WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES IN WOOD RAILROAD CROSSTIES

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13. ABSTRACT

This report presents the procedure and results from the tests of withdrawal resistance of cut track spikes driven into wood crossties. The tests were performed using conventional track spikes and chemically treated wood crossties, both solid and prebored. Five different, but common, crosstie materials were used, which included three hardwoods and two softwoods. Each test sample consisted of sixteen spikes, and a total of 192 spikes were tested. The measured variables included the driving force, withdrawal force and spike displacement.

All of the tests were conducted at the Track Research Laboratory of the Association of American Railroads Research and Test Department in Chicago, Illinois.

14. SUBJECT TERMS

Spike Driving Force
Spike Withdrawal Resistance
Track Spikes
Wood Crossties

15. AVAILABILITY STATEMENT

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EXECUTIVE SUMMARY

Tests were conducted at the AAR's Track Research Laboratory to obtain comparative data for the withdrawal resistance of cut track spikes, driven into commonly used hardwood and softwood railroad crossties (ties). Five types of chemically treated wood: gum, red oak, white oak, southern pine and douglas fir were used as the test ties. Each test sample consisted of 16 new spikes driven into both solid (no prebore) and prebored ties. The driving force, withdrawal force and spike displacement were measured and recorded during the full excursion of each test spike.

The results of this investigation are presented in terms of the average maximum forces obtained for each test sample, and indicate the following:

1. When driven into solid wood, the hardwoods required 8 to 47% higher spike driving forces than the softwoods;
2. Spikes driven into solid hardwoods required withdrawal forces that were 33 to 64% higher than those in solid softwoods;
3. Spikes driven into prebored red oak and southern pine ties required 10 to 13% higher withdrawal forces than spikes driven into the same solid woods.
4. Spikes driven into solid douglas fir, gum and white oak ties required 12 to 31% higher withdrawal forces than spikes driven into the same prebored ties.

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1.0 INTRODUCTION

A series of tests were conducted at the Association of American Railroads Track Research Laboratory, located in Chicago, Illinois, to determine the withdrawal resistance of track spikes that had been driven into different types of wooden railroad crossties. Each test sample consisted of 16 spikes driven into and pulled from five different chemically treated types of wood crossties, both solid and prebored. The sample size of 16 was based on information from a previous test performed using a much smaller sample size. Spike driving force, withdrawal force and spike displacement were measured and recorded during each test.

These tests were conducted under the Supplemental Test Series, Laboratory Test Plan for Stage 3 Testing, of Contract DOT-TSC-1541, sponsored by the Transportation Systems Center of the U. S. Department of Transportation for the Federal Railroad Administration, Office of Research and Development, Improved Track Structures Research Division.

2.0 TEST OBJECTIVES

The main objectives of this test series were to obtain comparative data describing:

A. the withdrawal resistance of cut track spikes from commonly used hardwood and softwood railroad crossties, and

B. the effect on withdrawal resistance of spikes driven into both prebored and solid (not prebored) ties.

3.0 TEST SPECIMENS

The test ties and spikes used in these tests conformed to the requirements for wood crossties and track spikes, as described by the American Railway Engineering Association (AREA) [1].*

The test ties represented common hardwoods and softwoods that were typical of those used in rail service, as follows:

A. Common Hardwoods

1. Gum - untreated
2. Gum - treated
3. Red Oak - treated
4. White Oak - treated

B. Common Softwoods

1. Southern Pine - treated
2. Douglas Fir - treated

The test ties were treated AREA No. 5, 7" x 9" x 8' - 6", and the spikes were standard AREA 5/8" x 6" cut track spikes, used as received from the supplier. The test ties were not subjected to any special handling procedures; they were, however, stored indoors for about 10 months prior to the conduct of the tests.

4.0 TEST PROCEDURE

The tests were conducted in accordance with the test matrix shown in Table 1. Each test run consisted of driving and pulling 16 spikes in each tie material for both the solid (no prebore) and prebored condition [2].

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*The numbers in square backets [ ] refer to the References, listed in Section 8.0 of this Report.

Table 1

Test Matrix

	Tie Type	Test Conditions: Solid	Test Conditions: ½ Inch Prebore +	Test Conditions: 9/16 Inch Prebore *
1.	Gum-Untreated	x		x
2.	Red Oak-Treated	x		x
3.	Southern Pine-Treated	x	x	
4.	Douglas Fir-Treated	x	x	
5.	Gum-Treated	x		x
6.	White Oak-Treated	x		x

+AREA Recommendation [2] for a 5/8 Inch Spike in Softwood.

*AREA Recommendation [2] for a 5/8 Inch Spike in Hardwood.

The determination of sample size is shown in Appendix A.

Sixteen spikes were placed and driven in a row along the full length of the tie, maintaining an edge distance of 2-1/2 inches and a 4 inch minimum spacing between adjacent spikes. The other side of the same tie was prebored, using the same relative spike spacing, prior to the second group of sixteen spikes being driven. Thus, both the solid and prebored tests were conducted on opposite sides of the same tie. No special effort was made to avoid small splits, hard spots or areas adjacent to knots; however, the test spikes were not driven directly into knots. Figure 1 shows the general arrangement of a tie in the test fixture. Figure 2 shows the driving and pulling jacks, and Figure 3 shows the instrumented spike puller.

All of the spikes were driven in and pulled out hydraulically, at a constant rate as slow as the equipment could be operated. This rate was determined to be about two inches per minute, which varied slightly with resistance. The spike-driving fixture was contoured to match the spike head radius, which minimized skewing of the spike during the driving operation. The spike puller conformed to AREA Plan 9-62, and was instrumented to record the spike withdrawal force.

A typical test involved driving 16 spikes, changing the loading fixture and instrumentation from the push to the pull mode, and pulling the spikes within an hour after the initial driving. Spikes were driven to a depth of 5 inches to compensate for the thickness of the rail base and tie plate. The measured driving force, pulling force, and spike displacement were recorded on a two pen XYY' graphical plotter. One pen plotted the force

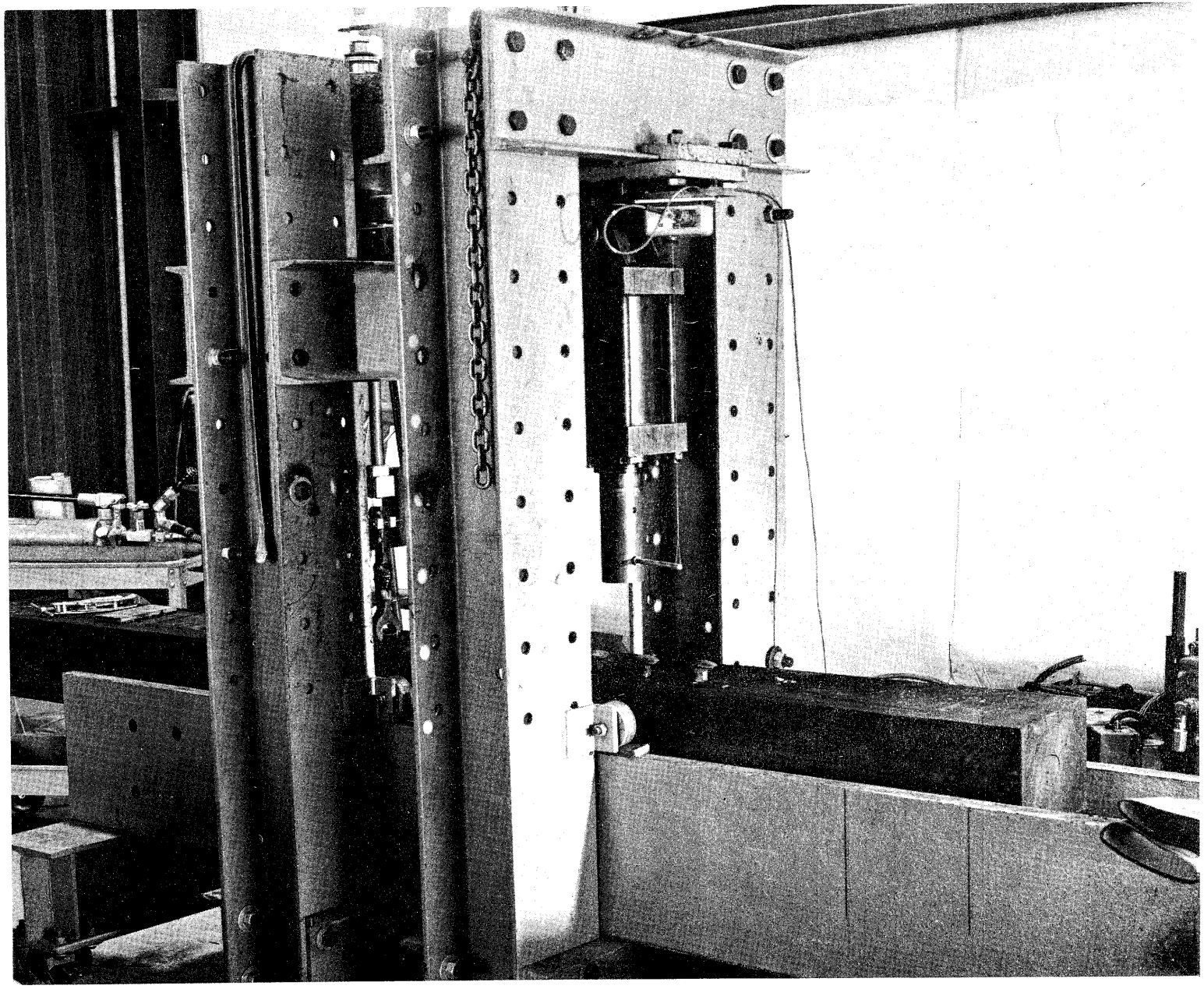

Figure 1. General Arrangement of a Wood Tie in the Test Fixture.

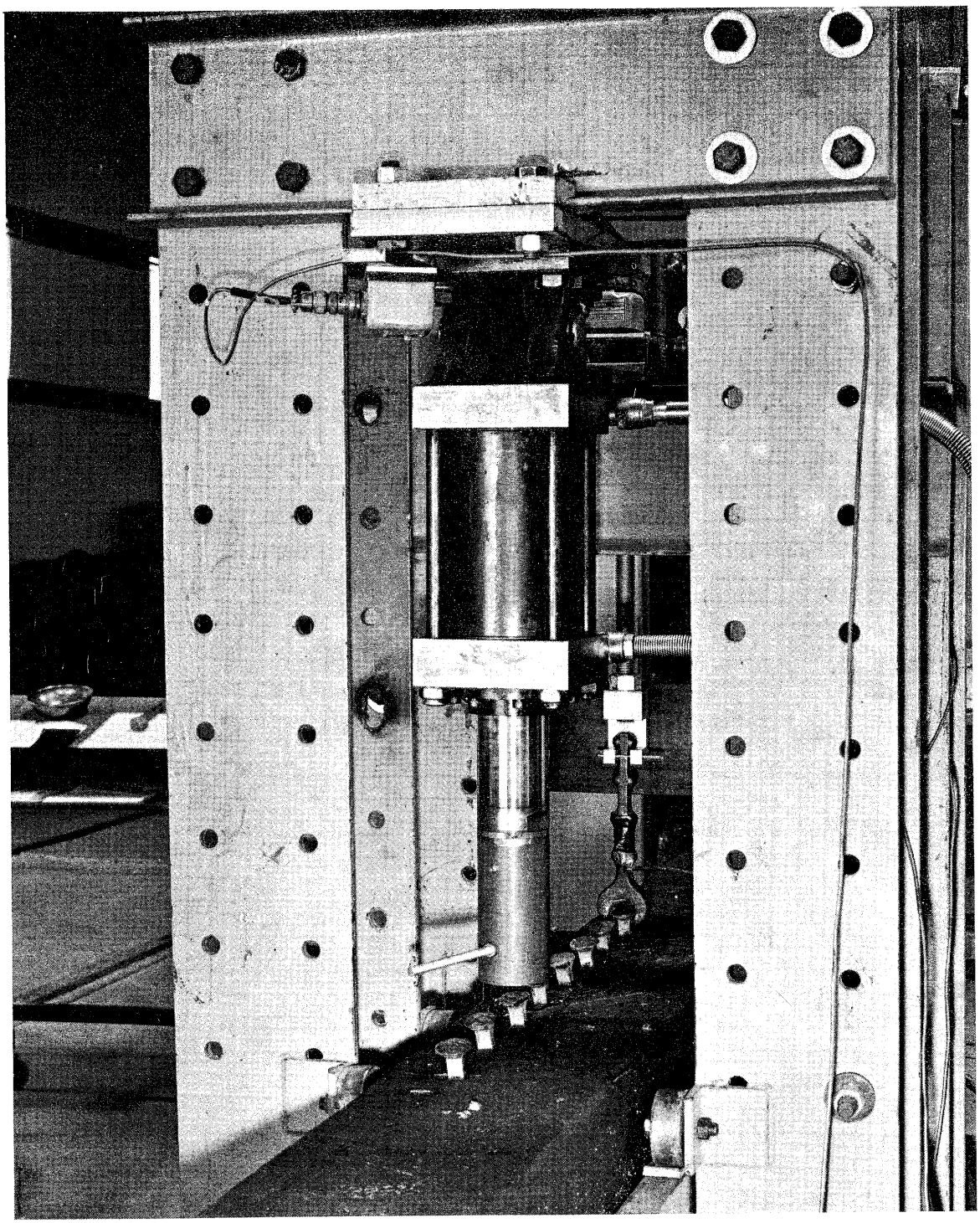

Figure 2. Wood Tie Test Fixture, Showing the Spike Driver (Foreground) and Spike Puller (Background).

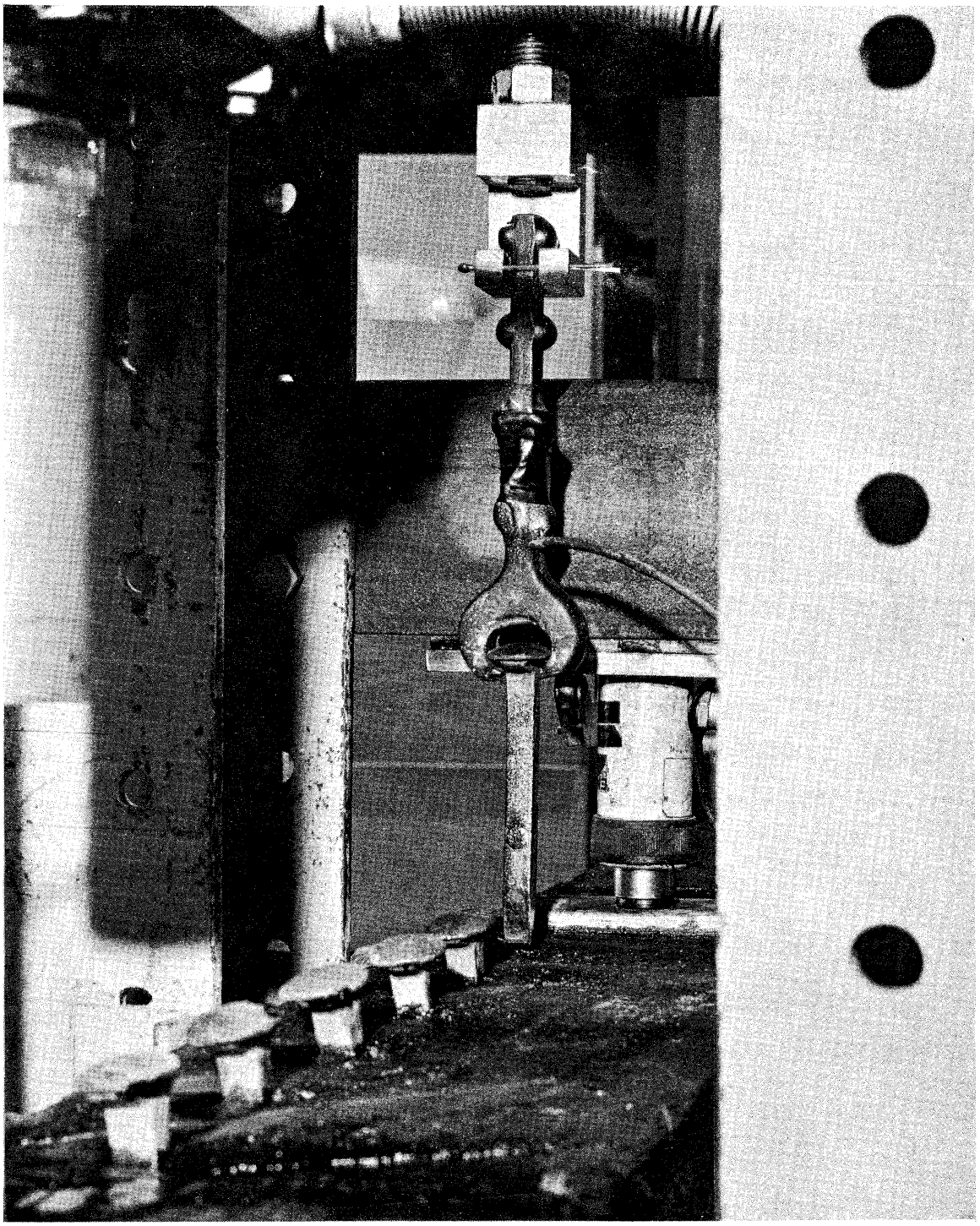

Figure 3. Instrumented Spike Puller.

versus displacement curve during the driving cycle, and a second pen plotted the corresponding force versus displacement curve during the withdrawal cycle for the same spike. Figure 4 shows a typical recorded force versus displacement curve.

5.0 INSTRUMENTATION

Spike displacement was measured with a Celesco Model PT-101-10 displacement transducer. Driving force was calculated by use of an AAR-constructed 3000 psi hydraulic pressure transducer, and then converting the measured pressure to force. Spike withdrawal force was measured directly by use of the strain gaged spike puller. The four sides of the rectangular shank were ground flat between the first and second lobes, to provide the proper surface for applying strain gages. A full four arm strain gage bridge was then applied to the spike puller and calibrated in a special fixture. The recorder used was a Hewlett-Packard Model 7046B XYY' Plotter.

6.0 TEST RESULTS

The results from this investigation are summarized in Tables 2 and 3. The results shown for Tie No. 1 (untreated gum) are included as information, but will not be discussed, since untreated ties are no longer common. Tables 2 and 3 show the highest forces developed by any single spike in each 16 spike sample. The maximum driving and withdrawal forces are not necessarily for the same spike. The average column shows the average value of the maximum forces developed in the 16 spike sample. The standard deviation is also shown for each sample. The complete test results are given in Appendix 9.B for each spike sample and test condition.

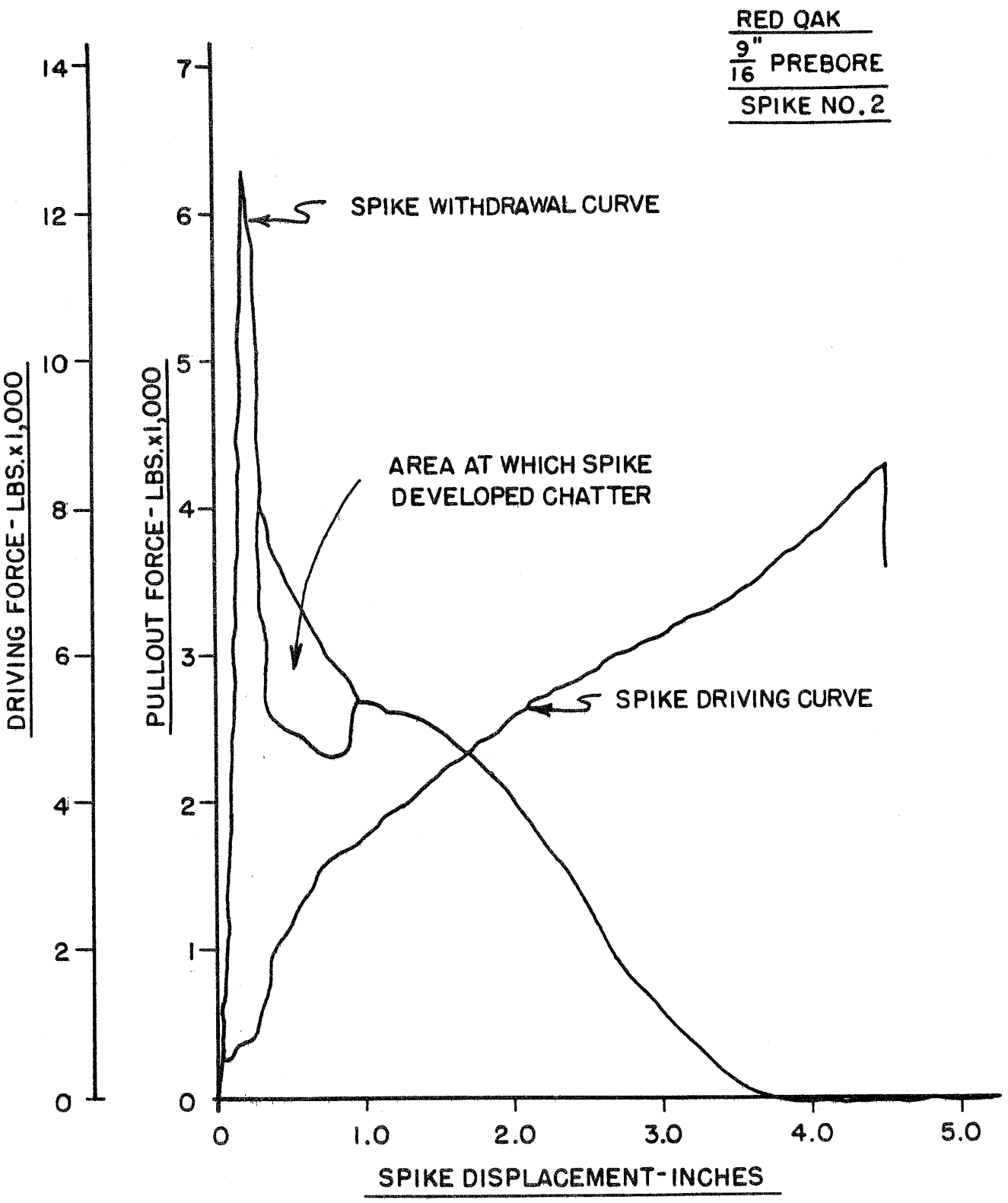

Figure 4. Typical Force-Displacement Curve for a 5/8 x 6 Inch Cut Spike in a Red Oak Tie with a 9/16 Inch Prebore.

Table 2

Summary of Spike Driving Force Test Results

Tie Sample		Driving Force (Pounds) Maximum +	Average *	Standard Deviation
1 (a)	Gum - Untreated	13,450	10,015	1,407
(b)	Gum - Untreated - 9/16" prebore	9,800	6,580	1,341
2 (a)	Red Oak - Treated	11,000	9,662	642
(b)	Red Oak - Treated - 9/16"	11,400	9,181	1,105
3 (a)	Southern Pine - Treated	5,800	5,153	407
(b)	Southern Pine - Treated - ½" prebore	5,150	4,428	518
4 (a)	Douglas Fir - Treated	6,900	5,562	565
(b)	Douglas Fir - Treated - ½" prebore	6,400	4,409	888
5 (a)	Gum - Treated	7,200	6,029	524
(b)	Gum - Treated - 9/16" prebore	6,650	5,286	535
6 (a)	White Oak - Treated	10,250	9,212	645
(b)	White Oak - Treated - 9/16" prebore	9,900	9,059	622

Note:

+ Indicates highest force developed by a single spike within each sample.

* Average of the maximum forces developed for each spike sample.

Table 3

Summary of Spike Withdrawal Force Test Results

Tie Sample		Withdrawal Force (Pounds) Maximum +	Average *	Standard Deviation
1 (a)	Gum - Untreated	5,750	4,239	813
(b)	Gum - Untreated - 9/16" prebore	4,570	3,648	648
2 (a)	Red Oak - Treated	9,100	5,618	1,557
(b)	Red Oak - Treated - 9/16" prebore	7,500	6,275	673
3 (a)	Southern Pine - Treated	4,800	3,765	662
(b)	Southern Pine _ Treated - ½" prebore	4,960	4,315	452
4 (a)	Douglas Fir - Treated	3,980	3,209	636
(b)	Douglas Fir - Treated - ½" prebore	3,400	2,220	653
5 (a)	Gum - Treated	7,900	5,956	785
(b)	Gum - Treated - 9/16" prebore	6,750	5,248	775
6 (a)	White Oak - Treated	9,050	8,834	363
(b)	White Oak - Treated - 9/16" prebore	9,100	7,603	1,011

Notes:

+ Indicates highest force developed by a single spike within each sample.

* Average of the maximum forces developed for each spike sample.

In this discussion, no attempt has been made to relate the elapsed time between driving and pulling the spike to the withdrawal force. The discussion is based on the average maximum force of each test sample, rather than the maximum force developed by any one spike.

The highest average driving and withdrawal forces were developed in the red oak and white oak hardwood ties. The average spike driving force was 9,662 lbs. in solid red oak, and 9,181 lbs. into the 9/16" prebored holes. The average spike driving force was 9,212 lbs. in solid white oak and 9,059 lbs. into the 9/16" prebored holes.

The highest average spike withdrawal force was 5,619 lbs. in solid red oak, and 6,275 lbs. from the 9/16" prebored holes. The highest average spike withdrawal force was 8,834 lbs. in solid white oak, and 7,603 lbs. from the 9/16" prebored holes. The forces developed with the gum ties were somewhat lower than those developed for both red or white oak.

Lower average driving and withdrawal forces occured with the southern pine and douglas fir softwood ties. The lowest average withdrawal force was found with the douglas fir tie. The average spike withdrawal force was 3,209 lbs. in solid douglas fir, and 2,221 lbs. from the 1/2" prebored holes.

The question of which has the greater withdrawal resistance, spikes driven into solid wood or into prebored wood, is reflected in Table 3 [3]. Contrary to intuition, the results showed that spikes driven into prebored red oak and southern pine (Tie Nos. 2 and 3) exhibited higher withdrawal resistances than spikes driven into solid wood. All of the other ties showed the opposite effect, where spikes driven into solid wood had higher withdrawal resistances than those driven into the prebored

wood.

The standard deviations for each test sample, shown in Tables 2 and 3, are measures of dispersion about the mean values, and provide some insight regarding the variations in wood grain structure along the length of the tie and other variables, such as surface condition of the spikes, straightness of the spike in the tie, and small splits in the tie.

7.0 CONCLUSIONS

This laboratory test program was conducted in order to obtain track spike withdrawal resistance data, using a variety of both solid and prebored hardwoods and softwoods that are commonly used in railroad tracks. Based on the results of these tests, the following conclusions were made:

A. For solid wood ties, the hardwood spike withdrawal forces were 33 to 64% higher, and the spike driving forces were 8 to 47% higher, respectively, than those in softwood ties.

B. Spikes driven into prebored red oak and southern pine ties required 10 to 13% higher withdrawal forces than spikes driven into the same solid woods.

C. Spikes driven into solid douglas fir, gum and white oak ties required 12 to 31% higher withdrawal forces than spikes driven into the same prebored ties.

8.0 REFERENCES

1. American Railway Engineering Association, Manual for Railway Engineering, Washington, D. C., 1976, Chapter 3, "Tie and Wood Preservation," Part 1, "Timber Cross Ties."
2. Ibid, Section 1.6, "Sizes of Holes Bored for Spikes."
3. U. S. Department of Agriculture, Wood Handbook, No. 72, Forest Product Laboratories, Madison, Wisconsin, 1955, p. 169.
4. Knoblock, O. W., "A Comparative Study of the Physical Properties of Various Types of Wood Used in Railroad Crossties," Association of American Railroads Report No. R-255A, Chicago, Illinois, July, 1977.
5. Private Communication, Dr. M. B. Hargrove, Manager - Engineering Economics, A. A. R., Washington, D. C. to Dr. A. M. Zarembski, Manager - Track Research, A. A. R., Chicago, Illinois, on February 26, 1980.

9.0 APPENDICES

9.A Determination of Sample Size

9.B Test Results

9.A Determination of Sample Size

Based on the spike pullout data listed in Reference [4], an average withdrawal force of 5,000 lbs, with a standard deviation of 2,500 lbs., could be expected with hardwood ties for a sample size of 8 spikes.

For this test series, a sample size of 16 was established [5] in order to obtain more consistent individual test results and still complete the test within the scheduled time frame.

The following table gives the sample size for maximum errors of 10% and 25%, with corresponding confidence factors of 95% and 99%, respectively.

ε / Z	10%	25%
95%	100	16
99%	225	36

The sample size is evaluated from the following expression:

$$n = \frac{Z^2 \sigma^2}{\varepsilon^2}$$

where:

n = sample size;

Z = confidence factor, where Z = 2 for 95%,

Z = 3 for 99%;

σ^2 = variance of the individual measurements; and

ε = maximum error.

For a maximum error of 25%, and a deviation from the true mean value of 0.25x5,000=1,250, with 95% confidence, the sample size (n) is:

$$n = \frac{(2)^2(2500)^2}{(1250)^2} = 16$$

9.B Test Results

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 1

TIE MATERIAL - GUM (UNTREATED)

PREBORE - NONE

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	3900	9000
2	3800	9100
3	3600	9750
4	4000	11200
5	3400	10900
6	3300	8950
7	3800	9950
8	5000	11000
9	4800	10600
10	4000	9900
11	2850	8200
12	4400	13450
13	5100	11850
14	5250	9000
15	5750	9000
16	4880	8400
	AVE. = 4239	AVE. = 10015
	STD. DEV. = 813	STD. DEV. = 1407

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 1

TIE MATERIAL - GUM (UNTREATED)

PREBORE - 9/16"

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	3200	5350
2	2800	4950
3	2450	6050
4	3630	6800
5	3200	5800
6	3450	5950
7	4240	5500
8	3490	6100
9	2870	9800
10	4570	7250
11	4520	8750
12	4500	7600
13	3980	7750
14	4180	6550
15	3700	5500
16	3600	5568
AVE. =	3648	AVE. = 6580
STD. DEV. =	648	STD. DEV. = 1341

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 2

TIE MATERIAL - RED OAK (TREATED)

PREBORE - NONE

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	9100	10800
2	8400	11000
3	7000	9900
4	6600	9500
5	5200	9600
6	5100	10000
7	4150	9100
8	4850	9200
9	455C	10000
10	4000	9300
11	4150	9600
12	3600	8700
13	5300	8600
14	6000	9900
15	5900	9600
16	6000	9800
AVE. =	5618	AVE. = 9662
STD. DEV. =	1557	STD. DEV. = 642

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 2

TIE MATERIAL - RED OAK (TREATED)

PREBORE - 9/16"

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	7250	8300
2	6300	8600
3	5900	9000
4	7050	10800
5	7000	8700
6	7500	9000
7	5700	8000
8	5650	11400
9	6700	10300
10	5900	9200
11	5800	7700
12	6300	9400
13	5450	10800
14	5300	8700
15	6600	9100
16	6000	7900
AVE. =	6275	9181
STD. DEV. =	673	1105

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 3

TIE MATERIAL - SOUTHERN PINE (TREATED)

PREBORE - NONE

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	4200	4900
2	4690	5250
3	3940	5400
4	3350	4650
5	3200	4800
6	3100	5000
7	3550	4700
8	3080	4300
9	3300	5150
10	2700	5600
11	3980	5200
12	4550	5200
13	4800	5800
14	4700	5550
15	3580	5350
16	3520	5600
AVE. =	3765	AVE. = 5153
STD. DEV. =	662	STD. DEV. = 407

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 3

TIE MATERIAL - SOUTHERN PINE (TREATED)

PREBORE - 1/2"

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	4550	4500
2	4500	4750
3	4250	4000
4	3600	3450
5	3700	3600
6	3850	4000
7	4300	4550
8	3750	3950
9	4000	4200
10	4800	4900
11	4960	5000
12	4950	4800
13	4500	4700
14	4230	5000
15	4900	5150
16	4200	4300
AVE. =	4315	AVE. = 4428
STD. DEV. =	452	STD. DEV. = 518

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 4

TIE MATERIAL - DOUGLAS FIR (TREATED)

PREBORE - NONE

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	1780	5200
2	1800	4800
3	2950	4800
4	3230	5000
5	3300	5450
6	3300	5800
7	3830	5950
8	3700	6900
9	2950	5400
10	3580	6150
11	3980	5850
12	3230	5650
13	3400	5950
14	3380	5200
15	3880	5900
16	3060	5000
AVE.	= 3209	AVE. = 5562
STD. DEV.	= 636	STD. DEV. = 565

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 4

TIE MATERIAL - DOUGLAS FIR (TREATED)

PREBORE - 1/2"

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	1550	3200
2	1700	3500
3	2100	3500
4	2470	4550
5	2950	4900
6	2700	4600
7	3180	4200
8	3400	4800
9	2200	6400
10	2200	5000
11	1650	5200
12	1750	4300
13	2700	4900
14	2350	4750
15	1530	4000
16	1100	2750
AVE. =	2220	4409
STD. DEV. =	653	888

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 5

TIE MATERIAL - GUM (TREATED)

PREBORE - NONE

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	6050	5400
2	6300	6190
3	5600	5990
4	5050	5890
5	5650	5800
6	5900	6050
7	6300	5950
8	7900	7200
9	6050	6000
10	5600	5250
11	5200	5600
12	5950	5950
13	5700	6600
14	7498	7000
15	5500	6000
16	5050	5600
AVE. =	5956	6029
STD. DEV. =	785	524

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 5

TIE MATERIAL - GUM (TREATED)

PREBORE - 9/16"

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	5500	6650
2	4400	4600
3	5290	5000
4	5650	5000
5	6400	5390
6	4700	6000
7	5700	5050
8	4750	5300
9	4800	5450
10	4400	4600
11	5000	5200
12	4700	5000
13	6100	5200
14	5790	4800
15	4050	5900
16	6750	5450
	AVE. = 5248	AVE. = 5286
	STD. DEV. = 775	STD. DEV. = 535

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 6

TIE MATERIAL - WHITE OAK (TREATED)

PREBORE - NONE

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	7750	8400
2	8250	9600
3	9000	9050
4	8650	8200
5	8850	8600
6	9050	9250
7	9050	10250
8	8650	9900
9	9050	9000
10	9050	8900
11	9050	8450
12	8800	8800
13	8900	9200
14	9000	9900
15	9000	9900
16	9050	10000
AVE. =	8834	9212
STD. DEV. =	363	645

WITHDRAWAL RESISTANCE OF CUT TRACK SPIKES

TIE NUMBER: 6

TIE MATERIAL - WHITE OAK (TREATED)

PREBORE - 9/16"

SPIKE NO.	MAX. WITHDRAWAL FORCE-LBS	MAX. DRIVING FORCE-LBS
1	8500	9000
2	9100	9800
3	8100	8400
4	8300	9400
5	8100	8800
6	6700	9000
7	7100	9250
8	6700	8800
9	7300	9900
10	5300	8800
11	6500	9900
12	8250	8250
13	7550	7900
14	9100	9900
15	7250	8600
16	7800	8200
	AVE. = 7603	AVE. = 9059
	STD. DEV. = 1011	STD. DEV. = 622