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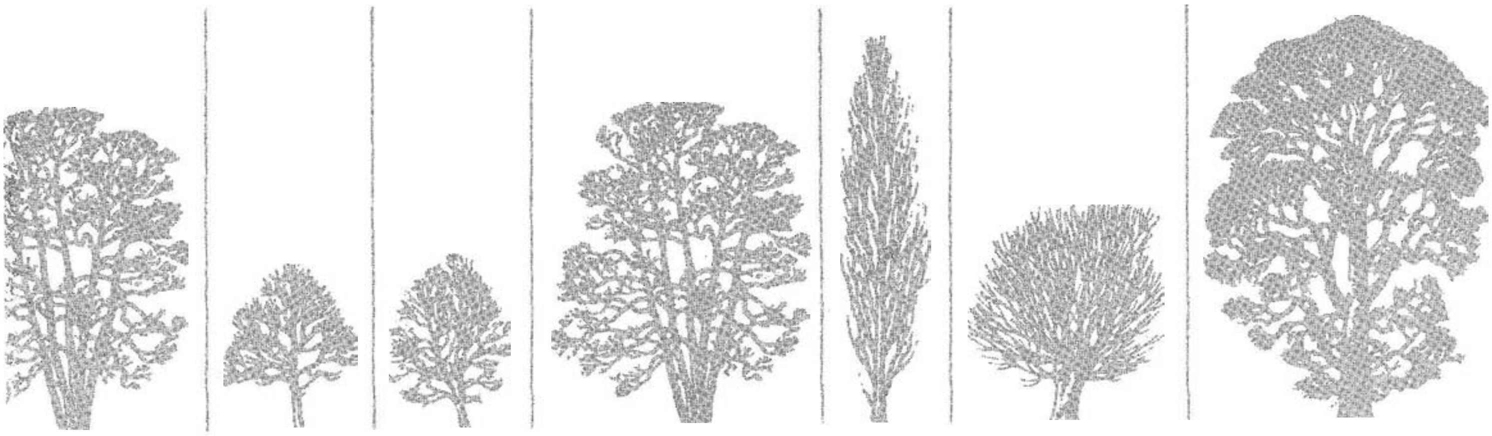
APPALACHIAN HARDWOODS FOR PALLETS

CORRELATION BETWEEN SERVICE AND LABORATORY TESTING



ABSTRACT

The Forest Products Laboratory conducted revolving drum tests of statistically random samples of similar pallets before and after 4 years of service with Eckert Orchards, Inc. of Carbondale, Ill. Reusable pallets of the types tested were estimated to be serviceable for about 4 to 12 years, depending upon the pallet type and composition. The work also indicated that the descending order of rough-handling resistance of reusable pallets was picture-frame, 3-stringer (control), and notched-stringer pallets. Laboratory revolving drum testing indicated an unrealistically longer service life for lighter weight pallets (such as those made of yellow-poplar). Nevertheless, it's believed that the testing technique used here provides a suitable basis for determining total service life.

APPALACHIAN HARDWOODS FOR PALLETS

CORRELATION BETWEEN SERVICE AND LABORATORY TESTING

By R.K. STERN[1] and D. E. DUNMIRE[2,3]

Forest Service
U.S. Department of Agriculture

INTRODUCTION

This study is a part of a research series conducted at the Forest Products Laboratory, to demonstrate the utility of Appalachian hardwoods for making pallets. The research was done in cooperation with the North Central Forest Experiment Station (NCFES), Forestry Sciences Laboratory at Carbondale, Ill., and with the Northeastern Forest Experiment Station and their Forest Products Marketing Laboratory at Princeton, W. Va. A summary of the major results of the preceding work is given in Appendix I.

Laboratory rough-handling tests of wood pallets are usually conducted until one or more of the parts of each become(s) dislodged. Tests of this nature can be conducted rapidly, inexpensively, and under well-controlled conditions when compared to evaluation by use in service. However, laboratory testing fails to reproduce some time-dependent conditions that affect pallet strength and durability; e.g., nailed joints that generally tend to lose strength with time, structural weakness created by weathering, and the associated progressive checking and splitting of members with time. Additionally, the mechanical strength of members tends to increase as the wood members dry.

There are positive and negative aspects of pallet appraisal based on laboratory testing or field usage. Ideally, the correlation between these two tests should be established. Tests could then be conducted on an accelerated laboratory testing basis with more assurance as to the application of results. This work was conducted to initially establish a relationship.

Specifically investigated was the development of an approximate correlation between laboratory

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[3] The authors gratefully acknowledge the assistance of R. E. Bodkin, a Physical Science Technician of the Carbondale laboratory who made detailed periodic observations of the pallets in service, and R. K. Geier, an Engineering Technician at FPL who conducted the experimental portion of this work.

testing of pallets to their destruction and their total service life under actual handling environmental conditions, before initial repair became necessary.

PROCEDURE

Materials and Assembly

Two sets of 120 pallets were constructed jointly by the Carbondale laboratory and FPL. Both sets of pallets were made from wood members under the same conditions from the same species groups and selected by systematic randomization. One new set was evaluated by laboratory testing one month after construction, and the results were presented in a Forest Service Research Paper.[4] The set of pallets discussed herein differed from the first in that some pallets were lost in service or repaired and, therefore, not included in the final testing. The essential details of the materials used and the construction of the pallets are given in Appendix II of this report for completeness and for the convenience of the reader.

Field Service

NCFES personnel at the Carbondale laboratory made periodic inspection trips and kept detailed notes on their observations during the 4 years of field service use at Eckert Orchards, Inc. One important observation was that the reusable-type pallets (i.e., the picture-frame, notched-stringer, and 3-stringer control types) were used to a much greater extent than the expendable types in the orchard operation. This was because of the greater rigidity of the reusable types and the resulting fork truck operator preference for this type to avoid spilling, collapse, etc. NCFES personnel estimated that reusable pallets were handled on the average of twice a week, but that most were customarily placed in storage for about 4-1/2 months per year. The 120 test pallets initially comprised about 15 percent of the 800 platform-type pallets employed at that time by Eckert Orchards, Inc.

Of the original set of 120, 77 unrepaired pallets qualified for laboratory testing after 4 years of use. During this period, 43 pallets were eliminated: 31 were lost in service and 12 others were repaired. Because this study was conducted to provide an estimate of service life before initial repair was necessary, these 43 pallets were not included in the experiment.

Subsequent Laboratory Testing

After a careful examination of all pallets returned to FPL, it was decided that the most relevant results would be obtained if all of the 77 unrepaired pallets were tested to a predetermined failure point by the revolving drum test. This type of test was selected (1) because of the similarity between loading of the pallets and rough handling of pallets during service, and (2) because, if other types of tests had been conducted with their corresponding end points as in the preceding test series,[4,5] a large number of the pallets would have been classified as “having failed” even before the laboratory tests had begun.

Therefore, each pallet was revolved in the drum until it was considered to be “completely unserviceable.” This condition usually occurred when at least three major components were separated from the pallet but complete unserviceability might have involved dislodgement of fewer (or more) than three major parts. For example, a pallet might have become completely unserviceable, yet still have lost fewer than three major parts. Also, several parts might have separated on the last drop of the test, and the resulting total might have become greater than three. Damage characteristics were noted and recorded continuously during the tests,

A drum 14 feet in diameter and revolving at the rate of one revolution per minute and having

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[4] Kurtenacker, R. S., Heebink, T. B., and Dunmire, D. E. 1967. Appalachian Hardwoods for Pallets--A Laboratory Evaluation. U.S. Forest Serv. Res. Pap. FPL 76. Forest Prod. Lab., Madison, Wis.

[5] Kurtenacker, R. S. 1969. Appalachian Hardwoods for Pallets: Effect of Fabrication Variables and Lumber Characteristics on Performance. U.S.D.A. Forest Serv. Res. Pap. FPL 112. Forest Prod. Lab., Madison, Wis.

a hexagonal interior was used for testing. During the tests the pallets slid, tumbled, and impacted the sides of the drum and the attached hazards until failure occurred.

PALLET CONDITIONING AND PERFORMANCE

The forms of damage observed included the following:

(1) Joint failure (i.e., pulled nails or staples and nailhead "pull–through"). This same phenomenon was indicated less obviously by joint looseness and racking.

(2) Failure of the fasteners themselves (broken nails or staples).

(3) Splitting of wood component parts (often beginning with existing splits accrued during nailing and seasoning checks, especially at fasteners).

(4) Separation of major pallet parts from the pallet proper.

A detailed list of the results is given in table 1.

Figures 1 through 14 give the reader a visual impression about the condition of representative pallets before and after laboratory testing at FPL. The condition just after service of a typical hickory pallet of each style is shown in figures 1 through 5. Residual pallet performance capability could not be estimated by the visible degradation resulting from field service. A typical range of pallet conditions after service, progressing from worst to best, that existed in each set is shown in figures 6, 1, and 7.

Some of the failure patterns after testing are shown in figures 8 through 14. By nature of their construction, picture–frame pallets resisted racking best, and they usually failed by separation of deckboards as shown in figure 8. Less rigid forms of pallet construction often underwent severe racking during the testing (fig. 11); this produced loose joints and hastened destruction of the pallets.

The nature of the failures appeared to be definitely related to the species of lumber used to make the pallets. For example, the relative presence of splits at failure is shown for oak and yellow–poplar pallets, respectively, from the same construction–type group in figures 12 and 14. The pallets made from both species had similar checks shortly after construction, but the checks in the yellow–poplar pallets elongated much more rapidly.

Rating of Damage

Initially, the possibility of rating the progression of revolving drum test damage was considered as being directly correlated with failure. Ideally, a comprehensive, weighted, rating scale would be used to appraise the remaining strength before failure of the pallet during service and laboratory testing.

Rating systems of this sort were tried and found to be cumbersome and impractical, because of the following factors:

(1) Uncertainty about the relative importance of individual factors contributing toward failure of pallet as a unit.

(2) The need, difficulty, and expense of checking pallets over carefully after each fall.

(3) The hidden or subtle progression of the following factors that can lead to failure:

(a) Broken nails.

(b) Nailhead pullthrough.

(c) Checks and splits.

(4) The difficulty of relating the nonlinearity of the racking–failure phenomena with number of falls in the revolving drum.

(5) Variations inherent to the tests themselves.

Service Life Estimation

In view of these uncertainties, it was decided to use a much simpler approach as follows:

$$\frac{(n_t - R)}{n_t} = \frac{2.5}{x} \qquad (1)$$

Therefore

$$x = \frac{2.5n_t}{(n_t - R)} \qquad (2)$$

where n_t = average number of falls in laboratory revolving drum tests of comparable[6] pallets,

[6] "New" pallets were those which had been assembled for 1 month and had not been used for testing or service previously.

$\underline{R}$ is the residual number of falls in laboratory revolving drum tests following 4 years of service in Eckert Orchard, Inc.'s system, $(n_t - R)$ is the relationship between 4 years of service and an equivalent amount of Laboratory rough handling, and $\underline{x}$ is the probable and adjusted total number of years of serviceability of pallets used throughout the year under similar service conditions. (Note: A factor of "2.5" was used in equations (1) and (2), instead of "4.0," because the pallets were actually used only 62.5 percent of 4 years in service.)

For each group of pallets the number of falls required to dislodge the first n_1, second n_2, and third components n_3 of each were averaged individually and then pooled for an overall average n_t. Mathematically,

$$n_t = \frac{n_1 + n_2 + n_3}{3} \qquad (3)$$

A graphical summary of data obtained for the individual groups, as presented in table 1, is shown in figure 15.

As expected, all reusable pallets exhibited a definite drop between initial performance and that after 4 years. Expendable-type pallets produced contradictory failure data because they were essentially unused in service,

Adjusted average life expectancy values for pallets of the reusable type were calculated by equation (2) (table 2). This computation indicated that adjusted average service life expectancy for reusable pallets varied between 12.0 years for a hickory picture-frame pallet to 4.2 years for yellow-poplar picture-frame pallets and hickory notched-stringer pallets.

Laboratory revolving drum testing indicated an unrealistically longer service life for lighter weight pallets such as those made of yellow-poplar. This is not borne out by control information gained from actual service. However it is believed that the "before and after" testing technique used in the Laboratory provides a suitable basis for determining total service life. The greatest average performance from the standpoint of design was obtained with the picture-frame styles. In descending order, the 3-stringer style was next, and the notched-stringer style was last.

CONCLUSIONS

(1) Reusable pallets made of the materials and styles included in this work can be expected to function properly in general service from about 4 to 12 years before initial repair.

(2) Yellow-poplar pallets, being lighter in weight than similar pallets made from hickory or oak, initially resist a substantially greater number of impacts in the revolving drum test. However, the strength loss rate for similar yellow-poplar pallets is much greater than that for oak and hickory pallets of the same design. Therefore, it is concluded that pallets made from hickory or oak are usable substantially longer than similar pallets made from yellow-poplar.

(3) The overall descending order of serviceability of reusable pallets before initial repair is required is picture-frame, 3-stringer (control), and notched-stringer types.

(4) The equivalence between service life and laboratory testing was not established for expendable pallets because they were essentially unused during the 4-year period.

(5) Using the data given in this report, one can estimate the percent reduction in life expectancy for the included reusable pallet types and species under these service conditions.

Table 1.--Failures of pallet members

Pallet No.	Wood components[1]							Fastening[2]			Impacts to failure		
	Leading edge deckboard		Interior deckboard		Stringers		Block separated	Nails: broken	Nails pulled	Wood splits	First separation	Second separation	Third separation
	Top	Bottom	Top	Bottom	Split	Separated							
PICTURE FRAME--HICKORY													
H-2		1	2					5	11	10	96	104	170
H-3	2						1	27	0	14	94	115	[5]120
H-4		1		3			5	3	2	8	95	108	[5]120
H-6							3	15	5	6	140	168	172
H-9		2					1	26	1	0	44	54	55
H-11	[3]1						1	8	7	0	87	[3]127	--
H-14		2					1	20	1	5	118	[3,5]138	138
Totals	3	6	2	3			12	104	27	43	674	814	775
Average[4]								15	4	6	96	116	129
Range								3-27	0-11	0-14	44-140	54-168	55-172
Grand Average											114		
PICTURE FRAME--OAK													
0-2		3					6	32	0	4	137	[3,5]139	139
0-3	1	1					1	8	4	3	189	[3,5]199	199
0-6		1					2	13	0	0	159	162	174
0-10	1	1	1					11	20	0	135	138	139
0-15	1	1	1					33	3	2	146	[3,5]158	158
0-16		1					1	9	1	7	82	[3]133	--
Totals	3	8	2				10	106	28	16	848	929	809
Average[4]								18	5	3	141	155	162
Range								8-33	0-20	0-7	82-189	133-199	139-199
Grand Average											153		
PICTURE FRAME--YELLOW-POPLAR													
P-1	1	1					1	10	5	18	210	222	247
P-2		1					3	11	1	22	101	[3,5]288	288
P-6		1					2	5	0	20	36	124	248
P-9		1	1				1	19	0	9	152	221	240
P-10		1					2	6	1	7	131	151	179
P-11		2					1	7	4	15	170	233	269
P-14		1					2	6	1	7	143	224	228
P-15		1					2	2	1	7	118	154	157
Totals	1	9	1				14	66	13	105	1,061	1,617	1,856
Average[4]								8	2	13	133	202	232
Range								2-19	0-5	7-22	36-210	124-288	157-288
Grand Average											189		

Table 1.--Failures of pallet members--continued

Pallet No.	Wood components[1]							Fastening[2]			Impacts to failure		
	Leading edge deckboard		Interior deckboard		Stringers		Block separated	Nails broken	Nails pulled	Wood splits	First separation	Second separation	Third separation
	Top	Bottom	Top	Bottom	Split	Separated							
							NOTCHED STRINGER--HICKORY						
H-2		2		1				23	2	2	46	[3,5]74	74
H-3	1	2						14	2	11	[6]0	[6]0	[5]64
H-6	1	1		1	1			20	1	3	47	91	[5]93
H-10		5			5			14	1	1	30	57	[5]64
H-13	1	1		1				17	1	9	59	110	111
H-15	1	2						21	1	5	65	85	88
Totals	4	13		3	6			109	8	31	247	417	494
Average[4]								18	1	5	41	70	82
Range								14-23	1-2	1-11	0-65	0-110	64-111
Grand Average											64		
							NOTCHED STRINGER--OAK						
O-1	3							26	1	0	70	79	90
O-9	1	2			1			23	1	0	35	60	[5]69
O-12	1	2						22	1	4	46	[3,5]64	64
O-13	1	2			2			16	0	5	28	76	[5]120
O-14	1	2						22	1	4	51	57	73
O-15	1	1				1		18	0	0	54	55	66
Totals	8	9			3	1		127	4	13	284	391	482
Average[4]								21	1	2	47	65	80
Range								16-26	0-1	0-5	28-70	55-79	64-120
Grand Average											64		
							NOTCHED STRINGER--YELLOW-POPLAR						
P-1	2	1						21	0	6	89	100	105
P-12	1	1	1					24	1	2	116	120	128
Totals	3	2	1					45	1	8	205	220	233
Average[4]								23	1	4	103	110	117
Range								21-24	0-1	2-6	89-116	100-120	105-128
Grand Average											110		
							CONTROL--HICKORY						
H-1	1	2						14	1	12	58	100	104
Totals													
Average[4]													
Range													
Grand Average													

(Sheet 2 of 5)

Table 1.--Failures of pallet members--continued

Pallet No.	Wood components[1]							Fastening[2]			Impacts to failure		
	Leading edge deckboard		Interior deckboard		Stringers		Block separated	Nails broken	Nails pulled	Wood splits	First separation	Second separation	Third separation
	Top	Bottom	Top	Bottom	Split	Separated							
CONTROL--OAK													
0-6	1	1		1				18	4	8	97	102	121
0-7		2	1					12	0	6	83	114	120
0-8		2	1					28	0	2	100	121	130
0-11		2	1					19	2	6	74	78	80
0-12		2	1					23	0	4	90	97	102
0-16	1	2						19	0	7	63	88	99
Totals	2	11	4	1				119	6	33	507	600	652
Average[4]								20	1	7	85	100	109
Range								12-28	0-4	2-8	63-100	78-121	80-130
Grand Average											98		
CONTROL--YELLOW-POPLAR													
P-3	1		2					11	2	14	97	185	188
P-6		1				1		23	0	14	[6]0	174	199
P-8	1	1		1				16	0	11	125	172	186
P-14	2	1						16	2	13	65	108	122
P-16	1	1				1		17	0	31	166	176	186
Totals	5	4	2	1		2		83	4	83	453	815	881
Average[4]								17	1	17	113	163	176
Range								11-23	0-2	11-31	0-166	108-185	122-199
Grand Average											151		
MIL-P-26966--HICKORY													
H-1	1						2	0	0	28	6	14	21
H-4		1					3	1	6	19	[5]23	23	23
H-5		1					5	0	0	39	[5]19	19	28
H-7		1					3	0	8	18	[5]5	5	5
H-11			1				3	0	0	34	22	[5]34	34
H-12		1					2	0	0	21	[5]1	6	19
H-13		1					2	1	0	19	[5]4	4	4
Totals	1	5	1				20	2	14	178	80	105	134
Average[4]								--	2	25	11	15	19
Range								0-1	0-8	18-39	1-23	4-34	4-34
Grand Average											15		

(Sheet 3 of 5)

Table 1.--Failures of pallet members--continued

Pallet No.	Wood components[1]							Fastening[2]			Impacts to failure		
	Leading edge deckboard		Interior deckboard		Stringers		Block sepa-rated	Nails: broken	Nails pulled	Wood splits	First separation	Second separation	Third separation
	Top	Bottom	Top	Bottom	Split	Sepa-rated							
MIL-P-26966--OAK													
0-2		1					3	0	0	19	[5]35	[5]103	03
0-9		1					3	0	0	26	[5]46	6	46
0-13		1					2	0	2	10	[5]39	39	39
0-14		1					3	17	0	9	[5]75	[5]75	75
0-16		1					2	0	0	11	[5]50	[5]50	50
Totals		5					13	17	2	75	245	313	313
Average[4]								3	--	15	49	63	63
Range								0-17	0-2	9-26	35-75	39-103	39-103
Grand Average:											58		
MIL-P-26966--YELLOW-POPLAR													
P-2		1					2	0	0	19	[5]86	86	90
P-4		1					3	0	0	14	[5]45	45	45
P-6		1					2	0	0	8	49	59	87
P-7		1					2	0	0	22	2	24	55
P-9		1					3	0	5	21	[5]49	49	49
Totals		5					12	0	5	84	231	263	326
Average[4]								--	1	17	46	53	65
Range									0-5	8-22	2-86	24-86	45-90
Grand Average:											55		
SLICEWOOD--HICKORY													
H-5	1	1	1					21	6	6	38	81	91
H-7	1	2						16	11	9	35	67	85
H-8	1	1	1					4	25	3	39	43	52
H-11	1	2						21	2	1	[6]0	16	[5]44
H-13	1	2						6	20	10	57	62	70
H-15	2	2						0	45	0	71	76	[5]81
Totals	7	10	2					68	109	29	240	345	423
Average[4]								11	18	5	40	58	71
Range								0-21	2-45	0-10	0-71	16-81	44-91
Grand Average:											56		

(Sheet 4 of 5)

Table 1 .--**Failures of pallet members**--continued

Pallet No.	Wood components[1]							Fastening[2]			Impacts to failure		
	Leading edge deckboard		Interior deckboard		Stringers		Block separated	Nails broken	Nails pulled	Wood splits	First separation	Second separation	Third separation
	Top	Bottom	Top	Bottom	Split	Separated							
SLICEWOOD--OAK													
0-4	1	2						1	35	0	4	22	27
0-7	1	1	1					0	12	0	[6]0	[6]0	[5]7
0-11	1	2						0	36	0	12	34	74
Totals	3	5	1					1	83	0	16	56	108
Average[4]								--	28	--	5	19	36
Range								0-1	12-36	--	0-12	0-34	7-74
Grand Average:											20		
SLICEWOOD--YELLOW-POPLAR													
P-6		1	1					0	19	2	[6]0	[6]0	[5]53
P-12	1	1	1					3	23	3	64	74	77
P-13	1		1	2				0	47	0	[5]105	105	[5]109
P-15			1	2				0	29	0	38	[5]46	46
Totals	2	2	4	4				3	118	5	207	225	285
Average[4]								1	30	1	52	56	71
Range								0-3	19-47	0-3	0-105	0-105	46-109
Grand Average:											60		

[1]Indicates which members of each pallet failed.

[2]Numbers of each type of failure.

[3]Test stopped because the pallet was judged to be useless at this point.

[4]Rounded off to the nearest whole number.

[5]Two or more major parts dislodged by the same fall.

[6]Missing when test began.

(Sheet 5 of 5)

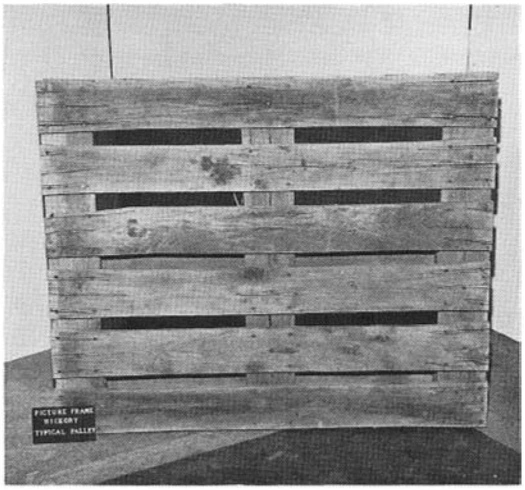

Figure 1.--A picture-frame pallet. (M 138 344-4)

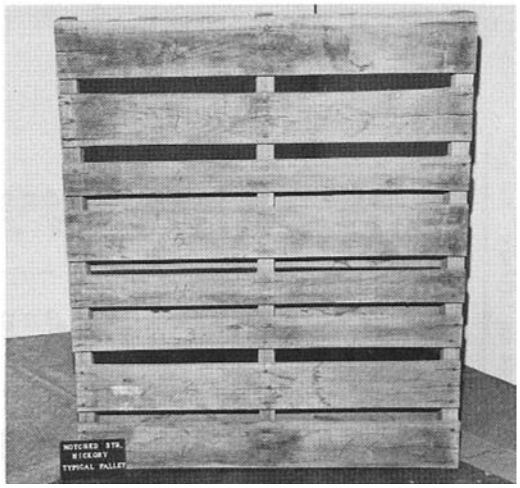

Figure 2.--A notched stringer pal let, (M 138 344-3)

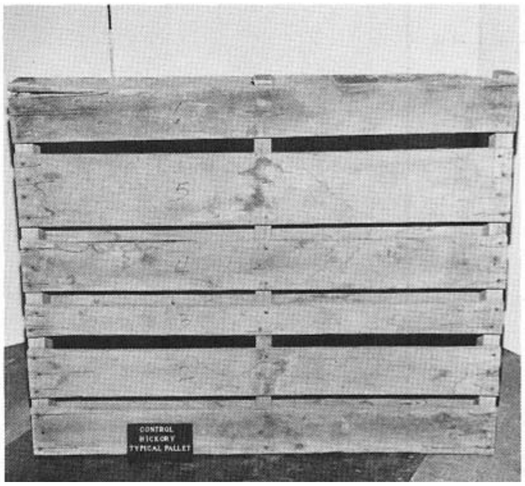

Figure 3.--A three-stringer (Control) pallet. (M 138 345-12)

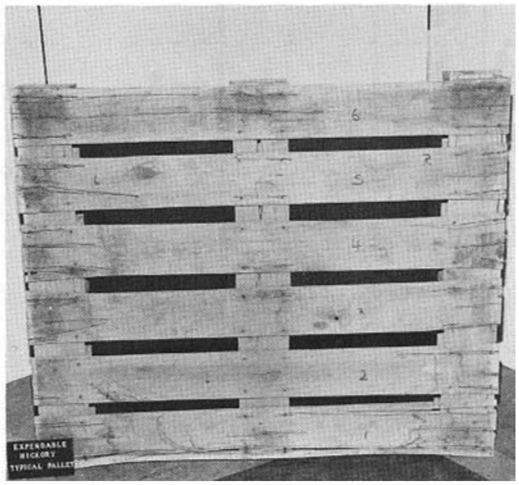

Figure 4.--A MIL-P-26966 (expendable) pal let. (M 138 344-1)

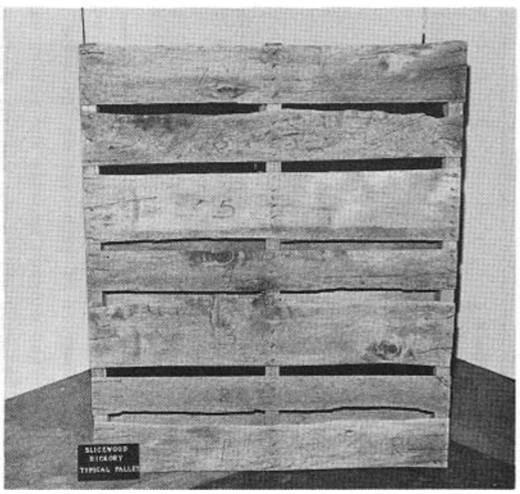

Figure 5.--An expendable slicewood pallet. (M 138 344-2)

Typical hickory pallets after 4 years of service (untested by FPL).

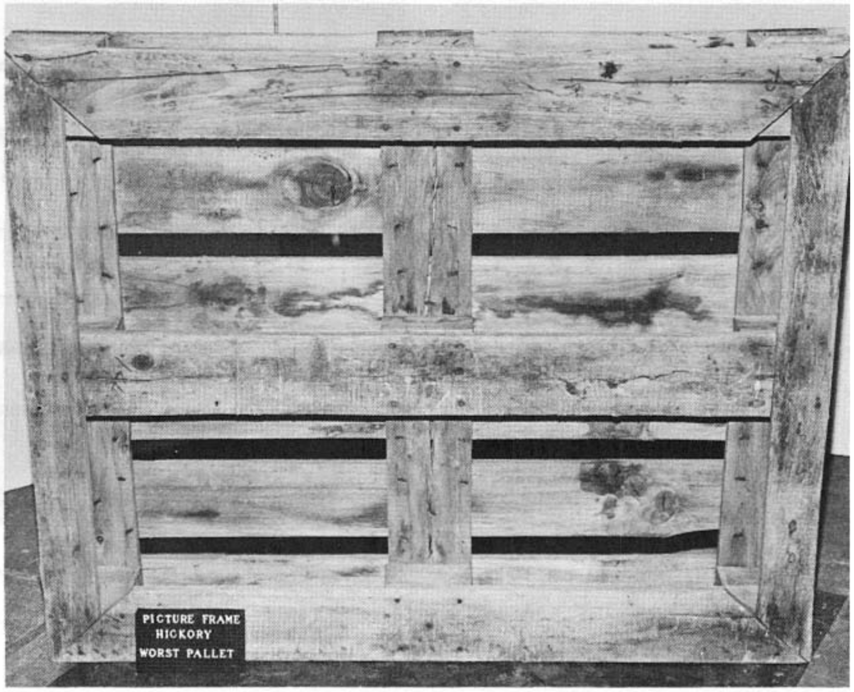

Figure 6.--Worst in a series of hickory, picture-frame pallets after 4 years of service.

(M 138 347-5)

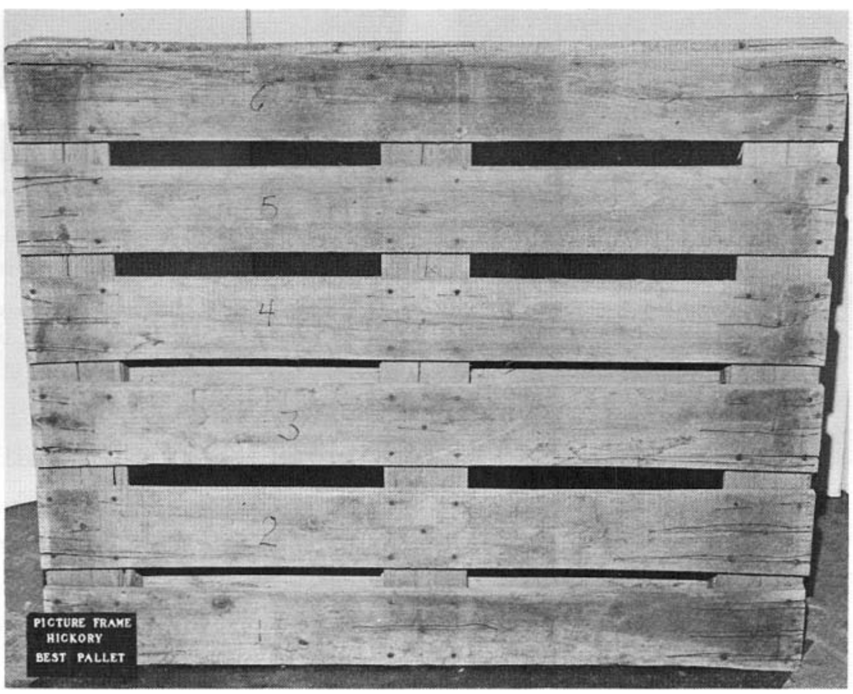

Figure 7.--Best in a series of hickory, picture-frame pallets after 4 years of service.

(M 138 347-4)

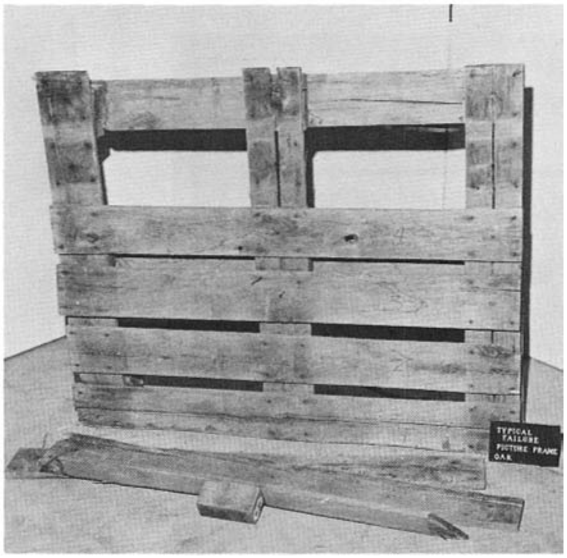

Figure 8.--An oak, picture-frame pallet. (M 138 570-11)

Figure 9.--A yellow-poplar, notched stringer pallet. (M 138 569-2)

Figure 10.--A hickory, three-stringer (control) pallet. (M 138 570-12)

Figure 11.--An oak, three-stringer (control) pal let showing racked condition at failure. (M 138 570-4)

Typical failure patterns of pallets after revolving drum testing.

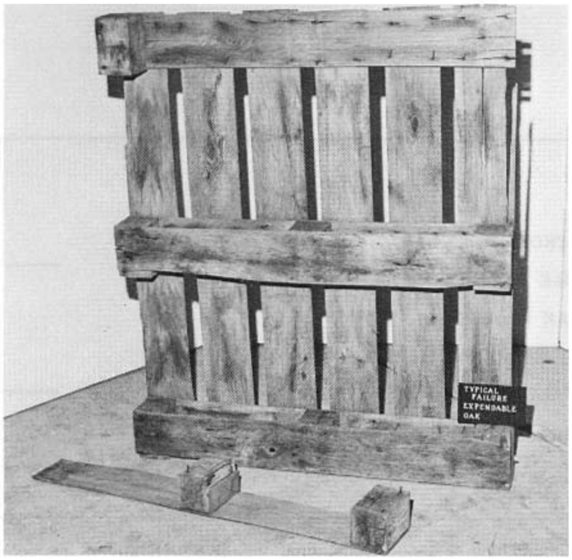

Figure 12.——An oak, MIL-P-26966 (expendable) pallet. (M 138 570–8)

Figure 13.——An oak slicewood (expendable) pallet. (M 138 570–1)

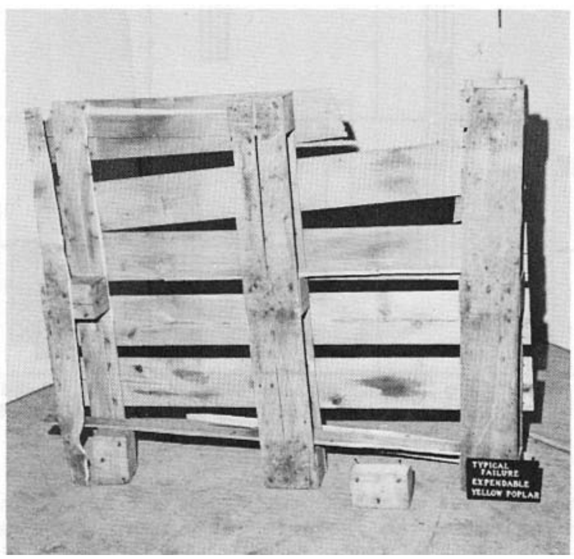

Figure 14.——A yellow–poplar MIL-P-26966 (expendable) pallet. (M 138 570–7)

Typical failure patterns of pallets after revolving drum testing.

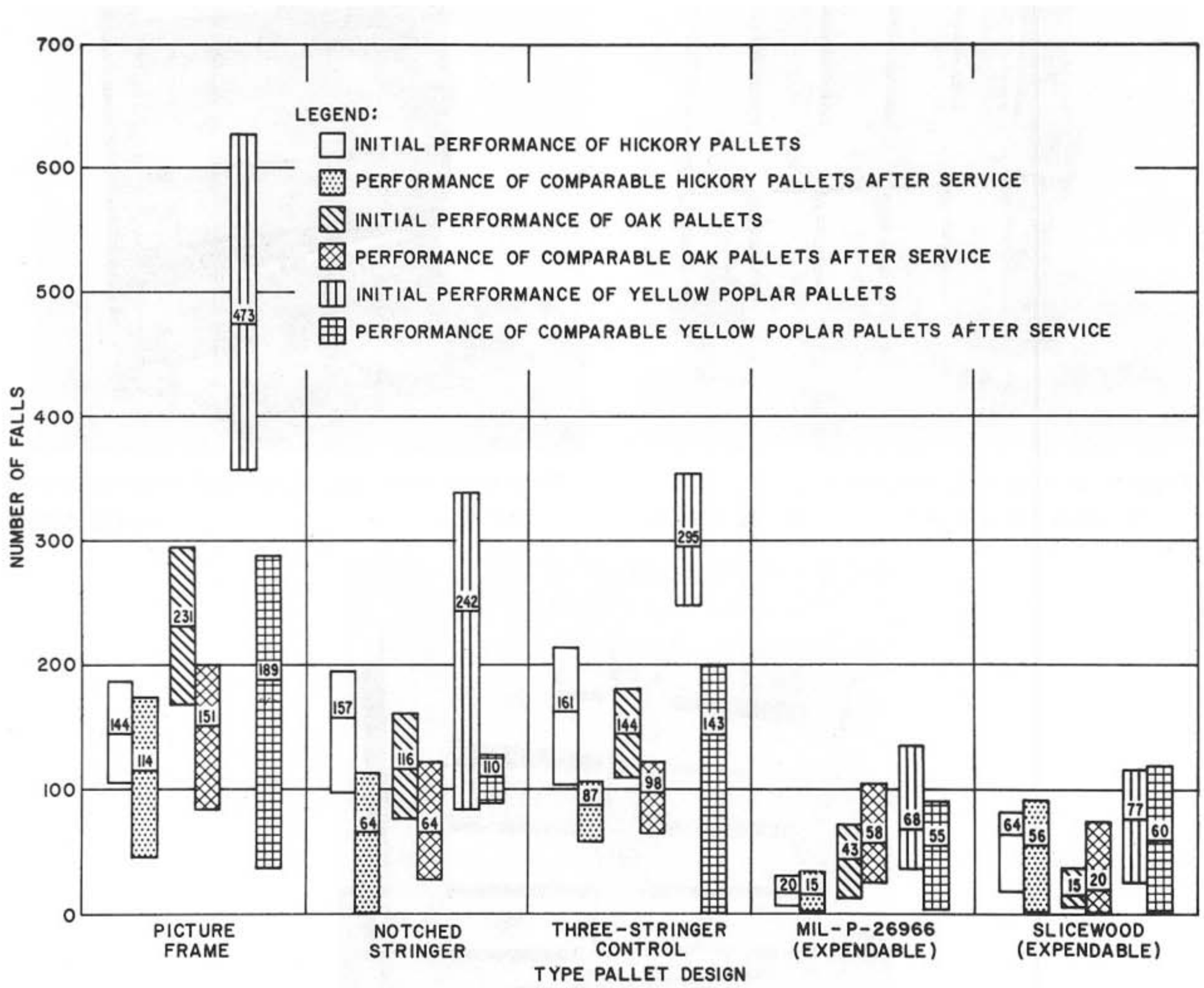

Figure 15.--A comparison of pallet performance before and after 4 years of service. The length of each bar indicates the range in performance for that group. The number corresponding to the horizontal line inside each bar indicates the average number of falls for the group. (M 139 779)

Table 2.--A summary of laboratory rough-handling performance data and estimates of pallet service life

Pallet types	Species	Weight at 7% M.C.	Falls in the FPL revolving drum: New pallet[1]: Average[5]	Falls in the FPL revolving drum: After field use[2]: Average[5]	Falls in the FPL revolving drum: Reduction in falls due to service[3]	Ratio of pallet weight to falls in drum for new pallets	Estimated pallet life[4]
		Pounds					Years
Picture-frame	Hickory	81	144	114	30	.56	12.0
	Oak	73	231	153	78	.32	7.4
	Yellow-poplar	49	473	189	284	.10	4.2
Notched-stringer	Hickory	71	157	64	93	.45	4.2
	Oak	64	116	64	52	.55	5.6
	Yellow-poplar	43	242	110	132	.18	4.6
Three-stringer (controls)	Hickory	71	161	87	74	.44	5.4
	Oak	64	144	98	46	.44	7.8
	Yellow-poplar	44	295	151	144	.15	5.1
MIL-P-26966 (expendable)	Hickory	43	17	15	[6]	[6]	[6]
	Oak	42	43	58	[6]	[6]	[6]
	Yellow-poplar	27	68	55	[6]	[6]	[6]
Slicewood	Hickory	43	64	56	[6]	[6]	[6]
	Oak	39	15	20	[6]	[6]	[6]
	Yellow-poplar	30	77	60	[6]	[6]	[6]

[1] Laboratory rough-handling tests of new pallets to destruction (1 month after fabrication and without field service).

[2] By Eckert Orchards, Inc. for 4 years.

[3] The rough-handling equivalent computed to 4 years of service to Eckert Orchards, Inc., $(n_t - R)$.

[4] By equation (2) in the text.

[5] Rounded off to the nearest whole number.

[6] Not computed.

APPENDIX I

PRINCIPAL CONCLUSIONS FROM PREVIOUS RESEARCH PAPERS IN THIS SERIES

FPL 76, Appalachian Hardwoods for Pallets: A Laboratory Evaluation

(a) Serviceable pallets of either the reusable or expendable types can be produced from any of the most prevalent Appalachian hardwood species: hickory, oak, or yellow-poplar.

(b) Splitting of boards resulting initially from nailing is a major cause of damage to pallets during service.

(c) "Picture-frame" pallets perform as well as, or better than, other styles included in the work

(d) An expendable-type slicewood pallet design is capable of producing acceptable pallet serviceability.

(e) Pallets of the notched-stringer design exhibit a characteristic tendency to split between notches during rough-handling tests.

FPL 112, Appalachian Hardwoods for Pallets: Effect of Fabrication Variables and Lumber Characteristics on Performance

(a) Established the relative order of effectiveness of various pallet fasteners in resisting impact loading conditions.

(b) Pallets with notched stringers do not perform as well m those made with blocks.

(c) Wane does not affect pallet rough-handling performance significantly.

APPENDIX II

MATERIALS AND ASSEMBLY

The most prevalent hardwood species in the Appalachian area (oaks, yellow-poplar, and hickories) were selected for study. The Forest Products Marketing Laboratory at Princeton, W. Va., obtained the raw materials for fabricating the two sets of 120 pallets. To make pallets of four of the five designs, rough greenlumber of each of the three species was shipped to the North Central Forest Experiment Station's project location at Carbondale, Ill.

Logs of each species, sufficient to produce material for the fifth 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 groups, 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.[7]--A 40- by 48-inch, four-way entry, double-face, nonreversible, flush type, nine block pallet.

(2) Notched-stringer design.--A 48- by 40-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 into pallet parts, with more than sufficient number being produced to permit elimination of

[7] Nicholson, S. S. 1965. Shipping Device. (A U.S. patent No. 3,204,583 assigned to American Can Co., New York, N.Y.)

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 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.

(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.

The defective pieces were discarded and the pallets were assembled. 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 kiln dried 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 for immediate evaluation. The other half were sent to Eckert Orchards, Inc., Carbondale, for service use and subsequent laboratory testing at FPL.

Slicewood Pallets

Pallets of only one design were fabricated at the Forest Products 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 crosscut into bolts, which, in turn, were sawn lengthwise into quarters or flitches. All flitches were submersed in steam-heated water with conditions controlled to bring the center of the flitches to within 10° F. of the desired temperature for slicing (190° F. for yellow-poplar and 210ÁF. for the oak and hickory). The flitches were cut into 3/8-inch-thick slicewood, on the Laboratory's slicer. After each flitch was sliced, there remained a backboard about 2 inches thick which was used to produce the stringer.

As with the sawn pallets, the slicewood pallets were assembled while the material was green, Pallets were then rapidly kiln dried 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 reached equilibrium conditions.

Half of the slicewood pallets were kept for immediate laboratory testing; the other half were sent through the North Central Experiment Station Forestry Sciences Laboratory at Carbondale to Eckert Orchards, Inc.

Fasteners

Helically threaded pallet nails, fivepenny cement-coated sinker nails, sixpenny common nails, and nylon-coated staples were used to assemble the pallets.