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PERFORMANCE COMPARISON OF SLENDER AND STANDARD SPIRALLY GROOVED PALLET NAILS

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PERFORMANCE COMPARISON OF SLENDER AND STANDARD SPIRALLY GROOVED PALLET NAILS

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Abstract

The performance of 0.110- by 2-1/4-inch hardened spirally grooved nails was compared with that of 0.120- by 2-1/2-inch standard pallet nails in wood pallets. A total of 120 simulated pallet corners, consisting of two short deck boards nailed to a stringer member, were evaluated both dynamically and statically. Variables included two species--oak and Douglas-fir--and three moisture contents at time of fabrication--12 and 22 percent and green (over 30 percent). Ten full-scale (40 by 48 inches) oak pallets were drop tested on their corners, and variables included two moisture contents at time of fabrication--green (over 30 percent) and 22 percent--and two styles of pallets--reversible (12 deck boards) and nonreversible (9 deck boards). The hardened pallet nails, which are slightly thinner and shorter than standard spirally grooved pallet nails, exhibited improved performance, especially in the dynamic tests of lateral resistance. Results with both tests of the simulated pallet corners and the full-scale pallets confirmed the superiority of the new slender nails.

Introduction

Pallet fabricators had been experiencing difficulties in driving standard "stiff stock" nails into dense woods that are relatively dry (less than about 22 percent moisture content). Nails with diameters of 0.120 inch split the ends of 1-inch-thick deck boards, and the ordinary pallet nails (stiff stock) bent objectionably

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

when driven in dry hardwoods. Manufacturers of nails then recommended a slightly thinner (0.110-inch diameter) and slightly shorter (2-1/4 inches) hardened nail for these conditions. They claimed that the new nail would minimize splitting and bending.

The slender hardened nail does not conform to the National Wooden Pallet Manufacturers Association's pallet specifications. Therefore, some exploratory tests were conducted to compare the performance in lateral resistance of the 0.110- by 2-1/4-inch hardened nail to the 0.120- by 2-1/2-inch "standard" pallet nail. Loading was produced dynamically. This evaluation was made at the U.S. Forest Products Laboratory, but was limited as follows: The specimens were made of oak; the moisture content at the time the specimens were fabricated was relatively low for hardwood pallet lumber, either 12 or 22 percent; and the testing was done immediately after the nails were driven. The results showed that the slender hardened nails performed better than the thicker nails within these limitations.

Before changing requirements in the nail specifications to permit the new nail, it was decided to investigate its effectiveness fully--by including variables of species and moisture content and incorporating some conditioning between the time of fabrication and the time of test. It was thought that a conditioning with respect to moisture content would more closely simulate conditions of average pallet usage.

A comparison of dynamic to static testing was included in this evaluation. Therefore, two sets of simulated pallet corners were prepared, one of which was tested in compression at relatively slow speeds, while the other was tested dynamically at fast speeds.

The design of the simulated pallet corners and the type of test used in these studies was chosen to simulate dynamic forces imposed on nails in normal pallet usage. Such correlation between the simulated pallet corner test results and full-scale pallet test results had not been demonstrated. Therefore, a few drop tests of pallets were made to determine if the results would substantiate those obtained on the simulated pallet corners. The test selected for the pallets was the free-fall-on-corner test described in document 171E that has been proposed by Technical Committee 51 of the International Organization for Standardization.

Preparation of Specimens

Types of Nails Used

The two types of spirally grooved nails used in making the specimens were 0.110- by 2-1/4-inch hardened and 0.120- by 2-1/2-inch stiff stock nails. The shanks of the slender hardened nails were threaded with four flutes at a pitch angle of about 61° to the nail axis. The shanks of the standard stiff stock nails were threaded with five flutes at a pitch angle of about 69° to the nail axis. Although the outside, or crest, diameter of each nail was 0.137 inch, the slender nail had a root diameter of 0.091 and the standard nail of 0.111 inch.

Simulated Pallet Corners

The simulated pallet corners for both the static and dynamic tests of lateral resistance of pallet nails were fabricated as shown in figure 1. They consisted of two 1- by 6-inch deck boards nailed to the two edges of a 2- by 4-inch stringer. The nails driven into the opposite edges of the stringers were staggered so that there was no danger of the points meeting in the center of the 2 by 4. Corners were rounded to minimize compression of the wood at the bearing points and to insure that the deflections measured during and after the loading accurately represented the give or rack in the joint.

Oak and Douglas-fir were used for the pallet corners. These were fabricated at three moisture contents--12 and 22 percent and green (over about 30 percent). For each combination of variables there were five replicates. This made a total of 120 specimens that were tested.

Full-Scale Pallets

Six full-scale reversible pallets were fabricated from "green" oak lumber, as shown in figure 2. There were three stringers and six deck boards both top and bottom. Four nonreversible pallets were fabricated from oak lumber at 22 percent moisture content, as shown in figure 3. They had three stringers with six deck boards on top and only three on the bottom.

The stringers were 1-5/8 by 3-5/8 by 40 inches long and the deck boards were 3/4 by 5-1/2 by 48 inches long. The nails were spaced and staggered in the same pattern as that used for the simulated pallet corners.

Conditioning

All test specimens were subjected to a period of conditioning to simulate the changes in moisture content of the wood that occur during use in pallets. Both the simulated pallet corners and the full-scale pallets that had been fabricated at 22 percent moisture content and green were placed in an 80° F. and 30 percent relative humidity room until the wood was dried down to about 7 percent moisture content. The specimens that had been fabricated at 12 percent moisture were conditioned first in an 80° F. and 90 percent relative humidity room until an equilibrium moisture content of about 20 percent was reached. Then they were transferred to an atmosphere of 80° F. and 30 percent relative humidity, where they also were dried down to 7 percent moisture content before testing.

Test Procedures

Dynamic Tests for Lateral Resistance of Pallet Nails

A Hatt-Turner impact machine was used to test the simulated pallet corners for lateral resistance of the nails. A 45-pound hammer falling between two vertical guides was dropped upon the specimens so that the lower flat surface of the hammer impacted the corner of the specimen, as shown in figure 4. The hammer was dropped first from a height of 1 inch, next 2 inches, and so on until complete failure occurred. A stylus attached to the hammer moved against paper mounted on a revolving drum to record the deflection or racking for each blow. Figure 5 is a sample record taken on the drum. These instantaneous deflections were plotted against their corresponding heights of drop as shown in the sample in figure 6.

Static Test for Lateral Resistance of Pallet Nails

The simulated pallet corner specimens were placed in a universal testing machine as shown in figure 7, and a load was applied to the top corner at a rate of 0.3 inch per minute. The rollers under the specimen were for the purpose of minimizing friction on the machine bed as the specimen racked and spread at the bottom. An automatic recording of the load-deflection curve was produced by the machine. A typical example of such a curve is shown in figure 8.

Drop Test of Full-Scale Pallets

The procedure for testing the full-scale pallet specimens was the one proposed by Technical Committee 51 of the International Organization for Standardization. It consisted of dropping the pallet on one corner from a height of 40 inches (fig. 9). Six such drops are required, and after each drop the change in length of the diagonals was measured. Measurements were made of both diagonals of both faces of the pallets, and the four values were averaged to represent the distortion. The surface upon which the drops were made was 1-1/2-inch-thick machined steel plate embedded in the floor and backed up by a large block of concrete.

Results of Tests

The results of the dynamic tests of the simulated pallet corners are presented in tables 1, 2, and 3. The maximum heights of drop at which failure occurred are shown in table 1, the heights of drop at which 1/2-inch deflection occurred are shown in table 2 and were taken off the curves; an example of which is shown in figure 6. The stiffness moduli are shown in table 3. The modulus of stiffness is the slope of the dashed line in figure 6, which was determined arbitrarily as follows: The coordinates of the 1- and 2-inch drops were averaged, the coordinates of the 3- and 4-inch drops were averaged, and the dashed line was drawn through the two averages (the squares in figure 6). The slope of this line was chosen as the stiffness modulus. The values for the two types of nails are presented opposite each other so they can be compared.

The results of the static tests of the simulated pallet corners are presented in tables 4, 5, and 6. The maximum loads are in table 4, the loads to cause 1/2-inch deflection are in table 5 and were taken off the curves, an example of which is shown in figure 8, and the stiffness moduli are shown in table 6. Stiffness modulus is the slope of the dashed line in figure 8. It was typical of each load-deflection curve that they started with a little curve, which is concave upward, then a straight line portion followed by a concave-downward curve. It was not difficult to draw the average straight line portion of the curve.

A comparison of the overall performance of the two nail types is presented in table 7. A ratio of slender to standard nail is presented for each test, both dynamically and statically determined.

The drop test results of the full-scale pallets are presented in the graphs of figures 10 and 11. The average distortion after six drops from 40 inches was: 2.06 inches for the reversible 12-board pallets assembled with the slender nails; 2.87 inches with standard nails; 1.62 inches for the nonreversible 9-board pallets assembled with slender nails; 2.17 inches with the standard nails. The curves in figures 10 and 11 were drawn through the points to represent the performance of each type of nail.

Discussion of Results

In tables 1 to 6 it is possible to compare the performance of slender hardened nails to the standard pallet nails by observing the average properties for each variable of species and moisture content. There are 36 such comparisons possible, and only five of them fail to demonstrate better performance for the slender nail. The significance of each one of these comparisons, however, is very questionable because of the small number of samples (five of each) and the large variability within each group. In order to effect a more meaningful comparison, table 7 was prepared. It contains in the first six lines, 36 ratios representing the relative performance of the slender nail to the standard nail. The seventh line contains ratios that represent the larger populations. It shows values for each property and includes all variables of species and moisture content. Thirty values were averaged for each nail to obtain each rating on the bottom line. These ratios, without exception, indicate superiority of the new nail.

To determine if each of the six ratios is significantly different from unity, an analysis of variance was made. The results showed that:

(1) The 1.03 ratio representing the heights of drop at which failure occurred is not significant.

(2) The 1.11 ratio representing the heights of drop at which a 1/2-inch deflection occurred is significant at the 1 percent level.

(3) The 1.09 ratio representing the dynamic stiffness moduli is significant at the 5 percent level.

(4) The 1.07 ratio representing the maximum loads to failure is significant at the 5 percent level.

(5) The 1.12 ratio representing the loads to cause 1/2-inch deflection is significant at the 1 percent level.

(6) The 1.11 ratio representing the static stiffness moduli is not significant.

It has not been determined which of the six evaluated properties best simulates the performance of nails in pallet usage. However, since pallets are rough handled and subjected to impacts and because pallet failures are more often caused by dynamic rather than static loading, it is reasoned that dynamic properties are more meaningful than static. Also, because pallets fail at much smaller distortions than those that occur at maximum heights of drop, it is reasoned that the height of drop to cause 1/2-inch deflection and the dynamic stiffness modulus are better properties to represent pallet performance than the maximum height of drop.

The results of the drop tests of full-scale pallets (figs. 10 and 11) show that those with the slender hardened nails distorted considerably less than those with standard pallet nails. This indicates better performance for the new nail. In all of the 10 tests, the changes in diagonal dimensions after six drops varied from 1.49 to 2.94 inches. When expressed as a percentage change, this range is from 2.5 to 4.9.

According to previous theory, the longer and thicker nails (standard) should have had more lateral resistance than the new slender and shorter nails. There are, however, several apparent reasons for the opposite results. They are: (1) The smaller nails were hardened and, therefore, stiffer. They deflected less under impact loads because of this. (2) The smaller nails had four flutes while the standard nails had five. The depth of thread of a 4-fluted nail is normally greater than a 5-fluted nail. Therefore, the withdrawal resistance was greater and was reflected in the lateral-resistance tests. (3) It was observed that the slender nails caused fewer hairline splits during driving than the standard ones. For this reason, it is believed that the joints made with standard nails were weaker.

No attempt should be made to use the data in this evaluation to compare the performance of oak and Douglas-fir or to compare the effects of moisture content. The reasons for this are that the supplies of lumber did not represent the two species with respect to density, quality, or texture. Also, the lots of lumber were not matched between the simulated pallet corners and the full-scale pallets fabricated at the three different moisture conditions.

Conclusions and Recommendations

The hardened pallet nails, which are spirally grooved and slightly thinner and shorter than standard spirally grooved pallet nails, exhibited improved performance, especially in the dynamic tests of lateral resistance.

The spirally grooved nail requirements in the National Wooden Pallet Manufacturers Association's pallet specifications as well as those in several government and military pallet specifications should be changed to permit the 0.110- by 2-1/4-inch hardened pallet nail. This can be done by specifying as follows: Length, 2-1/4 inches $\pm$1/16 inch; wire diameter, 0.110 inch $\pm$0.002 inch; and thread, four flutes (instead of minimum four flutes). A bend test should be developed and included to insure minimum strength and ductility. A bending strength requirement will reject unhardened nails, and a ductility test will reject nails that are too brittle or insufficiently tempered.

Appendix

An exploratory series of tests was conducted in an attempt to correlate a bending test with the performance of pallet nails in the dynamic lateral-resistance tests. Six types of spirally grooved pallet nails (fig. 12), all about the same size, were included in this study. Two of the types (A and F) were the two nails evaluated in the body of this report. Nail A was the standard and F the slender hardened nail. Nail B was the same as A, but it was produced by another manufacturer. C was a hardened nail, similar to F, but its diameter was larger--0.120 inch. Two twisted square stock nails were included: D had a minimum pitch angle, about 16° to the axis, and E was hardened and had a blunt chisel point.

Five simulated pallet corners were constructed and tested dynamically in the Hatt-Turner impact machine. The specimens were oak, fabricated green (over 30 percent) and dried down to 7 percent moisture content at the time of test. The heights of drop to cause 1/2-inch deflection are presented in table 8.

Identical samples of the nails that were used in the pallet corners were sent to the Joliet Works of the American Steel and Wire Division of the U. S. Steel Corp. for analysis. Their laboratory determined carbon content and hardness values, which are also presented in table 8.

Three each of the six nail types were tested in bending, center loaded on a 2-inch span. The machine was a universal hydraulic type operating at a speed of 0.07 inch per minute. The load-deflection characteristics of each nail are presented in figure 13 and the maximum loads to failure in table 8.

Several conclusions can be drawn from the data in table 8, and they may be significant to future research on pallet nails.

1. Although nail C was the best nail in the dynamic test and had the highest carbon content, any such correlation is poor for the rest of the nails. The one with the lowest carbon content is the second best in the dynamic test. It appears that carbon content is not a good indicator of performance.

2. The two best nails in the dynamic test, C and E, are hardened. Nail F is also hardened but of a smaller diameter. There is a good correlation between hardness and performance in dynamic lateral resistance.

3. The results of the bend test, as expressed by maximum loads, indicate good correlation to the performance of the simulated pallet corners. This means that since hardness tests are difficult to perform on pallet nails, perhaps the bend test is a logical test for inclusion in a performance specification to insure satisfactory pallet performance.

Table 1.--Height of drop at which simulated pallet corners tested dynamically failed in lateral resistance: The nails used were 0.110- by 2-1/4-inch hardened and 0.120- by 2-1/2-inch standard spirally grooved pallet nails

Species	Moisture content at time of fabrication[1]	Maximum height of drop		Species	Moisture content at time of fabrication[1]	Maximum height of drop	
		Hardened nail	Standard nail			Hardened nail	Standard nail
	Percent	Inches	Inches		Percent	Inches	Inches
Oak	12	23	19	Douglas-fir	12	13	17
		24	23			15	16
		23	20			17	16
		21	24			-	19
		22	22			-	15
	Average	22.6	21.6		Average	15.0	16.6
	22	24	20		22	18	16
		20	22			15	15
		21	21			14	15
		22	20			18	16
		22	21			15	15
	Average	21.8	20.8		Average	16.0	15.4
	Green	25	19		Green	12	16
		21	22			14	17
		21	19			17	14
		24	23			17	15
		18	18			16	11
	Average	21.8	20.2		Average	15.2	14.6

[1]Specimens fabricated green and at 22 percent moisture content were conditioned at 80° F. and 30 percent relative humidity to about 7 percent moisture content for testing. Those fabricated at 12 percent moisture content were conditioned first at 80° F. and 90 percent relative humidity to about 20 percent moisture content and then to 7 percent moisture content for testing.

Table 2.--Height of drop at which 1/2-inch deflection occurred in lateral-resistance tests on simulated pallet corners tested dynamically. The nails used were 0.110- by 2-1/4-inch hardened and 0.120- by 2-1/2-inch standard spirally grooved pallet nails

Species	Moisture content at time of fabrication[1]	Height of drop: Hardened nail	Height of drop: Standard nail	Species	Moisture content at time of fabrication[1]	Height of drop: Hardened nail	Height of drop: Standard nail
	Percent	Inches	Inches		Percent	Inches	Inches
Oak	12	11.5	10.2	Douglas-fir	12	8.1	7.9
		12.0	10.3			9.0	7.6
		11.8	10.3			8.9	8.0
		12.1	10.0			-	7.9
		12.0	10.8			9.8	8.0
	Average	11.8	10.4		Average	9.0	7.8
	22	11.0	10.1		22	7.5	5.6
		10.3	10.3			6.4	6.9
		10.4	9.3			6.9	6.9
		11.8	9.4			6.9	7.2
		9.0	10.0			7.2	6.2
	Average	10.6	9.8		Average	7.0	6.6
	Green	11.8	7.9		Green	6.2	5.7
		9.4	9.3			7.2	6.2
		10.3	9.0			6.5	5.9
		9.6	9.3			6.3	4.8
		8.7	8.5			7.0	6.3
	Average	10.0	8.8		Average	6.6	5.8

[1] Specimens fabricated green and at 22 percent moisture content were conditioned at 80° F. and 30 percent relative humidity to about 7 percent moisture content for testing. Those fabricated at 12 percent moisture content were conditioned first at 80° F. and 90 percent relative humidity to about 20 percent moisture content and then to 7 percent moisture content for testing.

Table 3.--Stiffness modulus for simulated pallet corners tested dynamically to evaluate the lateral resistance of the nails. The nails were 0.110- by 2-1/4-inch hardened and 0.120- by 2-1/2-inch standard spirally grooved pallet nails

Species	Moisture content at time of fabrication[1]	Stiffness modulus: Hardened nail	Stiffness modulus: Standard nail	Species	Moisture content at time of fabrication[1]	Stiffness modulus: Hardened nail	Stiffness modulus: Standard nail
	Percent	Inches per inch	Inches per inch		Percent	Inches per inch	Inches per inch
Oak	12	36.4	30.8	Douglas-fir	12	18.2	23.5
		28.6	28.6			22.2	20.0
		26.77	23.5			28.6	20.0
		30.8	26.7			-	17.4
		36.4	28.6			25.0	26.7
	Average	31.8	27.6		Average	23.6	21.6
	22	28.6	26.7		22	16.7	12.9
		26.7	28.6			14.7	14.3
		26.7	26.7			15.4	15.7
		30.8	28.6			17.4	18.2
		36.4	26.7			15.4	13.8
	Average	29.8	27.4		Average	16.0	15.0
	Green	28.6	21.0		Green	14.3	12.0
		19.1	28.6			16.7	13.3
		28.6	22.2			15.4	12.9
		21.0	25.0			14.3	12.5
		25.0	21.0			16.0	16.0
	Average	24.4	23.6		Average	15.4	13.6

[1]Specimens fabricated green and at 22 percent moisture content were conditioned at 80° F. and 30 percent relative humidity to about 7 percent moisture content for testing. Those fabricated at 12 percent moisture content were conditioned first at 80° F. and 90 percent relative humidity to about 20 percent moisture content and then to 7 percent moisture content for testing.

Table 4.--Static loads at which simulated pallet corners failed in lateral resistance: The nails were 0.110- by 2-1/4-inch hardened and 0.120- by 2-1/2-inch standard spirally grooved pallet nails

Species	Moisture content at time of fabrication[1]	Maximum load: Hardened nail	Maximum load: Standard nail	Species	Moisture content at time of fabrication[1]	Maximum load: Hardened nail	Maximum load: Standard nail
	Percent	Pounds	Pounds		Percent	Pounds	Pounds
Oak	12	2,320	2,310	Douglas-fir	12	1,200	1,290
		2,220	1,980			1,080	1,070
		2,150	1,700			1,320	1,160
		2,190	1,430			1,100	1,190
		2,240	1,640			1,470	1,030
	Average	2,220	1,810		Average	1,230	1,150
	22	2,020	2,180		22	1,250	1,010
		1,820	1,720			950	1,110
		2,210	2,220			1,000	1,100
		2,200	1,780			1,230	1,000
		2,300	2,060			1,330	950
	Average	2,110	1,990		Average	1,150	1,030
	Green	2,360	2,120		Green	950	1,100
		1,630	1,960			1,130	1,080
		1,960	1,840			890	1,130
		1,940	2,010			1,290	1,060
		1,910	2,200			1,160	1,140
	Average	1,960	2,030		Average	1,080	1,100

[1] Specimens fabricated green and at 22 percent moisture content were conditioned at 80° F. and 30 percent relative humidity to about 7 percent moisture content for testing. Those fabricated at 12 percent moisture content were conditioned first at 80° F. and 90 percent relative humidity to about 20 percent moisture content and then to 7 percent moisture content for testing.

Table 5.--Static load at which 1/2-inch deflection occurred in lateral resistance tests on simulated pallet corners. The nails were 0.110- by 2-1/4-inch hardened and 0.120- by 2-1/2-inch standard spirally grooved pallet nails

Species	Moisture content at time of fabrication[1]	Load: Hardened nail	Load: Standard nail	Species	Moisture content at time of fabrication[1]	Load: Hardened nail	Load: Standard nail
	Percent	Pounds	Pounds		Percent	Pounds	Pounds
Oak	12	1,850	1,580	Douglas-fir	12	1,200	1,240
		1,880	1,630			1,060	1,020
		1,740	1,560			1,240	1,080
		1,880	1,220			1,010	1,010
		1,870	1,390			1,200	940
	Average	1,830	1,480		Average	1,140	1,060
	22	1,600	1,530		22	1,200	900
		1,820	1,400			960	-
		1,640	1,320			1,010	1,090
		1,810	1,400			980	890
		1,670	1,530			1,190	920
	Average	1,710	1,440		Average	1,070	950
	Green	1,810	1,680		Green	930	950
		1,380	1,530			1,030	930
		1,500	1,450			860	850
		1,570	1,540			1,060	970
		1,620	1,580			950	900
	Average	1,580	1,560		Average	970	920

[1]Specimens fabricated green and at 22 percent moisture content were conditioned at 80° F. and 30 percent relative humidity to about 7 percent moisture content for testing. Those fabricated at 12 percent moisture content were conditioned first at 80° F. and 90 percent relative humidity to about 20 percent moisture content and then to 7 percent moisture content for testing.

Table 6.--Stiffness modulus for simulated pallet corners tested statically to evaluate the lateral resistance of the nails. The nails were 0.110- by 2-1/4-inch hardened and 0.120- by 2-1/2-inch standard spirally grooved pallet nails

Species	Moisture content at time of fabrication[1]	Stiffness modulus		Species	Moisture content at time of fabrication[1]	Stiffness modulus	
		Hardened nail	Standard nail			Hardened nail	Standard nail
	Percent	Pounds per inch	Pounds per inch		Percent	Pounds per inch	Pounds per inch
Oak	12	8,500	6,700	Douglas-fir	12	6,700	5,900
		10,900	6,500			5,750	6,500
		12,300	9,800			5,500	4,400
		9,450	6,450			4,000	3,800
		7,100	8,600			5,150	7,200
	Average	9,650	7,610		Average	5,420	5,560
	22	9,800	9,900		22	10,200	6,600
		9,300	10,000			6,200	-
		6,900	5,900			5,400	6,300
		9,700	5,250			4,800	4,800
		9,200	4,200			9,700	6,100
	Average	8,980	7,050		Average	7,300	6,000
	Green	11,600	11,600		Green	8,600	15,000
		9,600	8,900			6,100	8,700
		11,000	13,200			6,900	5,700
		10,100	8,900			11,100	6,400
		12,100	10,100			6,300	5,700
	Average	10,900	10,500		Average	7,800	8,300

[1]Specimens fabricated green and at 22 percent moisture content were conditioned at 80° F. and 30 percent relative humidity to about 7 percent moisture content for testing. Those fabricated at 12 percent moisture content were conditioned first at 80° F. and 90 percent relative humidity to about 20 percent moisture content and then to 7 percent moisture content for testing.

Table 7.--Summary of results (tables 1 to 6) for simulated pallet corners evaluated in lateral resistance, expressed as ratios of properties for 0.110- by 2-1/4-inch hardened nails as compared to 0.120- by 2-1/2-inch standard spirally grooved pallet nails

Species	Moisture content at time of fabrication[1]	Dynamic testing			Static testing		
		Maximum height of drop	Height of drop at a 1/2-inch deflection	Stiffness modulus	Maximum load	Load at a 1/2-inch deflection	Stiffness modulus
	Percent						
Douglas-fir	12	1.05	1.13	1.15	1.23	1.24	1.27
	22	1.05	1.08	1.09	1.06	1.19	1.27
	Green	1.08	1.14	1.03	.97	1.01	1.04
Oak	12	.90	1.15	1.09	1.07	1.12	.98
	22	1.04	1.06	1.07	1.08	1.13	1.05
	Green	1.04	1.14	1.13	.97	1.24	.94
Average		1.03	1.11	1.09	1.07	1.12	1.11

[1] Specimens fabricated green and at 22 percent moisture content were conditioned at 80° F. and 30 percent relative humidity to about 7 percent moisture content for testing. Those fabricated at 12 percent moisture content were conditioned first at 80° F. and 90 percent relative humidity to about 20 percent moisture content and then to 7 percent moisture content for testing.

Table 8.--Properties of six types of pallet nails

Nail description: Size	Nail description: Form	Dynamic lateral resistance test (height of drop to 1/2-inch deflection)	Carbon content	Hardness "R_c"[1]	Bend test (maximum load)
Inches		Inches	Percent		Pounds
A. 0.120 by 2-1/2	5 flute, stiff stock	8.5	0.46	16	75
B. 0.130 by 2-1/2	5 flute, stiff stock	9.1	.46	25	101
C. 0.120 by 2-1/2	4 flute, hardened	11.3	.56	48	154
D. [2]0.103 by 2-1/2	4 flute, minimum pitch	9.3	.33	28	87
E. [2]0.106 by 2-1/2	Twisted, square stock, hardened	10.7	.20	45	138
F. 0.110 by 2-1/4	4 flute, hardened	10.0	.39	45	101

[1]R_c = Rockwell Hardness (ASTM Designation: E18-59T). A number derived from the net increase in depth of impression as the load on a penetrator is increased from a fixed minimum load to a higher load and then returned to the minimum load. The subscript C is the Scale Symbol. The penetrator was a diamond cone, and the major load was 100 kilograms.

[2]Square stock nails. Dimension is of side of square cross section.

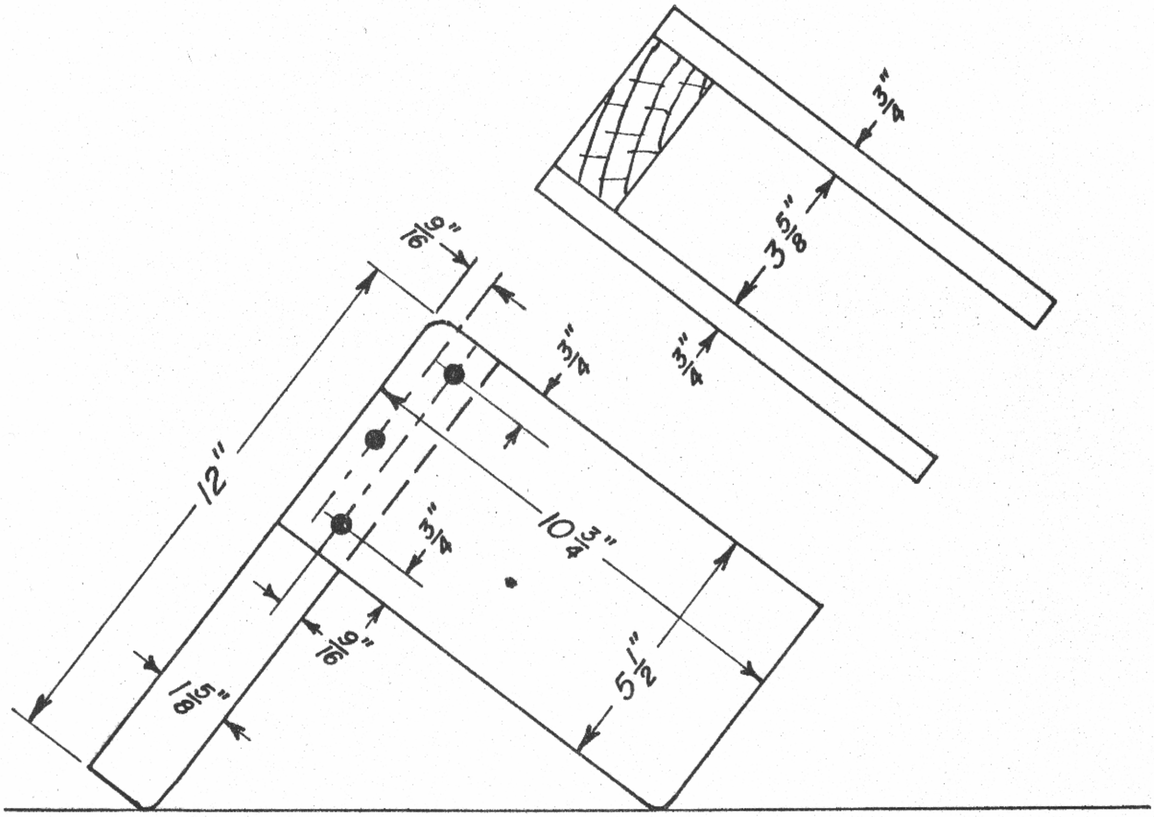

Figure 1.--Simulated pallet corner tested in lateral resistance of pallet nails.

Report No. 2238

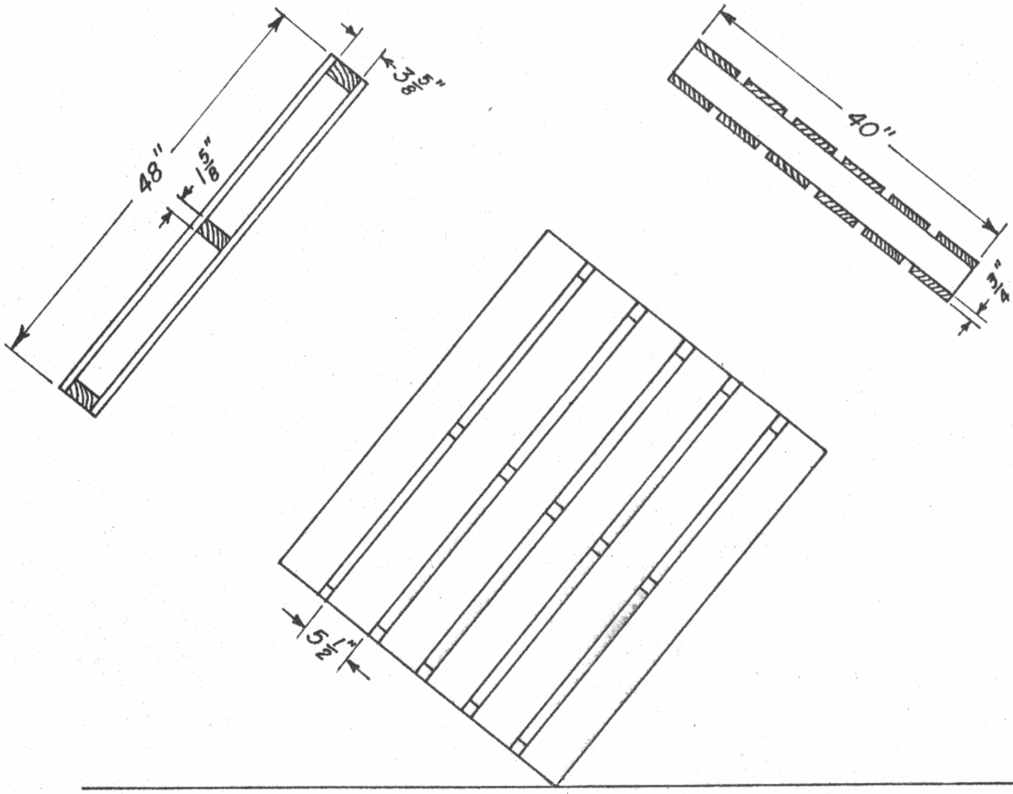

Figure 2. --Full-scale reversible pallet used in corner drop test. (12 deckboards)

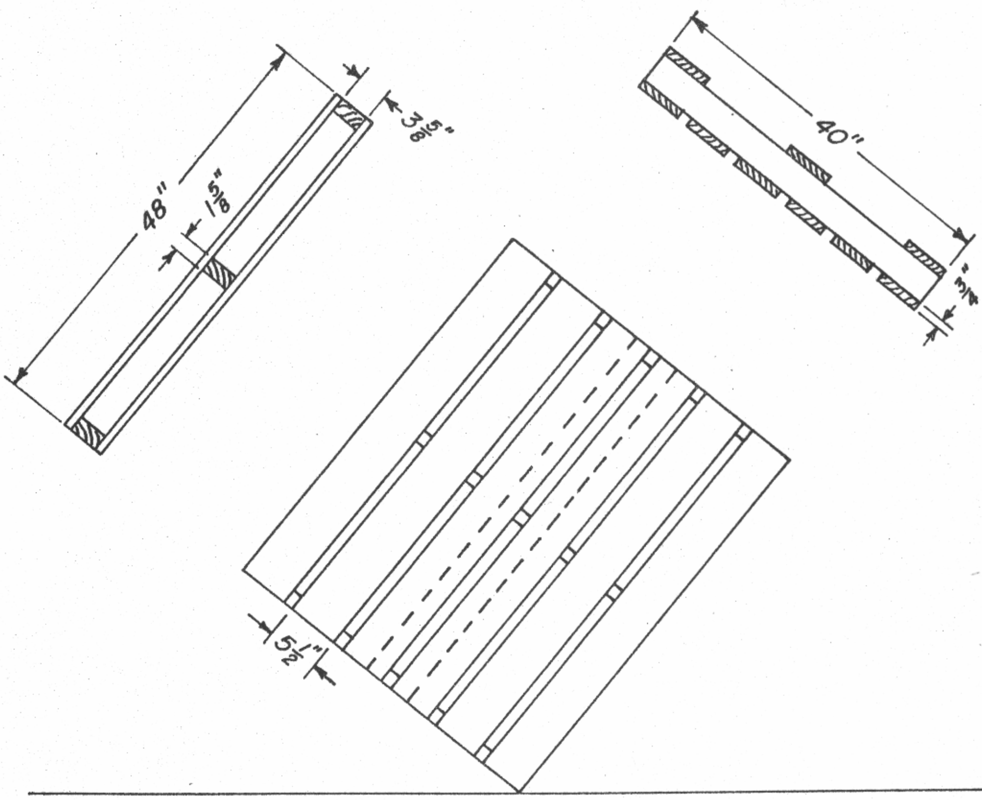

Figure 3. --Full-scale nonreversible pallet used in corner drop test. (9 deckboards)

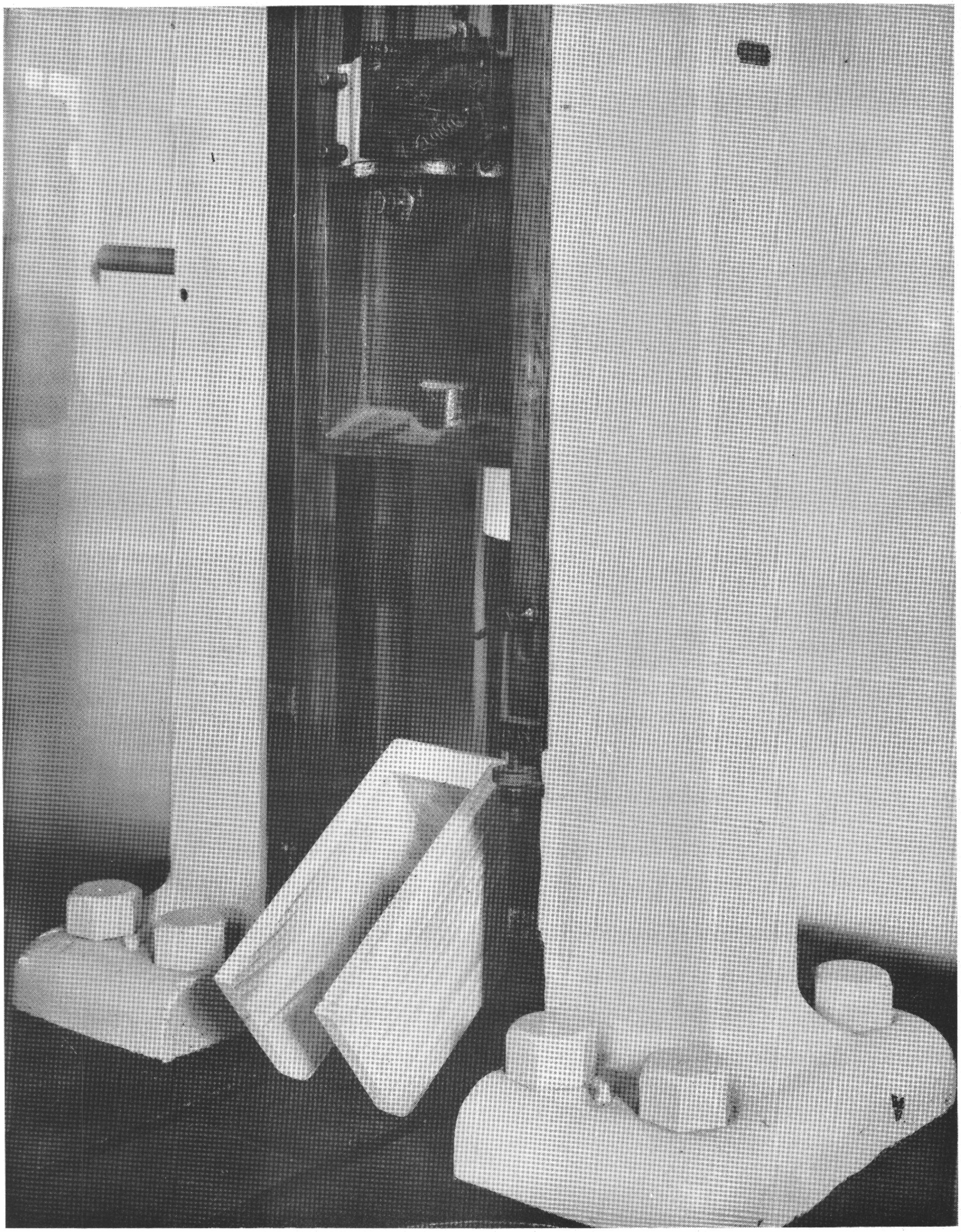

Figure 4.--A simulated pallet corner in the Hatt-Turner impact machine. The hammer weighs 45 pounds, is raised with an electro-magnet, and when dropped impacts the top of the specimen with its flat bottom surface.

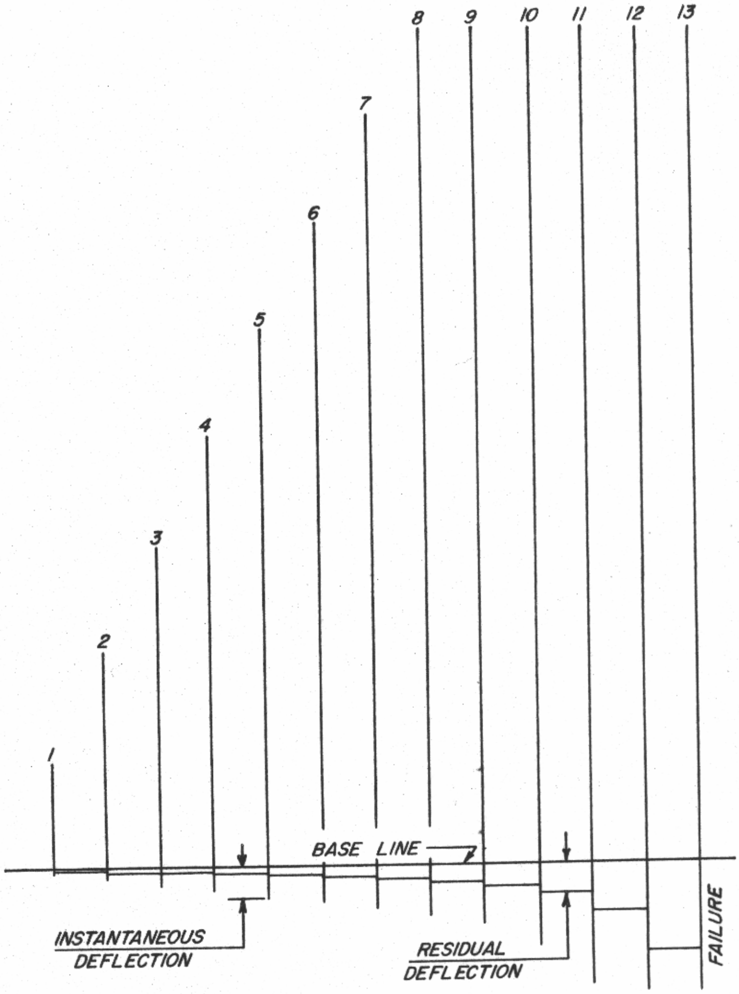

Figure 5.--Sample of record sheet taken from impact machine used in dynamic test for lateral resistance of pallet nails. (Numbers represent heights of drops in inches.)

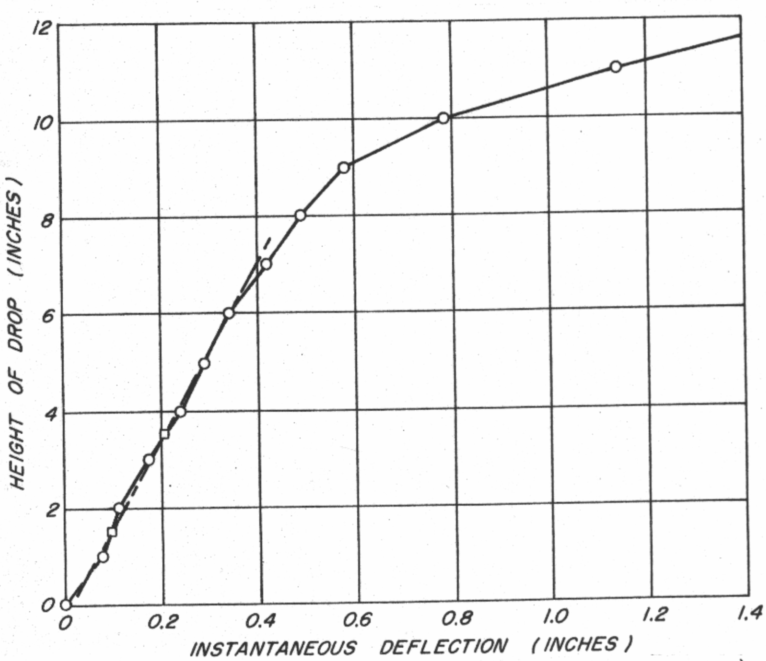

Figure 6.--Sample plot of dynamic test data. Dashed line (through squares) represents the stiffness modulus.

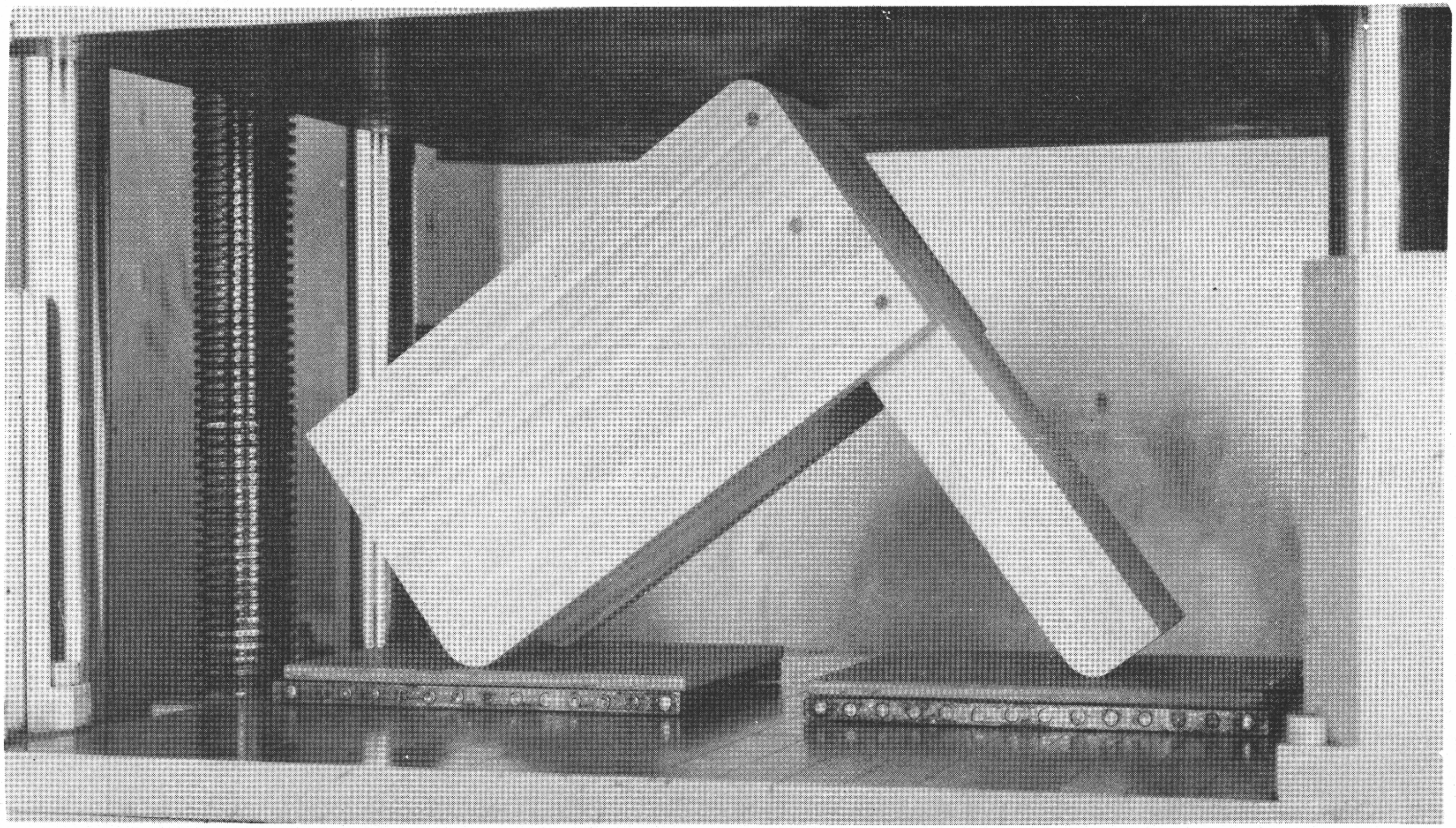

Figure 7.--Setup-for static test of simulated pallet corner in a universal hydraulic testing machine.

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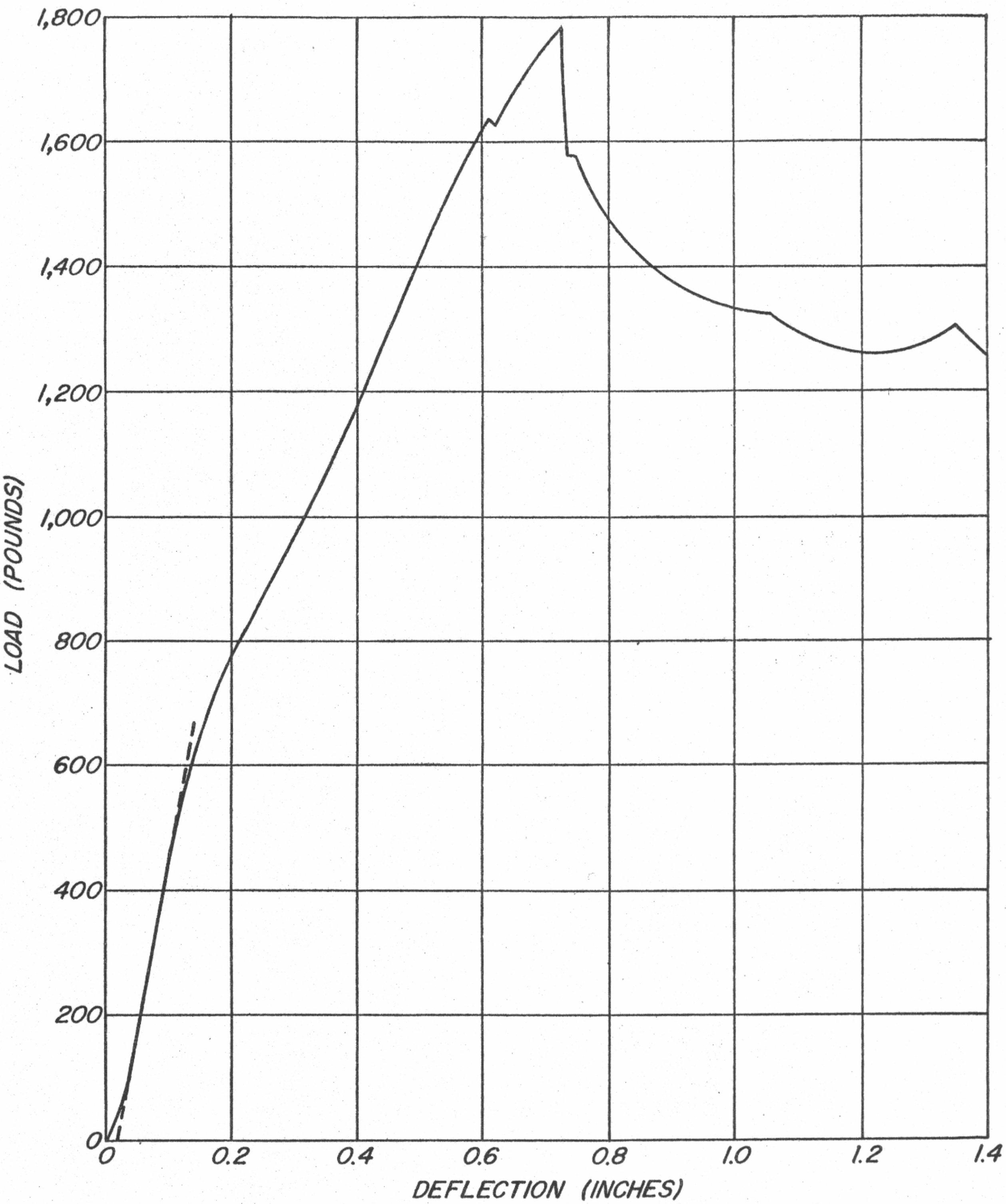

Figure 8. --Example of a typical load-deflection curve for static test of lateral resistance of pallet nails. Dashed line represents stiffness modulus.

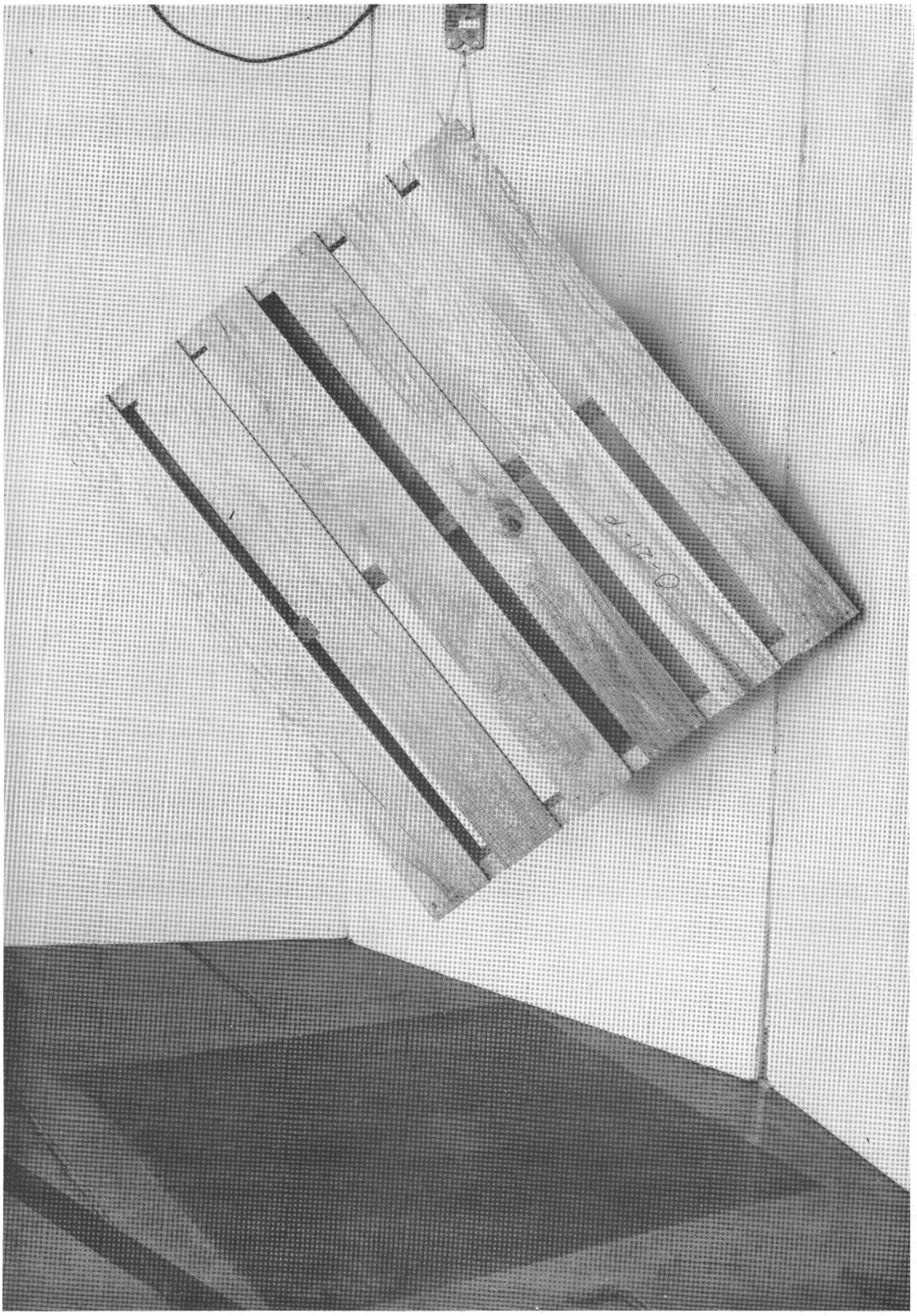

Figure 9.--Setup for drop test of a 40- by 48-inch wood pallet. Each specimen was dropped from a height of 40 inches six times on its bottom corner.

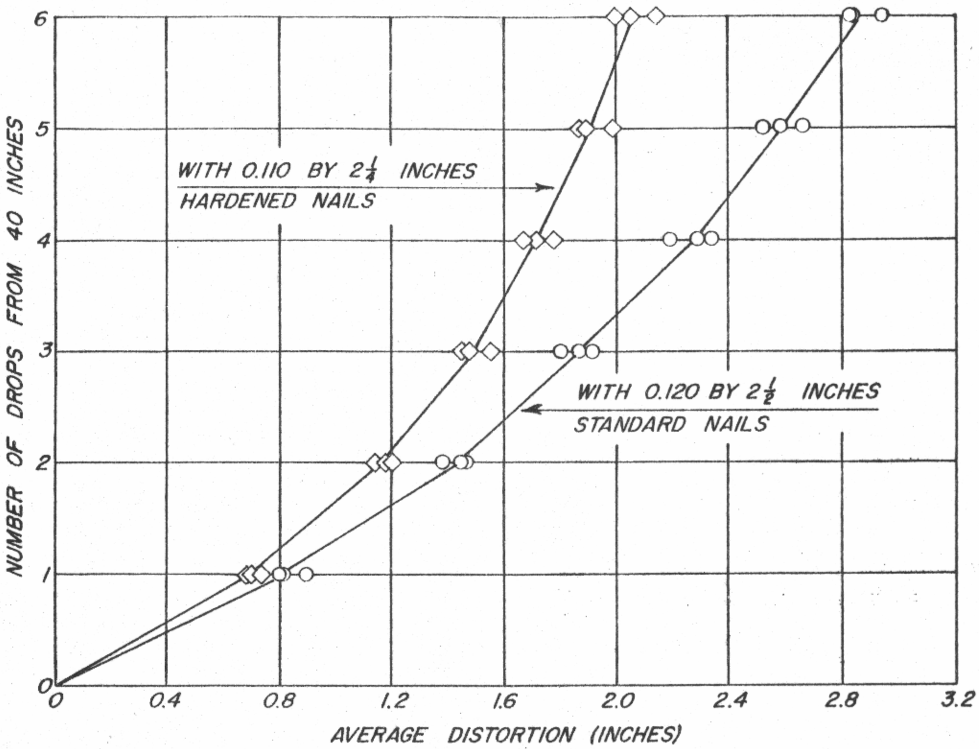

Figure 10.--Curves representing number of drops plotted against distortion for drop tests of six reversible (12 deckboards) pallets assembled from green (over 30 percent moisture content) oak lumber and tested at 7 percent moisture content.

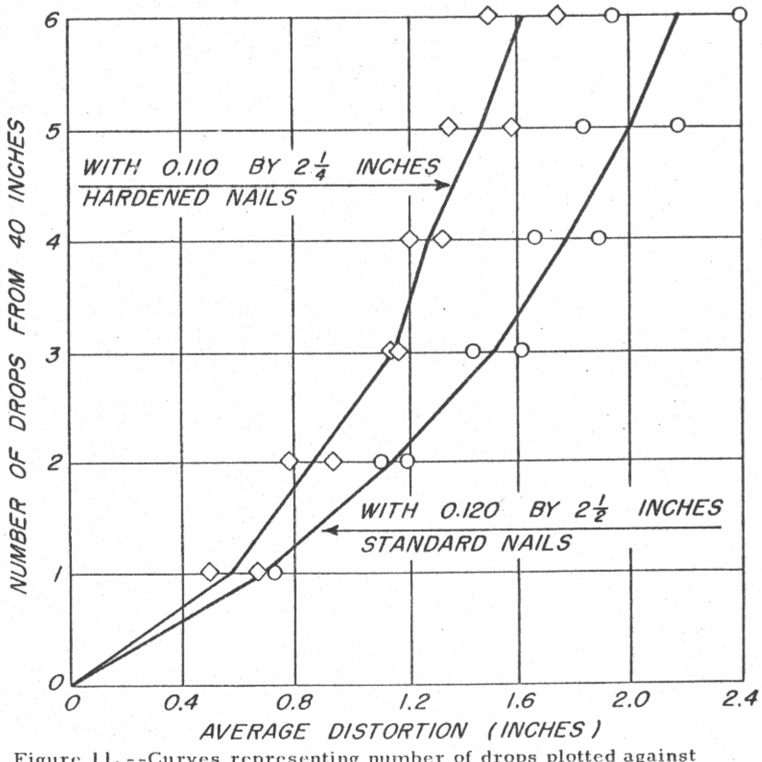

Figure 11.--Curves representing number of drops plotted against distortion for drop tests of four nonreversible (9 deckboards) pallets assembled from oak lumber at 22 percent moisture content and tested at 7 percent moisture content.

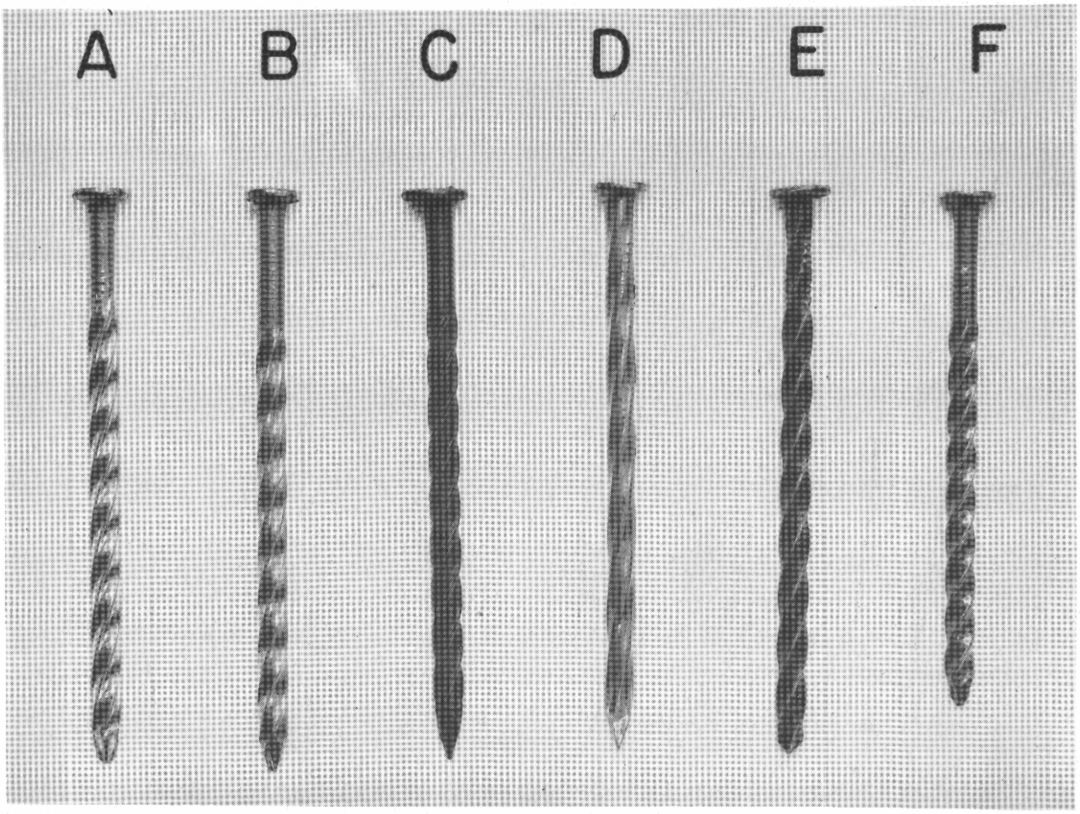

Figure 12. --The six pallet nails that were tested in bending and compared with respect to carbon content, hardness and dynamic lateral resistance.

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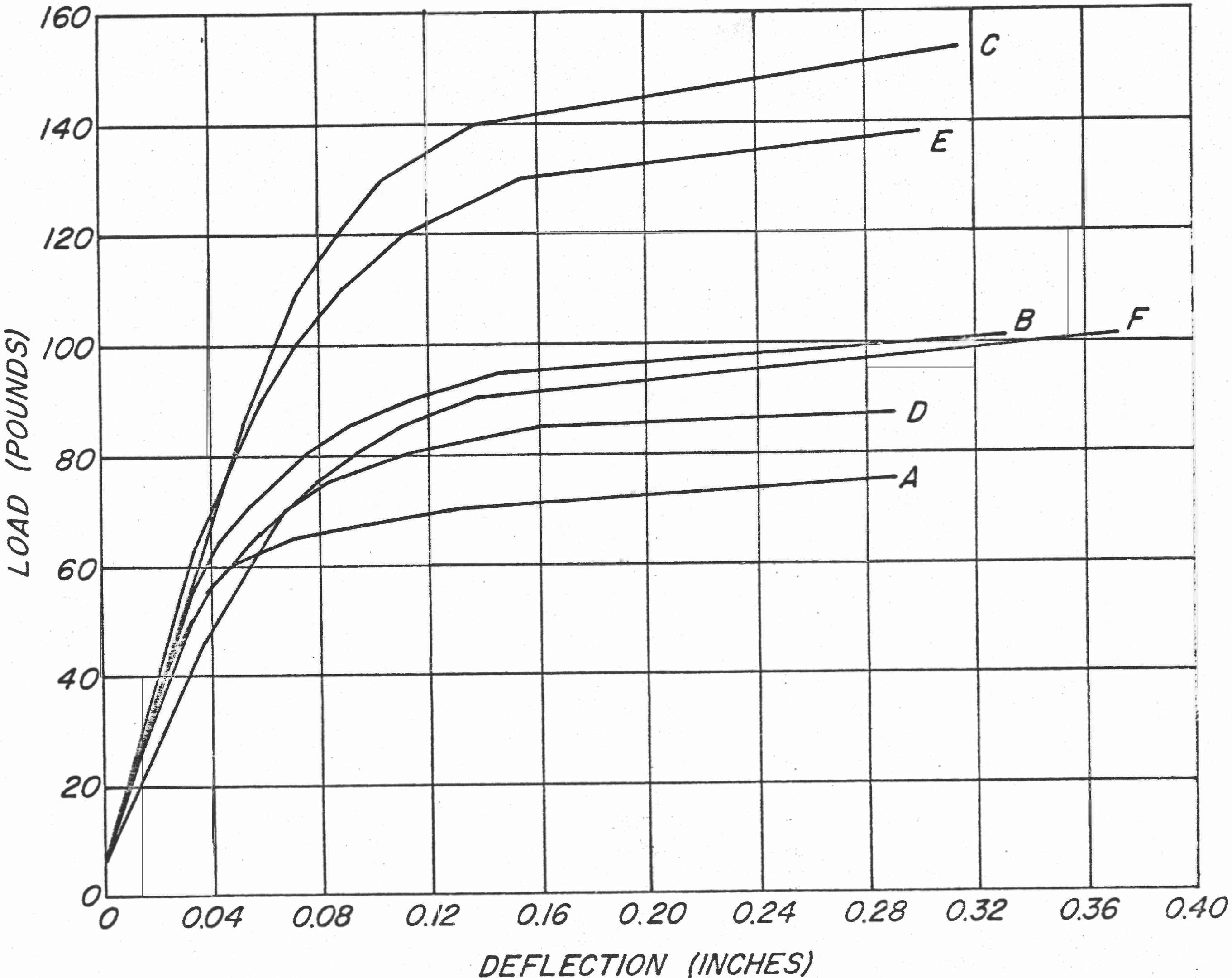

Figure 13.--Load-deflection curves for six different types of spirally grooved pallet nails, which were tested in bending, center loaded on a 2-inch span. (Each curve represents the average of data from three tests.)