

by E. Paul Craft

**Construction - Grade
PLYWOOD
from Grade 3
APPALACHIAN OAK**



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PLYWOOD FROM LOW-GRADE OAKS

IN AN EFFORT to find a use for a large volume of the low-grade oak logs of Appalachia, we processed a sample of these logs in a typical southern-pine sheathing plant and determined the feasibility of converting them into construction-grade plywood.

These low-grade logs are available to new industry in large volumes, without disturbing the supply of logs to existing industry. The forests of Appalachia are growing hardwood sawtimber more than twice as fast as it is being used. A major cause for the underutilization of Appalachian hardwoods is the predominance of low-grade logs: about 50 percent of the commercial forest inventory consists of timber that will yield factory grade 3 logs,¹ yet only 30 percent of the logs used by sawmills are grade 3.

Commercial oak species represent 40 percent of the hardwood timber volume in the Appalachians, and they occur in sufficient concentration to support a number of medium-size plywood mills. One-half of the surplus growth of grade 3 oak in West Virginia alone is sufficient to support three plants, each capable of consuming 10 million board feet of timber annually. Therefore, only the oaks were considered in this study, and West Virginia was assumed to be representative of the Appalachian hardwood area (see appendix 1).

¹Grade 3 logs referred to in this report are those that meet the requirements for USDA Forest Service Factory grade 3 logs as described in A GUIDE TO HARDWOOD LOG GRADING, USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania, 1965.

STUDY PROCEDURE

The sample logs for the pilot test were purchased from a log yard located in Taylor County, West Virginia. Grade 3 oak logs were separated from woods-run logs as they arrived at the log yard. No distinction was made within the grade or among the oak species, except that logs with heart defects that would interfere with chucking in a lathe were rejected. The sample contained 105 logs, of which 77 were chestnut oak, 12 were white oak, and 15 were red oak. The average diameter was 11.7 inches.

The sample logs were processed at the Chesapeake Bay Plywood Company's automated pine-sheathing plant (a subsidiary of U.S. Plywood Corporation) at Pocomoke City, Maryland. No changes were made in the production procedure, machinery, or machinery adjustments normally used for pine, except as noted in the following manufacturing procedure.

MANUFACTURING PROCEDURE

Log-handling system.—The sample logs were loaded by fork truck from the yard onto the receiving deck of a Beloit² automatic log-handling system. The logs were moved by chain conveyors to a 35-inch Cambio ring-type debarker and debarked at 90 feet per minute. Logs were then moved by chain conveyors to a 5-foot diameter swing-type cutoff saw and were equalized to 8½-foot lengths. Finally, they were conveyed to storage bins.

Log-conditioning vats.—Logs were moved from storage bins by fork truck to an end-loaded surface-type hot water spray conditioning room and treated with 190°F. water for 24 hours.

Lathe charger.—Logs were moved from the conditioning room by fork truck to the plant receiving deck and were moved by chain conveyor to a Coe automatic centering and prespotting lathe charger.

² Mention of a particular product should not be taken as endorsement by the Forest Service or the U. S. Department of Agriculture.

Lathe.—Logs moved automatically from the lathe charger to a Coe M263 108-inch lathe equipped with Redco automatic controls with operator-option speed control and 3½-inch and 5½-inch dual chucks. The motor was operated at 1,350 rpm, reduced by 4.84 to a 3-inch spindle. Knife bevel was 1¾ inches, knife thickness was ⅝ inch, and knife angle was 90° at 18 inches from the spindle and 88½° at 4 inches from the spindle. The lathe was equipped with a ⅝ inch bronze whipple roller nose bar, 12/32 inch from the center to the knife. The horizontal opening from the surface of the roller bar to the knife edge was 0.110 to 0.115 inch. The lathe was set to cut 0.126 inch veneer. Chuck pressure was set at 450 p.s.i. holding pressure. The logs were peeled at an average of 1.7 logs per minute.

Tray system.—A Redco 5-deck, 120-foot-long tray system was charged by an operator-option manual or automatic tipple. Normally, the roundup waste is dropped through a gate in front of the tipple onto a conveyor that feeds the chipper, and green defect clippings are returned to this conveyor by a belt extending from the end of the grading table under the tray system back to the chipper conveyor. However, because the plant could not permit hardwood chips in their pine chip system, the gate was kept closed, and all roundup material was moved with the veneer through the tray system and was discharged over the end of the grading table. This caused considerable delay in the green-line production and frequently interrupted the veneer flow. In order to obtain accurate log-peeling times, downtime due to these interruptions was recorded and applied to the peeling-rate calculations.

Green clipper.—The green veneer was discharged from the trays over fixed unloader aprons, controlled by auto-magnestats, to an automatic Elliott Bay 108-inch clipper. The clipper was set to clip 54-inch and 27-inch widths and had operator over-ride controls to salvage random widths of usable veneer 6 inches and wider.

Green sorting table.—Clipped veneer passed over a 60-foot-long sorting table at 220 f.p.m.; the veneer was sorted to full-size sheets, 27-inch sheets, and random-width strips. All green waste

was discharged over the end of the table and collected for weighing.

Dryer.—Green veneer was transferred by fork truck from the sorting-table stack to dead-roll cases in front of the dryer loader. A Coe 16-section, 4-line, steam-heated, jet-type dryer was charged with veneer by a Coe automatic loader that was hand-charged from the dead-roll cases.

The dryer temperature ranged from 385°F. at the green end to 360°F. at the dry end. Drying time required to attain 4- to 6-percent moisture content was 16 minutes. Thickness and width was measured at random on 10 full-size sheets before and after drying (table 1).

Dry-grading line.—The veneer passed from the dryer through a cooling section and was discharged by a Coe unloader onto a dry-grading table. All veneer was passed through a Laucks-Sentry bar-type moisture detector. Veneer with more than 6-percent moisture content was marked automatically for redrying.

The dry veneer was separated into stacks of faces (grade C and better); full size sheets for backs and cores (grade D); full-length strips, 27 inches wide; fish tails and random-width strips; and cull. The veneer was graded according to U.S. Product Standard PS 1-66 for softwood plywood, except that veneer better than grade C was not segregated.

Table 1.—Results of veneer shrinkage tests

Sample No.	Species of oak	Thickness			Width		
		Green	Dry	Shrinkage	Green	Dry	Shrinkage
		<i>Inches</i>	<i>Inches</i>	<i>Percent</i>	<i>Inches</i>	<i>Inches</i>	<i>Percent</i>
1	Red	0.142	0.130	8.5	54 $\frac{1}{2}$	51 $\frac{1}{8}$	6.2
2	Chestnut	.134	.118	11.9	53 $\frac{7}{8}$	50 $\frac{5}{8}$	6.1
3	Chestnut	.133	.125	6.0	53 $\frac{1}{2}$	49 $\frac{3}{8}$	7.3
4	Chestnut	.136	.120	11.8	54 $\frac{1}{16}$	50 $\frac{1}{16}$	7.6
5	White	.136	.123	9.6	54 $\frac{1}{8}$	49 $\frac{7}{8}$	7.9
6	White	.124	.114	8.1	54 $\frac{7}{8}$	51 $\frac{3}{8}$	6.5
7	Red	.144	.137	4.9	54 $\frac{7}{8}$	51 $\frac{3}{4}$	6.0
8	Red	.140	.129	7.9	54 $\frac{1}{2}$	51 $\frac{1}{4}$	6.0
9	Chestnut	.140	.132	12.9	54 $\frac{1}{4}$	51 $\frac{1}{2}$	5.1
10	Chestnut	.136	.133	2.2	56	50 $\frac{1}{2}$	11.6

Glue line.—All grade C and better veneer was moved by fork truck to the lay-up line along with the grade D backs and cores. The balance of usable veneer was cut into 1/2-inch-long pieces by a Globe band saw, for crossbands. All crossbands were transferred to the glue line by fork truck.

Crossbands were fed through a Globe glue spreader (40-durometer rubber rolls with 9- and 11-thousandth-inch grooving) to the lay-up line.

Crossbands were coated with Reichhold's phenolic-resin-based adhesive mix at the rate of 83 pounds per thousand square feet of double glue line, according to the following formula:

2,500 pounds Reichhold plyophen
718 pounds water
400 pounds furafil
150 pounds wheat flour
125 pounds 50-percent caustic solution
20 pounds soda ash

This formula was selected from 18 different phenolic formulations that were tested previously at the Reichhold Chemicals Company laboratory. Seventy-three panels were tested using the various mixes at a variety of press-cycle, glue-spread, and assembly-time specifications (table 2).

Lay-up.—The veneer was laid up manually into 3/8-inch, 1/2-inch, 5/8-inch, and 7/8-inch panels (table 3).

Pre-press.—The panels were moved manually over roll conveyors to a Globe hydraulic pre-press and were pressed at 150 p.s.i.

Hot press.—Panels were moved to the hot-press loading elevator over roll conveyors and were loaded manually into a Williams White, hydraulic-operated, steam-heated, 36-opening hot press. The panels were pressed at 200 p.s.i. with platen temperatures of 310°F. (table 3).

Test samples.—After the panels were unloaded automatically from the hot press, the top and bottom layer of each load was marked for test samples. Samples were tested for glue-line quality at the American Plywood Association (A.P.A.) laboratory according to PS 1-66 standards for construction-grade softwood plywood.

Table 2.—Abbreviated results from laboratory tests for glue-line quality

Glue No. ¹	No. of panels	Glue spread ² (double glue line)	Assembly time ²	Press cycle	Temp.	Press	Shear ^{2,3}	Wood failure ^{2,3}	Species	Moisture content
		<i>Lbs./M sq. ft.</i>	<i>Min.</i>	<i>Min.</i>	<i>°F.</i>	<i>P.s.i.</i>	<i>P.s.i.</i>	<i>Percent</i>	<i>Oaks</i>	<i>Percent</i>
22-398	4	71	15	7½	290	200	296	65	Mixed	5 to 6
22-398+	6	67	18	7½	290	200	278	66	White	5 to 6
EPH2551	9	85	20	7½	290	200	221	32	White	5 to 6
EPH2601	9	76	17	8	290	211	281	69	White	5.6
EPH2500	5	80	60	8	290	225	253	66	White	5 to 6
EPH2551	5	80	18	7½	310	225	290	71	Mixed	5 to 6
E2148	1	80	15	7½	310	225	338	76	White	5 to 6
26-6000	3	80	15	7½	310	225	412	57	Chestnut	5 to 6
EPH2500	5	80	15	7½	310	225	295	70	Mixed	5 to 6
EPH2551	8	80	15	7½	310	225	307	67	Mixed	6 to 7
EPH2551	6	80	20	7½	310	225	270	51	Chestnut	6 to 7
EPH2551	4	86	10	7½	310	225	256	66	Chestnut	3
100R22-01	1	83	10	7½	310	225	309	78	Chestnut	6.8
EPH2501	4	83	10	7½	310	225	276	38	Chestnut	4.4

¹ All numbers are Reichhold Chemicals Company's designation for specific southern pine phenolic adhesive formulation. Duplicate numbers have different mix proportions.

² Figures are average for the panel numbers indicated.

³ Panels were tested by vacuum-pressure method as described in PS 1-66 standards for exterior glue-line quality.

Table 3.—Panel assembly and press specifications

No. of panels	Glue-spread (double glue line)	Total assembly time	Hold time	Pre press time	No. of plies	Panel thickness	Hot press	Hot press time
	<i>Lbs./M sq. ft.</i>	<i>Min.</i>	<i>Min.</i>	<i>Min.</i>		<i>Inches</i>	<i>Psi-°F.</i>	<i>Min.</i>
16	83	8	0	0	5	$\frac{5}{8}$ *	200-310	9
15	83	14	0	0	5	$\frac{5}{8}$	200-310	9
20	83	22	3	4	5	$\frac{5}{8}$ **	200-310	9
23	83	21	3	4	5	$\frac{5}{8}$	200-310	9
20	83	20	7	4	5	$\frac{5}{8}$	200-310	9
19	83	19	4	4	4	$\frac{1}{2}$	200-310	7
12	83	20	12	0	4	$\frac{1}{2}$	200-310	7

*Included two $\frac{3}{8}$ -inch, 3-ply panels.

**Included one $\frac{7}{8}$ -inch, 7-ply panel.

Trim and grading line.—The panels were moved by fork truck from the hot press to a Cardwell feeder and automatically fed through a Cardwell panel sizing and grading system equipped with Globe trim and skinner saws.

Packaging.—Finished panels were banded for shipment by an Interlake strapping machine.

LOG YIELDS

The sample logs scaled 3,567 board feet, Doyle scale; or 4,933 board feet, International 1/4-inch scale. The yield of usable veneer was 222 cubic feet, the equivalent of 2.18 square feet of 3/8-inch panels per board foot of log input, Doyle scale; or 1.50 square feet of 3/8-inch panels per board foot of log input, International 1/4-inch scale.

It should be noted that the average diameter of the sample logs was only 11.7 inches as compared to the estimated average 13.1-

Table 4.—Log yields

Item	Actual ¹		Recalculated ²	
	Volume	Scaled volume	Volume	Scaled volume
	<i>Cu. ft.</i>	<i>Percent</i>	<i>Cu. ft.</i>	<i>Percent</i>
Scaled input	678	—	840	—
Yield output:				
Green waste ³	442	65	373	44
Dry waste ⁴	144	21	183	22
Veneer	222	33	409	49
Total output ⁵	808	—	965	—

¹ Yield from pilot test using 8½-foot logs with an average diameter of 11.7 inches peeled on an 8½-foot lathe.

² Computed yield using 8½-foot logs with an average diameter of 13.4 inches peeled on an 8½-foot lathe, and cores re-peeled on a 4½-foot lathe (see appendices 3, 4, and 5 for calculations).

³ Green waste includes all chippable waste—cores, taper, roundup, and green clippings.

⁴ Dry waste includes shrinkage, degrade veneer, fishtail ends, spreader rejects, and trim waste.

⁵ Total output exceeds scaled input because log-taper volume is not included in scale input. Taper volume was 130 cubic feet or 19 percent of the actual scaled input and 15 percent of the recalculated input, and this volume is included in green waste.

inch diameter of grade 3 Appalachian oaks³ (see appendix 2). Therefore, additional veneer yield could be expected from a more representative sample of grade 3 oak logs. Additional veneer yield could have been obtained by repeeling cores above 6 inches in diameter in a 4½-foot lathe. With this additional yield, the yield relationship becomes 2.83 square feet of ¾-inch plywood per board foot of log input, Doyle scale; or 2.08 square feet per board foot of log input, International ¼-inch scale.

Green chippable waste—including material from roundup, defect clippings, cores, and taper—accounted for 65 percent of the scaled cubic input volume. A comparison of actual log yields and recalculated yields is shown in table 4.

A tabulation of data collected is shown in appendix 3, an analysis of data from field results is shown in appendix 4, and an analysis of recalculated data is shown in appendix 5.

THE PLYWOOD PRODUCT

Finished plywood from the pilot test consisted of:

<i>4- by 8-foot panels (No.)</i>	<i>Thickness (inch)</i>	<i>Plys (No.)</i>
1	7/8	7
91	5/8	5
31	1/2	4
2	3/8	3

Because of the way oaks branch, the knots occurred in an alternate pattern over the faces and backs of the panels as compared to the strip pattern that occurs in pine plywood from whorled branches (fig. 1). End splits occurred in nearly all the oak panels, because of end checking of the sample logs while in storage. However, these splits did not exceed those allowed in the PS 1-66 standards for C-D softwood plywood.

Two of the panels were sanded, grooved, and finished with

³ Diameter distribution data from USDA Forest Service Research Paper FPL-63, June 1966: tables 21, 27, and 33.

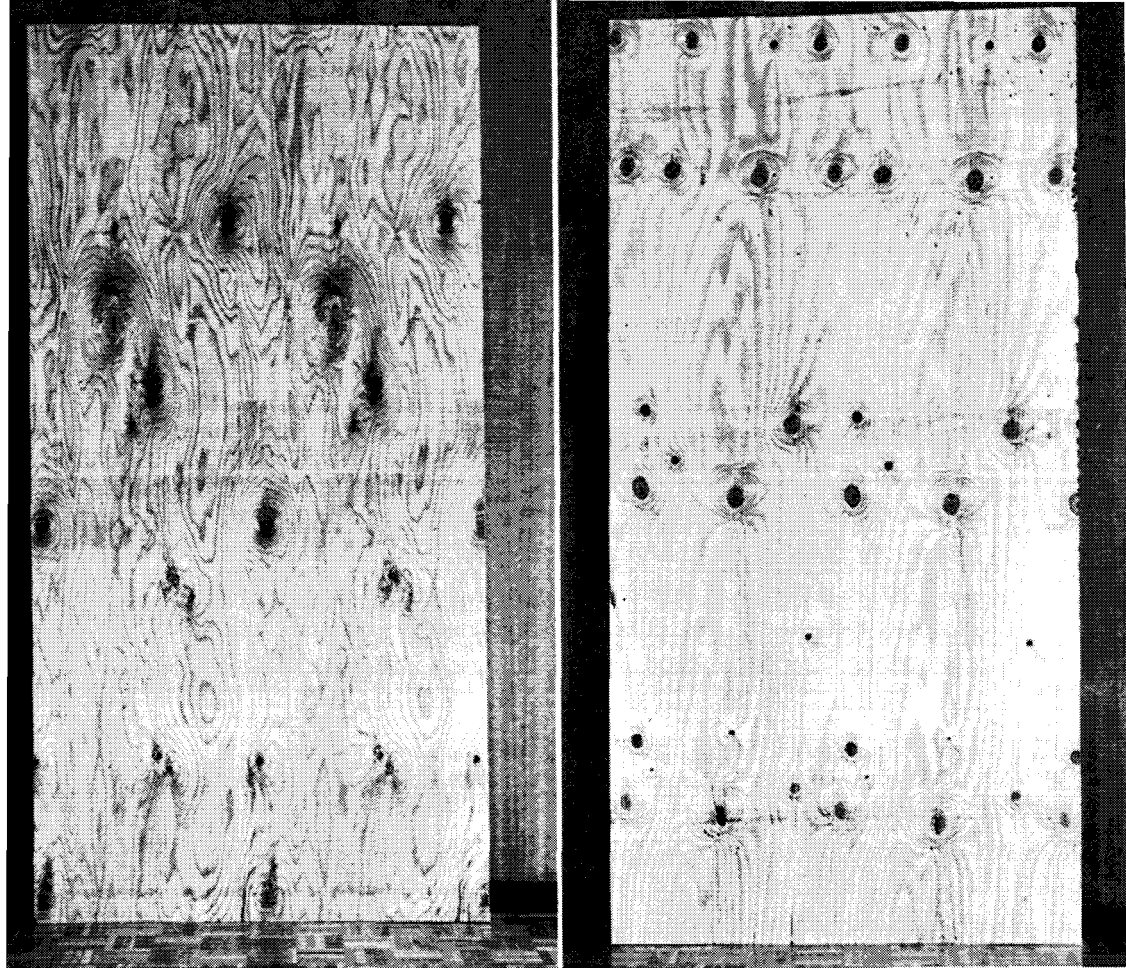


Figure 1.—Grade D back of a typical oak test panel (left), and grade D back of a typical southern pine panel (right).

sealer and lacquer as examples of character-marked interior paneling (fig. 2).

Twenty-five of the $\frac{5}{8}$ -inch panels were used for top decks on 50 experimental 48- by 40-inch notched stringer warehouse pallets (fig. 3). These pallets meet the specifications of the Grocer Manufacturers of America and the National Wooden Pallet and Container Association's specifications for grade AA pallets. All 50 pallets were stored outside to evaluate the effect of weather on the oak plywood. After 9 months of exposure, no serious deterioration had been noted. These pallets will be included in an experimental program to palletize bulk mail in shipping routes

between Dayton, Ohio, and Springfield, Massachusetts. All pallets are labeled so that an accurate record of the field performance of each unit can be recorded.

The remaining panels will be used for roof sheathing and siding on an experimental storage building and a lumber dry kiln control room at the Forest Products Marketing Laboratory at Princeton, West Virginia.

None of the panels tested met wood failure requirements after

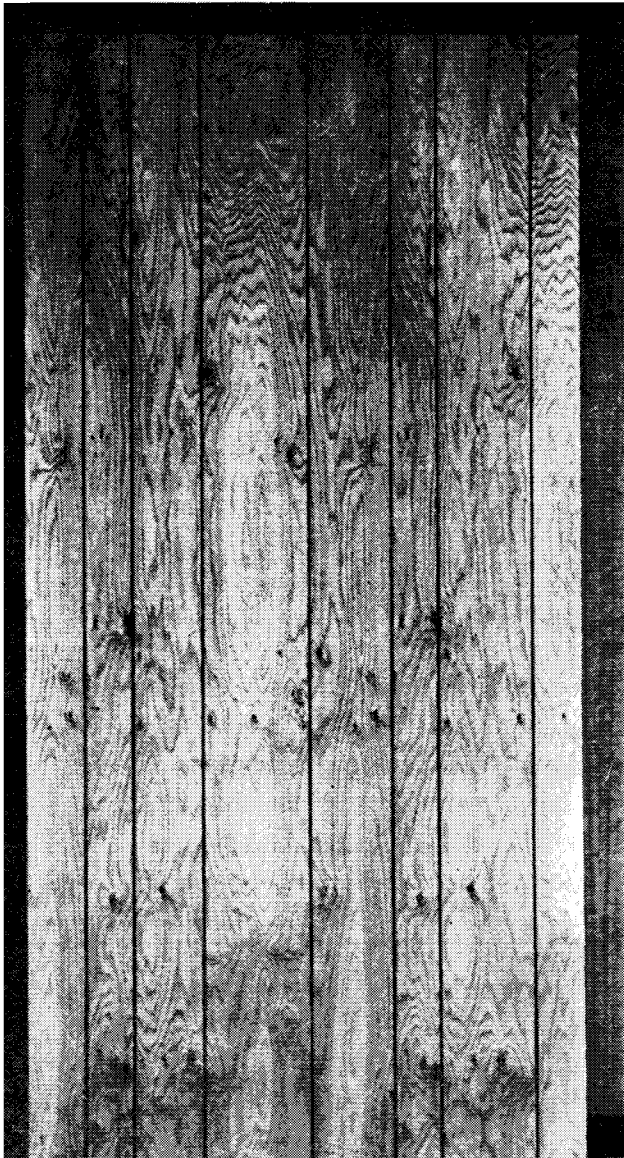


Figure 2.—Grade C face of an oak panel that was sanded, grooved, and finished with sealer and lacquer.

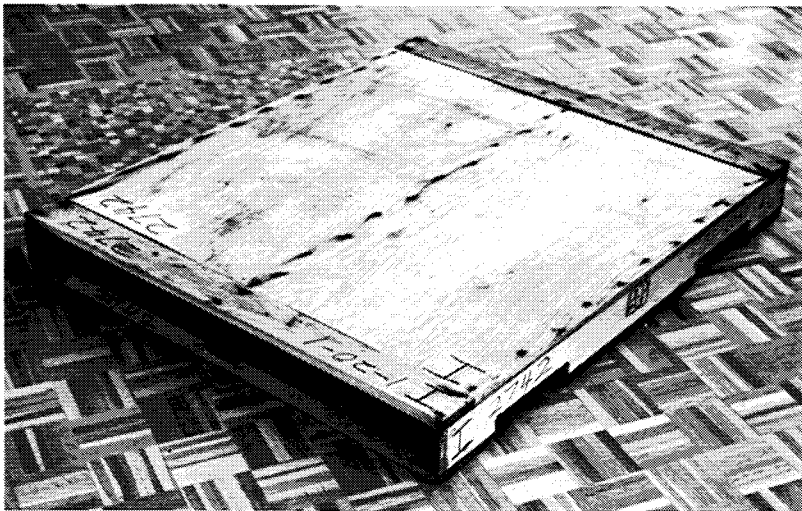
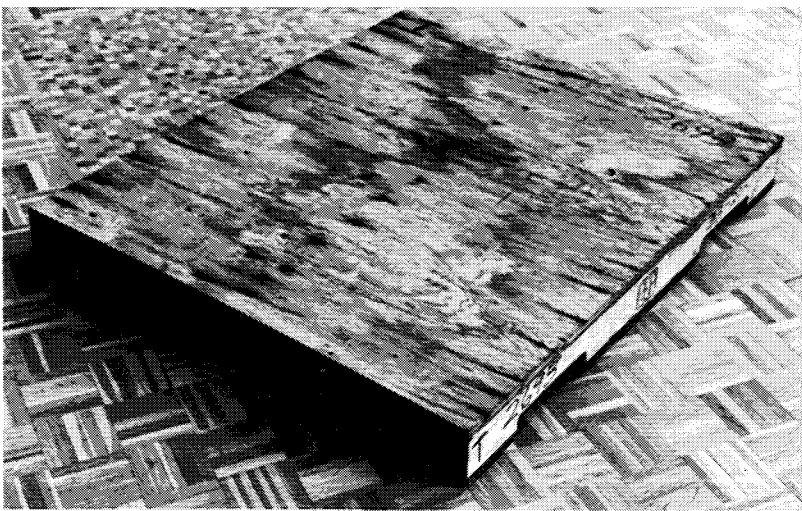


Figure 3.—Full oak plywood deck (*top*), and an oak plywood deck in combination with a lumber edge (*bottom*) on 40- by 48-inch notched stringer pallets.

being subjected to the vacuum pressure, soak test as prescribed under paragraph 4.42 of the PS 1-66 standards for construction grade softwood plywood. Wood failure ranged from 0 to 27 percent (average for five individual exterior shear samples). Both of these extremes were for panels that failed at loads of 200 pounds per square inch. Eighty-percent wood failure is required by PS 1-66 standards. Load failure for all the sample panels ranged from 100 to 250 pounds per square inch.

Many of the laboratory specimens (table 3) exceeded the

requirements for a waterproof bond as described in the CS 35-61 standards for hardwood plywood, but these standards are not applicable to construction-grade plywood.

The adhesives used did not duplicate earlier laboratory results (table 2), nor did they meet the requirements of either CS 35-61 hardwood standards or PS 1-66 softwood standards for exterior-type glue line.

Until appropriate standards are developed for construction-grade hardwood plywood, and a low-cost waterproof adhesive is developed for oak, construction-grade oak plywood would be restricted to interior use. It is expected that this problem will not exist with the less-dense hardwood species.

USES FOR HARDWOOD PLYWOOD

Because of the wide range in density of hardwoods, the plywood product can be divided into two density groups. The group of higher density includes oak, hard maple, ash, hickory, birch, cherry, sycamore, gum, and elm. Potential uses for the construction grade plywood from this group are sheathing, subflooring, concrete forms, pallet decks, framing for upholstered furniture, furniture backs, truck floors, heavy industrial crating, and other uses where nail-holding capacity, resistance to abrasion, resistance to splitting, and toughness are important.

Construction-grade plywood from the species of lower density, such as poplar, basswood, aspen, cucumber, and soft maple, could be used for roof and side sheathing, underlayment, truck and boxcar linings, cable reels, and other uses where light weight is important. A combination of dense faces and less dense interplys and backs might be used where characteristics of the dense species are desirable and weight is a factor. However, a set of standards for glue-line quality, applicable to hardwood plywood, should be developed before marketing these products.

A smaller market might exist for decorative paneling where character marks, unusual grain patterns, or a rustic or barn-board appearance is desirable.

PRODUCTION-PLANT ESTIMATES

In this study, the proposed plant size for the production of construction-grade hardwood plywood was based on a survey of raw-material supply within an economic hauling distance of four selected areas of West Virginia (appendix 1). It was found that a plant capable of using about 12 million board feet of grade 3 logs annually could be supplied with raw material at three of the selected locations.

An automated plywood plant capable of consuming 12 million board feet of raw material would produce about 35 million square feet of $\frac{3}{8}$ -inch plywood per year. A plant of this size was opened in May 1966 by Weldwood of Canada at Longlac, Ontario. This plant produces construction-grade plywood from Canadian aspen. It is highly automated and operates with 22 production personnel per shift. The advertised cost of this plant, fully equipped, was \$1,500,000. The estimated cost of a similar plant—quotations from U.S. manufacturers (1966 prices)—is within \$100,000 of this cost.

In this study, the initial investment in the physical plant and

Table 5.—Estimated annual costs of operating a 1.5-million-dollar utility grade hardwood plywood plant¹

Item of cost	Based on pilot test yield ²	Based on recalculated yield ³
Logs	\$ 912,240	\$ 641,340
Adhesive	226,800	226,800
Utilities	136,836	96,201
Direct operating labor	308,880	308,880
Direct supervision	30,888	30,888
Payroll overhead	49,421	49,421
Investment-related costs	150,000	150,000
Selling and management	272,260	255,529
Total annual operating costs	\$2,087,325	\$1,729,059

¹ Costs determined using Coolidge and Pfeiffer system for estimating cost.

² See appendix 6 for calculations.

³ See appendix 7 for calculations.

Table 6.—Annual break-even production cost estimates for operating a utility-grade hardwood plywood plant

Item	Based on pilot test yield	Based on recalculated yield
A. Operating cost ¹dollars	2,087,325	1,729,059
B. Production of 5/8-inch plywood...M sq. ft.	22,680	22,680
C. Chip productiontons	77,607	34,170
D. Chip revenue ²dollars	388,035	170,850
E. Net operating cost (A-D)dollars	1,699,290	1,558,209
F. Break-even cost (E/B) ³dollars	74.92	67.82

¹ See table 5.

² At \$5 per ton.

³ Per 1000 sq. ft. of 5/8-inch plywood.

the required production force was assumed to be equal to that for the Longlac plant.

The price of grade 3 logs, as published by those sawmills in West Virginia that buy logs by grade, ranges from \$25 to \$50/M board feet, Doyle log scale. Woods-run logs range in price from \$45 to \$65/M board feet, Doyle log scale. For our cost estimates, the price for grade 3 logs was assumed to be \$50/M board feet, Doyle log scale, for logs 8 feet long with a 6-inch trim allowance.

We used the system of estimating cost for wood industries developed by Coolidge and Pfeiffer. The actual yields from the pilot test were used for calculations in appendix 6. The calculated yields were used for the estimates in appendix 7. Results from these calculations are compared in tables 5 and 6.

SUMMARY

A study was conducted in the fall of 1968 to determine the feasibility of producing a construction-grade plywood from grade 3 oak logs.

Facilities of a typical automated southern-pine sheathing plant were used for the test; and no basic changes were made in the production process or machinery from that used for pine-sheathing production.

Actual test production (in percent of scaled volume)—from an input volume scaled at 668 cubic feet—was as follows: usable grade C and D veneer, 33 percent; green chippable waste including cores, 45 percent; dry waste, 22 percent; additional chippable green waste (not included in scaled volume) resulting from log taper, 147 cubic feet or 22 percent.

The average diameter of the sample of logs was 11.7 inches. The average diameter of grade 3 oak logs in the Appalachians is 13.17 inches. By calculating the additional veneer that could be expected from the larger diameters and the additional veneer obtained by repeeling cores 6 inches and larger on a 4½-foot lathe, the production (in percent of scaled volume)—from an input volume scaled at 840 cubic feet—was as follows: usable grade C and D veneer, 50 percent; green chippable waste including cores, 27 percent; dry waste, 23 percent; and additional green waste from log taper, 18 percent.

A phenolic adhesive formulation similar to that used for pine was used for the test. Test panels failed to meet the required PS 1-66 vacuum pressure-soak test. This indicates that an oak utility-grade plywood could not compete in a market where an exterior glue is required.

When the test results are applied to a plant operating-cost system, as developed by Coolidge and Pfeiffer in their "Cost Estimating for Wood Plants," the break-even cost for producing 5/8-inch C-D plywood—in a plant with an initial investment of \$1,500,000—is about \$75 per M square feet. When the results from recalculated yield data are applied to the same system, the break-even cost for producing C-D grade plywood was reduced to about \$68 per M square feet of 5/8-inch plywood.

CONCLUSIONS

Veneer of the quality required for C-D construction-grade plywood can be cut from grade 3 oak logs. Plant systems used for production of pine plywood are readily adaptable to production of oak plywood. Production machinery is available from existing manufacturers' models. The only appreciable difference

in machinery requirements is that production of oak plywood would require about 40-percent more dryer capacity than is required for production of pine plywood.

The adhesives evaluated were similar to those used in the manufacture of southern pine sheathing-grade plywood. Unfortunately, the adhesives used did not duplicate earlier laboratory results, nor did they meet the requirements of either CS 35-61 hardwood standards or PS 1-66 softwood standards for exterior-type glue line. Further research for a suitable low-cost adhesive was indicated. Cost estimates for this report were made on the assumption that such an adhesive can be developed.

Based on 1966 machinery and construction prices and the current wholesale price for softwood sheathing, profits in excess of 50 percent per invested dollar before income taxes could be expected from such a hardwood plywood venture.

There is a need for further research to (1) determine veneer yields by grade for oak and the other commercial grade 3 hardwood species, (2) determine the economic diameter limit for hardwood veneer production, (3) examine the market acceptance of hardwood construction-grade plywood, and (4) develop appropriate glue-line standards for construction-grade hardwood plywood.



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Table 7.—Available grade 3 oak sawtimber for new industry
in selected areas of West Virginia¹

[In million board feet]

Selected area ²	One-half annual growth ^{3*}	Annual cut ^{4*}	Unused growth ^{5*}	Unused growth ^{5**}	One-half inven- tory ^{3*}	One-half inven- tory ^{6**}	Annual available inventory over—	
							20 yrs.**	30 yrs.**
Beckley	25.7	9.0	16.7	12.9	888.9	684.5	34.2	22.8
Huntington	5.8	1.2	4.6	3.5	168.0	129.4	6.5	4.3
Elkins	18.7	6.0	12.7	9.8	734.0	565.2	28.3	18.5
Richwood	18.9	7.7	11.2	8.6	689.0	530.5	26.5	17.7

¹ Basic data were taken from TIMBER INDUSTRY OPPORTUNITIES IN SELECTED AREAS OF WEST VIRGINIA by Perry Hagenstein, 1964; tables 3, 19, 27, 35, and 51.

² Within a 50-mile radius.

³ One-half of the growth was assumed to be inaccessible or unavailable. Grade 3 growth was taken as 45 percent of total growth from THE TIMBER RESOURCE OF WEST VIRGINIA by Roland H. Ferguson, 1964.

⁴ Grade 3 cut was taken as 5/9 of 30 percent of the total cut from THE TIMBER RESOURCE OF WEST VIRGINIA by Roland H. Ferguson, 1964.

⁵ Unused growth = difference between grade 3 growth and grade 3 cut.

⁶ International 1/4-inch scale was converted to Doyle scale by multiplying the International 1/4-inch volume by 0.77. The multiplier was found by comparing International 1/4-inch volume to Doyle volume for 300 logs of the diameter distribution shown in appendix 2.

*International 1/4-inch log scale.

**Doyle log scale.

APPENDIX 2

Table 8.—Species distribution by diameter

Diam. ¹ (in.)	Species distribution for the 105-log sample			Diam. ¹ (in.)	Desired species distribution for 105 logs ²		
	White oak	Red oak	Chestnut oak		White oak	Red oak	Chestnut oak
8	0	0	4	8	1	2	1
9	1	0	4	9	4	3	4
10	1	4	20	10	5	7	4
11	3	3	12	11	5	2	4
12	3	4	15	12	5	4	3
13	4	2	10	13	3	3	4
14	0	1	4	14	2	3	3
15	0	1	4	15	3	2	2
16	0	0	2	16	2	3	1
17	0	0	0	17	0	1	1
18	0	0	1	18	1	1	2
19	1	0	0	19	1	1	2
20	0	0	1	20	1	0	2
21	—	—	—	21	0	1	—
22	—	—	—	22	1	1	—
23	—	—	—	23	—	0	1
24	—	—	—	24	—	1	1
25	—	—	—	25	1	—	—
Total	13	15	77	Total	35	35	35

¹ D.i.b. at small end.

² Diameter distribution for upland grade 3 oaks taken from USDA Forest Service Research Paper FPL-63, June 1966.

APPENDIX 3

Data From Pilot Test

I. Scaled input volume	
A. 105 logs, 8.5 feet long x 11.7 average d.i.b. at the small end	668 cu. ft.
II. Yields	
A. Green waste	
1. Cores	224 cu. ft.
2. Roundup and defect clippings (weight of all green veneer waste = 14,150 pounds, oak @ 80 percent moisture content weighs 65 pounds/cu. ft.)	
Total roundup + clipping waste = $\frac{14,150}{65}$..	218 cu. ft.
3. Total waste for chip production (224 + 218) ..	442 cu. ft.
B. Dry waste (including shrinkage)	
1. Degrade veneer stack ($1\frac{1}{6}$ ft. x $4\frac{1}{2}$ ft. x $8\frac{1}{2}$ ft.) =	44.6 cu. ft.
2. Fishtail end stack ($2\frac{1}{3}$ ft. x $4\frac{1}{2}$ ft. x $4\frac{1}{4}$ ft.) =	44.6 cu. ft.
3. Spreader reject stack ($11\frac{1}{2}$ ft. x $4\frac{1}{2}$ ft. x $4\frac{1}{4}$ ft.) =	17.5 cu. ft.
4. Trim:	
a. Rough panels ($8\frac{1}{2}$ ft. x $4\frac{1}{2}$ ft. x $6\frac{1}{6}$ ft.)	235.9 cu. ft.
Less finished panels (8 ft. x 4 ft. x $6\frac{1}{6}$ ft.)	197.3 cu. ft.
Net panel trim =	38.6 cu. ft.
b. Rough unused veneer ($19\frac{1}{24}$ ft. x $4\frac{1}{2}$ ft. x $8\frac{1}{2}$ ft.)	30.3 cu. ft.
Less trimmed veneer ($19\frac{1}{24}$ ft. x 4 ft. x 8 ft.)	25.3 cu. ft.
Net unused veneer trim =	5.0 cu. ft.
5. Total dry waste ($44.6 + 44.6 + 17.5 + 38.6 + 5.0$) =	150.3 cu. ft.
C. Usable veneer	
1. Panel stack (4 ft. x 8 ft. x $6\frac{1}{6}$ ft.)	197.3 cu. ft.
2. Unused veneer stack ($19\frac{1}{24}$ ft. x 4 ft. x 8 ft.)	25.3 cu. ft.
3. Total veneer yield ($197.3 + 25.3$)	222.6 cu. ft.
III. Taper (over-run)	
A. Log taper was not included in scaled volume. Therefore, total yield exceeds scaled input.	
1. Total yield minus scaled input = taper volume ($442 + 150 + 223$) - 668 =	147. cu. ft.

APPENDIX 4

Data Analysis: Based on Pilot Test Yields

I. Yields (based on actual production test results expressed as a percentage of scaled volume input)		
A. Usable veneer		
197 cu. ft.		
$\frac{197 \text{ cu. ft.}}{668 \text{ cu. ft. input}} =$		29%
2. Leftover usable veneer (less trim)		
25 cu. ft.		
$\frac{25 \text{ cu. ft.}}{668 \text{ cu. ft. input}} =$		4%
3. Total veneer yield (29 + 4)		33%
B. Core volume		
224 cu. ft.		
$\frac{224 \text{ cu. ft.}}{668 \text{ cu. ft. input}} =$		34%
C. Green waste not including cores and taper		
1. Roundup and green clippings		
Total green waste	218 cu. ft.	
Less taper waste	147 cu. ft.	
	<u>71 cu. ft.</u>	
$\frac{71 \text{ cu. ft.}}{668 \text{ cu. ft. input}} =$		11%
D. Dry waste		
1. Fishtails, degrade veneer, spreader rejects and trim		
		150 cu. ft.
2. $\frac{150 \text{ cu. ft.}}{668 \text{ cu. ft.}} =$		22%
E. Chippable waste for revenue		
1. Cores		224 cu. ft.
2. Green waste (including taper waste)		218 cu. ft.
Total		<u>442 cu. ft.</u>
$\frac{442 \text{ cu. ft.}}{668 \text{ cu. ft.}} =$		66%

APPENDIX 5

Data Analysis: Based on Recalculated Yields

I. Justification

A sheathing plant for the production of hardwood plywood should be equipped with both 8½- and 4½-foot lathes. The 4½-foot lathe would be used for peeling short straight sections from logs with excessive sweep and for re-peeling large cores dropped at the 8½-foot lathe. The test plant used was not equipped with a 4½-foot lathe, therefore the additional veneer available from re-peeling all cores 6 inches in diameter and above is considered as usable veneer yield in the recalculated data analysis.

Additional yield expected from the cutting of logs with excessive sweep into 4½-foot lengths rather than 8½-foot lengths before peeling is not considered in this analysis.

The average diameter of the logs used in the test was 11.7 inches. The average diameter of grade 3 oak logs in the Appalachians is 13.14 inches. Therefore, the additional veneer expected as a result of the larger diameter is considered in the calculated data analysis.

II. Scaled input volume

- A. 105 total logs x (vol. of 13.14-inch diam. by 8½-foot long log) = 840 cu. ft.
- B. 105 total logs x (vol. of 11.7-inch diam. by 8½-foot long log) = 668 cu. ft.
- C. $\frac{840 \text{ cu. ft.}}{668 \text{ cu. ft.}}$ = percent calculated vol. of actual volume = 126%

III. Yields (expressed as percent of scaled volume)

A. Usable veneer

1. Repeeled cores 4½ feet long

Diam. (in.)	Volume (cu. ft.)	4 in. diam. core volume (cu. ft.)	Veneer vol. per core (cu. ft.)	Cores (No.)	Salvaged veneer (cu. ft.)
6	0.88	—	0.39	25	12.25
7	1.20	—	.39	7	5.67
8	1.57	—	.39	18	21.24
9	1.99	—	.39	10	15.90
10	2.45	—	.39	7	14.42
Total rough veneer =					69.48 cu. ft.
Trim (16.3% of 69.48)					11.33 cu. ft.
Total salvaged veneer from cores (69.48 — 11.33)					58.15 cu. ft.

2. Diameter adjustment	
Scaled volume from 13.14-inch diam. logs	840 cu. ft.
Scaled volume from 11.7-inch diam. logs	668 cu. ft.
Additional volume of rough veneer (840-668) . . .	172 cu. ft.
Less trim (16.3% of 172)	28 cu. ft.
Net usable veneer (172-28)	144 cu. ft.
3. Panel volume from 11.7-inch diam. logs	197 cu. ft.
4. Unused veneer from 11.7-inch diam. logs	25 cu. ft.
5. Total usable veneer (58 + 144 + 197 + 25) . . .	424 cu. ft.
6. Percent of scaled volume $\left(\frac{424}{840}\right)$	50 percent
B. Dry waste	
1. Trim (including shrinkage)	
Total trim	
a. From test results	44 cu. ft.
b. From re peeled cores . . .	11 cu. ft.
c. From diameter adjustment	28 cu. ft.
Total trim (44 + 11 + 28)	83 cu. ft.
2. Degrade veneer	45 cu. ft.
3. Fishtail ends	45 cu. ft.
4. Spreader reject veneer	17 cu. ft.
Total dry waste (83 + 45 + 45 + 17)	190 cu. ft.
Percent of scaled volume $\left(\frac{190}{840}\right)$	23 percent
C. Green waste	
1. Cores (224 cu. ft. less 69 cu. ft. of salvaged veneer)	155 cu. ft.
2. Taper waste (from 11.7-inch diam. logs)	147 cu. ft.
3. Net roundup and defect clippings (218-147) . . .	71 cu. ft.
Total green waste (155 + 71)	226 cu. ft.
4. Percent of scaled volume $\left(\frac{226}{840}\right)$	27 percent
D. Chippable waste for revenue	
1. Cores (155) + roundup (71) + taper (147) . .	373 cu. ft.
2. Percent of scaled volume $\left(\frac{373}{840}\right)$	41 percent

APPENDIX 6

Estimate of Annual Operating Costs and Profits For a Utility Grade Hardwood Plywood Plant Based on Pilot Test Yields

ANNUAL LOG COSTS

Production Requirements

30,000 sq. ft. of $\frac{5}{8}$ -inch thick, five-ply plywood per 8-hour shift, or
90,000 sq. ft. per 3-shift day.

Log Volume Requirements

Average log = 12-inch d.i.b. by 8-foot long (with 6-inch allowance for
chucking and trim.)*

$$\text{Average log volume} = \pi r^2 L = \pi \times \left(\frac{6}{12}\right)^2 \times 8 = 6.28 \text{ cu. ft.}$$

Amount of $\frac{1}{8}$ -inch veneer per average log = 6.28 cu. ft. $\times$ 8 $\times$ 12 =
602.88 sq. ft.

Assuming 67-percent waste in processing logs into plywood, the net yield
of $\frac{1}{8}$ -inch veneer per average log = 602.88 sq. ft. $\times$.33 = 198.95
sq. ft.

Daily requirements for $\frac{1}{8}$ -inch veneer = 90,000 (sq. ft.) $\times$ 5 (ply) =
450,000 sq. ft.

$$\text{Daily log requirements} = \frac{450,000 \text{ (sq. ft.)}}{198.95 \text{ (sq. ft./log)}} = 2,261 \text{ logs per day.}$$

Each log contains 32 board feet (Doyle log scale).

Daily log volume requirement = 2,261 logs $\times$ 32 = 72,352 board feet,
Doyle scale.

Daily log cost @ \$50 per M board feet, Doyle scale = \$50 $\times$ 72.4 =
\$3,620.

Annual log cost = \$3,620 $\times$ 252 days = \$912,240.

ESTIMATE OF ANNUAL REVENUE FROM CHIPS

A. Annual log volume as weight input.

2,261 logs per day $\times$ 252 days = 569,772 logs/year.

11.71-inch diameter $\times$ 8.5-foot long logs = 0.7466 sq. ft. $\times$ 8.5 ft. =
6.35 cu. ft./log.

6.35 $\times$ 569,772 = 3,618,052 cu. ft. input/year.

$\frac{3,618,052 \text{ cu. ft.} \times 65 \text{ lbs./cu. ft.}}{2,000 \text{ lbs.}} = 117,587 \text{ tons input/year.}$

*Trim allowance is not included in veneer-yield and log-volume calculations because (1) the veneer is trimmed to a net width of 8 feet; and (2) trim allowance is not included in board-foot log scale calculations. However, trim allowance is included in cubic volume input-output calculations because green trim waste is actually part of chippable refuse.

B. Annual chip production.

From appendix 4, green waste for chips = 66% of scaled volume.
 117,587 tons x 66% = 77,607 tons/year.

C. Revenue from chips

77,607 tons @ \$4.00/ton = \$310,428.00

77,607 tons @ \$5.00/ton = \$388,035.00

77,607 tons @ \$6.00/ton = \$465,642.00

77,607 tons @ \$8.00/ton = \$620,856.00

ANNUAL PLANT OPERATING COSTS**

Total physical plant costs	\$ 1,500,000
Rated capacity of plant per shift (sq. ft. of $\frac{5}{8}$ -inch plywood)	30,000
Estimated shifts per day	3
Expected production days per year	252
Rated capacity of plant per year (sq. ft. of $\frac{5}{8}$ -inch plywood)	22,680,000
A. Cost of raw materials	
1. Logs	\$ 912,240
2. Glue @ \$5/double glue line/1,000 ft. (2 double lines per 5-ply panel)	\$ 226,800
B. Utilities (15 percent of log costs)	\$ 136,836
C. Direct operating labor (66 persons @ \$2.25 per hour and 260 paid days per year)	\$ 308,880
Labor-determined costs:	
1. Direct supervision (10 percent of direct labor) ..	\$ 30,888
2. Payroll overhead (16 percent of direct labor) ...	\$ 49,421
Total labor-determined costs	\$ 80,309
D. Investment-determined costs. (10 percent of physical plant. Includes general overhead; maintenance and operation supplies; depreciation; taxes; and insurance.)	\$ 150,000
Total production costs	\$1,815,065
E. Selling and management costs (15 percent of total production costs)	\$ 272,260
Total of all operating costs	\$2,087,325

PROFIT ESTIMATE†

A. Total plant investment (physical plant + initial work capital) (initial working capital = 3 months operating costs) ..	\$2,021,831
B. Estimated annual production (M sq. ft. of $\frac{5}{8}$ -inch plywood)	\$ 22,680

**From table 6, page 24 and 25 of COST ESTIMATING FOR WOOD PLANTS by L. D. Coolidge and J. R. Pfeiffer.

†From table 8, page 35 COST ESTIMATING FOR WOOD INDUSTRIES by L. D. Coolidge and J. R. Pfeiffer.

C. Estimated annual sales = (B x expected average selling price) + \$388,035 chip sales @ \$5.00/ton.
With expected average selling price

@ \$70 per M sq. ft.	\$1,975,635
80	2,202,435
90	2,429,235
100	2,656,035
110	2,882,835
120	3,109,635
130	3,336,435
140	3,563,235

D. Estimated annual operating costs \$2,087,325

E. Net annual revenue or loss before income taxes (C-D)

@ \$ 70	\$-111,690
80	115,110
90	341,910
100	568,710
110	795,510
120	1,022,310
130	1,249,110
140	1,475,910

F. Profit per invested dollar (E/A) @ \$ 80

\$ 0.057
.169
.281
.393
.505
.618
.730

G. Profit per sales dollar (E/C) @ \$ 80

\$ 0.052
.141
.214
.276
.329
.374
.414

H. Profit per unit (M sq. ft. produced) (E/B) @ \$ 80

\$ 5.08
15.08
25.08
35.08
45.08
55.08
65.08

APPENDIX 7

Estimate of Annual Operating Costs and Profits for a Utility Grade Hardwood Plywood Plant Based on Calculated Yields

ANNUAL LOG COSTS

Production Requirements

30,000 sq. ft., 5/8-inch thick, five-ply plywood per 8-hour shift or
90,000 sq. ft. per 3-shift day.

Log Volume Requirements

Average log = 13-inch d.i.b. by 8-foot long (with 6-inch allowance for
chucking and trim).*

$$\text{Average log volume} = \pi r^2 L = \pi \times \left(\frac{6.5}{12}\right)^2 \times 8 = 7.370 \text{ cu. ft.}$$

Amount of 1/8-inch veneer per average log = 7.37 cu. ft. x 8 x 12 =
707.52 sq. ft.

Assuming 50-percent waste in processing logs into plywood, the net
yield of 1/8-inch veneer per average log = 707.52 sq. ft. x 50 =
353.76 sq. ft.

Daily requirements for 1/8-inch veneer = 90,000 (sq. ft.) x 5 (ply) =
450,000 sq. ft.

$$\text{Daily log requirements} = \frac{450,000 \text{ (sq. ft.)}}{353.76 \text{ (sq. ft./log)}} = 1,272 \text{ logs per day.}$$

Each log contains 40 board feet (Doyle log scale).

Daily log volume requirements = 1,272 logs x 40 = 50,880 board feet,
Doyle scale.

Daily log cost @ \$50 per M board feet, Doyle scale = \$50 x 50.9 =
\$2,545.00.

Annual log cost = \$2,545.00 x 252 days = \$631,340.00.

ESTIMATE OF ANNUAL REVENUE FROM CHIPS

A. Annual log input.

1272 logs per day x 252 days = 320,544 logs per year.

13.14-inch diam. x 8.5-foot long logs = .9417 sq. ft. x 8.5 ft. = 8.0
cu. ft./log.

8.0 x 320,544 = 2,564,352 cu. ft. input/year.

$$\frac{2,564,352 \times 65 \text{ lbs. per cu. ft.}}{2,000 \text{ lbs.}} = 83,341 \text{ tons input/year.}$$

*Trim allowance is not included in veneer-yield and log-volume calculations because (1) the veneer is trimmed to a net width of 8 feet; and (2) trim allowance is not included in board-foot log scale calculations. However, trim allowance is included in cubic volume input-output calculations because green trim waste is actually part of chippable refuse.

B. Annual chip production.

From appendix 5, green waste for chips = 41 percent of scaled volume.
 $83,341 \times .41 = 34,170$ tons/year.

C. Revenue from chips

34,170 tons @ \$4.00/ton = \$136,680.00

34,170 tons @ \$5.00/ton = \$170,850.00

34,170 tons @ \$6.00/ton = \$205,020.00

34,170 tons @ \$7.00/ton = \$239,190.00

34,170 tons @ \$8.00/ton = \$273,360.00

ANNUAL PLANT OPERATING COSTS**

Total physical plant costs	\$ 1,500,000
Rated capacity of plant per shift (sq. ft. of $\frac{3}{8}$ -inch plywood)	30,000
Estimated shifts per day	3
Expected production days per year	252
Rated capacity of plant per year (sq. ft. of $\frac{3}{8}$ -inch plywood)	22,680,000
A. Cost of raw material	
1. Logs	\$ 641,340
2. Glue @ \$5 per 1,000 ft. of double glue line (2 double glue lines per 5-ply panel)	\$ 226,800
B. Utilities (15 percent of log costs)	\$ 96,201
C. Direct operating labor (66 persons @ \$2.25 per hour and 260 paid days per year)	\$ 308,880
Labor determined costs:	
1. Direct supervision (10 percent of direct labor)	\$30,888
2. Payroll overhead (16 percent of direct labor)	\$49,421
Total labor-determined costs	\$ 80,309
D. Investment-determined costs (10 percent of physical plant including: general overhead; maintenance and operation supplies; depreciation; taxes; and insurance)	\$ 150,000
Total production costs	\$ 1,503,530
E. Selling and management costs (15 percent of total production costs)	\$ 225,529
Total all operating costs	\$ 1,729,059

PROFIT ESTIMATE FOR HARDWOOD UTILITY GRADE PLYWOOD†

(Calculated data $\frac{3}{8}$ -inch basis)

A. Total plant investment

(physical plant + initial work capital)

(initial working capital = 3 months operating costs) ... \$1,932,265

**From table 6, page 24 and 25 of COST ESTIMATING FOR WOOD PLANTS by L. D. Coolidge and J. R. Pfeiffer.

†From table 8, page 35 COST ESTIMATING FOR WOOD INDUSTRIES by J. D. Coolidge and J. R. Pfeiffer.

B. Estimated annual production (M sq. ft. of 5/8-inch plywood)		22,680
C. Estimated annual sales = (B x expected average selling price) + \$170,850 chip sales @ \$5/ton. With expected average selling price		
	@ \$ 70 per M sq. ft.	\$1,758,450
	80	1,985,250
	90	2,212,050
	100	2,438,850
	110	2,665,650
	120	2,892,450
	130	3,119,250
	140	3,346,050
D. Estimated annual operating costs		\$1,729,059
E. Net annual revenue before income taxes (C-D)		
	@ \$70	\$ 29,391
	80	256,191
	90	482,991
	100	709,791
	110	936,591
	120	1,163,391
	130	1,390,191
	140	1,616,991
F. Profit per invested dollar (E/A)	@ \$ 70	\$ 0.015
	80	.133
	90	.250
	100	.367
	110	.485
	120	.602
	130	.719
	140	.837
G. Profit per sales dollar (E/C)	@ \$ 70	\$ 0.167
	80	.290
	90	.218
	100	.291
	110	.351
	120	.402
	130	.446
	140	.483
H. Profit per unit (M sq. ft.) produced (E/B) @ \$ 70		\$ 1.296
	80	11.296
	90	21.296
	100	31.296
	110	41.296
	120	51.296
	130	61.296
	140	71.296

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THE FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.