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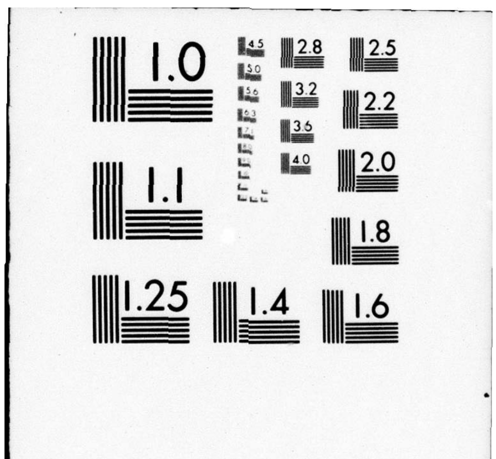
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LEVEL II

STUDY OF FORCE EFFECTS ON SELECTED MATERIALS USED IN CARGO TO VEHICLE RESTRAINT SYSTEMS FOR RAIL TRANSPORT

VOLUME 1

SUMMARY REPORT

Rept. for Apr 73 - Nov 77

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58p.

APR[redacted] 1978

SARAC [redacted]-DEV-4-73-3

MTMC [redacted]-TR-73-14-1

Military Traffic Management Command
Transportation Engineering Agency
Newport News, Virginia 23606

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ABSTRACT

Movement of cargo by any of the various modes of transportation - ship, railroad, or truck - requires the employment of some type of restraining device. The present methods of restraining cargo were developed by using the "trial and error" approach. The amount of dunnage was determined, more or less by the experience of the packaging personnel or by using static test results along with a good margin of safety. This method of designing cargo restraints suggested the need for developing a technological base for selecting various materials to be used in cargo to vehicle restraint systems.

Therefore, in April 1973, the US Army Materiel Development and Readiness Command (DARCOM) Ammunition Center and the Military Traffic Management Command (MTMC) Transportation Engineering Agency (TEA) decided to participate in a joint project to conduct a series of tests to develop such a technological base. Because of the limited amount of information available on the reaction of dunnage material to dynamic forces, major emphasis was directed toward the effect of shocks on materials in cargo restraint systems.

To accomplish this joint project, an extensive test program was conducted primarily to evaluate the strength of wood-nail assemblies and the effect of wheel chocks in chain and wire rope restraint systems designed for rail transport. Because rail impact tests are difficult to control and are costly, a major portion of the tests were conducted using laboratory facilities.

Results from the tests, conducted between April 1973 and November 1977, are presented in six volumes under the general title of "STUDY OF FORCE EFFECTS ON SELECTED MATERIALS USED IN CARGO TO VEHICLE RESTRAINT SYSTEMS FOR RAIL TRANSPORT." The title of each volume is as follows:

VOLUME 1 SUMMARY REPORT

VOLUME 2 LABORATORY DYNAMIC TESTS ON WOOD-NAIL ASSEMBLIES

VOLUME 3 RAIL IMPACT TESTS ON WOOD-NAIL ASSEMBLIES

VOLUME 4 STUDY OF THE EFFECTS OF NAIL COATING

VOLUME 5 EFFECTIVENESS OF WHEEL CHOCKS IN THE CHAIN RESTRAINT SYSTEM ON DODX 80-TON FLATCAR

VOLUME 6 EFFECTIVENESS OF WHEEL CHOCKS IN A RESTRAINT SYSTEM USING 3/8 INCH, 1/2 INCH, OR 5/8 INCH WIRE ROPE

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2. OBJECTIVES.

a. Determine the effect of specific gravity of the floor lumber on the strength of a wood-nail assembly.

b. Determine the effect of specific gravity of the floorline blocking (cleat) lumber on the strength of a wood-nail assembly.

c. Compare the strength of a joint using nailable steel flooring with a joint using Oak lumber as the floor material.

d. Determine if the strength of a wood-nail joint is affected by the orientation of the wood grain of the cleat with respect to the wood grain of the floor lumber.

e. Determine the strength relationship between high carbon (AISI 1040 steel) nails and low carbon (AISI 1020 steel) nails.

f. Determine the effect of coated nails on the strength of wood-nail assemblies.

g. Determine the relationship between withdrawal resistance and (a) nail size and (b) specific gravity of the floor lumber.

h. Determine the effectiveness of wheel chocks in a chain tie-down restraint system installed on a rail car.

i. Determine the effectiveness of wheel chocks in a wire rope tie-down restraint system installed on a rail car.

3. APPROACH. Laboratory dynamic tests that simulated shocks on cargo caused by the impacting of railroad cars, were conducted on wood-nail assemblies by using an inclined impact test apparatus.

Test specimens that were used in the laboratory consisted of floorline blocking sections nailed to a simulated flatcar floor. A total of 336 laboratory test specimens, three samples per specimen, were tested. Five species of wood (one hardwood and four softwoods) were used to represent the blocking and flooring sections. In addition to wood flooring, nailable steel flooring was used in four tests. The selection of woods provided a specific gravity range of 0.63 for Oak to 0.35 for Engelmann Spruce. Three sizes of lumber were used for the blocking, 2" X 4", laminated 2" X 6", and 4" X 6". The blocking and floor lumber had a moisture content equal to or below 18%.

Nails used to fasten the boards were made from low carbon and higher carbon (AISI 1040 tempered) steel with a cement coated or bright finish. Eight nail sizes were used with 8d being the smallest size and 60d being the largest. These sizes resulted in a depth of penetration that varied from 1 inch to 2-1/2 inches.

For all of the tests, load cells, accelerometers, and a displacement gage were used to obtain the pertinent data.

The data were recorded on a magnetic tape and were processed with the aid of a Texas Instrument Model 960 computer.

Several studies were made to obtain data that would be valuable in explaining the test results. Some of these studies were: X-ray analysis of failed nails, the effects of nail coating, and comparison with static test results.

To determine if the laboratory data could be applied to full-scale blocking and bracing designs, rail impact tests were performed on thirteen wood-nail assemblies. The primary difference between the full-scale wood-nail assemblies and their comparable laboratory assemblies is that the quantity of lumber and nails were greater for the full-scale application. Test loads for the rail impact tests consisted of one 12,815 lb concrete block and one 3,612 lb concrete block. By increasing the speed of the 50 ton flatcar for each successive impact, the dynamic force into the blocking was increased until the blocking failed or impending failure was apparent.

The effectiveness of wheel chocks in a chain tie-down restraint system was determined by testing a military 2-1/2 ton cargo truck that was restrained to a DODX 80 ton flatcar. The railroad car was equipped with a chain restraint system.

The same 2-1/2 ton truck was used in a wire rope restraint system to obtain additional data on the effectiveness of wheel chocks.

Test results from the actions described above are presented in six volumes under the general title of "STUDY OF FORCE EFFECTS ON SELECTED MATERIALS USED IN CARGO TO VEHICLE RESTRAINT SYSTEMS FOR RAIL TRANSPORT." The title of each volume is shown below.

VOLUME 1 SUMMARY REPORT

VOLUME 2 LABORATORY DYNAMIC TESTS ON NAILED WOOD ASSEMBLIES

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VOLUME 5 EFFECTIVENESS OF WHEEL CHOCKS IN THE CHAIN RESTRAINT SYSTEM ON DODX 80 TON FLATCAR

VOLUME 6 EFFECTIVENESS OF WHEEL CHOCKS IN A RESTRAINT SYSTEM USING 3/8 INCH, 1/2 INCH, OR 5/8 INCH WIRE ROPE

4. CONCLUSIONS.

a. The strength of a wood-nail assembly increases with an increase in the specific gravity of the floor lumber.

b. There is no significant difference in the strength of wood-nail joints when various species of wood are used for the cleat. One exception is the combination of an Oak cleat with high carbon coated nails, which develops increased strength.

c. Nailable steel flooring provides an approximately 17% stronger joint than when Oak is used in the wood-nail assembly.

d. The orientation of the wood grain of the cleat with respect to the wood grain of the floor lumber does not affect the strength of a wood-nail joint provided the floor is rigidly fastened to its supporting structure.

e. High carbon (AISI 1040 steel) nails in a wood-nail joint provide approximately the same resistance to lateral forces as a joint that contains low carbon (AISI 1020 steel) nails of the same size.

f. Coated nails affect the strength of a wood-nail joint only when high carbon coated nails are driven through or into Oak wood.

g. Withdrawal resistance for nails from wood increases with an increase in nail size and also with an increase in specific gravity of the floor lumber.

h. For most practical cases, the yield point of a wood-nail joint is approximately one-half the maximum force.

i. Wheel chocks are effective in reducing the longitudinal movement of a vehicle and in reducing the force into the tie-downs of a chain restraint system; however, the shock into the truck is much larger when wheel chocks are used.

j. Wheel chocks are also effective in reducing the longitudinal movement of a vehicle and in reducing the force into the tie-downs of a wire rope restraint system. The three-piece wheel chocks should not be used in a wire rope restraint system.

5. RECOMMENDATIONS. It is recommended that:

a. The floor of carriers be constructed of lumber selected from the highest specific gravity wood that is available.

b. Lumber for the cleat or blocking be chosen from low specific gravity wood, such as Western Hemlock, provided the density of the cleat is sufficient to withstand the pressure from the load - to prevent crushing.

c. Caution be exercised in the layout of floorline blocking. Because some floors are not rigidly fastened to its supporting structure, a cleat that is oriented so that its wood grain is parallel to the wood grain of the floor will not have the holding capability of a cleat installed perpendicular to the wood grain of the floor.

d. High carbon (AISI 1040 steel) nails not be used in the blocking and bracing of military cargo.

e. Only bright nails be used in the blocking and bracing of military cargo.

f. When the blocking will be subjected to the design force for more than one time, the quantity of nails used in the blocking should be increased. The maximum number of nails required to restrain a load for a large number of shock loadings is twice the number of nails calculated for one design force.

g. Wheel chocks be used only to reduce the longitudinal movement of a wheeled vehicle.

h. Three-piece wheel chocks similar to AAR Pattern 17 not be used in the blocking of military vehicles.

II. INTRODUCTION

Movement of cargo by any of the various modes of transportation - ship, railroad, or truck - requires the employment of some type of restraining device. In the past, the cargo restraints were developed by using the "trial and error" approach. The amount of dunnage was determined, more or less by the experience of the packaging personnel or by using static test results along with a good margin of safety.

In April 1973, the US Army Materiel Development and Readiness Command (DARCOM) Ammunition Center and the Military Traffic Management Command (MTMC) decided to participate in a joint project to conduct a series of tests to develop a technological base for selecting various materials to be used in cargo restraint systems. Because of the limited amount of information available on the reaction of dunnage material to dynamic forces, major emphasis was directed toward the effect of shocks on cargo restraint systems.

One major problem the designer of restraint systems must occasionally solve is the holding capability of nailed-wood assemblies. The problem is more severe when the restraint system is exposed to shock loading. In recent years the problem has been complicated by inflationary costs that are requiring designers to cut expenses by optimizing designs or operations.

Most of the cargo that is transported from one destination to another is moved by one or more of the following modes of transportation - truck, railroad, airplane, or ship. Each mode subjects the load to different dynamic forces. A truck exposes the load to a large number of low amplitude, short duration, vertical forces with oaccasional low level longitudinal forces. For this discussion, transportation by plane or ship can be considered to yield somewhat similar results on the load. This is to say, the rate at which the force is applied to the restraint system results in low level dynamic loads. Shipments by railroads expose the restraint systems to the most severe dynamic forces, primarily in the longitudinal direction. Based on this information, components for restraint systems that are designed for shocks similar to those produced by the impacting of uncushioned railroad cars will be adequate as restraint material for all modes of transport.

III. WOOD-NAIL ASSEMBLIES

In many restraint systems or procedures, wood is used for various purposes - from filling a void to serving as the major component in the system. An example of the latter function of wood is shown in Figures 1 and 2. When wood-nail assemblies are used to provide resistance to the major forces expected from the shipment of an item, it is important to use the correct number of nails in the assemblies. Through extensive testing of wood-nail assemblies, a better understanding of the failure characteristics of these assemblies has been achieved.

Wood can be considered a nonhomegeneous material. There are properties of wood that can affect the strength of a wood-nail assembly. Some of these properties are: moisture content, grain orientations, species, number of knots, and amount of pitch. These properties, along with the type of nail used to join two pieces of lumber, will cause wood-nail assemblies to have different strength characteristics.

Examples of the effects of wood and nail characteristics on the strength of a joint are shown in Figures 3 through 7. These curves show some interesting properties of wood-nail assemblies. For instance, observe the three curves in Figure 3 representing the forces sustained by 2" X 4" oak cleats nailed to an oak floor with four 20d nails. Each arrangement withstood approximately the same maximum force; however, the permanent displacements of the cleats at the maximum forces vary considerably. Figure 8 shows the permanent deformation of nails in a 2" X 6" laminated joint.

The yield points shown in Figures 3 and 5 indicate the force above which failure of the joint will ultimately occur and below which failure of the assembly will not occur. The yield points for wood-nail assemblies

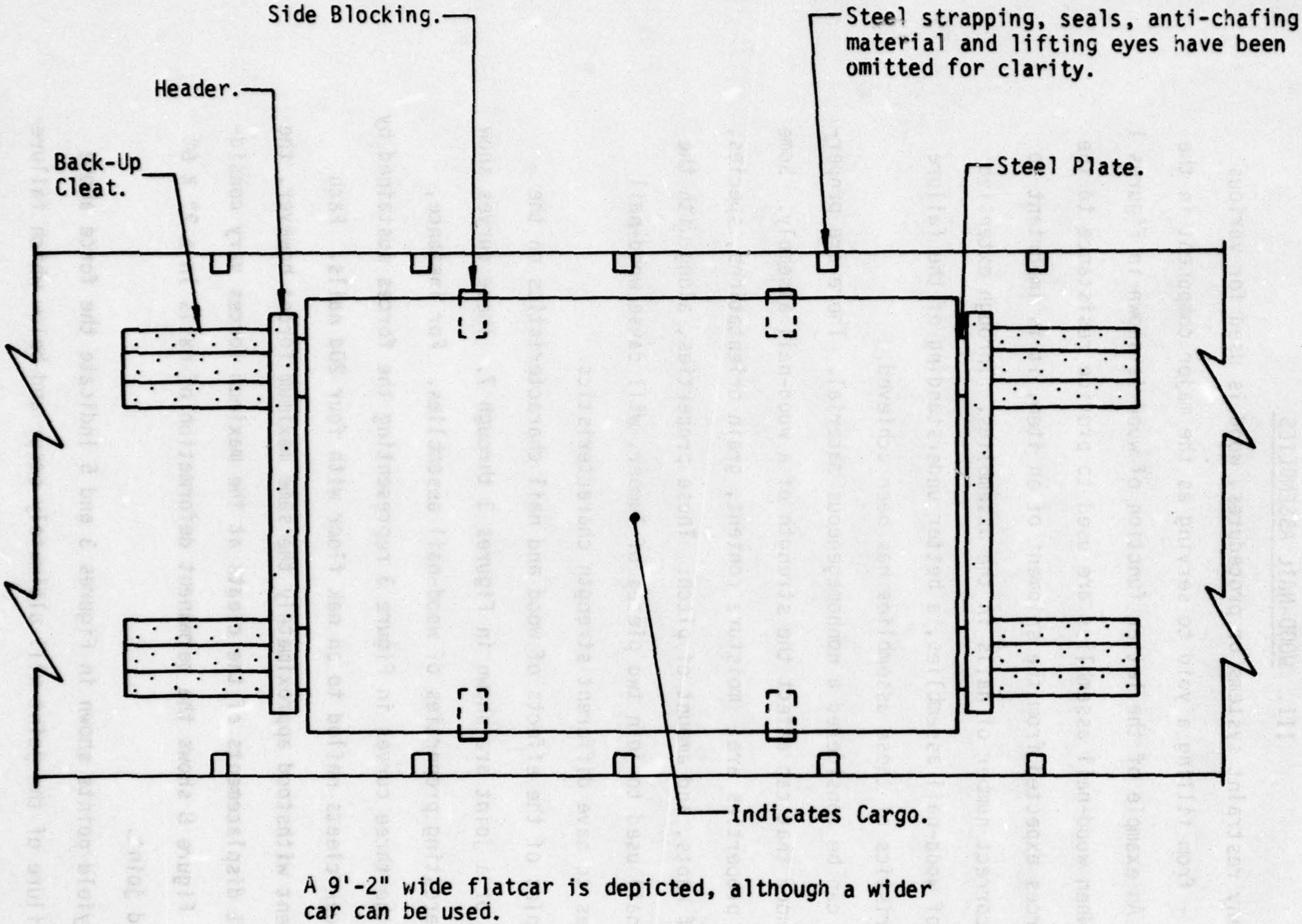

Figure 1. Floorline Blocking for an Octagon Shaped Item, Plan View.

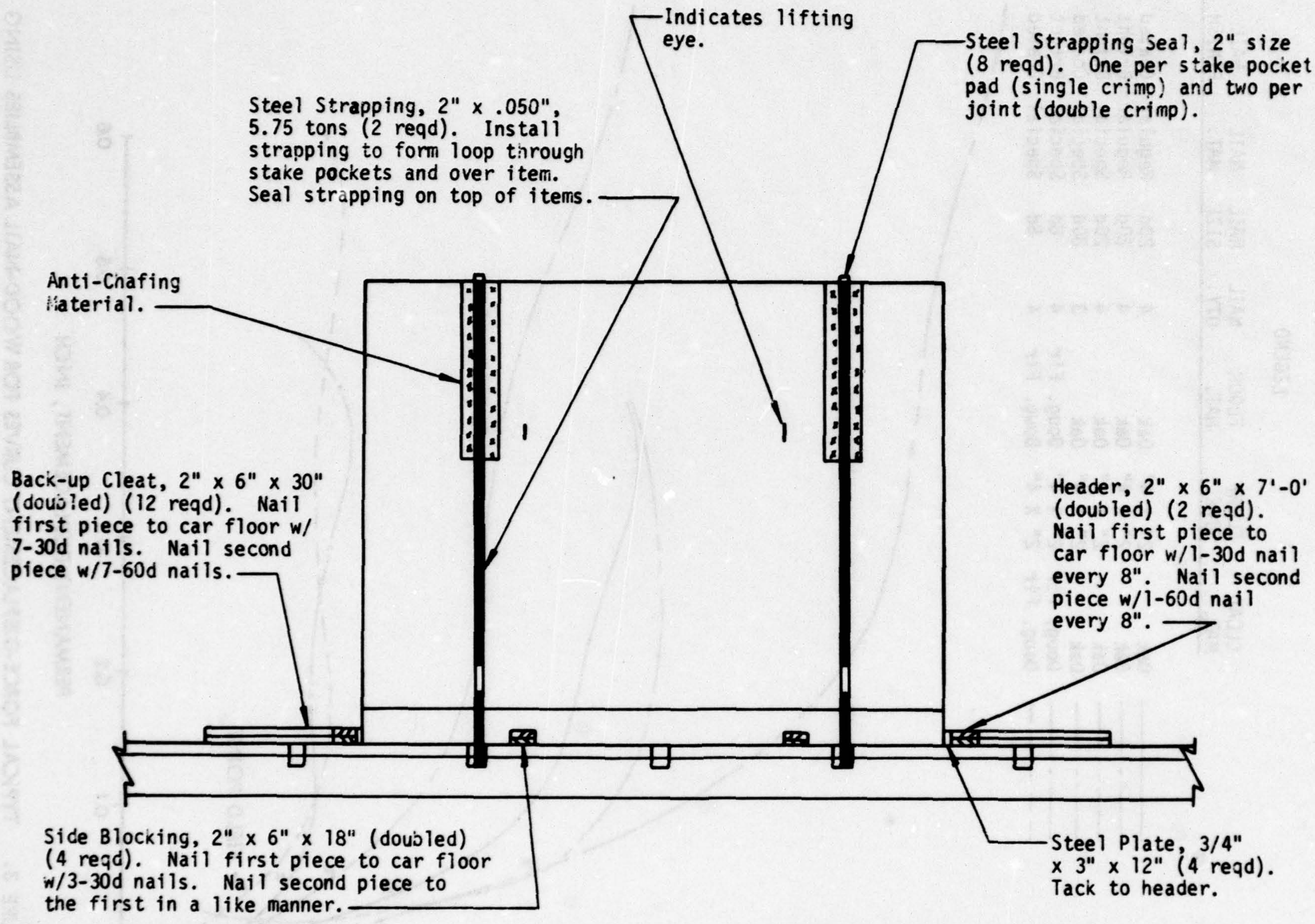

Figure 2. Floorline Blocking for an Octagon Shaped Item, Side Elevation View.

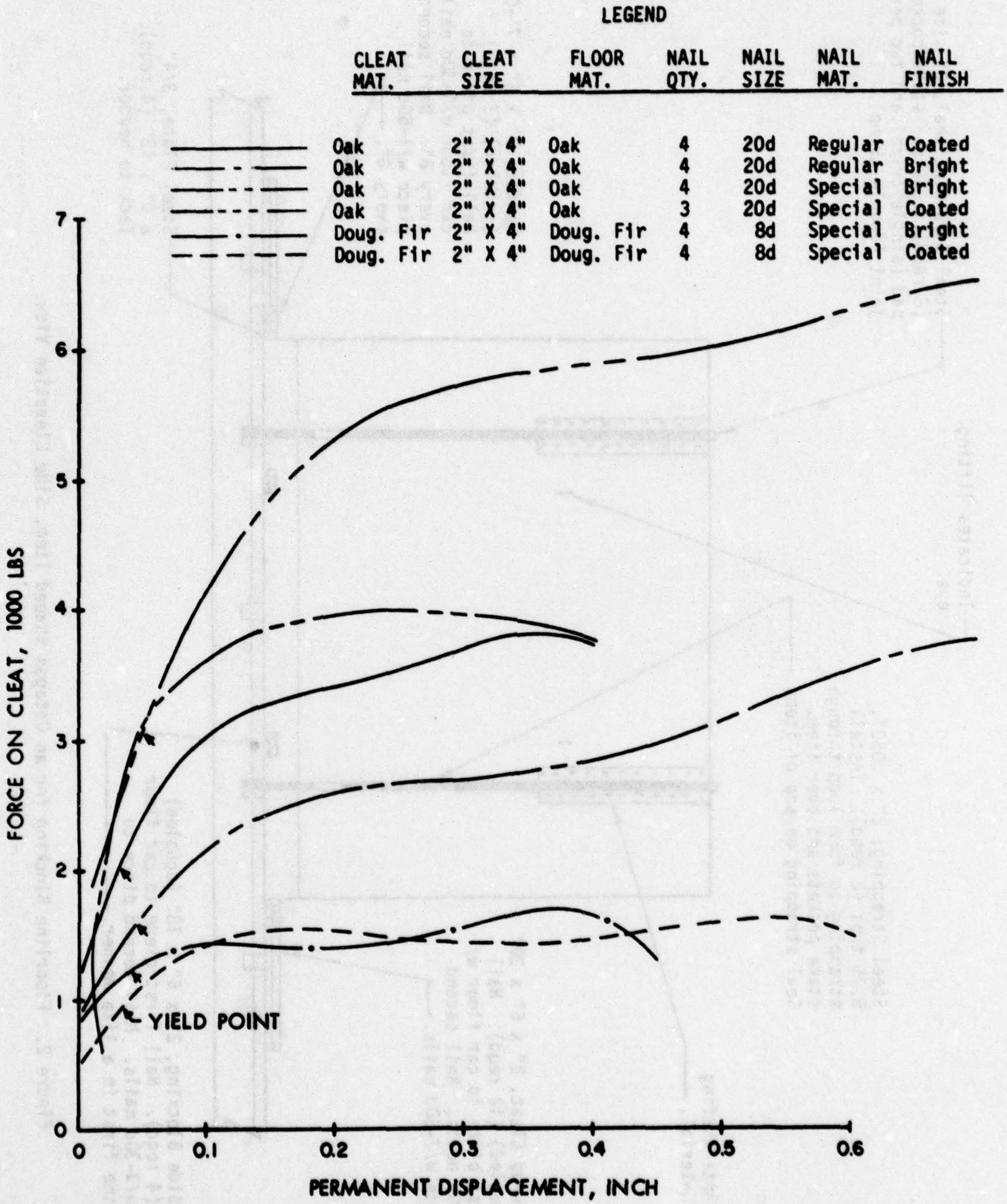

FIGURE 3. TYPICAL FORCE-DISPLACEMENT CURVES FOR WOOD-NAIL ASSEMBLIES USING A 2" X 4" CLEAT.

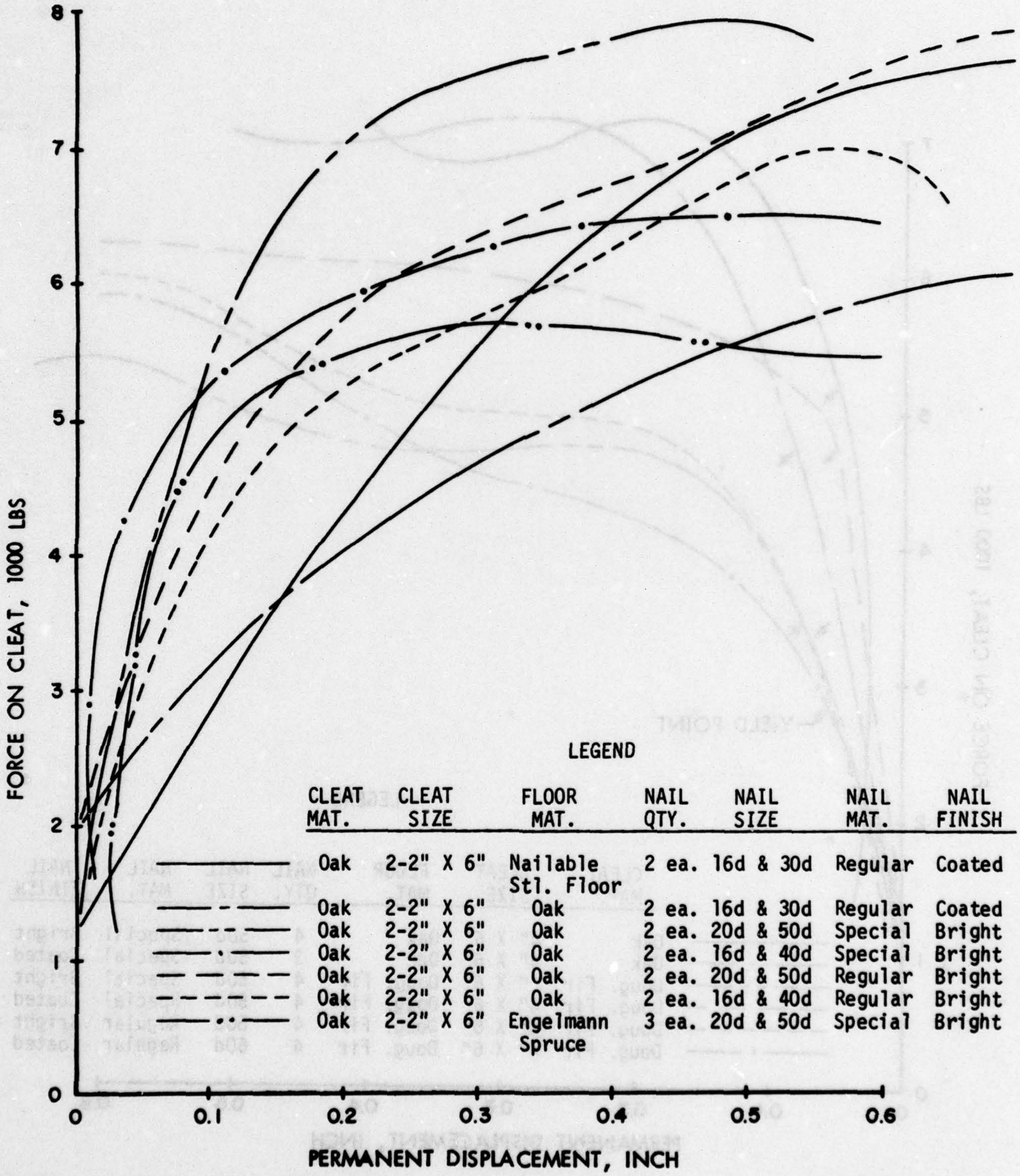

FIGURE 4. TYPICAL FORCE-DISPLACEMENT CURVES FOR WOOD-NAIL ASSEMBLIES USING A 2" X 6" LAMINATED CLEAT.

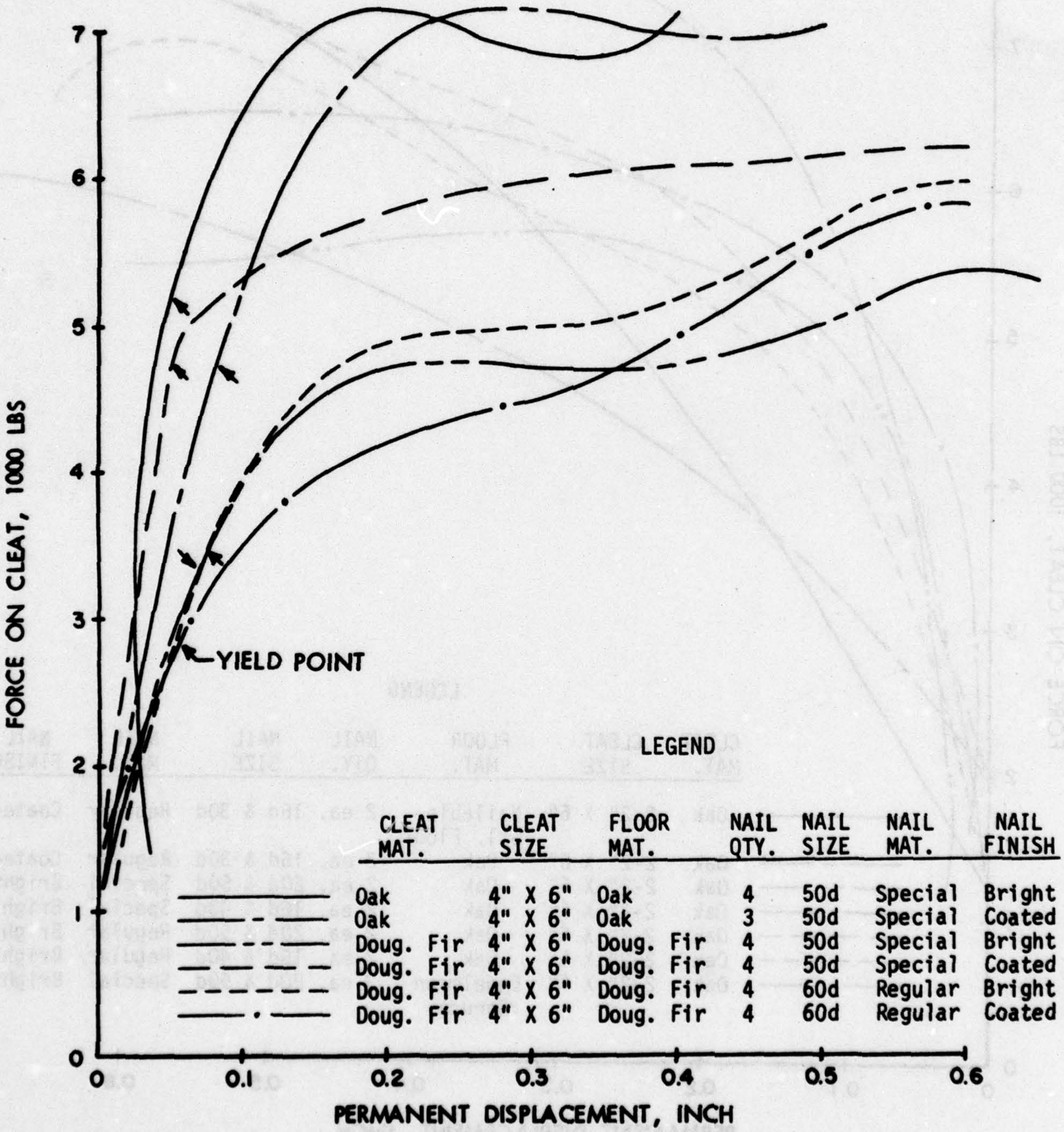

FIGURE 5. TYPICAL FORCE-DISPLACEMENT CURVES FOR WOOD-NAIL ASSEMBLIES USING A 4" X 6" CLEAT.

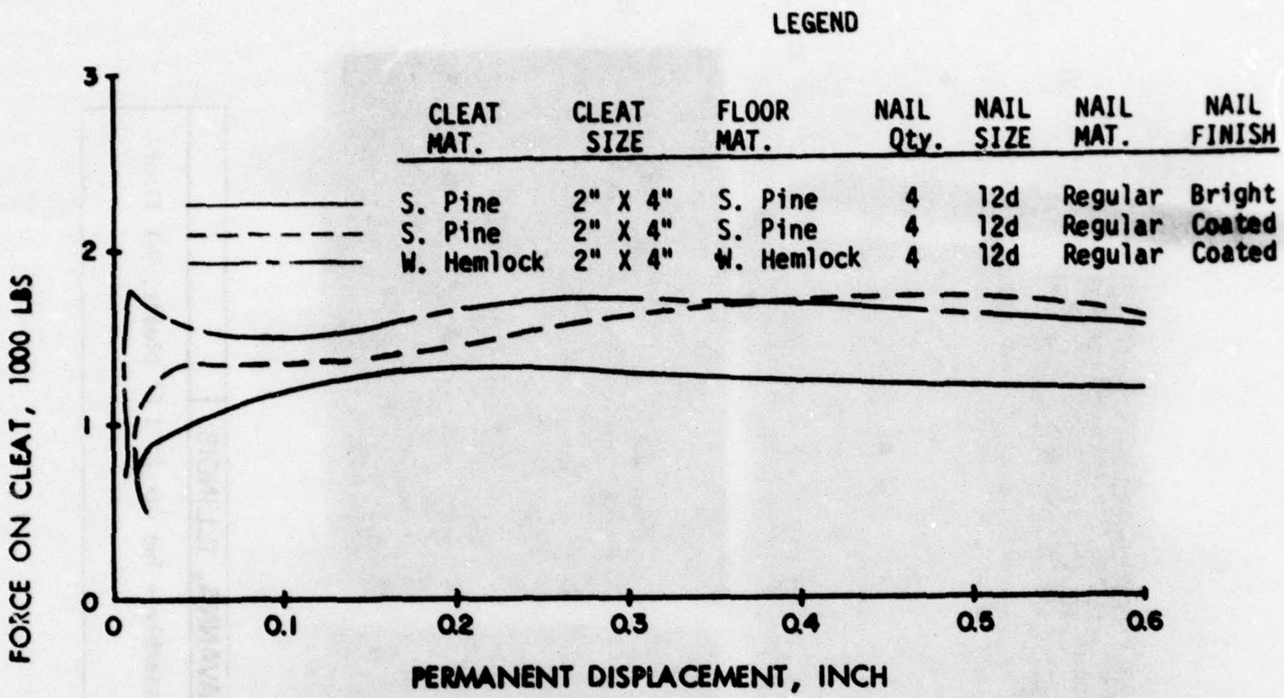

FIGURE 6. TYPICAL FORCE-DISPLACEMENT CURVE FOR A WOOD-NAIL ASSEMBLY SHOWING WITHDRAWAL RESISTANCE.

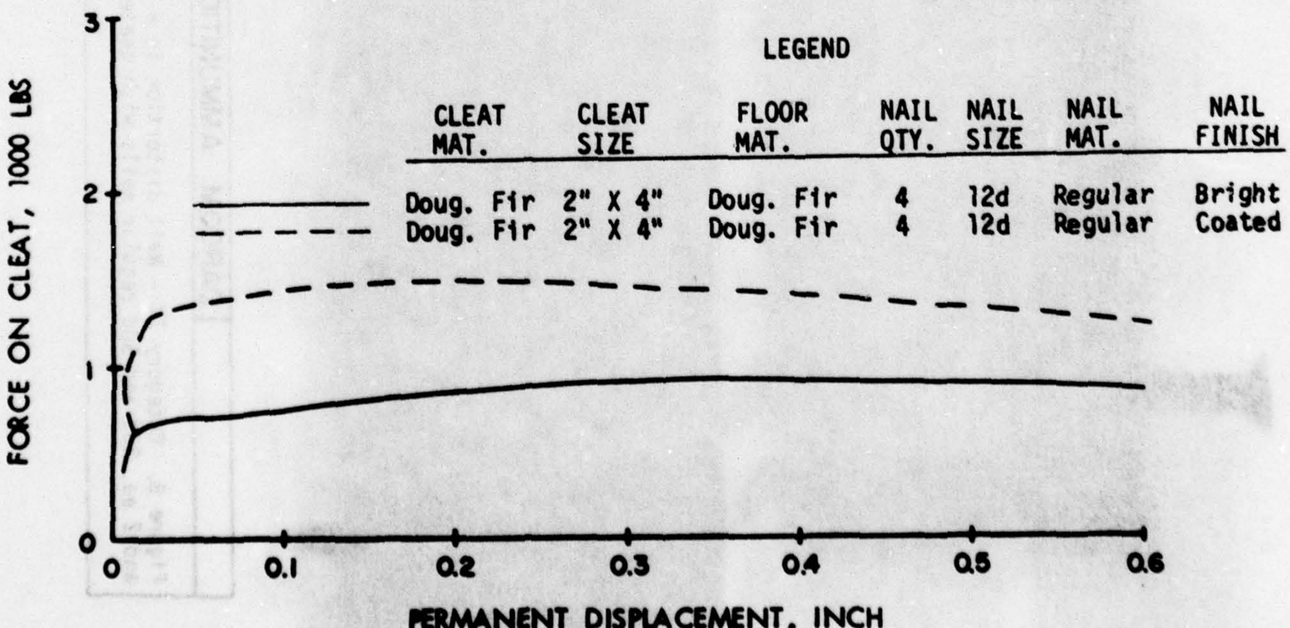

FIGURE 7. TYPICAL FORCE-DISPLACEMENT CURVES FOR WOOD-NAIL ASSEMBLIES SHOWING WITHDRAWAL RESISTANCE.

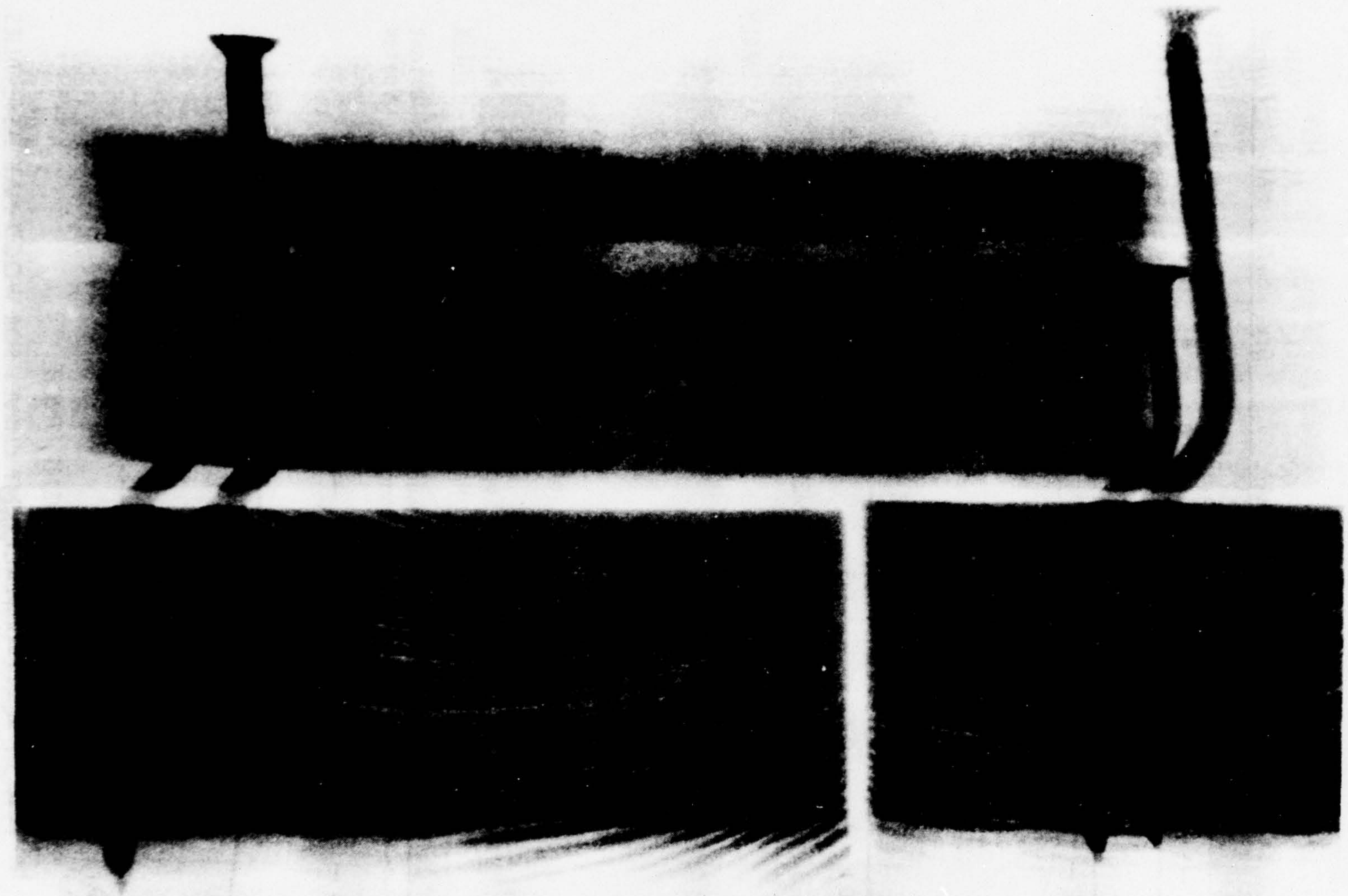

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Figure 8. Category IV - Nail distortion in a failed wood-nail assembly - Two Oak 2" X 6" cleats, Oak floor and 2 ea. 20d and 50d regular nails with coated finish.

were determined by the rate of change in the permanent displacement per potential energy input to the cleat, and not by stress-strain curves used to determine the yield point in metals. A wood-nail assembly can withstand a small number of impacts when the impact force is equal to the maximum force that the assembly can restrain. For an impact force equal to the yield point, the assembly can withstand approximately 75 to 100 impacts.

Strengths of wood-nail assemblies using 2" X 4", laminated 2" X 6", and 4" X 6" cleats are shown in Appendix A. The data in this appendix were used as a basis for the following conclusions.

1. For a cleat that is oriented so that its wood grain is parallel to the wood grain of the floor, the holding capability of the assembly seems slightly higher than when the cleat is perpendicular to the floor. However, full scale tests show that the floors on flatcars can cause a parallel board, or header, to have a rolling effect. This rolling effect can decrease the resistance of a wood-nail assembly.

2. The strength of a wood-nail assembly increases with an increase in the specific gravity of the wood in the floor. Comparatively, there appears to be no significant difference in the strength of most wood-nail joints when various species of wood are used for the cleat.

3. Results of limited testing indicate that nailable steel flooring provides a 17% stronger joint than when oak is used as the floor material.

4. Coated nails do not significantly increase the lateral resistance of a wood-nail assembly to dynamic forces. Nail coating is effective only for a special higher-carbon-steel (AISI 1040), cement-coated nails driven through or into oak wood.

5. The lateral resistance of a wood-nail assembly constructed using regular bright finished low carbon steel nails, AISI 1020, is approximately the same as the resistance of an assembly constructed using bright finished special higher-carbon steel nails, AISI 1040.

6. For most practical cases, the yield point of a wood-nail joint is approximately one-half the maximum force.

The conclusions presented in the above paragraphs were used to select the data for the curves shown in Figures 9 and 10. No safety factor was used in the development of the curves, however, the lowest forces measured during the laboratory tests were used in the analysis.

An example of how the curves can be used is explained in the calculation for the recommended number of nails to be used in floorline blocking to meet the requirements of the American Association of Railroads (AAR). To meet the AAR 8 mph impact requirement, a 1,000 lb load of cargo would generally subject an 8,000 lb force to the floorline blocking. If 4" X 6" lumber and 50 penny nails are used to fabricate the blocking, Figure 9 shows that the number of nails required in the blocking are 9 (8,000 ÷ 965 = 8.29 and rounded up to the next whole number, 9). The curve for softwood flooring is used because some railroad cars have softwood floors. Similar calculations were made to develop Table 1.

The number of nails required in the floorline blocking shown in Figure 1 can be calculated by using Figure 9. The cargo weight of 6,000 lbs is to withstand four impacts at 8 mph. From Figure 9 a 60d nail into softwood can withstand a force of 1,300 lbs and a 30d nail can withstand 1,030 lbs. Therefore, one pair of 60d and 30d nails will withstand a total force of 2,330 lbs. Since the wood-nail combinations will be subjected to more than

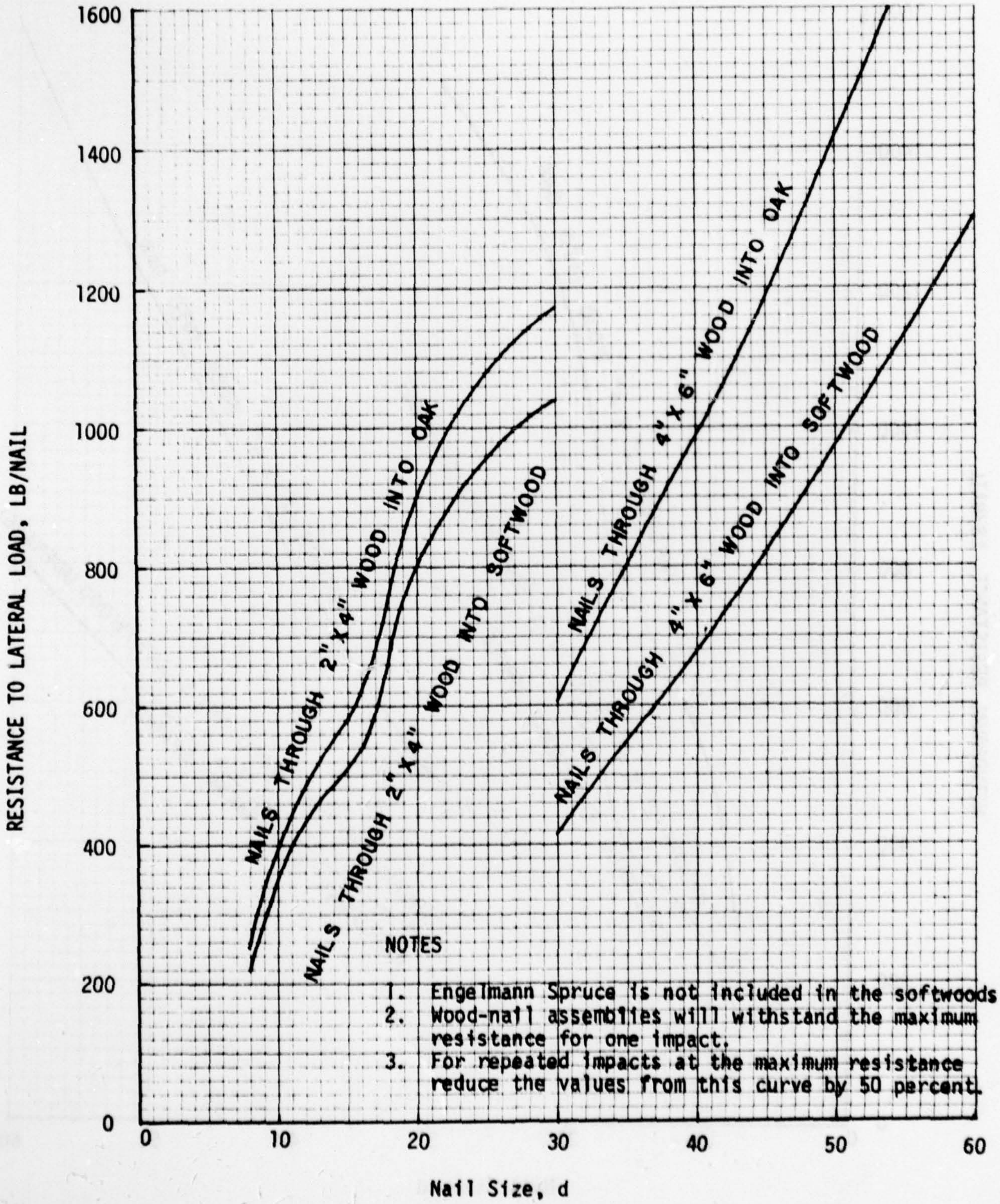

Figure 9. Resistance to Lateral Loads for Wood-Nail Assemblies

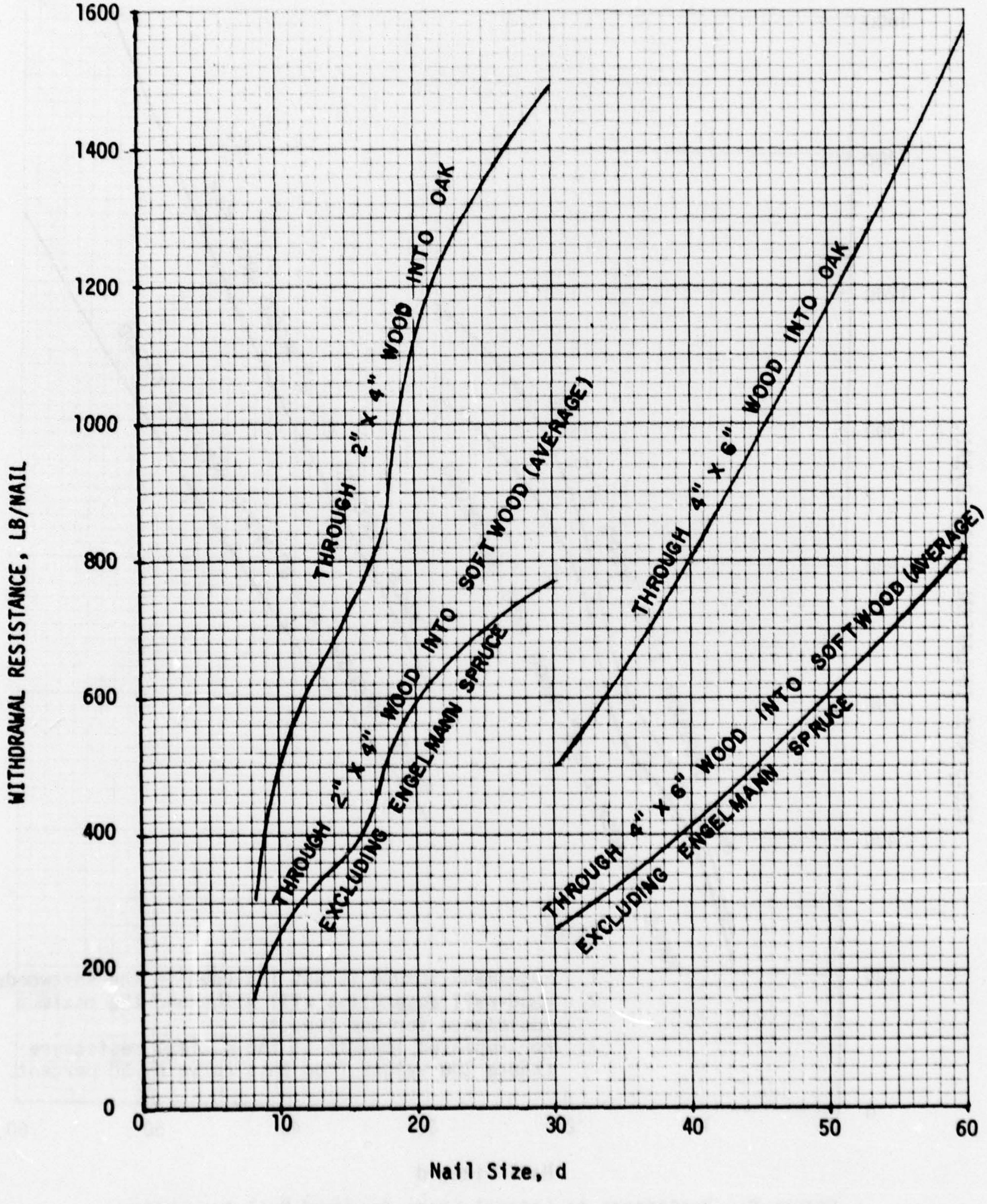

Figure 10. Withdrawal Resistance for Wood-Nail Assemblies.

one impact at 8 mph, the data from Figure 9 should be reduced. Assuming the yield point is approximately one-half the maximum value, the total resistance for the pair of 60d and 30d nails is 2,330 ÷ 2 = 1,165 lbs. Therefore, the number of nails required in the blocking should be 6,000 x 8 ÷ 1,165 = 41.2 or 42 pair of nails. The value, 8, used in the preceding equation represents the dynamic loading caused by the 8 mph impact.

An example for using the data presented in Appendix A is shown in Appendix B.

TABLE 1

RECOMMENDED NUMBER OF NAILS TO BE USED IN FLOORLINE BLOCKING TO MEET AAR REQUIREMENTS

For Each 1,000 Lbs of Cargo

NAIL SIZE, PENNY	2-INCH THICK BLOCKING*	4-INCH THICK BLOCKING*
8	37	
10	29	
12	19	
16	15	
20	10	
30	8	20
40		12
50		9
60		6

*Actual thicknesses are 1-1/2 inch and 3-1/2 inch

IV. EFFECTIVENESS OF WHEEL CHOCKS

1. CHAIN RESTRAINT SYSTEM. Railroad cars which utilize chain restraint systems either have a built-in cushioning system or the cars are uncushioned, and the chain restraint system itself has cushioning devices.

Wheel chocks are not normally used in a chain restraint system. If wheel chocks are used in the system, the force into the tie-downs is reduced but the truck chassis will have a higher acceleration when the flatcar is subjected to an impact. Relationships for the force versus speed of the flatcar at time of impact and acceleration of the truck chassis as a function of coupler force are shown in Figures 11 and 12 respectively. Figure 13 shows the relationship between coupler force and the speed of the flatcar at time of impact.

2. WIRE ROPE RESTRAINT SYSTEM. Wire rope is often used as the major component in a restraint system. When wire rope is used to restrain vehicles, wheel chocks and side blocking are usually a part of the system.

Tests have shown that side blocking is primarily a back-up for the system in case one of the cables would break while the shipment is in transit.

Wheel chocks are effective in reducing the longitudinal movement of a vehicle and in reducing the force into the tie-downs by approximately 8,000 lbs or 21 percent - when a restrained vehicle is subjected to an 8 mph impact. However, the reduced longitudinal movement causes the acceleration of the truck chassis to increase by 36 percent. If wheel chocks are used, the three-piece chock (AAR Pattern 17) should not be used.

Effects of wire rope size when used with and without wheel chocks are

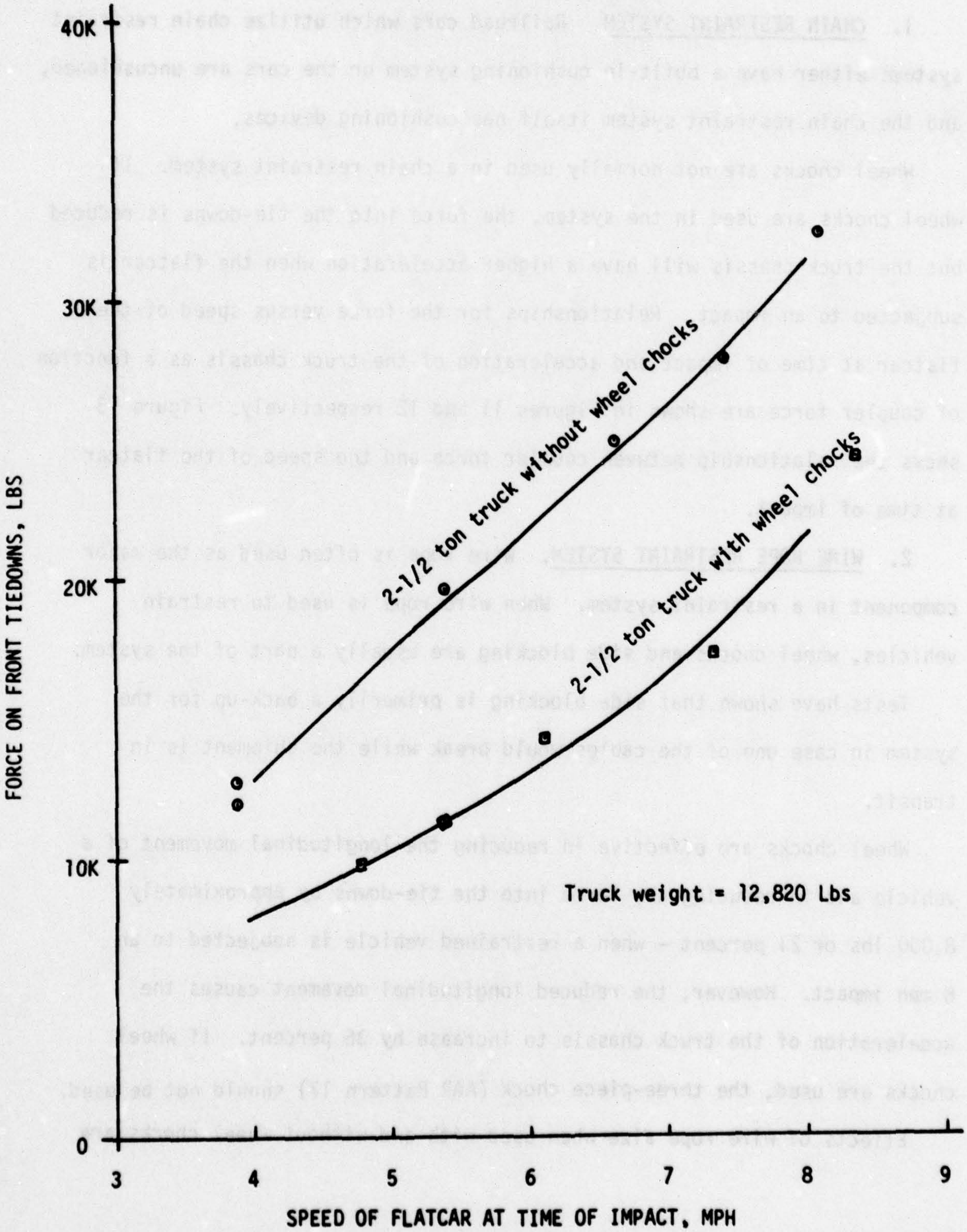

Figure 11 Relationship between force on tiedown and speed of flatcar - with and without wheel chocks

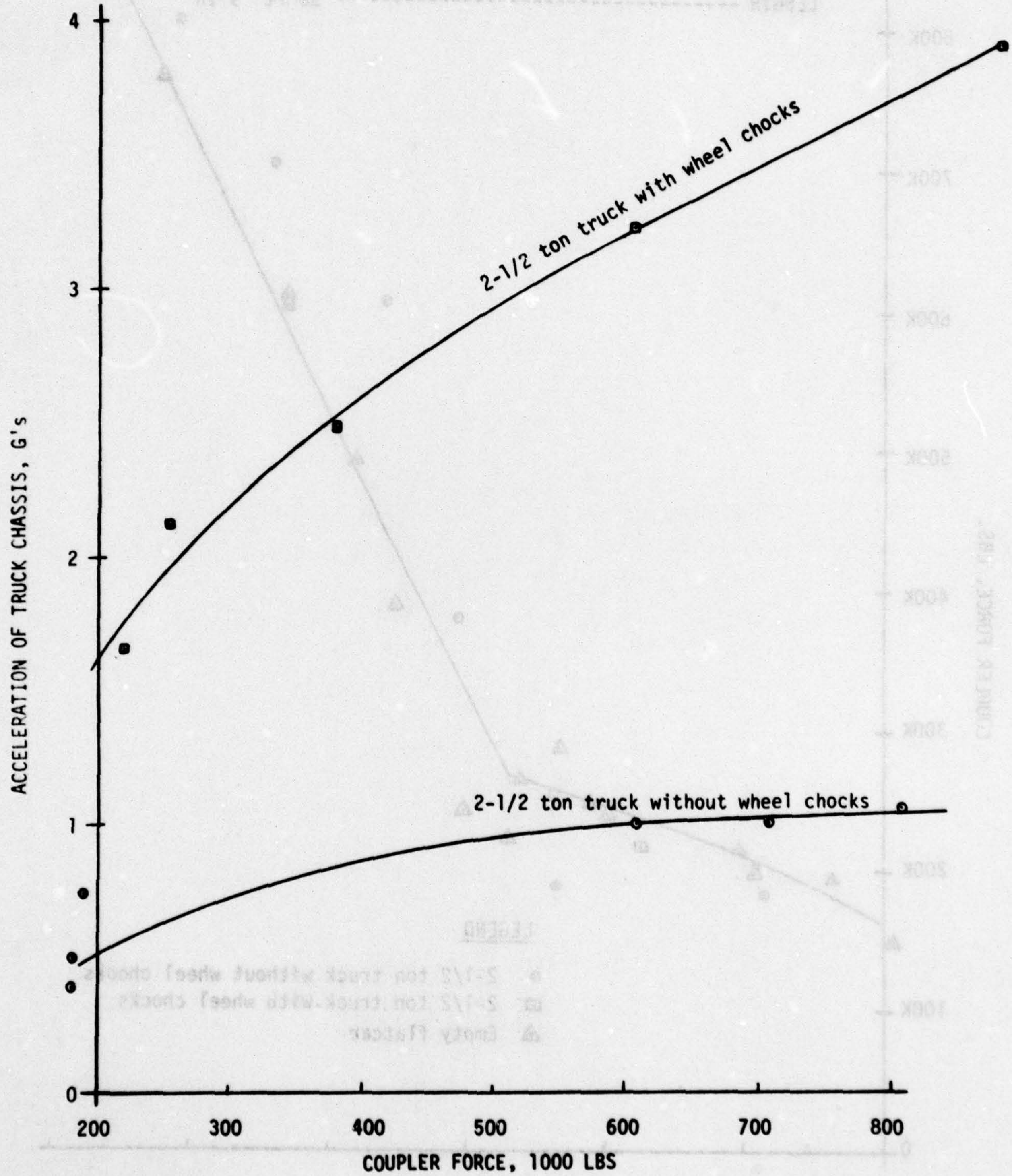

Figure 12. Acceleration of truck chassis versus coupler force. With and without wheel chocks

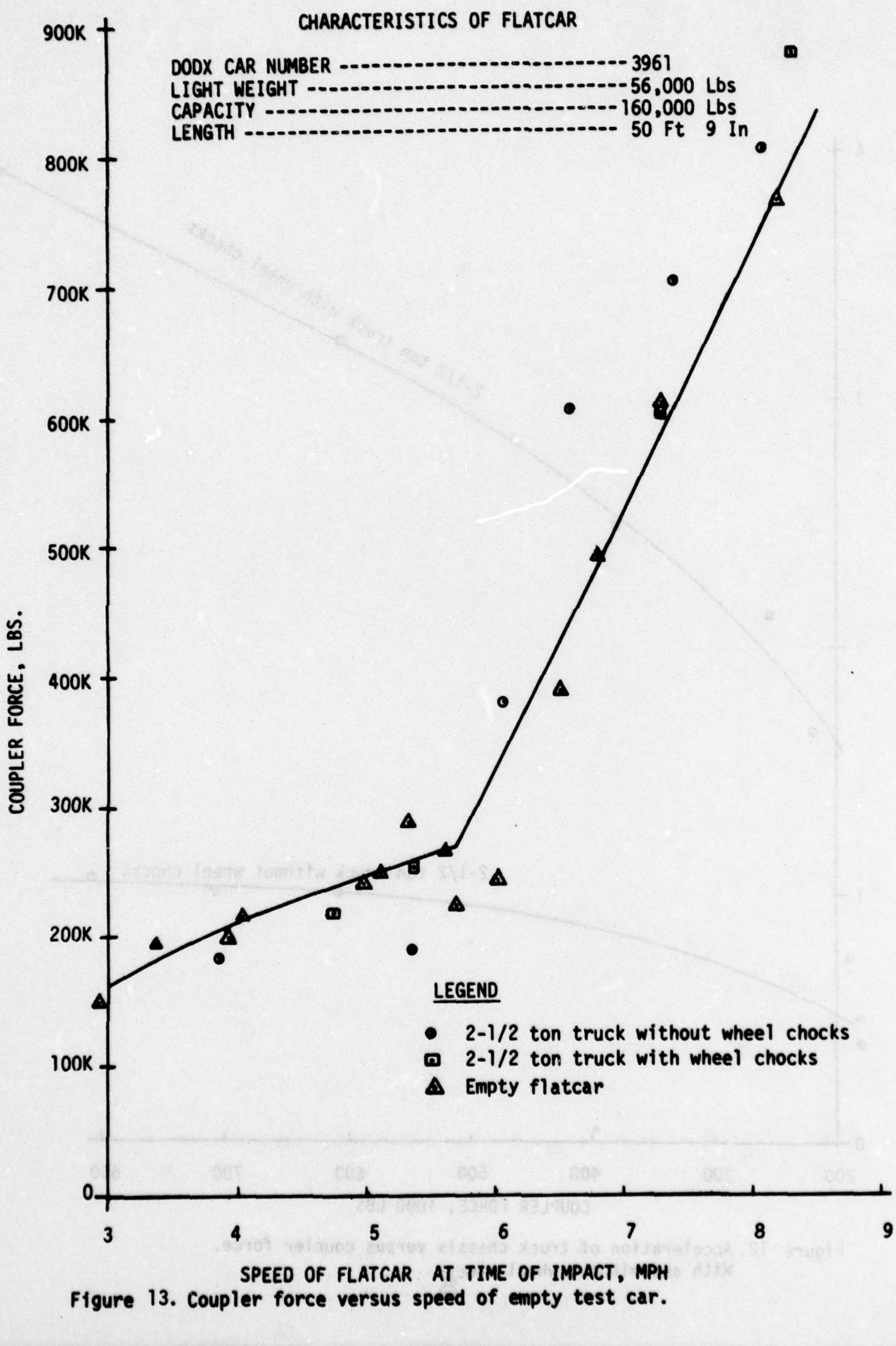

Figure 13. Coupler force versus speed of empty test car.

shown in Figures 14 and 15 respectively. The relationship between the coupler force and the speed of the flatcar at the time of impact is shown in Figure 16.

The rated breaking strength of a wire rope is multiplied by 1.55 to obtain the design strength of a wire rope loop as used in a restraint system.

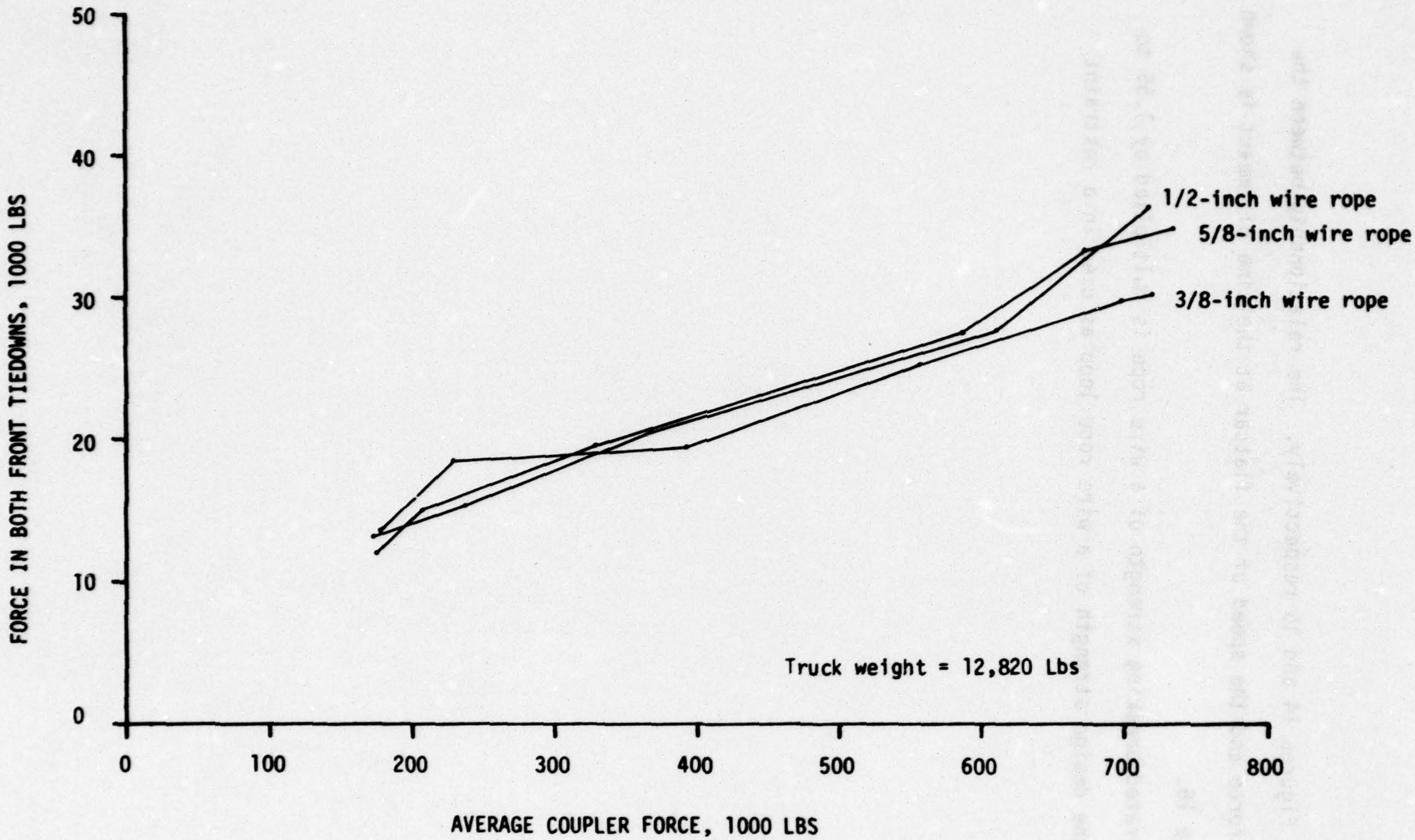

FIGURE 14. Effect of wire rope size when used with solid wheel chocks to restrain a 2-1/2 ton truck.

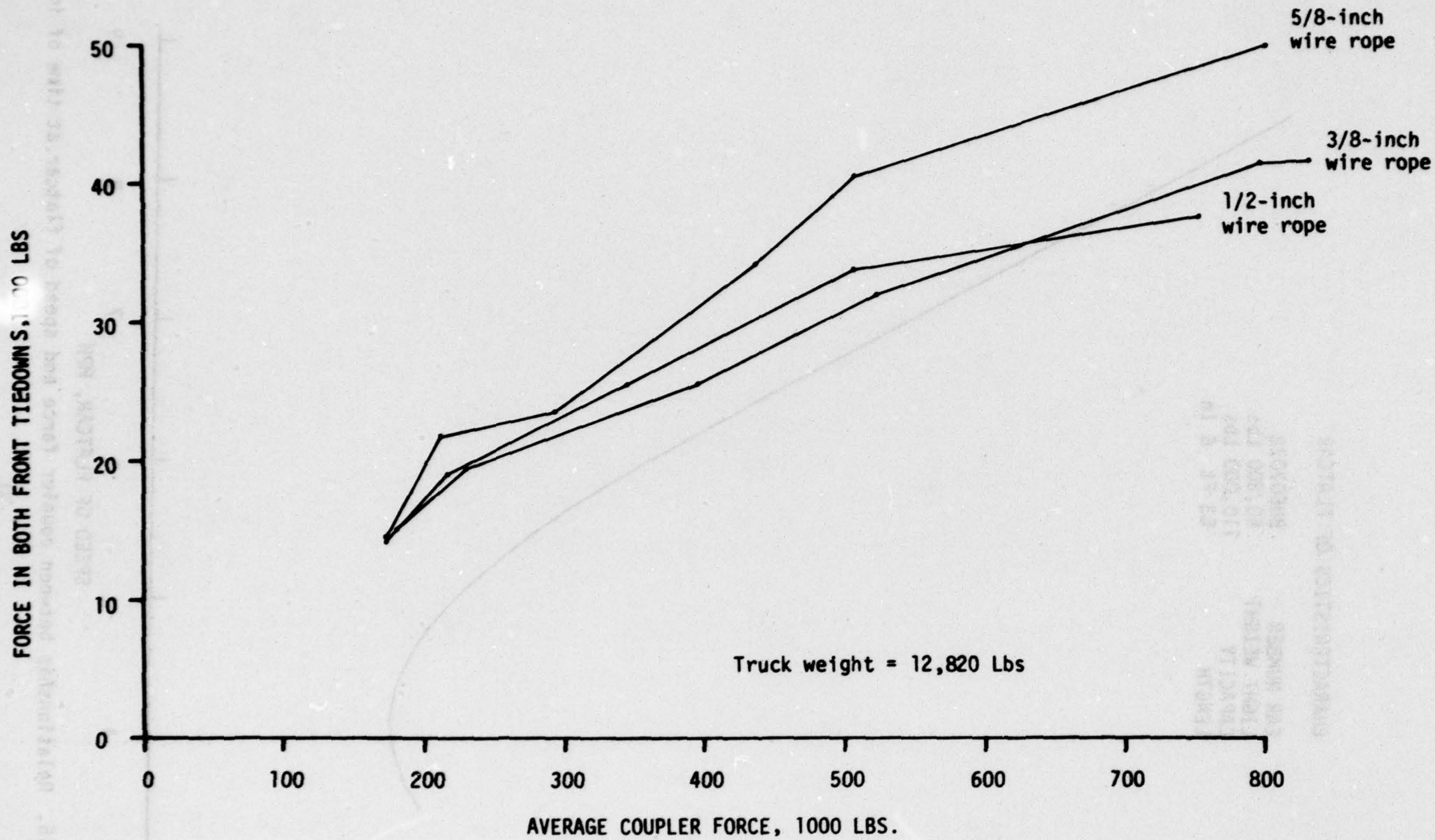

FIGURE 15. Effect of wire rope size when used without wheel chocks to restrain a 2-1/2 ton truck.

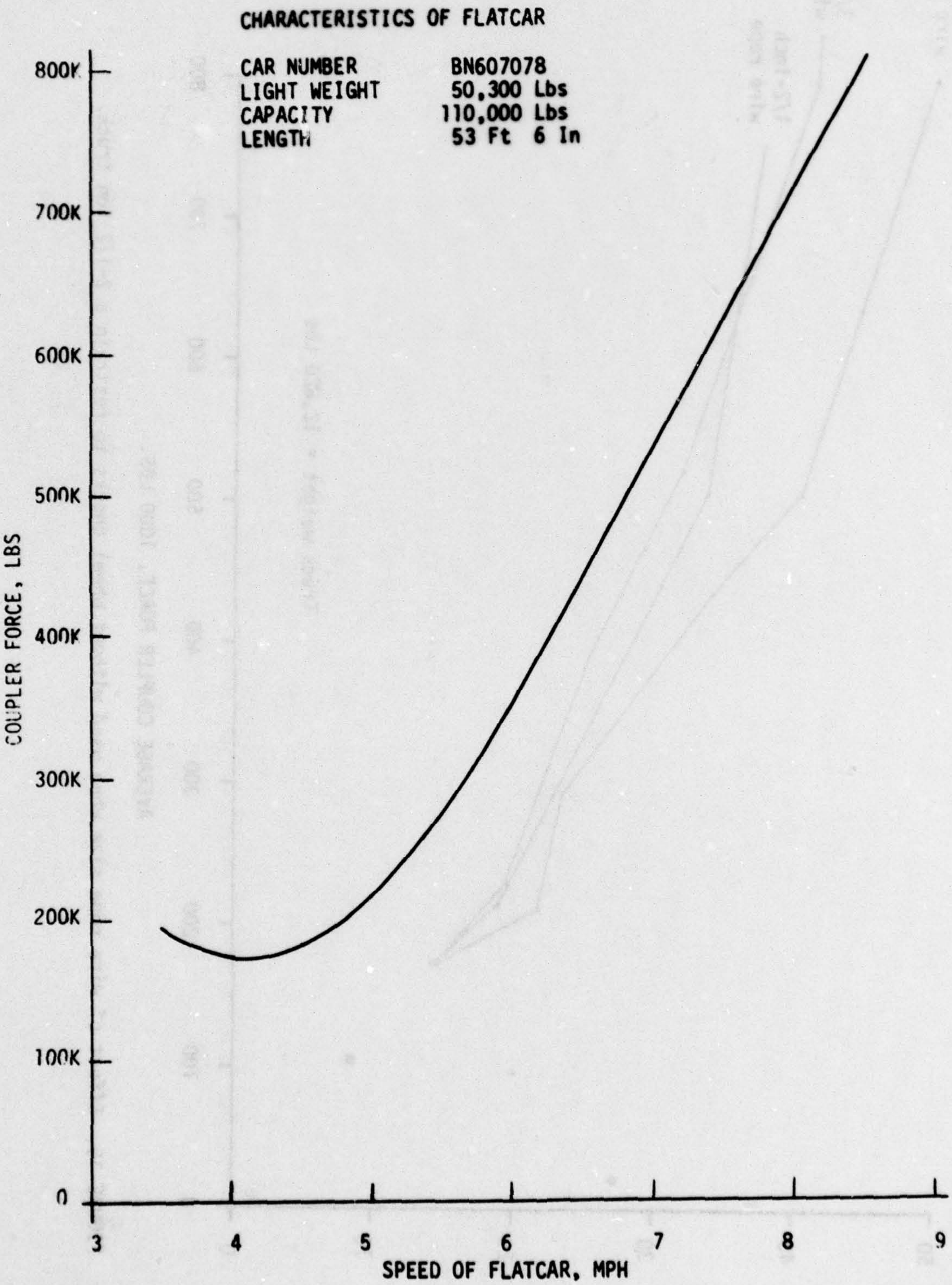

FIGURE 16. Relationship between coupler force and speed of flatcar at time of impact

APPENDIX A

APPENDIX A-1. STRENGTHS FOR WOOD-NAIL ASSEMBLIES USING 2" X 4" CLEATS

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS	LOWEST MAX STRENGTH, POUNDS	HIGHEST MAX STRENGTH, POUNDS	AVERAGE YIELD STRENGTH, POUNDS	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENE-TRATION	AVERAGE PD* @MAX FORCE	AVERAGE HAMMER ACCEL.
Oak	Oak	985	938	1013	785	20d	Special	Bright	2.5	0.194	7.01
"	"	1068	1025	1095	742	"	"	"	"	0.254	7.67
"	"	978	960	1008	803	"	"	"	"	0.265	7.17
"	"	2184	2013	2333	1113	"	"	Coated	"	0.799/	11.04/
										0.586	7.7
"	"	925	900	938	518	"	Regular	Bright	"	0.587	8.26
"	"	955	898	998	573	"	"	Coated	"	0.557	7.36
Oak	Oak	865	820	903	643	16d	Special	Bright	2.0	0.210	6.31
"	"	1583	1460	1653	856	"	"	Coated	2.0	0.467	5.10
"	"	1318	1265	1368	604	"	Regular	Bright	2.0	0.692	6.93
"	"	565	520	655	390	"	"	Coated	2.0	0.357	8.3
Oak	Oak	1091	1038	1173	614	12d	Special	Coated	1.75	0.548	6.03
"	"	554	440	653	320	"	Regular	"	"	0.601	--
Southern Pine	Oak	989	853	1060	677	20d	Special	Bright	2.5	0.346	7.30
Douglas Fir	Oak	867	748	1018	659	20d	Special	Bright	2.5	0.136	6.08
" " (1)	"	1263	1170	1370	915	"	"	"	"	0.216	6.18
Western Hemlock	Oak	1092	770	1118	632	20d	Special	Bright	2.5	0.329	7.56
" " (1)	"	1070	1023	1105	823	"	"	"	"	0.098	5.41
Engelmann Spruce	Oak	1004	898	1093	595	20d	Special	Bright	2.5	0.189	6.62
" " (1)	"	1028	980	1100	590	"	"	"	"	0.270	5.16
Oak	Southern Pine	869	763	980	631	20d	Special	Bright	2.5	0.306	6.43
"	" "	1531	1493	1580	824	"	"	Coated	"	0.544	5.08
Southern Pine	Southern Pine	582	530	645	420	12d	Special	Bright	1.75	0.179	7.34
" "	" "	545	515	620	418	"	"	"	"	0.259	7.00
" "	" "	753	725	780	468	"	"	Coated	"	0.381	5.77
" "	" "	840	780	940	529	"	"	"	"	0.636	7.33

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS	LOWEST MAX STRENGTH, POUNDS	HIGHEST MAX STRENGTH, POUNDS	AVERAGE YIELD STRENGTH, POUNDS	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENE-TRATION	AVERAGE PD* @ MAX FORCE	AVERAGE HAMMER ACCEL.
Southern Pine	Southern Pine	472	448	515	370	8d	Special	Bright	1.0	0.228	5.8
" "	" "	485	425	520	372	"	"	"	"	0.142	5.01
" "	" "	443	430	470	345	"	"	Coated	"	0.259	8.18
" "	" "	553	503	595	387	"	"		"	0.371	9.40
Oak	Douglas Fir	1039	920	1123	720	20d	Special	Bright	2.5	0.182	5.20
"	" "	1442	1340	1530	801	"	"	Coated	"	0.697	5.45
Douglas Fir	Douglas Fir	528	463	573	392	12d	Special	Bright	1.75	0.420	6.12
" "	" "	477	453	513	374	"	"	"	"	0.251	6.59
" "(1)	" "(1)	549	513	573	450	"	"	"	"	0.177	6.91
" "(1)	" "(1)	410	333	543	262	"	"	"	"	0.604/ 1.212	9.74/ 6.11
" "	" "	612	583	655	380	"	"	Coated	"	0.609	11.03
" "	" "	590	565	615	381	"	"	"	"	0.460	11.15
" "(1)	" "(1)	579	560	590	382	"	"	"	"	0.456	10.9
" "(1)	" "(1)	548	455	600	363	"	"	"	"	0.453	10.17
Douglas Fir	Douglas Fir	379	373	385	286	8d	Special	Bright	1.0	0.148	4.5
" "	" "	399	380	415	298	"	"	"	"	0.189	4.77
" "(1)	" "(1)	393	360	423	281	"	"	"	"	0.229	4.75
" "(1)	" "(1)	363	330	393	315	"	"	"	"	0.114	3.89
" "	" "	383	365	390	245	"	"	Coated	"	0.396	11.6
" "	" "	398	378	423	241	"	"	"	"	0.452	8.01
" "(1)	" "(1)	368	308	400	258	"	"	"	"	0.272	11.07
" "(1)	" "(1)	429	380	488	308	"	"	"	"	0.248	8.44
Oak	Western Hemlock	524	500	548	381	12d	Special	Bright	1.75	0.292/ 0.211	3.96/ 6.34
"	" "	991	963	1040	681	20d	"	"	2.5	0.296	7.10
"	" "	1478	1373	1588	806	"	"	Coated	"	0.547	5.98
Western Hemlock	Western Hemlock	435	293	620	357	12d	Special	Bright	1.75	0.462	6.01
" "	" "	441	403	478	333	"	"	"	"	0.274	5.82
" " (1)	" "(1)	387	280	520	287	"	"	"	"	0.229	5.33
" "(1)	" "(1)	475	438	510	329	"	"	"	"	0.359	6.16

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS	LOWEST MAX STRENGTH, POUNDS	HIGHEST MAX STRENGTH, POUNDS	AVERAGE YIELD STRENGTH, POUNDS	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENE- TRATION	AVERAGE PD* @ MAX FORCE	AVERAGE HAMMER ACCEL.
Western Hemlock	Western Hemlock	484	443	548	263	12d	Special	Coated	1.75	0.370/	8.82/
										0.568	3.98
" "	" "	454	390	528	290	"	"	"	"	0.397	7.59
" " (1)	" "(1)	497	483	518	314	"	"	"	"	0.474	9.33
" " (1)	" "(1)	501	455	530	308	"	"	"	"	0.575/	4.24/
										0.514	10.03
Western Hemlock	Western Hemlock	296	255	318	253	8d	Special	Bright	1.0	0.226	3.69
" "	" "	453	448	458	360	"	"	"	"	0.243	5.24
" " (1)	" "(1)	379	248	520	286	"	"	"	"	0.137	5.82
" " (1)	" "(1)	302	298	308	238	"	"	"	"	0.255	3.77
" "	" "	276	220	345	165	"	"	Coated	"	0.425	9.22
" "	" "	356	308	440	207	"	"	"	"	0.551	10.9
" " (1)	" "(1)	301	273	323	207	"	"	"	"	0.375	9.29
" " (1)	" "(1)	339	308	400	222	"	"	"	"	0.338/	9.74/
										0.386	6.48
Oak	Engelmann Spruce	800	730	878	567	20d	Special	Bright	2.5	0.222/	10.8/
										0.258	5.8
"	" "	1257	1245	1275	465	"	"	Coated	"	0.748	4.43
Oak	Engelmann Spruce	500	485	508	363	12d	Special	Bright	1.75	0.309	6.13
Engelmann Spruce	Engelmann Spruce	419	390	458	322	12d	Special	Bright	1.75	0.532	4.72
" "	" "	489	453	545	364	"	"	"	"	0.263	5.87
" " (1)	" "(1)	388	380	400	270	"	"	"	"	0.126	4.34
" " (1)	" "(1)	418	398	440	334	"	"	"	"	0.226	4.90
" "	" "	524	505	540	308	"	"	Coated	"	0.523	9.22
" "	" "	489	483	500	278	"	"	"	"	0.585	8.97
" " (1)	" "(1)	532	505	580	331	"	"	"	"	0.466	9.45
" " (1)	" "(1)	450	425	515	259	"	"	"	"	0.425	8.64

*PD - Permanent Displacement

APPENDIX A-2. STRENGTHS FOR WOOD-NAIL ASSEMBLIES USING LAMINATED 2" X 6" CLEATS

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS*	LOWEST MAX STRENGTH, POUNDS*	HIGHEST MAX STRENGTH, POUNDS*	AVERAGE YIELD STRENGTH, POUNDS*	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENE-TRATION	AVERAGE PD** @ MAX FORCE	AVERAGE HAMMER ACCEL.
Oak	Oak	2852	2685	2973	---	50d& 20d	Special	Bright	2.5& 2.5	0.351	8.06
"	"	3649	3377	3893	2593	"	"	"	"	0.298	11.60
"	"	3453	----	----	2280	"	"	"	"	0.148	11.08
"	"	3976	2940	6875	2269	"	"	"	"	0.463	9.57
"	"	5083	4900	5325	2780	"	"	Coated	"	0.671	7.77
"	"	4778	4580	4910	3292	"	"	"	"	0.459	8.08
"	"	3469	3015	3780	1632	"	Regular	Bright	"	0.543	5.73
"	"	3972	3740	4275	1618	"	"	"	"	0.660	6.43
"	"	3328	2930	3770	1584	"	"	Coated	2.25& 2.5	0.553	6.53
"	"	4070	3950	4190	1581	"	"	"	"	0.723	6.17
Oak	Oak	3012	2840	3170	1476	40d& 16d	Special	Bright	2.0& 2.0	0.491	4.17
"	"	3212	2910	3500	1780	"	"	"	"	0.482	3.80
"	"	3428	3030	3815	1810	"	"	Coated	"	0.459	5.54
"	"	3152	2895	3300	1753	"	"	"	"	0.461	5.00
"	"	2997	2810	3110	1053	"	Regular	Bright	"	0.635	3.79
"	"	3343	3180	3445	1268	"	"	"	"	0.588	4.55
"	"	3557	3250	4020	1360	"	"	Coated	"	0.786	4.98
"	"	2738	2470	4355	1402	"	"	"	"	0.572	3.25
Oak	Oak	3037	2925	3130	1759	30d& 16d	Special	Coated	1.5& 2.0	0.231	4.40
"	"	3008	2730	3315	1496	"	"	"	"	0.505	3.82
"	"	3066	2867	3215	1315	"	Regular	"	"	0.681	4.65
"	"	2873	2625	3165	----	"	"	"	"	0.534	4.89

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS*	LOWEST MAX STRENGTH, POUNDS*	HIGHEST MAX STRENGTH, POUNDS*	AVERAGE YIELD STRENGTH, POUNDS*	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENE-TRATION	AVERAGE PD** @ MAX FORCE	AVERAGE HAMMER ACCEL.
Southern Pine	Oak	3160	2680	3410	----	50d& 20d	Special	Bright	2.5& 2.5	0.504	8.19
" "	"	2720	2550	2870	1434	"	"	"	"	0.368	4.76
" "	"	2538	2413	2663	1502	"	"	"	"	0.354	7.11
" "	"	2609	2253	2830	1939	"	"	"	"	0.432	7.31
" "	"	2024	1717	2330	1394	"	"	"	"	0.389	5.97
" "	"	2689	2593	2790	1809	"	"	"	"	0.351	7.58
" "	Weathered Oak	2827	2680	2980	1863	"	"	"	"	0.385	5.41
" "	" "	2640	2395	3080	----	"	"	Coated	"	0.528	5.24
Douglas Fir	Oak	2359	1737	2717	----	50d& 20d	Special	Bright	2.5& 2.5	0.259	6.50
" "	"	3342	3310	3360	2441	"	"	"	"	0.515	5.92
" "(1)	"	2514	2180	2753	----	"	"	"	"	0.195	6.96
" "(1)	"	3312	3160	3495	2507	"	"	"	"	0.355	5.63
Western Hemlock	Oak	2269	2010	2500	----	50d& 20d	Special	Bright	2.5& 2.5	0.401	6.03
" "	"	2683	2550	2750	1997	"	"	"	"	0.307	4.67
" "(1)	"	2611	2020	3163	----	"	"	"	"	0.363	6.31
" "(1)	"	3148	2620	3540	1911	"	"	"	"	0.465	5.60
Engelmann Spruce	Oak	3317	3153	3587	----	50d& 20d	Special	Bright	2.5& 2.5	0.505	8.08
" "	"	2967	2940	3010	1651	"	"	"	"	0.637	4.95
" "(1)	"	2938	2880	2987	----	"	"	"	"	0.340	6.78
" "(1)	"	2992	2870	3185	1510	"	"	"	"	0.566	5.09
" "(1)	Weathered Oak	2292	2220	2370	----	"	"	"	"	0.387	4.88
" "(1)	" "	1892	1850	1970	1228	"	Regular	"	"	0.370	3.44

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS*	LOWEST MAX STRENGTH, POUNDS*	HIGHEST MAX STRENGTH, POUNDS*	AVERAGE YIELD STRENGTH, POUNDS*	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENE-TRATION	AVERAGE PD** @MAX FORCE	AVERAGE HAMMER ACCEL.
Oak	Southern Pine	2422	2233	2660	1834	50d& 20d	Special	Bright	2.5& 2.5	0.307	6.27
"	" "	2564	2423	2675	1693	"	"	"	"	0.436	4.91
"	" "	3472	3260	3615	1825	"	"	Coated	"	0.683	5.42
"	" "	4102	4190	4565	----	"	"	"	"	0.489	5.94
Oak	Douglas Fir	2236	2080	2510	----	50d& 20d	Special	Bright	2.5& 2.5	0.350	5.42
"	" "	2228	2173	2290	981	"	"	"	"	0.446	4.91
"	" "	2467	2400	2585	2008	"	"	"	"	0.205	3.99
"	" "	1950	2020	2057	1281	"	"	"	"	0.278	4.89
"	" "	2900	2280	3460	1308	"	"	Coated	"	0.753	4.01
"	" "	2635	2433	2837	----	"	"	"	"	0.217	5.58
Southern Pine(1)	Douglas Fir Used	2191	1977	2383	965	50d& 20d	Special	Bright	2.5& 2.5	0.368	6.47
" "	" " "	2613	2047	3180	1080	"	Regular	"	"	0.577	6.92
Engelmann Spruce	Douglas Fir Used	2047	1887	2280	882	50d& 20d	Special	Bright	2.5& 2.5	0.362	5.84
" "	" " "	2728	2297	3063	1295	"	Regular	"	"	0.578	7.98
Oak	Western Hemlock	2025	1773	2303	----	50d& 20d	Special	Bright	2.5& 2.5	0.266	5.63
"	" "	2077	2023	2130	1502	"	"	"	"	0.287	4.76
"	" "	3366	3070	4000	1788	"	"	Coated	"	0.605	4.87
"	" "	2406	2347	2503	----	"	"	"	"	0.230	5.72

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS*	LOWEST MAX STRENGTH, POUNDS*	HIGHEST MAX STRENGTH, POUNDS*	AVERAGE YIELD STRENGTH, POUNDS*	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENE-TRATION	AVERAGE PD** @ MAX FORCE	AVERAGE HAMMER ACCEL.
Oak	Engelmann Spruce	1894	1793	1963	----	50d& 20d	Special	Bright	2.5& 2.5	0.442	5.37
"	"	1957	1677	2127	1212	"	"	"	"	0.290	4.7
"	"	2897	2835	3010	1305	"	"	Coated	"	0.676	4.28
"	"	2110	1933	2387	----	"	"	"	"	0.374	4.51
Southern Pine(1)	Nailable Stl. Fl.	2850	2640	3080	----	30d& 16d	Regular	Bright	1.5& 2.0	0.936	5.51
" "	"	3427	3290	3665	----	"	"	Coated	"	0.810	6.81
Engelmann Spruce	"	3110	2910	3245	----	"	"	Bright	"	0.976	5.86
" "(1)	"	3660	3175	3940	----	"	"	Coated	"	0.626	7.42

* - Force per Pair of Nails
** - Permanent Displacement

APPENDIX A-3. STRENGTHS FOR WOOD-NAIL ASSEMBLIES USING 4" X 6" CLEATS

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS*	LOWEST MAX STRENGTH, POUNDS*	HIGHEST MAX STRENGTH, POUNDS*	AVERAGE YIELD STRENGTH, POUNDS*	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENE-TRATION	AVERAGE PD** @ MAX FORCE	AVERAGE HAMMER ACCEL.
Oak	Oak	1646	1550	1788	1279	50d	Special	Bright	2.0	0.225	6.64
"	"Av. Cond.	1614	1278	1803	974	"	"	"	"	0.236	6.25
"	"Fair Cond.	1054	925	1163	615	"	"	"	"	0.245	4.37
"	"	1662	1498	1840	1161	"	"	"	"	0.294	7.11
"	"	3113	2503	3484	1741	"	"	Coated	"	0.507/	8.9/
										0.512	6.49
"	"	2159	1938	2353	1594	"	"	"	"	0.550/	6.87/
										0.389	4.84
"	"	2055	1880	2238	1290	"	Regular	Bright	"	0.472/	7.71/
										0.723	6.77
"	"	1679	1278	2277	1052	"	"	"	"	0.205/	7.21/
										0.735	10.08
"	"	1694	1540	1958	938	"	"	Coated	1.75	0.517	6.29
"	"	1450	1175	1687	904	"	"	"	"	0.352/	5.97/
										0.417	4.78
Oak	Oak	1212	1115	1315	944	40d	Special	Bright	1.5	0.299	5.94
"	"	1212	1073	1303	966	"	"	"	"	0.255/	4.49/
										0.208	6.59
"	"	1964	1928	2030	1305	"	"	Coated	"	0.584	6.33
"	"	1885	1730	1977	1212	"	"	"	"	0.500	4.05
"	"	1342	1218	1430	834	"	Regular	Bright	"	0.360	6.44
"	"	1155	805	1490	768	"	"	"	"	0.411/	6.01/
										0.514	5.92
"	"	1509	1473	1555	860	"	"	Coated	"	0.466	7.16
"	"	1112	1065	1195	724	"	"	"	"	0.533	5.75

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS*	LOWEST MAX STRENGTH, POUNDS*	HIGHEST MAX STRENGTH, POUNDS*	AVERAGE YIELD STRENGTH, POUNDS*	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENE-TRATION	AVERAGE PD** @ MAX FORCE	AVERAGE HAMMER ACCEL.
Oak	Oak	1503	1113	1543	1123	30d	Special	Bright	1.0	0.296	5.20
"	"	1035	870	1130	732	"	"	"	"	0.144/	5.05/
										0.244	4.77
"	"	1983	1930	2010	1401	"	"	Coated	"	0.509	6.99
"	"	1341	1310	1360	961	"	"	"	"	0.365	4.46
"	"	1376	1268	1553	706	"	Regular	Bright	"	0.517	4.14
"	"	905	838	965	675	"	"	Coated	"	0.281	4.57
"	"	786	393	1205	540	"	"	"	"	0.332/	3.89/
										0.407	4.58
Southern Pine	Oak	1577	1538	1598	1220	50d	Special	Bright	2.0	0.310	7.95
" "	"	1488	1310	1653	1066	"	"	"	"	0.196	7.56
Douglas Fir	Oak	1760	1645	1898	1091	50d	Special	Bright	2.0	0.374	6.78
" "	"	1542	1513	1583	1164	"	"	"	"	0.333	5.31
" "(1)	"	1401	1393	1410	1059	"	"	"	"	0.285/	5.42/
										0.362	7.18
" "(1)	"	1522	1428	1588	1158	"	"	"	"	0.379	7.87
Western Hemlock	Oak	1695	1650	1718	1113	50d	Special	Bright	2.0	0.384	6.65
" "	"	1424	1308	1505	1171	"	"	"	"	0.250	5.08
" "(1)	"	1806	1730	1858	1196	"	"	"	"	0.429	7.12
" "(1)	"	1473	1435	1515	945	"	"	"	"	0.392	5.24
Engelmann Spruce	Oak	1742	1515	1930	1237	50d	Special	Bright	2.0	0.284	7.04
" "	"	1453	1333	1588	1078	"	"	"	"	0.247	5.51
" "(1)	"	1699	1570	1780	1129	"	"	"	"	0.344	6.91
" "(1)	"	1459	1315	1668	1155	"	"	"	"	0.257	5.26

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS*	LOWEST MAX STRENGTH, POUNDS*	HIGHEST MAX STRENGTH, POUNDS*	AVERAGE YIELD STRENGTH, POUNDS*	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENE-TRATION	AVERAGE PD** @ MAX FORCE	AVERAGE HAMMER ACCEL.
Oak	Southern Pine	1574	1460	1663	1277	50d	Special	Bright	2.0	0.249/ 0.171	7.84/ 6.55
"	" "	1304	1235	1363	941	"	"	"	"	0.288	6.82
"	" "	1691	1658	1720	1080	"	"	Coated	"	0.506	6.16
"	" "	1845	1805	1913	1184	"	"	"	"	0.505	5.66
Southern Pine	Southern Pine	1229	1188	1288	751	60d	Regular	Bright	2.5	0.598	4.89
" "	" "	1549	1530	1560	907	"	"	"	"	0.509	6.40
" "	" "	1254	1160	1318	711	"	"	Coated	"	0.558	4.98
" "	" "	1419	1315	1565	931	"	"	"	"	0.544	6.37
Southern Pine	Southern Pine	1567	1515	1630	1227	50d	Special	Bright	2.0	0.214	7.69
" "	" "	1318	1258	1423	1095	"	"	"	"	0.172	----
" "	" "	1364	1360	1368	838	"	"	Coated	"	0.515	4.60
" "	" "	1483	1413	1555	962	"	"	"	"	0.519	4.99
Oak	Douglas Fir	1426	1285	1583	1058	50d	Special	Bright	2.0	0.245	6.05
"	" "	1178	1125	1275	868	"	"	"	"	0.295	5.92
"	" "	1464	1378	1525	1010	"	"	Coated	"	0.249	5.47
"	" "	1677	1653	1693	1108	"	"	"	"	0.690	5.61
Douglas Fir	Douglas Fir	1467	1395	1555	913	60d	Regular	Bright	2.5	0.511	5.84
" "	" "	1484	1460	1510	902	"	"	"	"	0.665	6.11
" "(1)	" "(1)	1315	1238	1405	966	"	"	"	"	0.650	5.12
" "(1)	" "(1)	1380	1288	1490	861	"	"	"	"	0.533	5.69
" "	" "	1556	1525	1588	969	"	"	Coated	"	0.493	6.39
" "	" "	1358	1290	1400	849	"	"	"	"	0.565	5.56
" "(1)	" "(1)	1293	1185	1350	953	"	"	"	"	0.564	5.33
" "(1)	" "(1)	1325	1255	1378	879	"	"	"	"	0.546	5.37

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS*	LOWEST MAX STRENGTH, POUNDS*	HIGHEST MAX STRENGTH, POUNDS*	AVERAGE YIELD STRENGTH, POUNDS*	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENE-TRATION	AVERAGE PD** @ MAX FORCE	AVERAGE HAMMER ACCEL.
Douglas Fir	Douglas Fir	1245	1205	1318	864	50d	Special	Bright	2.0	0.285	4.86
" "	" "	1259	1128	1430	928	"	"	"	"	0.442	5.26
" "(1)	" "(1)	1350	1295	1420	916	"	"	"	"	0.310	7.41
" "(1)	" "(1)	1115	920	1280	717	"	"	"	"	0.590	----
" "	" "	1569	1518	1640	1109	"	"	Coated	"	0.554	5.09
" "	" "	1267	1215	1345	782	"	"	"	"	0.553	4.45
" "(1)	" "(1)	1610	1503	1688	1265	"	"	"	"	0.427	5.62
" "(1)	" "(1)	1578	1460	1715	855	"	"	"	"	0.568	6.09
Oak	Western Hemlock	1435	1388	1503	784	50d	Special	Bright	2.0	0.389	5.31
"	" "	1437	1433	1445	913	"	"	"	"	0.333	5.00
"	" "	1450	1400	1530	1013	"	"	Coated	"	0.227	5.40
"	" "	2027	1950	2155	1311	"	"	"	"	0.557	6.27
Western Hemlock	Western Hemlock	1599	1535	1645	917	60d	Regular	Bright	2.5	0.550	6.28
" "	" "	1414	1290	1503	909	"	"	"	"	0.481	5.87
" "(1)	" "(1)	1643	1600	1695	996	"	"	"	"	0.536	6.41
" "(1)	" "(1)	1474	1438	1515	970	"	"	"	"	0.469	6.27
" "	" "	1444	1320	1583	711	"	"	Coated	"	0.578	6.04
" "	" "	1303	1243	1400	773	"	"	"	"	0.565	5.42
" "(1)	" "(1)	1480	1375	1608	825	"	"	"	"	0.529	6.25
" "(1)	" "(1)	1214	1085	1283	689	"	"	"	"	0.517	5.18
Western Hemlock	Western Hemlock	1284	1263	1313	974	50d	Special	Bright	2.0	0.155	4.94
" "	" "	1316	1278	1390	711	"	"	"	"	0.463	7.56
" "(1)	" "(1)	1141	1075	1218	823	"	"	"	"	0.357	4.45
" "(1)	" "(1)	1286	1228	1350	931	"	"	"	"	0.424	5.53
" "	" "	1767	1643	1940	1139	"	"	Coated	"	0.610	6.76
" "	" "	1489	1445	1575	861	"	"	"	"	0.437	5.78
" "(1)	" "(1)	1825	1463	2103	1121	"	"	"	"	0.630	6.01
" "(1)	" "(1)	1805	1795	1815	1191	"	"	"	"	0.482	6.72

BLOCKING MATERIAL	FLOOR MATERIAL	AVERAGE MAX STRENGTH, POUNDS*	LOWEST MAX STRENGTH, POUNDS*	HIGHEST MAX STRENGTH, POUNDS*	AVERAGE YIELD STRENGTH, POUNDS*	NAIL SIZE	NAIL MATERIAL	NAIL FINISH	CALCULATED FLOOR PENETRATION	AVERAGE PD** @ MAX FORCE	AVERAGE HAMMER ACCEL.
Oak	Engelmann Spruce	1119	1030	1188	687	50d	Special	Bright	2.0	0.388	4.31
"	"	1289	1230	1355	774	"	"	"	"	0.308	4.55
"	"	1414	1338	1480	800	"	"	Coated	"	0.543	5.25
"	"	1482	1405	1575	772	"	"	"	"	0.528	4.76
Engelmann Spruce	Engelmann Spruce	1014	950	1055	608	50d	Special	Bright	2.0	0.387	4.05
" "	"	975	935	1025	---	"	"	"	"	0.614	5.74
" "(1)	" (1)	1080	1038	1153	471	"	"	"	"	0.490	4.41
" "(1)	" (1)	1163	1040	1280	801	"	"	"	"	0.349	4.82
" "	"	1081	----	----	696	"	"	Coated	"	0.570	4.14
" "	"	1280	----	----	600	"	"	"	"	0.635	5.61
" "	"	1344	----	----	566	"	"	"	"	0.539	6.44
" "	"	1286	----	----	622	"	"	"	"	0.542	6.75
" "	"	1313	----	----	598	"	"	"	"	0.518	7.58
" "	"	1015	905	1393	588	"	"	"	"	0.474	6.73
" "	"	920	790	1105	509	"	"	"	"	0.593	4.03
" "(1)	" (1)	1130	1090	1150	645	"	"	"	"	0.511	5.94
" "(1)	" (1)	850	805	928	478	"	"	"	"	0.647	5.12

* - Force per Nail
**PD - Permanent Displacement

APPENDIX B

PROBLEM: Calculate the number of nails required to restrain a 4,800 lb howitzer so that the restraint system will meet AAR requirements.

Given: Weight of Howitzer = 4,800 lbs

Dynamic loading = Approximately 8 G's

Floor material = Assume Douglas Fir

Blocking material = Douglas Fir

Nail size = 50d through two layers of 2" X 8" boards

SOLUTION: Using Figure 9 the force that a 50d nail can withstand in a 4" X 6" softwood is 970 lbs. Therefore for a dynamic load of 8 G's the number of nails required is:

$$\frac{4800 \times 8}{970} = 39.59 \text{ or } 40 \text{ nails}$$

Since the actual thickness of a 4" X 6" board is 1/2 inch thicker than two 2" X 8" boards, the number of nails as calculated above has an increased safety factor because of the increased depth of penetration the nails have through two 2" X 8" boards.

Using Table 1, the number of nails required is 9 x 4.8 = 43 nails. The three additional nails are due to the values in the table being rounded off to the next highest whole number.

If the lumber is unused and in sound condition, the designer can use the data in Appendix A-3 to reduce the number of nails. The appendix shows that a joint fabricated from 50d nails and Douglas Fir cleats and floor has an average maximum strength of 1,242 lbs. The value that should be used in the restraint system depends upon the degree of risk the designer is willing to apply to the system. For somewhat better than a 50/50 chance of success, the 1,242 lb strength could be used. The 1/2 inch deeper depth of penetration obtained by using two 2" X 8" boards instead of one 4" X 6" timber will provide additional strength. The number of nails required to restrain the Howitzer would be $4800 \times 8 \div 1{,}242 = 31$ nails. This is a reduction of 9 nails.

APPENDIX C

GLOSSARY

AVERAGE MAXIMUM STRENGTH. An arithmetic average of the maximum forces each wood-nail assembly withstood when subjected to dynamic forces under laboratory conditions. The average is based on a small sample size, usually three, for each configuration.

BLOCKING AND BRACING SYSTEM. A group of materials, such as wood and nails, that are arranged to restrain an item. The material arrangement depends upon the magnitude, direction, and type of forces to which the item will be subjected.

CLEAT. The piece of lumber of a wood-nail assembly that is normally used to restrain a cargo by transferring its force to the floor component of that assembly. A cleat is also referred to as a floorline blocking.

CONBUR TYPE INCLINED RAMP. Laboratory equipment used to simulate railroad car impacts. The equipment consists primarily of two inclined rails onto which a two axle dolly can travel and impact into a rigid barrier. The speed of the dolly prior to impact and the time and duration of the shock are controllable.

DEPTH OF PENETRATION. The distance the nail travels into the floor member of the wood-nail assembly. Calculated penetration is the length of the nail minus the thickness of the cleat.

FAILED WOOD-NAIL ASSEMBLY. An assembly that cannot resist a force greater than the largest force it has already withstood.

FLOOR. The wood-nail assembly component that provides support for the cleat and holds the nail point.

HEADER. An assembly that distributes forces to several pieces of blocking.

HIGH CARBON NAILS. Nails that are manufactured from AISI 1040 steel and have a Rockwell hardness of at least C-42. These nails are custom manufactured.

HIGHEST MAXIMUM STRENGTH. For a specific configuration in the laboratory tests, the largest of the individual maximum forces that were recorded for each sample or schedule.

LOW CARBON NAILS. Nails manufactured from AISI 1020 steel. These nails are commonly used.

LOWEST MAXIMUM STRENGTH. For a specific configuration in the laboratory tests, the smallest of the individual maximum forces that were recorded for each sample or schedule.

MOISTURE CONTENT. The amount of water contained in the wood, usually expressed as a percentage of the weight of the ovendry wood.

NAILABLE STEEL FLOORING. Steel flooring manufactured with special seams that extend across the width of a railroad car. The seams are constructed so that they receive the nails which deform within the seam during the nail driving process.

RESTRAINT SYSTEM. Materials installed in or on a transport medium to secure cargo.

RESTRAINING DEVICE. A component of a restraint system.

SCHEDULE. Specific configurations within the test specimen.

SPECIFIC GRAVITY. The ratio of the weight of a body to the weight of an equal volume of water at 4^{o}C or other specified temperature.

SPECIMEN. A family of related wood-nail assembly configurations wich have identical cleat and flooring size,and orientation of the cleat with respect to the flooring and to the applied force. Wood and nail types are varied within the specimen.

WITHDRAWAL RESISTANCE. The resistance of a nail to direct withdrawal from a piece of wood.

WOOD-NAIL ASSEMBLIES. An assembly fabricated by driving nails through one or more pieces of lumber (cleat) into another piece of lumber (floor). A wood-nail assembly is also referred to as a wood-nail joint.

YIELD POINT. The force above which failure of a wood-nail joint will ultimately occur and below which failure of the joint will not occur. Unlike the yield point for metals, the yield point for wood-nail joints were determined by the rate of change in the permanent displacement per potential energy input to the cleat. Note: This definition for yield point of wood-nail joints was established for this project.

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