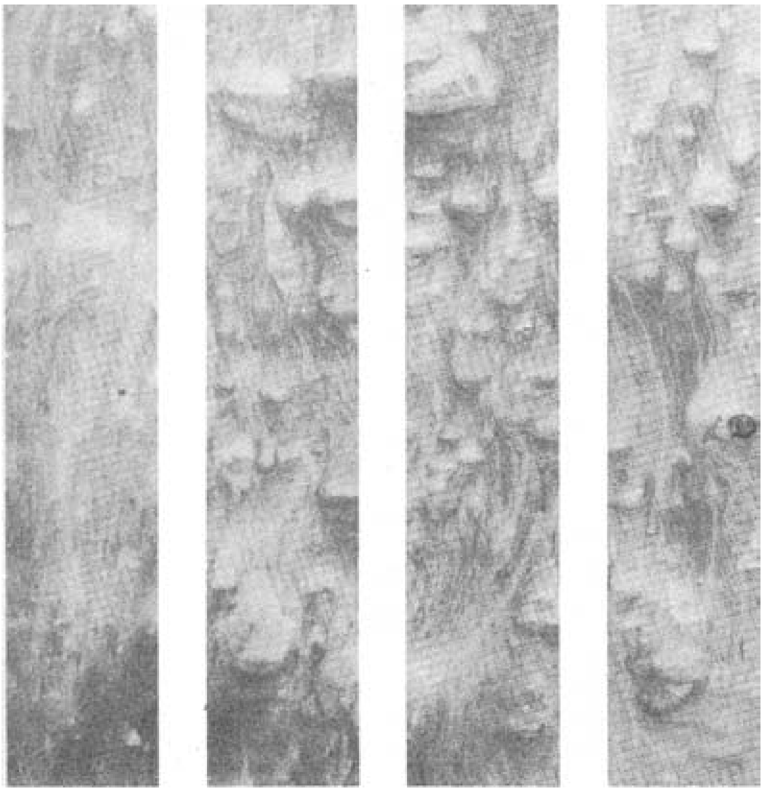

WOOD AND LOG CHARACTERISTICS AFFECTING VENEER PRODUCTION

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ABSTRACT

The suitability of a wood species for use a5 veneer depends on the characteristics of that wood and on the end use of the veneer, This paper describes in general terms the physical and mechanical wood properties, and specific characteristics of veneer logs, that are related to veneer production and use. It further points out the veneer characteristics that are important for use as construction plywood, faces of decorative panels, core and crossbands of decorative panels, and as containers.

CONTENTS

Acknowledgment

Many people participated in the compilation and coordination of information contained herein, and their aid is gratefully acknowledged. Space prevents the listing of all such contributors from industrys the Forest Service in general, and particularly many members of the Forest Products Laboratory staff. Special mention must be made, however, of the help received from Thomas E. Batey Jr. of the American Plywood Association and William J. Groah of the Hardwood Plywood Manufacturers Association. To all, the author expresses his thanks.

Names of common U.S. woods and others mentioned in this report are given in the Appendix by common and botanical name. and by the commercial description of the veneer.

WOOD AND LOG CHARACTERISTICS AFFECTING VENEER PRODUCTION

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FOREST PRODUCTS LABORATORY[1]

FOREST SERVICE

U.S. DEPARTMENT OF AGRICULTURE

INTRODUCTION

Because of the growth of softwood and hardwood veneer industries and the reduction of timber supplies of the well-known veneer species. the search continues for alternate species, either domestic or foreign. In screening for new veneer species, it is helpful to know which factors are important for veneer use.

This paper includes guidelines for selecting potential veneer species. The more information known about a species, the better the prediction. In general, a good guess can be made of the veneer potential of a species if the volume. size, and form of the trees are known, as well as the physical and mechanical properties of the wood. The final judgment is best made on the basis of veneer cutting and drying evaluations made with representative logs.

Thus information on wood and log characteristics that can affect veneer production and use should be of interest to plant owners, timber growers, and timber buyers. While there is some published information on this subject, it is scattered and not readily available. This paper pulls together some of the most pertinent information about established veneer species.[2]

An idea of the size of the veneer industry can be obtained from the statistics available for plywood. In 1969, the production of softwood plywood (mainly for construction) in the United States was about 14 billion square feet on a 3/8-inch-thick basis During the same year the production of hardwood plywood (mainly decorative) in the United States was about 2 billion square feet surface measure. Imported hardwood plywood amounted to about 4 billion square feet surface measure. Thus the overall U.S. consumption of hardwood plywood was about 6 billion square feet surface measure, It is predicted that the production and use of both construction and decorative plywood will continue to increase during the next 10 years.

In addition to veneer used as plywood, about 2 billion surface feet of veneer was used in 1969 as single ply in containers. Stated another way, approximately 6 billion board feet of softwood logs and 1 billion board feet of hardwood logs were cut into veneer in the United States in 1969.

Veneer Quality

For purposes of this paper, veneer is defined as wood cut 1/100 to 1/4 inch in thickness by a knife, whether by rotary or slicing methods. Our concern here is with wood and log characteristics that may affect quality of the resulting veneer.

Quality of clear veneer refers primarily to uniformity of thickness, surface roughness, and freedom from buckle or wrinkling when green as well as when dry. For some uses such as face veneer, it is also desirable to control color, figure, and depth of checks into the veneer, Veneer quality may also be judged on the basis of natural defects. such as knots, splits. and presence of gum

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

[2] In this publication, species are listed by common name. The more specific botanical names are given in Appendix.

End Uses of Veneer

Four broad categories of veneer uses and some wood qualities as they relate to uses of veneer are given in tables 1-4.

The classification of species of veneer specified in Products Standard PS 1-66, Softwood Plywood, Construction and Industrial, is listed in table 2. The classification is based primarily on the stiffness and strength of the species. Group 1 woods are the stiffest and strongest and group 4 the least stiff and strong, Properties that are considered include bending (modulus of elasticity and modulus of rupture), compression parallel and perpendicular to the grain, and shear.

Classification of species of veneer specified in Product Standard TS 116A for Hardwood Plywood is given in table 3. As indicated in the table, the classification is on the basis of specific gravity.

Species for use in wirebound boxes as specified in Federal Specification PPP-B-585b are listed in table 4. The four groups are based on specific gravity and other properties of importance in containers such as strength as a beam, resistance to nail withdrawal, shock resistance, and tendency to split when nailed or stapled.

An indication of the importance, for specific end uses, of all of the wood and log properties that are discussed in this paper is shown in table 5.

Hardwoods or Softwoods for Veneer

Most species can be successfully cut into veneer. However, some are much easier to process than others. Hardwoods, as a class, are easier to cut into veneer than softwoods. This probably is because hardwoods can be bent more readily than softwoods (38).[3] All veneer bends severely as it passes over the knife that separates it from a bolt or flitch. Hardwoods, having better bending properties, take this bend with less damage as checks in the veneer than softwoods.

The reasons for the better bending properties of hardwoods are not definitely known. Two possible explanations are that the hardwoods have less lignin than the softwoods and the lignin in hardwoods is more thermoplastic than the lignin in softwoods.

While construction plywood is generally made from softwoods, hardwoods are preferred for most other uses listed in table 1. Good bending properties are particularly useful for containers such as bushel baskets.

PHYSICAL PROPERTIES OF WOOD

Generally. the first information about a species is obtained by a wood taxonomist or wood anatomist. Working with herbarium material and small wood samples, he classifies the species and describes its structure. This information is valuable for screening species to be considered for use as veneer. Such information is often available from libraries or by contacting federal and state wood research laboratories or wood technology departments of forestry schools throughout the world.

Physical properties of wood of Interest to potential veneer producers include: Specific gravity, moisture content, permeability, shrinkage, extraneous cell contents, figure, odor, and cell size, type, and distribution.

Specific Gravity

Specific gravity or density is easily obtained and is often one of the first properties known about a species. As indicated in table 1, it can be used as a general guide in screening woods for use as veneer. For example, a wood with moderately low specific gravity is preferred for use as core and crossbands of decorative plywood.

Detailed information is available about the variation of specific gravity of many species, and additional data are being collected for other species. A recent example of how this information was valuable was in guiding the southern pine plywooddevelopment.

When the southern pine plywood industry started, the question was asked if all species of southern pine could be used and still make a product that could be marketed in the same strength category as Douglas-fir for structural softwood plywood. [Species are placed in various groups for use as structural plywood primarily on the basis of stiffness and strength)

In general the strength of wood is related to specific gravity. Based on the recorded strength

[3] Underlined numbers in parentheses refer to literature specifically cited in the Bibliography at the end of the report.

Table 1.--Veneer characteristics as related to end uses

Broad end-use category	Typical specific end uses	Typical species	How generally cut	Typical specific gravity range	Typical veneer thickness	Desirable veneer qualities	Veneer characteristics permitted in faces	Veneer characteristics permitted in inner or back plies
					Inch			
Construction plywood PS-1-66*	Building construction as subfloor, wall sheathing, roof sheathing, siding panels, overlaid panels, concrete form.	Douglas-fir, southern pine, western hemlock, white fir, western larch	Rotary	0.41 to 0.55	1/12 to 1/4	High stiffness (MOE) and strength, moderate weight, readily glued	A grade: 18 patches in a 4- x 8-foot panel B grade: Sound, tight knots to 1-inch diameter, 1/32-inch split C grade: Knots or knotholes to 1-1/2-inch diameter, splits 3/8 inch by full panel length	C grade: Same as faces D grade: Tight knots, knotholes to 3-inch diameter, pitch pockets 2-1/2 inches across grain, splits up to 1 inch wide, some white pocket. D grade is not permitted in Exterior type panels.
Face veneer for hardwood plywood and decorative panels, TS 116a*	Prefinished decorative wall panels, furniture, faces of flush doors, kitchen cabinets and case goods, plywood block flooring	Birch, maple, sweetgum, tupelo, oak, lauan	........do........	.43 to .60	1/28 to 1/6	Attractive figure Moderately hard, readily glued	Grade 1: A few small burls, pin knots, and inconspicuous small patches Grade 2: Discoloration, knots to 3/4-inch diameter, and burls to 1-inch diameter	(Not applicable)
		Walnut, pecan cherry, African and Honduras mahogany, oak	Flat sliced, quarter sliced, rift cut, half-round	.45 to .65	1/50 to 1/24	..........do...........		
Core and crossband veneer for decorative plywood, TS 116a*	Inner plies for products like prefinished wall panels, furniture, flush doors, and case goods	Yellow-poplar, basswood cativo, lauan	Rotary	.32 to .45	1/20 to 1/6	Low weight, low shrinkage, straight grain, fine uniform grain, easily glued	(Not applicable)	Grades 1 and 2: As described for hardwood face veneer Grade 3: Knotholes to 1-inch diameter, splits 3/16 inch by one-half panel length Grade 4: Knots, knotholes to 3-inch diameter, splits 1 inch by one-fourth panel length, 1/2 inch by one-half panel length, 1/4 inch by full panel length, small areas of shake and doze
Container veneer and plywood PS 1-66* TS 116a* PPP-B-585b**	Wirebound boxes, bushel baskets, paper-overlaid veneer, cleated panel boxes, plywood-sheathed crates	Sycamore, cottonwood, sweetgum, tupelo, elm, oak, hickory, Douglas-fir, southern pine, hemlock, white fir, ponderosa pine	Rotary and sliced	.36 to .65	1/16 to 1/4	High stiffness (MOE), high shock resistance (MOR), high resistance to splitting (strength in tension perpendicular to the grain), light color, free from odor	Same as A, B, C, D for softwoods and 1, 2, 3, 4 for hardwoods as described above.	

*Commercial Standards
**Federal Specification

Table 2.--Classification of species for Product Standard PS-1-66, Softwood Plywood, Construction and Industrial

Group 1	Group 2	Group 3	Group 4	Group 5
Birch*	Cedar, Port-Orford-	Alder, Red*	Aspen, Quaking*	Balsam fir
Yellow			Bigtooth	
Sweet	Douglas-fir 2	Cedar, Alaska-yellow-		Balsam poplar*
			Birch, Paper*	
Caribbean pine	Fir	Pine		
	California red	Jack	Cedar	
Douglas-fir 1	Grand	Lodgepole	Incense	
	Noble	Ponderosa	Western red	
Larch, Western	Pacific silver	Spruce		
	White		Fir, Subalpine	
Maple, Sugar*		Redwood		
	Hemlock, Western		Hemlock, Eastern	
Pine, Southern		Spruce		
Loblolly	Lauan*	Black	Pine	
Longleaf	Red	Red	Sugar	
Shortleaf	Tangile	White	Eastern white	
Slash	White			
	Almon		Poplar, Western*	
Tanoak*	Bagtikan			
			Spruce, Engelmann	
	Maple, Black*			
	Meranti*			
	Mengkulang*			
	Pine			
	Pond			
	Red			
	Western white			
	Spruce, Sitka			
	Sweetgum*			
	Tamarack			

*Hardwoods

values and specific gravity records, loblolly, longleaf, shortleaf, and slash pine were permitted to be marketed in the same category as West Coast Douglas-fir. The minor southern pines, which have lower specific gravities, did not meet these requirements. Thus, while not foolproof, specific gravity can be used to quickly screen new species for tentative classification.

While most species can be cut into veneer by suitable manipulation of the cutting conditions, it is more difficult to cut wood at the two extremes of the range of specific gravity. Very lightweight species tend to cut with a fuzzy surface. Dense species require more power to cut and tend to develop deep cracks in the veneer as it passes over the knife. Basswood, with a specific gravity (based on green volume and ovendry weight) of about 0.32, is toward the low end of the gravity range for species that are successfully cut into veneer, and hickory with about 0.65 is near the high end. But a valuable species like rosewood, specific gravity of 0.75, can be successfully sliced

Table 3.--Density categories of the most commonly used species based on specific gravity ranges for Product Standard TS-116A, Hardwood and Decorative Plywood

Category A High-density species (0.56 or more specific gravity)	Category B Medium-density species (0.43 through 0.55 specific gravity)	Category C Low-density species (0.42 or less specific gravity)
Ash, commercial white	Ash, black	Alder, red
Beech, American	Avodire	Aspen
Birch, yellow, sweet	Bay	Basswood, American
Bubinga	Cedar, Eastern red[1]	Box elder
Elm, rock	Cherry, black	
		Cativo
Madrone, Pacific	Chestnut, American	Cedar, Western red[1]
Maple, black (hard)	Cypress[1]	Ceiba
Maple, sugar (hard)	Elm, American (white, red, or gray)	Cottonwood, black
Oak, commercial red		Cottonwood, Eastern
Oak, commercial white	Fir, Douglas-[1]	
Oak, Oregon		Pine, white and ponderosa[1]
	Gum, black	
Paldao	Gum, sweet	
Pecan, commercial	Hackberry	Poplar, yellow
Rosewood	Lauan (Philippine mahogany)	Redwood[1]
Sapele	Limba	Willow, black
Teak		
	Magnolia	
	Mahogany, African	
	Mahogany, Honduras	
	Maple, red (soft)	
	Maple, silver (soft)	
	Primavera	
	Sycamore	
	Tupelo, water	
	Walnut, American	

[1] Softwood.

into face veneer by suitable heating and limiting cutting to thin veneer.

Typical specific gravities of woods used for construction plywood are 0.41 to 0.55; for hardwood face veneer 0.43 to 0.65; for core and crossband veneer of decorative panels from 0.32 to 0.45; and for container veneer from 0.36 to 0.65 (table 1). There are exceptions to these general guidelines. For example, butternut, with a specific gravity of 0.36, is a high value face veneer. It is suitable for wall paneling but less suitable where hardness is a factor, such as the top of a desk.

Green Moisture Content

Veneer is often cut from logs soon after the trees are felled. Such bolts or flitches have essentially the moisture content found in the living tree. This moisture content in the wood has a distinct effect on cutting. In general, wood with a moisture content above fiber saturation but not excessively high is best suited for cutting into veneer; this makes the wood more pliable than drier wood. In a number of studies we have

Table 4.--Species for wirebound boxes as listed in Federal Specification PPP-B-585b

Group I*	Group II*	Group III*	Group IV*
Aspen (popple)	Douglas-fir	Ash (except white ash)	Ash, white
Basswood	Hemlock	Elm, soft	Beech
Buckeye	Larch, western	Maple, soft	Birch
Cedar	Pine, southern yellow	Sweetgum	Elm, rock
Chestnut	Tamarack	Sycamore	Hackberry
Cottonwood		Tupelo	Hickory
Cypress			Maple, hard
Fir (true firs)			Oak
Magnolia			Pecan
Pine (except southern yellow)			
Redwood			
Spruce			
Yellow-poplar			
Willow			

*Based on specific gravity and other properties of importance in container construction. When a group is specified any species in the group can be used.

found that species with a natural uniform moisture content of about 50 to 60 percent cut well.

Some of the free water is forced out during cutting. This water apparently acts as a lubricant between the wood and the knife and pressure bar and aids the cutting process.

The driest wood that we have cut successfully into veneer at the Forest Products Laboratory was a flitch of teak with 8 moisture content of 25 percent. Like all teak, this flitch had a waxy extractive that probably aided the cutting.

We tried cutting even drier wood, but were not successful. This came about because a manufacturer wanted to slice air-dried planks of ponderosa pine into 1/16-inch-thick veneer. The wood. which was at about 15 percent moisture content, was heated to about 200° F. in water. Continuous sheets of veneer were produced from the flitches but the veneer had pronounced checks on the side that was next to the knife during cutting. After cutting, the veneer sheets immediately curled into tight rolls like window shades, so were unsatisfactory.

Because slicing of the wood at 15 percent moisture content was unsuccessful, we took sapwood air-dried planks from the same shipment, and pressure-treated them with water to a moisture content of over 100 percent. Veneer 1/16 inch thick was then successfully sliced from these planks. In other words, when water is put back into relatively dry wood, the wood can be cut into veneer.

Table 5.--Importance of physical and mechanical wood properties and log characteristics as related to manufacture and use of the veneer

Property	Construction plywood	Decorative face veneer	Core and crossband veneer for decorative panels	Container veneer and plywood	Comments
Physical property					
Specific gravity	A	B	A	B	
Green moisture content	B	B	B	B-C	
Permeability	B	C	B	B-C	
Shrinkage	B	B	A	B	
Close grain	B	A-B	A	B-C	
Fine texture	C	B	B	C	
Straight grain	A	A-B	A	B	
Parenchyma	B	B	B	B-C	
Wax	B	B	B	B	
Polyphenols	B	B	B	B	
Color of heartwood	C	A	C	A-B	
Dimensional stability	B	B	A	B	
Resin	B	A	A	B	
Gum	B	A	A	B	
Hard deposits	B	A-B	B	B	
Figure	C	A	C	C	Figure is desirable for face veneer and undesirable for other uses
Odor	C	A	A	A	Odor is important for containers used with food.
Mechanical property					
Strength in tension perpendicular to grain	B	B	B	B	
Hardness	B	B	C	B	
Modulus of elasticity	A	C	C	B	
Modulus of rupture	A	C	C	A	
Shear	A	C	C	C	
Compression perpendicular to grain	A	B	C	B	
Compression parallel to grain	A	C	C	B	
Log characteristic					
Cylindrical form	A	B	A	B	
Taper	A	B	A	B	
Eccentricity	B	B	B	B	
Tension wood	B	A	A	B	
Compression wood	A	B	A	B	
Sweep	A	B	A	B	
Growth stress	B	B	B	B	
Log end splits	A	B	B	B	
Ring shake	A	A	A	A	
Knots	B	A	A	B	
Epicormic branches and adventitious buds	C	B	B	C	
Burls	B	B	B	B	
Color	C	A	C	B	
Pitch pockets	B	A	A	B	Pitch in crossbands may bleed through face veneer
Bark pockets	B	A	A	B	
Grub holes	B	A	A	B	
Pinworm holes	B	B	C	B	Heavy pinhole damage will degrade all veneer
Decay	A	A	A	A	Some types of decay are permitted in Construction grade plywood
Fire scars	B	A	A	B	
Frost cracks	B	A	A	B	Veneer from other parts of the log may be top grade
Mineral streak	C	A	C	C	
Other stains	C	A	C	B	
Bird peck	C	A	B	B	
Stump pull	A	A	A	A	
Felling splits	A	A	A	A	
Handling damage	A	A	A	A	
Embedded metal	A	A	A	A	
Growth rate	B	A	B	B	

A--Of major importance
B--Of moderate importance
C--Of little importance
} These ratings are not hard and fast but are indicative of relative importance of various characteristics

Figure 1 .--"Shelling" or shattering of redwood veneer that was rotary-cut from a "sinker" log. The scale is in inches.

(M 88966)

Some species have a higher moisture content in one part of the tree than another. For example, the sapwood of Douglas-fir has approximately three times as much water as the heartwood. Butt logs of redwood often have much higher moisture content than upper logs. In addition to requiring long drying times, wood having a very high moisture content is more difficult to cut into veneer than wood of the same species but with a lower moisture content. Examples are some western hemlock (as high as 215 pct.). redwood (as high as 245 pct.), and Douglas-fir (as high as 130 pct.).

In normal veneer cutting, the wood is compressed just ahead of the knife. Wood with a very high moisture content has no place for the compression to take place until some water is forced out. As water is relatively noncompressible, it is forced from the wood structure at such a rate that it causes local rupture of the wood (19), figure 1. Commercial experience indicates that high moisture content in "sinker" logs of species like redwood makes them undesirable for veneer because of cutting and drying problems. Likewise, for a long time sapwood veneer of Douglas-fir was not considered A-grade, partly because of the difficulty in cutting it into smooth veneer as easily as the heartwood, which has a lower moisture content.

Wood grown in a warm climate and having a high moisture content may be damaged by freezing if it is stored in a cold climate. Southern pine sapwood was damaged when logs were stored outdoors during the winter in Madison. Wis. Even worse damage was observed in a sweetgumlog stored through a winter at Madison when the temperature went alternately from above freezing to as low as -20° F. The end of a bolt cut from this log is shown in figure 2. Ice was found in many of the cracks seen on this end section. Industry reports that walnut logs grown in California and shipped by rail to the East froze when crossing the Rocky Mountains. Veneer cut from those logs was nearly useless due to splits caused by freezing.

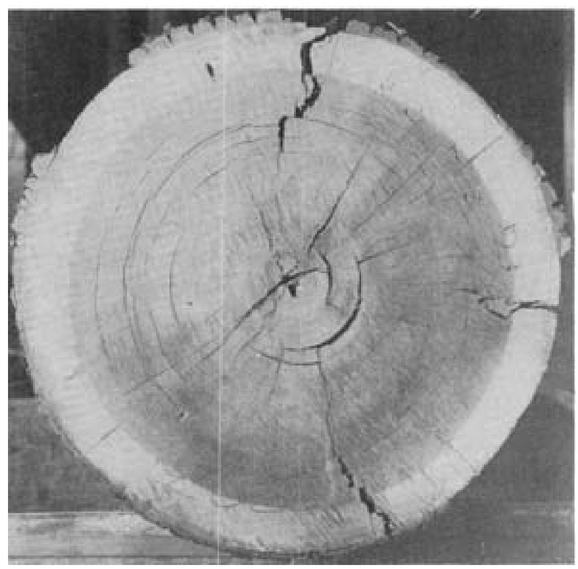

Figure 2.--Splits and shake in this sweetgum log were caused by alternate freezing and thawing.

(M 84166 F)

Generally speaking then, the moisture content in the trees, while important, is not a decisive factor in determining whether a species is suitable for use as veneer. Wood with a very high moisture content is usually more difficult to process than wood having a moderate moisture content such as 50 to 60 percent. On the other hand, it is very difficult or impossible to cut good veneer from wood below the fiber-saturation point, approximately 30 percent for all species.

Permeability

Permeability has a distinct effect on veneer cutting, drying, and gluing characteristics. Sapwood is often more permeable than heartwood of the same species. Bacterial attack in log storage may increase the permeability of wood and change its cutting characteristics (18). Wood that is permeable is easier to cut because water is readily forced from the wood; as a result, forces that could rupture the wood do not develop. Furthermore, plywood made from veneer that is naturally permeable, such as yellow-poplar, is less subject to “blowouts” in the hot press than plywood made from relatively impervious veneer such as spruce. Extremely permeable veneer, such as the sapwood of pine that has been attacked by bacteria, may require a heavy glue spread or changes in gluing technique to obtain satisfactory bands.

Shrinkage

Low shrinkage is a desirable characteristic for all wood that is to be cut into veneer. In general, low shrinkage is related to low specific gravity. However, there is a considerable range of shrinkage for various species having the same specific gravity. The low shrinkage of teak and mahogany is one reason these are preferred woods for face veneer.

High shrinkage is undesirable because: It puts mare stress on plywood gluelines with changes in moisture content; it is more prone to cause cracks in face veneer during service of cross-banded panels; and finally it tends to cause warping unless the crossbanded panels are perfectly balanced.

Radial shrinkage is generally less than tangential shrinkage. Consequently, quarter - sliced veneer will often perform better as face veneer or crossband veneer than flat-sliced or rotary-cut veneer of the same species.

Longitudinal shrinkage may also be a factor in use of veneer. On several occasions we have seen serious bowing of thin decorative plywood panels caused by different longitudinal shrinkage characteristics of the face and back veneer. Excessive longitudinal shrinkage may be due to short grain. to compression wood in softwoods, or tension wood in hardwoods.

Shrinkage is a factor in all veneer uses but perhaps is most important for core and crossband veneer.

Drying conditions may affect the total shrinkage of refractory species like some eucalypts.

Wood Structure and Growth Rate

In general it is desirable to have uniform wood structure for ease of cutting, drying, and processing of wood intoveneer. The relatively uniform structure, regardless of growth rate, is one reason why diffuse-porous hardwoods like yellow-poplar, sweetgum, and yellow birch are such good veneer species. Similarly, softwoods like white pine and Klinki pine are good veneer species. Uniform structure is particularly desirable for crossbands of decorative panels to minimize “telegraphing” of the grain to the face.

Such species as Douglas-fir, southern pine, and the oaks have a pronounced difference in density between springwood and summerwood. Assuming other factors are equal, veneer producers generally prefer slow-grown wood of such species. In practice this is not always possible; for example, most construction plywood is made from Douglas-fir and southen pine, much of it fast grown However, veneer from slow-grown logs of these species cuts better, dries with less buckle, and is generally preferred by production personnel to fast-grown wood of the same species. For ease in cutting and drying, veneer logs of such species should have a minimum of six rings per inch. Ponderosa pine growing in the southeastern United States often has 30 rings or more per radial inch of growth. In Laboratory tests, we found this to be excellent wood for cutting into veneer.

One of the problems that sometimes occurs with fast-grown softwoods is “shelling,” a local separation of the annual rings at the springwood-summerwood boundary. The first few layers of springwood cells are apparently weaker in resistance to shear than cella formed later in the year. Shelling may also occur with slow-grown wood that has soft, weak springwood and high moisture content. Examples are western redcedar and redwood. Shelling is aggravated by use of high compression by the nosebar and by excessive heating of the wood prior to cutting.

Fast-grown wood of species such as Douglas-fir and southern pine may cause problem in drying, gluing, and finishing (17).

The same relationship holds for ring-porous hardwoods like oak. In such woods, it is desirable that the springwood portion of the annual ring be narrow and the summerwood be of moderate density. In other wards. the desirable thing is to get as uniform wood structure as possible. Such oak wood cuts well, does not shell readily between rings. and perform well as furniture, paneling, or flooring.

Texture. -- Open-grained or coarse-textured woods such as oak and ash have large pores, This is relatively unimportant in veneer cutting and drying but my be important in finishing. A furniture wood with pores larger than those in birch must have the pores filled to get a continuous film of finish. Large pores also affect the appearance of the wood. The size of the pores and the color of the filler used to fill them will affect the appearance of the finished wood surface. If desired, the filler can be used to accent the figure of the wood.

Straight vs. irregular grain--For ease of veneer processing and for most end uses, straight grain is desirable.

Straight-grained wood is easier to cut than irregular grain and the veneer is more likely to remain flat. On the other hand, the market value of certain finished items of irregular grain may be high enough to pay for the extra care needed in handling it. Examples are the curly grain in species like walnut and maple and interlocked grain in mahogany. The curly grain often shows on a flat-cut or tangential surface. Interlocked grain shows as a stripe on quarter-cut or radial surfaces, Identifying irregular grain in logs is discussed further under "Log Properties."

Geneticists (40) are studying the inheritance of interlocked grain in species like red gum with be objective of selecting straight-grained trees efficiently to use them in an applied program of breeding for lumber and veneer production.

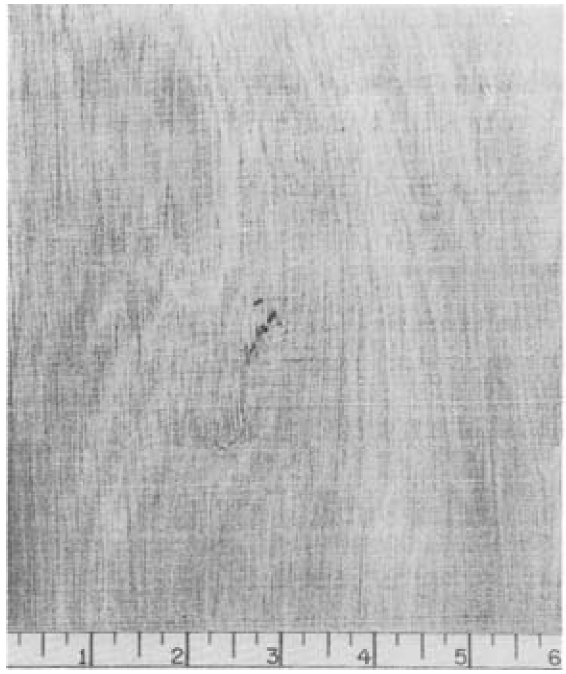

Figure 3.--Separation of a parenchyma band in rotary-cut Brazil nut veneer. The scale is in inches.

(M 136 450)

Parenchyma.--Parenchyma occurs most frequently in wood rays and as concentric bands at the edge of growth rings. These cells are comparatively thin-walled and function primarily for storage of food. They are generally weaker than most other wood cells and so may form zones of weakness when they occur in large bands.

Terminal bands of parenchyma in angelique make it difficult to rotary-cut that species without getting a "shelling" type of failure at the bands of parenchyma. To a lesser extent this same problem occurred when rotary-cutting veneer from Brazil nut (fig. 3).

Parenchyma in wood rays may be troublesome when quarter-slicing veneer. The cut will be smooth when the knife moves across the wood in the direction in which the rays run out at the surface being cut. Conversely, when the rays run out at the surface in the direction opposite to the movement of the knife, the cut is rough. In the first instance, the rays are compressed by the cutting action and so cut smoothly. In the second case, the rays are stressed in tension perpendicular to the grain by the cutting action. As they are weak in tension, they split ahead of the knife into the wood and cause a rough surface. This phenomenon of different roughness of the surface also applies to the orientation of annual rings and fibers (15).

Extraneous Cell Contents and Some Effects

Cellulose, hemicellulose, and lignin are the primary structural elements of the cell wall. Being polymeric in nature they are essentially insoluble in water and neutral organic solvents.

Many other materials may also be present in the wood. They are not part of the wood structure, but they contribute to the wood such properties as color, odor and resistance to decay. They are grouped under the general heading of extraneous materials and include tannins, essential oils, resins, waxes, hard deposits, and the like. They can generally be removed from the wood by neutral solvents such as water, alcohol, acetone, benzene, and ether.

The range and mixture of extraneous compounds found in wood is very large (10,11,41). Many of them have not been fully identified. Further, the amount of extractives varies widely from tree to tree and often within a tree. Therefore, only a few of the extraneous materials that may affect the use of wood as veneer will be discussed here.

In general, the extractives constitute only a small percent of the dry weight of the wood. In exceptional cases, however, such as the resin in longleaf pine stumps. the total may be as high as 20 percent. Often the high concentration of extraneous materials that cause difficulties in processing veneer results from a tree's response to injury. Heavy oleoresin concentrations are often found in southern pine trees that have been tapped for resin, Pitch pockets and blisters are generally considered to be caused by injury to the cambium of trees such as Douglas-fir that secrete oleoresin. The wood contains pockets of oleoresin, which flows out readily when the defect is cut open. Fires are reported to stimulate gum production in several species. Insect attack is considered a principal cause of gum spots in black cherry, Wounding of hickories or pecans by cambium-boring insects often results in deposits of calcium carbonate or magnesium carbonate that are hard and large enough to nick a sharp knife.

These examples suggest that the percentage of veneer logs free of objectionable concentrations of extraneous materials can be increased in two ways: By selection of tree breeding stock that is resistant to insect attack, and by silvicultural practices that minimize injury to the trees.

The terminology concerning extractives is sometimes confusing to nonspecialists in this field. This problem is complicated because most extractives consist of more than one compound.

Gum.--The word "gum" has been used in the past to describe any plant exudate that feels gummy when fresh and that hardens on exposure to air. In recent years chemists have used the word "gum" specifically for certain types of polysaccharides. True gum is more or less soluble in water and insoluble in nonpolar organic solvents. Arabinogalactan, which may be present in amounts sufficient to interfere with the gluing of veneer cut from butt logs of western larch, is a true gum Gum spots in black cherry probably consist of true gum and polyphenols, the latter causing their dark brown color. While a slight amount of gum is permitted in cherry face veneer (35), moderate or heavy concentrations of gum lower the grade. Figure 4 shows the gum that limits use of Brazil nut for veneer.

Figure 4.--Gum in a sheet of rotary-cut Brazil nut veneer. (M 136 441)

Resin and oleoresin.--In contrast to gum, resin denotes materials that are insoluble in water but soluble in neutral organic solvents. Resins occur in ray parenchyma cells of both hardwoods and softwoods. Oleoresin is a mixture of resin and essential oils. It is insoluble in water but soluble in alcohol, alkalies, and most organic solvents. Oleoresin is secreted by vertical and horizontal resin canals in such softwood genera as Picea, Pinus, Pseudotsuga, and Larix. In Tsuga, Abies, and Sequoia species, resin canals are normally absent hut may he produced by injury to the tree.

In veneer cutting, resin is a handicap. It may collect on the pressure bar and encourage chips to jam between the pressure bar and the wood bolt, causing depressions in the veneer. Frozen or solidified resin in knots is very hard and will quickly blunt a sharp knife.

Ether--soluble resin occurs in small amounts in many U.S. hardwoods, but generally has little effect on their use for veneer. The relatively large amounts of ether-soluble components found in basswood may explain why this species is more difficult to glue than would be expected from its specific gravity. Resin in core and crossply veneers, such as may occur in the heartwood of cativo and southern pine, is objectionable because it may bleed through the face veneer. Similarly resin in face veneer species like white pine can interfere with furniture finishes. This is particularly true if the end product is a TV cabinet, which becomes warm during use.

Among the hardwoods vertical and horizontal resin canals are found only in certain Dipterocarpaceae. The contents of these canals usually appear white or yellow. In general they do not cause trouble in using the wood for veneer.

Polyphenols. -- Polyphenols can be broadly grouped into tannins and nontannins. Most tannins are of a molecular size generally soluble in water. Polyphenols that are not soluble in water can be removed from wood with polar organic solvents like alcohol or alcohol-benzene. Polyphenols occur in most species and are generally more common in the heartwood than in the sapwood.

Color.--One reason polyphenols are important is because they give wood its typical color. Colored heartwood of decorative face veneer of species like rosewood is much more valuable than light-colored sapwood.

Almost all sapwood is white. This light color is preferred for some face veneer of species like maple. Eight-colored wood may also be preferable for containers as it makes a good background for stenciling or other markings. Color is of little importance for construction plywood or for core and crosshand veneers.

Metal stain.--Many polyphenols react with iron and steel in the presence of water to form a blue-black stain This becomes very obvious and objectionable on face veneer of species like oak and redwood if the wet wood is in contact with iron or steel for even a brief time. Hot wet wood will stain more readily than cold wet wood.

Dimensional stability.--Nearn (20) showed that many heartwood extractives will partially stabilize the wood dimensionally. One result is that dry, rotary-cut heartwood veneer of species like yellow-poplar and Douglas-fir has less end wrinkling and buckle than sapwood veneer cut from the same logs. Flat veneer is easier to handle in plant processing than buckled or wavy veneer.

Checks in veneer.--Checks in the heartwood veneer of rotary-cut types are measurably deeper than checks in the sapwood veneer cut under the same conditions, Similarly, high-speed photographs have shown that breaks into the heartwood veneer of yellow birch were more conspicuous than breaks into sapwood veneer cut in the same revolution of the bolt. One possible explanation of these phenomena is that the polyphenols in the heartwood make it less plastic than the sapwood.

Wax.--A few species of wood have waxy extractives that seem to be an advantage when cutting veneer. Pencil manufacturers recognize this advantage and add wax to incense-cedar pencil blanks to improve the whittling properties of the wood. Conversely, waxy extractives make wood more difficult to glue and finish. Examples of wood that feel waxy to the touch include teak, determa, and cypress.

Hard deposits.--The ash content of wood is usually less than 1 percent but in small areas in the wood it can be much greater. The principal inorganic deposits contain calcium, magnesium, or silica. Concentrated minerals have a distinct blunting effect on sharp tools. However, scattered individual crystals of calcium oxalate. which axe common in the longitudinal parenchyma and ray cells of many hardwoods, do not have an obvious effect on veneer cutting.

Hard deposits that do cause rapid dulling of hives are limited to a few native species such as maple, pecan, and hickory. The ash content in mineral streaks of hard maple is reported to average 5.2 percent and to be high in manganese. As mentioned earlier, calcium deposits are concentrated in hickory and pecan that is injured by cambium-mining insects. These deposits will nick a sharp knife.

In contrast to continental United States species, many tropical hardwoods contain silica. If the silica content exceeds 0.5 percent it causes rapid blunting of cutting tools.

Figure

Figure is defined as the pattern produced in a wood surface by annual growth rings, rays, hots. deviations from regular grain such as interlocked and wavy grain, and irregular coloration. Figure is one of the most important characteristics of decorative face veneer. However, for uses of veneer other than decorative face stock, highly figured wood is generally not desired.

Odor

Most woods have little odor when dry. Some species, such as cedars. have a pleasant odor that is used to promote the use of the wood. Other woods have a sour or unpleasant odor, particularly if they become damp. Logs stored in a warm climate may develop objectionable odors due to the action of bacteria. Such odors are particularly objectionable in veneer that is to be used for products like food containers or paneling for walls of homes.

MECHANICAL PROPERTIES OF WOOD

Besides physical properties, the information most generally available about a species is its mechanical properties. The most likely sources of information on mechanical properties of wood are libraries, federal and state wood research laboratories, and wood technology departments of forestry schools around the world. Mechanical properties of particular interest for veneer are strength in tension perpendicular to the grain. hardness, modulus of elasticity, modulus of rupture, shear, and compression parallel and perpendicular to the grain.

A wood strong in tension perpendicular to the grain is desirable for veneer because it is less likely to split in log form, when cutting into veneer, or in subsequent handling of the veneer.

Hardness is of interest in veneer used for furniture and flooring. or other places where it will receive impacts during service.

Modulus of elasticity, or stiffness, is important to veneer because stiffness is vital in many plywood uses. Stiffness of the plywood is generally the critical factor for such structural uses as subflooring and roofing.

Modulus of rupture is a measure of the ultimate bending strength of the wood. It is of interest for containers and for construction plywood.

Shear is important in structural applications such as the use of plywood as the web in a box beam

When plywood is used as a stressed skin, strength in compression parallel to the grain is important.

Compression perpendicular to the grain is an important property when a bearing load is involved, such as a refrigerator on a plywood subfloor.

Referring to end uses listed in table 1, construction plywood is generally made from softwoods. A major reason is that, for a given specific gravity, softwoods generally have a higher modulus of elasticity than hardwoods, The longer cells and higher lignin content of the softwoods may account for the higher stiffness.

Softwood logs are also more readily available in large quantity and are less expensive than veneer-grade hardwood logs.

PROPERTIES OF VENEER LOGS

Selection of species for use as decorative face veneer is based primarily on the appearance of the wood. Other physical and mechanical properties are important for such uses as construction plywood, core and crossband veneer, and container veneer. Once these properties of a species are known, the next question is the tree and log properties.

The average diameter and form of the trees are of obvious interest to any timber user. At one time it was thought that only prime logs, large in diameter and clear of defects, could be used for veneer. While only partially true, this popular concept of an "ideal" veneer log nicely introduces the subject of log grades.

"Ideal" Veneer Log

An "ideal" veneer log is cylindrical in form with the pith in the geometric center of the log end sections. The bark surface of the log and the end sections are entirely free from blemishes. The annual rings on the end sections indicate uniform slow growth so the specific gravity and texture of the wood varies a minimum amount. The grain of the log is straight. The minimum diameter of this ideal log is 14 inches if it is to be rotary cut, 18 inches if it is to be flat-sliced, and 24 inches if it is to be quarter sliced.

Very few logs meet the criteria of an ideal veneer log. But logs having other characteristics may still be eminently suited and valuable for veneer. For example, the most obvious exception to this concept is if fancy face veneer is planned; here irregular grain of a particular type is desired.

Function of Log Grades

Wood is a natural product and has many variable characteristics. Such characteristics as sweep, log end splits, and knots, and many others are evaluated when grading a log. Based on all these considerations, the log grader estimates the quality and quantity of veneer that can be produced from the logs. For example, the official Log Scaling and Grading Rules far five western softwood grading Bureaus (28) gives as one criterion for a No, 1 Douglas-fir peeler, that it be suitable for manufacture of clear uniform-coloredveneer, to an amount nut less than 50 percent of the net scaled content. Log quality used in softwood plants today go from No. 1 peelers to almost any log that can be held by the lathe chucks and turned into veneer.

Changing Requirements for Veneer Logs

While plant managers and production foremen would rather work with high-grade peeler logs, the availability of raw material and the changing end uses of veneer and plywood have resulted in the veneer industry adapting their practices to successfully handle lower grade logs. Improved methods for handling small logs (37) have made it practicable to manufacture veneer from species like aspen, birch, and southern pine with log diameters of 12 inches and even smaller. Equipment developments such as retractable chucks, driven roller bars and lathe chargers have permitted economic handling of lower grade logs.

One reason for this switch has been the change in the end use of the veneer, Atone time the main end products of the softwood plywood industry were such things as wall paneling and faces for doors. Now the major use is structural C-D grade plywood. Knots as large as 3 inches in diameter and splits as wide as 1 inch can be tolerated in this end product. As a result, the raw material requirements have shifted from peeler grade loge to No. 1 and No. 2 grade sawlogs.

The same sort of change has occurred in the requirements for hardwood face veneer. At one time such veneer had to be perfectly clear. In recent years such characteristics as small pin hots, insect tracings, and slight stain have been well accepted by the public for prefinished wall paneling, the major use for hardwood plywood. As a result lower grade logs are suitable for manufacture into hardwood face veneer.

Log Grades for Use as Lumber

Much more experimental work has been done relating log grades to lumber recovery than to veneer recovery. Information developed in lumber studies is useful for veneer log evaluations, as log properties that are important for lumber are generally. also important for veneer. The major factors that affect the quality of factory hardwood logs are position in the tree. (butt or upper), size of the log, straightness of the log, amount and distribution of scaleable defects, and imperfections in the usable wood. In practice each log is visually squared up and divided into four faces. Each face is evaluated for clear cuttings. Defects in hardwood logs are described in (14,22,39).

Log and tree grades have been published for southern pine that is to be used for yard and structural lumber (33,34) andfor hardwood growing stock (2). Grade 1 pine logs have three or four clear faces, grade 2 logs one or two dear faces. and grade 3 logs no clear faces. In addition the pine logs are graded on the basis of sweep and rot. Specifications for hardwood growing stock include diameters, length of butt log, sweep, lean and surface defect indicators.

Veneer Log Grades

Veneer log grades have not been studied as much as lumber log grades. While there are some formal veneer log grades, many mills have their own local rules for acceptable logs. In their simplest form they specify minimum diameter and length of logs and the size and number of permissible surface defects, like hots.

Harrar (7) has described the frequency and importance of defects in southern hardwood veneer logs. Grading rules for northern hardwood and softwood veneer logs are published by the Northern Hardwood and Pine Manufacturers Association (23). A guide to Hardwood Log Grading (22) describes a veneer log class. Veneer log scaling and grading of western softwoods have been consolidated into one set of rules (28).

SPECIFIC CHARACTERISTICS OF INTEREST FOR VENEER LOGS

The relative importance of any one characteristic in a veneer log depends on the end use of the veneer. For example, figured wood may be desirable for hardwood face veneer but undesirable for core and crossband veneer. A summary of some log characteristics and their relative importance according to the end use is given in table 5.

Diameter and Length

While it is true that logs as small as 10 inches or less are rotary-cut into veneer, this is not the preferred diameter. Other factors being equal, large-diameter logs are preferred far all veneer cutting. Large-diameter logs mean less handling for a given volume of veneer. Better quality veneer can be rotary-cut from large-diameter logs than those of small diameter. This is particularly true for thick veneer such as 1/6 inch.

Log diameter is even more important for sliced veneer where the width of the veneer is limited to the width of the Bitch. The minimum diameter of logs that are used for flat-slicing is about 15 inches and for quarter-slicing, 21-22 inches.

In terms of log length, a species that does not have an 8-foot or longer bole is of limited value for veneer. Most bolts that are rotary-cut are 8 feet long, even though shorter bolts are cut for furniture and far containers. Most face veneer slicers are 12 or 16 feet long. While much of the sliced veneer is used in 8-foot and shorter lengths. a premium is paid for 12- and 16-foot lengths.

Log Form

For rotary-cutting, it is important that veneer logs have a cylindrical form with the pith in the geometrical center of the log ends. Laboratory and industry tests show that 5 to 6 percent of a typical veneer bolt is lost in rounding it to obtain usable widths of veneer.

Taper and eccentricity.--Taper in a log is more of a problem than slight eccentricity. This is because narrow widths of veneer are usable. but short lengths. fishtails, generally are not. Taper also causes short grain in rotary-cut veneer. Such short grain is weak in bending and shrinks excessively in length. It may also lead to bleed-through of the glue in thin face veneer.

Logs with pronounced eccentricity result in many narrow pieces of rotary-cut veneer. This veneer tends to be rougher than veneer cut from cylindrical logs because a part of each revolution of veneer is cut against the grain of the annual rings. Eccentric logs are also undesirable because they frequently have the abnormal wood, tension wood in hardwoods or compression wood in softwoods.

Taper and eccentricity may also increase the amount of thick and thin veneer produced.

Sweep.--Sweep or lengthwise curvature of a log is a defect for both rotary and sliced veneer. For one thing such logs often have tension wood or compression wood. Sweep limits the amount of full-length sheets that can be produced from the log. Sometimes sweep can be minimized by judicious bucking of the logs into bolts for rotary-cutting, but individual bolts must be straight. Slight sweep can be tolerated in logs that are to be sliced, but the flitches should be so sawn that the sweep in the log is perpendicular to the plane of the knife used in slicing. This will permit production of full-length veneers from the start of slicing.

Abnormal Wood

Cylindrical logs, with the pith in the center, are unlikely to have tension wood or compression wood. Both of these abnormal woods shrink more in length than normal wood and so cause buckling of the veneer during drying.

Tension wood.--Tension wood (27) is often found in leaning hardwood trees. It is most pronounced in low-density species such as cottonwood and aspen. Identifying characteristics in log form include an eccentric pith and silvery, crescent-shaped bands on the log cross section When tension wood is pronounced, the bands are fuzzy or stringy, because the saw did not cut them cleanly (fig. 5). Tension wood is characterized by having little of the lignin that stiffens normal fibers. As a result, the wood tends to bend and cling to the knife rather than sever cleanly in

Figure 5.--Tension wood in a cottonwood log.

(M 75160)

Figure 6.--Compression wood in a southern pine log.

(M 28425 F)

veneer cutting. The cutting of tension wood can be improved by using an extra hard knife (such as a 62-64 on the Rockwell C-scale) and keeping the knife very sharp. The wood is sometimes cooled to about 40° F. with low-density species like basswood to improve the cutting of the softer wood.

Compression wood. - - Compression wood is typically found in softwood logs that have a pronounced eccentric pith. The crescent-shaped bands are most often found on the wide radius. They are dull, hornlike in appearance. and sometimes have a reddish cast (fig, 6). Compression wood is dense and superficially appears like extra-wide bands of summerwood. Because it is lignified, compression wood cuts well to form a smooth wood surface. However, the stresses in severe compression wood will often cause the green veneer to buckle. The buckle becomes worse in drying and may cause warping in plywood. Reference (25) gives further information.

Growth Stresses

Most species of wood have growth stresses. However, the severity of these stresses varies widely. Kubler (12) and others have demonstrated

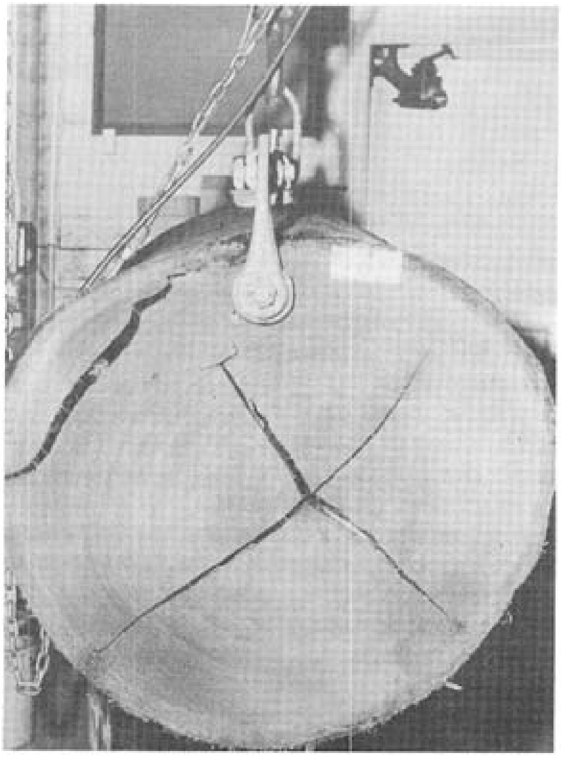

Figure 7.--Splits in the end of a Brazil nut bolt. The splits came from growth stresses in the tree and were greatly enlarged by heating the bolt to 200° F.

(M 136 337-1)

that the wood near the surface of the log is in tension in the longitudinal direction, while the wood near the center of the log is in compression in the longitudinal direction In the transverse plane of cross section of the log, the wood is in compression near the outside of the log and in tension near the center of the log. In some cases these stresses cause the log ends to split as soon as the log is cut to length. Such an observation should serve as a caution sign when considering a species for veneer.

Log End Splits Due to Growth Stresses

Splits that are in the log typically radiate from the pith like spokes of a wheel. When green wood is heated, it expands tangentially and shrinks radially, enlarging these splits (fig. 7). Splits are particularly bad in logs that are to be rotary-cut, because of the corresponding splits in the veneer. Veneer splits are limiting defects as defined by the product standards for both hardwood and softwood plywood (table 1 and references 35,36).

Log end splits are not quite so serious when the wood is to be sliced, The log can often be sawed to eliminate the major split by making the first saw cut through the split. It is sometimes possible to eliminate other splits if the log is to be quarter- or rift-sliced.

Even with careful cutting, some of the stresses in the tree are retained in the flitches. Consequently the flitches tend to bow toward the bark side, particularly during heating. Sometimes flitches are strapped together during heating to reduce this bow. The bow in the flitch that is to be flat-sliced can often be pushed out when the flitch is mounted on the flitch-table just prior to slicing. On the other hand. the bow in a quartered flitch is not changed when the flitch is mounted and sliced. Bowed veneer results in considerable loss when the edges of veneer are made parallel by clipping.

All in all, a species that is known to have marked growth stresses will generally yield more quality by flat-slicing rather than quarter-slicing.

Ring Shake

Ring shake is another undesirable characteristic in logs that are to be used for veneer. Shake is accentuated by heating in water or steam just as log end splits are. Unfortunately, there is no way of eliminating ring shake as there is with log end splits. To prevent additional damage, plastic clips are sometimes driven across the ring shake to help hold the bolt together when rotary cutting. The plastic can be cut without damaging the knife edge. The use of a roller bar rather than a fixed nosebar reportedly permits a careful operator to come closer to shake without having it break out. The roller bar exerts less drag on the bolt, and so there is less shear force tending to cause the wood to break at the ring shake.

Knots

Knots are one of the most common and important imperfections in veneer logs. Knots may be sound and intergrown, encased, or decayed. Most encased or decayed hots fall out during the drying of veneer. Knot holes are more limiting defects in standard veneer grades than intergrown hats of the same diameter.

In general, there are fewer knots on logs of large diameter, on logs from trees grown in fully stocked stands, and on butt logs. Knots are also related to species. Logs of white fir and eastern hemlock for instance have many more hats than species like noble fir, longleaf pine, and yellow-poplar.

Some species have many knots because the limbs persist for many years. Paul's studies (24) show that limbs persist on Douglas-fir logs for up to 150 years. In contrast, the limbs of southern pine frequently fall off a few years after they die. The implication is that when all logs come from second-growth, 100 years or less in age, the southern pines will furnish more knot-free veneer than Douglas-fir.

Knot indicators are retained in the bark many years after the limbs have been overgrown. The ability to recognize these indicators is a key factor in accurate grading of logs (14). Figure 8 illustrates how an indicator on the surface of a log of Douglas-fir signaled a serious defect,

The one exception to the degrading effect of knots is decorative veneer of species like western redcedar and white pine. These specialized products call for flitches having sound intergrown knots 1 inch or smaller in diameter. A limited number of knots are permitted and are desirable in some but not all decorative veneers used as faces of paneling.

Epicormic branches and adventitious buds are relatively minor defects that occur on most hardwoods, particularly elm, oak, maple, and sweetgum (14). They are not permitted in clear veneer for some furniture grades but are accepted in many grades of wall paneling.

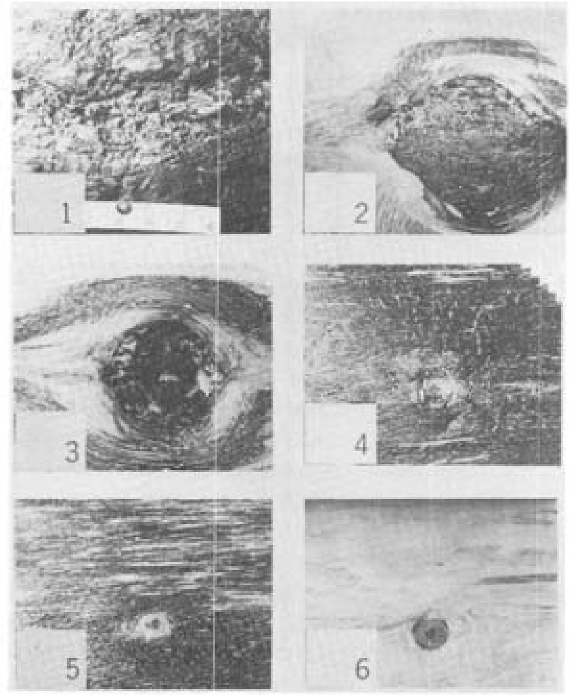

Figure 8.--Knot sequence from the indicator on the bark of Douglas-fir (1) to bolt diameters of 38 inches (2), 35 inches (3), 30 inches (4), 21 inches (5), and 17 Inches (6).

(M 87667 F)

Straight and Irregular Grain

Straight grain is generally considered desirable for veneer logs, A typical commercial veneer log grade will state that deviation from straight grain shall not exceed so many inches per foot of length of log. As described under physical properties of wood, straight-grained wood is easier to cut and dry and generally performs better in plywood panels than veneer having irregular grain.

The one exception to this rule is for logs suitable for decorative face veneer. In some cases irregular grain is desired because it enhances figure in the veneer cut from the log,

The detection of figured wood in standing trees and logs is described in reference (26). Essentially the method is based on examining the bark and log end sections for inclination and waviness of the cellular structure of the wood. In some instances this can be detected from the rough outer bark. For example, yellow birch with a smooth bark is generally straight grained, while that with rough irregular bark often contains curly or other irregularities in the grain. Curly grain may not be apparent in the outer bark but if the outer bark is removed with a draw shave to reveal the soft layers of the inner bark, then the grain pattern can be seen. Figured wood may also be indicated by the shape of splits in the log end surface. If the splits have alternate zig-zag patterns, the wood will almost certainly have a pronounced figure.

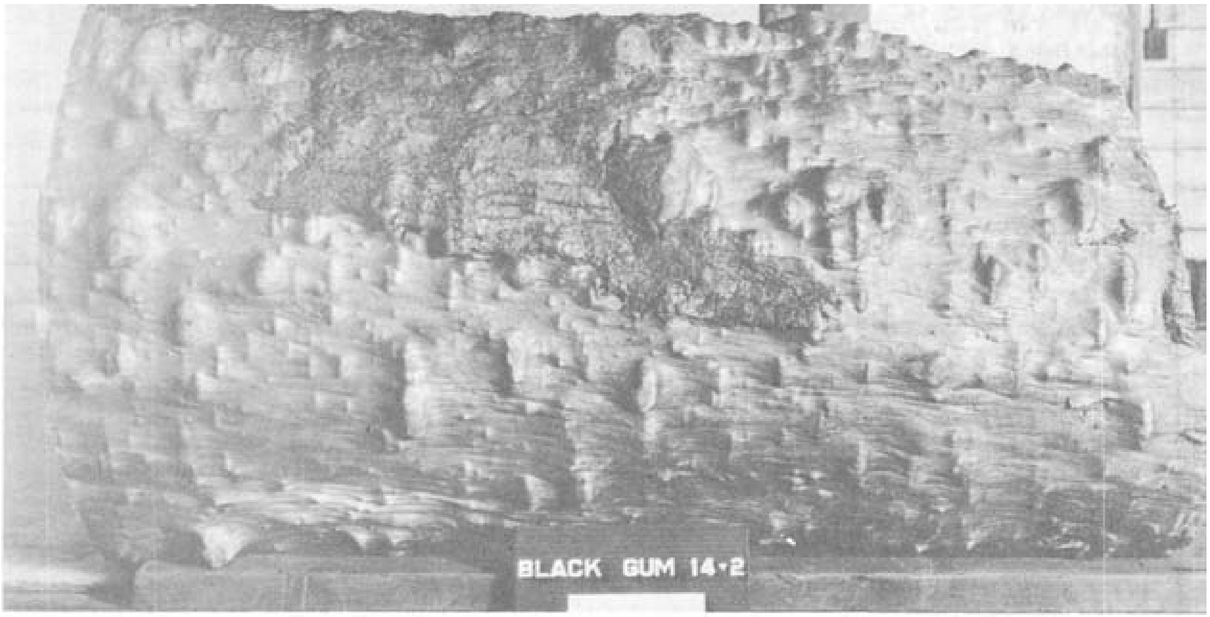

Figure 9.--A bolt of black gum with many burls on the surface, Veneer cut from this bolt is shown in figure 10. (M 91476 F)

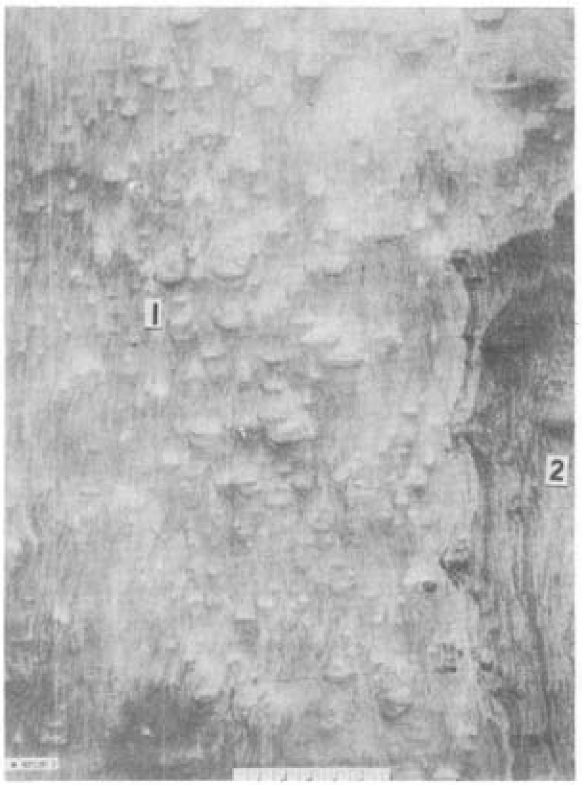

Figure 10.--Burls in the sapwood 1, and heartwood 2, of rotary veneer cut from the bolt shown in figure 9. The burls persisted to the 8-inch core of the bolt. The scale is in inches. (M 92128 F)

Another technique is to cut a small section from the log end in a radial direction and then split this piece. The split will follow the grain direction and indicate if it is wavy or curly.

Burls on the surface of the log may indicate that the entire log has irregular grain (fig. 9 and 10). Veneer that is figured throughout from small or large burls is often valued for its decorative effects. Other face veneers (table 1) are limited in the size and number of burls that are permitted.

Color

In general a uniform color is desirable in veneer logs, but the color desired varies with the end use. Light-colored wood is appropriate for containers as it makes a good background for marking and is psychologically pleasing to the consumer. Maple logs with wide sapwood zones are currently in demand because of the popularity of white face stock. In contrast the heartwood color is in demand for species like cherry and walnut.

Non-uniformity in color between logs can cause problems. For example the preferred color of walnut is a light gray-brown. Green and purple tinges that sometimes occur in walnut are not wanted because they cause special problems in finishing.

Studies at the Forest Products Laboratory (21) show that the color of walnut varies with the geographic area in which the trees grow. There is some evidence that the color of walnut heartwood is related to the type of soil in which the tree has gown. In addition, color in veneer can be regulated to some extent by the heating and drying process (16).

When a mixture of species, such as the lauans, is used, the material typically available for faces will display a variety of heartwood colors. Recently some veneer and plywood manufacturers have bean using electronic devices to separate such veneer into several groups according to color. This simplifies the finishing process, and aids in marketing the products made from variable color species.

Gum Streaks and Pockets

Gum streaks and pockets in hardwood logs can sometimes be seen on log ends. Large gum pockets may be detected as bulges on the log. While a small amount of gum can be permitted in some products, gum is generally regarded as undesirable.

Pitch and Pitch Pockets

Pitch is found in one hardwood genus and in many softwoods like Douglas-fir, ponderosa pine, and southern pine. Massed pitch and pitch pockets can often be detected on log ends. Pitch pockets are limiting defects in veneer (table 1).

Bark Pockets

Bark pockets occur in some softwoods and in hardwoods like the oaks and hickories. They may show on log ends or as overgrowths on the bark (14). Bark pockets are limiting defects for most veneer uses.

Holes

Large holes such as those resulting from a rotted branch stub or a woodpecker nest are major defects in veneer logs.

Medium holes up to 1/2 inch in diameter may be made by grubs that tunnel in living trees of species like oak. Some other causes of medium-sized holes are tap holes in butt logs of sugar maple, bullet holes, and holes made by an increment borer. Medium-size holes can often be detected by close examination of the bark and of log end sections. Medium-size holes are generally accompanied by severe stain. If extensive, they seriously degrade the log for use as veneer.

Pin worm holes made by ambrosia beetles occur in hardwoods like oak and ash and also in various softwoods. This defect can be particularly serious with tropical hardwoods. Pin worm holes can sometimes be detected on log end sections. A few scattered pin worm holes can be tolerated in most veneer uses, but heavy attack seriously degrades the veneer.

Decay

Decay is a severe defect in veneer logs, especially for rotary-cutting. If the log center is decayed and soft, the chucks may not be able to hold the veneer bolts securely enough to permit rotary cutting, Slightly or moderately decayed logs can sometimes be cut into veneer, providing the wood is still reasonably firm. The best example of this is Douglas-fir that has been attacked by *Fomes pini* (white-pocket). Millions of square feet of softwood plywood have been made from rotary-cut Douglas-fir veneer containing white-pocket. Sound flitches for slicing can sometimes be sawn from logs with considerable decay.

Fire Scars

Fire scars are generally obvious on the cross section of a log, and often indicate associated decay. Extensive fire scars make logs of doubtful value for use in veneer.

Seams

Seam are radial cracks that may or may not be overgrown They may be caused by wind, lightning, or frost. Seams generally originate at the surface of the log and occur in the standing tree. In contrast, splits due to growth stresses start at the pith and generally do not extend to the surface of the log. As a result, seam are visible on the standing tree but splits are not. As seams occur through the cambium layer they may be overgrown by callus tissue. Splits never have such overgrown tissue. Species that may have seam include oak, ash, maple, beech, and birch. The seriousness of this defect depends on how deeply it penetrates the log and whether it is parallel to the log length or spiralled. A straight seam can be clipped from the veneer with less waste than that caused by a spiralled seam.

Bird Peck

Bird peck and associated stain is a common characteristic on such species as yellow-poplar and hickory. Bird peck can be detected by characteristic holes in the bark and by stain on the log ends. Logs with this characteristic are generally suitable for core and crossband veneer but may be limited for use as face veneer.

Stain

The term "stain" has been used to describe several different phenomena. Causes of some stains are known. such as fungal or contact with iron, while others are still being studied. Further, the severity of some stains is directly related to the amount of sapwood and the environment in which the log is held, One way of separating stains for practical purposes is to considerthose in the standing tree as opposed to those that may develop after the tree is felled.

Stain in standing trees.--The terminology concerning stain in standing trees is not well accepted. For example, some authors limit the term mineral stain to small olive or greenish-black discolorations in the heartwood and sapwood of the maples and the gums. Others use the same term to describe brown stains in species like aspen and oak. Still other authors attribute these and other stains in oak and aspen and other hardwoods to oxidation of cell materials and call them oxidation stains. Bacteria have also been reported as associated with various stains in living trees,

For purposes of this publication, stains in standing trees will not be separated. Stains are found in both heartwood and sapwood of the living tree and are often associated with injury to the tree such as insect attack or broken branches.

In addition to the discoloration, intense areas of stain are more likely to collapse and check during drying. Higher ash content has been found in dark green or black stained maple than in normal bright wood. Some plant personnel report more rapid dulling of tools when cutting such stained wood.

Brown stain is common in oak trees growing on upper slopes or ridge tops, Because of the poor growth site, these trees are generally also of poor form and do not supply many potential veneer logs. Oak trees growing on moist soils that may be water saturated for extended periods are also subject to stain. Logs from such trees may in other respects appear to be of quality suitable for veneer,

Stain in standing trees may be sporadic and localized to small streaks or it may occur over broad areas. Consequently, the stain may or may not be visible on freshly cut log ends.

Some recent reports on stain in the living tree include (4,29,32).

Stain that may develop in stored logs or green veneer.--Four types of stain that may develop in stored logs or during veneer processing are sap stain, mold, oxidative stain, and iron stain.

Sap stain is fungal in origin and is most commonly blue in color. It is particularly troublesome in the sapwood of species like sweetgum and southern pine if the logs are stored during periods of warm, humid weather. The color is caused by a concentration of hyphae. For many veneer uses, blue stain is objectionable. It should be controlled by keeping log storage to a minimum and if necessary by use of chemical sprays or water sprays. Veneer can be protected by drying the stock as rapidly as possible or by dipping or spraying with an antistain solution if drying is to be delayed.

Molds are also fungal in origin, but the color which may be yellow, brown, red, purple, green, blue, or black comes mainly from spores of the fungi. Mold is characterized by a downy growth on the surface of the wood. Mild temperature, still air, and abundant moisture promote growth of mold. Under these conditions mold may be a problem in green sapwood veneer that is stored 3 or more days before drying. Control methods are similar to those suggested for blue stain.

Oxidative stain is a chemical stain that is thought to be the result of oxidation, sometimes promoted by enzymatic action on certain materials stored in the wood cells. Like blue stain and mold. it develops in the sapwood of logs and green veneer when favorable moisture and temperature exist. It has caused objectionable discoloration of light-colored face veneers of species like birch and maple. In logs, the stain progresses gradually in from the ends during warm weather storage, so cold-weather storage or reducing storage time is the best method for preventing this stain. Use of a white lead paste end coating or especially of a water-spray during storage may materially reduce this stain but will not stop it, Drying the veneer as soon as possible after cutting also reduces the chance of oxidation stain. Concentrated oxalic acid will generally bleach oxidation stain but not fungal-caused blue stain.

Tannin and other polyphenols react with iron and steel in the presence of water to form a blue-black stain. This becomes very obvious and objectionable on face veneer of species like oak and redwood if the wet wood is in contact with iron or steel for even a brief time. Concentrated oxalic acid or hydrofluoric acid will bleach out iron stain. These acids must then be flushed from the wood or the stain may reappear.

Some references on stains originating during processing logs into veneer include (5,30,31).

Man-made Defects Other than Holes

Man-made defects include stump pull, felling splits, log handling damage, and embedded metal.

Stump pull and felling splits.--Both of these defects cause splits in the veneer cut from the logs. Stump pull is generally obvious as a jagged hole on the log end. Butt logs should be carefully examined as felling splits may close and be difficult to detect.

Log handling damage.--Handling logs with tongs is a needless source of defect. Not only may the tongs put holes in otherwise clear veneer. but they also frequently embed sand or grit that damages the knife used to cut the veneer. Similar problems occur with logs that have dirt or gravel embedded in the outer sapwood when the logs were dropped or dragged on a gravel or cinder surface.

Embedded metal.--Buried metal is a serious problem in logs cut from street trees and fence rows. Because barbed wire and nails will generally damage a veneer lathe or slicer knife, many veneer log buyers will not purchase logs that come from along fences or streets. Buried metal may be detected because it has formed a bump on the log. Many veneer mills have magnetic metal detectors for screening all logs and flitches.

Soft lead from buck-shot and small arms can be cut without damaging the lathe or slicer knife. However, steel-jacketed bullets or shrapnel such as may be found in timber from a battle zone are very serious defects. Aside from the damage to the knives used to cut the veneer, buried metal often causes extensive stain in the wood.

VENEER YIELD IN A PRODUCTION PLANT

Once the appearance of the wood, its physical and mechanical properties and the quality of log is known, the final step before committing a plant to using a veneer species is to make a plant production run. Naturally it is vital to get representative logs for such a run. The best technique is to completely describe the logs and tally the recovery of veneer by grade from each individual log. One way of doing this for hardwood veneer is described in (9). Some results of using the Forest Products Laboratory hardwood veneer grades are given in (8). Another approach to hardwood veneer recovery is given in a study of aspen veneer yields (3).

Veneer yield studies of two softwoods, Douglas-fir (13) and ponderosa pine (1) show how veneer recovery can be estimated from log grades.

Two factors are important in yield studies--the total yield of usable veneer and the yield in various widths and grades of veneer, In general. the total yield should at least equal the log scale. The yield of face veneer, preferably in 4- and 2-foot widths, should be at least one-third of the total veneer yield. These are general guidelines and may well be modified depending on the intended end product.

VOLUME OF TIMBER NEEDED TO SET UP A VENEER PLANT

A typical softwood plywood plant in the United States uses approximately 40 million board feet of logs per year. The smallest economically suitable softwood plywood plant uses about 15 million board feet of logs a year. If the volume of wood available at a site is less than this, there is little point in considering it for structural softwood plywood.

Hardwood plywood plants are often smaller than softwood plywood plants. In addition, they frequently use a variety of species. Therefore while 12 to 15 million board feet of logs may be used in a year, a hardwood species that could be supplied at the rate of 5 million boardfeet a year could probably be used satisfactorily.

An even greater diversity of species is cut by mills making face veneers. Manufacturers of face veneers state that it is imperative that a continuing supply of a new face veneer must be available. Otherwise the cost of advertising and other promotion needed to get a new species accepted Is not warranted.

Core and crossband veneer are generally not specified by the ultimate customer. Hence, introducing a new species is not as difficult as with face veneers. The technical properties of the wood and the volume availability at a reasonable cost are important for core and crossband veneers.

Container veneer often is made from a variety of species. Typical plants are small and use less volume of logs than plywood plants. The end product is generally an expendable low-cost container. Cheap stumpage is essential. Lower quality logs than those acceptable for plywood panels are successfully used for container veneer.

Two examples of the importance of available timber are the development of southern pine softwood plywood and hickory- or pecan-faced hardwood plywood during the 1960's. Both of these groups of species are relatively difficult to process into veneer and plywood. Yet, because of the large available timber supply of each, southern pine is challenging the western softwood plywood industry and hickory and pecan are one of the major groups of woods used for decorative face veneer.

In some mixed forests of the tropics, the total stumpage is large, but no one species occurs in large volume. In these areas it is often difficult to exploit new species for veneer. This is true even for a species that has good technical properties for use as veneer.

The cost of developing information on a new species, determining how it should be handled in production, introducing it and promoting it in a product line is very costly. If a species is available only on a sporadic basis, it is generally not economical for a manufacturer to utilize the species.

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APPENDIX

IDENTIFICATION OF CONTINENTAL U.S. WOODS

AND OTHERS MENTIONED IN THIS REPORT[1,2]

Commercial name of veneer	Common name	Botanical name
	Continental U.S. Hardwoods	
Alder:		
Red alder	Red alder	Alnus rubra
Ash:		
Black ash	Black ash	Fraxinus nigra
Oregon ash	Oregon ash	F. latifolia
Pumpkin ash	Pumpkin ash	F. profunda
White ash	Blue ash	F. quadrangulata
	Green ash	F. pennsylvanica
	White ash	F. americana
Aspen	Bigtooth aspen	Populus grandidentata
	Quaking aspen	P. tremuloides
Basswood	American basswood	Tilia americana
	White basswood	T. heterophylla
Beech	Beech	Fagus grandifolia
Birch:		
White birch	Gray birch	Betula populifolia
	Paper birch	B. papyrifera
	River birch	B. nigra
Yellow birch	Sweet birch	B. lenta
	Yellow birch	B. alleghaniensis
Box elder	Boxelder	Acer negundo
Buckeye	Ohio buckeye	Aesculus glabra
	Yellow buckeye	A. octandra
Butternut	Butternut	Juglans cinerea
Cherry	Black cherry	Prunus serotina

(continued)

[1]Names of wood from continental United States are taken from "Check List of Trees of the United States," by Elbert L. Little Jr. U.S.D.A., Agriculture Handbook 41, 1953.

[2]All species of a size that could be used for veneer. Many are not generally used at present.

Chestnut	Chestnut	*Castanea dentata*
Cottonwood	Balsam poplar (Balm of Gilead)	*Populus balsamifera*
	Eastern cottonwood	*P. deltoides*
	Swamp cottonwood	*P. heterophylla*
	Black cottonwood	*P. trichocarpa*
Cucumber	Cucumbertree	*Magnolia acuminata*
Dogwood	Flowering dogwood	*Cornus florida*
Elm:		
Rock elm	Cedar elm	*Ulmus crassifolia*
	Rock elm	*U. thomasii*
Soft elm	Winged elm	*U. alata*
	American elm	*U. americana*
	Slippery elm	*U. rubra*
Gum	Sweetgum	*Liquidambar styraciflua*
Hackberry	Hackberry	*Celtis occidentalis*
	Sugarberry	*C. laevigata*
Hickory	Mockernut hickory	*Carya tomentosa*
	Pignut hickory	*C. glabra*
	Shagbark hickory	*C. ovata*
	Shellbark hickory	*C. laciniosa*
Holly	American holly	*Ilex opaca*
Ironwood	Eastern hophornbean	*Ostrya virginiana*
Locust	Black locust	*Robinia pseudoacacia*
	Honey locust	*Gleditsia triacanthos*
Madrone	Pacific madrone	*Arbutus menziesii*
Magnolia	Southern magnolia	*Magnolia grandiflora*
	Sweetbay	*M. virginiana*
Maple:		
Hard maple	Black maple	*Acer nigrum*
	Sugar maple	*A. saccharum*
Oregon maple	Bigleaf maple	*A. macrophyllum*
Soft maple	Red maple	*A. rubrum*
	Silver maple	*A. saccharinum*

Mulberry	Red mulberry	*Morus rubra*
Oak:		
Red oak	Black oak	*Quercus velutina*
	Blackjack oak	*Q. marilandica*
	California black oak	*Q. kelloggii*
	Cherrybark oak	*Q. falcata* var. *pagodaefolia*
	Laurel oak	*Q. laurifolia*
	Northern pin oak	*Q. ellipsoidalis*
	Northern red oak	*Q. rubra*
	Nuttall oak	*Q. nuttallii*
	Pin oak	*Q. palustris*
	Scarlet oak	*Q. coccinea*
	Shumard oak	*Q. shumardii*
	Southern red oak	*Q. falcata*
	Water oak	*Q. nigra L.*
	Willow oak	*Q. phellos*
White oak	Blue oak	*Q. douglasii*
	Bur oak	*Q. macrocarpa*
	California white oak	*Q. lobata*
White oak	Chestnut oak	*Quercus prinus*
	Chinkapin oak	*Q. muehlenbergii*
	Live oak	*Q. virginiana*
	Oregon white oak	*Q. garryana*
	Overcup oak	*Q. lyrata*
	Post oak	*Q. stellata*
	Swamp chestnut oak	*Q. michauxii*
	Swamp white oak	*Q. bicolor*
	White oak	*Q. alba*
Oregon myrtle	California-laurel	*Umbellularia Californica*
Osage orange	Osage-orange	*Maclura pomifera*
Pecan	Bitternut hickory	*Carya cordiformis*
	Nutmeg hickory	*C. myristicaeformis*

Pecan (con.)	Water hickory	C. aquatica
	Pecan	C. illinoensis
Persimmon	Common persimmon	Diospyros virginiana
Poplar	Yellow-poplar	Liriodendron tulipifera
Sassafras	Sassafras	Sassafras albidum
Sycamore	American sycamore	Platanus occidentalis
Tanoak	Tanoak	Lithocarpus densiflorus
Tupelo	Black tupelo	Nyssa sylvatica
	Ogeechee tupelo	N. ogeche
	Water tupelo	N. aquatica
Walnut	Black walnut	Juglans nigra
Willow	Black willow	Salix nigra
	Peachleaf willow	S. amygdaloides

Continental U.S. Softwoods

Cedar:		
Alaska cedar	Alaska-cedar	Chamaecyparis nootkatensis
Incense cedar	Incense-cedar	Libocedrus decurrens
Port Orford cedar	Port-Orford-cedar	Chamaecyparis lawsoniana
Eastern red cedar	Eastern redcedar	Juniperus virginiana
Western red cedar	Western redcedar	Thuja plicata
Northern white cedar	Northern white cedar	T. occidentalis
Southern white cedar	Atlantic white-cedar	Chamaecyparis thyoides
Cypress	Baldcypress	Taxodium distichum
	Pondcypress	T. distichum var. nutans
Douglas-fir	Coast	Pseudotsuga menziesii
	Interior west	P. menziesii
	Interior north	P. menziesii var. glauca
	Interior south	P. menziesii var. glauca
Fir:		
Balsam fir	Balsam fir	Abies balsamea
Noble fir	Noble fir	A. procera
White fir	Subalpine fir	A. lasiocarpa
	California red fir	A. magnifica

White fir (con.)	Shasta red fir	A. magnifica var. shastensis
	Grand fir	A. grandis
	Noble fir	A. procera
	Pacific silver fir	A. amabilis
	White fir	A. concolor
Hemlock		
Eastern hemlock	Eastern hemlock	Tsuga canadensis
Mountain hemlock	Mountain hemlock	T. mertensiana
West Coast hemlock	Western hemlock	T. heterophylla
Juniper, western	Alligator juniper	Juniperus deppeana
	Rocky Mountain juniper	J. scopulorum
	Western juniper	J. occidentalis
Larch, western	Western larch	Larix occidentalis
Pine:		
Digger pine	Digger pine	Pinus sabiniana
Jack pine	Jack pine	P. banksiana
Jeffrey pine	Jeffrey pine	P. jeffreyi
Knobcone pine	Knobcone pine	P. attenuata
Limber pine	Limber pine	P. flexilis
Lodgepole pine	Lodgepole pine	P. contorta
Norway pine	Red pine	P. resinosa
Ponderosa pine	Ponderosa pine	P. ponderosa
Sugar pine	Sugar pine	P. lambertiana
Idaho white pine	Western white pine	P. monticola
Northern white pine	Eastern white pine	P. strobus
White bark pine	White bark pine	P. albicaulis
Southern pine	Loblolly pine	P. taeda
	Shortleaf pine	P. echinata
	Longleaf pine	P. palustris
	Slash pine	P. elliottii
	Spruce pine	P. glabra
	Pondpine	P. serotina
	Virginia pine	P. virginiana
	Pitch pine	P. rigida
	Sand pine	P. clausa
	Table mountain pine	P. pungens

Redwood	Redwood	Sequoia sempervirens
	Giant sequoia	S. gigantea
Spruce:		
Eastern spruce	Black spruce	Picea mariana
	Red spruce	P. rubens
	White spruce	P. glauca
Engelmann Spruce	Blue spruce	P. pungens
	Engelmann spruce	P. engelmannii
Sitka spruce	Sitka spruce	P. sitchensis
Tamarack	Tamarack	Larix laricina
Pacific yew	Pacific yew	Taxus brevifolia
	Other Species	
Angelique	Angelique	Dicorynia guianensis
Avodire	Avodire	Turraeanthus africanus
Brazil. nut	Brazil nut	Bertholletia excelsa
Bubinga	Bubinga	Guibourtia spp.
Cativo	Cativo	Prioria copaifera
Ceiba	Ceiba	Ceiba pentandra and samauma
Determa	Determa	Ocotea rubra
Klinki	Klinki pine	Araucaria klinkii
Lauan	Philippine mahogany	
Dark red	Tangile	Shorea polysperma
Light red	Almon	Shorea almon
Light red	Bagtikan	Parashorea plicata
Limba	Limba	Terminalia superba
Mahogany	Honduras mahogany	Swietenia macrophylla
	African mahogany	Khaya spp.
Mengkulang	Mengkulang	Tarrietia spp.
Meranti	Meranti	Shorea spp.
Paldao	Paldao	Dracontomelon spp.
Primavera	Primavera	Cybistax donnell-smithii
Rosewood	Rosewood	Dalbergia spp.
Sapele	Sapele	Entandrophragma cylindricum
Teak	Teak	Tectona grandis
Caribbean pine	Caribbean pine	Pinus caribaea