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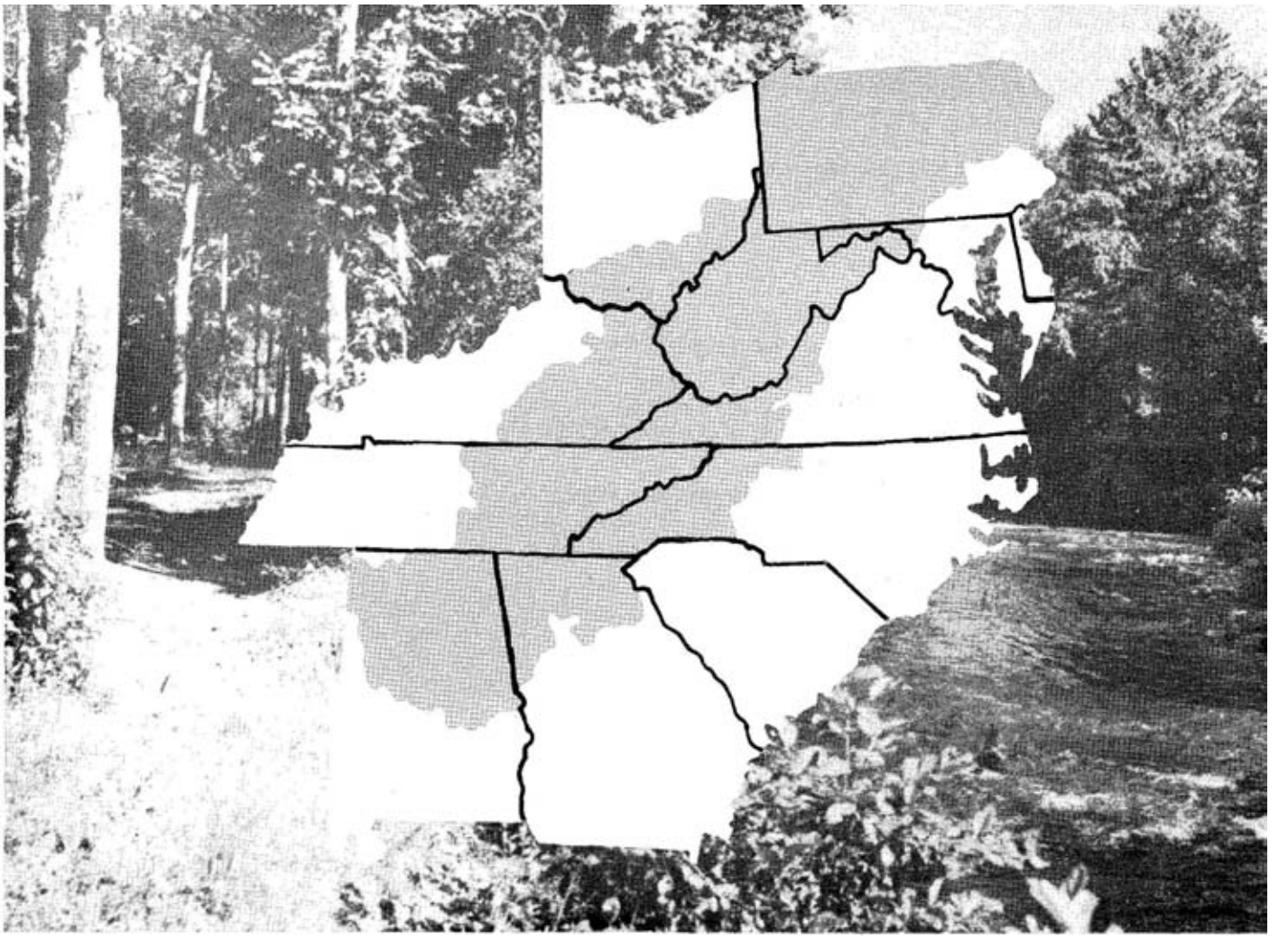
APPALACHIAN HARDWOODS FOR PALLETS-- A LABORATORY EVALUATION



ABSTRACT

The Forest Products Laboratory, in cooperation with the North Central and Northeastern Forest Experiment Stations, studied, by laboratory techniques, the performance capabilities of pallets fabricated from three hardwoods native to an area popularly referred to as Appalachia. These hardwoods have a number of advantages for pallet use--high bending strength, toughness, and nail-holding ability. The laboratory evaluation of different pallet designs and methods of assembly indicates that serviceable pallets of either the reusable or expendable types may be fabricated from yellow-poplar, oak, or hickory, although species and design tend to influence performance.

A new expendable type slicewood-design pallet assembled with staples should be considered acceptable, even though results indicate a longer staple is desirable. Deck board splitting at the nails, which developed during nailing and drying, contributed to the pallet damage. The notched stringer pallets exhibited an apparent design weakness--splitting of the stringers from notch to notch. Details of the different pallet designs evaluated for each wood species are presented, together with an analysis and comparison of their performance.

Appalachian Hardwoods for Pallets--A Laboratory Evaluation[1]

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INTRODUCTION

As part of a national program to promote and improve the economic growth of an area commonly known as Appalachia, the Forest Products Laboratory investigated the performance characteristics of pallets made from three hardwoods native to the area, The Appalachian area encompasses the state of West Virginia, most of Pennsylvania, and portions of Maryland, Virginia, North Carolina, Georgia, Alabama, Tennessee, Kentucky, and Ohio (fig. 1). The research was conducted in cooperation with the Northeastern Forest Experiment Station and their Forest Products Marketing Laboratory at Princeton, W. Va.; also, the North Central Forest Experiment Station, and their project location at Carbondale, Ill.

Figure 1.--Map outline of the area referred to as Appalachia. (M 131 470)

[1] Report issued by the Forest Products Laboratory, Madison, Wis. Collection of material, grading and sorting, fabrication of pallets, testing, and preparation of this report were handled cooperatively by the Laboratory, the North Central Forest Experiment Station, St. Paul, Minn., and the Northeastern Forest Experiment Station, Upper Darby, Pa,

[2] Engineers at the Forest Products Laboratory, maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Associate Technologist at the North Central Forest Experiment Station's project location at Carbondale, Ill., In cooperation with Southern Illinois University.

Yellow-poplar, hickory, and mixed red and white oak were used to fabricate pallets of five different designs. These were evaluated by either three or four laboratory test procedures. A similar number of pallets of each design were placed in service in a fruit processing plant in southern Illinois.[4]

Two relatively new pallet designs were compared to established designs and two new methods of pallet fabricating were utilized in a lightweight expendable pallet. In addition to the expendable type, reusable pallets were included as were both two-way and four-way entry designs.

The objective was to investigate Appalachian hardwoods with respect to their application and performance in new wood pallet designs and possible new pallet assembly methods. Appalachian hardwoods have a number of advantages that make them worthy of consideration in these applications. The species in this area are generally high in bending strength, toughness, and nail-holding capabilities. The timber is located near large eastern centers of industry, agriculture, and population, which tend to create a favorable marketing environment. Through research and application of the results, an accelerated trend in pallet usage would result and expand the markets for hardwoods available in this area. Drawbacks with these species are that at least oak and hickory are difficult to dry and, when dry, are extremely difficult to nail. However, the general practice of pallet manufacturers is to assemble the pallets when the lumber is green and driving nails is somewhat easier. This practice, however, creates subsequent problems when the pallets dry out in service.

MATERIALS

The most prevalent hardwood species in the Appalachian area are oaks (mixed red and white), yellow-poplar, and hickories: thus, these three species were selected for study. The Forest Products Marketing Laboratory at Princeton, W. Va., obtained the raw materials for fabricating the pallets. To fabricate pallets of four of the five designs, a sufficient quantity of rough green lumber of each of the three species was shipped to the North Central Forest Experiment Station's project location at Carbondale, Ill. Logs of each of the three species, sufficient to produce material for me design, were procured and shipped to the U.S. Forest Products Laboratory. Logs were end-coated and the lumber carefully wrapped in plastic film to maintain the green condition.

Sawn Pallets

At Carbondale, the lumber was graded and sorted according to species and thickness. The lumber grades for the study lumber were: yellow-poplar. No. 2B Common; hickory, No. 2 Common; and red oak species group, No. 3 Common. The material was further sorted randomly into four lots from which pallets of four designs were fabricated, briefly described as follows:

(1) Picture frame design.[5]--A 40 by 48 inch, four-way entry, double-face, nonreversible, flush type, nine block pallet.

(2) Notched stringer design.--A 40 by 48 inch modified four-way entry, double-face, nonreversible, flush stringer pallet.

(3) Three-stringer control design.--A 40 by 48 inch, two-way entry, double-face, nonreversible, flush stringer pallet.

(4) Specification MIL P-26966 design.--A 40 by 48 inch, four-way entry, double-face, nonreversible, flush type, nine block pallet.

The green lumber was machined by individual lots on a conveyorized rough mill into pallet parts, with more than a sufficient number being produced to permit elimination of defective parts before assembly.

Pallet parts were permitted to contain certain defects as follows:

1. Physical.
   a. Knots, knot holes, and other holes--up to three-eighths the width of the member (measured perpendicular to the length).
   b. Surface checks--those judged not to

[4]This program is being monitored by the Carbondale Project, Carbondale, Ill.

[5]Nicholson, S. S. 1965. Shipping device. (U.S. Patent No. 3,204,5831, assigned to American Can Co. New York, N.Y.

weaken the member.

c. Splits and shakes--up to the width of a member.

d. Cross grain--where slope is not greater than 1 in 10.

e. Bark pockets--up to three-eighths of the width of the member.

f. Mineral streaks and stain--unlimited amounts.

g. Tension wood--unlimited.

h. Wane--up to one-half the thickness and one-sixth the width of the member.

i. Decay--prohibited.

2. Machining.

a. Warp (cup, bow, twist, and crook)

(1) Slight cup--3/16 inch or less in 6 inches of width,

(2) Bow and twist--that could be straightened by nailing.

(3) Crook--prohibited in stringers and edgeboards, but allowed up to 1/4 inch in interior deckboards.

b. Hit and miss dressing-up to 1/16 inch deep.

c. Torn grain--up to 1/16 inch deep and three-eighths the width of the member,

After discarding the defective pieces, the remining parts for each of the four pallet designs were sorted randomly into 16 sublots with sufficient parts in each sublot fer one pallet. After fabricating, the completed pallets were inspected for protruding nail points (shiners). These were prohibited on the exposed face of outside stringers or blocks. Because of numerous nail splits during assembly, especially in hickory, it was not feasible to maintain strict controls on splitting at the nails.

After assembly and inspection, the pallets were rapidly dried in a kiln to approximately 7 percent moisture content to simulate severe in-use drying. One-half of the pallets of each species and design were shipped to the Forest Products Laboratory.

Slicewood Pallets

Only one pallet design was fabricated at the Laboratory. This was the slicewood design--a 48 by 40 inch, modified four-way entry, double-face, nonreversible, flush stringer pallet. For these pallets, the logs were first crosscut into bolts and each bolt was sawn lengthwise into quarters or flitches. The flitches then were cut into 3/8-inch-thick slicewood, on the Laboratory's slicer. This method of preparing the flitches caused a variation of grain orientation—thefirst portion of a sliced flitch produced flat-grained material while the last slices were more quarter-grained. After each flitch was sliced, there remained a backboard about 2 inches thick which was used to produce the stringers.

For slicing, all flitches were heated by submersion in steam-heated water with conditions controlled to bring the center of the flitches to within 10° F. of the desired temperature (190° F. for yellow-poplar and 210° F. for the oak and hickory).

In general, knots cut smoothly but the short-grained areas surrounding the knots cut rougher than the clear wood. In hickory, hots as large as 3 inches were encountered and were cut without damage to the knife. Knife checks caused cupping of the green slicewood of all three species.[6] It was noted that hickory cut the roughest and yellow-poplar cut the smoothest of the three species. Tear-out (wood that was torn instead of cut from the flitch as the knife completed its pass through the wood) occurred most frequently with hickory and least frequently with yellow-poplar .

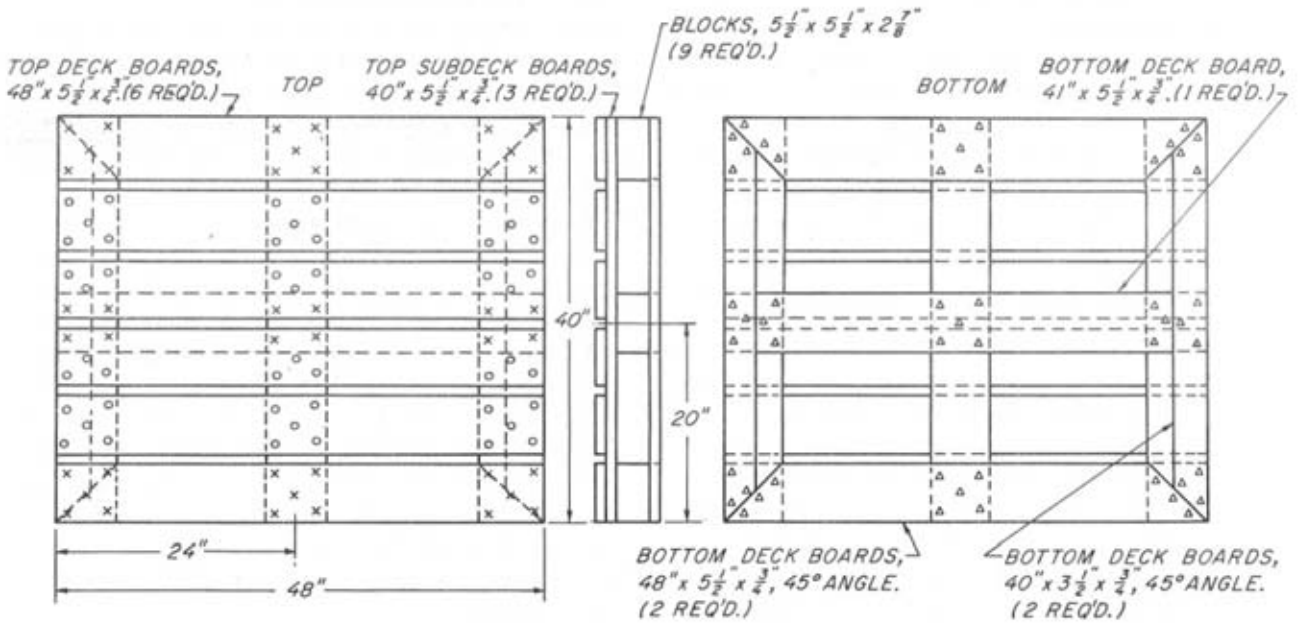
As with the sawn pallets, the slicewood pallets were assembled while the material was green. Pallets were then rapidly dried in a kiln to about 7 percent moisture content by placing them in an atmosphere of 130° F. and 50 percent relative humidity for 5 days, and then at 130° F. and 30 percent relative humidity until they had reached equilibrium conditions.

Fasteners

The helically threaded pallet nails used to assemble the pallets were supplied by a commercial nail manufacturer, while the fivepenny cement-coated sinker nails and sixpenny common nails were taken from laboratory stock. The nylon-coated staples and the pneumatically operated gun for driving them were furnished

[6] Although not used to make pallets, some sliced veneer of all three species was flat after being successfully dried in a roller-conveyor dryer.

by a commercial manufacturer. The details of the various pallet constructions and assemblies are given in figures 2 through 6.



NAILING LEGEND

	TYPE AND SIZE NAIL	NO. REQ'D. PER PALLET	METHOD OF NAILING
o	SIXPENNY COMMON	48	THROUGH TOP DECK BOARDS, TOP SUBDECK BOARDS, AND CLINCHED.
×	HELICALLY THREADED, HARDENED NAILS. (0.120-IN. DIA. BY 3 1/4 IN. LONG)	42	THROUGH TOP DECK BOARDS, TOP SUBDECK BOARDS, AND INTO BLOCKS.
△	HELICALLY THREADED, HARDENED NAILS. (0.110-IN. DIA. BY 2 1/4 IN. LONG)	51	THROUGH BOTTOM DECK BOARDS INTO BLOCKS.

Figure 2.--Design details of picture frame pallets.

(M 132 882)

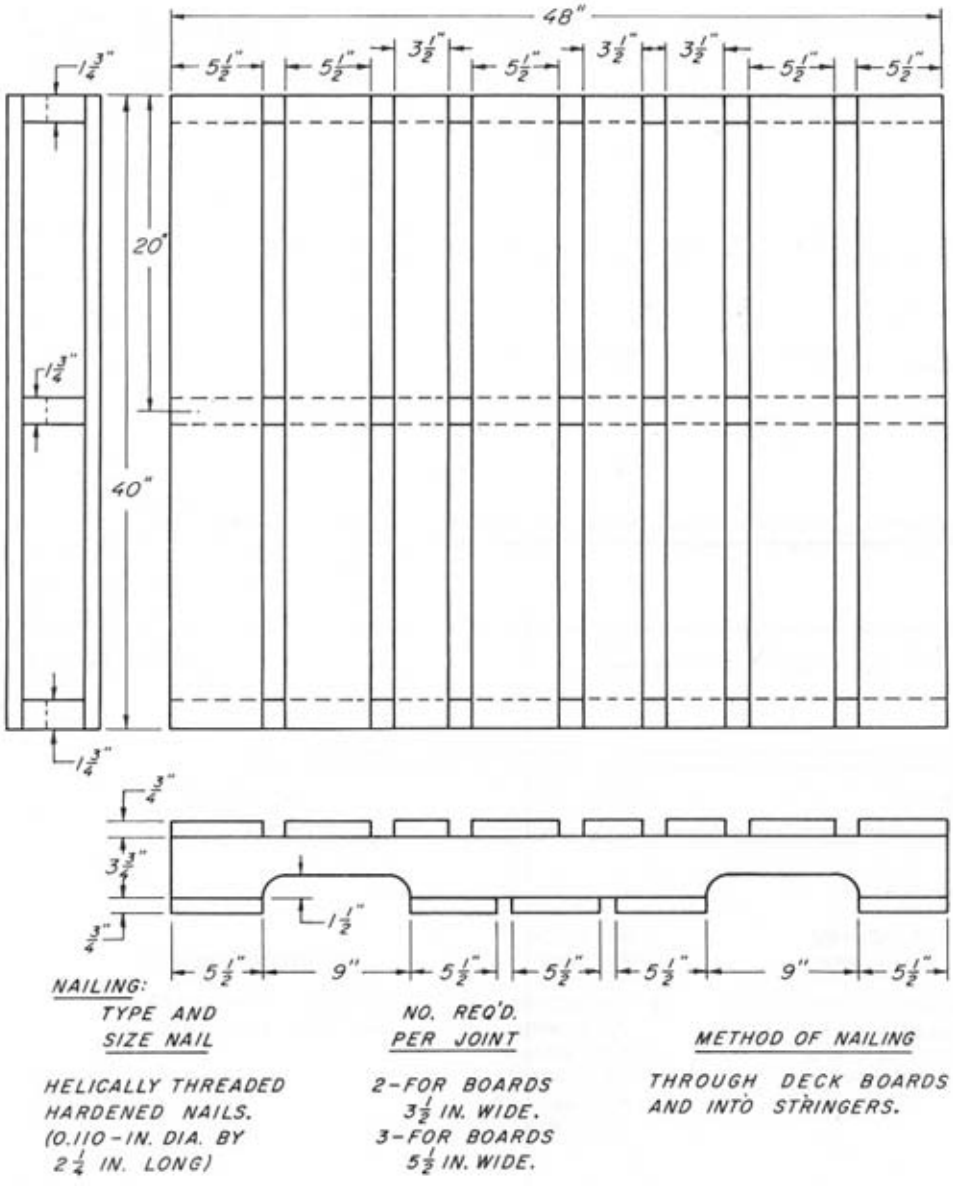
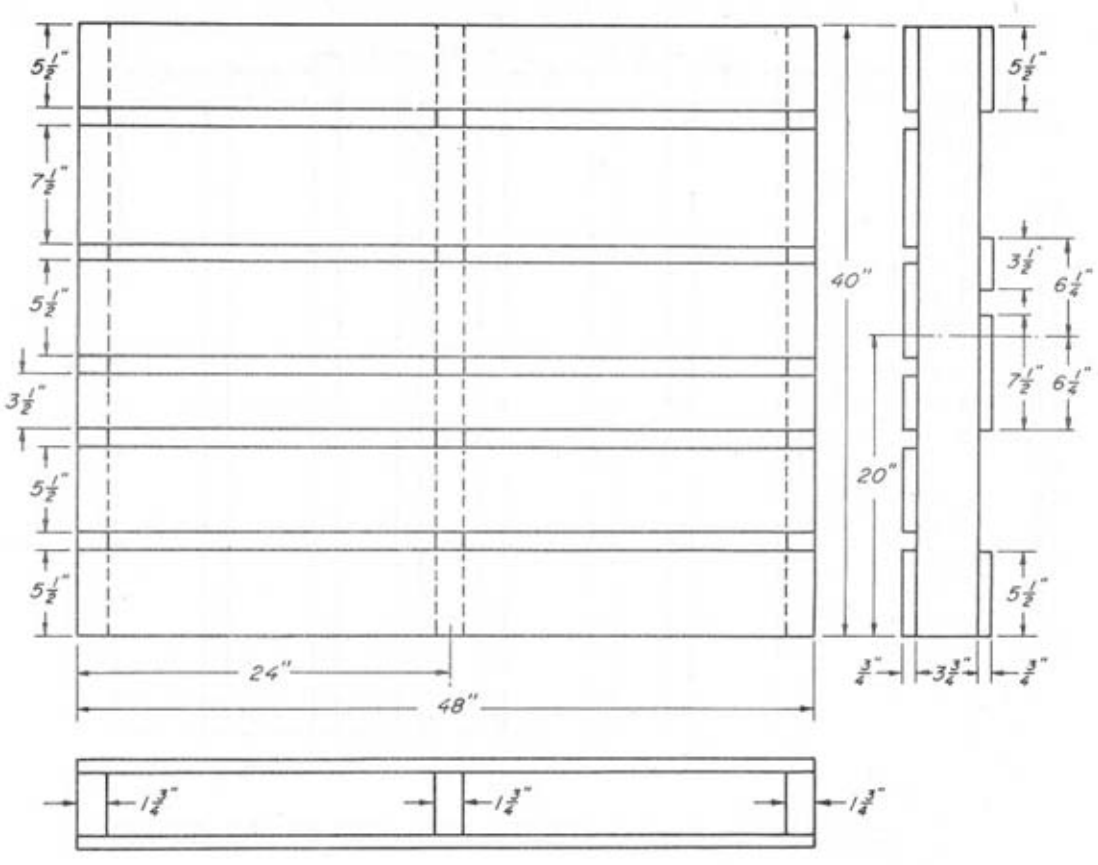


Figure 3.––Design details of notched stringer pallets.

(M 132 883)

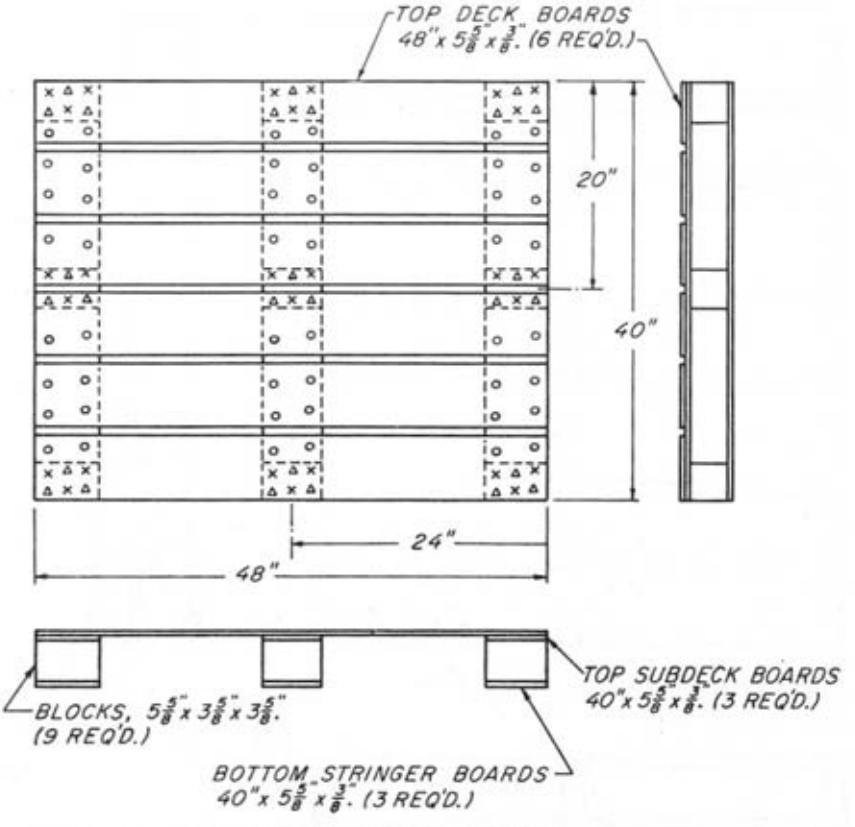


NAILING:

TYPE AND SIZE NAIL	NO. REQ'D. PER JOINT	METHOD OF NAILING
HELICALLY THREADED PALLET NAILS. (0.120-IN. DIA. BY 2 1/2 IN. LONG)	2-FOR BOARDS 3 1/2 IN. WIDE. 3-FOR BOARDS 5 1/2 IN. WIDE. 4-FOR BOARDS 7 1/2 IN. WIDE.	THROUGH DECK BOARDS AND INTO STRINGERS.

Figure 4.--Design details of three-stringer control pallets.

(M 132 884)



NOTE: DECK AND SUBDECK BOARDS ARE 3/8" RESAWN

NAILING LEGEND

	TYPE AND SIZE NAIL	NO. REQ'D. PER PALLET	METHOD OF NAILING
o	FIVEPENNY CEMENT-COATED SINKER NAILS	48	THROUGH TOP DECK BOARDS, TOP SUBDECK BOARDS AND CLINCHED.
×	HELICALLY THREADED PALLET NAILS. (0.120 - IN. DIA. BY 2 1/2 IN. LONG)	27	THROUGH TOP DECKBOARDS, TOP SUBDECK BOARDS, AND INTO BLOCKS.
△	HELICALLY THREADED PALLET NAILS. (0.120 - IN. DIA. BY 2 1/2 IN. LONG)	27	THROUGH BOTTOM STRINGER BOARDS AND INTO BLOCKS.

Figure 5.––Design details of MIL-P-26966 pallets.

(M 132 885)

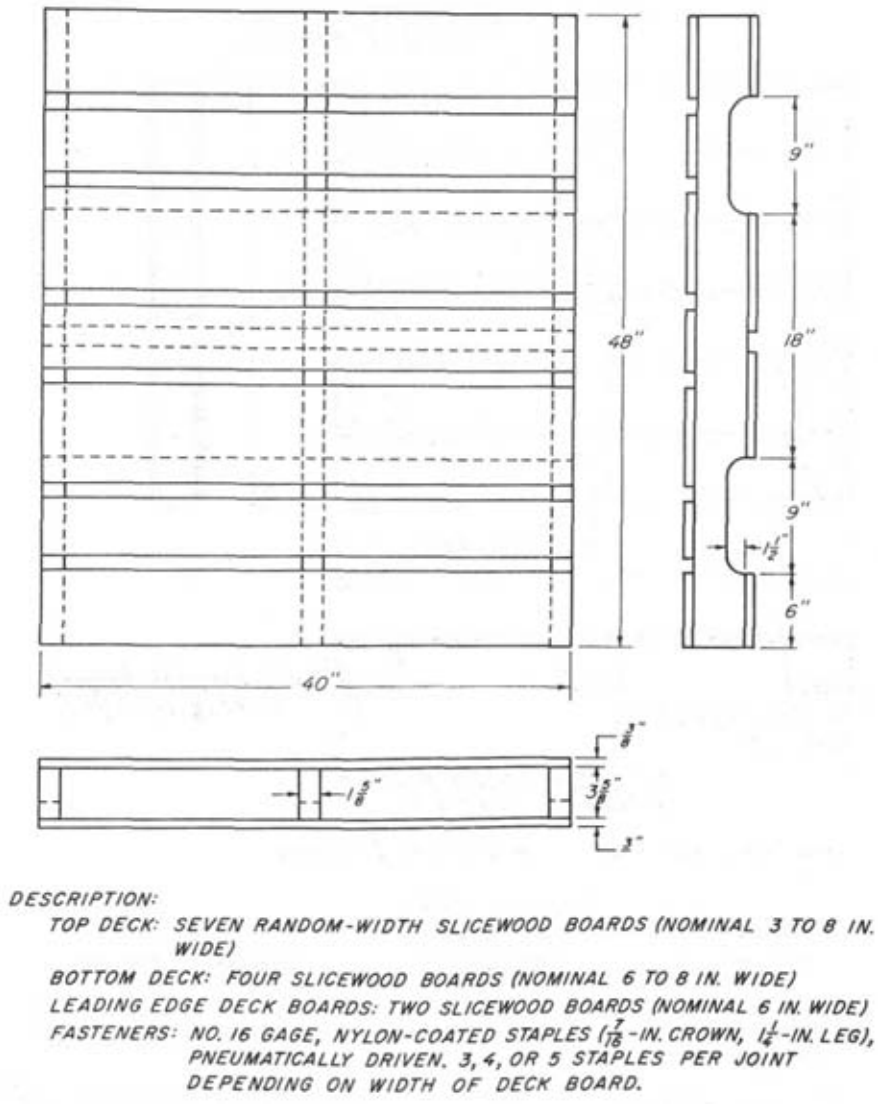


Figure 6.--Design details of slicewood pallets. (M 132 886)

LABORATORY EVALUATION

To evaluate the pallets in the laboratory, 120 were selected for four different testing procedures. Pallets of each design were randomly selected from each of the three species far the different tests. The bending stiffness test was nondestructive so those pallets were also subsequently used in either the revolving drum or the cornerwise drop test. A description of the evaluation procedures follows.

Bend —Stiffness Test

This test was conducted in a large platen universal testing machine to determine the overall pallet stiffness when loaded as a beam. Each pallet was loaded on two spans, which were 4 inches less than the width and 4 inches less than the length, both with the top deck up. The pallets were supported an two nominal 3 inch pipes placed crosswise to the span and positioned 2 inches back from each end, Loading was applied through two more nominal 3 inch pipes placed crosswise to the span and located at the quarter points of the span (fig, 7). Between each piece of pipe and the adjacent pallet surface there was a piece of plywood 4 inches wide by 3/8 inch thick extending beyond the edges of the pallet. To measure deflection, two micro-

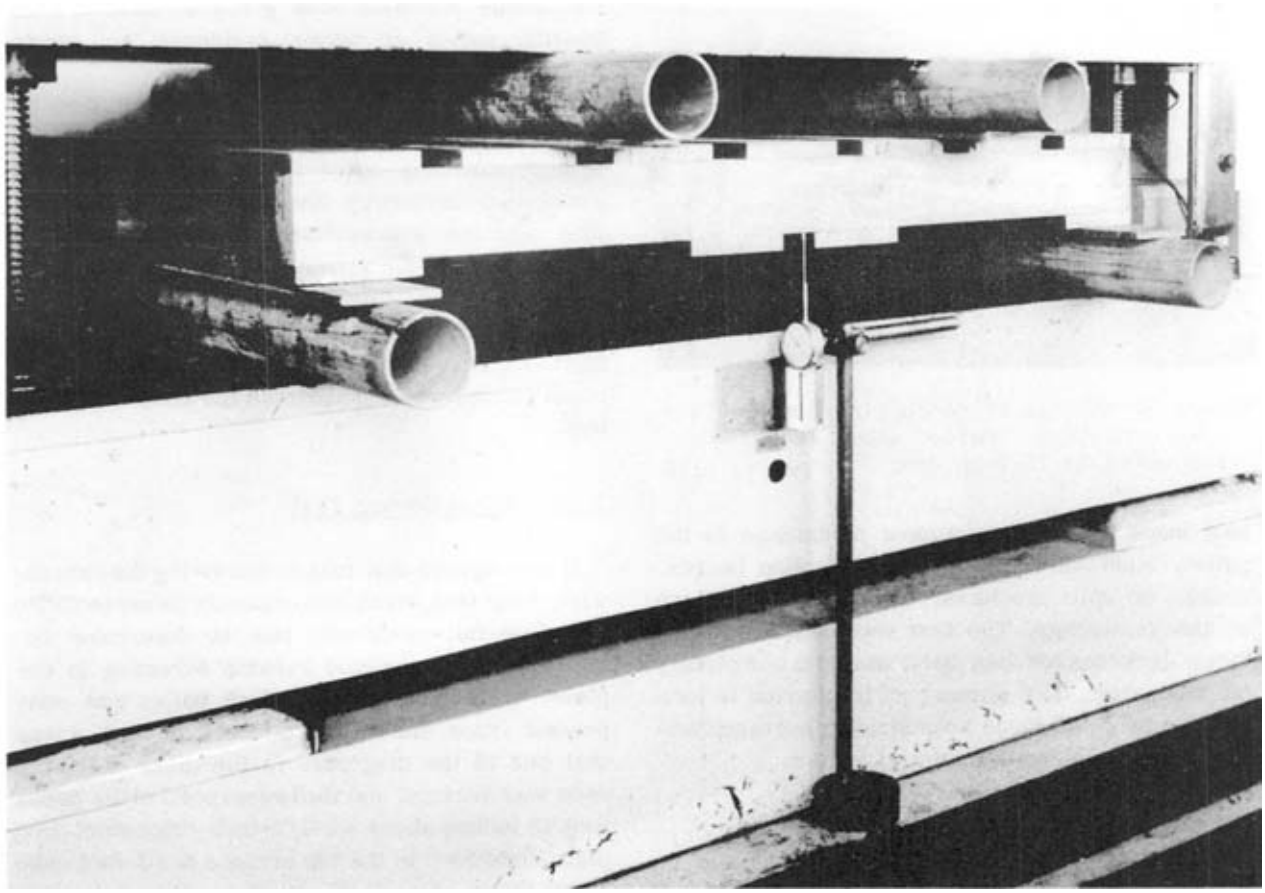


Figure 7.--Method of conducting bending stiffness test.

(M 126 012)

meter dials were mounted at the midspan and one on each edge of the pallet. Readings were taken at each increment of load. An initial load of 10 pounds was applied to the expendable pallets (the slicewood and Specification MIL-P-26966 types), while for the other three designs. the initial load was 100 pounds. The load was applied at a uniform head-movement rate of 0.1 inch per minute, with deflection readings being taken at 10-pound increments up to a loading of 100 pounds for the expendable pallets and at 100-pound increments up to 1,000-pound loading for the other pallet designs. Each pallet was loaded twice and there were two pallets of each design for each species.

These pallets were also used in the drum test or the cornerwise drop test. The observations permitted the calculation of a comparative value, by arithmetical means, indicative of pallet relative stiffness, that is, the average load in pounds necessary to deflect the pallet a total of 1 inch.

Revolving Drum Test

This test provided a measure of the ability of a flat pallet to resist severe handling impacts, as simulated by falls in the 14-foot diameter revolving drum Five pallets of each design for each species were tested separately by placing each pallet, top deck up, in drum hazard No. 1. As the drum revolved at a speed of one revolution per minute, the pallet slid, tumbled, and fell from face to face of the drum, usually skipping every other face (those without hazards). Thus, the pallet was subjected to three falls per revolution of the drum. During the evaluation, a record

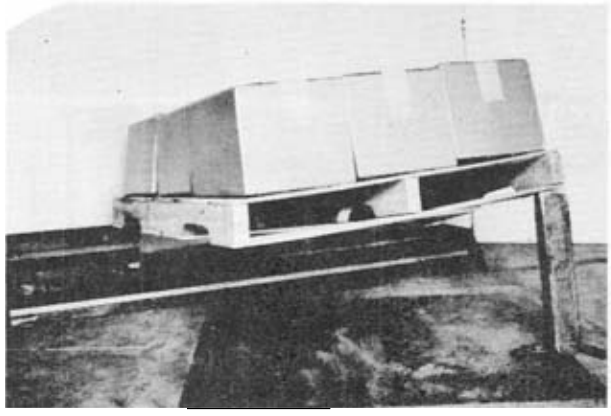


Figure 8.--Method of conducting corner-wise drop test. Pallet shown is being subjected to 18-inch drop. (M 130 141)

was made of the development of damage to the pallet, such as racking, splits, broken boards, broken or split blocks or stringers, and failure of the fastenings. The test was continued until three deck boards had been knocked completely off the pallet. The number of falls prior to loss of one, two, and three boards were averaged and arbitrarily used as the point of failure.

Cornerwise Drop Test

This teat is suitable for comparing the resistance of loaded flat pallets to damage when dropped on the comers. A total of 45 pallets was subjected to this test, three replicates for each of five designs for each of three species. As shown in figure 8, the loaded pallet was positioned with one corner placed on a nominal 6-inch-high block and the other corner of the same end on a 12-inch-high block. The opposite end was raised so that the lowest corner was 6 inches above the dropping surface. The pallet was then released and allowed to drop freely. Next, the pallet was turned 90° in the horizontal plane and dropped on the adjacent corner. This procedure was continued until the pallet had been dropped on all four corners from a height of 6 inches. Then, each of the four Corner drops was repeated from heights of 12, 18, and 24 Inches. If the pallet was still serviceable after these 16 drops; four additional edgewise drops were made--two 24-inch falls on one bottom edge while the opposite bottom edge was supported on a 6-inch-high rim-ber, and two similar falls on the previously supported edges. After each drop, all changes or breaks in the pallet were noted and recorded. Particular attention was given to broken deck boards, pulled or broken fasteners, and splits in stringers, blocks, or deck boards.

Loading of the. pallets was accomplished by means of nine sealed fiberboard cartons arranged to approximately cover the entire top deck and simulate a uniformly distributed load. The total load for the expendable-type pallets was 250 pounds and for the reusable designs the load was 1,000 pounds.

It was arbitrarily decided that a 16-inch-long split in three stringers or deck boards (or combination) would determine the end point in this test.

Free-Fall on Corner Test

It was agreed that pallets surviving the corner-wise-drop test would subsequently be subjected to the free-fall-on-corner test to determine the resistance to dynamic racking stresses in the plane of the pallet deck Each pallet was sus-pended from one of its corners in such a way that one of the diagonals in the plane of the top deck was vertical and the lowest point of the pallet was 40 inches above a 1-1/2-inch-thick steel drop plate embedded in the top surface of 3-foot cube of concrete. The pallet was released by a solenoid-operated drop mechanism and allowed to fall freely onto the impact surface. After each fall, the pallet was restrained to prevent any rebound or second-ary falls. This procedure was repeated six times, all on the same corner. After each drop, the change in length of each diagonal of both top and bottom decks was measured and recorded. A diagonal was considered as the distance between two diagonally opposite corners in the plane of the top or bottom deck of the pallet. The average amount of racking was then calculated from the change in the four diagonal measurements.

OBSERVATIONS, RESULTS, AND DISCUSSION

Slicing of the yellow-poplar and red oak did not present any serious problems. Hickory, how-ever, was difficult to heat properly and, when sliced, produced extremely rough surfaces.

In fabricating the slicewood pallets, it was noted that the air pressure to the pneumatic

stapler had to be adjusted for the different species to obtain a satisfactorily driven staple. For yellow-poplar the pressure was approximately 18 p.s.i. (pounds per square inch), red oak required about 24 p.s.i., while hickory required about 30 p.s.i. The stapling operation did not produce any visible splitting even at deck board ends. During the drying cycle, the slicewood deck boards warped badly around knots and some splitting occurred at the deck board ends. In some instances, shrinkage caused deck boards to separate from stringers and expose as much as 1/4 inch of staple legs. The oak and hickory pallets warped about the same amount but more than the yellow-poplar pallets. Deck board ends of yellow-poplar slicewood pallets split the least. They averaged only eight splits per pallet while hickory averaged the most--28 splits per pallet. Oak was in between with an average of 19 splits per pallet.

At Carbondale, hand nailing and board shrinkage caused splitting at deck board ends. Since splitting at the nails might influence pallet serviceability, differences in splitting were compared on the basis of pallet design, species, type of nail, and thickness and width of deck board. Comparisons were based on a percentage figure obtained by dividing the number of splits due to nailing and board shrinkage by the total number of nails in the deck board ends and multiplying by 100. The results of these comparisons are given in table 1.

Thickness of Deck Boards

In all species, the thinner deck boards (3/8 inch) split more than the thicker deck boards (3/4 inch)--yellow-poplar three times more, oak two times more,. and hickory 11 percent more.

Width of Deck Boards

A comparison of the amount of splitting that occurred at the end nails in the various-width deck boards showed more splitting in boards of 6-inch width than in boards of 4-inch width, but more splitting in the 4-inch-wide boards than in boards of 8-inch width. Investigators at Carbondale also reported that these deckboard splits were accentuated by the drying cycle. Examination after the drying cycle revealed that splits at the nails in yellow-poplar occurred more frequently during drying than during nailing, and that oak split more than hickory during drying.

Bending Stiffness Test

The calculated comparative values indicating relative pallet stiffness are given in table 2 for each species, design, and span.

Both the design of the pallet and the wood species influenced the relative stiffness of the pallet.

Table 1.--Comparison of the amounts of splitting occurring at nails in deck boards of pallets

Type pallet design	Fastener location	Nail description: Size	Nail description: Type	Number of splits divided by total number of nails in deck board ends for--: Yellow-poplar	Oak	Hickory
		Inch		Percent	Percent	Percent
Notched stringer	Through top and bottom deck boards into stringers.	0.110 by 2-1/4	Helically threaded	3	22	62
Three-stringer control	Through top and bottom deck boards into stringers.	.120 by 2-1/4	Helically threaded	7	29	73
Picture frame	Through top deck and subdeck boards and into blocks.	.120 by 3-1/4	Helically threaded	10	35	78
	Through top deck and subdeck boards and clinched.	.112 by 2	Common	16	53	81
Average				13	44	80
Military specification	Through top deck and subdeck boards and into blocks.	.120 by 2-1/2	Helically threaded	24	58	81
	Through top deck and subdeck boards and clinched.	.086 by 1-5/8	Cement-coated sinker	7	27	79
Average				16	43	80

Table 2.--Calculated comparative values indicating relative pallet stiffness

Species	Average calculated load to deflect pallet 1 inch[1]			
	44-inch span		36-inch span	
	First loading	Second loading	First loading	Second loading
	Pound	Pound	Pound	Pound
PICTURE FRAME DESIGN				
Yellow-poplar	3,800	4,440	2,820	3,380
Oak	3,810	4,520	3,680	4,350
Hickory	3,870	4,460	3,770	4,570
THREE-STRINGER CONTROL				
Yellow-poplar	2,510	2,660	10,400	10,700
Oak	2,650	2,820	11,500	12,600
Hickory	3,070	3,030	8,250	9,350
NOTCHED STRINGER DESIGN				
Yellow-poplar	6,420	6,640	4,220	4,370
Oak	6,440	6,620	4,840	5,180
Hickory	6,290	6,620	5,260	5,520
SPECIFICATION MIL-P-26966 DESIGN				
Yellow-poplar	160	170	885	1,080
Oak	205	210	1,030	1,210
Hickory	200	210	630	810
SLICEWOOD DESIGN				
Yellow-poplar	5,400	5,950	705	910
Oak	5,000	5,470	750	880
Hickory	5,240	5,730	870	1,050

[1]Average was obtained from two replicates of each species and design.

The notched stringer design and the picture frame design exhibited more uniform stiffness regardless of the span than did the other three designs. The three-stringer control pallets were more than twice as stiff for the 36-inch span than either of the other two reusable pallet designs, but were the least stiff of the reusable designs when comparing the 44-inch span values. The notched-stringer pallets were the stiffest for the 44-inch span,

Both of the expendable pallet designs varied greatly in stiffness, depending upon the span. The slicewood design was extremely stiff in the 44-inch span, but this was to be expected since the three stringers were acting as beams in this loading. In the three pallet designs that used stringers, the stiffest condition occurred when loading was such that the stringers acted as beams. In the notched stringer design the effective depth of the stringers as a beam was reduced because of the notches and, thus, the stiffness was more uniform regardless of span or stringer direction. It should be remembered that this pallet had nominal 1-inch-thick deck boards while the similarly designed slicewood pallet only had 3/8-inch-thick deck boards. Nevertheless, the stiffness of these two designs was not extremely different for the 44-inch span.

In comparing the stiffness values in table 2

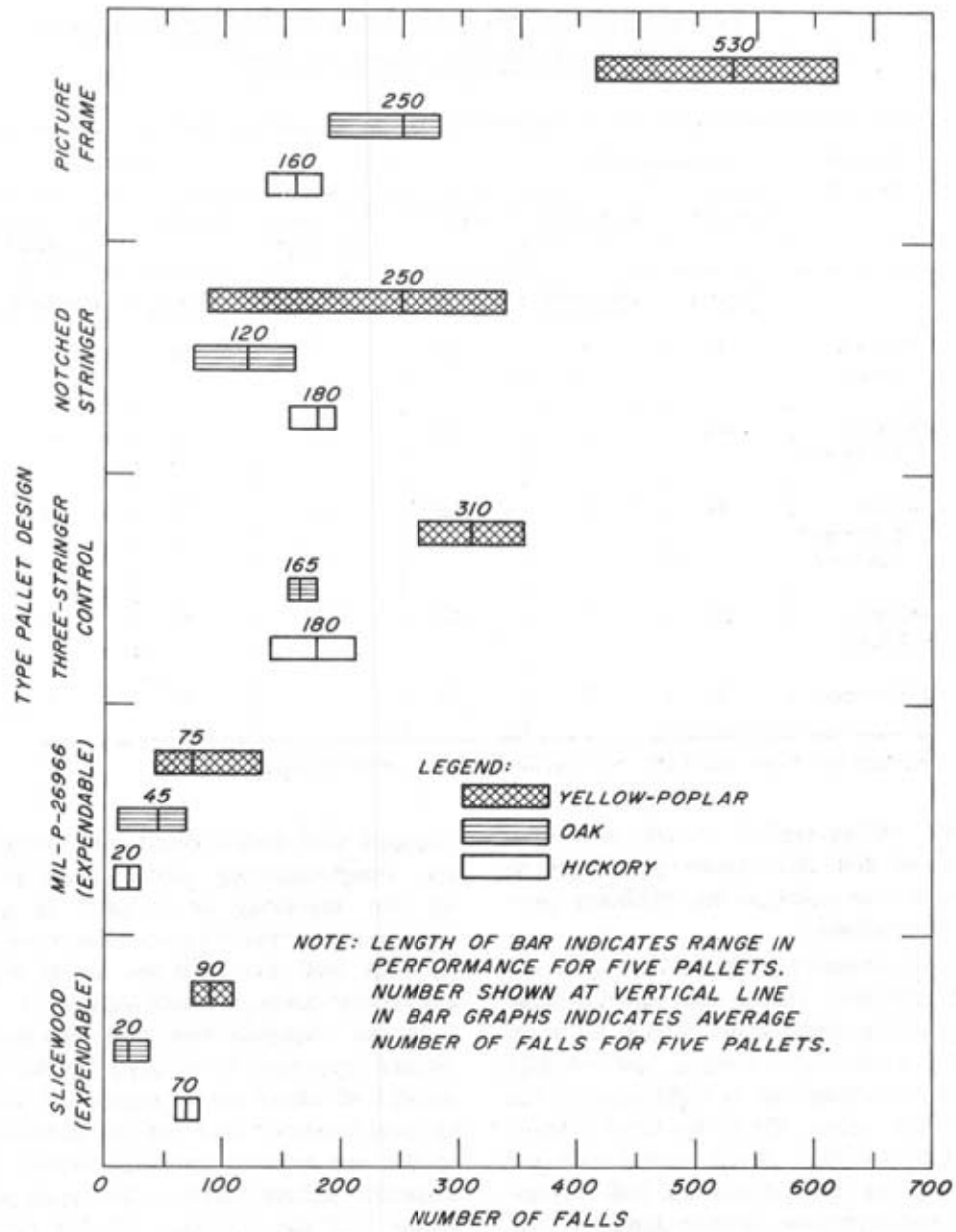


Figure 9.--Average performance of Appalachian pallets in revolving drum tests.

(M 132 887)

on the basis of species, pallets of oak and hickory are generally stiffer than similar pallets of yellow-poplar. These differences, however, de not appear to be as great as might be anticipated, judging from the published average values for specific gravity and modulus of elasticity for the species. In many instances the differences between oak and hickory do not appear to be significant and, thus, there may be some question as to whether oak or hickory pallets were stiffer. Judging from specific gravity and modulus of elasticity values, one might expect hickory to be the stiffest of the three species. It should be remembered, however, that the pallets were assembled green and then rapidly dried to a moisture content of approximately 7 percent. During the drying, shrinkage took place and the hickory pallets (especially the stringers) shrunk

Table 3.--Average weights and moisture contents of Appalachian pal lets evaluated in revolving drum[1]

Pallet design	Yellow-poplar		Oak		Hickory	
	Weight	Moisture content	Weight	Moisture content	Weight	Moisture content
	Pound	Percent	Pound	Percent	Pound	Percent
Picture frame	49	7	73	8	81	8
Notched stringer	43	7	64	8	71	8
Three-stringer control	44	7	64	8	71	8
MIL-P-26966	27	7	42	7	43	8
Slicewood	30	7	39	7	43	7

[1] Based on five pallets for each species and design.

more and the yellow-poplar shrunk less than the average, so that the resulting changes in dimension tended to equalize the stiffness performance of the pallets.

In general, the second loading resulted in somewhat higher stiffness values than did the first loading, A possible explanation is that some of the deflection in the first loading was actually movement of the joints due to tightening of the fasteners in the wood. Thus, the first loading was influenced by this slack which was not present during the second loading and, consequently, the stiffness was slightly higher in the second loading.

Since this test was nondestructive in nature, there were no visible failures to report.

Revolving Drum Test

The results of the revolving drum test are shown in bar-chart form in figure 9. The length of each bar represents the range of performance for five pallets of a particular species and design, while the number shown at the vertical line in each bar graph represents the average number of falls for five pallets. From this it appears that both species and design influenced the rough-handling performance as measured by the revolving drum test. In general, the yellow-poplar pallets performed best of the three species and the reusable pallet designs outperformed the expendable pallets.

In the reusable designs, the yellow-poplar pallets appeared to be significantly better than pallets of either oak or hickory. It is interesting to note, however, that with the possible exception of the oak notched stringer pallets, none of the reusable pallets had a performance significantly lower than the arbitrary 150-fall minimum performance level. The difference in performace between oak and hickory pallets was not too noticeable except possibly in the picture frame design, where the oak pallets outperformed those of hickory. It is interesting to note from figure 9 that, for any of the five pallet designs, the range between minimum and maximum performance for the oak and hickory pallets was less than for the yellow-poplar pallets. Also, some designs appeared to exhibit a wider range of performance than did others.

The average weights and moisture contents of the pallets at time of test, are given in table 3. Moisture contents were measured with

a resistance-type moisture meter. From table 3 it can be seen that the average moisture content did not vary significantly and, thus, did not influence performance. Further, there was not any great difference between the average weights of the hickory and oak pallets and, with possibly me or two exceptions, there was practically no significant difference in their performance.

Failures in this test varied with pallet design and sometimes with the species. The picture frame design had a variety of conditions causing failure, particularly with yellow-poplar. Deck boards and blocks of this species often split as they dried. Deck boards were split at the nails or the nails sheared from the ends of the deck boards. Some blocks were completely split in two and there were some pulled nails. The hickory pallets of this design had many nails pulled through splits in the deck boards, an occasional split block, and some nail pull. The condition of the oak picture frame pallet was characterized by broken and pulled nails as well as deck boards sheared from nails or nail heads pulled through deck board splits. A typical picture frame pallet failure is shown in figure 10.

In the notched stringer design, there was deck board splitting at the nails and shearing of the deck boards from the nails. Some nail pull was evident in the yellow-poplar pallets, while broken nails occurred in hickory and oak pallets. Many oak and yellow-poplar notched stringer pallets had stringers split from notch to notch. Typical failures of notched stringer pallets are shown in figures 11 and 12.

The three-stringex control pallets had the deck hoards split and sheared from the nails, apparently starting from initial splits during nailing or drying. Also, these were broken and pulled nails. Typical condition of these pallets after the drum test is shown in figure 13.

The Specification MIL-P-26966 pallets had deck boards split from the nails and nail heads pulled through deck board splits. Occasionally a block was split and there were some pulled nails. The splitting appeared to have developed from initial defects originating during nailing and drying. A typical failure of a MIL-P-26966 pallet is shown in figure 14.

The failure of the slicewood design was predominately pulled staples (fig. 15), regardless of species.

Figure 10.--Typical failure of picture frame design pallet in revolving drum test.

(M 130 135)

Figure 11.--Type of top deck board failures in revolving drum test of notched stringer design pallets.

(M 130 139)

Figure 12.--Typical splits in stringers of notched stringer design pallets in revolving drum.

(M 130 138)

Figure 13.--Typical condition of control pallet after revolving drum test.

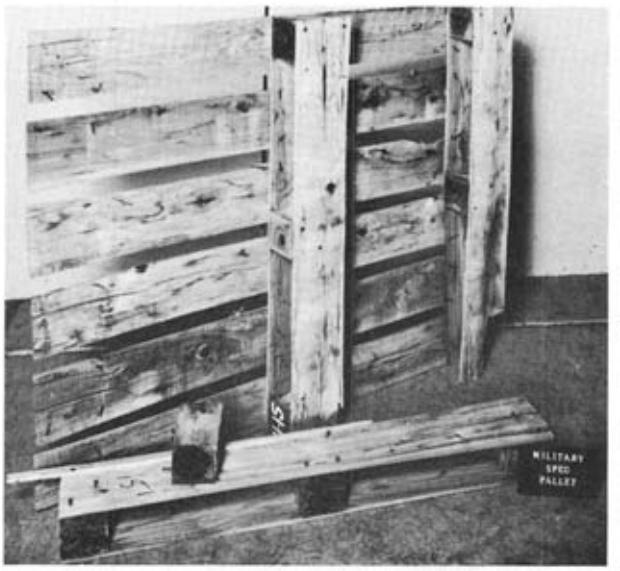


Figure 14.--Typical failure of Specification MIL-P-26966 pallet.

(M 130 136)

Cornerwise Drop Test

This test revealed an apparent characteristic weakness in the notched stringer design, regardless of species. These pallets generally failed by having the three stringers split from notch to notch. Failure generally occurred during the 18-inch cornerwise drops. Three pallets failed during the 24-inch cornerwise drop, and one survived all falls but it had two split stringers. Species did not appear to influence the behavior of these loaded pallets during rough handling.

The picture frame and three-stringer control designs which also carried a 1,000-pound uniformly distributed load were all serviceable after this test. The condition of the pallets appeared to be excellent and the only visible damage was some slight splitting of bottom deck boards. There was no difference in the appearance or

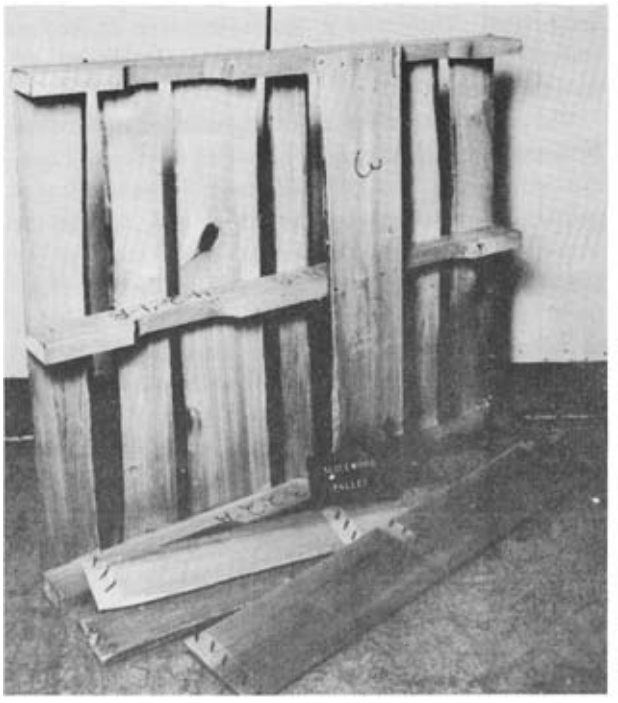


Figure 15.--Typical slicewood pallet after revolving drum test.

(M 130 137)

performance of these designs that could be attributed to species.

Both expendable designs (Specification MIL-P-26966 and the slicewood pallets) were extremely flexible and, although only loaded with 250 pounds, withstood the entire series of drops and were still considered serviceable. As with the reusable designs, there were no significant differences between species. The Specification MIL-P-26966 pallets developed some occasional splitting, generally in the bottom deck boards, while the slicewood pallets showed evidence of slight staple pull along with an occasional split.

Free-Fall-on-Corner Test

The average results of the free-fall-on-corner drop test are given in table 4. The notched stringer design was not subjected to this test because these pallets failed in the cornerwise drop test.

From table 4 it can be seen that the picture frame design was the most rigid. Pallets fabri-

Table 4.--Average racking in the free-fall-on-corner drop test expressed as a percentage of the original diagonal measurement

Species	Pallet design[1]			
	Picture frame	Three-stringer control	Specification MIL-P-26966	Slicewood
	Percent	Percent	Percent	Percent
Yellow-poplar	1.0	3.3	[2]2.5	4.9
Oak	1.5	4.8	[2]3.7	[2]11.7
Hickory	1.9	8.6	(3)	5.4

[1]Notched stringer design not tested because pallets failed during cornerwise drop test.

[2]One pallet failed.

[3]All pallets failed and no average data available.

cated from hickory generally appeared to distort the most. This was probably due to the numerous splits at the fasteners.

The Specification MIL-P-26966 hickory pallets failed because of excessive splitting of the deck boards at the nails. The failure of the one yellow-poplar and one oak pallet in this design was also due to splitting at the nails.

The slicewood pallets appeared to be the least resistant to diagonal distortion, The single oak pallet that failed in this design was due to staples pulling from the stringers.

CONCLUSIONS

The laboratory evaluation indicates that serviceable pallets of either the reusable or expendable type may be produced from any of the three most prevalent Appalachian hardwood species--yellow-poplar, oak, and hickory.

Both species and design influenced the overall performance of the pallets. There is room for question as to whether the differences in performance due to species and design were significant in all instances. Based on the revolving drum test averages, the yellow-poplar pallets significantly outperformed the other two species in each of the three designs of reusable pallets. The performance variability of these yellow-poplar pallets, however, was considerably greater than for the other two species. In the expendable designs, where the weight differential is less, the better average rough-handling performance of the yellow-poplar pallets was not as great. Although the performance variability for the yellow-poplar expendable pallets was greater than for the other two species, the range of performance was not as noticeable as it was with the reusable pallets.

Considering all of the laboratory evaluations, the picture frame design pallet generally performed as well or possibly slightly better than any of the other designs. It was certainly the most resistant to diagonal distortion. The picture frame design was the heaviest of the three reusable designs with little or no noticeable difference between the other two designs.

The notched stringer design exhibited a characteristic weakness of the stringers splitting from notch to notch. especially in the cornerwise drop test. This was a characteristic of design rather than species since it developed in all three species.

There was no consistent significant difference between the two expendable pallet designs. Thus, the slicewood design indicated a capability of providing satisfactory service and should be considered as an acceptable expendable pallet design. In any further consideration of the slicewood design, a longer staple is recommended to overcome the excessive number of pulled staples. All three species were suitable for slicewood pallets.

The splitting; that developed at the fasteners during nailing and drying, especially in the nailed pallets. accounted for much of the damage sustained by the pallets. Some of this damage could be reduced and performance improved if dry material could be used to fabricate the pallets. Undoubtedly some of this initial damage is aggravated by the fact that hickory and oak are generally difficult to dry.

The results of this laboratory evaluation provide an indication of the relative life expectancy and overall performance of Appalachian hardwood pallets. Further data in this regard are being obtained from the inservice tests now in progress at the Carbondale Project. Carbondale, Ill.

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