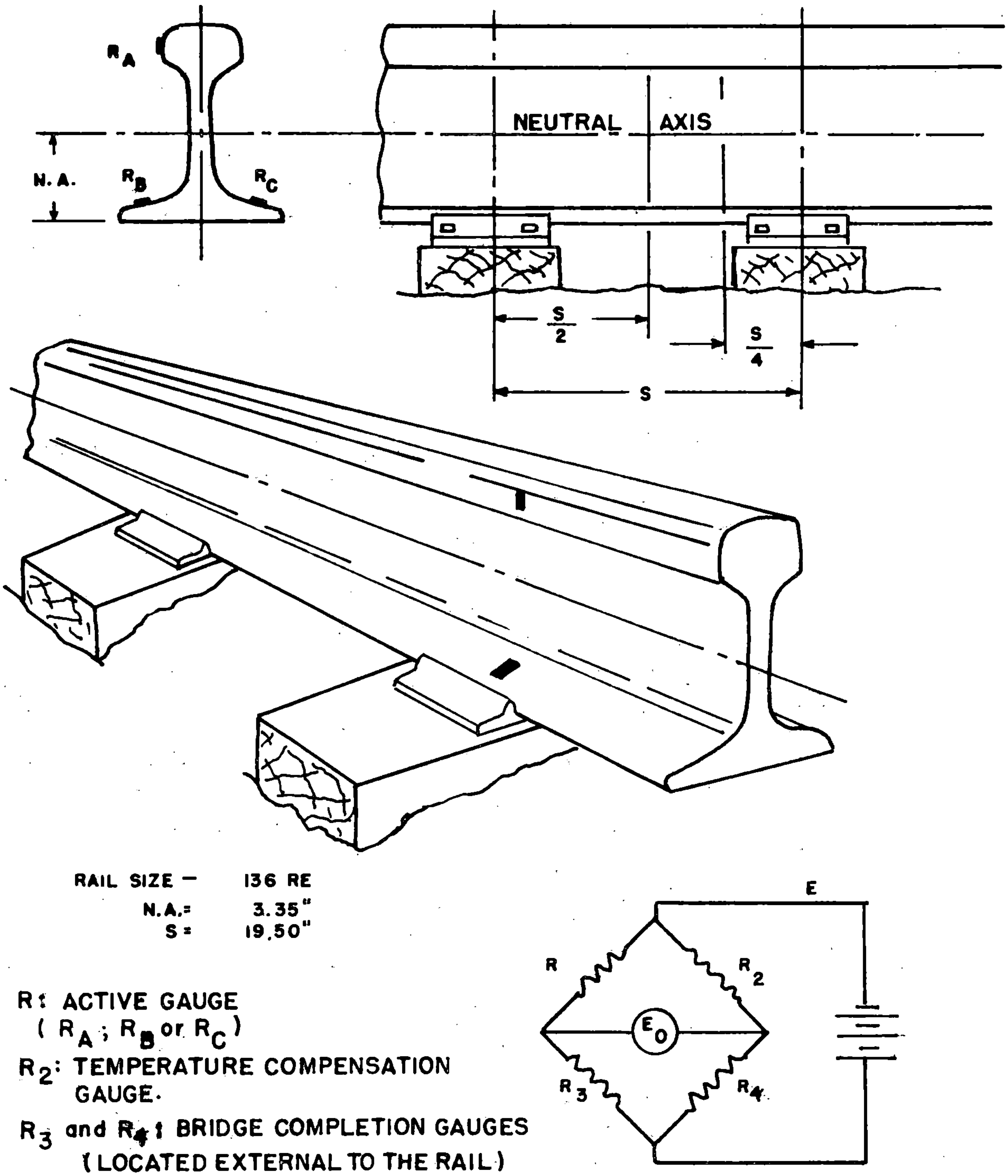


FIGURE 7. SCHEMATIC SHOWING RAIL-MOUNTED STRAIN GAUGE ORIENTATIONS AND ELECTRICAL BRIDGE MEASUREMENT CIRCUITRY.

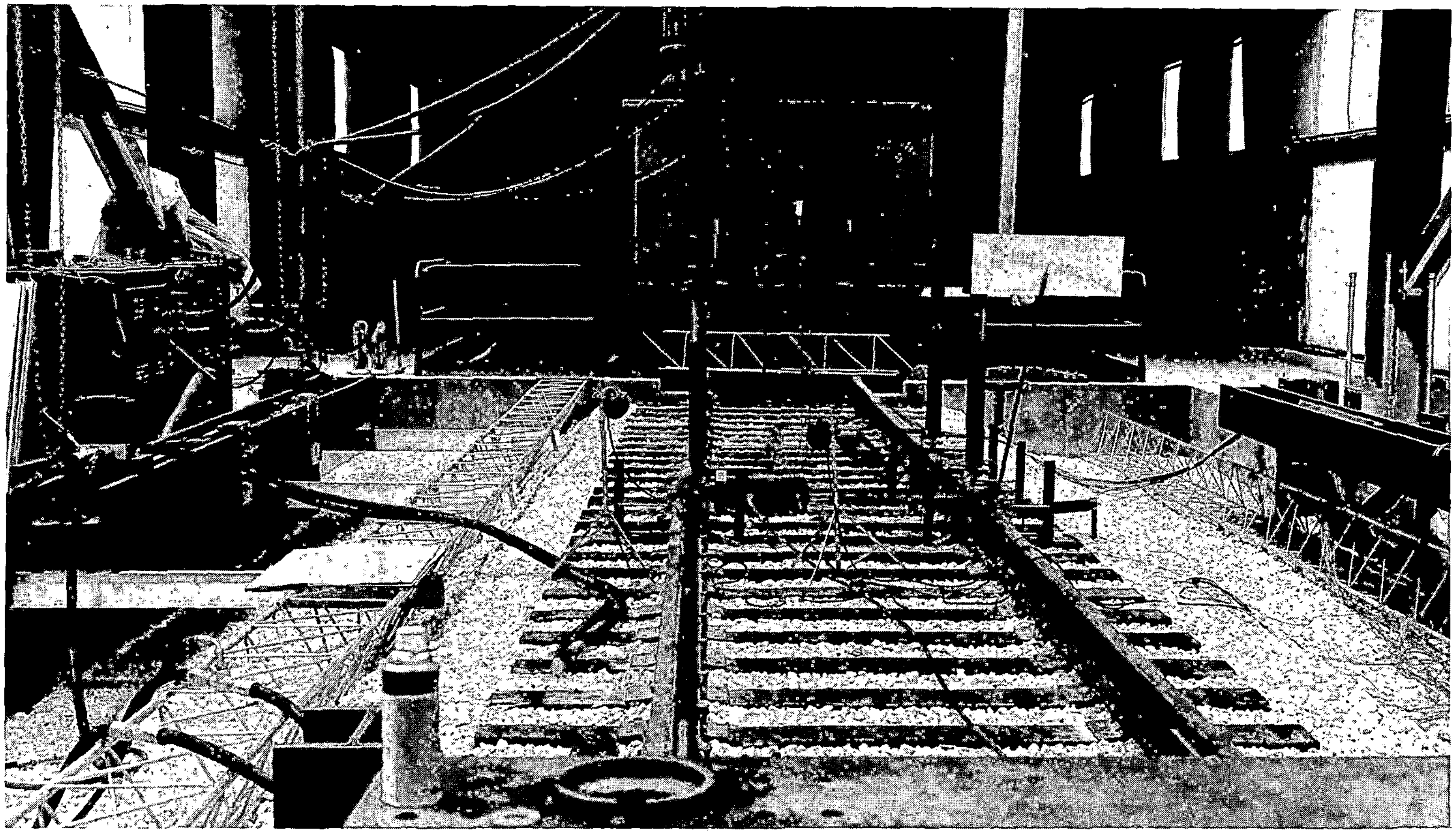


Figure 8. Basic Gauge Widening Tests, With Operator's Indicator Showing Two Inch Deflection of the East Rail Head.

test was taken as the reference zero for the following test.

The same procedure was followed for the series B (gauge spikes removed) and series C (field spikes removed) tests, using the vertical loads and deflection limits shown in Table 1. Figure 9 shows the relative order and locations of the spikes that were removed during test series B and C.

The raw data from these tests were recorded on both magnetic and paper tape, and later reduced, using the technique defined in Reference (6), Appendix A.

3.3 Results

Examples of typical results from this test series are shown in Tables 2 and 3, and Figure 10.

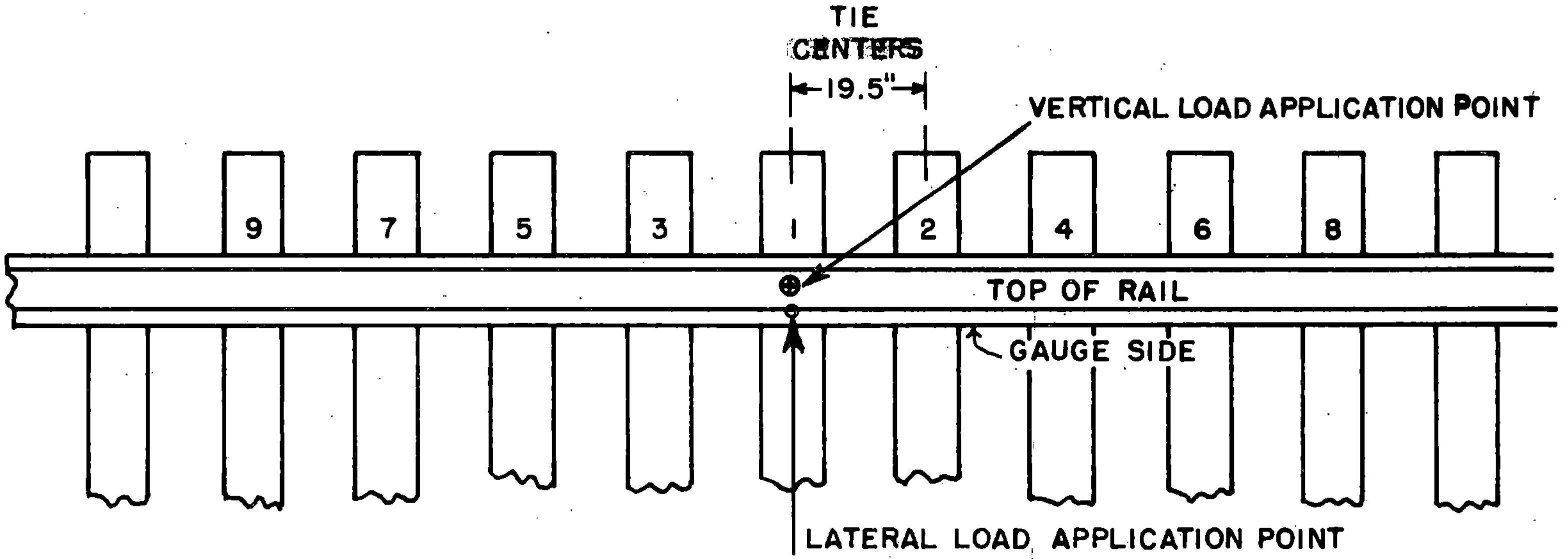
Table 2 shows the rail and absolute track deflections resulting from various lateral loads, for a 5 Kip vertical load.

Table 3 lists the rail strains corresponding to the same lateral loads shown in Table 2.

Figure 10 is a typical graphical data plot, showing various rail deflection vs lateral loads, for zero vertical load.

Complete data tables and graphical plots for the entire "Laboratory Investigation of Track Gauge Widening Characteristics" Test Program are available from the AAR.

Figure 11 is a graph showing lateral vs vertical rail loads from the present tests (for the 0.25 and 0.50 inch gauge widening limits shown in Table 1) in comparison with previous data reported by J. R. Lundgren of the Canadian National (7). Although identical comparisons cannot be made,



NOTE: THE FOLLOWING SPIKES WERE REMOVED AT THE SAME TIME: #4-5, #6-7, #8-9.

FIGURE 9. ORDER OF SPIKE REMOVAL FOR "PULLED SPIKE" TESTS. (SERIES B AND C.)

TABLE 2: BASIC GAUGE WIDENING TESTS - LATERAL LOADS AND RAIL DEFLECTIONS, FOR 5 KIP VERTICAL LOAD.

TEST NUMBER 4
1.00 IN. GAUGE WIDENING LIMIT
NEW TRACK

LATERAL LOAD	DEFLECTIONS (MEASURED AT LOAD APPLICATION POINTS)					
	LAT. RAIL HEAD			LAT.RAIL BASE		
(LB)	(IN.)	(IN.)	(IN.)	(IN.)	(IN.)	(IN.)
82.51	-0.1771	-0.1768	-0.1803	0.0003	-0.0001	-0.0050
4140.60	-0.0943	-0.0704	-0.0289	-0.0001	0.0053	0.0021
4819.44	0.0138	0.0449	0.0976	-0.0003	0.0067	0.0033
6072.12	0.0895	0.1421	0.2217	-0.0004	0.0078	0.0057
7801.12	0.1704	0.2448	0.3523	-0.0005	0.0093	0.0105
9725.15	0.2519	0.3475	0.4834	-0.0005	0.0111	0.0168
11709.19	0.3296	0.4495	0.6121	-0.0004	0.0126	0.0242
13895.75	0.4071	0.5512	0.7404	-0.0003	0.0144	0.0311
16577.39	0.4748	0.6527	0.8694	-0.0004	0.0166	0.0387
14098.28	0.4468	0.6026	0.8024	0.0000	0.0162	0.0368
12500.55	0.4131	0.5513	0.7362	0.0002	0.0158	0.0343
11394.14	0.3804	0.5072	0.6783	0.0003	0.0156	0.0325
10246.47	0.3417	0.4549	0.6141	0.0004	0.0153	0.0302
9136.32	0.3000	0.3997	0.5450	0.0003	0.0150	0.0274
8183.68	0.2642	0.3523	0.4847	0.0003	0.0145	0.0250
6222.15	0.1816	0.2486	0.3516	0.0004	0.0134	0.0195
4406.88	0.1000	0.1443	0.2197	0.0005	0.0120	0.0137
2775.40	0.0255	0.0448	0.0918	-0.0007	0.0103	0.0114
1665.24	-0.0726	-0.0683	-0.0423	0.0000	0.0083	0.0097
37.51	-0.1785	-0.1739	-0.1671	0.0003	0.0059	0.0053

	VERT. RAIL BASE			WEST RAIL			ABS.
				L-H	L-B	V-B	(IN.)
82.51	-0.1507	-0.1617	-0.1647	-0.1515	-0.0024	-0.1440	0.0308
4140.60	-0.0807	-0.0900	-0.0795	0.0434	0.0461	-0.0343	0.0350
4819.44	0.0131	0.0053	0.0229	0.1104	0.0550	0.0151	0.0356
6072.12	0.0803	0.0675	0.1202	0.2547	0.0601	0.1305	0.0371
7801.12	0.1513	0.1321	0.2219	0.3708	0.0660	0.2176	0.0398
9725.15	0.2233	0.2134	0.3251	0.4960	0.0692	0.3127	0.0419
11709.19	0.2918	0.2850	0.4243	0.6162	0.0708	0.4068	0.0440
13895.75	0.3571	0.3589	0.5248	0.7528	0.0736	0.5181	0.0462
16577.39	0.4181	0.4391	0.6254	0.8579	0.0792	0.5981	0.0484
14098.28	0.3947	0.4390	0.5738	0.8020	0.0794	0.5529	0.0485
12500.55	0.3657	0.4387	0.5205	0.7385	0.0791	0.4991	0.0482
11394.14	0.3378	0.4101	0.4754	0.6841	0.0788	0.4516	0.0482
10246.47	0.3047	0.3686	0.4232	0.6205	0.0780	0.3998	0.0475
9136.32	0.2684	0.3231	0.3695	0.5570	0.0770	0.3472	0.0460
8183.68	0.2370	0.2821	0.3223	0.5011	0.0761	0.3023	0.0454
6222.15	0.1653	0.1926	0.2174	0.3780	0.0730	0.2090	0.0412
4406.88	0.0929	0.1022	0.1148	0.2535	0.0719	0.1191	0.0356
2775.40	0.0249	0.0187	0.0162	0.1345	0.0712	0.0311	0.0336
1665.24	-0.0609	-0.0781	-0.0890	0.0329	0.0594	-0.0420	0.0332
37.51	-0.1511	-0.1652	-0.1734	-0.1588	0.0284	-0.1780	0.0342

TABLE 3: BASIC GAUGE WIDENING TESTS - LATERAL LOADS AND RAIL STRAINS, FOR 5 KIP VERTICAL LOAD

TEST NUMBER 4
1.00 IN. GAUGE WIDENING LIMIT
NEW TRACK
VERTICAL LOAD = 5 KIPS

LATERAL LOAD (LB)	STRAINS (MEASURED AT LOAD APPLICATION POINTS) ($\times 10^{-6}$ IN./IN.) RAIL BASE GAUGE SIDE	RAIL BASE FIELD SIDE	RAIL HEAD FIELD SIDE
82.5	93.42	46.55	-19.19
4140.6	-90.44	174.61	177.27
4819.4	-125.78	212.23	228.95
6072.1	-175.94	243.39	314.07
7801.1	-238.07	274.55	425.98
9725.2	-306.85	305.71	548.53
11709.2	-369.55	324.14	679.63
13395.8	-435.48	335.16	821.56
16577.4	-503.82	337.44	990.09
14093.3	-472.72	340.85	875.52
12500.6	-436.43	340.48	785.84
11394.1	-407.17	344.66	718.39
10245.5	-376.39	345.23	643.72
9136.3	-345.23	340.29	570.57
8183.7	-316.73	330.98	509.77
6222.1	-248.71	291.65	376.58
4406.9	-174.61	241.30	250.23
2775.4	-100.13	194.56	139.27
1665.2	-42.94	149.15	56.62
37.5	28.31	82.84	-7.60

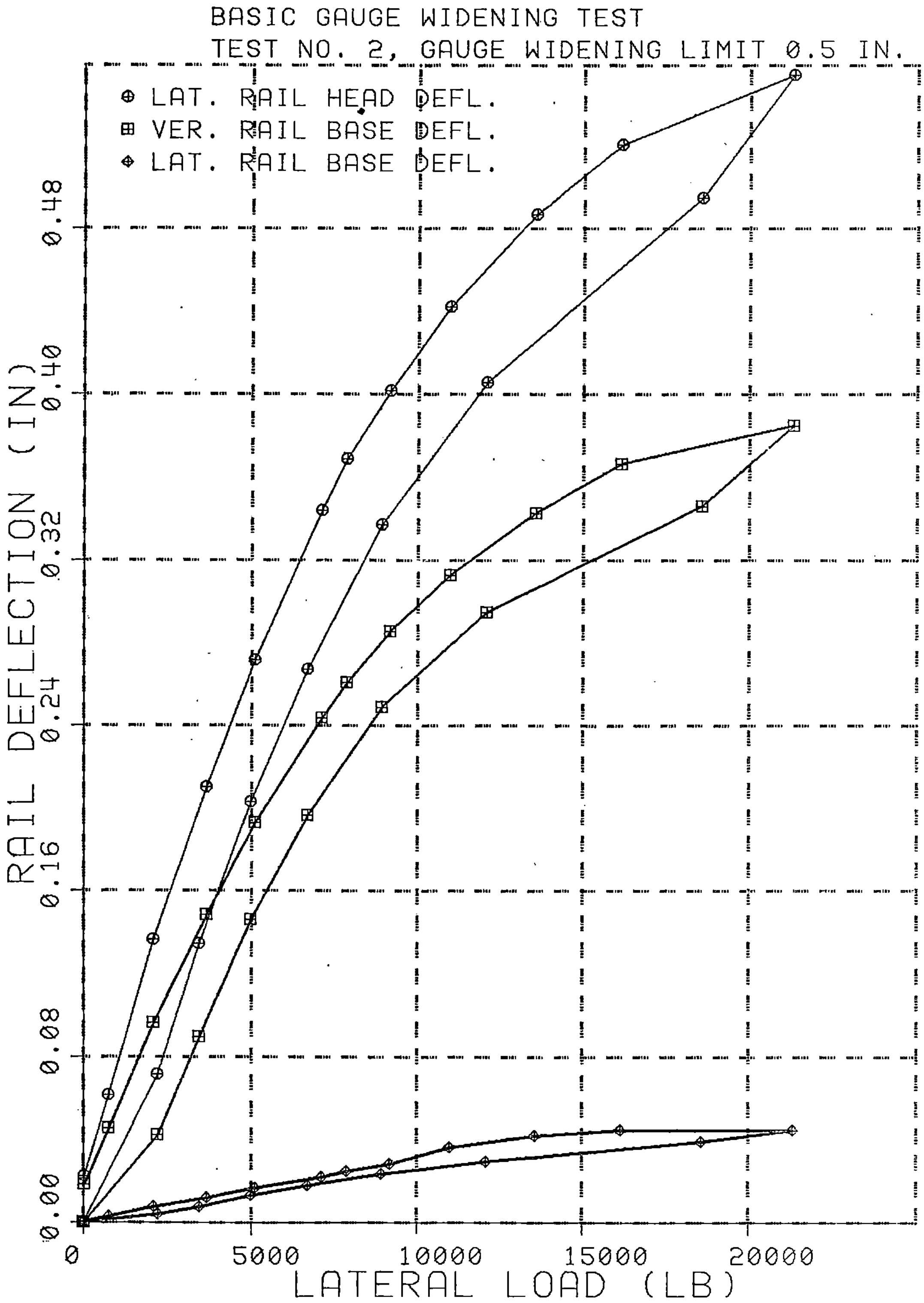


FIGURE 10. GRAPH SHOWING VARIOUS RAIL DELECTIONS VS LATERAL LOADS, FOR ZERO VERTICAL LOAD.

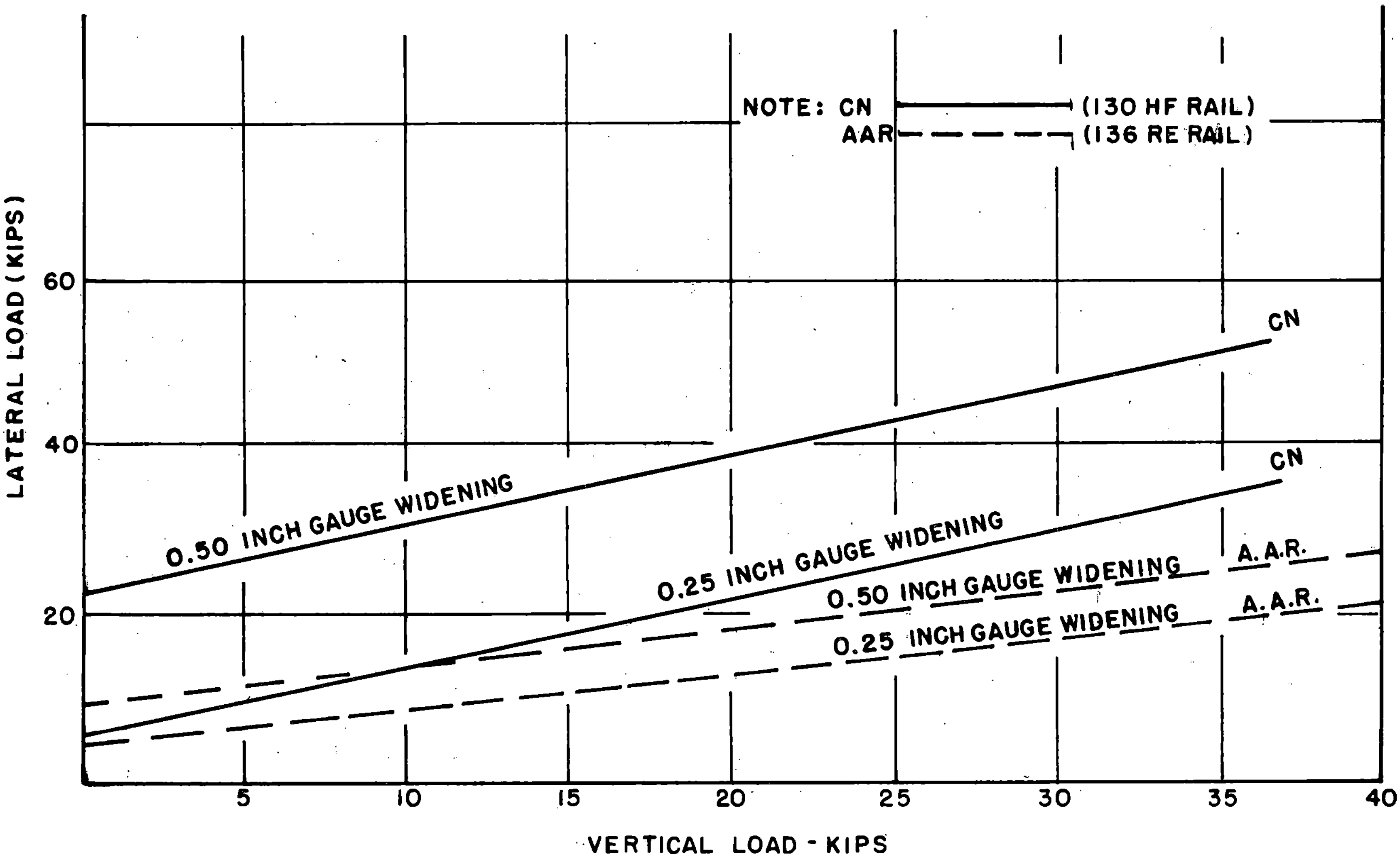


FIGURE 11. LATERAL VS. VERTICAL RAIL LOADS - COMPARISON BETWEEN A.A.R. AND CANADIAN NATIONAL (7) TEST DATA

due to differences in rail size (e.g. 136 RE vs 130 HF rail), fastener conditions and tie conditions, both sets of test data show similar characteristics.

Figure 12 is a graph showing lateral vs vertical rail loads, for 0.20 inch rail head deflections (Test Series A). This graph shows that track that has been progressively loaded to produce correspondingly greater rail head deflections can be considered to be "pre-damaged," because it exhibits progressively lower lateral restraint capabilities.

Figure 13, corresponding to 0.40 inch rail head deflections, shows similar characteristics.

3.4 Conclusions

With reference to Figure 10 it can be seen that, for new track in good condition, most of the measured lateral rail head deflections resulted from rail rotation, since the rail base deflections were minimal.

Figure 12 and 13 indicate that the lateral loads required to displace the rail head by predetermined amounts, decrease when the track has been previously damaged."

Figure 14 is a graph showing measured rail head deflections vs "pre-damaged" deflections (i.e. the maximum predetermined rail head deflections attained during test series A), for various applied loading L/V ratios and a 15 Kip Vertical load.

Figure 15 is similar to Figure 14, but for a 10 Kip applied vertical load.

In order to determine "pre-damaged" railhead deflections by the application of known lateral loads (in the pre-

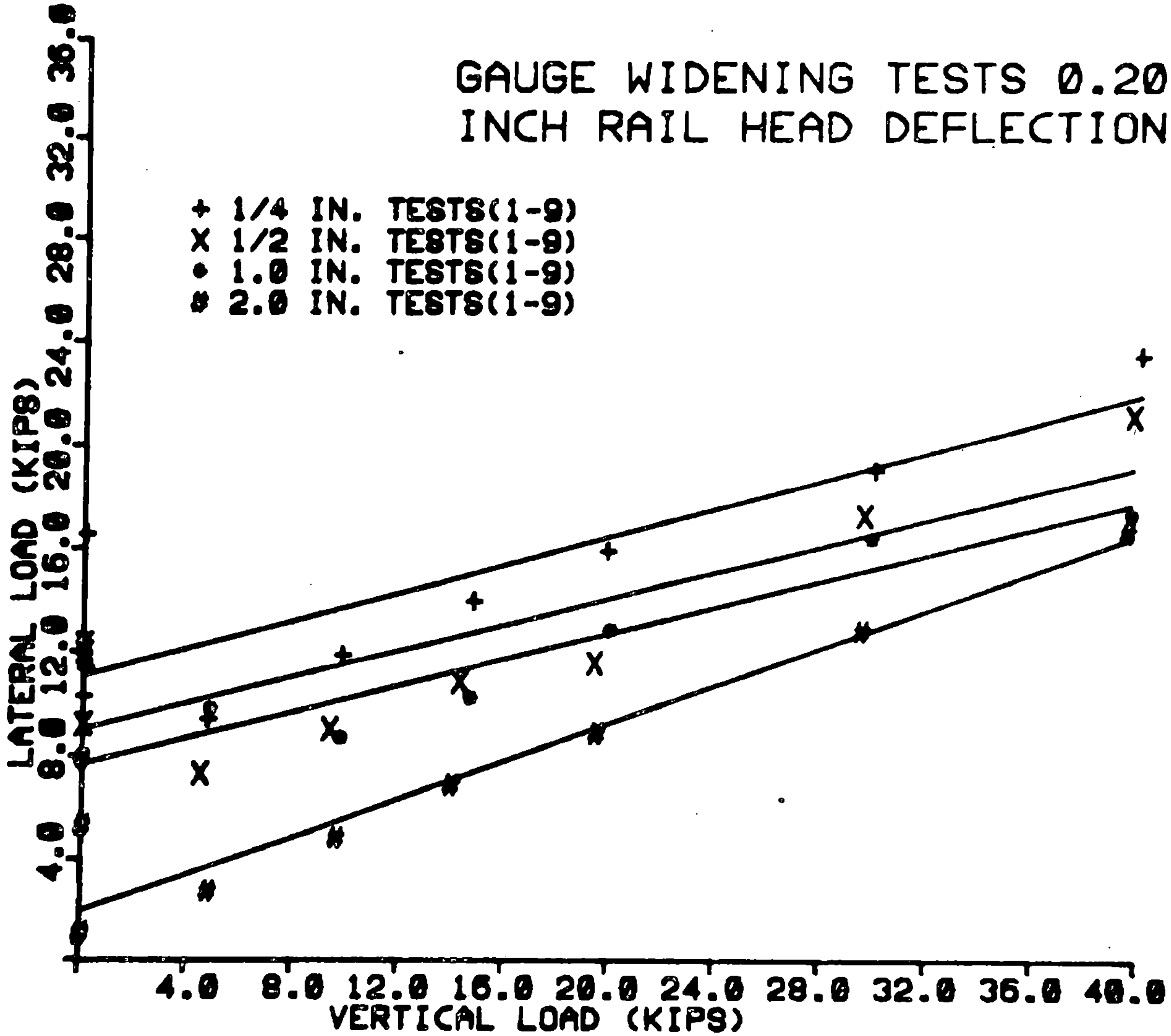


FIGURE 12. LATERAL VS VERTICAL LOADS, FOR 0.20 INCH RAIL HEAD DEFLECTION (TEST SERIES A)

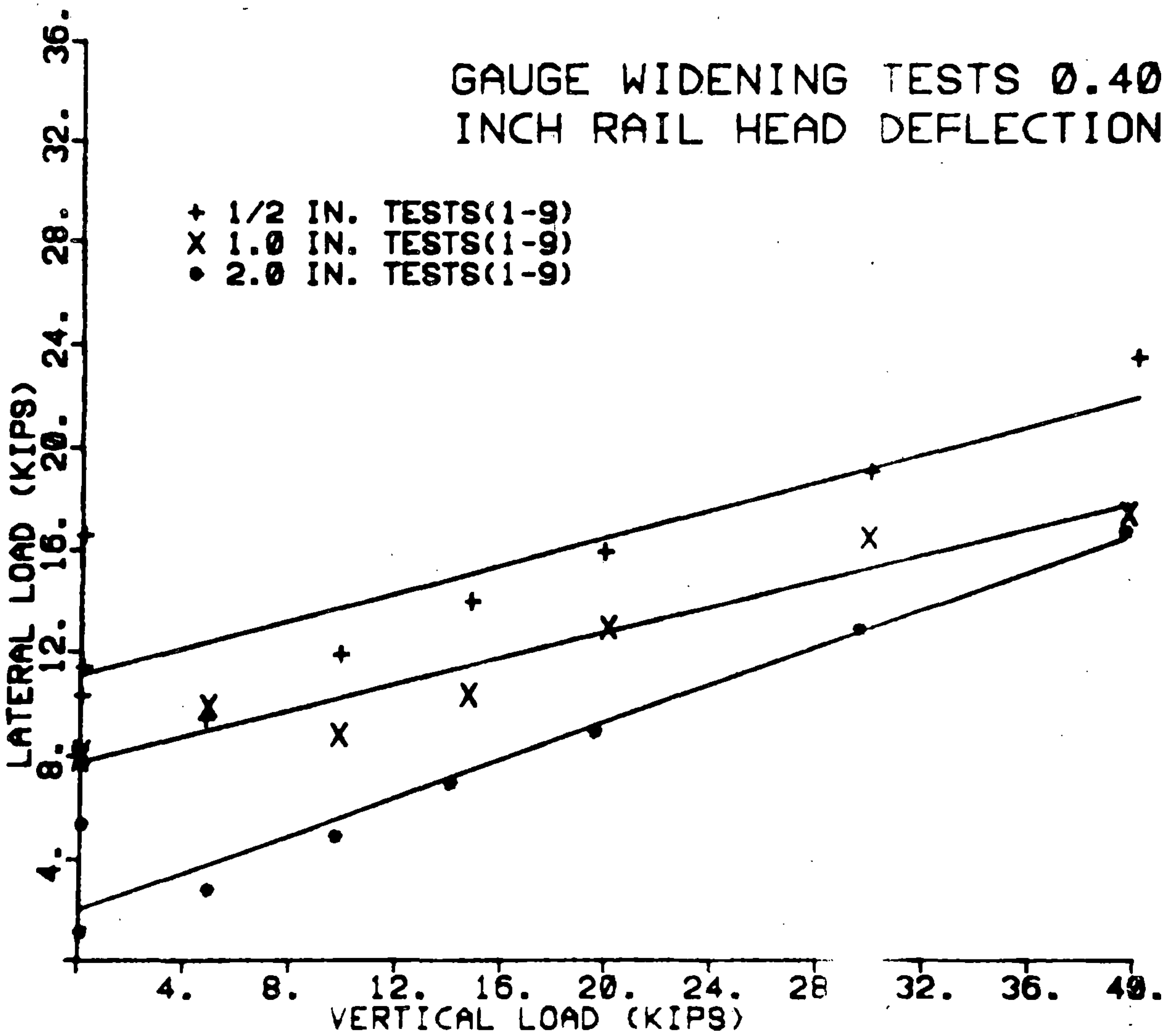


FIGURE 13. LATERAL VS VERTICAL RAIL LOADS OR 0.40 INCH RAIL HEAD DEFLECTION (TEST SERIESS A)

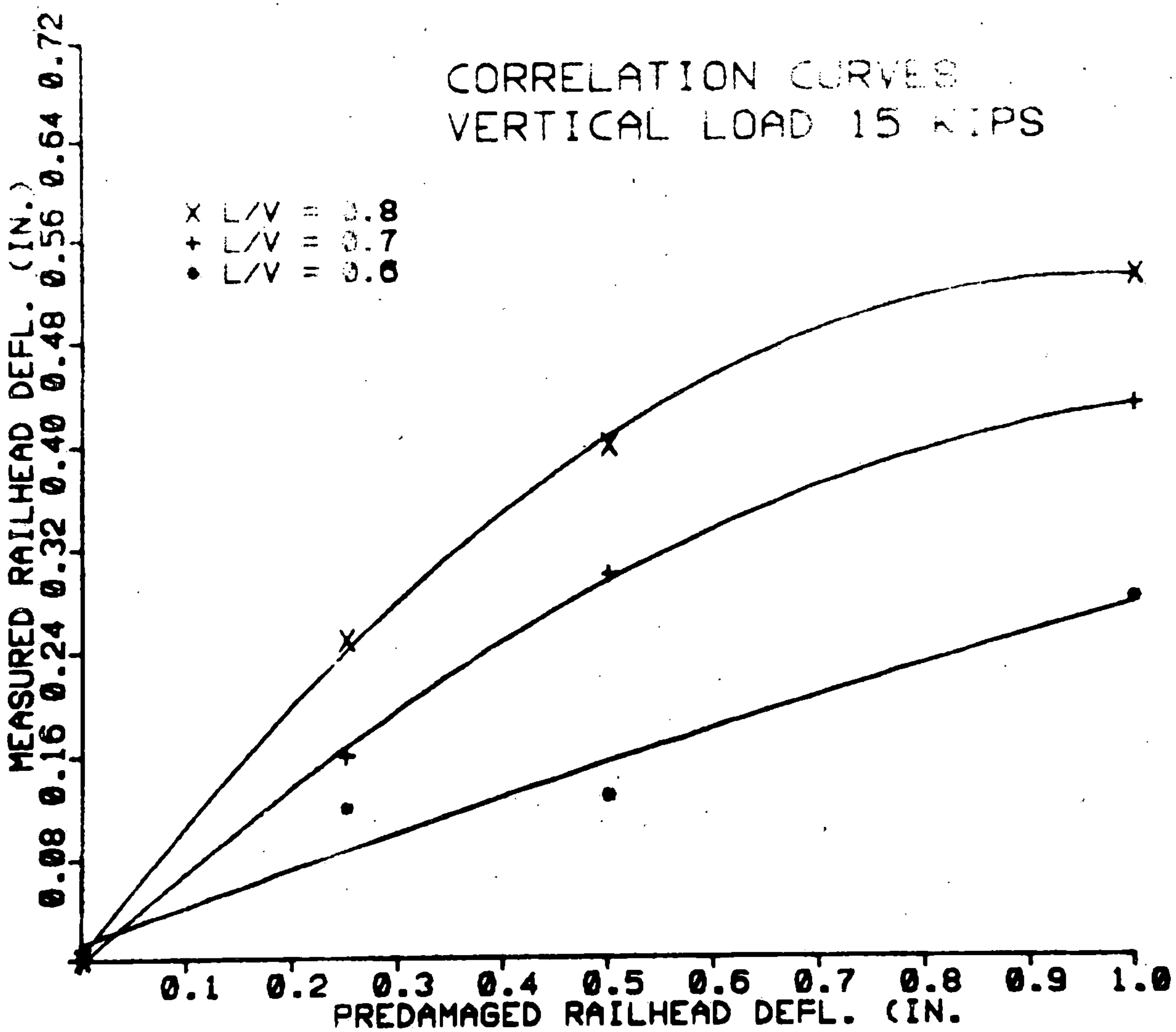


FIGURE 14. MEASURED VS PREDAMAGED RAIL HEAD DEFLECTIONS, FOR VARIOUS L/V LOADING RATIOS, AT CONSTANT VERTICAL LOAD.

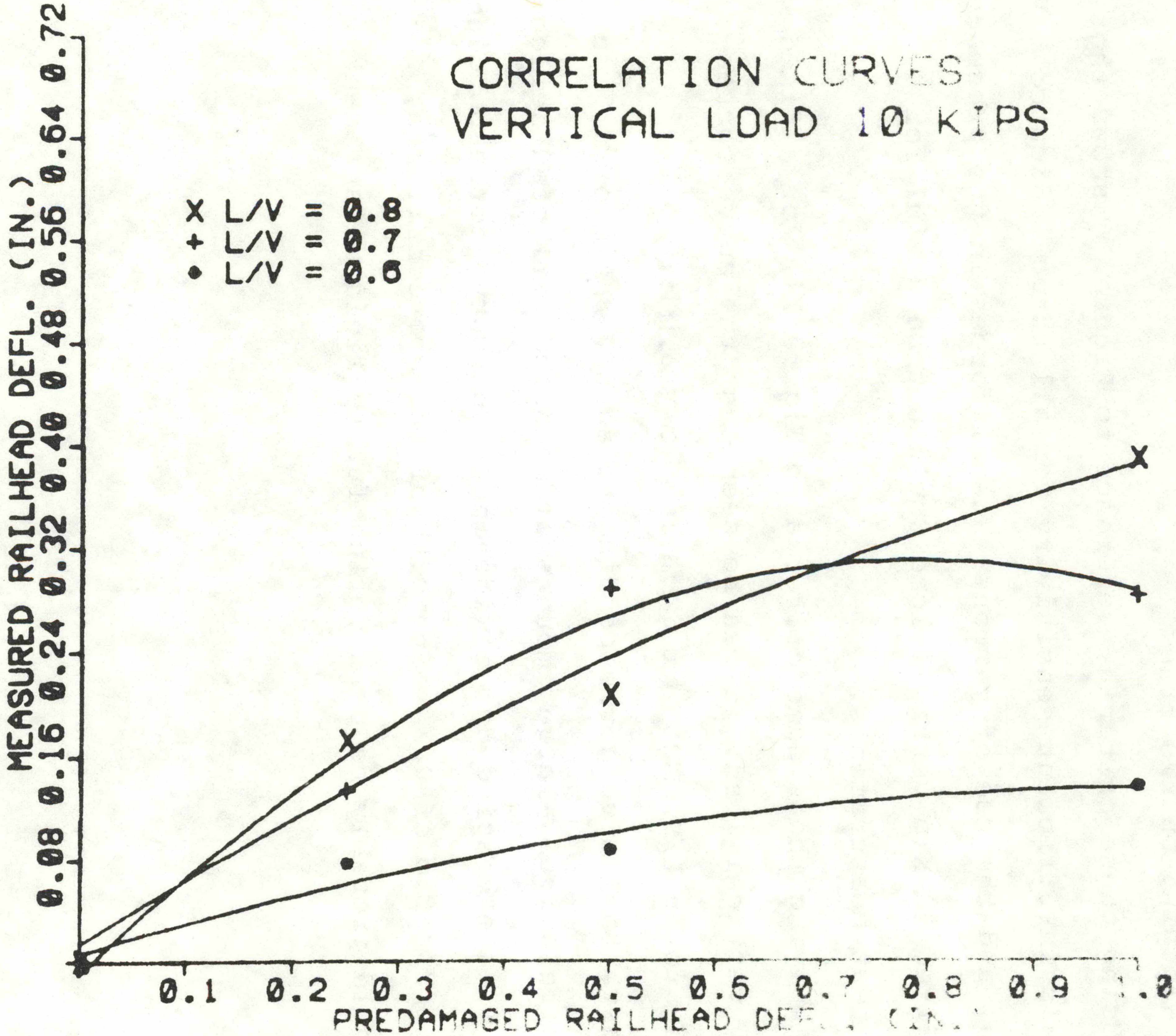


FIGURE 15. MEASURED VS PREDAMAGED RAIL[illegible]
VARIOUS L/V LOADING RATIOS, AT CONSTAN[illegible]

sence of fixed vertical loads), sufficient to produce a predetermined amount of "measured" railhead deflection, the resulting relationships should exhibit good sensitivity (adequate slope), without the need to reach "unsafe" levels of gauge widening on the track.

Using these criteria, reference to Figure 15 shows that there is insufficient sensitivity for all three indicated L/V ratios, and the use of various lateral forces in the presence of a fixed 10 Kip vertical load would not be useful for field test measurements.

Applying these same criteria to Figure 14, for a fixed 15 Kip vertical load, it can be seen that the curve corresponding to an L/V ratio of 0.6 exhibits low sensitivity. In contrast, the curve corresponding to an L/V ratio of 0.8 involves relatively large amounts of measured rail head deflection, i.e. excessive gauge widening. The curve corresponding to an L/V ratio of 0.7 meets both of the above criteria, and could probably be used during future field measurements.

4. ADJACENT LOADS

The purpose of the adjacent load test series was to study the effects of a second (adjacent) set of vertical and lateral loads on the gauge widening characteristics of the track structure. The test series consisted of fifteen tests under varying vertical and lateral load combinations (Table 4). A maximum lateral railhead deflection limit of 0.5 inch was used throughout the series.

4.1 Test Procedure

The test track for the adjacent load test series was the same one used in the basic tests, Section 3.1. The spike holes resulting from the pulled spike tests were filled with Racine Tie Saver and new spikes driven. The remaining spikes were checked, and either redriven or replaced after using Tie Saver to plug the spike holes.

The track was loaded in a manner similar to the previous test series (Figure 2). Adjacent simulated axle loads were applied 70 inches from the primary load, thus approximating the wheel spacing of a 100-ton capacity freight car truck. Both sets of vertical and lateral applied loads were independently controlled during the tests.

Deflections were measured at the four rail loading points. As in the previous test series, three sets of deflection data were taken at each location: lateral railhead, and vertical and lateral railbase deflections. In addition, absolute vertical track deflections, measured at the point of main vertical load application, were also taken, bringing the

TABLE 4: VERTICAL/LATERAL LOADING SEQUENCES

FOR GAUGE WIDENING TESTS WITH SIMULATED

SINGLE AND DUAL-AXLE (TRUCK) LOADINGS

	Primary Load (Simulated Single Axle)		Adjacent Load (Simulated Second Axle)		
	Vertical Load (V1) (Kips)	Lateral Load (L1) (Kips)	Vertical Load (V2) (Kips)	Lateral Load (L2) (Kips)	Gauge Widening Limit (in.)
Group 1	0	*	0	0	0.5
	0	*	10	0	0.5
	0	*	20	0	0.5
	0	*	40	0	0.5
Group 2	20	*	0	0	0.5
	20	*	10	0	0.5
	20	*	20	0	0.5
	20	*	40	0	0.5
Group 3	40	*	0	0	0.5
	40	*	10	0	0.5
	40	*	20	0	0.5
	40	*	40	0	0.5
Group 4	20	15	20	*	0.5
	30	20	30	*	0.5
	40	30	40	*	0.5

* Load increased until gauge widening limit (maximum desired displacement of railhead) was obtained.

total number of data channels to thirteen.

The test loadings, as defined in Table 4, were divided into four groups:

1) Various adjacent vertical loads (V2), for zero primary vertical (V1) and zero adjacent lateral (L2) loads: 4 Tests
2) Various adjacent vertical loads (V2), for 20 Kip primary vertical (V1) and zero adjacent lateral (L2) loads: 4 Tests
3) Various adjacent vertical loads (V2), for 40 Kip primary vertical (V1) and zero adjacent lateral (L2) loads: 4 Tests
4) Various equal primary (V1) and adjacent (V2) vertical loads, for various primary lateral (L1) loads: 3 Tests

In the four tests in Group 1, each vertical adjacent load (V2), shown in Table 4, was first applied. The primary lateral load (L1) was then applied and increased incrementally until a total rail head deflection of 0.5 inch was obtained. Deflection data was also taken for each incremental step. This lateral load (L1) was then decreased incrementally to zero, with corresponding deflection data readings being taken. Each test was concluded when the vertical load (V2) was released to zero. The procedure was then repeated for the remaining tests in Group 1. For Group 2 and 3, the same test procedure was used, however, only the adjacent vertical load (V2) were released after each test, since V1 was being held constant. In the Group 4 tests, the vertical loads V1 & V2 were first applied, the constant lateral load (L1) was then applied, and finally the adjacent lateral load (L2) was increased incrementally to produce a 0.5 inch maximum rail head deflection. The railhead deflections for this test group were measured at the adjacent lateral load (L2) application point. At the conclusion of each test in Group 4, all of the applied loads were released to zero.

4.2 Results

The results of this adjacent load test series are presented here in a manner similar to those from the basic gauge widening tests. For a complete set of the test results, the reader is referred to the AAR.

A typical set of data (Group 2 - Test B) is presented in Table 5 and shown graphically in Figure 16. Table 5 shows all of the various applied loads and the corresponding measured deflections, including lateral railhead (L-H), lateral railbase (L-B) and vertical railbase (V-B). Table 5 also includes the primary lateral loads (L1) at which the deflections were measured, and the primary (V1) and adjacent (V2) vertical loads on the track. The graph shown in Figure 16 is a plot of various deflections (rail head lateral and rail base lateral/vertical vs applied primary lateral load, for constant primary and adjacent vertical loads. Most of the rail head deflection resulted from rail rotation, since less than ten percent of the total deflection was cause by rail base displacement.

Figure 17 is a graph showing railhead deflection vs primary lateral load, for various adjacent vertical loads and a 20 Kip primary vertical load. Figure 18 is similar, but

TABLE 5: GAUGE WIDENING TESTS - ADJACENT LOADS
PRIMARY VERTICAL LOAD (V1) = 20 KIPS
ADJACENT VERTICAL LOAD (V2) = 10 KIPS
ADJACENT LATERAL LOAD (L2) = ZERO

DEFLECTIONS

(ADJACENT LOADING POINT)

PRIMARY LATERAL LOAD (L1)	EAST RAIL			WEST RAIL		
	L-H	L-B	V-B	L-H	L-B	V-B
(LB)	(IN.)	(IN.)	(IN.)	(IN.)	(IN.)	(IN.)
9264.97	0.0005	-0.0002	0.0004	-0.0002	-0.0001	0.0004
12883.21	0.0019	-0.0002	0.0014	0.0012	-0.0001	0.0004
15755.31	0.0061	0.0002	0.0039	0.0078	0.0005	0.0006
17952.51	0.0144	0.0005	0.0087	0.0161	0.0017	0.0011
20108.46	0.0276	0.0008	0.0179	0.0439	0.0019	0.0222
22110.68	0.0472	0.0008	0.0337	0.0691	0.0021	0.0429
25110.27	0.0657	0.0010	0.0485	0.1018	0.0021	0.0695
28949.74	0.0786	0.0011	0.0593	0.1182	0.0021	0.0835
34240.25	0.0848	0.0008	0.0652	0.1228	0.0020	0.0870
25998.90	0.0806	0.0011	0.0599	0.1177	0.0022	0.0828
21679.49	0.0623	0.0008	0.0451	0.0832	0.0023	0.0562
19752.26	0.0474	0.0005	0.0331	0.0587	0.0024	0.0372
17821.28	0.0247	0.0005	0.0154	0.0316	0.0026	0.0166
15560.34	0.0110	-0.0001	0.0068	0.0119	0.0018	0.0043
13153.18	0.0066	-0.0002	0.0040	0.0041	0.0005	0.0011
10524.79	0.0022	-0.0004	0.0013	-0.0006	0.0001	-0.0005
4630.61	0.0002	-0.0005	0.0004	-0.0022	0.0000	-0.0010
86.24	-0.0011	-0.0005	-0.0003	-0.0028	-0.0001	-0.0013

(PRIMARY LOADING POINT)

	EAST RAIL			WEST RAIL			ABS.
	L-H	L-B	V-B	L-H	L-B	V-B	
9264.97	0.0476	0.0105	0.0016	0.0413	0.0076	0.0098	0.0006
12883.21	0.0991	0.0142	0.0297	0.0787	0.0114	0.0335	0.0020
15755.31	0.1508	0.0184	0.0641	0.1416	0.0152	0.0811	0.0032
17952.51	0.2021	0.0225	0.1013	0.1984	0.0180	0.1256	0.0045
20108.46	0.2542	0.0261	0.1408	0.2683	0.0207	0.1827	0.0060
22110.68	0.3047	0.0298	0.1792	0.3309	0.0234	0.2313	0.0072
25110.27	0.3564	0.0350	0.2152	0.4027	0.0271	0.2865	0.0102
28949.74	0.4075	0.0412	0.2480	0.4579	0.0331	0.3250	0.0128
34240.25	0.4602	0.0516	0.2788	0.5014	0.0410	0.3473	0.0161
25998.90	0.4064	0.0482	0.2466	0.4513	0.0381	0.3157	0.0158
21679.49	0.3447	0.0449	0.2020	0.3650	0.0359	0.2473	0.0146
19752.26	0.3022	0.0431	0.1688	0.3087	0.0348	0.2022	0.0142
17821.28	0.2523	0.0407	0.1311	0.2458	0.0334	0.1504	0.0133
15560.34	0.1942	0.0379	0.0866	0.1798	0.0319	0.0970	0.0116
13153.18	0.1471	0.0344	0.0525	0.1233	0.0292	0.0531	0.0101
10524.79	0.0979	0.0296	0.0194	0.0798	0.0261	0.0217	0.0088
4630.61	0.0456	0.0151	0.0035	0.0342	0.0147	0.0039	0.0060
86.24	0.0074	0.0055	-0.0012	0.0054	0.0037	-0.0003	0.0048

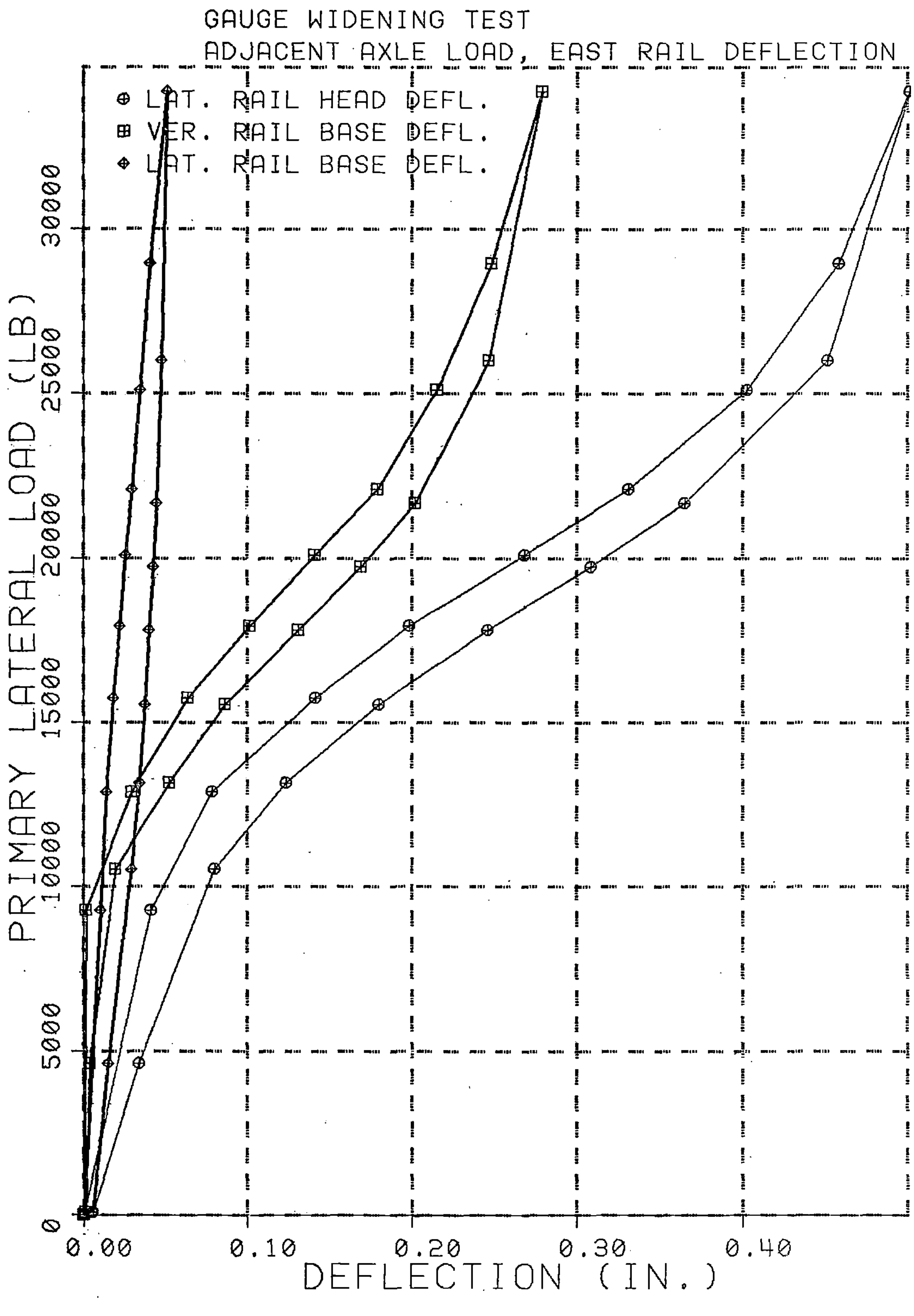


FIGURE 16. RAIL HEAD DEFLECTION VS PRIMARY LATERAL LOAD, FOR CONSTANT 20 KIP PRIMARY VERTICAL AND 10 KIP ADJACENT VERTICAL LOAD

for a 40 Kip primary vertical load.

With reference to Figure 17, for applied primary lateral loads below 15 Kip, and corresponding railhead deflections up to 0.15 inch, the magnitude of the applied adjacent vertical load has little effect. For higher values of rail head displacement, however, adjacent vertical loads have an apparent "stiffening" effect on the track structure. Similar comments also apply to the data, shown graphically in Figure 18, with the exception that the adjacent vertical loads have an even greater track "stiffening" effect.

From the twelve tests in Groups 1, 2, and 3, the primary lateral loads required to displace the rail head 0.4 inch were determined. These values were then plotted vs primary vertical load, for various values of adjacent vertical load, as shown in Figure 19 . (The indicated slopes were calculated using the least - square method.). This graph shows that the lateral load required to displace the rail head by 0.4 inch increases with increasing adjacent vertical loads.

4.3 Conclusions

Referring to Figure 19, the lateral load required to displace the rail head 0.4 inch increases when an adjacent vertical load is present. As an example, for a 40 Kip vertical load (V1) there is a 22% difference in the lateral load (L1) requirement in the presence of a 40 Kip adjacent vertical load (V2). This difference is also apparent in Figure 18.

In order to compare the relative effects of simulated

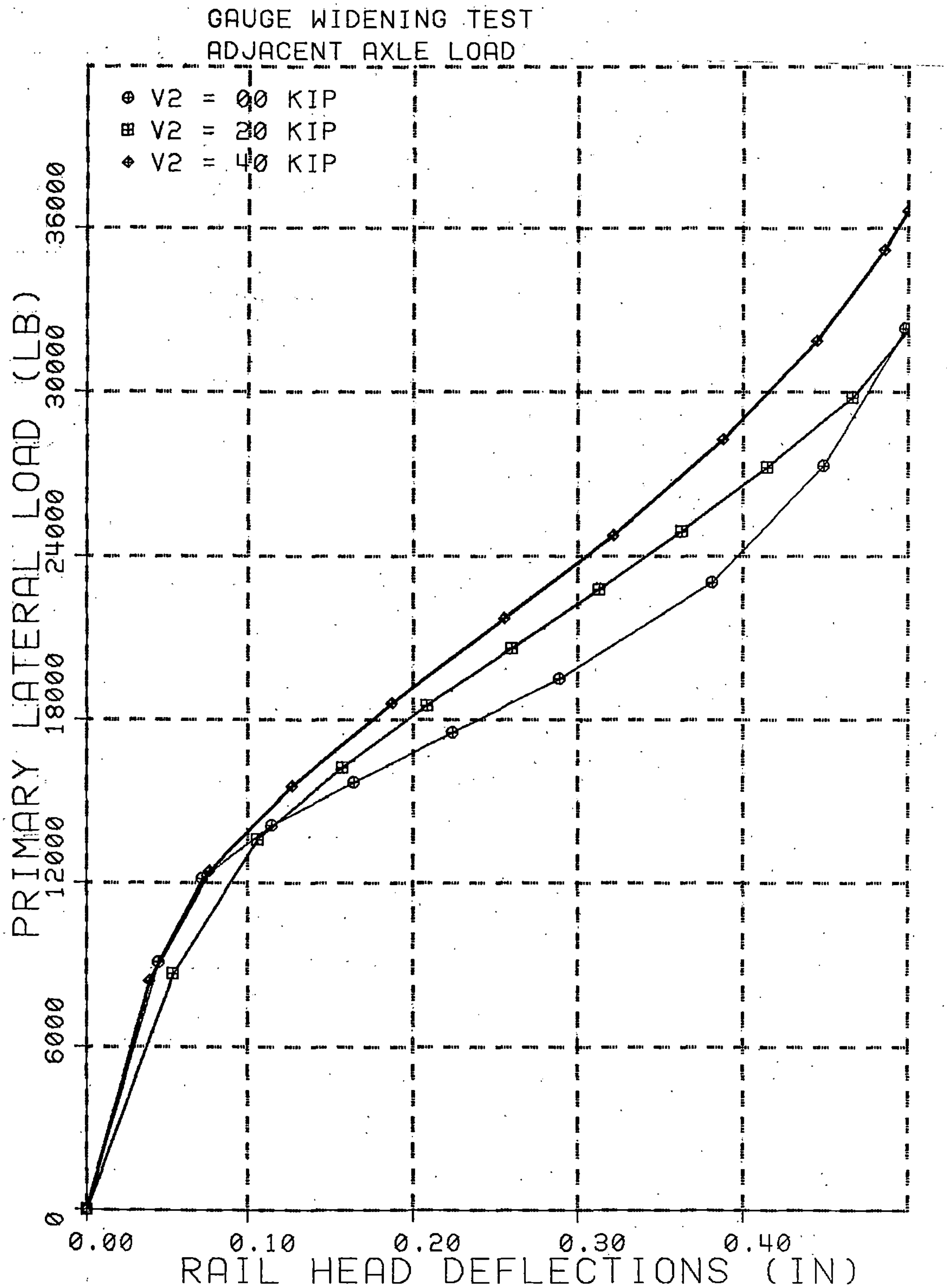


FIGURE 17. RAIL HEAD DEFLECTION VS PRIMARY LATERAL LOAD, FOR VARIOUS ADJACENT VERTICAL LOADS AND CONSTANT 20 KIP PRIMARY VERTICAL LOAD.

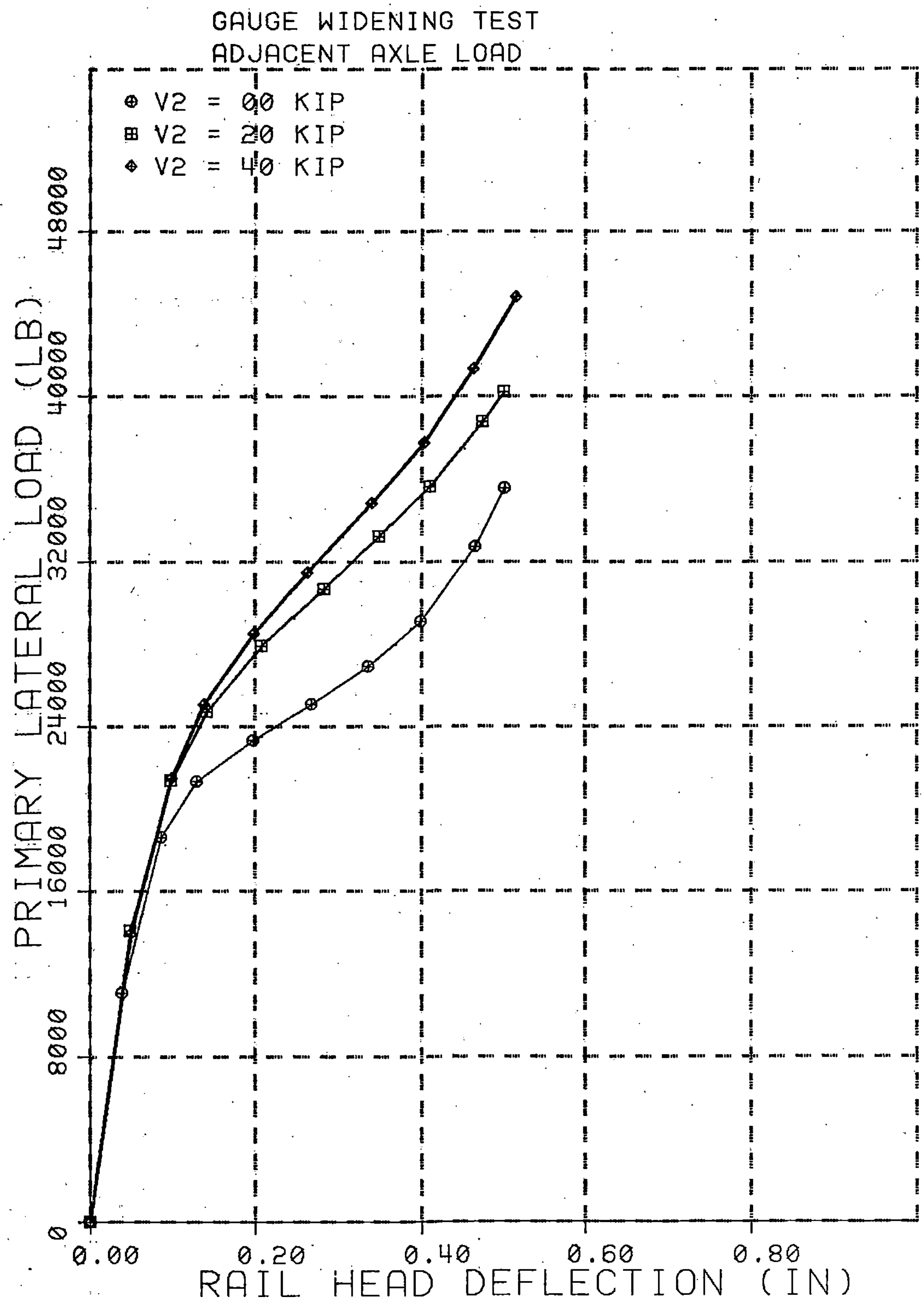


FIGURE 18. RAIL HEAD DEFLECTION VS PRIMARY LATERAL LOADS, FOR VARIOUS ADJACENT VERTICAL LOADS AND CONSTANT 40 KIP PRIMARY VERTICAL LOAD.

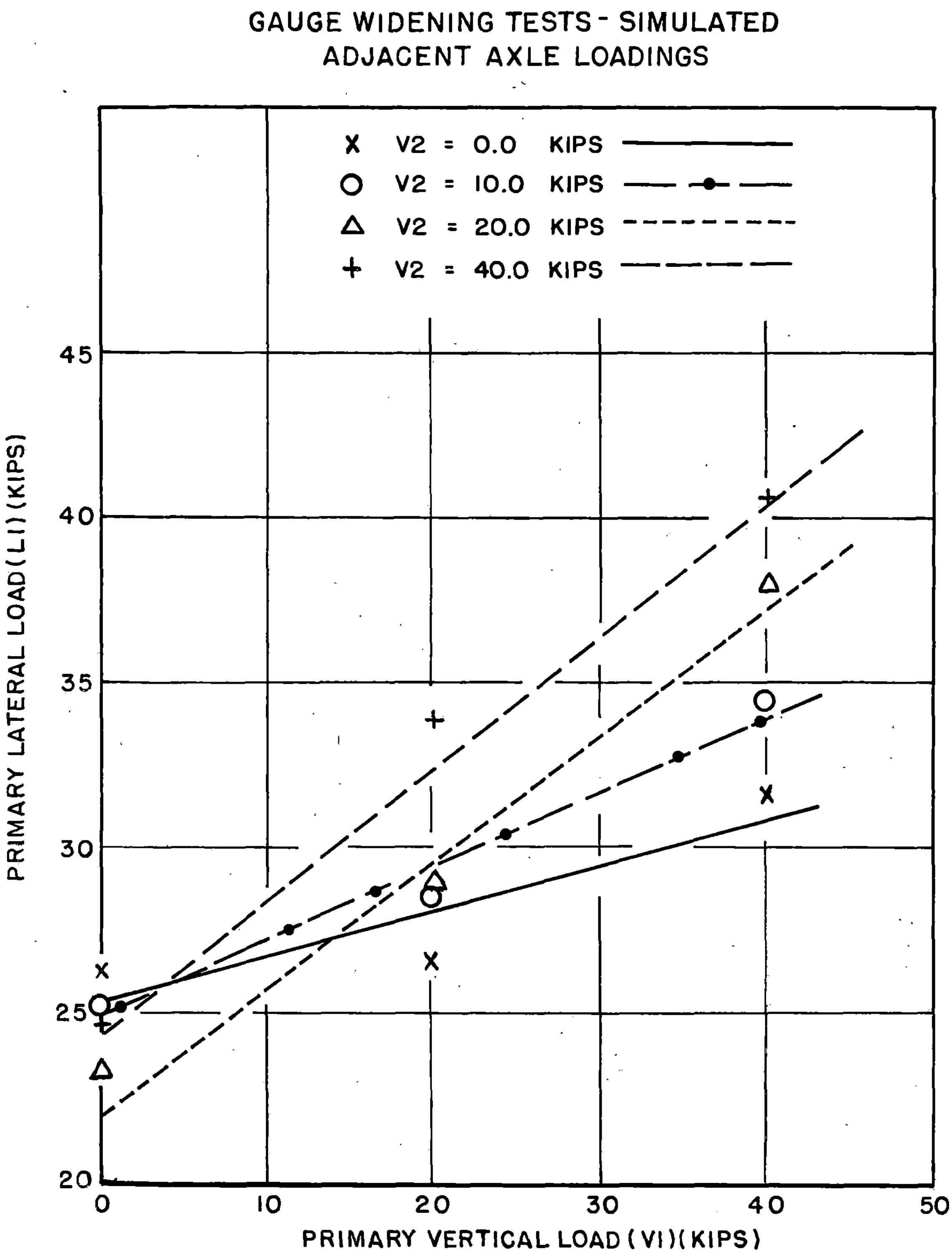


FIGURE 19. PRIMARY VERTICAL VS. PRIMARY LATERAL LOADS REQUIRED TO PRODUCE 0.4 INCH OF RAIL HEAD DEFLECTION FOR VARIOUS ADJACENT VERTICAL LOADS.

single and dual-axle loadings upon gauge widening, the corresponding L/V ratios were calculated from the measured data, and plotted vs railhead deflections, as shown in Figure 20. For simulated single axle loadings, significant railhead deflections were obtained for L/V ratios greater than 0.5. In contrast, simulated dual-axle (truck) loadings produced significant rail head displacements (e.g. as much as 0.40 inch) with L/V ratios equal to or less than 0.5.

Based on the results of this test series, it can be concluded that the presence of adjacent vertical loads increases the gauge widening resistance of the track structure.

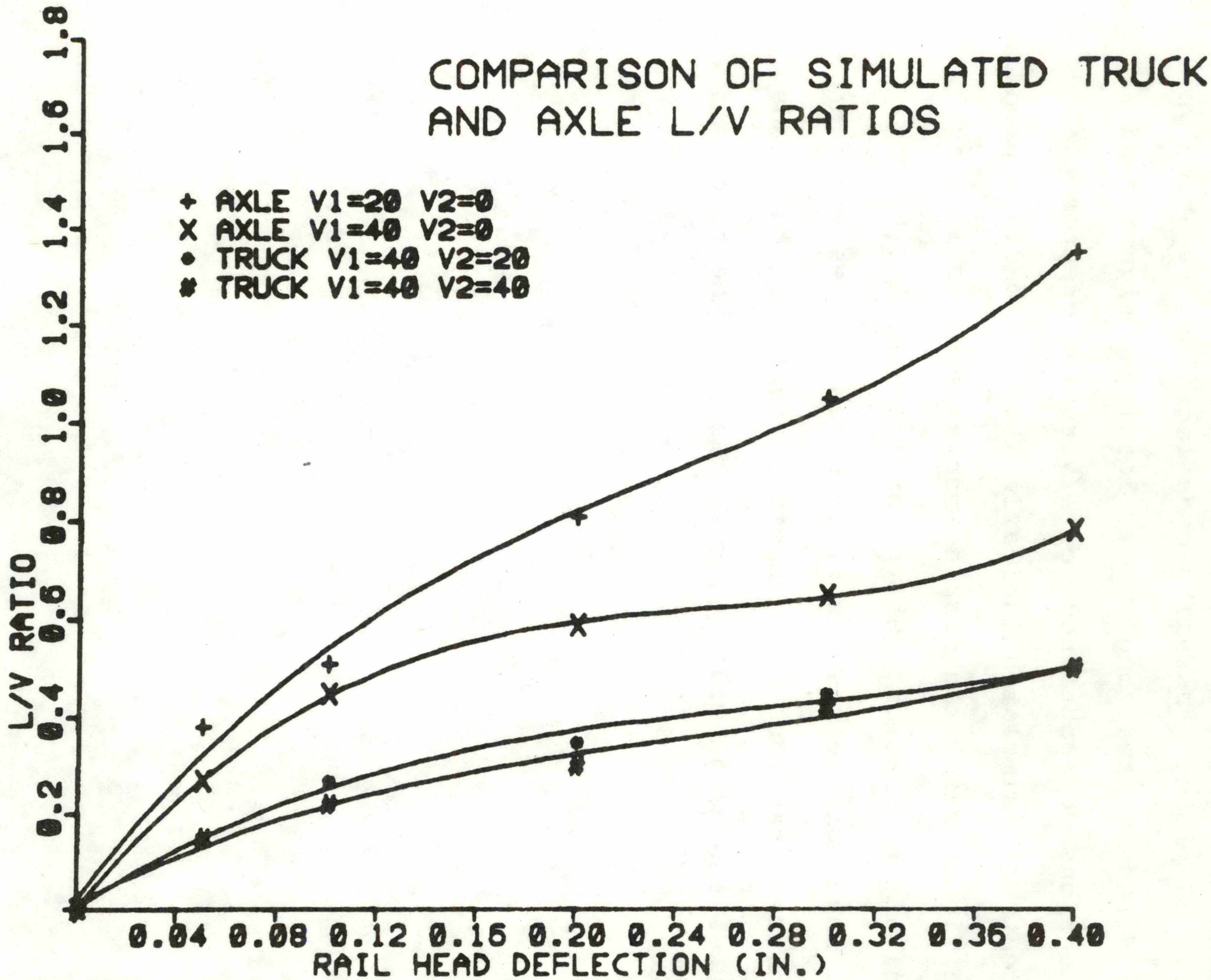


FIGURE 20. RAIL HEAD DEFLECTIONS VS SIMULATED SINGLE AND DUAL-AXLE (TRUCK) L/V RATIOS.

5. DYNAMIC LOADS

In order to examine the effects of dynamically-applied lateral impuse loads on gauge widening, a series of dynamic load tests were conducted. Table 6 shows the nine separate vertical/lateral loading sequences, each involving impulse loads for seven different time durations.

5.1 Test Procedure

The set-up for the dynamic gauge widening test series differed from the previous tests in that the lateral loading was applied only to one rail. The same test track was used, but the west rail was braced (at a point opposite the load application point on the east rail) to prevent movement.

Figure 21 shows the bracing arrangement of the west rail, consisting of five tie plates with one edge placed under the west rail head, and the other spiked to their associated ties.

The Amsler hydraulic system was used to apply static vertical loads to both test track rails, as in the earlier test series. The lateral load, applied to the east rail only, was obtained from the same hydraulic system used in the earlier test runs, except for system modifications to enable the generation and application of dynamic impulse loads, of variable time duration. Figure 22 shows the schematic diagram for the hydraulic impulse loading system. The principal system components were as follows: Webster 40 HP pump, with rated capacity of 20 gallons per minute at 2000 psi (maximum); hydrualic accumulator, 10 gallon capacity at 3000 psi (maximum); directional control valve,

TABLE 6. VERTICAL/LATERAL LOADING SEQUENCES FOR DYNAMIC GAUGE WIDENING TESTS

STATIC VERTICAL LOAD (Kips)	LATERAL IMPULSE LOADS	
	PEAK AMPLITUDE (Kips)	TIME DURATION (Milliseconds)
0	10	A
0	20	A
0	30	A
20	10	A
20	20	A
20	30	A
40	10	A
40	20	A
40	30	A

NOTE A: 50, 100, 200, 500, 1000, 2000 and 5000 Milliseconds.

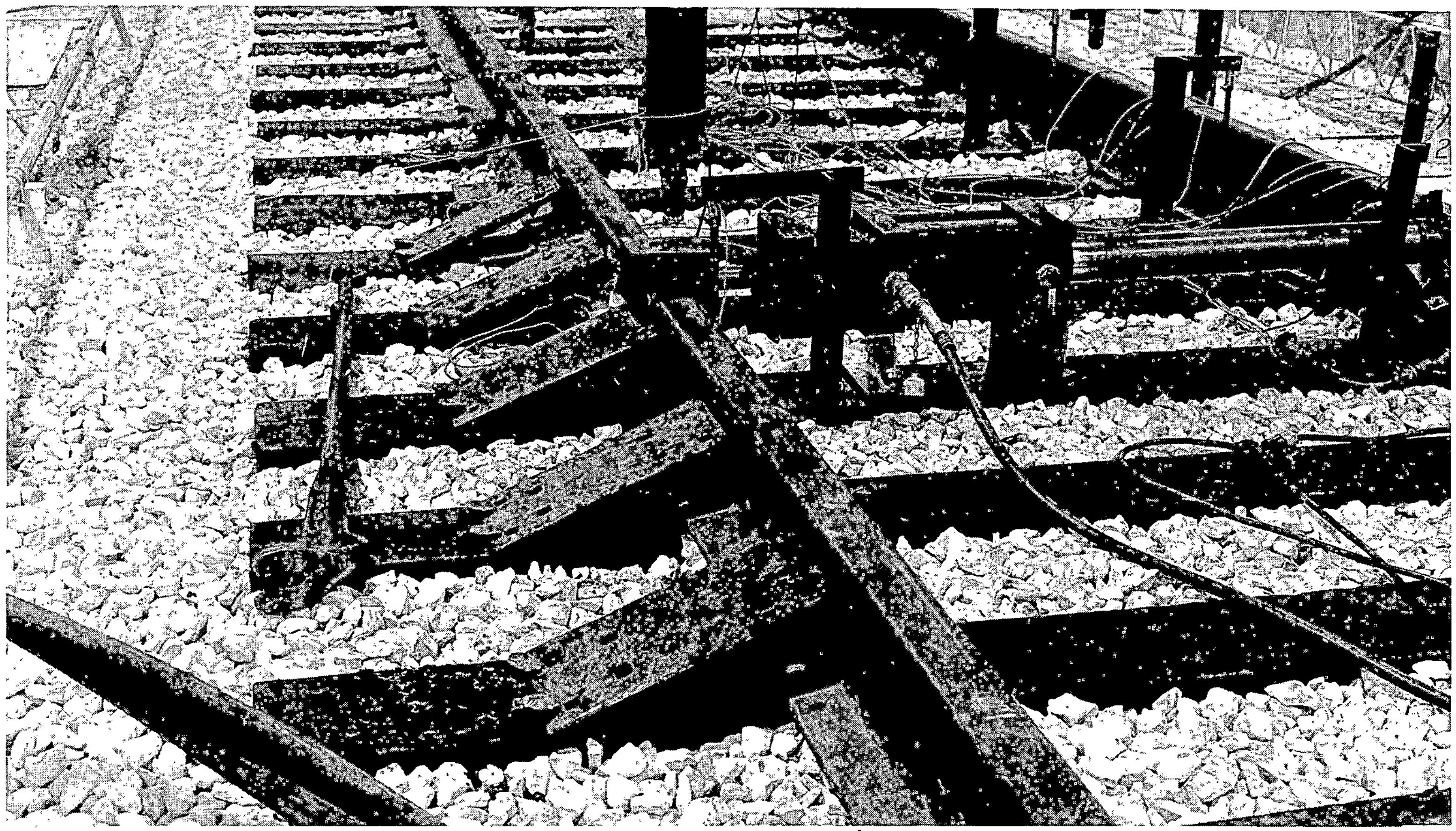


Figure 21. West Rail Bracing Arrangement for Dynamic Gauge Widening Tests.

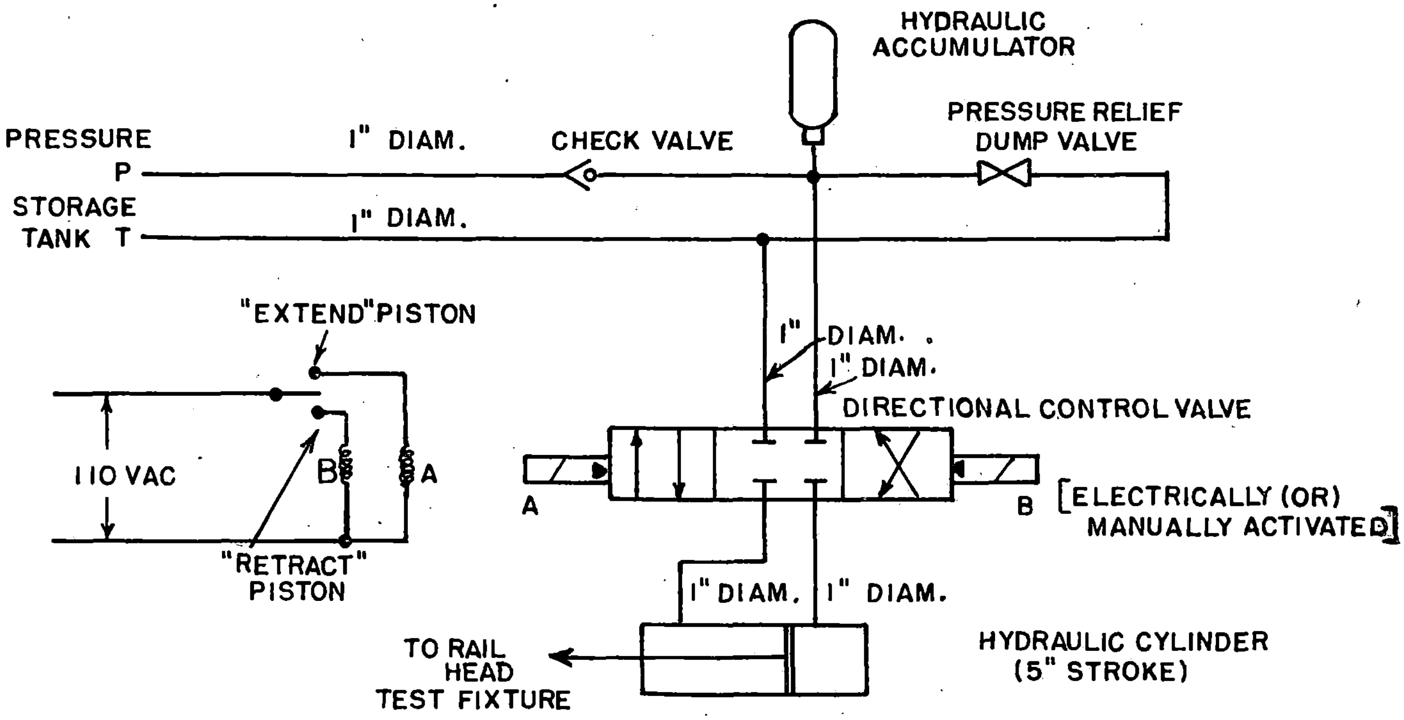


FIGURE 22. SCHEMATIC DIAGRAM FOR HYDRAULIC IMPULSE LOADING SYSTEM

electrically or manually activated.

The lateral impulse load time durations were controlled by means of the directional control value. Load cells, of the type shown earlier in Figure 5, were used to measure lateral load amplitudes and time durations. The east railhead lateral and rail base lateral/vertical deflections were measured at the lateral loading point. Analog recording instrumentation, shown in Figure 23, was used to record the data on both magnetic tape and oscillograph charts.

During each test, the vertical loads were first applied to both rails, and the hydraulic accumulator charged up to the required pressure. Subsequent operation of the directional control valve allowed the pressurized hydraulic fluid from the accumulator to flow into the hydraulic cylinder, producing a dynamic lateral impulse load that was applied to the east rail head. This procedure was then repeated until all seven impulse load time durations had been applied to the east rail. The vertical loads were then released, and the test track structure checked for damage (No damage was noted in any of the tests). The above procedure was then repeated in accordance with the desired loading sequences shown in Table 6. Figure 24 shows the general test track arrangement during the dynamic gauge widening tests.

Each of the nine tests (shown in Table 6) was originally run using an electrically-activated directional control valve, resulting in impulse loading waveforms whose time durations could not be adequately controlled or reproduced.

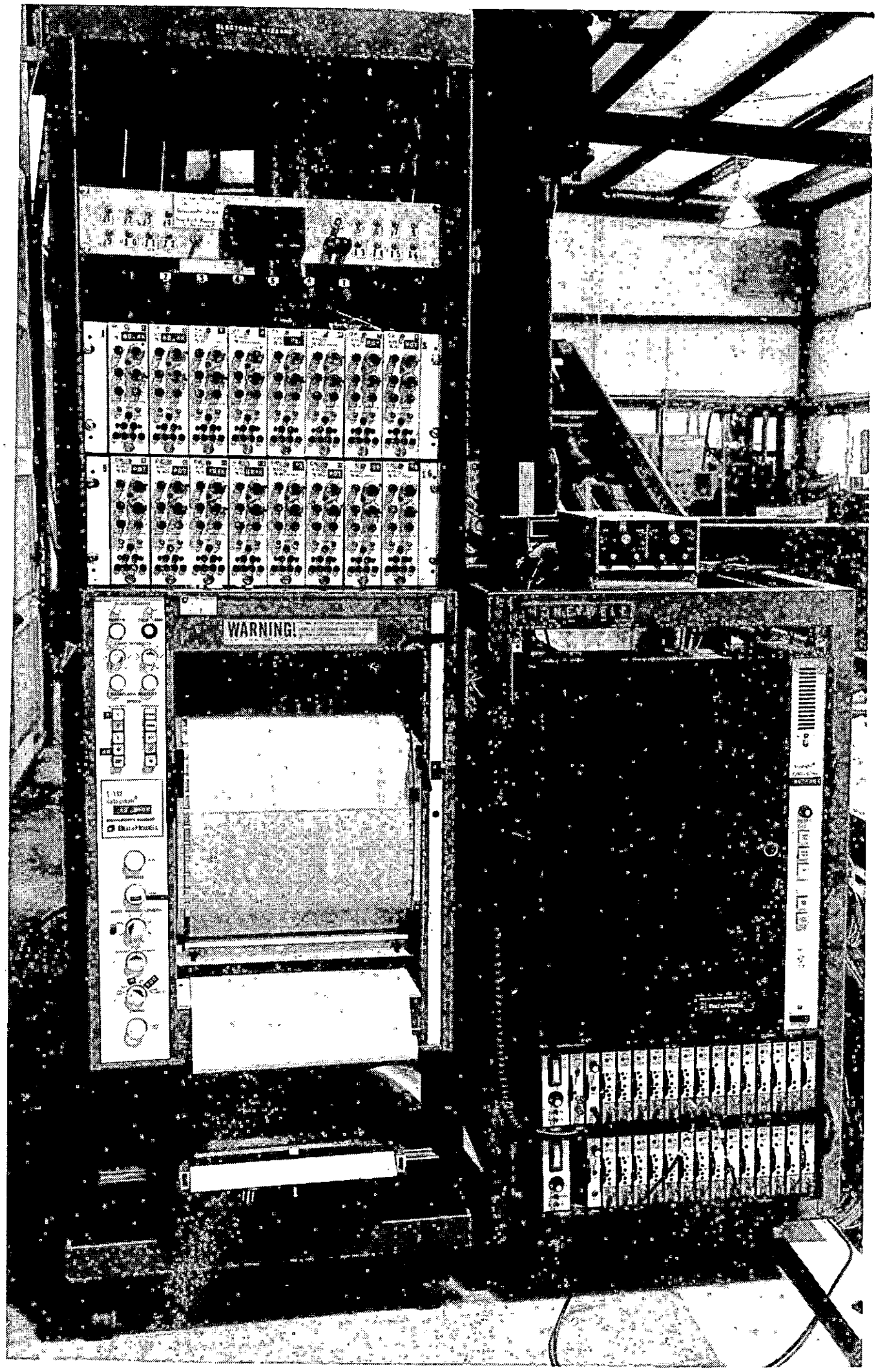


Figure 23. Analog Recording System Used
in the Dynamic Gauge Widening Tests.

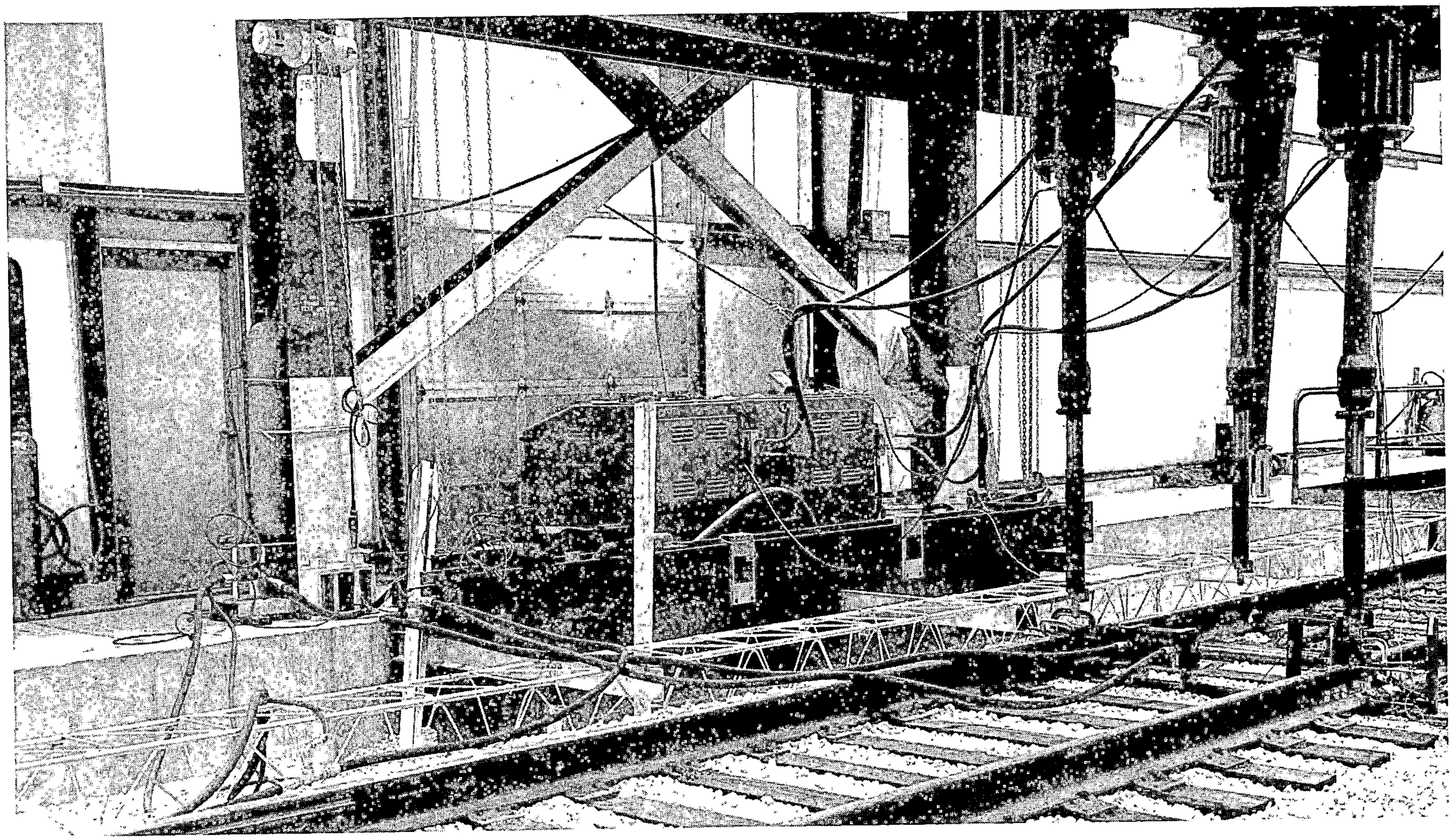


Figure 24. Test Set-Up for Dynamic Gauge Widening Tests.

This valve was then replaced by a manually-activated valve, which resulted in much better control and generation of the desired waveforms. All nine tests were then repeated to obtain more consistent data.

5.2 Results

Table 7 shows the results from a typical dynamic test run, although the remaining data obtained during the dynamic loading test series are available from the AAR.

Figure 25 is a typical graph showing lateral rail head deflection vs time durations of a 19.5 Kip lateral impulse load, for a constant 40 Kip vertical load.

Figure 26 is a typical recording oscillograph trace showing the waveforms of a 9.7 Kip lateral impulse load, and the resulting 0.05 inch east rail head deflection, for a constant 40 Kip vertical load. It should be noted that the applied lateral impluse load and resulting rail head deflections are in phase, both exhibit some oscillatory behavior, and both waveforms decay relatively rapidly.

5.3 Conclusions

From the trace relationships shown in Figure 26, the following conclusions can be made:

1. The in-phase nature of the two waveforms indicates no physical separation occurring between the impulse loading jack stilt and the rail head test fixture.
2. A dynamically-loaded rail head exhibits a slightly oscillatory displacement waveform, which correlates with the results from published mathematical models (8) for this type of system.

TABLE 7. DYNAMIC GAUGE WIDENING TESTS - LATERAL IMPULSE LOADS AND RAIL DEFLECTIONS, FOR VARIOUS VERTICAL LOADS.

DYNAMIC IMPULSE
TEST 4
RUN 1

LATERAL LOAD (LB)	TIME (MSEC) RISE	DURATION	FALL	DEFLECTION (IN) RAIL HEAD	RAIL BASE	RAIL BASE LIFT	VERTICAL LOAD (LB)
23556	200	500	150	.525	.038	.336	19,037
15970	200	1000	175	.313	.025	.186	6,012
11977	200	300	200	.207	.019	.103	9,017
10380	150	600	175	.116	.019	.052	12,023
7985	150	1500	150	.078	.006	.026	19,428
7895	150	1700	150	.090	.006	.013	20,039
9981	125	1800	125	.052	.006	.010	20,039
9981	125	1675	150	.039	.006	.010	20,039
9981	125	1875	150	.052	.006	.010	20,039

RUN 2

LATERAL LOAD (LB)	TIME (MSEC) RISE	DURATION	FALL	DEFLECTION (IN) RAIL HEAD	RAIL BASE	RAIL BASE LIFT	VERTICAL LOAD (LB)
9981	25	125	25	.073	.018	.016	20,039
9981	25	225	25	.032	.012	.008	20,039
9669	50	350	25	.065	.010	.008	20,039
9669	50	725	50	.065	.010	.010	20,039
9669	25	1050	50	.065	.018	.008	20,039
9981	25	1825	25	.065	.010	.008	20,039
9669	50	1525	50	.065	.012	.012	20,039
9669	25	1800	50	.065	.012	.008	20,039

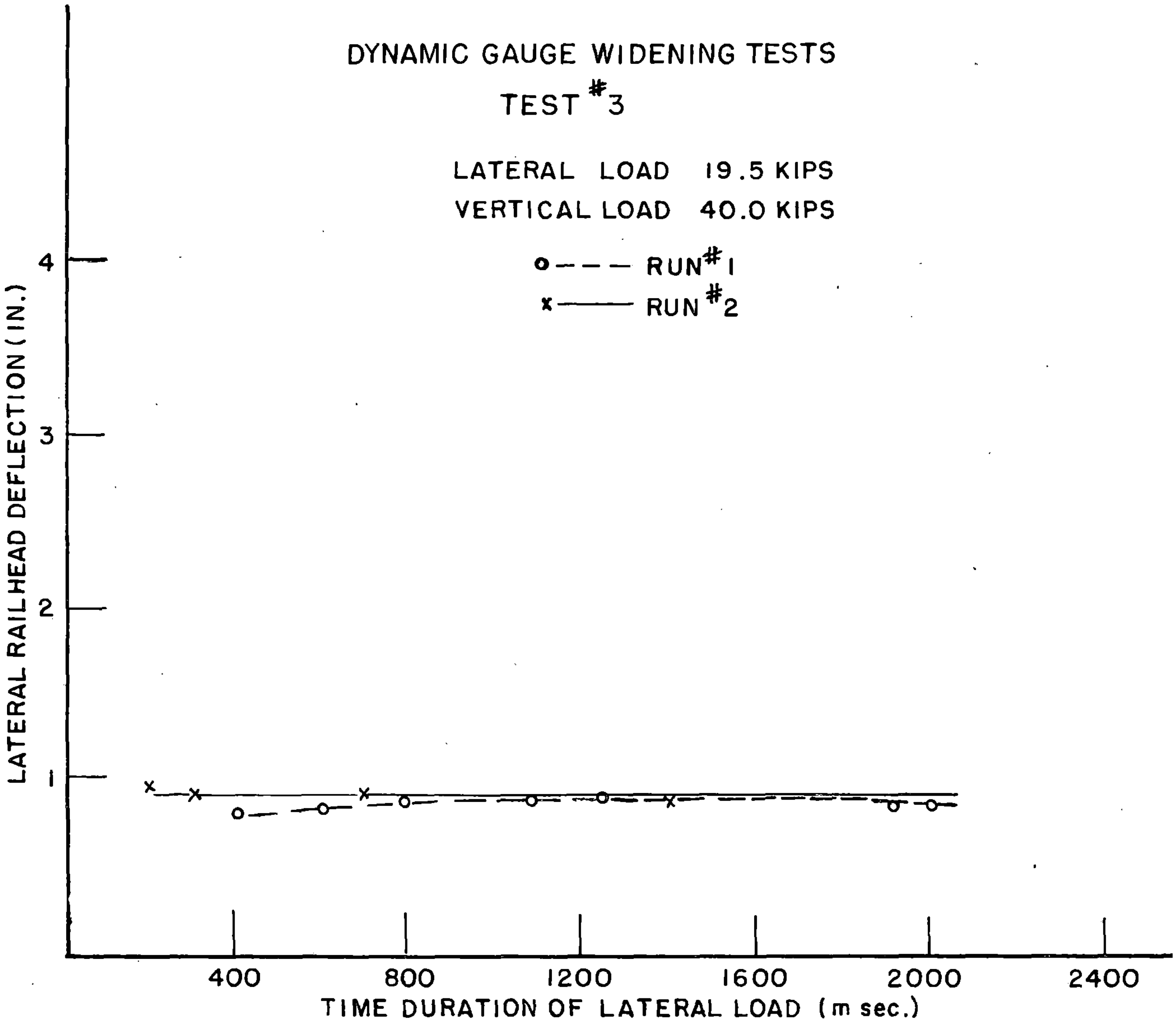


FIGURE 25. LATERAL RAILHEAD DEFLECTIONS VS. TIME DURATIONS OF A 19.5 Kip LATERAL IMPULSE LOAD, FOR A CONSTANT 40 Kip VERTICAL LOAD.

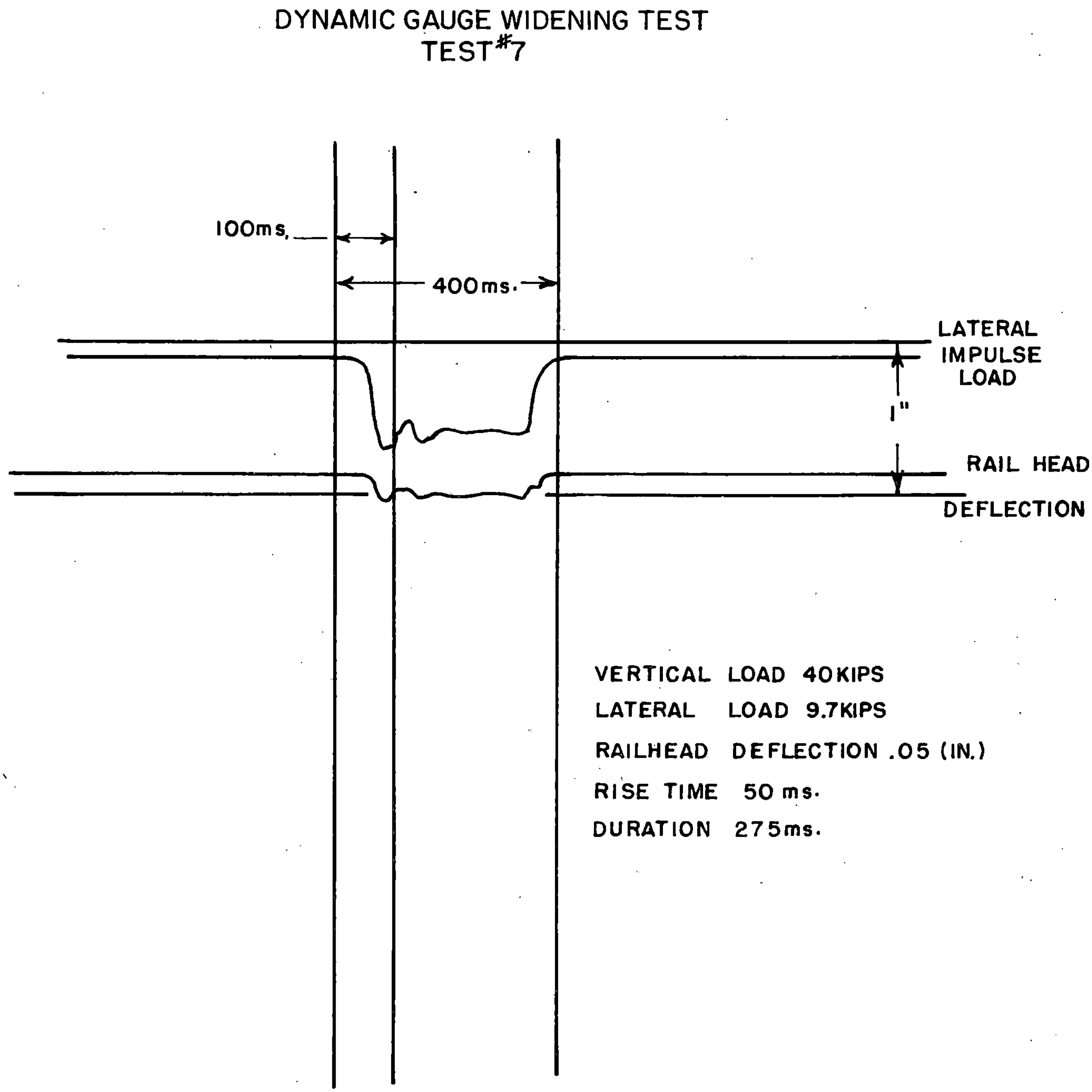


FIGURE 26. RECORDING OSCILLOGRAPH TRACE SHOWING WAVEFORMS OF 9.7 Kip LATERAL IMPULSE LOAD, AND RESULTING 0.05 INCH EAST RAILHEAD DEFLECTION, FOR A CONSTANT 40 Kip VERTICAL LOAD.

3. The rail head returns to its original (unloaded) position within the first 100 milliseconds after the lateral impulse load is applied.

6. LONGITUDINAL LOADS

In order to determine the effects of longitudinal compressive rail loads upon gauge widening, and to create a data base of load-deflection curves for various combinations of static vertical, lateral and longitudinal forces, a series of twelve load tests were conducted. Table 8 shows the longitudinal, vertical and lateral rail loading sequences for this series of gauge widening tests.

6.1 Test Procedure

The test track set-up for this test series was the same as for the previous dynamic load tests. The west rail bracing arrangement, shown in Figure 21, was retained and all of the spikes were redriven.

During these tests, the track was subjected to combined vertical, lateral and longitudinal loads. The vertical load were applied by the Amsler hydraulic system through the rail head test fixture, described in section 3.1. The vertical loads were measured using a strain-gauge load cell of the type shown in Figure 5. Longitudinal loads were applied by means of a hydraulic rail puller. Figure 27 shows the test set-up with the rail puller in position. Additional lengths of pulling rod allowed the pulling brackets to be centered 14 feet from the vertical and lateral loading point which permitted a total test track length of 28 feet. The rail pullers were capable of applying a 250 Kip (maximum) compressive load to the rail. Lateral loads, which were also measured with strain-gauged load cells, were applied

TABLE 8: LONGITUDINAL RAIL LOADING

SEQUENCES FOR GAUGE WIDENING TESTS

Vertical load (V) (Kips)	Longitudinal Load (P) (Kips)	Lateral Load (L) (Kips)
40	0	30
20	0	30
0	0	30
40	75	30
20	75	30
0	75	30
40	150	30
20	150	30
0	150	30
40	240	30
20	240	30
0	240	30

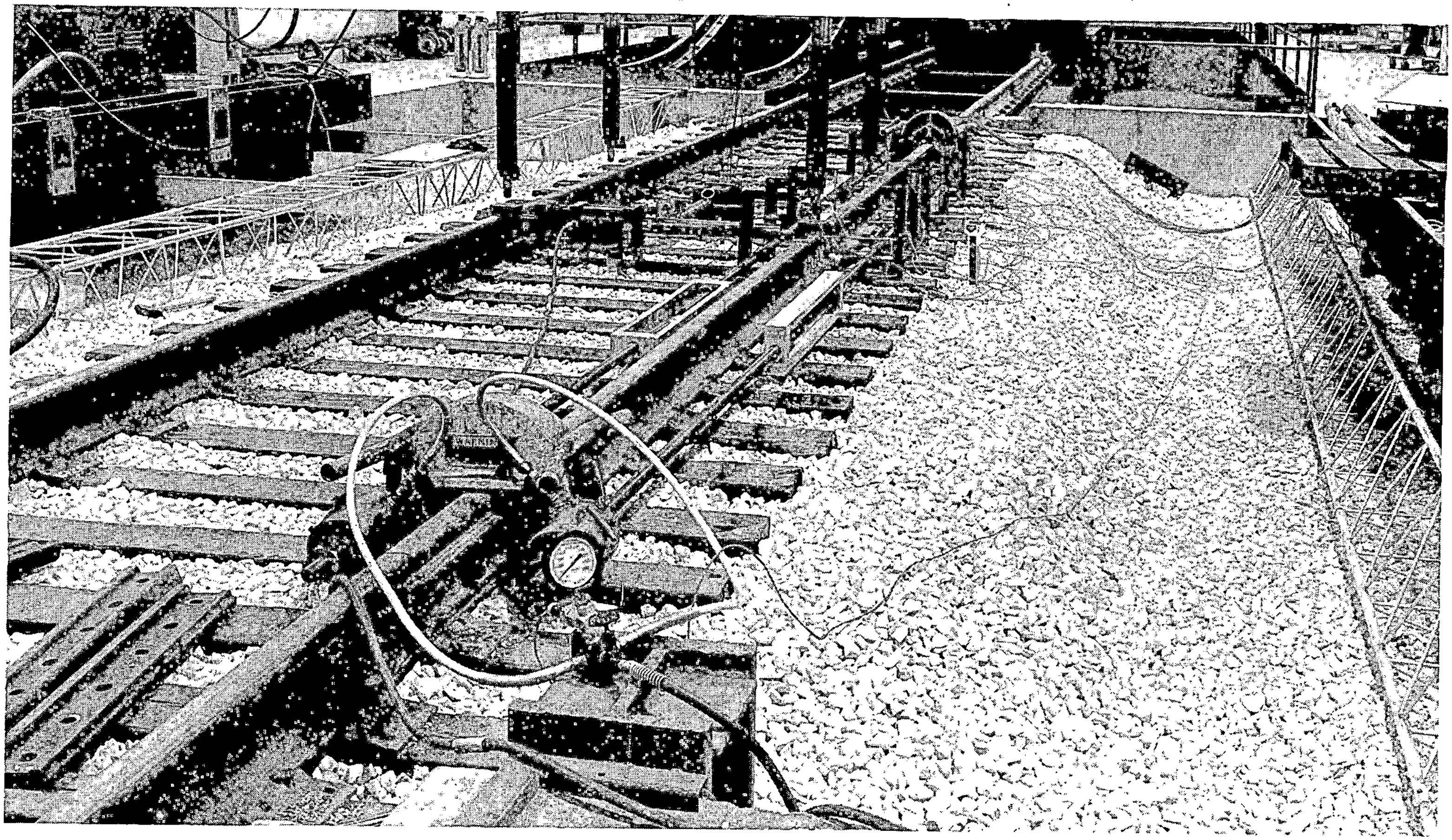


Figure 27. Test Set-Up for Longitudinal Load Tests, Showing Hydraulic Rail Puller in Position.

using several actuators and hand pumps, as in the previous test series. The various vertical, lateral and longitudinal static loads were applied to the east rail only.

Rail deflections were measured at the east rail loading point, and at distances of one, two, four and six tie centers from the loading point, in a northerly direction only. Rail head lateral and rail base lateral/vertical deflections were taken at each location, resulting in fifteen data channels. Figure 28 shows the instrumentation set-up for the longitudinal load tests.

During each test, the vertical load was applied first, followed by the longitudinal load. The lateral load was then applied and incrementally increased until the desired maximum value of 30 Kips was reached, as shown in Table 8. Deflection data, corresponding to each increment of applied lateral load, was measured and recorded. The lateral load was then reduced incrementally to zero, the vertical and longitudinal loads released, and the procedure repeated for the next test in the loading sequence. The spikes were not redriven between tests.

6.2 Results

Table 9 is a typical data table from one of the longitudinal loading tests, showing lateral railhead/base deflections (at the five measurement locations) vs applied lateral load, for constant 75 Kip longitudinal and 40 Kip vertical loads. Location "2S" (first deflection column) is the actual east rail loading point for vertical and lateral loads. Location "O" (center deflection column) represents the test track center line, from the end walls with location"2S"

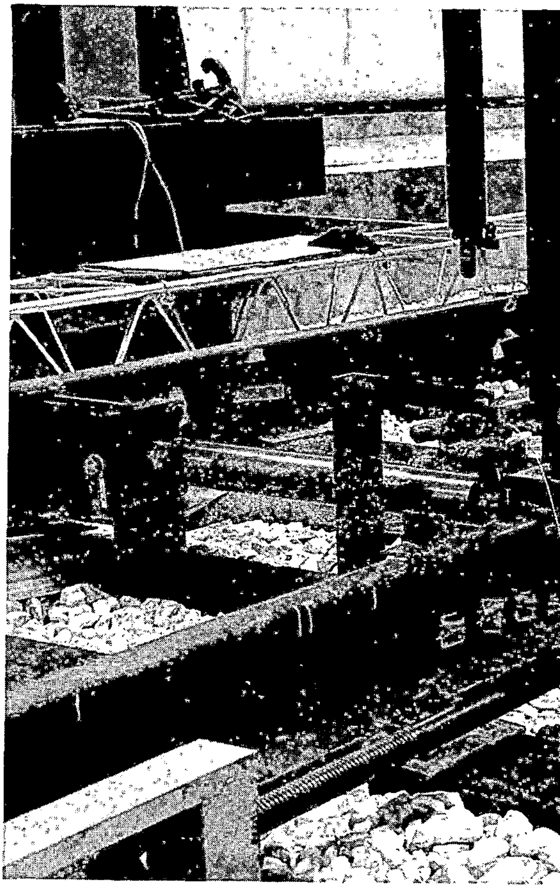
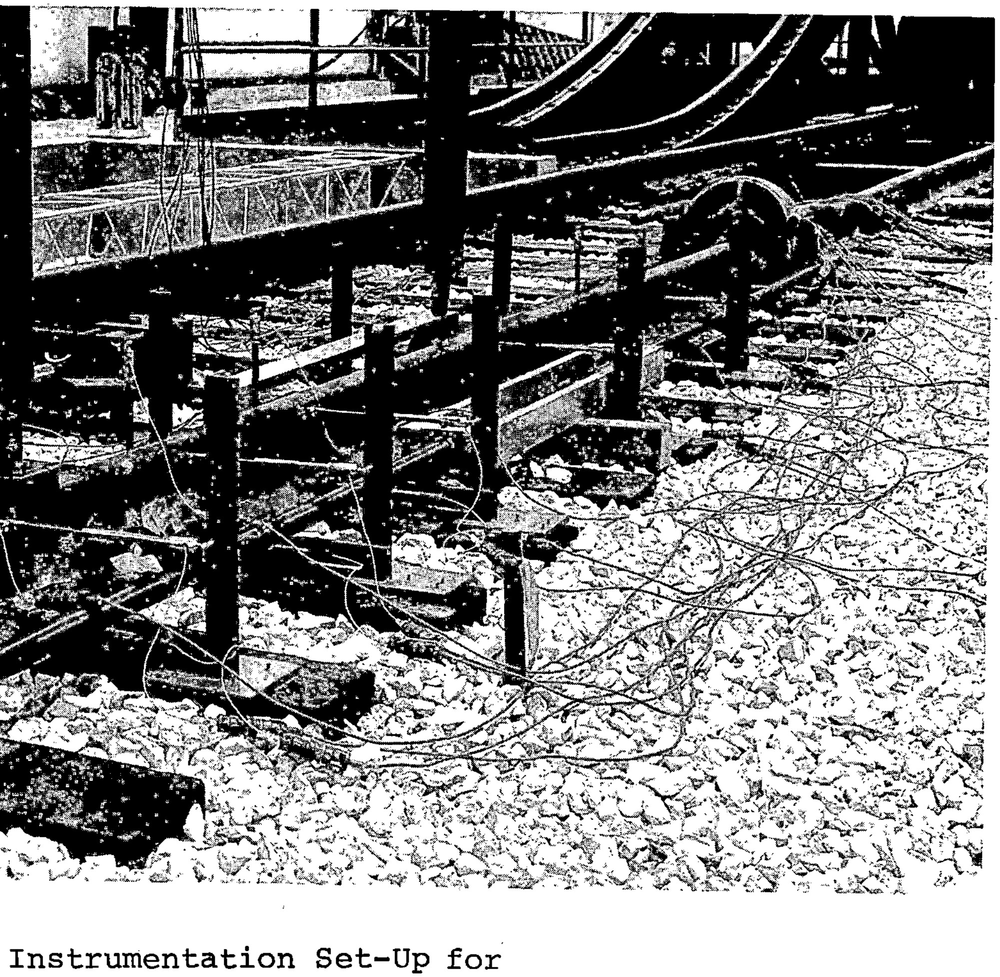


Figure 28.



Instrumentation Set-Up for

Longitudinal Load Tests.

TABLE 9: GAUGE WIDENING TESTS - LONGITUDINAL LOADS, LATERAL LOADS AND RAIL DEFLECTIONS, FOR CONSTANT 75 KIP LONGITUDINAL AND 40 KIP VERTICAL LOADS

LATERAL LOAD	LATERAL RAIL HEAD DEFLECTIONS				
	* @ 2S	@ 1S	@ 0	@ 2N	@ 4N
(LB)	(IN.)	(IN.)	(IN.)	(IN.)	(IN.)
172.25	-0.0290	-0.0392	-0.0172	-0.0065	-0.0033
5058.90	-0.0106	-0.0302	-0.0143	-0.0059	-0.0031
9694.67	0.0106	-0.0168	-0.0101	-0.0053	-0.0029
14607.53	0.0426	0.0062	-0.0028	-0.0045	-0.0025
19254.53	0.0961	0.0466	0.0119	-0.0024	-0.0014
24182.37	0.2765	0.1988	0.1232	0.0660	0.0352
28997.87	0.4933	0.3940	0.2793	0.1564	0.0608
29975.20	0.5385	0.4343	0.3117	0.1732	0.0641
29522.11	0.5350	0.4313	0.3105	0.1728	0.0642
24848.90	0.4133	0.3244	0.2239	0.1295	0.0573
20138.24	0.2023	0.1330	0.0645	0.0240	0.0146
15064.36	0.1146	0.0637	0.0167	-0.0042	0.0006
10458.56	0.0879	0.0465	0.0088	-0.0062	-0.0005
314.54	0.0098	0.0022	-0.0080	-0.0094	-0.0031
	LATERAL RAIL BASE DEFLECTIONS				
172.25	-0.0057	0.0005	-0.0002	-0.0005	-0.0006
5058.90	-0.0038	0.0012	0.0002	-0.0005	-0.0006
9694.67	0.0016	0.0025	0.0006	-0.0005	-0.0006
14607.53	0.0134	0.0090	0.0021	-0.0005	-0.0005
19254.53	0.0204	0.0241	0.0041	-0.0006	-0.0004
24182.37	0.0240	0.0315	0.0091	-0.0014	-0.0009
28997.87	0.0345	0.0362	0.0105	-0.0015	0.0004
29975.20	0.0368	0.0371	0.0108	-0.0015	0.0005
29522.11	0.0373	0.0373	0.0110	-0.0010	0.0007
24848.90	0.0373	0.0367	0.0110	-0.0010	0.0001
20138.24	0.0364	0.0356	0.0110	-0.0011	-0.0004
15064.36	0.0320	0.0345	0.0101	-0.0011	-0.0008
10458.56	0.0255	0.0334	0.0093	-0.0016	-0.0008
314.54	-0.0023	0.0199	0.0046	-0.0020	-0.0011

* EAST RAIL LOADING LOCATION

being two tie centers south of location "O".

Figure 29 is a typical graph, showing lateral rail head deflection vs lateral load, for constant 75 Kip longitudinal and 20 Kip vertical loads.

Figure 30 is a graph showing rail head deflection vs lateral load, for various longitudinal loads, and zero vertical load. The presence of a 240 Kip longitudinal load produced less than a six percent increase in rail head deflection, showing that longitudinal forces have little effect upon the gauge widening resistance of "good track."

This is also indicatied in Figure 31, a graph showing maximum lateral rail head deflection vs longitudinal load, for various vertical loads, and constant 30 Kip lateral load. The change in line slope with increasing vertical load indicates that, as the vertical load increases, the effects of the longitudinal load increase, e.g. at a 40 Kip vertical load, a 250 Kip longitudinal load increases the rail head deflection by up to 24%.

Figure 32 is a graph showing maximum lateral rail head deflection vs measurement location, for various vertical loads, constant 240 Kip longitudinal and 30 Kip lateral loads. This Figure shows that maximum rail head deflection decreases with increasing vertical load, independent of any longitudinal loads that are present, since the longitudinal load is constant at 240 Kips.

Figure 33 is a graph showing maximum lateral railhead deflection vs measurement location, for various longitudinal loads, constant 20 Kip vertical and 30 Kip lateral loads. The effects of longitudinal rail forces are detectable for

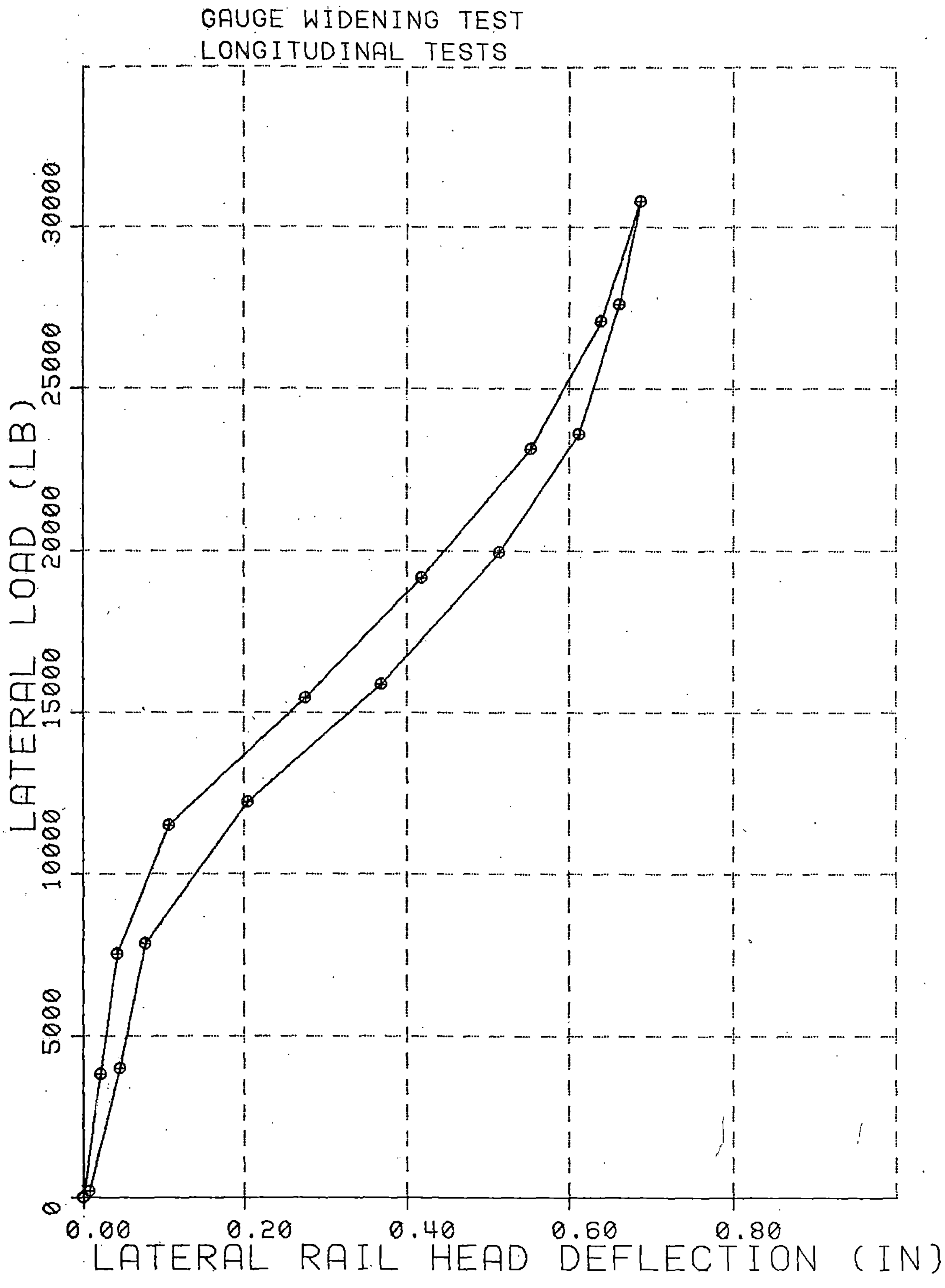


FIGURE 29. LATERAL RAIL HEAD DEFLECTION VS LATERAL LOAD, FOR CONSTANT 75 KIP LONGITUDINAL AND 20 KIP VERTICAL LOADS.

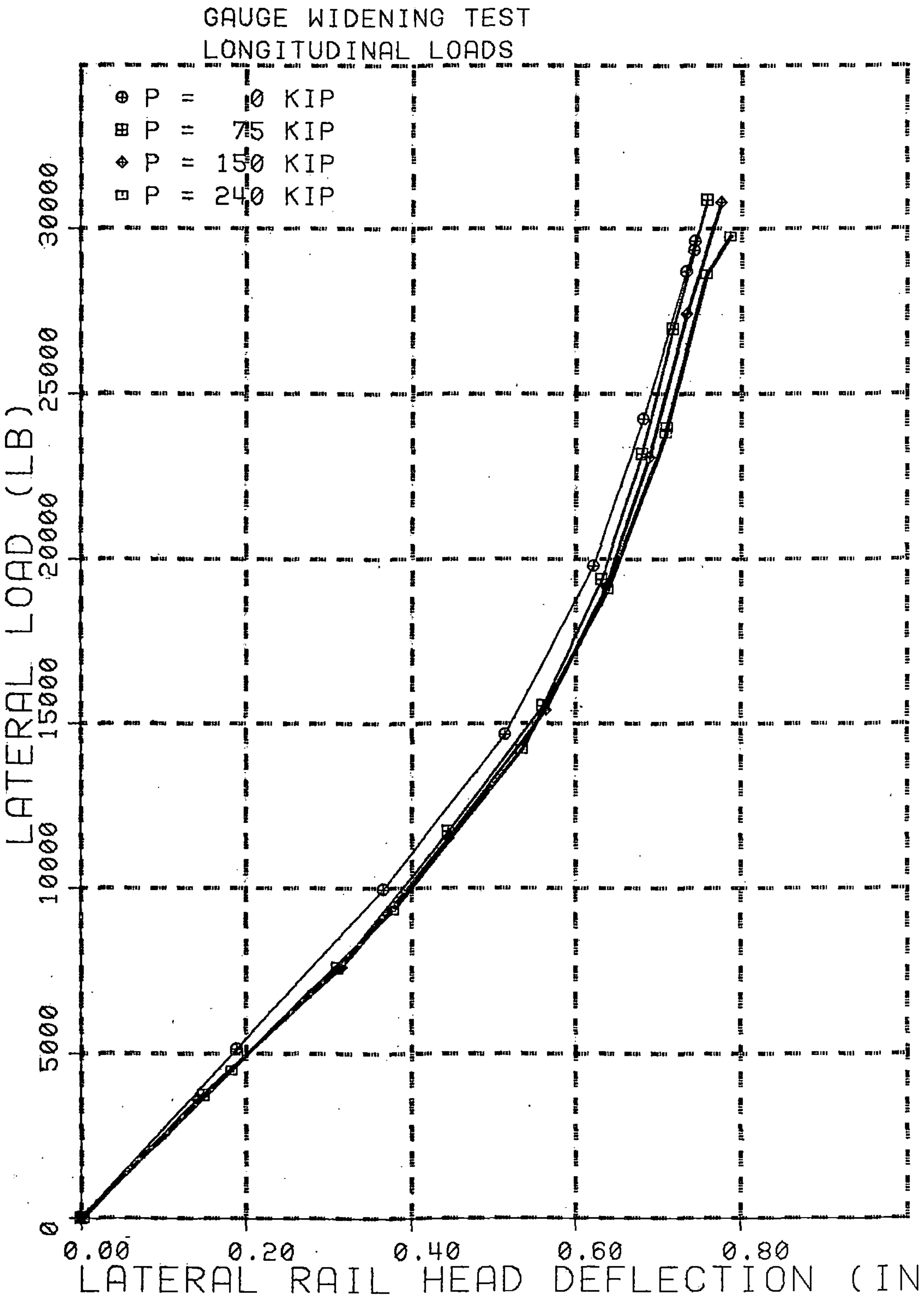


FIGURE 30. LATERAL RAIL HEAD DEFLECTION VS LATERAL LOAD, FOR VARIOUS LONGITUDINAL LOADS AND ZERO VERTICAL LOAD.

GAGE WIDENING TESTS-LONGITUDINAL LOADS

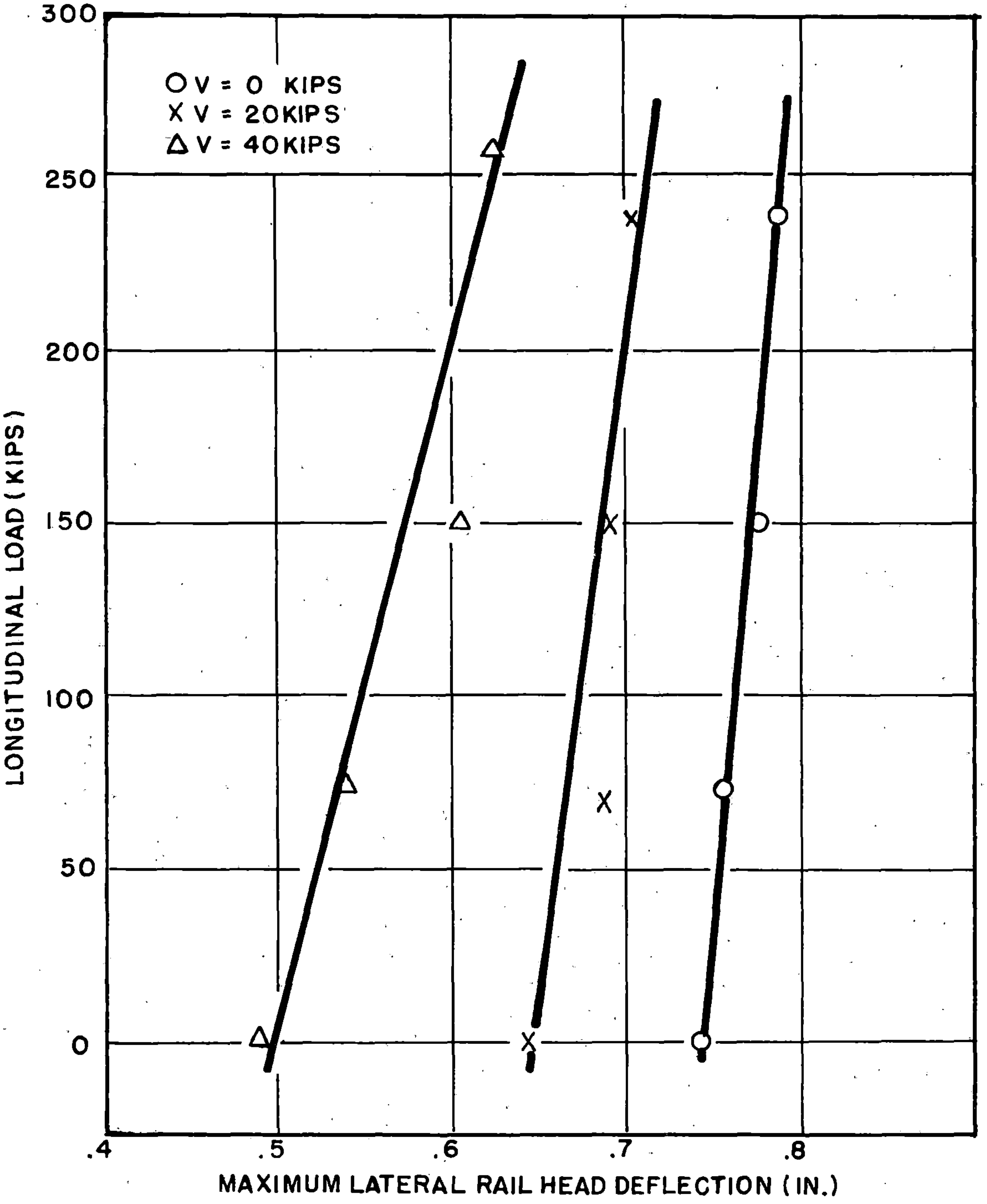


FIGURE 31. MAXIMUM LATERAL RAIL HEAD DEFLECTION VS. LONGITUDINAL LOAD, FOR VARIOUS VERTICAL LOADS AND CONSTANT 30 Kip LATERAL LOAD.

LONGITUDINAL LOAD TESTS
LATERAL RAILHEAD DEFLECTIONS

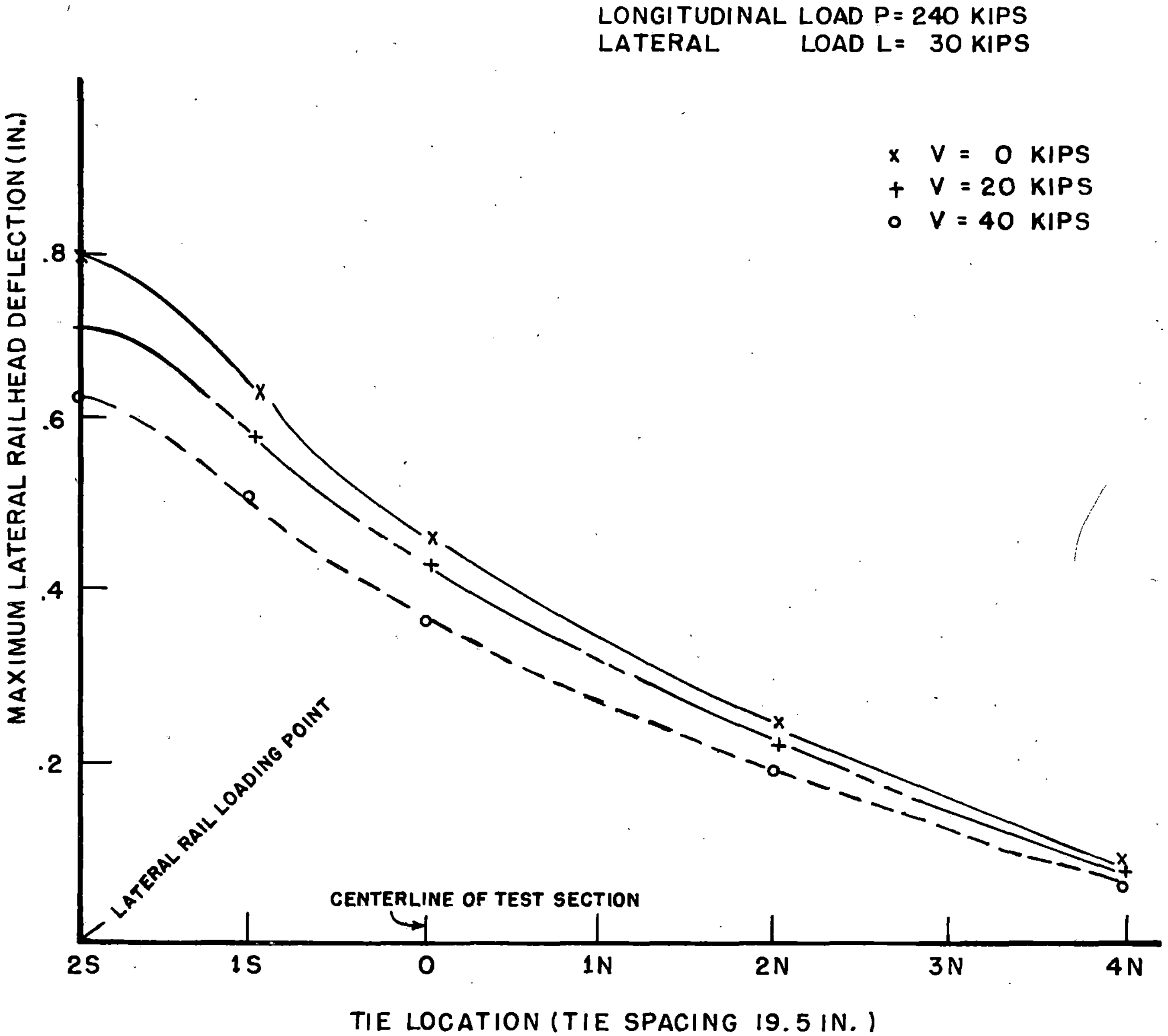


FIGURE 32. MAXIMUM LATERAL RAILHEAD DEFLECTION VS. MEASUREMENT LOCATION, FOR VARIOUS VERTICAL LOADS, AND CONSTANT 240 Kip LONGITUDINAL AND 30 Kip LATERAL LOADS.

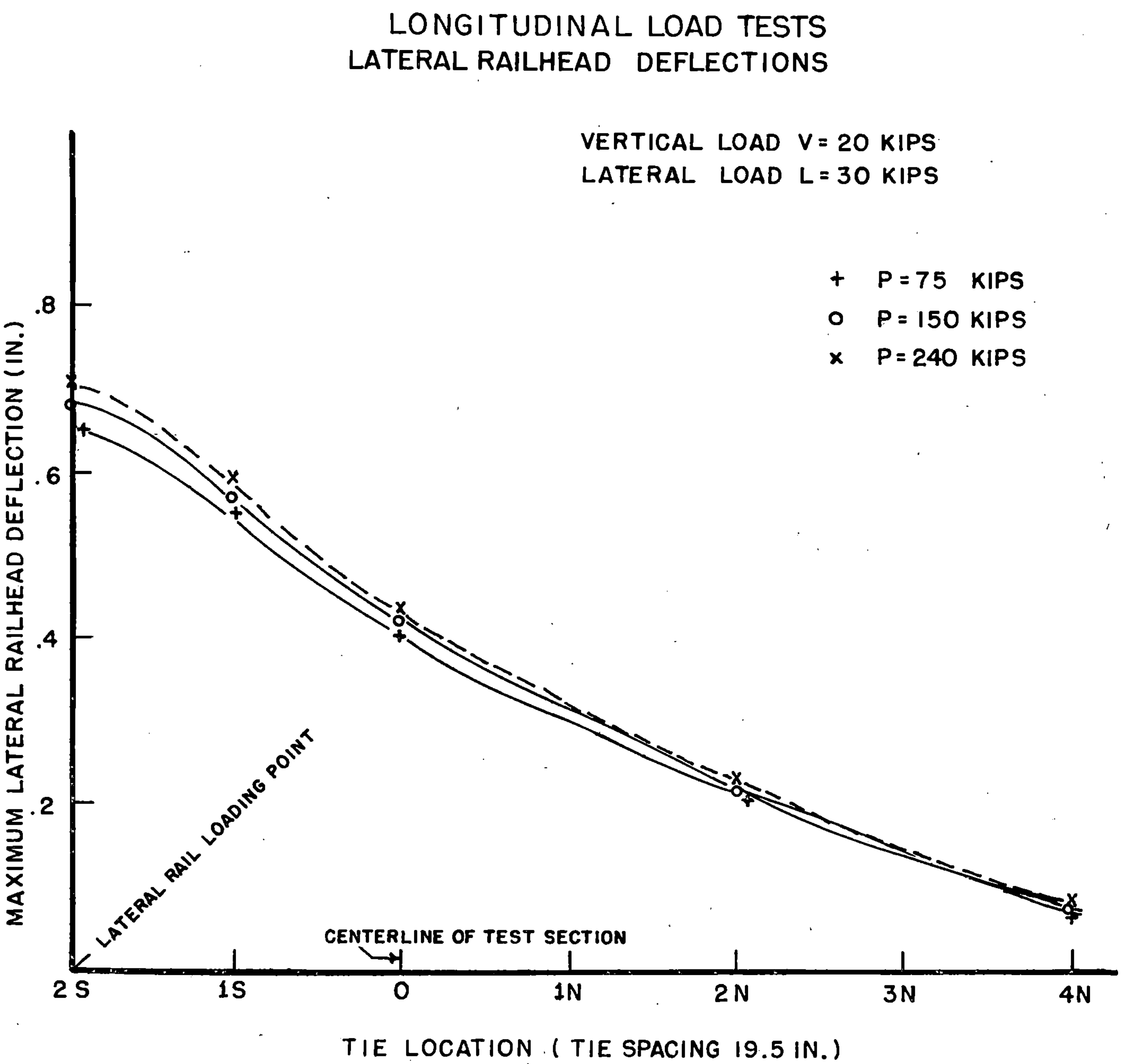


FIGURE 33. MAXIMUM LATERAL RAILHEAD DEFLECTION VS. MEASUREMENT LOCATION, FOR VARIOUS LONGITUDINAL LOADS, AND CONSTANT 20 Kip VERTICAL AND 30 Kip LATERAL LOADS.

approximately two tie center spacings beyond the loading point In contrast, the effect of vertical loads, shown in Figure 32, are detectable up to five tie center spacings beyond the loading point.

Figure 34 is a graph showing gauge widening of the test rail vs tie location (relative to test section center line), for various longitudinal loads, at constant 20 Kip lateral and zero vertical loads. It presents a comparison between the present laboratory test data and previously published field test data (9). The graph shows an excellent agreement between the two data sets at zero applied longitudinal load, but poor agreement when longitudinal loads were present. Although the field test used 42 Kips, and the laboratory tests used 75 Kips, of applied longitudinal load, the close proximity of the latter curve to the zero longitudinal force curve suggests that a 42 Kip curve would be very close to the 75 Kip curve, had it been measured. The field test lateral deflections were, therefore, about 174% higher than the corresponding ones obtained in the laboratory tests, when a 42 Kip longitudinal load was present. The authors' believe that the observed discrepancies can be explained by the differences between the two track sections. The laboratory test track had new 136 RE rail and new cross ties. The field track was a section of branch line with worn 100 lb. rail and 25 year old hardwood ties. The sequence of load application was also different. In the laboratory tests, involving zero vertical loads, the longitudinal load was applied first, followed by the lateral load. The field tests used the reverse order of load application, which

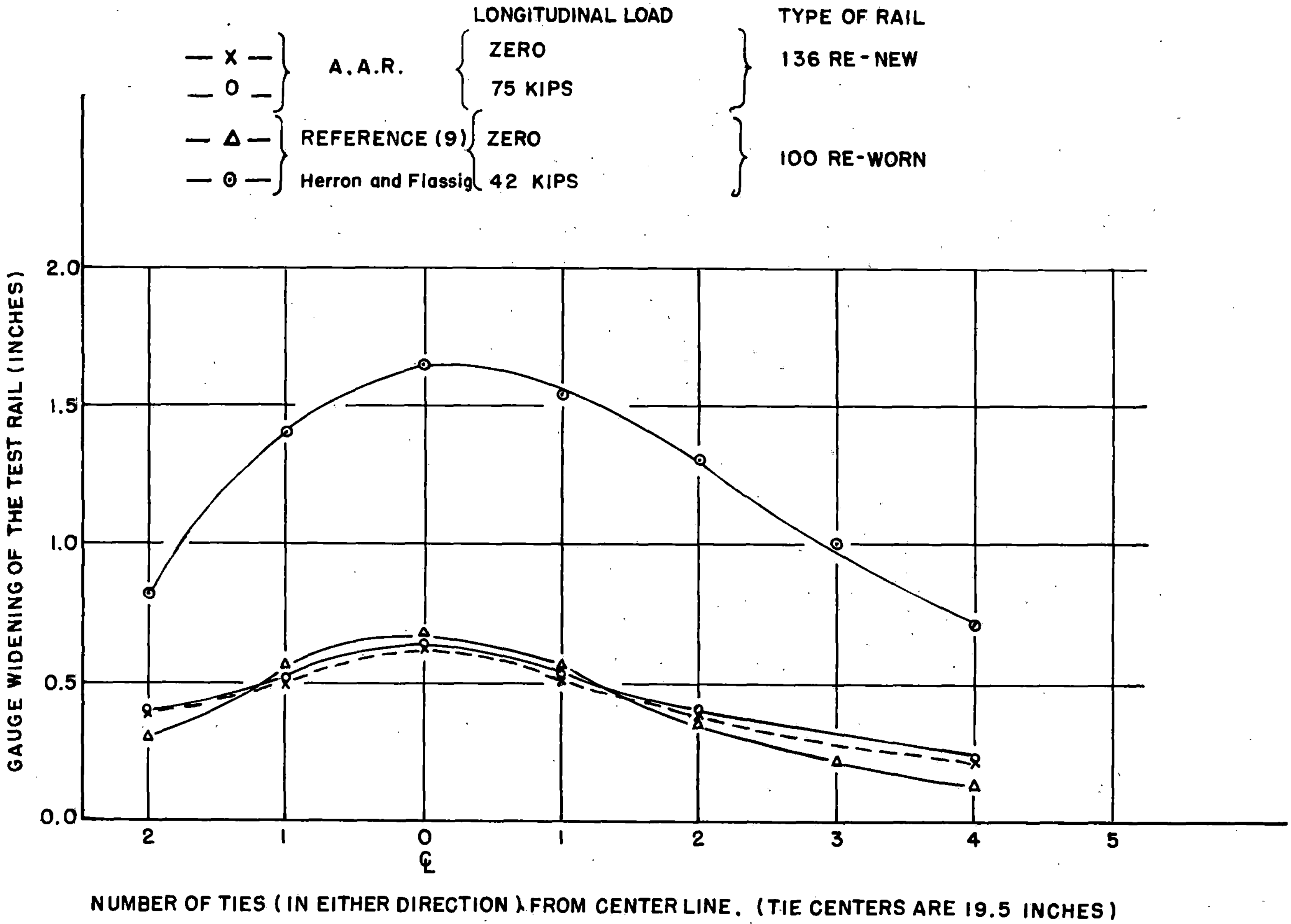


FIGURE 34. GAUGE WIDENING OF TEST RAIL VS. TIE LOCATION. (RELATIVE TO TEST SECTION CENTERLINE) FOR VARIOUS LONGITUDINAL LOADS, AT CONSTANT 20 Kip LATERAL AND ZERO VERTICAL LOADS. COMPARISON OF A.A.R. LABORATORY AND FIELD TEST (9) DATA.

would suggest the presence of a misalignment in the rail, at the time the longitudinal load was applied. As a result, the longitudinal forces produced significant changes in the lateral rail head deflections.

6.3 Conclusions

As noted earlier, the test rail with a 33 Kip vertical load, corresponding to the vertical axle loading in 100 - ton capacity freight car, experiences less than a ten percent increase in lateral deflection (for a constant lateral load) when a 240 Kip longitudinal load is applied. A 100 Kip longitudinal load, under the same conditions, causes less than a four percent increase in lateral deflection.

With reference to Figures 32 and 33, it can be seen that for a constant lateral load, a 40 Kip vertical load produces approximately three times the effect on lateral rail head deflection than a 240 Kip longitudinal load.

Based upon the results of these longitudinal loading tests, it appears that longitudinal rail forces have negligible effects upon the gauge widening of track in good condition. Additional work, however, on aged or deteriorated track is needed to more fully understand the effect of longitudinal forces on various track structures.

7. DISCUSSION AND RECOMMENDATIONS

This test program was conducted to obtain data about the gauge widening mode of track failure, and included four specific test series, each involving distinctly different types of loading conditions.

The primary objective was to determine if non-destructive gauge widening tests could be used to detect damaged or weakening track, and to predict the ultimate strength of track towards failure by gauge widening.

Evaluation of the test data from Section 3, covering the basic gauge widening tests, indicates that gauge widening "pre-damage" of up to 1.0 inch can be detected by applying a "safe" loading level, i.e. a suitable lateral/vertical load combination that would not cause the rail head to deflect (laterally) more than 0.5 inch, even for track in a relatively-weakened condition. The preliminary correlation curves, shown in Figures 14 and 15, illustrate this concept. Additional field testing, however, has to be conducted to see if these relationships are valid for various field conditions, including both main and branch line track with various rail sections, tie sizings, fastener configurations, etc. It is recommended that these field tests be conducted using a vertical load of 15,000 lbs and a lateral load of 10,500 lbs., resulting in an L/V ratio of 0.7.

The ability to detect damaged track by a field measurement technique would provide the track engineer with a useful tool to supplement the existing visual inspection methods.

Another objective of this test program was to examine the effects of a simulated adjacent axle load on the gauge widening behavior of the track. The data indicates that the presence of an adjacent load has a "beneficial" effect, i.e. the resistance of the track to gauge widening is increased.

In examining the effects of simulated single and dual-axle (truck) loading L/V ratios, as shown in Figure 20, it was found that significant gauge widening can occur for any simulated truck L/V ratio, including those that are less than 0.5. In contrast, significant gauge widening occurred only for simulated single axle loading L/V ratios greater than 0.5.

It is, therefore, the authors' opinion that the simulated single axle loading L/V ratios be used for studies of gauge widening and rail overturning behavior.

A third objective of this test program was to examine the effects of dynamic (impulse) loads of varying time duration upon the gauge widening behavior of track. Unfortunately, the results were inconclusive, because there were little observed differences between the earlier static and these "dynamic" loading tests. It was found that the hydraulic impulse system could only generate loading waveforms with rise times ranging from 50 to 150 milliseconds. This approximated quasi-static loading conditions, and in the absence of impulse loads with fast rise times, true "dynamic" behavior could not be observed. The measured data was, however, in agreement with gauge widening behavior predicted by preliminary mathematical modelling (8).

The fourth objective of this test program was to study the influence of compressive rail longitudinal forces upon gauge widening behavior.

The results showed that longitudinal rail loads have only minimal effects upon the gauge widening behavior of track in "good" condition, i.e. heavy rail and relatively new ties. As an example, the presence of longitudinal rail load at levels normally encountered in track (e.g. up to 100,000 lbs.) increased the lateral rail head deflection (resulting from constant applied lateral and vertical loads) by less than ten percent. These results did not agree with those obtained by Herron and Flassig (9), who conducted field tests on actual track in "poor" condition, i.e. worn 100 RE rail and poor ties. These authors found that longitudinal rail loads produced significant increases in gauge widening.

The test results, summarized in this report, represent a comprehensive study of track gauge widening behavior under various static and quasi-static loading conditions. It is hoped that they will provide a useful data base for future field and laboratory studies that provide a more complete understanding of the gauge widening restraint characteristics of track.

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