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LATERAL RESISTANCE OF NEW AND RELAY RED OAK CROSSTIES

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16. Abstract

To explore the effect of in-service use, comparative lateral resistance tests were performed on eight red oak crossties--four 24-year-old relay (used) ties and four new ties. One end of each tie was tested individually and the other was tested in a four-tie-group test. The ties were tilted to a 1 in 2 slope and the rail was loaded plumb. Displacements of the rail head and base were recorded as a function of load. Measured wood properties of small specimens from the relay ties were found to be comparable to properties of specimens from the new ties. Only one tie (individual, new) had the spikes bend (into an S shape) during the lateral resistance tests, but the rail base displaced laterally less than 0.5 inch at an applied load of 130,000 pounds.

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Preface

This research, to better understand the lateral resistance provided by in-service wood cross-ties compared with new crossties, was funded in part by the Federal Railroad Administration Office of Research and Development.

The Forest Products Laboratory at Madison, Wis. conducted the static loading tests on rail-tie systems consisting of a single tie end, short rail section, tie plate, and spikes, and a group of four tie ends, a longer rail section, tie plates, and spikes.

Burlington Northern Inc., provided the test materials, and the Transportation Test Center (near Pueblo, Colo.) provided auxiliary test data reported in Appendix D.

Table of Contents

Page

Background 1

Problem and Objectives 3

Test Materials 3

Material Selection 3

Specimen Preparation 5

Test Setup and Procedure 7

Wood Properties. 7

Lateral Resistance 7

Spike Withdrawal 9

Test Results and Discussion. 9

Wood Properties. 9

Lateral Resistance 15

Spike Withdrawal 21

Conclusions. 21

Appendices A 23

B 44

C 55

D 60

List of Abbreviations and Symbols

AAR	Association of American Railroads
AREA	American Railway Engineering Association
ASTM	American Society for Testing and Materials
BN	Burlington Northern Inc.
FPL	Forest Products Laboratory
FRA	Federal Railroad Administration
LVDT	Linear variable differential transducer
MOE	Modulus of elasticity
MOR	Modulus of rupture
NTSB	National Transportation Safety Board
δ_B	Rail base displacement
δ_H	Rail head displacement
δ_i	Rail displacement at i th LVDT (i = 1 to 10)

LATERAL RESISTANCE OF NEW AND RELAY RED OAK CROSSTIES

By

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U.S. Department of Agriculture

BACKGROUND[2/]

On December 16, 1976, Amtrak passenger train No. 6, traveling at 53 miles per hour on the Burlington Northern (BN) Railroad, derailed 2.1 miles west of Ralston, Nebr. (Ralston is 7.6 miles west of Omaha.) One person died and 47 others of the 178 passengers and 15 crew members were injured.

Train No. 6 consisted of two SDP-40F diesel-electric locomotives and 11 various purpose passenger service cars. The second locomotive and all the cars were derailed. Investigation disclosed these details:

While negotiating an average 2°30' curve (~2,300 ft radius), a wheel of the trailing truck of the second locomotive dropped inside the low (inner) rail (marking it on the gage side). This wheel did not immediately contact the ground but moved the rail toward the field side. Twenty-seven feet farther down the track, another wheel of the same truck dropped from the high rail, eventually causing the rail to roll over toward the field side. Both actions allowed a gross widening of gage, leading to the general derailment.

For the initial wheel descent to have occurred, substantial wide gage must have existed for some track length preceding the incident. This was evident from markings on certain crosstie (top) surfaces preceding the point of derailment (first wheel drop). Crosstie surfaces under the

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1/ Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

2/ This section was paraphrased from Railroad Accident Report NTSB-RAR-77-8, adopted October 6, 1977, by the National Transportation Safety Board for public use.

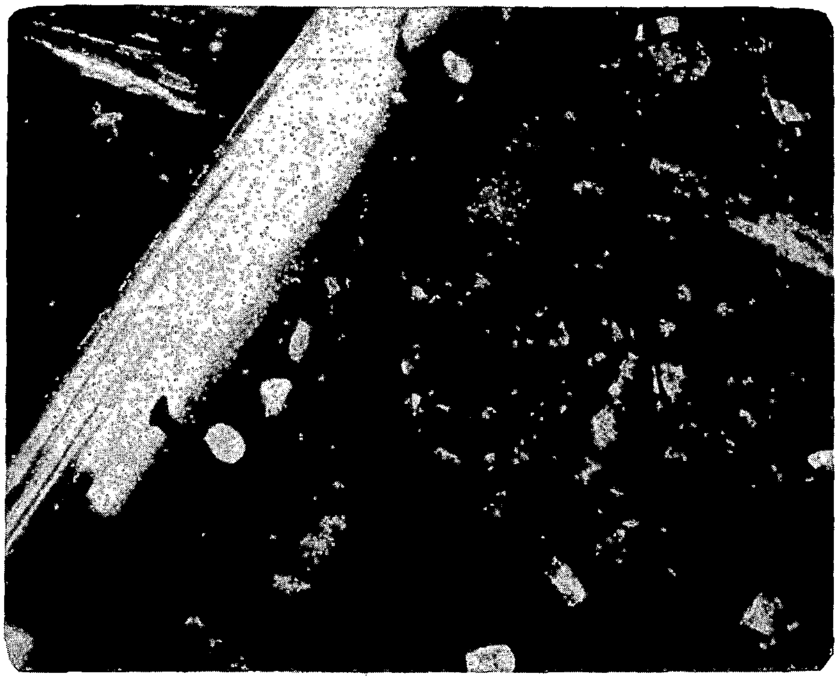


Figure 1.--Intrack tie plate translation without rail turnover.

(M 146 628)

high rail 54 feet uptrack showed evidence of spike hole enlargement and tie plate translation but no rail rollover.

Figure 1 shows tie plate translation on two ties several feet uptrack of the derailment point. The original tie plate position and amount of translation is readily discernible. This photograph was taken prior to derailment-related track repair.

The outward tie plate translation varied progressively from 1/8 to 5/8 inch in the first 23 feet and then from 1/16 to 1-7/8 inches in the next 31 feet. Lateral tie plate displacement in the absence of rail rollover is called tie plate translation, and is one cause of the "sudden wide-gage" effect.

PROBLEM AND OBJECTIVES

"What forces were necessary to produce lateral tie plate displacement in the absence of rail rollover in the ties at Ralston?" To answer the question, a series of comparative tests were conducted at the Forest Products Laboratory (FPL) in Madison, Wis. Wood properties were measured of: Relay ties which showed lateral plate translation from the derailment, relay ties immediately uptrack from the derailment, and new ties.

Lateral resistance was measured in comparative tests between the uptrack relay ties and new ties. Because lateral resistance could not be measured on the relay ties involved in the derailment, the measured wood properties of the "involved" relay ties and uptrack relay ties were compared. The comparative wood properties test would show any measurable difference in basic wood properties between the relay and new ties.

The lateral resistance tests addressed the specific question of "What static forces are necessary to produce only lateral tie plate displacement in individual relay ties (from Ralston) and new ties, and in a group of four relay ties and a group of four new ties?"

TEST MATERIALS

Material Selection

Twelve red oak crossties were selected for test materials. Lateral resistance tests used materials from eight ties while wood properties tests used material from all twelve ties.

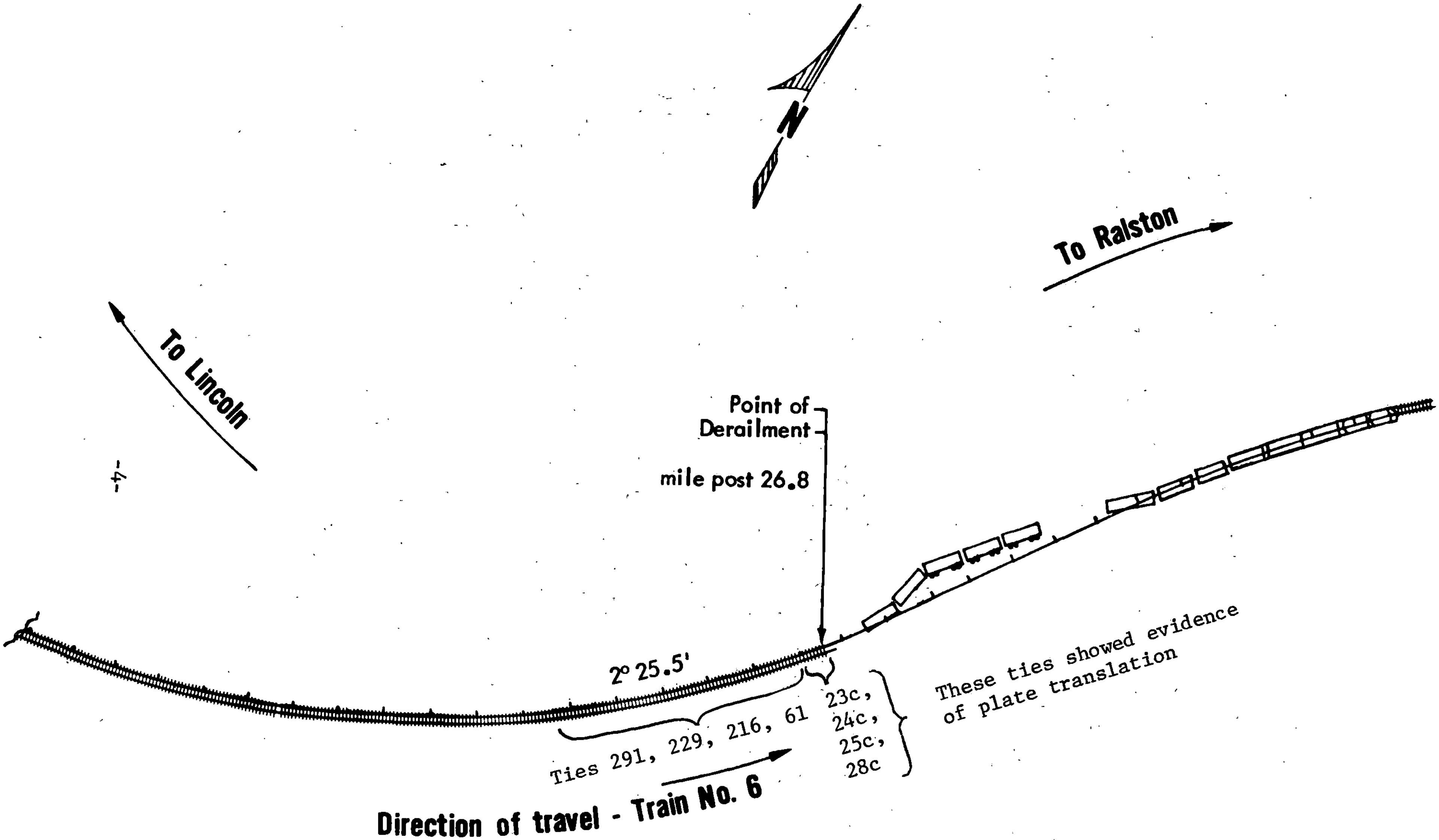


Figure 2.--Location of relay ties used in tests.

Four of the ties came from the track in the 54 feet preceding the point of derailment and which had visible tie plate translation (fig. 2); four from 515 feet of track preceding the first sign of plate translation; and four new ties from railroad stores. In this report the test ties are designated as:

Near Derailment (visible tie plate translation)	Uptrack (No sign of plate translation)	New ties
23C	61	N3
24C	216	N4
25C	229	N6
28C	291	N7

The C ties were selected by personnel from the National Transportation Safety Board and stored at the BN Como Labs in St. Paul. The N ties were predrilled for 136 pound rail. The uptrack ties were selected by FPL personnel with the following criteria: Unused spike holes (for rail holding spikes), nonjoint ties, and uniformity of degradation (no visible checks through spike holes to be used in tests).

Ties 23C, 24C, 61, 216, 229, and 291 were marked as treated in 1953 and ties N3 and N4 were marked as treated in 1977. Appendix A contains intrack pictures of ties 61, 216, 229, and 291 as well as individual description sheets on all twelve ties tested.

Each tie was divided into three sections (discarding ends) as diagrammed in figure 3. The gage section (~34 inches) of all ties provided samples from which ASTM tests for wood properties could be performed. The field sides (shaded in fig. 3) of the uptrack tie series and the new tie series provided specimens for group and individual lateral resistance tests.

Specimen Preparation

Wood Properties

Test specimens used to measure wood properties (shear parallel to grain, compression perpendicular to grain, MOE and MOR in bending, and compression parallel to grain) had their edges parallel to the tie edges (i.e., no regard to ring orientation). Specimen sizes and relation to tie orientation are shown in figure 4, where the coordinate axes (7, 9, 8-6) represent tie orientation (7 by 9 in. by 8 ft-6 in.). The specimens were cut on a bandsaw and knife-planed such that splits, rocks, and spikes were avoided.

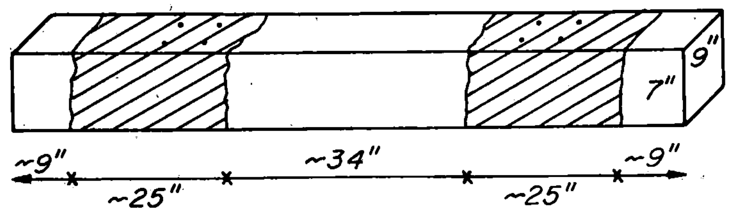


Figure 3.--Tie portions used for tests: Ends discarded; central gage portion for ASTM tests; field (shaded portions) for lateral resistance tests.

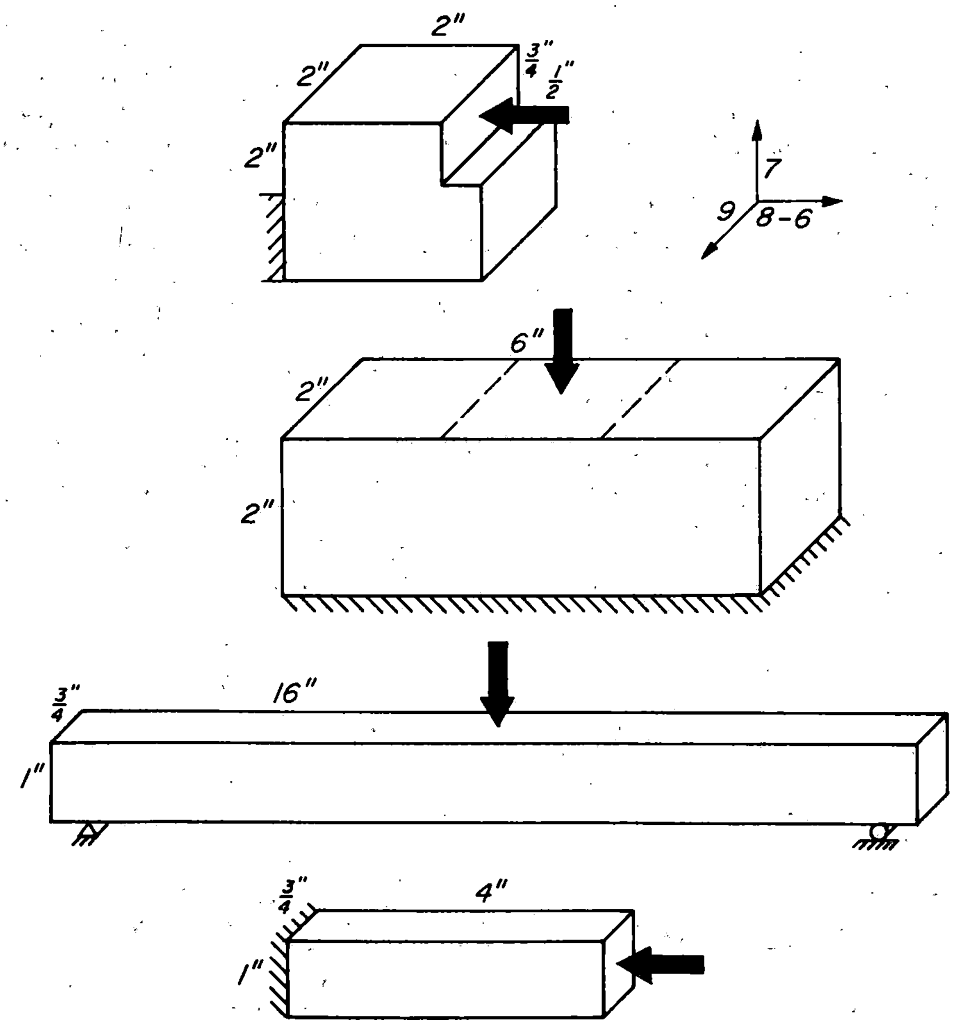


Figure 4.--Small specimen geometry for wood properties test and relation to tie orientation (7 x 9 in. by 8 ft-6 in.)

(M 146 674)

Lateral Resistance

Lateral resistance tests included eight individual tie tests and two 4-tie-group tests. Of the uptrack series, the four high field sides of the ties were grouped together and the low field sides were tested individually. Each N series tie provided a field side for a group test and a field side for an individual test.

Two new rail spikes cut 5/8 in. by 6 in. per tie plate were driven with an (AREA) spike maul flush with the rail base and then backed off enough to get an (AREA) claw bar underneath the head, which raised it up approximately 1/2 inch (representing a common intrack condition). In the relay ties, new or unused spike holes were used. The spikes were rail-holding spikes and the tie plate (with a 1:40 slope) canted the rail as intrack.

Spike Withdrawal

The N series tie portions used in the lateral resistance tests contained unused spike holes into which new spikes were driven and backed off approximately 1/2 inch above the tie plate.

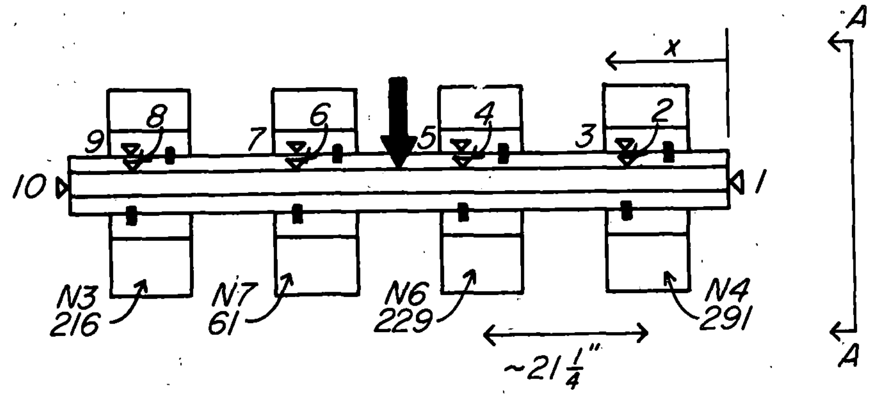
TEST SETUP AND PROCEDURE

Wood Properties

Testing procedures to measure (1) modulus of elasticity in bending and modulus of rupture, (2) compression parallel to grain, (3) compression perpendicular to grain, and (4) shear parallel to grain--were conducted according to ASTM D-143.

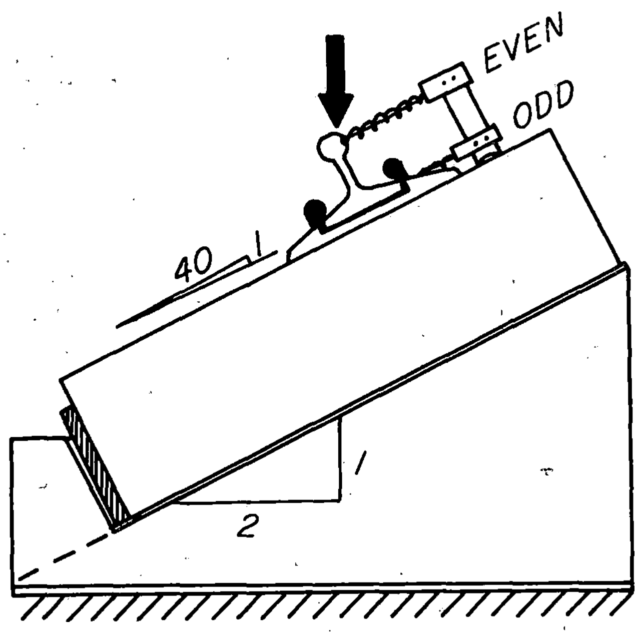
Lateral Resistance

In the lateral resistance tests, the ties were slanted to a slope of 1:2 and the load was applied plumb (refer to fig. 5). The slope of 1:2 was chosen so the load vector trajects just inside the edge of the rail base, thus precluding rail rollover. The tie plate (with 1:40 sloped base) canted the rail towards the load (arrow in fig. 5). Figure 5 is a schematic for a group tie test with appropriate placement of displacement LVDT's (open triangles in plan view and labeled EVEN, ODD in end view). Figure 6 shows a group tie test.



LOCATION OF LVDT'S (inches) FROM END OF RAIL

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
RELAY TIES	0	$9\frac{5}{8}$	$9\frac{1}{8}$	$28\frac{1}{2}$	29	50	$50\frac{1}{2}$	72	$72\frac{1}{2}$	78
NEW TIES	0	$9\frac{1}{2}$	9	$30\frac{3}{8}$	$29\frac{7}{8}$	$51\frac{3}{4}$	$51\frac{1}{4}$	$72\frac{1}{2}$	72	78



END SCHEMATIC

Figure 5.--Schematic of group tie lateral resistance test setup. Load represented by black arrow. Displacement LVDT's are represented by open triangles in plan view and labeled EVEN, ODD in end view.

(M 146 675)

Loading was applied by a screw-type machine at a head rate of 0.05 inch per minute up to 130,000 pounds (at which load the rail dents). Load and ten displacements were measured and recorded every 30 seconds for the group tests. Load and two displacements were recorded simultaneously on an $X\text{-}Y_1Y_2$ plotter for the individual tie tests. The only difference between the group and individual tie test is that load is located between the two center ties for the group test and directly over the tie for an individual tie test.

Spike Withdrawal

Using a screw-type loading machine, a backed-off spike was withdrawn at a head speed of 0.1 inch per minute with a spike puller grip (fig. 7). A machine load-head displacement curve was obtained on an X-Y recorder from which maximum load was taken.[3/]

TEST RESULTS AND DISCUSSION

Wood Properties

The results of the wood properties tests are given in table 1. The first number in a property column gives the mean, the second is the unbiased standard deviation, and the third is number of specimens tested. Because the number of ties tested is small, there is no statistical basis to compare these results to any larger population. Also, specimen orientation was relative to tie geometry, further preventing comparison to clear wood values. Therefore, ranges of tie means for the three series, rather than the series mean, are given in figure 8.

No appreciable difference is apparent, from figure 8, in the range of the three series of ties tested. The gross density of the specimens includes creosote and water. Therefore, a difference of 6 pounds per cubic foot in creosote retention could account for the higher gross density of the new ties.

3/ The technical staff of the Transportation Test Center near Pueblo, Colo., conducted intrack spike pull-out resistance tests. Their procedure and data are reported in Appendix D.

Figure 6.--Group tie lateral resistance test setup.

(M 145 893-5)

Table 1.--Small specimen properties[1/]

Tie ID	Modulus of elasticity	Modulus of rupture	Compression parallel maximum stress	Compression perpendicular proportional limit stress	Shear parallel maximum stress	Gross density in creosote and water	Spike withdraw maximum load
	$\bar{x}$ s (n)	$\bar{x}$ s (n)	$\bar{x}$ s (n)	$\bar{x}$ s (n)	$\bar{x}$ s (n)	$\bar{x}$ s (n)	$\bar{x}$ s (n)
	kpsi	psi	psi	psi	psi	gm/cm^3	lb
23C	1540; 81 (9)	11150; 1930 (9)	6910; 770 (9)	1153; 377 (6)	1540; 70 (6)	0.746; 0.041 (9)	
24C	1643; 183 (9)	13780; 2130 (9)	10040; 1610 (9)	1400; 176 (5)	2009; 108 (7)	.749; .053 (9)	
25C	1503; 181 (9)	11720; 2440 (9)	8530; 530 (9)	1424; 216 (7)	1616; 148 (8)	.675; .025 (9)	
28C	1599; 306 (8)	11380; 1790 (8)	8850; 1120 (9)	1152; 196 (6)	1636; 125 (8)	.759; .014 (9)	
61	1625; 118 (9)	9990; 1820 (9)	8460; 880 (9)	830; 192 (6)	1366; 193 (8)	.792; .023 (9)	
216	1416; 393 (9)	10210; 3350 (9)	8180; 450 (9)	1235; 60 (3)	1729; 74 (8)	.753; .014 (9)	
229	1587; 147 (9)	10420; 2100 (9)	7760; 450 (9)	871; 313 (8)	1589; 140 (6)	.713; .019 (9)	
291	1657; 256 (8)	12240; 1520 (8)	9620; 940 (9)	1102; 36 (7)	1492; 83 (8)	.777; .040 (9)	
N3	1271; 201 (9)	9250; 1440 (9)	4760; 1070 (9)	808; 110 (8)	1268; 100 (7)	.820; .038 (9)	4570; 600 (4)
N4	1726; 124 (9)	12390; 1800 (9)	6020; 1100 (9)	825; 139 (8)	1684; 101 (8)	.845; .051 (9)	4690; 1150 (4)
N6	1641; 147 (9)	10340; 1590 (9)	7820; 960 (9)	905; 85 (7)	1258; 139 (8)	.846; .038 (9)	4700; 910 (4)
N7	1494; 127 (9)	9860; 1290 (9)	6060; 630 (9)	690; 106 (4)	1214; 67 (8)	.849; .025 (9)	4810; 640 (4)

1/ $\bar{x}$ is the mean; s is the unbiased standard deviation; and the number in parentheses is the number of specimens tested.

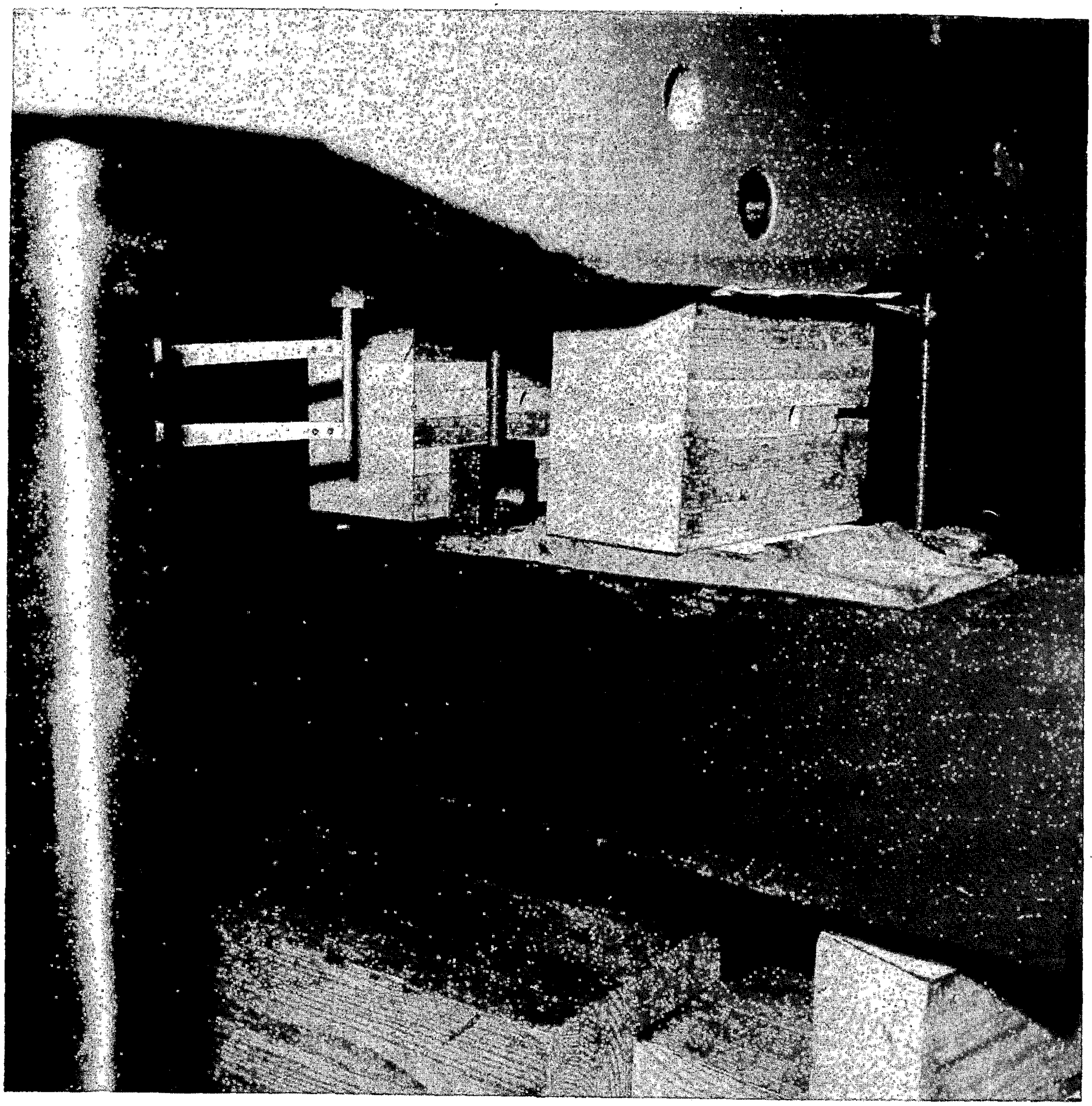


Figure 7.--Spike-withdrawal test setup.

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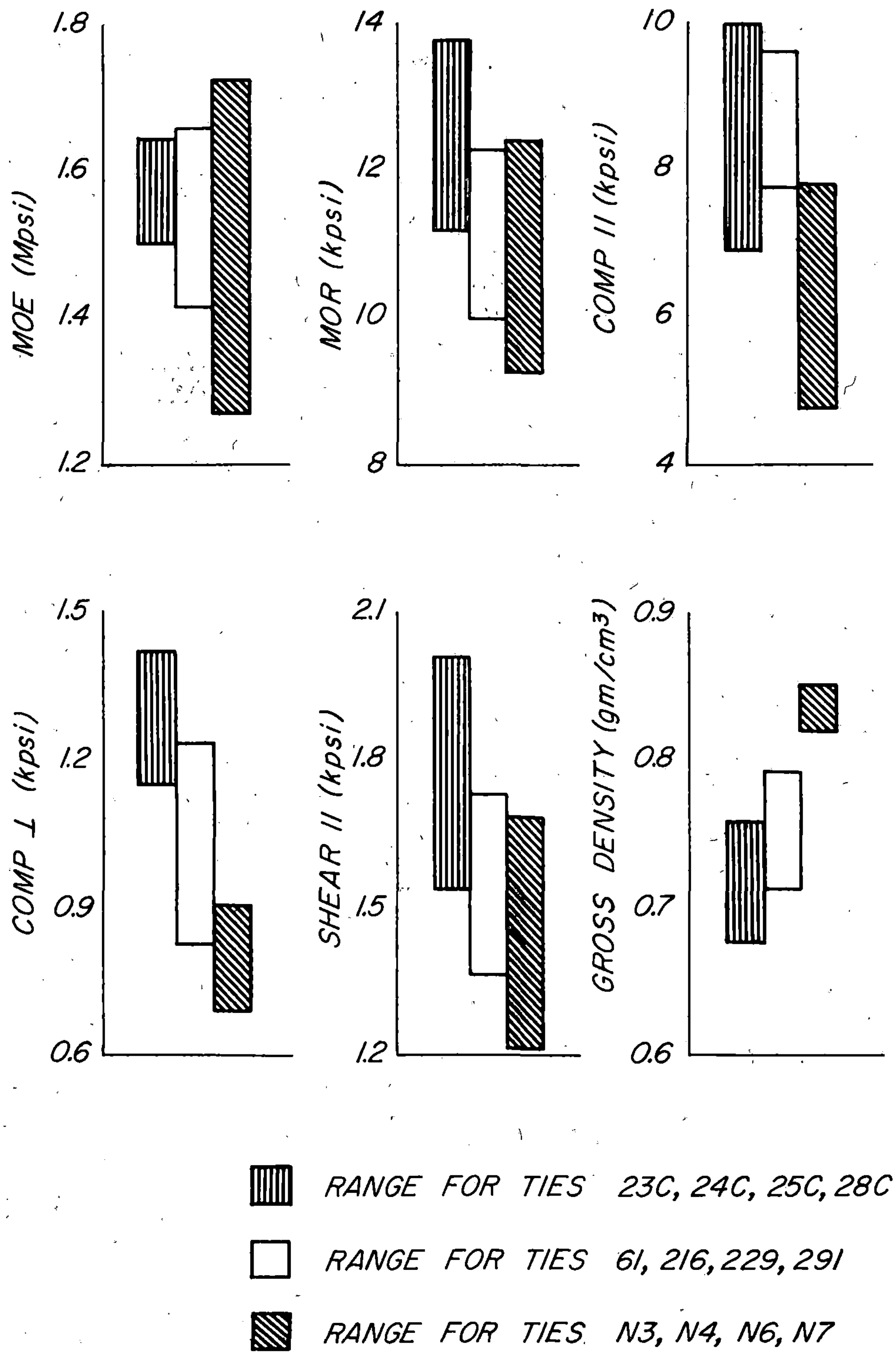


Figure 8.--Ranges of tie averages of small "clear" wood properties.

(M 146 673)

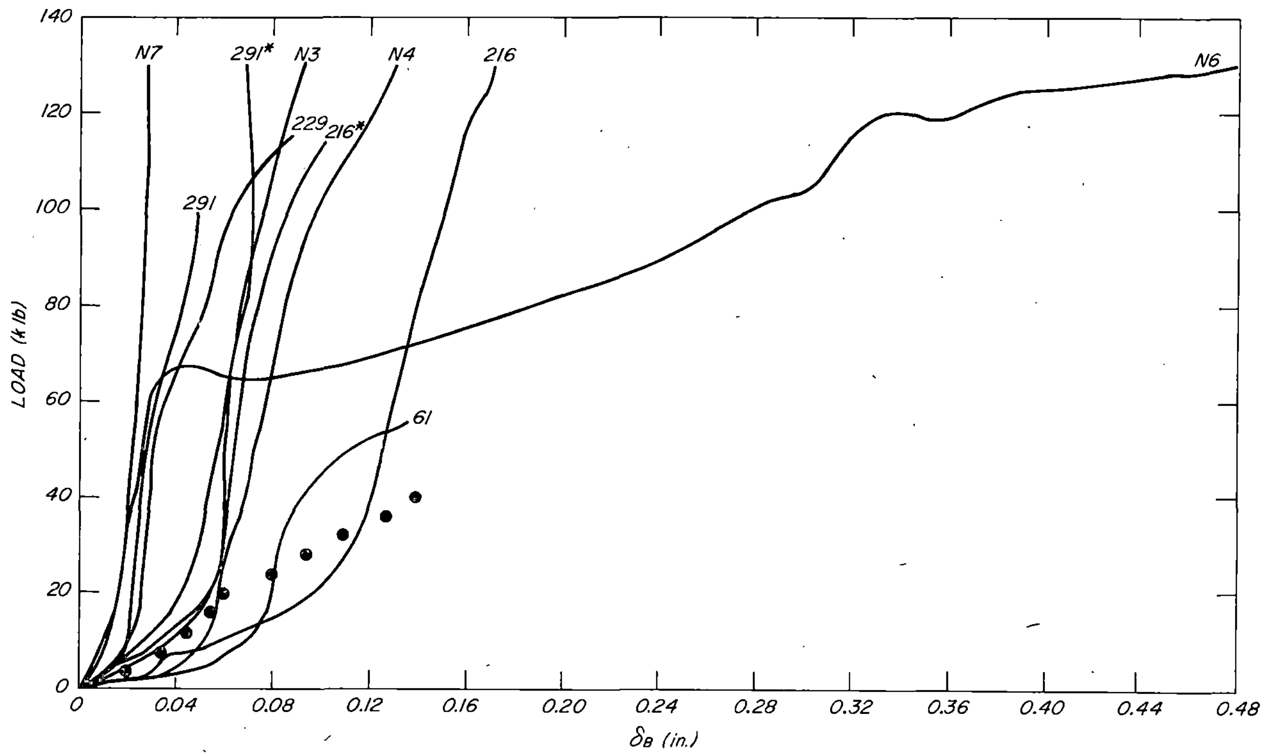


Figure 9.--Rail base displacement versus rail load of individual tie lateral resistance tests. Respiked ties have asterisks. Data points from AAR Report No. ER-77.

(M 146 670)

Lateral Resistance

Individual Tie Test

The load-displacement (rail base displacement or rail head-base differential displacement) curves for the individual ties are shown in figures 9 and 10. The tie plate of No. 61 crushed the tie sufficiently for the LVDT's to lose contact. The test results with less than 130,000 pounds were stopped short because of possible rail turnover (i.e., load plumb line approaching rail base edge). Plan photographs of the area under the tie plates are given in appendix B, with cross-sections of ties 291 and N6 given in figures B5 and B9. After group testing relay ties 61, 216, 229, and 291, the high field side of ties 216 and 291 (outermost in the group test) were tested individually with the intrack spike holes plugged and respiked (216*) and with the intrack spike holes just respiked (291*). Results from these two retested ties are also shown in figures 9 and 10.

Tie N6 was the only one to show lateral translation failure (figs. 9, 10, B8, B9), but this occurred above a load of 65,000 pounds and had a rail base translation of only 0.48 inch at 130,000 pounds.

The data points in figures 9 and 10 are data from AAR Report No. ER-77[4/] for an oak tie with 136-pound rail fastened by four spikes. The data follow the results for the N4 tie up to 20,000 pounds and then deviate (considerably for the base displacements). Two possible reasons for the difference in AAR results with those of the present study are (1) placement of measuring gages, where connecting them to the field side (as done by AAR) will pick up any compression parallel to grain, and (2) support of the tie; if the tie is only supported at two points (as done by AAR) with the load between, the gages will pick up railhead deflection due to tie bending. To check the plausibility of these two reasons, a white oak tie was tested up to 40,000 pounds in a two-point support configuration with dial gages fastened on the field side but with only two rail-holding spikes (AAR used four rail spikes). Recorded head movement was nearly identical to values AAR obtained, while recorded base movement was negative (probably due to plate turning and slipping). The results indicate that tie bending and compression can affect recorded displacement.

4/ Association of American Railroads Research Center. 1967. Capability of fasteners to resist rail overturning. Engineering Research Division Report No. ER-77. Association of American Railroads Research Center, Chicago, Ill. November.

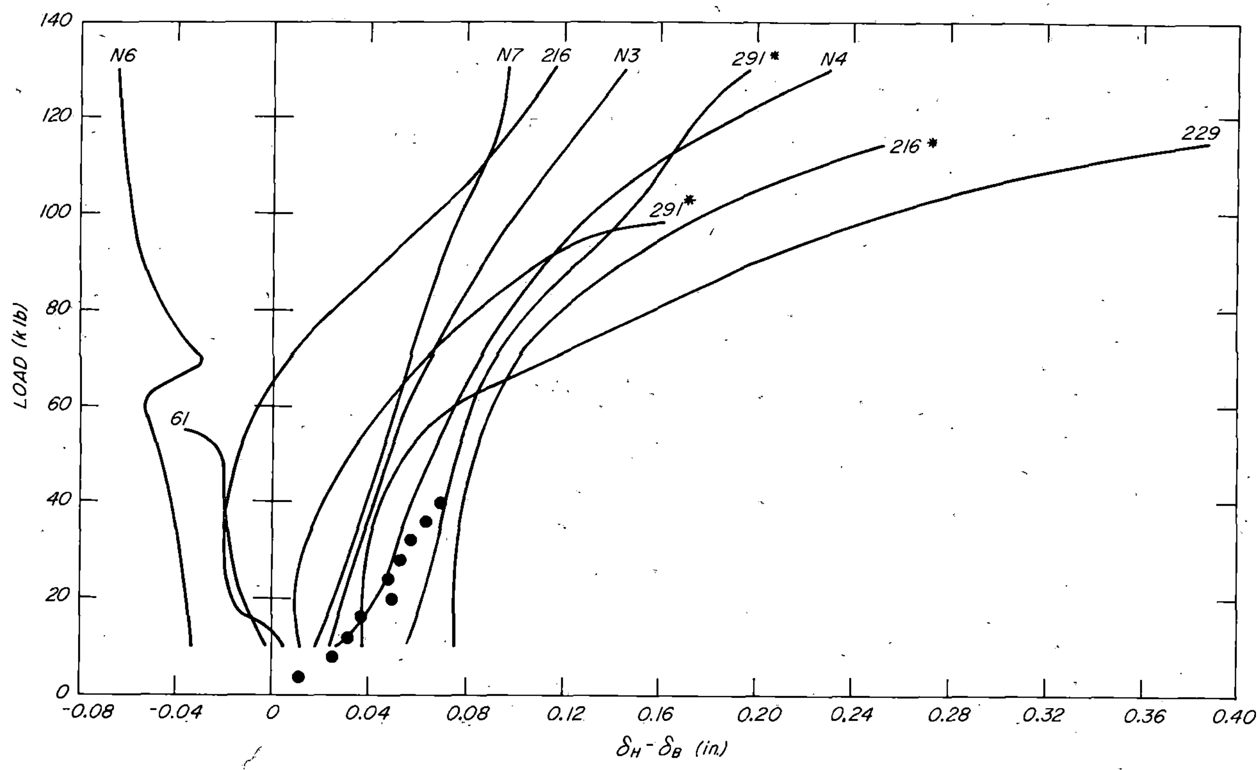


Figure 10.--Differential rail (head-minus-base) displacement versus rail load of individual tie lateral resistance tests. Respiked ties shown by asterisks. Data points from AAR Report No. ER-77.

(M 146 671)

The number of spikes resisting lateral translation will depend on the positioning of the spikes in the tie plate holes. If the holes are 3/4 inch square and the spikes are 5/8 inch square, one spike might have to deflect 0.125 inch before the other is even contacted. This non-contacted spike phenomenon could explain why the steepest slope of the load (base-) displacement curves starts at different displacements (from 0.02-0.12 in., fig. 10).

Nearly all individual tests had positive head-minus-base differential displacements, with the two exceptions being N6 and 61. Tie 229 had the highest differential displacement but this was less than 0.40 inch at 110,000 pounds. Figure 11 gives components of rail displacements and possible reasons for different recorded base movement and head movement. Actual rail movement would consist of one or more components.

Ties 61, 216, 229, and 291 showed wood crushing under the tie plates, figures B1-B5. The tie plate on tie 61 crushed the wood until its top surface was parallel to the top surface of the tie. This crushing phenomenon increased lateral resistance, since a lip was formed. Figure B5 shows a cross section of crushing extent. Tie 291 was chosen to be cross sectioned because two large splits emanate from the spike holes (fig. B4). Fearing the rail would overturn (which could damage the loading machine), the test of tie 291 was stopped at 110,000 pounds.

Crushing in the relay ties can be attributed to wood degradation by products of metal corrosion[5/], i.e., the wood has "metal sickness".[6/] This is not to be confused with wood decay. Characteristics of metal sickness are: (1) the affected wood is in contact with surrounding corroding metal, and (2) the wood has low tensile strength perpendicular to grain and low rolling shear properties, but still has some tensile strength parallel to grain. Results of the wood properties tests on specimens from between the rails, observations of excessive crushing under the tie plate, and the ability to roll the fibers to separate them, combine to indicate that the relay ties had extensive metal sickness and not decay.

The failure of the new tie N6 is possibly due to grain distortion around knots (fig. B9).

5/ Baker, A. J. 1974. Degradation of Wood by Products of Metal Corrosion. USDA Forest Serv. Res. Pap. FPL 229. Forest Products Lab., Madison, Wis.

6/ This conclusion was reached by FPL scientists in the Biodegradation of Wood Research Work Unit.

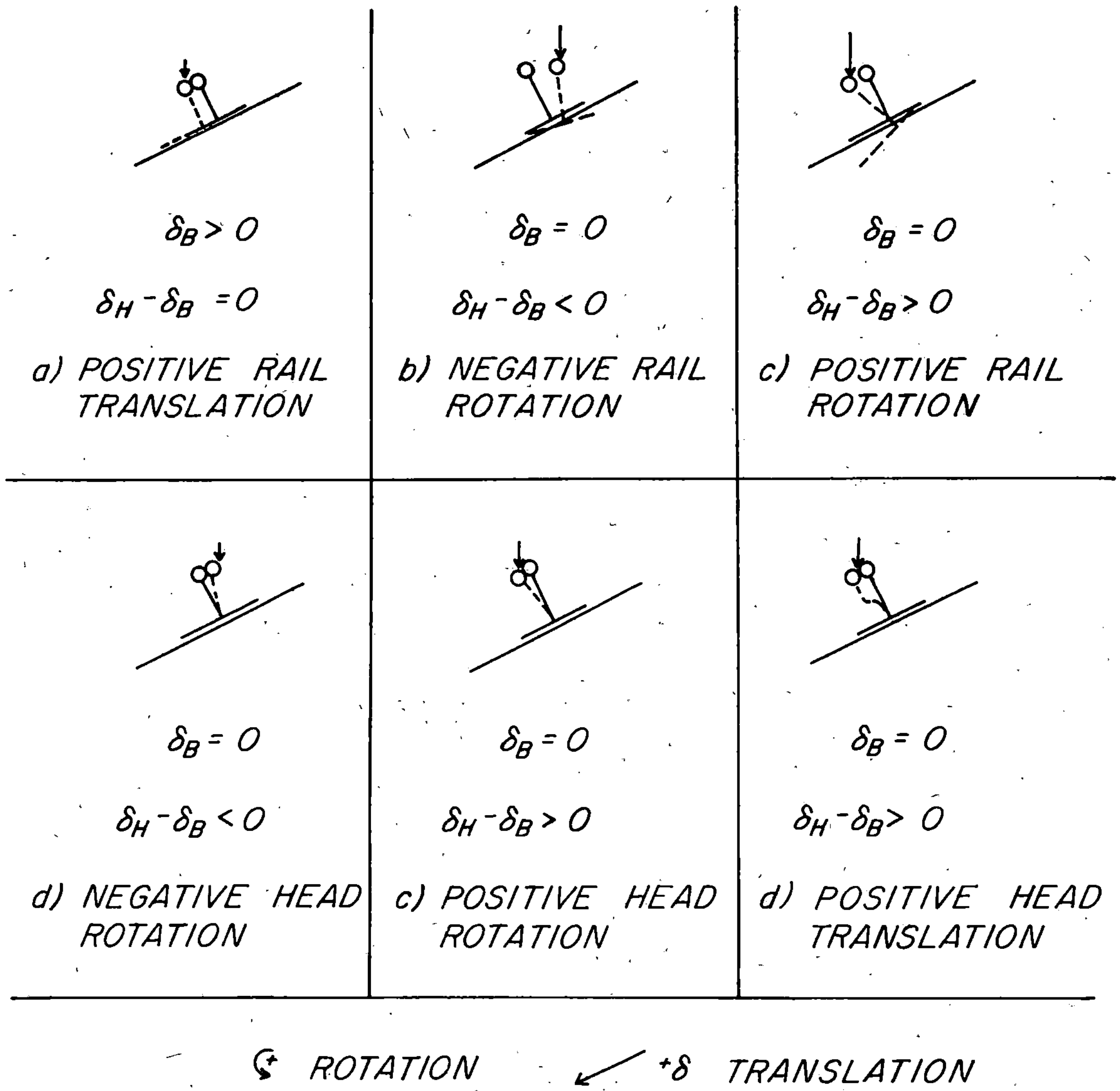


Figure 11.--Components of rail movement under a combined lateral and vertical load.

(M 146 676)

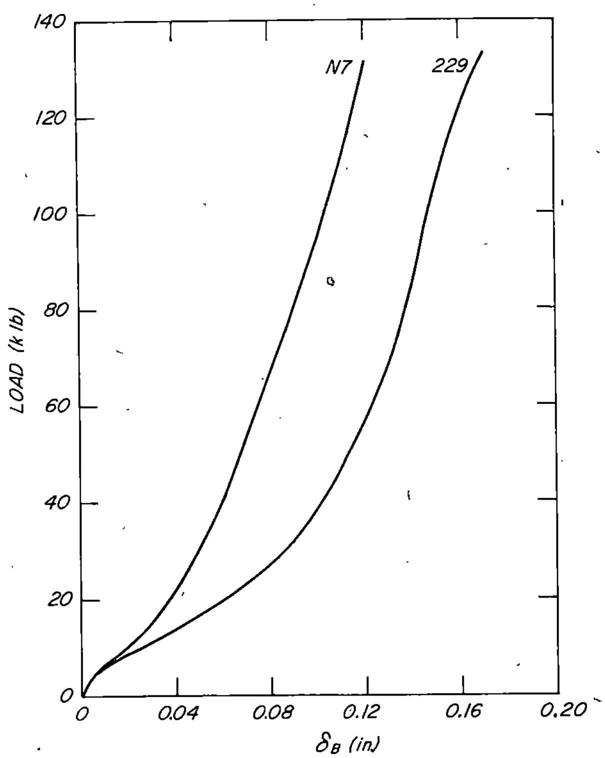


Figure 12.--Maximum rail base displacement versus rail load of group tie lateral resistance tests.

(M 146 669)

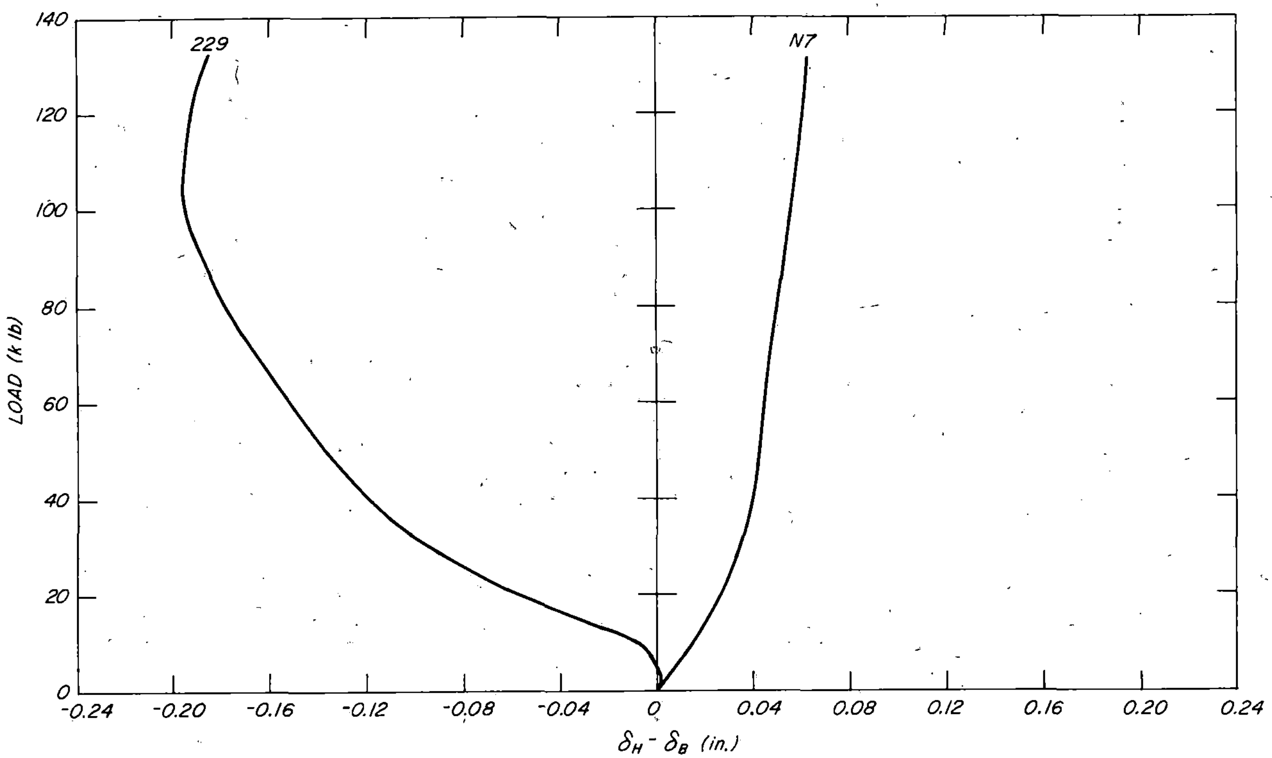


Figure 13.--Differential rail (head-minus-base) displacement versus rail load of ties with maximum rail base displacement of group tie lateral resistance tests.

(M 146 672)

Group Tie Tests

The recorded results for the group tie tests are given in appendix C. The load displacement curves of ties (229 and N7) with the maximum rail base displacements (center ties, fig. 5) are plotted in figures 12 and 13. In the group tests, the center two ties had the largest displacements, and the outer two the smallest. Considering the greatest base displacement in each group, the relay group showed less resistance to base displacement than the new group. The relay group also showed negative (head-base) differential displacement[7/] rather than the positive which the new group showed (fig. 13), but still less base displacement than the N6 individual tie test performance.

Spike Withdrawal

Results of spike withdrawal tests are given in table 1. The average maximum spike-withdrawal load ranges from 4,570 to 4,810 pounds (table 1).

CONCLUSIONS

These conclusions apply to the ties tested:

1. The tested wood properties of small specimens from the central gage portion of the eight relay ties are comparable to the tested wood properties of small specimens from the central gage portion of the four new ties.

2. The lateral resistance under loads of the magnitude and type applied of four relay ties (up to 24 years in track) are comparable to the lateral resistance under the same loads applied to the four new ties, even when one relay tie was plugged and respiked or when one relay tie was just respiked in the intrack holes.

3. One new tie failed the lateral resistance test under static load, such that the spikes bent into an S-shape; nevertheless the rail base displaced laterally less than 0.5 inch at a total load of 130,000 pounds (a 2:1 vertical:horizontal load ratio).

7/ Note: Even with negative differential displacement, gage widening is possible if the base displacement is larger!

4. In a four-tie group test, the center two ties have the greatest rail-base lateral displacement under static load, and the maximum in each group test behaves comparably to an individual tie test.

5. Crushing under the tie plate of the relay ties is the result of "metal sickness" (i.e. degradation of wood by products of metal corrosion). Although it benefits lateral resistance under static load, it can result in rail rotation (either direction) at high loads. The new ties did not exhibit crushing under the tie plate or signs of metal sickness. Specimens from the central gage portion of the relay and new ties did not show signs of metal sickness.

6. The maximum force needed to withdraw spikes from the new ties averaged greater than 4,500 pounds.

7. Evidence of tie plate translation on ties tested with a static load (in the lateral resistance tests) did not replicate the evidence of tie plate translation at the accident site (see fig. 1), where dynamic rail loads occurred.

APPENDIX A

Descriptions of red oak crossties 23C, 24C, 25C, 28C, 61, 216, 229, 291, N3, N4, N6, and N7. Photographs (both side and end views) are also shown for ties 61, 216, 229, and 291.

Crosstie Identification Marking: 23C

Stamped Date: 53G

General Description

Size: – X 7" X 9"

Straightness (bow, crook, cup, twist): Moderate 1/2"/6-1/2'

Growth Rate: Slow > 10/in.

Slope of Grain: 3/4"/12"

Natural Defects Present (splits, shakes, checks, knots, holes)

Extent: 1" wide check @ end

Species: Red oak

Cut From Log: Heart center

Decay Present: 1)

Treated: Creosote to center

Manufacturing Process (incised, machined, . . .): Sawn

Prebored Spike Holes: 6 @ one end-thru

For what size rail: 5-1/4" minimum base size spike: 9/16"

Ties Machine Adzed: @ tie plate

Antisplit Devices Present: No

Conditions Due to Emplacement

Heartwood Up: --

Ties Hand-Adzed: @ tie plate

Tie Pads Used: No

Tie Plate Size: 136

Hole Pattern: 8 holes 4 rail holding

Spike Used: 2 5/8" rail holding

Noticeable Plate Movement: Cutting 1/4-3/8"

Other Comments: Appearance of metal sickness

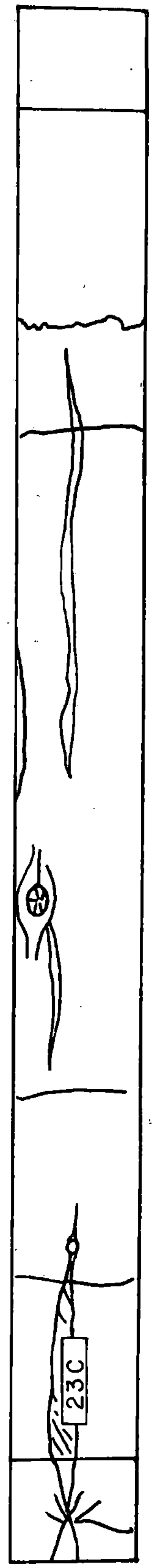


Figure A-1

M 146 654

Crosstie Identification Marking: 24C

Stamped Date: 53G

General Description

Size: – X 6-1/2" X 8-7/8"

Straightness (bow, crook, cup, twist): --

Growth Rate: Fast <6/in.

Slope of Grain: 3/4"/12"

Natural Defects Present (splits, shakes, checks, knots, holes)

Extent: 1" wide check 2" knot

Species: Red oak

Cut From Log: Heart center

Decay Present: 1)

Treated: Creosote to center

Manufacturing Process (incised, machined, . . .): Sawn

Prebored Spike Holes: 6 @ one end-thru (one plug)

For what size rail: 5-1/2" minimum base size spike: 5/8"

Ties Machine Adzed: Yes

Antisplit Devices Present: No

Conditions Due to Emplacement

Heartwood Up: --

Ties Hand-Adzed: No

Tie Pads Used: No

Tie Plate Size: 136

Hole Pattern: 8 holes 4 rail holding

Spike Used: 2 5/8" rail holding

Noticeable Plate Movement: Slight cutting 1/8"

Other Comments: Appearance of metal sickness

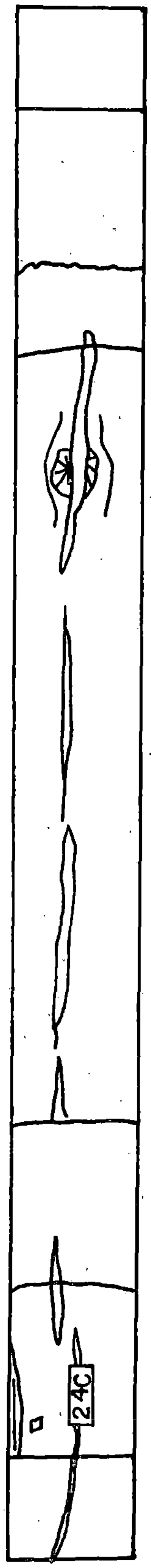


Figure A-2

Crosstie Identification Marking: 25C

Stamped Date: --

General Description

Size: - X 6-3/4" X 9"

Straightness (bow, crook, cup, twist): 1"/16" @ end

Growth Rate: Fast < 6/in.

Slope of Grain: 3/4"/24"

Natural Defects Present (splits, shakes, checks, knots, holes)

Extent: 5/8" wide check (stones embedded)

Species: Red oak

Cut From Log: Heart center

Decay Present: 1)

Treated: Creosote to center

Manufacturing Process (incised, machined, . . .): Hand hewn

Prebored Spike Holes: 7 @ one end-thru

For what size rail: 5-1/4" minimum base size spike: 9/16"

Ties Machine Adzed: @ tie plate

Antisplit Devices Present: No

Conditions Due to Emplacement

Heartwood Up: --

Ties Hand-Adzed: @ tie plate

Tie Pads Used: No

Tie Plate Size: 136

Hole Pattern: 8 holes 4 rail holding

Spike Used: 2-5/8" rail holding

Noticeable Plate Movement: Slight cutting 1/8"-3/16"

Other Comments: Appearance of metal sickness

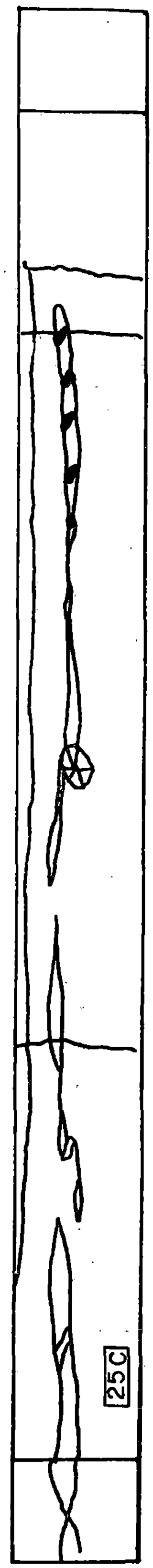


Figure A-3

Crosstie Identification Marking: 28C

Stamped Date: --

General Description

Size: 8'5-3/4" X 6-5/8" X 9-1/2"

Straightness (bow, crook, cup, twist): --

Growth Rate: Slow > 10/in.

Slope of Grain: 1-1/4" /24"

Natural Defects Present (splits, shakes, checks, knots, holes)

Extent: 1" wide split @ both ends

Species: Red oak

Cut From Log: Heart center

Decay Present: 1)

Treated: Creosote to center

Manufacturing Process (incised, machined, . . .): Hand hewn

Prebored Spike Holes: 10 @ one end-thru

For what size rail: 5-1/8" minimum base size spike: 5/8"

Ties Machine Adzed: No

Antisplit Devices Present: No

Conditions Due to Emplacement

Heartwood Up: --

Ties Hand-Adzed: Yes

Tie Pads Used: No

Tie Plate Size: 136

Hole Pattern: 8 holes 4 rail holding

Spike Used: 2 5/8" rail holding

Noticeable Plate Movement: Cutting 1/2"

Other Comments: Appearance of metal sickness

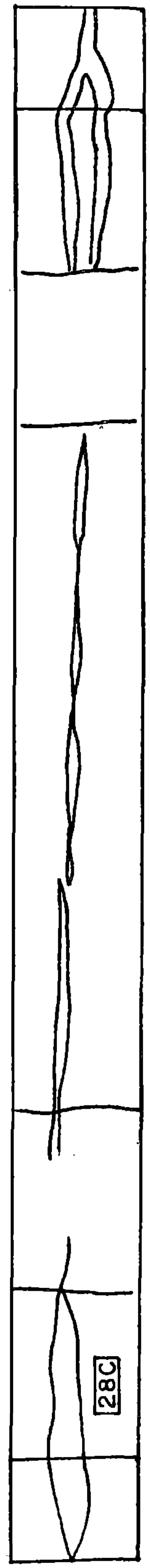


Figure A-4

Crosstie Identification Marking: 61

Stamped Date: 53G

General Description

Size: 8'7-1/2" X 7" X 9"

Straightness (bow, crook, cup, twist): Slight 3/8"/8'

Growth Rate: Medium 5-10/in.

Slope of Grain: 1/2"/12"

Natural Defects Present (splits, shakes, checks, knots, holes)

Extent: 3/4" wide check center

Species: Red oak

Cut From Log: Heart center

Decay Present: 1)

Treated: Creosote to center

Manufacturing Process (incised, machined, . . .): Sawn

Prebored Spike Holes: Yes

For what size rail: 5-3/4" minimum base size spike: 5/8"

Ties Machine Adzed: @ tie plate

Antisplit Devices Present: 2 nails in sides @ ends

Conditions Due to Emplacement

Heartwood Up: --

Ties Hand-Adzed: No

Tie Pads Used: No

Tie Plate Size: 136

Hole Pattern: See photograph

Spike Used: 2 5/8" rail holding

Noticeable Plate Movement: Cutting 1/2"

Other Comments:

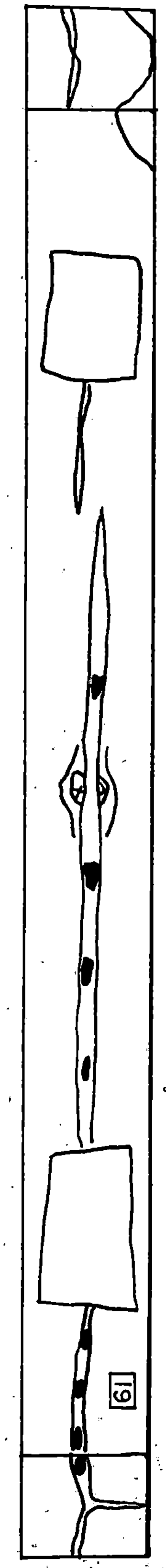


Figure A-5

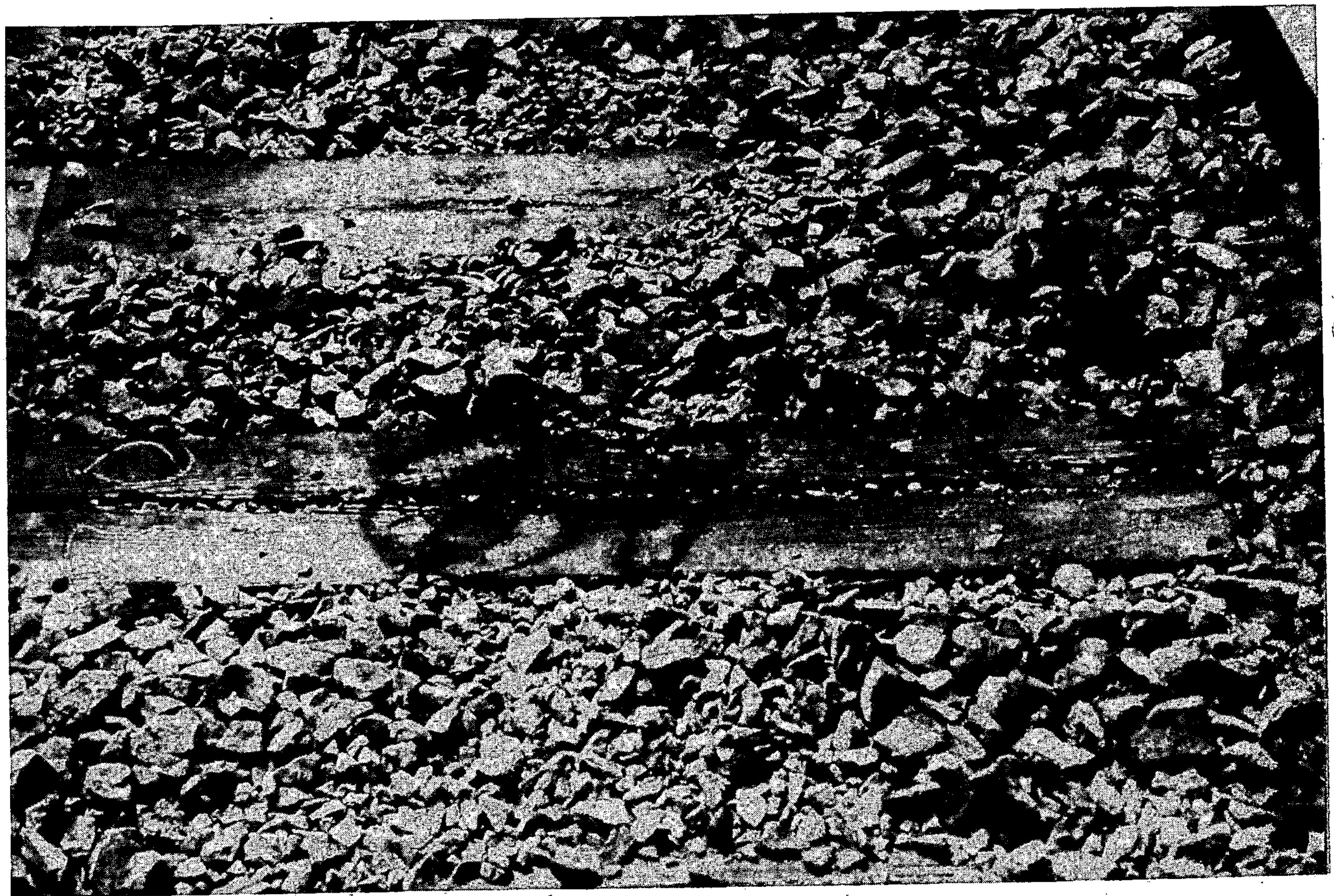


Figure A-6

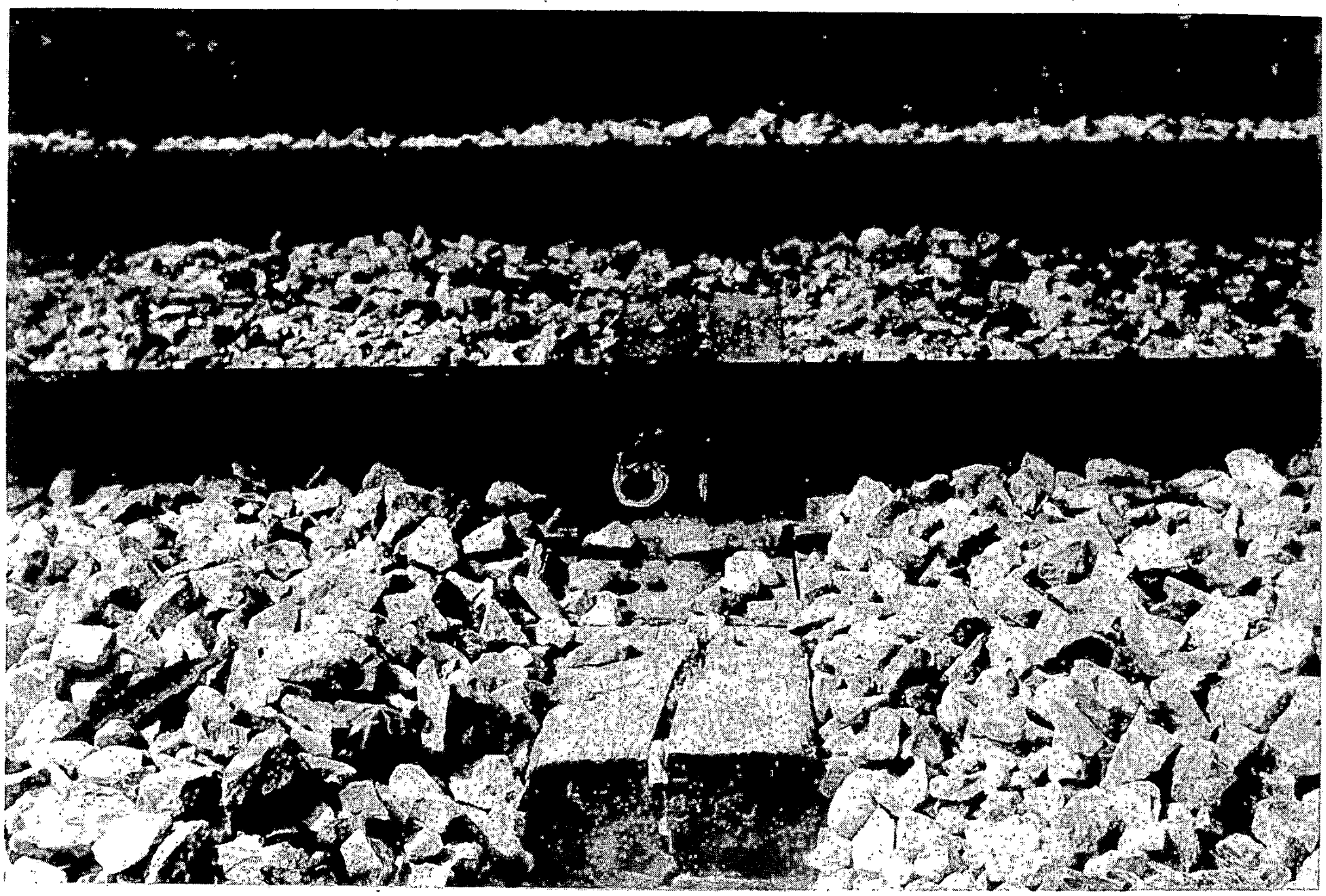


Figure A-7

Crosstie Identification Marking: 216

Stamped Date: 53G

General Description

Size: 8'5-3/4" X 6-5/8" X 8-3/4"

Straightness (bow, crook, cup, twist): Very slight

Growth Rate: Medium 6-10/in.

Slope of Grain: 5/8"/12"

Natural Defects Present (splits, shakes, checks, knots, holes)

Extent: 7/8" wide center check

Species: Red oak

Cut From Log: Heart center

Decay Present: 1)

Treated: Creosote to center

Manufacturing Process (incised, machined, . . .): Sawn

Prebored Spike Holes: Yes

For what size rail: 5-3/4" minimum base size spike: 5/8"

Ties Machine Adzed: @ tie plate

Antisplit Devices Present: Side nails

Conditions Due to Emplacement

Heartwood Up: --

Ties Hand-Adzed: @ tie plate

Ti Pads Used: No

Tie Plate Size: 136

Hole Pattern: See photograph

Spike Used: 2 5/8" rail holding

Noticeable Plate Movement: Cutting 0-1/4" high side

Other Comments:

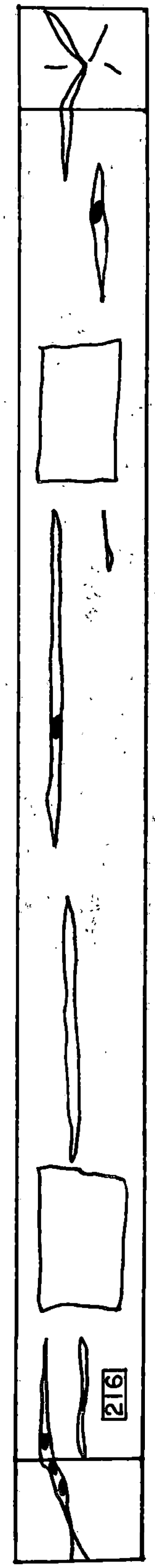


Figure A-8

M 146 659

Figure A-9

Figure A-10

Crosstie Identification Marking: 229

Stamped Date: 53G

General Description

Size: 8'4-1/2" X 7" X 9"

Straightness (bow, crook, cup, twist): --

Growth Rate: Fast < 5/in.

Slope of Grain: 7/8"/12"

Natural Defects Present (splits, shakes, checks, knots, holes)

Extent: 1/2" wide end check

Species: Red oak

Cut From Log: Heart center

Decay Present: 1)

Treated: Creosote to center

Manufacturing Process (incised, machined, . . .): Sawn

Prebored Spike Holes: Yes

For what size rail: 5-3/4" min. base size spike: 5/8"

Ties Machine Adzed: @ tie plate

Antisplit Devices Present: Side nails

Conditions Due to Emplacement

Heartwood Up: --

Ties Hand-Adzed: No

Tie Pads Used: No

Tie Plate Size: 136

Hole Pattern: See photograph

Spike Used: 2 5/8" rail holding

Noticeable Plate Movement: Cutting 1/4"

Other Comments:

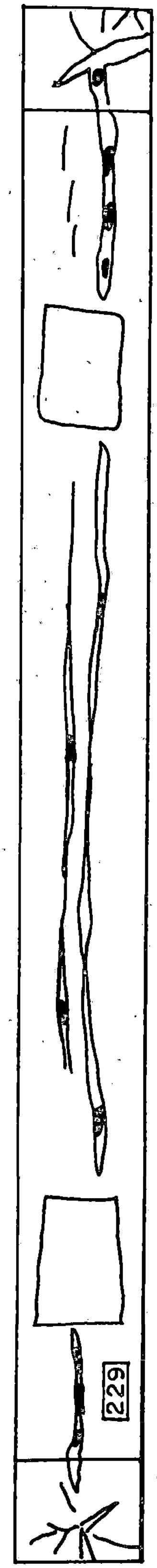


Figure A-11

Figure A-12

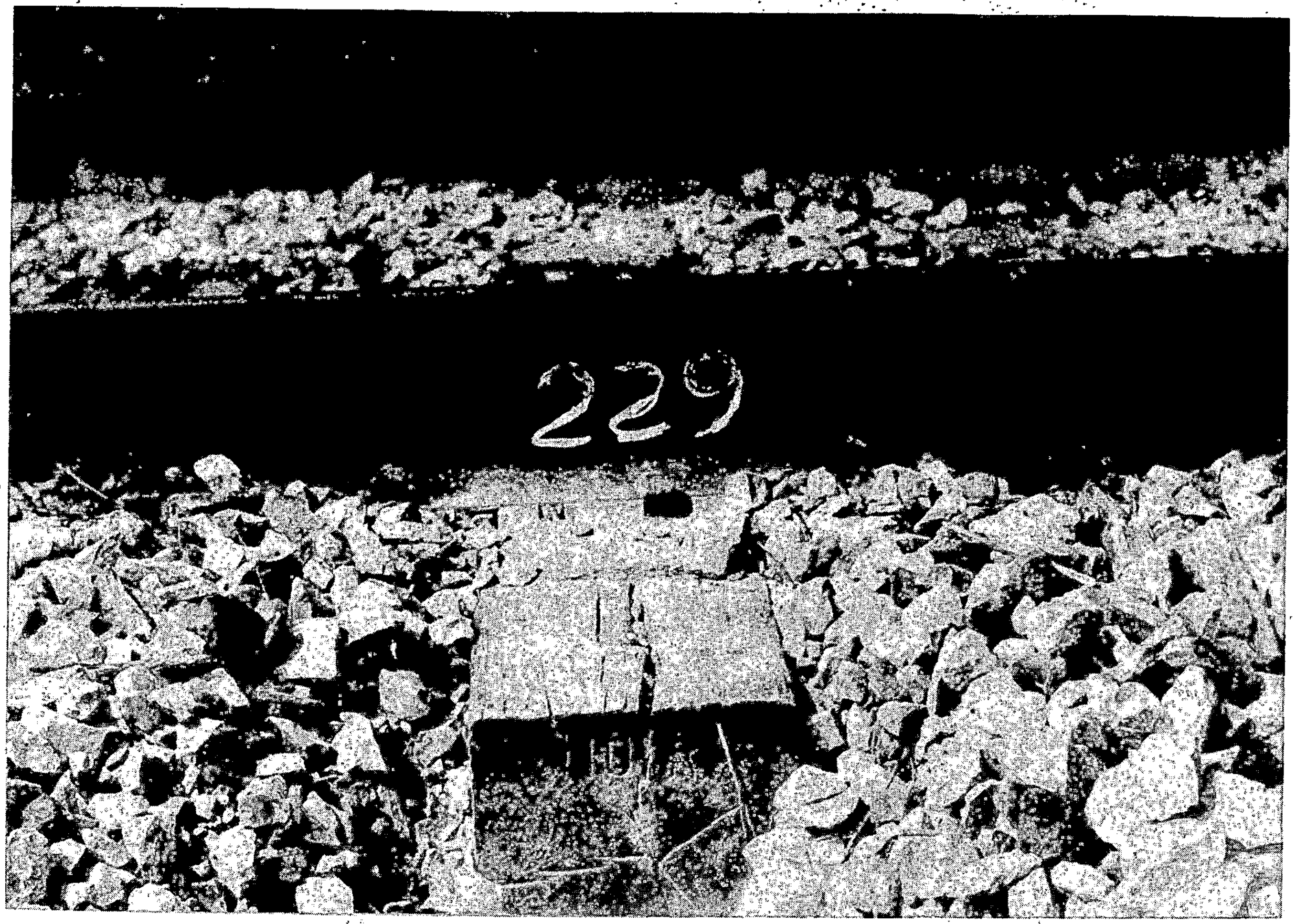


Figure A-13

Crosstie Identification Marking: 291

Stamped Date: 53G

General Description

Size: 8'7-1/2" X 6-3/4" X 8-1/2"

Straightness (bow, crook, cup, twist): --

Growth Rate: Slow > 10/in.

Slope of Grain: 1"/24"

Natural Defects Present (splits, shakes, checks, knots, holes)

Extent: 3/4" wide end check

Species: Red oak

Cut From Log: Heart center

Decay Present: 1)

Treated: Creosote to center

Manufacturing Process (incised, machined, . . .): Hand hewn

Prebored Spike Holes: Yes

For what size rail: 5-3/4" min. base size spike: 5/8"

Ties Machine Adzed: No

Antisplit Devices Present: Side nails

Conditions Due to Emplacement

Heartwood Up: --

Ties Hand-Adzed: @ tie plate

Tie Pads Used: No

Tie Plate Size: 136

Hole Pattern: See photograph

Spike Used: 2 5/8" rail holding

Noticeable Plate Movement: Cutting 1/4"

Other Comments:

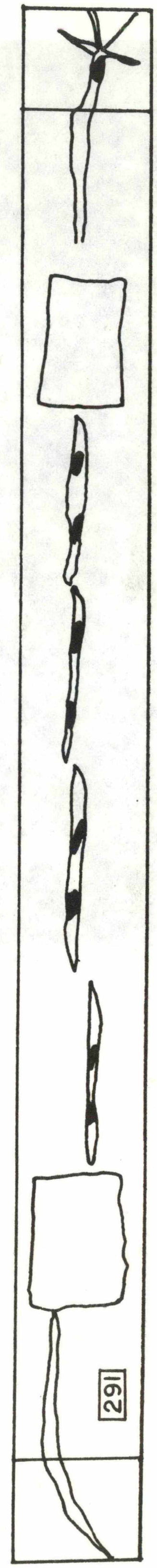


Figure A-14

M 146 661

Crosstie Identification Marking: N6

Stamped Date: --

General Description

Size: 8'4" X 7-1/8" X 9-1/4"

Straightness (bow, crook, cup, twist): --

Growth Rate: Medium 6-10/in.

Slope of Grain: 1-1/2"/24"

Natural Defects Present (splits, shakes, checks, knots, holes)

Extent: Very slight

Species: Red oak

Cut From Log: Heart center

Decay Present: --

Treated: Creosote to center

Manufacturing Process (incised, machined, . . .): Sawn

Prebored Spike Holes: Yes

For what size rail: 136 size spike: 5/8"

Ties Machine Adzed: @ tie plate

Antisplit Devices Present: No

Conditions Due to Emplacement

Heartwood Up: --

Ties Hand-Adzed: --

Tie Pads Used: --

Tie Plate Size: 136

Hole Pattern: See photograph

Spike Used: --

Noticeable Plate Movement: --

Other Comments: Open knot, bore holes might indicate decay.

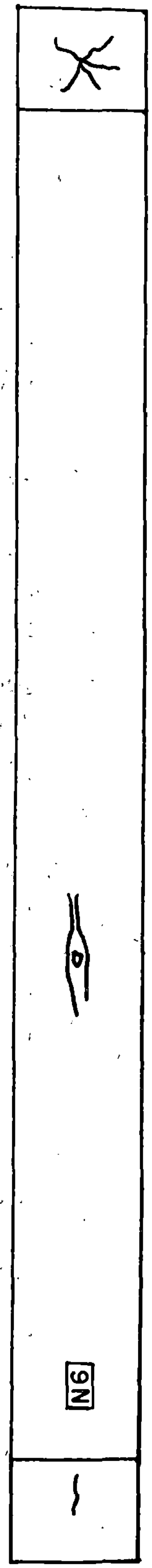


Figure A-19

M 146 664

Crosstie Identification Marking: N7

Stamped Date: --

General Description

Size: 8'5-3/8" X 7" X 9"

Straightness (bow, crook, cup, twist): Very slight

Growth Rate: Slow > 10/in.

Slope of Grain: 1"/24"

Natural Defects Present (splits, shakes, checks, knots, holes)

Extent: Slight

Species: Red oak

Cut From Log: Pith center (side on one end, top on other)

Decay Present: --

Treated: Creosote to center

Manufacturing Process (incised, machined, . . .): Sawn

Prebored Spike Holes: Yes

For what size rail: 136 size spike: 5/8"

Ties Machine Adzed: @ tie plate

Antisplit Devices Present: No

Conditions Due to Emplacement

Heartwood Up: Yes @ one end

Ties Hand-Adzed: --

Tie Pads Used: --

Tie Plate Size: 136

Hole Pattern: See photograph

Spike Used: --

Noticeable Plate Movement: --

Other Comments:

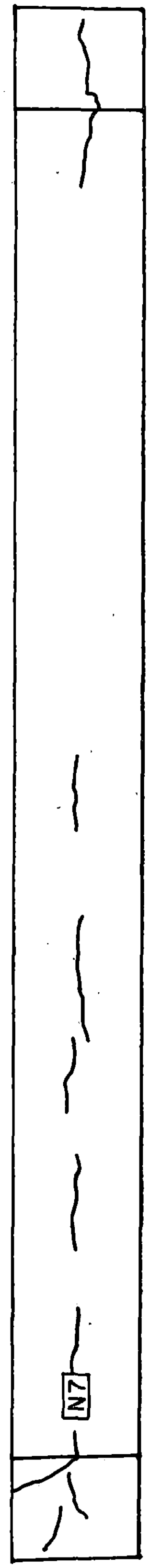


Figure A-20

APPENDIX B

Plan photographs of tie sections after individual tie lateral resistance tests for ties 61, 216, 229, 291, N3, N4, N6, and N7. Cross section photos are of ties 291 and N6.

Figure B-1

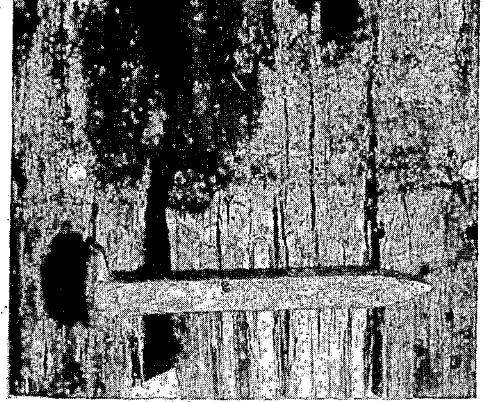


Figure B-2

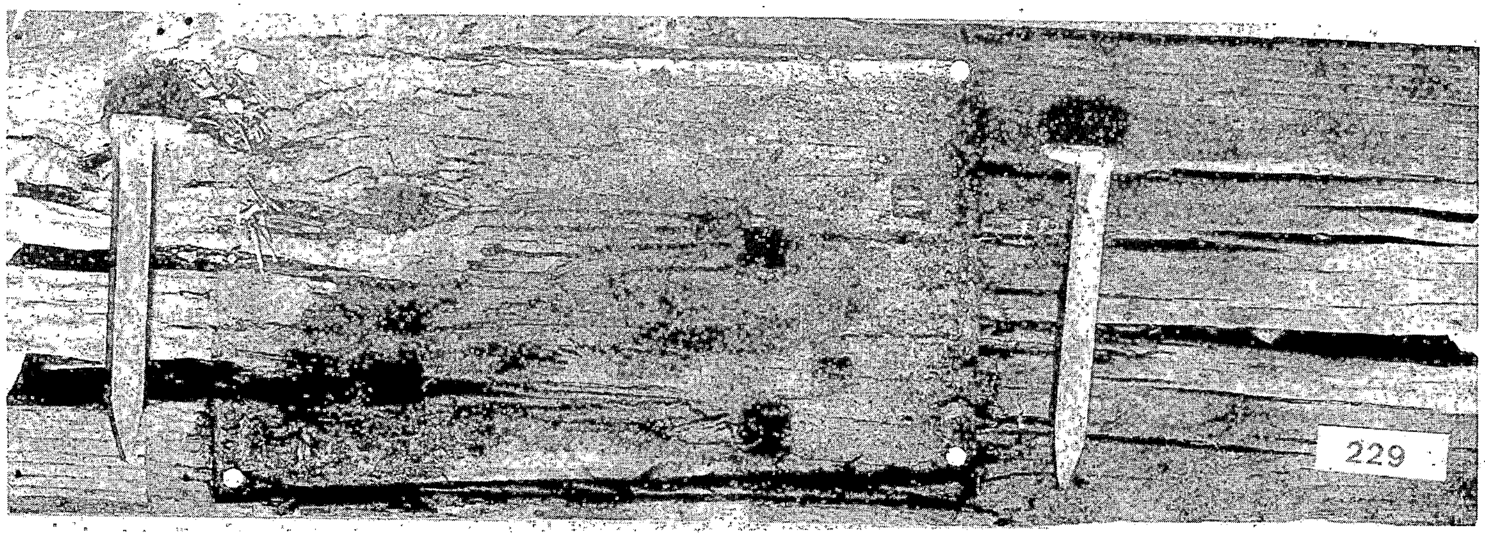


Figure B-3

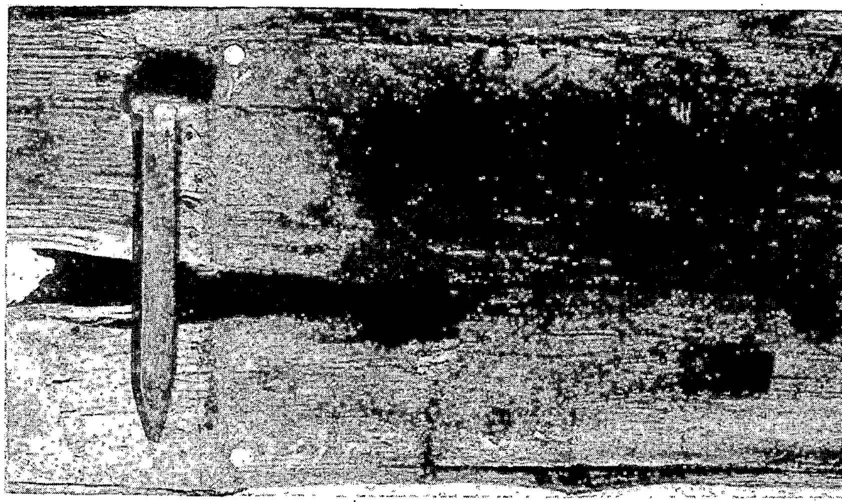
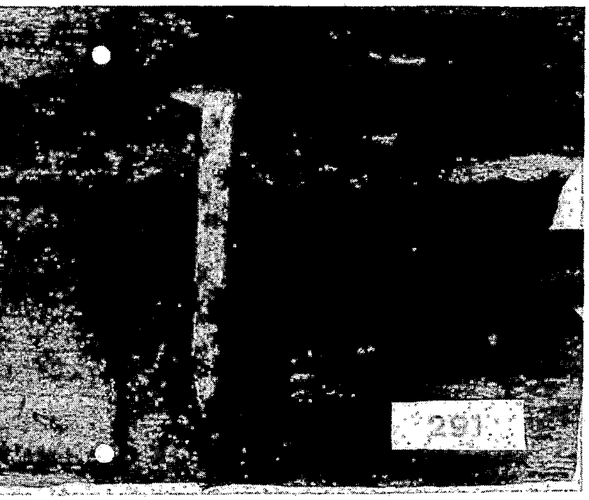


Figure B-4


291

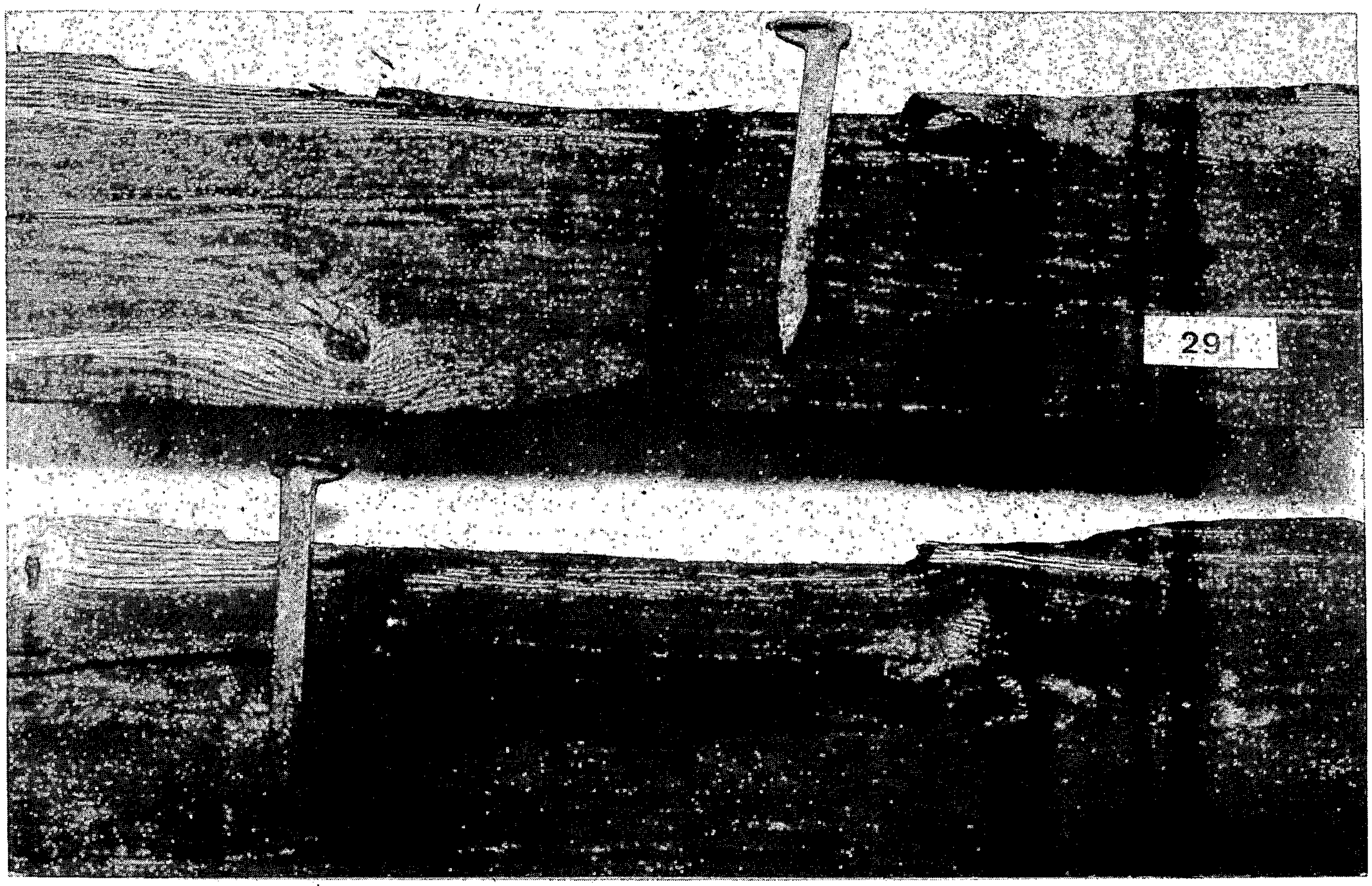


Figure B-5

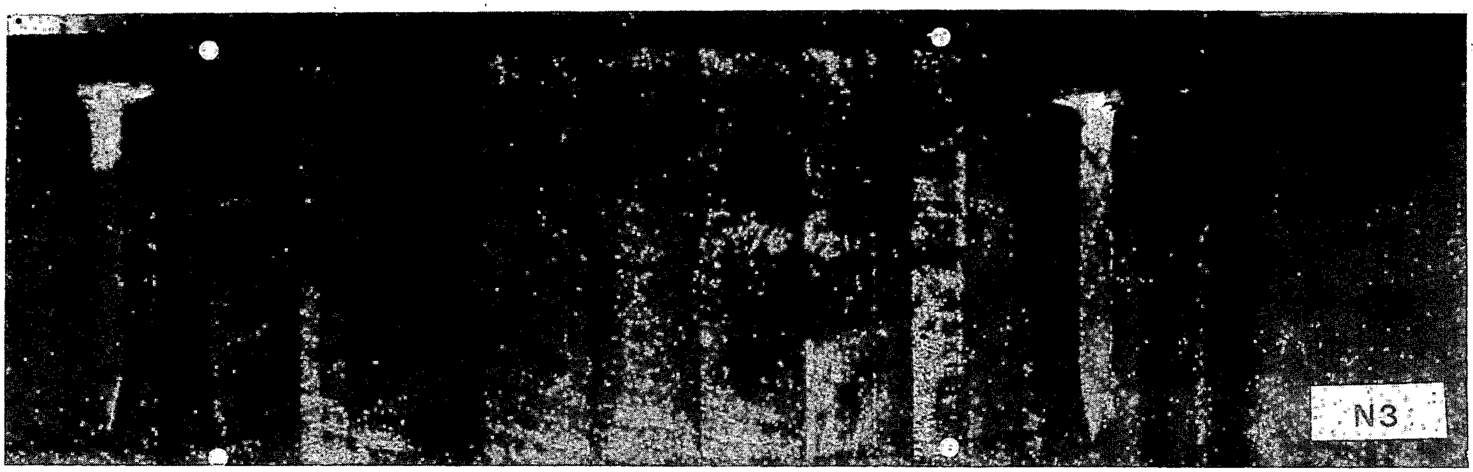


Figure B-6

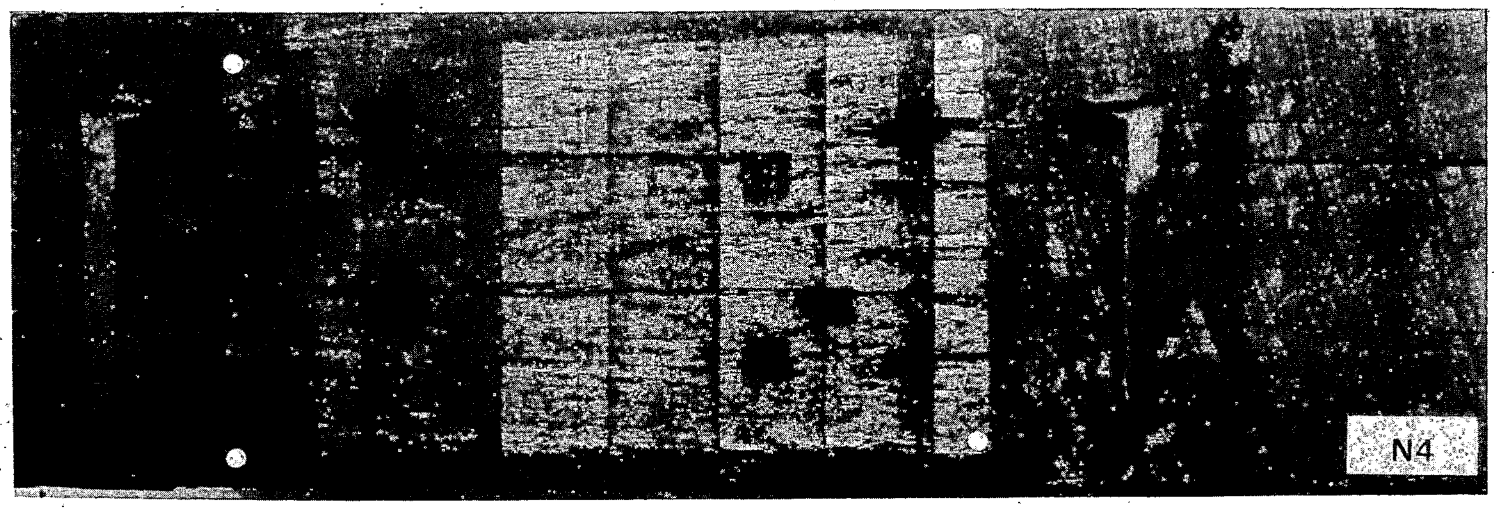
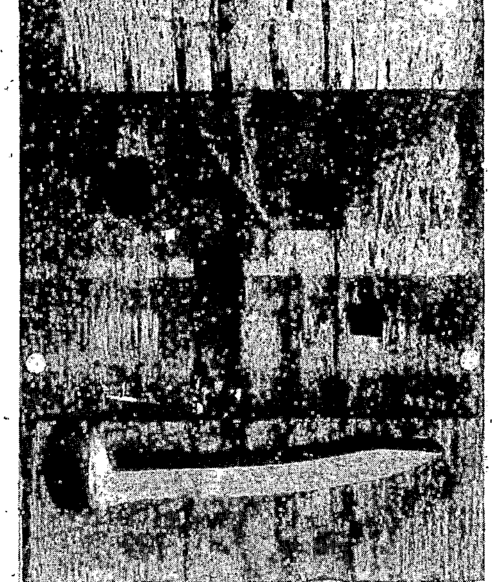


Figure B-7



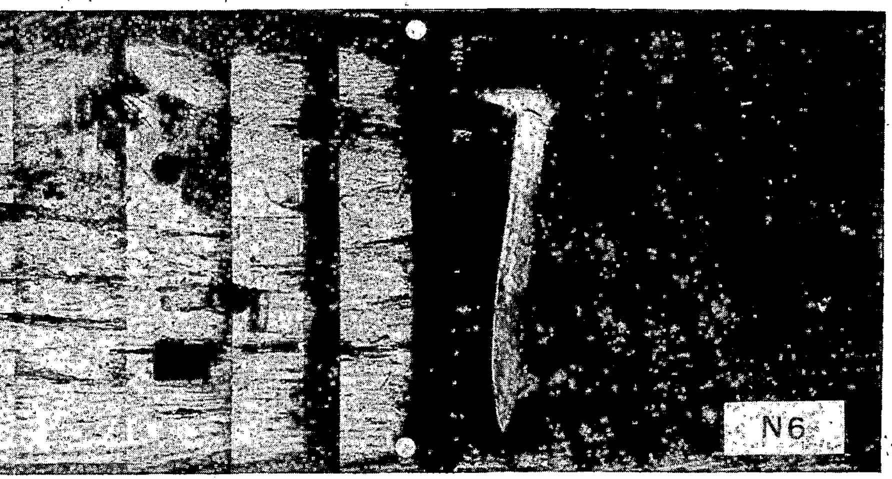


Figure B-8

Figure B-9

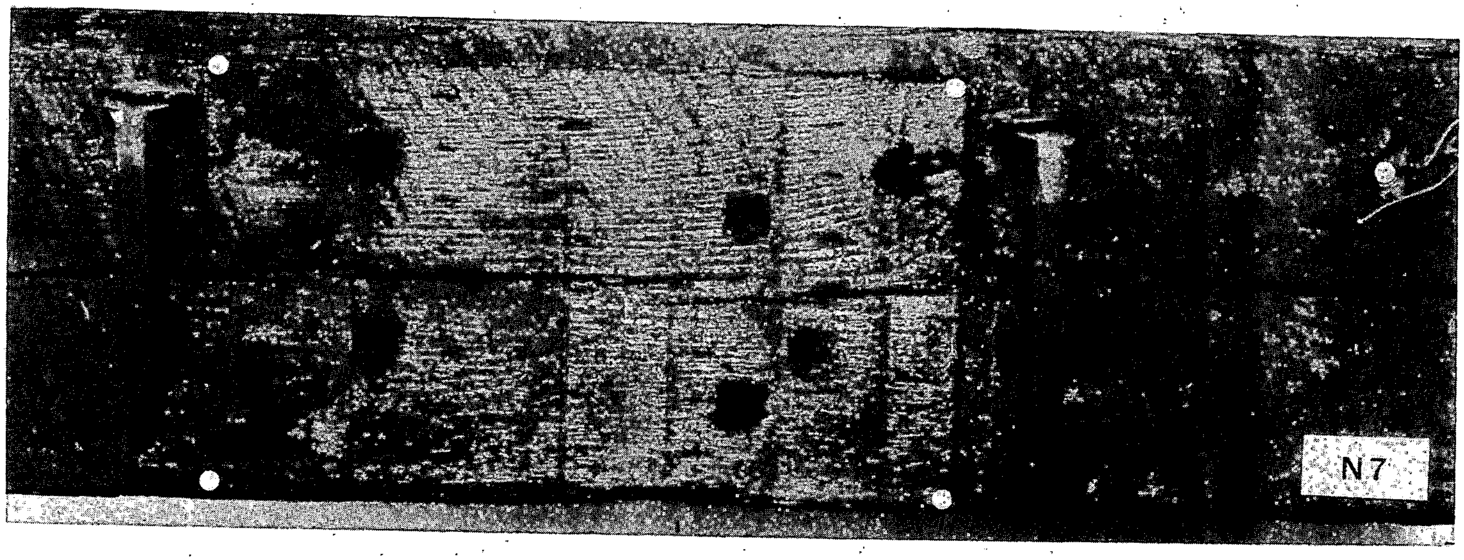


Figure B-10

APPENDIX C

Recorded measurements of group tie lateral resistance tests. Refer to figures 5 and 6 for location of displacement gages.

Test No. 1 Uptrack Ties

Load	δ_3	δ_5	δ_7	δ_9	δ_2	δ_4	δ_6	δ_8	δ_1	δ_{10}
klb					0.001 in.					
2.1	2	3	1	-1	3	6	1	7	-1	-1
4.8	8	6	1	-1	6	6	-1	10	-3	-2
7.1	11	13	3	-1	8	7	0	10	-4	-3
7.9	13	17	7	-1	11	15	6	12	-5	-3
8.4	15	21	10	-1	10	17	8	11	-6	-3
11.2	17	28	15	0	9	18	11	8	-4	-6
15.0	23	43	24	0	8	14	14	3	-3	-10
19.2	27	57	31	1	6	7	14	-1	-1	-12
20.2	28	63	34	1	6	6	16	-2	-1	-13
24.8	30	74	37	1	1	1	15	-6	3	-18
30.0	32	86	41	1	-4	-10	11	-12	8	-21
35.6	34	94	45	1	-8	-15	8	-15	13	-26
41.8	35	103	48	0	-11	-17	4	-20	20	-29
48.5	37	111	51	0	-12	-23	1	-24	26	-31
55.2	37	119	54	-1	-14	-26	-3	-26	34	-34
62.4	39	125	56	-2	-15	-30	-5	-29	42	-35
69.7	39	131	58	-3	-16	-33	-8	-31	50	-37
77.0	40	136	61	-4	-16	-36	-11	-32	59	-36
84.1	41	140	63	-5	-18	-41	-14	-32	68	-35
91.2	41	143	66	-6	-18	-44	-16	-32	78	-33
98.2	41	146	69	-7	-17	-48	-19	-32	89	-30
105.1	41	150	72	-9	-18	-45	-22	-31	100	-27
112.2	41	154	75	-11	-16	-40	-25	-30	112	-24
119.1	41	159	79	-12	-16	-32	-28	-29	122	-21
126.1	41	164	83	-12	-15	-23	-32	-27	134	-16
133.0	41	171	87	-13	-15	-15	-35	-25	143	-13

Test No. 2 Uptrack Ties

Load		δ_3	δ_5	δ_7	δ_9	δ_2	δ_4	δ_6	δ_8	δ_1	δ_{10}
k1b						0.001 in.					
0	set	31	115	49	7	-15	111	14	10	35	-9
0.7		33	114	51	8	-10	116	20	14	30	-6
3.2		36	118	57	8	-6	120	18	17	28	-6
6.3		38	123	62	7	-6	113	15	15	27	-8
7.3		37	124	63	5	7	118	27	24	29	-9
8.2		38	127	64	10	3	116	24	19	30	-11
9.4		37	129	65	5	13	120	34	26	30	-11
13.2		38	136	69	4	14	120	36	24	33	-16
17.8		41	146	71	4	12	112	35	19	37	-19
19.9		42	150	72	4	14	112	35	21	39	-21
23.7		42	155	75	4	9	102	29	14	43	-26
29.8		43	160	77	4	2	88	22	8	50	-32
36.7		44	165	80	3	-1	75	16	4	57	-36
44.4		44	169	82	2	-2	61	11	-1	65	-41
52.6		45	171	85	1	-4	46	7	-3	72	-44
61.6		45	172	87	1	-4	36	5	-4	79	-46
71.0		45	172	89	-1	-4	30	2	-4	85	-47
80.7		45	172	91	-1	-4	31	-1	-4	91	-46
91.0		45	172	93	-2	-4	35	-4	-3	96	-43
101.7		45	173	95	-2	-3	39	-6	-3	103	-38
112.5		45	176	97	-3	-4	49	-9	-2	109	-32
123.2		45	179	99	-3	-4	56	-12	0	117	-27
132.9		45	184	102	-4	-3	65	-16	1	124	-21

Test No. 1 New Ties

Load	δ_3	δ_5	δ_7	δ_9	δ_2	δ_4	δ_6	δ_8	δ_1	δ_{10}
klb					0.001 in.					
6.7	1	11	11	19	8	19	18	23	13	-13
7.7	1	12	14	24	14	26	26	27	17	-17
8.2	1	13	17	31	18	31	32	27	19	-19
11.3	2	16	23	35	20	33	40	27	27	-24
16.5	3	22	32	39	23	39	55	27	40	-30
19.9	4	25	37	41	28	45	66	27	47	-34
23.8	5	27	42	41	27	46	72	27	56	-35
31.3	7	31	51	42	28	47	86	27	66	-37
40.2	8	34	60	42	31	52	99	27	72	-36
49.9	8	38	68	43	35	57	110	27	77	-33
60.3	9	41	76	43	38	63	121	27	80	-28
71.0	10	44	84	44	41	68	132	27	84	-23
82.1	11	47	92	43	44	73	143	27	87	-18
93.6	12	50	99	44	47	78	154	27	91	-11
105.6	12	52	107	45	50	83	165	27	94	-5
118.1	13	54	115	45	53	88	175	27	97	2
131.0	13	57	121	45	55	93	186	27	101	8

Test No. 2 New Ties

Load		δ_3	δ_5	δ_7	δ_9	δ_2	δ_4	δ_6	δ_8	δ_1	δ_{10}
kip						0.001 in.					
0	set	4	36	49	45	21	37	59	43	13	-18
1.0		2	36	50	45	24	41	61	47	18	-20
4.8		3	41	58	46	26	50	75	51	34	-26
6.9		4	44	64	46	34	59	88	59	38	-28
8.4		4	45	67	47	38	65	97	65	41	-29
9.2		4	45	70	48	51	77	111	77	42	-31
14.1		5	51	80	48	50	82	127	80	51	-34
19.4		7	55	88	48	51	87	140	83	59	-35
21.6		7	57	90	49	46	84	140	79	63	-36
30.2		7	60	94	49	41	83	144	77	72	-33
40.7		7	63	99	49	41	86	153	75	79	-29
52.4		8	64	105	49	42	89	162	77	86	-22
65.0		8	66	111	48	44	94	170	77	92	-15
78.4		9	67	116	49	46	96	177	77	98	-8
92.7		9	68	121	49	50	100	184	77	103	0
108.1		9	69	126	48	52	105	191	77	108	8
124.2		9	71	133	48	55	110	201	79	113	15
137.5		10	73	139	48	56	115	210	80	116	21

APPENDIX D

Intrack spike withdrawal test report from the Transportation Test Center near Pueblo, Colo.

1.0 PURPOSE

The Transportation Test Center was requested to provide personnel and equipment to conduct a rail-spike pullout test in the line of the Burlington Northern Railroad at Ralston, Nebr. The test results will aid in the determination of certain characteristics of timber crossties at the scene of an Amtrak derailment in December 1976. The ties tested were red oak type installed in 1953. This report presents the data as taken at the test site.

2.0 REQUIREMENTS

As defined in the Test Plan/Specification dated October 21, 1977, the personnel from the Test Center were required to perform the following:

Field Testing

Conduct field tests to determine rail-spike pullout forces on ties previously designated by personnel from the U.S. Forest Products Laboratory. The ties were marked with yellow numbers on the side of the rail; the numbers derived from using a nearby switch for a reference. Refer to figure D1 for a diagram of the test location. Four spikes on each of twelve ties were tested; the numbers of which are shown on figure D1. Figure D2 shows the spike pattern typical on all twelve ties. As can be seen, all spikes were rail holding type.

3.0 DATA ACQUISITION METHODS AND OPERATIONS

An Instrumentation Engineer and an Instrumentation Technician were provided by the Transportation Test Center along with the necessary equipment to perform the testing. Figure D3 shows the test and recording equipment setup. The actual test fixture used to pull the spikes is shown in figure D4 and consists of a beam with two supports. The fixture straddles the rail with a load cell, hydraulic jack, and spike claw assembly mounted in a vertical position hanging from the horizontal beam of the test fixture.

When the claw is placed around the throat of the spike and pressure is applied by the hydraulic cylinder, the load cell produces a voltage proportional to the tensile load applied to the spike.

This signal is then conditioned, amplified, and recorded on both a pengraph recorder and a magnetic tape recorder.

The maximum force required to pull the spike, derived from the strip chart, was recorded on a data sheet by TTC personnel.

4.0 RESULTS

The data consists of maximum force data sheets. As can be seen from the maximum forces, most forces were in the range of 100 to 1,000 pounds. For the most part, these corresponded to ties with extensive checking and cracking. Some forces in the 3K- to 4K-pound region were encountered, but when the spikes were observed, it was found that several of them had throat cutting from the rail as shown in figure D5. When these spikes were pulled, it took an excessive force to overcome the indenture, and then, the force dropped to a nominal force consistent with the majority of other spikes. For this reason, several spikes on the maximum force data sheet show two force figures under the MAX FORCE column. The high number is the maximum force it took to overcome the throat-cut area, and the low number represents the output that the force dropped to after the spike overcame the undercut. The field spike of the low rail on tie 0184 (event 60) is a good example of this type of action.

In determining the position of each spike, certain acronyms were used on the data sheets. The following is a description of each:

HR - High Rail
LR - Low Rail
FRS - Field Rail Spike
GRS - Gage Rail Spike

Example: HR-FRS would be a rail-holding spike located on the field side of the high rail.

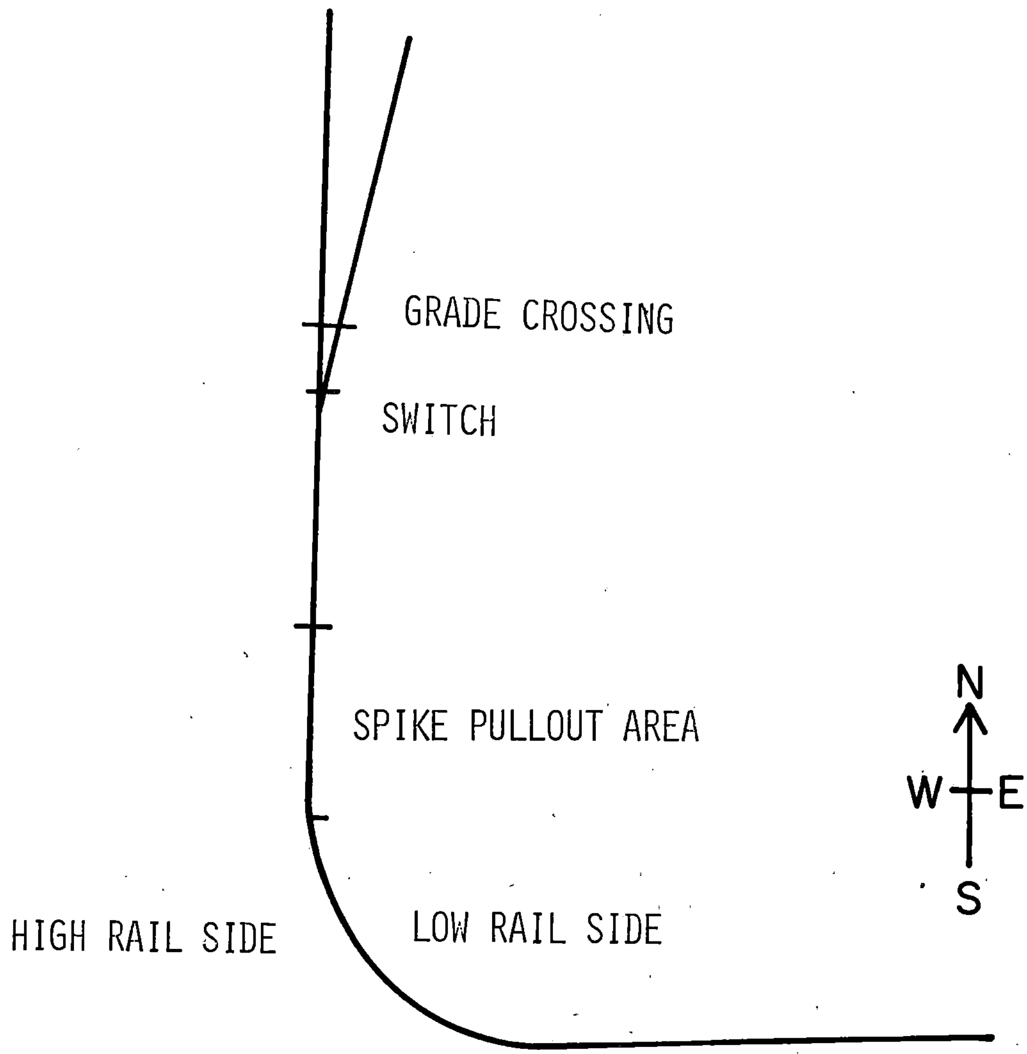


Figure D1.--Map of test site.

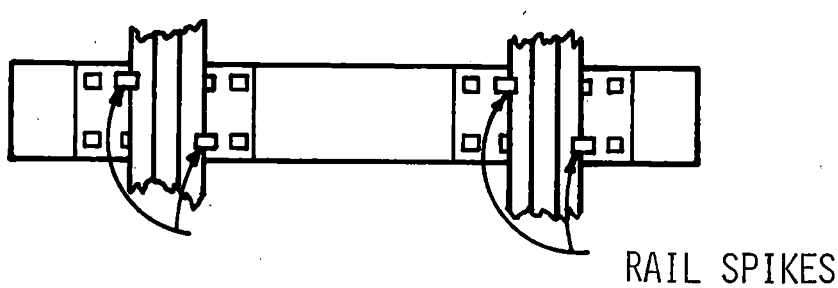


Figure D2.--Typical spike pattern.

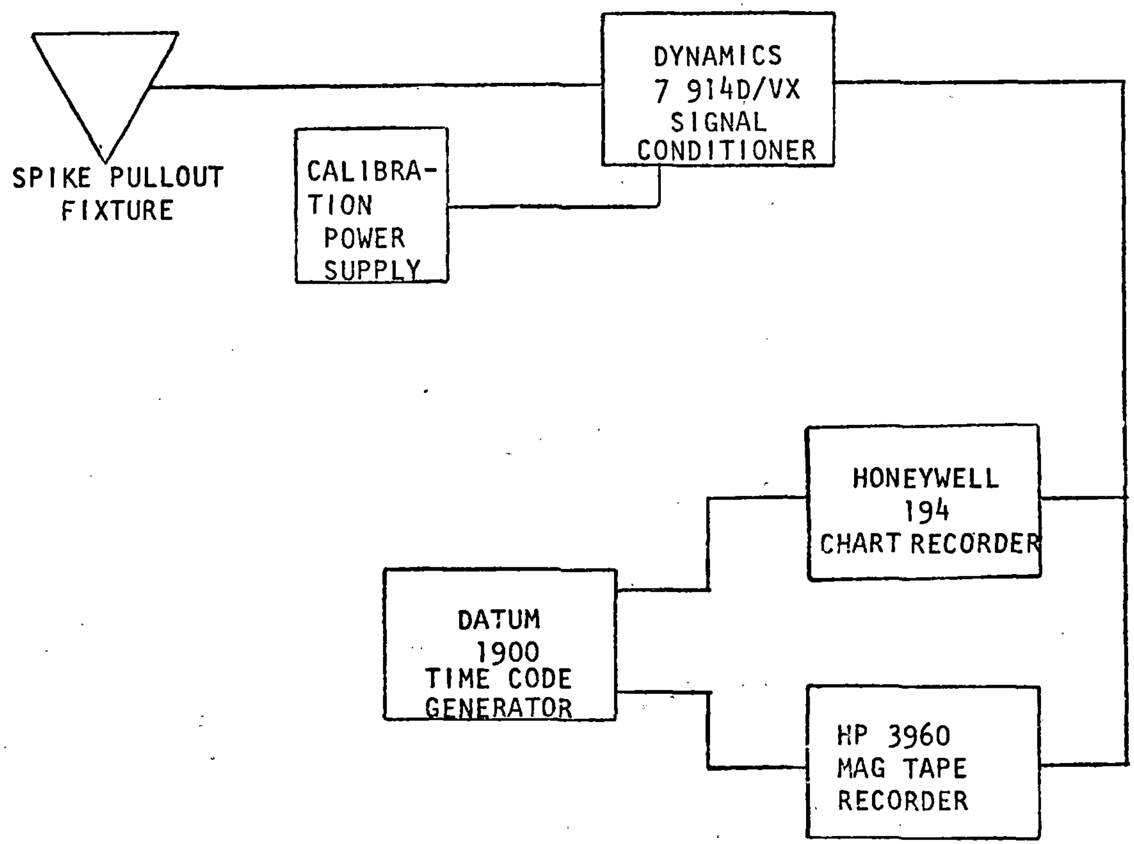


Figure D3.--Instrumentation configuration.

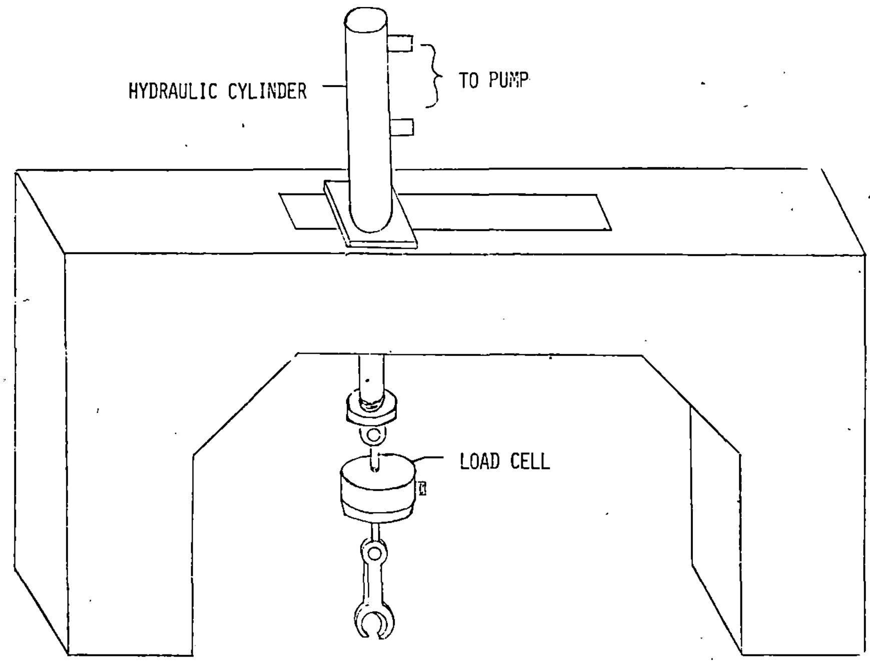


Figure D4.--Spike pullout fixture.

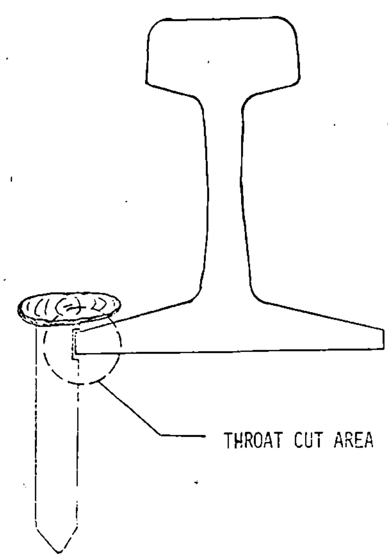


Figure D5.--Typical throat cutting encountered.

Nebraska BN spike pullout maximum force data[1/]

Tie number location	Rail location	Spike location	Run number	Max force	Comments
				Lbs	
0103	HR	FRS	1	400	
0103	HR	GRS	4	850	
0103	LR	GRS	5	200	
0103	LR	FRS	6	2,400/1,800	Throat cut spike. See text.
0110	HR	FRS	9	250	
0110	HR	GRS	10	150	
0110	LR	GRS	11	1,300	
0110	LR	FRS	12	700	
0117	HR	FRS	15	1,400	
0117	HR	GRS	16	1,200	
0117	LR	GRS	17	1,000	
0117	LR	FRS	18	2,000/800	Throat cut spike. See text.
0129	HR	FRS	21	800	
0129	HR	GRS	22	75	
0129	LR	GRS	23	1,000	
0129	LR	FRS	24	2,200	
0138	HR	FRS	27	700	
0138	HR	GRS	28	2,200	
0138	LR	GRS	29	100	
0138	LR	FRS	30	450	
0142	HR	FRS	33	600	
0142	HR	GRS	34	450	
0142	LR	GRS	35	500	
0142	LR	FRS	36	600	
0162	HR	FRS	39	500	
0162	HR	GRS	40	500	
0162	LR	GRS	41	500	
0162	LR	FRS	42	100	
0164	HR	FRS	45	650	
0164	HR	GRS	46	800	
0164	LR	GRS	47	1,000	
0164	LR	FRS	48	400	

(Page 1 of 2)

Nebraska BN spike pullout maximum force data[1/]

Tie number location	Rail location	Spike location	Run number	Max force	Comments
				Lbs	
0179	HR	FRS	51	300	
0179	HR	GRS	52	500	
0179	LR	GRS	53	1,800	
0179	LR	FRS	54	1,300	
0184	HR	FRS	57	600	
0184	HR	GRS	58	1,700	
0184	LR	GRS	59	3,000/1,500	
0184	LR	FRS	60	4,400/1,400	Throat cut spike. See text.
0185	HR	FRS	63	600	
0185	HR	GRS	64	1,200	
0185	LR	GRS	65	1,200	
0185	LR	FRS	66	800	
0190	HR	FRS	69	600	
0190	HR	GRS	70	1,400/400	Throat cut spike. See text.
0190	LR	GRS	71	3,600/800	Throat cut spike. See text.
0190	LR	FRS	72	550	

1/ November 18, 1977, tape No. 0001, operators: Simpson/Minor.

(Page 2 of 2)

5.0 SUMMARY

The data taken is typical of what might be expected with some scatter due to changing conditions such as checking and throat cutting. The data should be useful as an aid for any analysis of the track condition.

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