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U. S. FOREST SERVICE
RESEARCH PAPER NC-4
JUNE 1966

Effect of Initial Moisture Content on Performance of HARDWOOD PALLETS

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The Effect of Initial Moisture Content On Performance of Hardwood Pallets

Daniel E. Dunmire

The wooden pallet industry is big, competitive, and growing *(11)*.[1] Annual wooden pallet sales in 1963 were more than 3½ times greater than in 1949. Production of about 71,587,000 wooden pallets required more than 5 percent of the lumber produced in the United States in 1963 *(1)*.

The U.S. Forest Service has cooperated for many years with various industrial organizations and military agencies in wood pallet research. Information gained from both applied and basic research indicates that one of the many factors affecting the durability of wooden pallets is the moisture content of the parts at the time of assembly.

Many pallets are made from green lumber *(5, 6, 12, 14)* and, because green lumber shrinks and often warps as it dries, we studied the effects of the initial moisture content of hardwood pallet parts on service life and maintenance cost. After 4 years of service testing 90 hardwood pallets in a fruit processing plant, we found that a pallet made with green stringers and predrilled, air-dry deckboards gave better service and cost less to maintain than a pallet made entirely from either green or air-dry lumber.

WHAT WE DID

Pallet Specifications

We made 90 pallets of three types from native red oak lumber as follows:

30 pallets with green deckboards and green stringers
30 pallets with predrilled, air-dry deckboards and predrilled, air-dry stringers
30 pallets with predrilled, air-dry deckboards and green stringers

The above types are referred to as "all-green," "all-dry," and "dry-green," respectively, in this report.

Air-dried parts at time of assembly averaged 13.9 percent moisture content (MC), which was judged to be the outdoor equilibrium moisture content (EMC)[2] of wood in Southern Illinois during the 4-year testing period. Thus, checking and splitting of the air-dry wood parts should have been minimized.

The moisture content of the green parts at assembly time was about 76 percent and was determined by averaging the moisture content of 60 wood samples taken from the pallet lumber. The moisture content of the green parts was about the same as the accepted average green moisture content of northern red oak *(13)*.

Except for the moisture content of the parts, all pallets were made to be as similar as possible. Lumber used was No. 3A Common red oak and pallets were made according to the recommendations of the National Wooden Pallet Manufacturers Association (NWPMA) *(8)* and the U.S. Forest Products Laboratory *(3, 4, 5, 6)*. These recommendations define

[1]*Numbers in parentheses refer to Literature Cited, page 11.*

NOTE: The author is Associate Forest Products Technologist headquartered at the Station's field office in Carbondale, Illinois, which is maintained in cooperation with Southern Illinois University.

[2]*EMC is the moisture content of wood when the amount of moisture in the wood balances with the moisture in the atmosphere. The moisture in the atmosphere was determined after averaging the mean-daily relative humidities and temperatures.*

allowable physical defects in the parts, like knots, wane, shake, cross grain, and warp, and allowable manufacturing defects like torn grain and areas of skip from hit-or-miss dressing.

The pallets were general purpose, 40 by 48 inches two-way entry, double-faced, and nonreversible with flush stringers. The stringers were made from nominal 2- by 4-inch stock (actually 1¾ by 3¾ inches) and decking was made from nominal 1-inch-thick (actually ¾ inch) stock in random widths. Deckboards were between 3½ inches and 9 inches wide and edgeboards were from 5½ to 5¾ inches wide. Matched sets of deckboards with similar widths were used for the top and bottom decks. Average spacing between top deckboards was 1 5/16 inches. Total width of boards in the bottom decking was about 23 inches.

We used 2½-inch, stiff-stock, spiral-groove, diamond-point pallet nails.[3] The points were 5/32-inch long; the head diameters were 9/32 inch; and the wire diameters were 0.120 inch. The threaded body with four flutes had an outside diameter of 0.138 inch and a thread angle of 30 degrees with the axis of the nail.

The nails were driven in two staggered rows ¾ inch and 1 3/16 inches from the deckboard ends and not less than ¾ inch nor more than 1¼ inches from deckboard edges. Nails in the center stringer were driven in two staggered rows, starting not closer than ¾ inch to the deckboard edges and 9/16 inch to either edge of the stringer. At least two nails were used at each joint with a maximum interrow spacing between nails of 3 inches. A nailing template was used to insure uniform spacing and all pallets were assembled and hand-nailed in jigs.

Dry deckboards were predrilled with a 0.135-inch bit. Dry stringers were predrilled to a depth of 1½ inches with a 0.110-inch bit. In accordance with common commercial practice in 1959, green pallet parts were not predrilled.

After fabrication, all pallet defects were diagramed and the pallets were weighed.[4] The all-green pallets weighed an average of 95 pounds, the dry-green pallets 80 pounds, and the all-dry pallets 77 pounds.

[3]*The nails were donated by the Independent Nail and Packing Company, Bridgewater, Massachusetts.*

[4]*Allowable defects as defined above.*

The Pallets In Use

In January 1960, we put the pallets in service in a fruit processing plant (fig. 1).[5] This plant was ideal for service testing because all pallets were stored and used inside the plant and we were able to obtain data on daily pallet movement.

The pallets were used whenever fruit was handled for packing or storage. The plant was operated 462 days during the 4-year testing period. Each pallet was moved an average of 277 times or 0.6 times per day of use. They carried loads ranging from 1,350 to 4,750 pounds in cold storage conditions for approximately 3 days at a time. Storage rooms were maintained at a relative humidity of 80 percent and a temperature of 32 degrees Fahrenheit, which would result in a 16-percent EMC in the pallet parts.

Pallet Inspections

During the 4-year test we inspected almost every pallet about 10 times. We identified and recorded all defects, damage, and failures that occurred, and measured deckboard and stringer widths to determine shrinkage. When a deckboard or part of a deckboard came loose from one or more stringers, the failure was noted and repaired, either by renailing or replacing the deckboard, and the pallet was put back in service. We recorded the time and materials required to repair the pallets.

FIGURE 1.— The study site — a fruit processing plant.

[5]*The plant is owned by Eckert Orchards, Inc., Carbondale, Illinois.*

WHAT HAPPENED AND WHY

Performance of Pallets

Excluding accidental damage, such as that caused by ramming with lift forks, 54 pallets failed at least once during normal use. Pallets with air-dry deckboards, predrilled and nailed to green stringers, were clearly superior to pallets made from either all-green, undrilled parts or all-dry, predrilled parts (table 1). Eighty percent of the all-green pallets failed at least once compared to 60 percent of the all-dry and only 40 percent of the dry-green pallets. Furthermore, 40 percent of the all-green pallets failed more than once but only 13 percent of the all-dry and 3 percent of the dry-green pallets failed a second time. All-green pallets averaged 1.4 trips to the repair shop during 4 years of use; almost twice as many repair trips as the all-dry and 3 times as many as the dry-green pallets.

The effect of initial deckboard moisture content on pallet serviceability became evident early in the test *(7)*. The superiority of pallets with air-dry deckboards and green stringers began to show during the second year of use, and was most pronounced through the third year. During the fourth year there was little difference in performance between the three types of pallets.

Nail-popping, the projection of nailheads above the surface of the deckboards due to shrinking of stringers, was prevalent in pallets made with green stringers. It did not occur in the pallets made with dry stringers (fig. 2). Nail-popping developed during the early stages of the test while the green stringers were drying. Most nail-popping was slight and it was not regarded as a serious defect in this study.

Table 1.--Failure of pallets and maintenance required due to damage in normal use

Age of pallet when requiring initial repair (years)	Pallet type when fabricated					
	All-green		All-dry		Dry-green	
	Number	Percent	Number	Percent	Number	Percent
Less than 1	8	27	1	3	1	3
1-2	7	23	8	27	3	10
2-3	4	13	2	7	1	3
3-4	5	17	7	23	7	23
Total	24	80	18	60	12	1/ 40
Pallets not requiring repair	6	20	12	40	18	60
Pallets requiring repair more than once	12	40	4	13	1	3
Average number of trips to repair shop in 4 years	1.4		0.8		0.5	

1/ Percentage difference due to rounding of fractions.

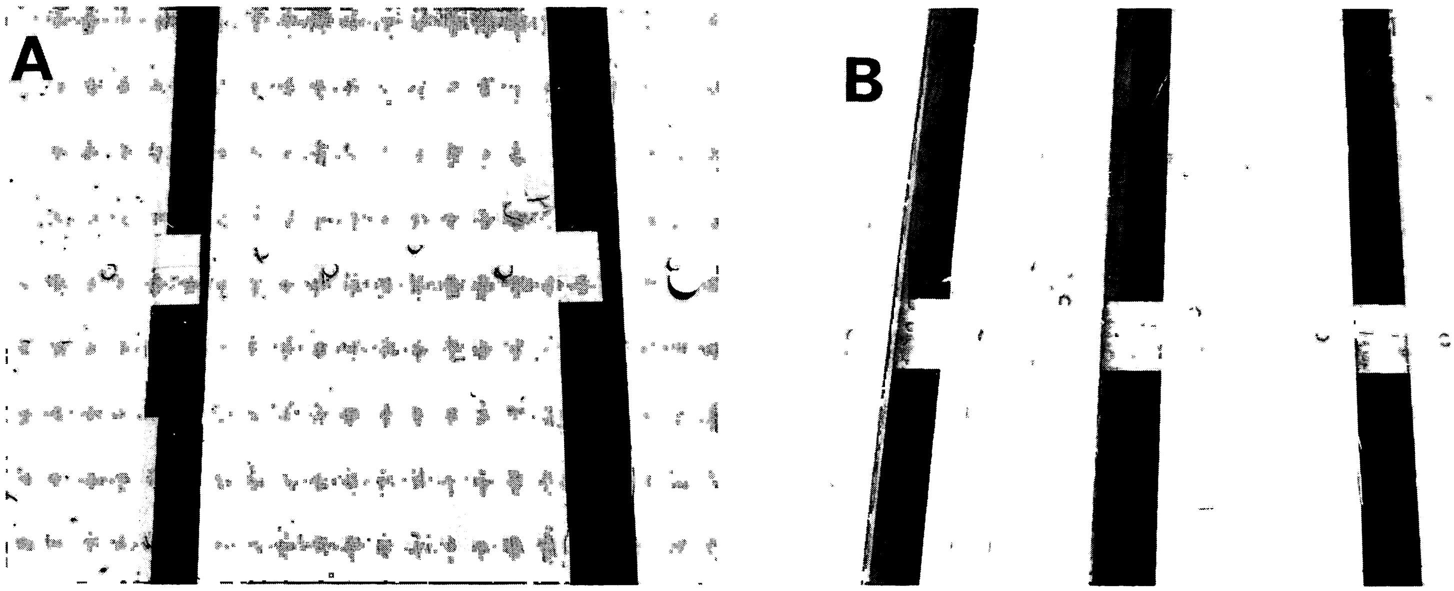

FIGURE 2.— (A) Nail-popping in an all-green pallet because of stringer shrinkage; (B) no nail-popping in an all-dry pallet because stringer did not shrink.

After 4 years of use the joints in most test pallets were tight and square regardless of the initial moisture content of the parts.

Type and Cause of Failures

Edge deckboard failure accounted for 88 percent of all damage to all-green pallets, 84 percent for all-dry pallets, and 90 percent for dry-green pallets. Of failures that occurred due to normal use, 97 percent were in edgeboards. Thus, this study showed that the life of a reusable pallet depends primarily upon the life of edgeboards and confirms data published by the NWPMA that 75 percent of all pallet failure occurs in the deckboards *(9)*.

During 4 years of use, all-green pallets had almost twice as many edgeboard failures as all-dry pallets, and 3 times as many as dry-green pallets (table 2). These failures resulted primarily from bumping, pushing, and prying action of lift-truck forks against edgeboards.

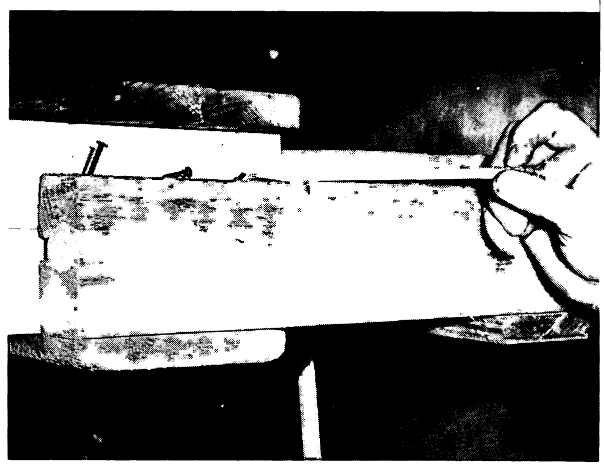

FIGURE 3.— Edgeboard separated from stringer. Leading nail (left) pulled through the deckboard. Pencil points at nail on inside edge of deckboard that sheared off.

Separation of Edgeboards from Stringers

Most often, particularly in the early stages of the test, edgeboards failed by coming loose from one or more stringers. When an edgeboard split at the nails, the nails usually pulled through the board. If the edgeboard was not split, the failure was usually because the nails sheared off between the stringer and the deckboard. Those nails closest to the leading or outside edge of the edgeboard most often pulled through, while those nearest the trailing or inside edge usually sheared off (fig. 3). Failure of the nails at the center of the joint was about equally divided between pullthrough and shearing.

When splits were present at the nails in edgeboards, the prying action of lift-truck forks caused the leading-edge nails to begin pulling through the deckboard. This increased the load on trailing-edge nails

Table 2.--Pallet edgeboard failure due to normal use during 4-year period

TOP EDGEBOARD FAILURES[1]

Length of service to failure (years)	Moisture condition of pallet parts when assembled					
	All-green		All-dry		Dry-green	
	Number	Percent	Number	Percent	Number	Percent
Less than 1	8	13	1	2	1	2
1-2	10	17	9	15	3	5
2-3	7	12	1	2	1	2
3-4	9	15	6	10	9	15
Total	34	57	17	[2]28	14	[2]23

BOTTOM EDGEBOARD FAILURES[1]

Length of service to failure (years)	All-green Number	All-green Percent	All-dry Number	All-dry Percent	Dry-green Number	Dry-green Percent
Less than 1	1	2	0	0	0	0
1-2	1	2	0	0	0	0
2-3	1	2	1	2	0	0
3-4	6	10	6	10	0	0
Total	9	[2]15	7	12	0	0
Grand total	43	36	24	20	14	12

1/ Percentages are ratio of edgeboard failures as a percent of total edgeboards. There are 60 top and 60 bottom edgeboards per pallet type.

2/ Percentage differences due to rounding of fractions.

and tended to shear them off. Since splits were more prevalent at nails in green deckboards (table 3), failure occurred most often in pallets with green decks.

Splitting of Edgeboards

In some cases edgeboards split from end to end and one or both halves of the edgeboard broke away from the stringers (fig. 4). These end-to-end splits developed gradually from short splits at the nails after repeated bumping and pushing by lift-truck forks. When splits (following cross grain) extended to the leading or trailing edge of the board, a wedge-shaped piece often broke off (fig. 5). After 4 years the number of wedges broken off the edgeboards averaged 3.1 per pallet for all-green pallets, 1.5 per pallet for all-dry pallets, and 1.9 per pallet for dry-green pallets. Wedge breakout did not cause edgeboards to be rejected or necessitate repair of the pallet.

Another type of splitting started in checks that developed in the bottom deckboards during the third year of the test. Long, deep, continuous checks developed on the upper face of many bottom edgeboards and wide interior deckboards (fig. 6). These checks sometimes extended the full length of the board. After the fourth year they were equally frequent and severe in all pallets regardless of original moisture content. In all-dry and dry-green pallets,

Table 3.--Occurrence of splits at nails in end joints of all pallet deckboards by pallet type, deckboard location, and time of splitting

(In percent)[1]

ALL DECKBOARDS

Time of splitting	Type of pallet: All-green	All-dry	Dry-green
Before nailing[2]	1.0	0.1	0.9
At time of nailing	29.9	1.5	.2
During use in:			
1960 (first year)	25.9	14.1	13.3
1961 (second year)	2.1	1.2	4.3
1962 (third year)	9.5	15.9	18.6
1963 (fourth year)	.3	4.9	.1
Total 1960-1963	37.8	36.1	[3]36.4
Total (at end of fourth year)	68.7	37.7	37.5
EDGEBOARDS ONLY[4]			
Total	72.0	50.0	48.0
INTERIOR BOARDS ONLY[5]			
Total	66.2	28.6	29.4

1/ Percentages are ratio of number of splits at nails in deckboard end joints to total nails in deckboard end joints. There are 1,656 nails in all-green, 1,658 nails in dry-green, and 1,693 nails in all-dry pallet end joints.

2/ Splits near the nails, but not caused by nailing.

3/ Percentage differences due to rounding of fractions.

4/ There were 720 nails in edgeboard end joints of each type of pallet.

5/ There are 936 nails in all-green, 973 in all-dry, and 938 in dry-green pallet interior deckboard end joints.

these checks averaged 34 inches in length, while in all-green pallets they averaged 37 inches in length. Oftentimes these checks extended through the board and developed into splits (fig. 7).

We believe this defect was caused by tension stresses in bottom deckboards that absorbed moisture from the floor causing the bottom face of the boards to swell while the upper face remained dry due to airflow across it. Cupping of the boards did not occur especially in all-dry pallets, because the boards were firmly nailed. Though these checks caused no failures during the 4-year test, it is likely that many boards eventually will fail because of them.

Influence of Initial Deckboard Moisture Content

The poor performance of green deckboards was due to numerous splits at the nails. Data on nail splits lead us to make the following conclusions:

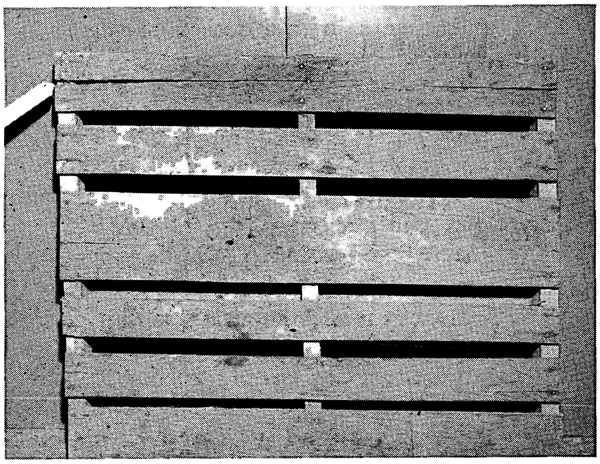

FIGURE 4.— Lengthened split causing edgeboard to split into two parts.

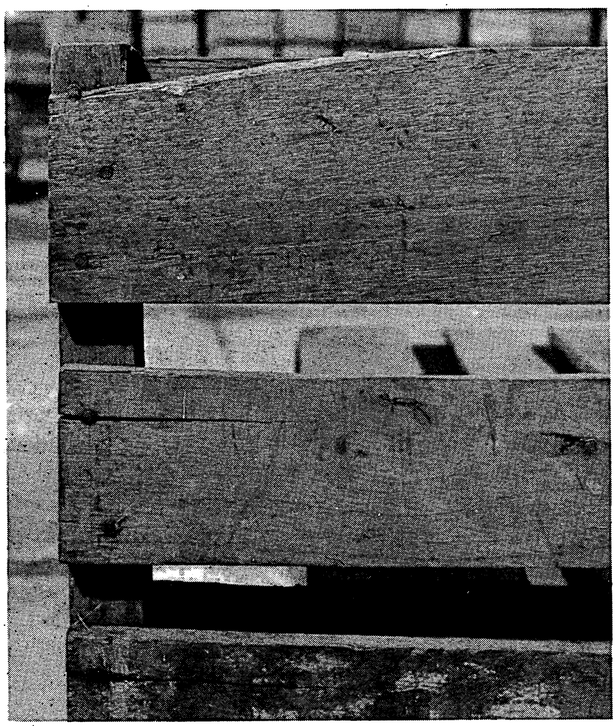

FIGURE 5.— Wedge breakout at leading (outside) corner of top edgeboard.

1. Most splitting of green deckboards occurred when the pallets were fabricated or during the first few months of the test, so splitting of green deckboards was probably due either to nailing or to stresses that developed at the nails as the deckboards dried.

2. Much of the splitting of deckboards was caused by bumping, pushing, or prying action of lift-truck

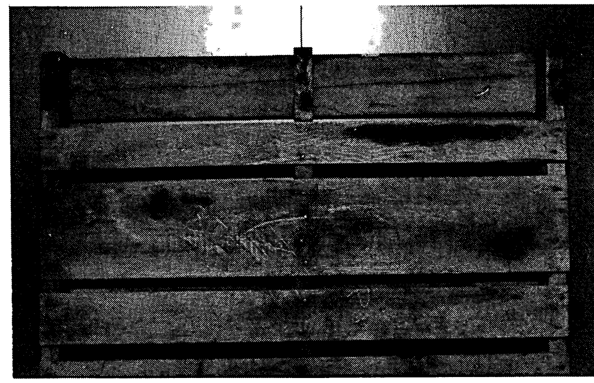

FIGURE 6.—Long, deep, continuous checking on upper surface of bottom edgeboard.

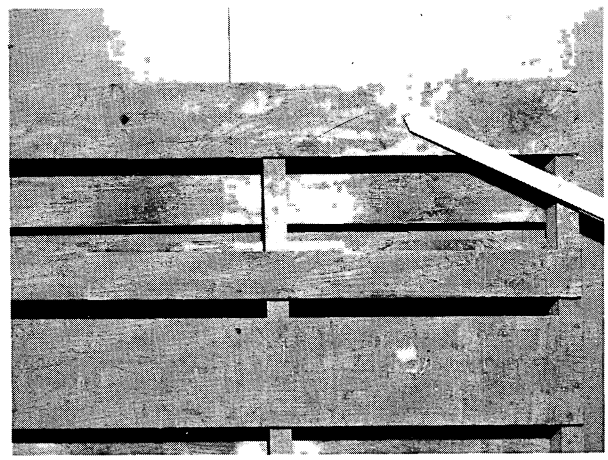

FIGURE 7.— Deep checking on upper face of bottom edgeboard has developed into a split on the bottom face. From left to right pointer indicates length of split.

forks during normal use as evidenced by:

a. Splits at 36 percent of the end joint nails in all dry and dry-green pallet deckboards. These splits were neither caused by nailing nor could they have been due to drying stresses in the deckboards.

b. Much more splitting occurred in the edgeboard end joints than in interior deckboard end joints on all pallet types.

3. Splitting of interior deckboards apparently had no detrimental effect on performance of the pallets. Splits developed at 66 percent of the end joint nails in green interior deckboards, yet only one interior deckboard failed in normal use. This suggests that for use conditions that existed in this test, life of green pallets might be materially increased by drying and predrilling the edge deckboards only. If so, the need for dry pallet parts and for predrilling would be minimized.

4. Predrilling dry deckboards practically eliminated splitting at the time of nailing and probably greatly reduced the development of splits at the nails during the first year of use. It is possible then that predrilling of green deckboards might have significantly improved the performance of all-green pallets.

5. There was practically no difference in the number of splits at deckboard end joint nails in all-dry and dry-green pallets so we must look for another explanation for the larger number of failures in the all-dry than in the dry-green pallets.

Performance of Dry versus Green Stringers

Green stringers shrank during the first few months of use and, as a result, joints between deckboards and stringers were loosened. When stringers shrank uniformly, the nailheads projected slightly above the surface of the deckboards. When stringers shrank into a diamond shape, the deckboards rested on the high side of the stringer and a gap opened between the deckboards and the low side of the stringer (fig. 8). We think the nails in these loosened joints yielded on impact of the lift-truck forks and absorbed much of the impact shock on the edgeboards of the dry-green pallets.

On the other hand, the nail joints in the all-dry pallets remained tight and rigid throughout the test. Nails did not yield on impact so repeated loading of the edgeboard caused splits at the nails to lengthen severely and, eventually, the deckboards came loose from the stringers.

FIGURE 8.— Stringer diamonding in an all-green pallet because of uneven shrinkage.

Predrilling of Green Deckboards

Deckboards of the all-green pallets used in this test were not pre-drilled because it was not required by NWPMA pallet specifications at that time *(8)* and is still not required in "A" Grade pallets today *(10)*.

Early in the test it became apparent that performance of all-green pallets might have been significantly improved by predrilling green deckboards. Consequently, we devised a supplemental test with a separate set of all-green pallets to study how predrilling before nailing might affect splitting.[6] We used 120 green-black oak edgeboards; 60 were predrilled and 60 were not. In each group of 60 edgeboards, 20 were plainsawed, 20 were quartersawed, and 20 were bastardsawed.[7]

These supplemental pallets were placed in the same warehouse, under the same environmental conditions, as the 90 test pallets, but were not used or moved by fork trucks. They were inspected periodically for splits at the end joint nails until, after 123 days, they reached 13.5 percent EMC.

The undrilled green edgeboards developed 3 to 6 times as many splits at the end joint nails as the predrilled green edgeboards, depending on the orientation of the annual rings in the boards (table 4). Nearly all splits occurred within 2 weeks after the pallets were made; only one split was added between 13 and 123 days after nailing. Equally important, quartersawed boards, both undrilled and predrilled, developed fewer splits at the end joint nails than either bastardsawed or plainsawed boards.

Most splits at the nails in the undrilled green boards were caused directly by nailing. Predrilling reduced the number of these splits by 86 percent, but it apparently did not reduce splitting due to shrinkage. Since it is reasonable to expect a high precentage of plain or bastardsawed boards in an average batch of pallet lumber, this supplemental study indicates that the performance of green pallets might be significantly improved by predrilling the edge deckboards. However, we believe that further tests of predrilled, green pallet deckboards *in use* are needed to better evaluate the benefits of predrilling.

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[6]*The nails were donated by Threaded Nails, Inc., Skokie, Illinois, and were of the same type as used in the earlier test.*

[7]*A plainsawed board has annual rings oriented at angles of 0 to 30 degrees, bastardsawed 30 to 60 degrees, and quartersawed 60 to 90 degrees with the face of the board.*

Table 4.--Percentage of nail splits caused by nailing and by deckboard shrinkage in supplemental test

(In percent)[1]

Board treatment	Green lumber type[2]		
	Plainsawed	Quartersawed	Bastardsawed
Predrilled	12.5	0.8	7.5
Undrilled	45.0	5.0	22.5

1/ Percent of nails at which splits occurred.
2/ Shrinkage rates from green to 13.5 percent MC were 5.0 percent for plainsawed, 3.0 percent for quartersawed, and 4.7 percent for bastardsawed lumber.

In this supplemental study the 5½-inch-wide quartersawed boards shrank less (0.17 inch) than the bastardsawed boards (0.26 inch) or the plainsawed boards (0.28 inch) when drying from the green condition to about 13.5 percent MC. The greater shrinkage in the plainsawed boards caused the two outer nails of edgeboard nail joints to bend about 3 degrees towards the center nail (fig. 9). The resistance of the nail to bending apparently restricted the movement of the wood during tangential shrinkage, weakened the end of deckboards, and made them more prone to splitting.

The pattern of nail bending in pallets in use was altered by repeated impacts from fork trucks. This was indicated by the difference of nail bending in the pallets that were service tested. In some pallets the leading nail bent about 5 to 6 degrees towards the center nail in a 3-nail edgeboard joint (fig. 10), but the trailing nail remained almost erect. The increased bending of the leading nail was evidence that the fork truck pushed the edgeboard back slightly, therefore increasing stresses at the leading nail and causing splits. When the grain sloped towards the leading edge, wedge breakout occurred. In pallets with dry deckboards most nails remained almost erect, thus indicating there were no serious stresses at nails.

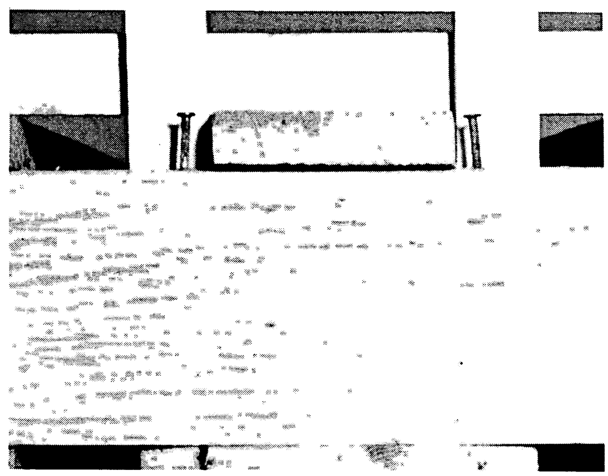

FIGURE 9.— Outer nails leaning 3 degrees toward board center in pallet that has not been moved by a fork truck. Lean is due to board shrinkage.

Pallet Maintenance

The moisture content of deckboards at the time of assembly subsequently affected maintenance. In this test, dry-green pallets required less maintenance. They needed about one-third fewer trips to the repair shop than all-green pallets and about one-half fewer trips than all-dry pallets (table 1). Furthermore, they needed about one-half as many replacement boards as dry-green pallets and about one-third as many replacement boards as all-green pallets (table 2).

At the repair shop, pallet maintenance consisted of either renailing the original deckboards or removing one or more deckboards and replacing them with new boards. With time studies we determined that replacement repairs take 2 to 3 times longer than renail repairs. Since dry-green pallets had fewer replacement-type failures (60 percent) than all-dry pallets (68 percent) and all-green pallets (90 percent), their maintenance took less time.

Consequently, dry-green pallets outperformed the other pallet types because (a) they required fewer trips to the repair shop; (b) they required fewer replacement boards; and (c) they required less labor per replacement board. These facts affected the longrun cost of using the test pallets.

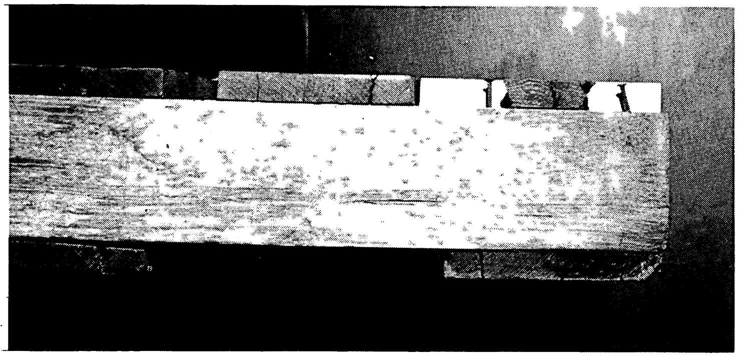

FIGURE 10.—Leading nail bending 6 degrees toward board center in pallet that has been moved about 277 times by fork trucks. Lean is due to impact loading and board shrinkage. Trailing nail is almost erect.

Table 5.--Average cost of producing and maintaining one pallet for 4 years[1]

(In dollars)

PALLET MANUFACTURING COSTS[2]

Materials and labor	Pallet type when fabricated		
	All-green	All-dry	Dry-green
Deckboard lumber	1.617	2.048	2.048
Stringer lumber	.580	1.009	.580
Nails (+ 10 percent)	.137	.137	.137
Labor (milling)[3]	.394	.394	.394
Labor (fabrication)[3/4]	.230	.558	.485
Machine replacement	.010	.010	.010
Total	2.968	4.156	3.654
4-YEAR PALLET MAINTENANCE COSTS			
Edgeboard replacement	.254	.179	.105
Transportation and overhead[5]	1.126	.626	.368
Labor[3]	1.057	.587	.345
Total	2.437	1.392	.818
Grand total cost	5.405	5.548	4.472

1/ Includes cost of labor, material, and equipment. Does not include costs of power, equipment maintenance, plant overhead, selling, and shipping, or profit.

2/ These costs probably do not represent commercial practice costs, but they do represent some indication of the percentage spread in costs between pallet types based on small-scale production experience.

3/ Labor based on $1.45 per hour for semiskilled labor.

4/ Only dry parts drilled.

5/ Rate based on a pallet maintenance study made of 59 pallet-using companies (2).

COST ANALYSIS

Pallet users are more interested in longrun cost than in the number and cause of failures of various kinds of pallets. So we recorded the cost of producing and maintaining the three types of pallets for 4 years (table 5). While the costs from our small-scale production probably differ somewhat from those found in a commercial operation, the percent differences in cost among the three types of pallets should be almost the same regardless of the number of pallets produced.

We estimate that the average 4-year cost of producing and maintaining a pallet made of dry deckboards and green stringers was about $0.93 less than the cost of a pallet made of all-green lumber and about $1.08 less than the cost of a pallet made of all-dry lumber. The annual cost of repairing a dry-green pallet was estimated to average $0.20. Total costs were $4.47, $5.40, and $5.55 for dry-green, all-green, and all-dry pallets, respectively.

SUMMARY

After 4 years of service testing in a fruit warehouse, red oak pallets made with predrilled air-dry deckboards and green stringers developed fewer failures than pallets made with predrilled all-dry or undrilled all-green parts. Most pallet failures were caused by bumping, pushing, and prying of lift-truck forks against edgeboards that had been weakened by splits at end joint nails. Most splits were caused by nailing or by shrinking of the edgeboards after nailing. Green edgeboard nail joints were weakened by splits that occurred at time of fabrication and by deckboard shrinkage.

Including both manufacturing and maintenance for 4 years, we estimate that a pallet made from air-dry deckboards and green stringers cost about $4.47 while one made from all-green parts cost $5.40 and one made from all-dry parts cost $5.55.

LITERATURE CITED

(1) Anonymous.
1964. Pallet production sets new record. *In* National Wooden Manufacturers Association News Release. South. Lumberman 208(2591): 48.

(2) Bolz, H. A. (Editor)
1958. Materials handling handbook. Amer. Soc. Mech. Eng. and Amer. Handl. Soc. 1,596 pp., Illus.

(3) Day, R. E.
1953. The wood pallet industry, its development and progress toward standardization. U.S. Forest Serv. Forest Prod. Lab. Rep. 1957, 20 pp.

(4) Heebink, T. B.
1958. Bin pallets for agricultural products. U.S. Forest Serv. Forest Prod. Lab. Rep. 2115, 10 pp., illus.

(5) ————
1959. Load carrying capacity of deckboards for general-purpose pallets. U.S. Forest Serv. Forest Prod. Lab. Rep. 2153, 10 pp., illus.

(6) ———— and Fobes, E. W.
1958. Hardwood pallet manufacturing. U.S. Forest Serv. Forest Prod. Lab. Rep. 2132, 25 pp., illus.

(7) Micklewright, J. T. and Dunmire, D. E.
1963. Use air-dry deckboards for better wooden pallets. U.S. Forest Serv. Res. Note CS-7, 4 pp., illus. Cent. States Forest Exp. Sta., Columbus, Ohio.

(8) National Wooden Pallet Manufacturers Association.
1954. Minimum standard specifications for warehouse, permanent, or returnable wooden pallets. 8 pp., illus.

(9) ————
1958. Care for wooden pallets can control maintenance costs to you. 16 pp., illus.

(10) ————
1962. Specifications and grades for hardwood warehouse, permanent or returnable pallets. 14 pp., illus.

(11) Sardo, William H., Jr., and Thomas, Gordon C.
1959. Are wooden pallets on their way out. Mod. Mater. Handl. 14: 104-106, illus.

(12) Sutherland, C. F., Jr.
1962. The market for wood pallets in the auto industry — a case study of the Ford Motor Company. U.S. Forest Serv. Lake States Forest Exp. Sta. Paper 104, 10 pp., illus.

(13) U.S. Forest Products Laboratory.
1955. Wood handbook. U.S. Dep. Agr. Handb. 72, 528 pp., illus.

(14) Warner, J. R., and Cowan, D. R.
1956. Wood pallets in the Minneapolis-St. Paul area: an outlet for low grade hardwoods. U.S. Forest Serv. Lake States Forest Exp. Sta. Paper 43, 34 pp., illus.