United States
Department of
Agriculture

Forest Service

**Northeastern
Research Station**

General Technical
Report NE-313

Defining Hardwood Veneer Log Quality Attributes

Jan Wiedenbeck
Michael Wiemann
Delton Alderman
John Baumgras
William Luppold

Abstract

This publication provides a broad spectrum of information on the hardwood veneer industry in North America. Veneer manufacturers and their customers impose guidelines in specifying wood quality attributes that are very discriminating but poorly defined (e.g., exceptional color, texture, and/or figure characteristics). To better understand and begin to define the most important attributes that distinguish veneer logs from sawlogs, and high-end from low-end veneer logs, we visited and interviewed veneer log buyers and sellers, veneer manufacturers, and veneer sales personnel. The first section of this report provides information on the demographics of the hardwood veneer industry and domestic and export market influences on veneer manufacturing. This is followed by a discussion of: 1) veneer quality requirements for different product markets, 2) veneer log quality evaluation procedures, 3) veneer log procurement systems, 4) regional variations in veneer log quality characteristics, and 5) species-specific quality requirements and issues.

The Authors

JAN WIEDENBECK is a research scientist with the USDA Forest Service, Northeastern Research Station in Princeton, WV. MICHAEL WIEMANN is a research scientist with the USDA Forest Service, Forest Products Laboratory in Madison, WI. DELTON ALDERMAN is a research scientist and JOHN BAUMGRAS and BILL LUPPOLD are Project Leaders with the USDA Forest Service, Northeastern Research Station in Princeton, WV.

Manuscript received for publication on 3 March 2003.

Published by:

USDA FOREST SERVICE
11 CAMPUS BLVD SUITE 200
NEWTOWN SQUARE PA 19073-3294

January 2004

For additional copies:

USDA Forest Service
Publications Distribution
359 Main Road
Delaware, OH 43015-8640
Fax: (740)368-0152

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Introduction

The pinnacle of log quality for hardwood products manufacturers is the appearance-grade veneer log — logs that can produce veneer that is highly visually appealing (as opposed to veneer that is used in hidden applications). But high-quality trees that contain these top-quality logs are relatively rare, representing less than 1 percent of the hardwood *sawlog*[1] inventory in the northeastern United States (Hoover and Gann 1999). Because of the high value of the veneer product that comes from appearance-grade veneer-quality trees and their relative scarcity in the forest, these trees command a significantly higher price than do trees that contain only sawlogs. The veneer logs cut from these highest quality trees typically cost 1.5 to 6 times the price of grade 1 sawlogs (Table 1). Because of the exceptionally high prices paid for veneer-quality trees, a large portion of a quality stand's timber value may be derived from only a small fraction of the trees in the stand. These price differentials can provide significant economic incentive for both the landowner and the logger to manage their resources to optimize the production and recovery of veneer logs.

When managing a timber stand, there are many things that can be done wrong that can damage trees and/or greatly reduce the price that the landowner receives when he/she decides to sell his/her timber. Timber value is lost if the timber harvest is mistimed, such as, if veneer-quality trees are removed before they are of sufficient size. Also, if potential veneer-quality growing stock is cut, injured, or crowded (poor between-tree spacing) during thinning operations, veneer log yields will be reduced. Other timber management strategies that might be less obvious also affect the value returned to the landowner. By enhancing our knowledge of veneer-quality requirements, we can better understand how these other management practices influence the yield of veneer-quality timber. With lower value products (e.g., rubberwood, medium density fiberboard, plywood) coming into greater use in the construction of furniture, worldwide demand for U.S. hardwood veneer is rapidly increasing. This will lead to continuing price inflation for veneer-quality timber and stronger incentives to manage prime timber stands to promote the yield of the highest grade sawlogs and veneer logs.

Even though hardwood veneer logs typically are regarded as the upper end of the log-quality spectrum, there can be significant variation in characteristics between logs. Variation in veneer log price is based not only on quality, but also on species, markets (e.g., *sliced veneer* for fine furniture vs. *rotary veneer* for panels/plywood), customers, and the veneer manufacturer's veneer *procurement* strategy.

For most appearance-grade veneer, the primary quality criterion is its "attractiveness." Of course, "attractiveness" is judged differently from one person to the next. The three key aspects of "attractiveness" are wood color, grain pattern, and blemish or defect content. The effect of a defect on appearance depends on the type, size, and location of the defect, as well as the method of veneer production (e.g., how the veneer log is sliced). Unfortunately, defects are sometimes revealed only after a log has been sliced into veneer. Defects that affect many veneer slices may render the log worthless for veneer resulting in a substantial monetary loss to the veneer manufacturer. The loss includes not only the purchase price but also log shipping and handling costs, the expense of log storage, and costs associated with log processing up to the point that the defect is discovered (processing costs for sliced, dried, and *clipped* veneer are high – approximately 10 times the cost for converting logs into lumber).

Since the 1950s, attempts have been made to identify defects and develop grading systems for hardwood veneer logs (Harrar 1954, Bethel and Hart 1960, Henley et al. 1963, Harrar and Campbell 1966). In spite of these attempts, the purchase of logs for high-quality veneer is still largely based on company-specific grading criteria with acceptable log characteristics and prices changing in response to market forces. Cassens (1992) published one of the most comprehensive discussions on the site, stand, tree, and log characteristics that affect hardwood veneer quality. His publication describes the methods of producing hardwood veneer and the markets that purchase and utilize the veneer. He relates these to the tree and log characteristics that determine veneer quality and uses.

This report is a synopsis of information on veneer tree, log, and product quality characteristics as they relate to

[1]Words in italics are defined in the Glossary on page 22.

Table 1.—Prices, by species, paid for delivered veneer logs (mbf Doyle scale) and price ratio for veneer logs compared to grade 1 sawlogs, according to five sources.[1]

	Pennsylvania[2]		Indiana[3]		Tennessee[4]		Kentucky[5]		Log Broker[6]	
Species	**$ per mbf[7]**	**x higher than grade 1 sawlog price**	**$ per mbf**	**x higher than grade 1 sawlog price**	**$ per mbf**	**x higher than grade 1 sawlog price**	**$ per mbf**	**x higher than grade 1 sawlog price**	**$ per mbf**	**x higher than grade 1 sawlog price**
Cherry	3,590	2.1	—	—	—	—	1,000-6,500	1.1-7.1	1,925	3.2
Hard maple	1,390	1.7	1,700-2,270	2.8–3.7	—	—	1,000-3,000	1.7-5.1	1,470	2.9
Red oak	1,290	1.6	1,100-1,600	1.8-2.7	1,100-1,500	1.4-1.9	700-2,000	1.1-3.1	850	2.6
White oak	1,170	2.5	1,350-1,800	2.7-3.6	900-1,500	1.6-2.7 3,000	650-	1.6-6.7	515	2.9
Walnut	—	—	2,200-3,500	3.0-4.7	1,500-2,000	2.3-3.1	1,000-6,000	1.5-9.0	—	—
Yellow-poplar	510	1.5	540-590	1.7-1.9	500	1.6	400-1,500	1.1-4.1	—	—

[1]One veneer log procurement specialist who reviewed this paper commented that the prices listed here "are rotary log prices in today's market. Sliced veneer (log prices) would be about twice (as high)."
[2]Pennsylvania Woodlands 2001 and 2002; Prices taken from four quarterly reports: third and fourth quarters of 2001 and first and second quarters of 2002.
[3]Hoover and Gann 2001.
[4]Tennessee Department of Agriculture, Division of Forestry 2002.
[5]Kentucky Department of Agriculture 2001.
[6]Wightman Lumber 2002.
[7]1,000 board feet

appearance-grade (face) veneer markets. It includes both generalized and specific information on veneer log quality standards. Some discussion is included of the lower-grade veneer markets and their associated quality characteristics, but the focus is on high-end veneer markets. It highlights veneer log attributes that are important in the marketplace for the most important veneer species. Regional and site-related variations in veneer log quality are presented. Ultimately, our goal is to learn more about those defects that vary based on the silvicultural treatment applied to the forest stand. Much of this information should be useful to forest landowners, consulting foresters, and less experienced log buyers/graders as it will increase their understanding of the relationship between forest management, tree quality, and tree/log value. This information also will help in identifying and prioritizing future hardwood tree and wood quality research.

Project Objectives

Our objective at the outset of this project was to better define the attributes of veneer logs that distinguish them from sawlogs so our research into the impacts of forest management on wood quality will have maximum impact. Increasing the production of high-quality timber is our ultimate goal. Rather than obtaining specific attribute criteria on a handful of important defects, our work to date has addressed two allied objectives: 1) to understand which log characteristics are most frequently the determinant characteristics that separate high-grade sawlogs from veneer logs, and 2) to better understand how these determinant characteristics are appraised for different markets by different log buyers. By meeting these objectives, we can focus future efforts on defining the criteria for the most important log attributes and identifying forest management practices that influence these criteria.

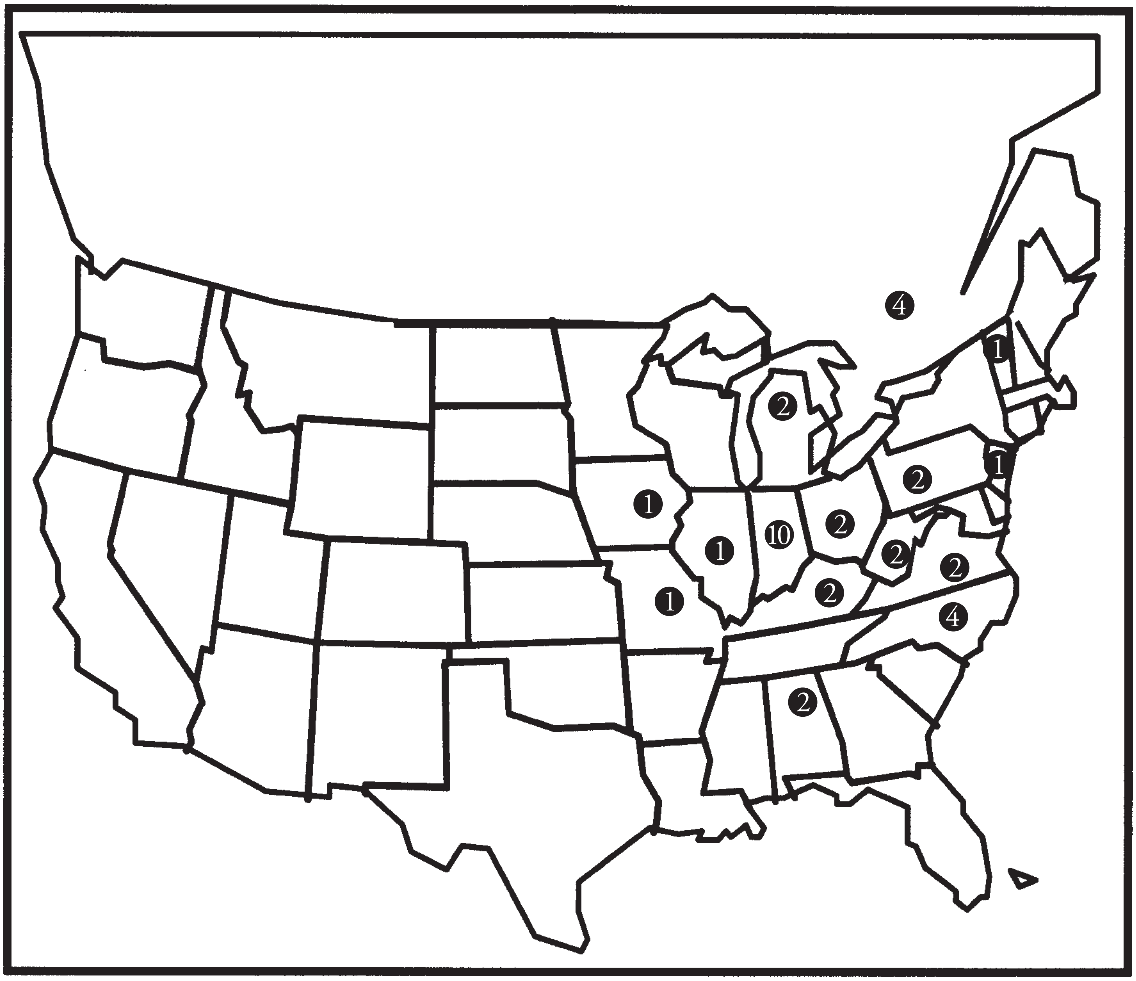

Figure 1.—Distribution of hardwood veneer slicing operations in North America. The numbered bullets represent the number of companies operating in each state and Canada. This plant location map was compiled based on information acquired from the internet and the Hardwood Plywood and Veneer Association (1998, 2001b). The map is approximate; omissions are unintentional.

North American Appearance-Grade Veneer Industry Overview

There are about 56 North American appearance-grade veneer manufacturing operations (Hardwood Plywood and Veneer Association 1998). Of these, an estimated 41 hardwood veneer slicing operations are located in North America, including 37 in the United States and 4 in eastern Canada (Fig.1) (Hardwood Plywood and Veneer Association 1998). All but two are east of the Mississippi. Most of these plants have multiple veneer slicers (or knives), as it is common for veneer plants to have both flat and *rotary slicing* capabilities. But there are about 15 veneer operations in North America that exclusively manufacture rotary veneer, which is used primarily for stock panels; all of these plants are located in the eastern states and provinces.

It is estimated that North American hardwood veneer plants operate 112 flat (or vertical) slicers, 36 *half-round slicers*, and 50 rotary lathes (Hardwood Plywood and Veneer Association 2001a, 2001b). It is possible we have overlooked some smaller veneer operations with single slicers and manufacturers that focus on softwood species, but occasionally slice hardwoods.

In 2000, sliced veneer production at North American plants was over 6.0 billion square feet, of which approximately 47 percent was exported (this percentage does not include sales between Canada and the United States) (Hardwood Plywood and Veneer Association 2001a). In addition, 3.3 billion square feet of rotary veneer was produced in North America in 2000.

The top five importers of hardwood veneer manufactured in the United States in 2002 were: Canada, Germany, Spain, China, and Italy (based on export value). Just 5 years earlier, the top five importers of domestic veneer were: Germany, Canada, Spain, the United Kingdom, and

Belgium-Luxembourg (Italy was seventh and China was not in the top 10) (Foreign Agricultural Service 2002). Veneer export figures for 2000 substantiate the escalating importance of the greater China region (China, Hong Kong, and Taiwan) in furniture production — 20 percent of the sliced hardwood veneer exported from North America went to the region (based on square footage) (Hardwood Plywood and Veneer Association 2001a). European countries consumed about 60 percent of North American sliced veneer production in 2000 while the rest of Southeast Asia consumed only 12 percent. The total value of U.S. veneer exports increased by approximately 41 percent between 1994 and 2000 and by 84 percent from 1992 to 2000 (Foreign Agricultural Service 2001).

In 2000, the most important species for sliced veneer manufactured in North America were: cherry (*Prunus serotina* Ehrh., 29 percent of production), red oak (*Quercus rubra* L., 20 percent), hard maple *(Acer saccharum* Marsh., 17 percent), white oak (*Quercus alba* L., 16 percent), and walnut (*Juglans nigra* L., 5 percent) (Hardwood Plywood and Veneer Association 2001a). However, veneer market demand can vary greatly over a short span of years. An example from the recent past is the U.S. market for white oak sliced veneer. Whereas white oak sliced veneer was only the fourth most important species in 2000 (the beginning of a soft domestic market for white oak sliced veneer), in 1999 and for several years prior, white oak sliced veneer production was second only to cherry.

The most important species of thin-sheet (≤1/28 inch) rotary veneer were: birch (*Betula* spp., 43 percent of production), red oak (28 percent), and hard maple (26 percent) (Hardwood Plywood and Veneer Association 2001b). Thick-sheet rotary veneer production constituted only 13 percent of total rotary veneer production in 2000. Hard maple and red oak are the two most important species for manufacturers of thick rotary veneer.

Variations in World Veneer Markets

An important market distinction that influences the value and quality requirements of veneer and veneer logs relates to differences in size, appearance, and form attributes preferred by domestic, European export, and Asian export markets. Regional market differences include species preference, packaging and form, veneer thickness, manufacturing process, and veneer quality differences. Since 47 percent of the sliced veneer produced in North America in 2000 was exported (Hardwood Plywood and Veneer Association 2001a), understanding these differences is vital.

For sliced veneer, certain species are more or less in demand in export markets compared to domestic markets. Red oak, which was the second most important species produced in North America in 2000 (20 percent of production), was tied for third in export importance (30 percent of total export volume) (Hardwood Plywood Veneer Association 2001a). Red oak veneer is not in demand in Europe but Southeast Asian companies purchase large volumes for manufacturing furniture, some of which will subsequently be sold in the United States and Canada. Asian furniture manufacturers also have developed strong markets in several Middle Eastern countries. Birch is another species that is less popular in export markets than North American sliced veneer markets - only 14 percent of the sliced birch veneer produced in North America in 2000 was exported. By contrast, white oak, which is in high demand in Europe, had the fourth largest production volume in 2000 (16 percent of total production), but was the second most important export species (23 percent of all exports). In fact, 51 percent of North American sliced white oak veneer was exported in 2000.

Just as there are significant year-to-year variations in the relative demand for different species in the domestic sliced veneer market, there also can be substantial shifts in international demand. For example, comparing U.S. veneer exports for 1999 and 2000, export value increased 5 percent for white oak, just less than 3 percent for red oak, 0 percent for hard maple, but 26 percent for cherry (Foreign Agricultural Service 2003)!

Sliced veneer prepared for export is edge and end clipped to remove unusable material after drying then assembled into 30-sheet *bundles* for ease of handling during grading and shipping. For example, it has been common practice in the production of maple veneer to clip out the *heartwood* from wider veneer sheets (that have at least 5 inches of *whitewood*), while *flitches* (bundles of veneer) from smaller diameter logs that yield smaller amounts of whitewood are not clipped for color. Traditionally, domestic veneer was not clipped and graded, but instead was restacked after drying into the quarter-, third-, or half-log flitches (log sections) from which it originated. Three sample sheets were removed from the flitch to demonstrate the quality of the flitch to potential buyers in veneer showrooms. This system still is used for domestic veneer sales but the export system of clipping, grading, and bundling is gaining supporters in North America. Whereas only 49 percent of North American hardwood sliced veneer production in 2000 was exported, 67 percent was clipped and bundled (Hardwood Plywood and Veneer Association 2001a).

Clipping improves the appearance of veneer bundles and increases the usable veneer volume/weight that is handled and shipped. But by clipping veneer, there is a risk that material will be removed from the sheets that could have been used by the buyer. Domestic furniture or dimension veneer markets that require shorter/smaller clear sections should continue to buy unclipped veneer flitches. If a veneer manufacturer lacks a good understanding of the specific veneer quality and size requirements of their customers, veneer clipping is likely to result in material waste.

Beginning in the 1980s, an important difference between domestic and export veneer markets has been veneer sheet thickness requirements. While 1/32-inch-thick veneer remained the standard thickness demanded by domestic buyers, export veneer buyers embraced 1/42-, 1/50-, 1/64-, 1/75- and even 1/100-inch veneer thicknesses. New veneer application and sanding technologies in Europe and Japan enabled super-thin veneer to be used. When slicing thinner veneer, much higher yields can be obtained (measured on a square-foot basis). A second important production benefit for manufacturers of super-thin veneer is an increase in drying efficiency. Lower temperatures and faster dryer throughput rates reduce energy requirements and bottlenecks at the veneer dryer. It has only been since the late 1990s that thinner veneer (usually 1/42 inch) has become more accepted by U.S. veneer buyers.

Veneer quality requirements vary among regional veneer markets. European, especially German, veneer markets are particularly focused on growth ring and texture consistency. Tighter growth rings are more important in European veneer markets than they are in domestic markets. Japan, which uses super-thin veneer (e.g., 1/100 inch), also demands tight growth rings. Domestic veneer markets usually accept more marks and more *figure* than do European markets. The same is true for China and other Southeast Asian markets.

Information Sources

To determine the most important attributes that distinguish veneer logs from sawlogs, and high-end veneer logs from low-end veneer logs, we visited three veneer log graders (buyers for a veneer producer), three veneer *log brokers*, 15 veneer producers, and one veneer broker in Indiana, Kentucky, New Hampshire, Ohio, Pennsylvania, Vermont, and West Virginia (Appendix 1).

Veneer producers and brokers are important sources of information on the quality aspects of veneer. Veneer log buyers and brokers are knowledgeable about the effects that external log attributes will have on veneer quality. Many log buyers spend time in the forest looking at timber sales so they also are sources of anecdotal information on how differences between sites affect veneer log quality attributes. Recognizing the link between the external appearance of logs and the appearance of finished veneer requires an understanding of how trees grow and respond to stresses as well as considerable field experience. Changing market conditions and consumer preferences (e.g., demand for dark versus light-colored wood) also are key factors in the determination of acceptability as a veneer-grade log.

We asked each of the veneer industry experts the following questions:

1. What are the most troublesome defects in each of your major veneer species?

2. Which log defects are hardest to spot/recognize when evaluating the exterior of the log prior to sawing and slicing?

3. Which log defects seem to have the greatest regional variation?

We also observed log grading and, when visiting veneer mills, the rotary cut, half-round, and vertically sliced veneer production processes. On several of these trips we were able to see the veneer being graded and talked with veneer sales personnel.

Veneer Product Requirements Dictate Veneer Log Requirements

Veneer log requirements are extremely variable, both between veneer operations and within a single operation. Variability is seen in the log species distribution, log sizes, and log quality/appearance. The variability is attributable to: product distinctions between veneer market segments (e.g., doors versus furniture), differences in individual customer requirements, regional differences in log supply and veneer demand, changes in market preferences over time, and the inherent variability of the log resource.

Veneer logs exported to international manufacturers must be of a quality that will produce veneer that meets their standards. Log brokers/resellers have log classification systems that address international veneer manufacturing requirements. For example, in Asia, many companies slice veneer from the outside-in and rotate the log to create eight slicing faces. This type of slicing requires logs that are free of bark-to-bark cracks (cracks that run the full diameter of the log end). Also in Asia there are some companies willing to purchase “shipper logs” — less expensive logs that are color-streaked and contain pin knots. Along with “shipper logs”, “*boule logs*” also are low-end veneer logs that frequently are shipped to international customers. At times, Italy has been a particularly good market for cherry boule logs from the United States. Veneer markets that are new, small, unfamiliar, or appear to be temporary may be risky for domestic manufacturers to try to serve. Log sales (rather than veneer sales) to these markets may offer a low-risk export alternative.

Veneer manufacturers indicate a strong preference for the highest quality logs since they can be sliced for the highest-end markets. Unfortunately, there are few of these highest quality or "perfect" veneer logs. However, lower quality veneer logs, if bought for the right price, also can produce a good profit margin, provided the veneer mill has a diverse customer base.

Veneer log prices vary based not only on quality but also on anticipated veneer market value, species, and the veneer manufacturer's veneer procurement methods. At the upper end of the veneer quality and value spectrum is veneer for architectural millwork (e.g., ornate moulding and wainscoting). After architectural millwork, the next most valuable veneers are those produced for the panel (4 by 8 feet room paneling) and door markets. Other important veneer markets, in descending order by value, are: furniture or dimension products, flooring, stock panels (e.g. hardwood plywood), and backing or substrate panels. Prices paid for architectural veneer may be 2 to 3 times the prices paid for panel veneer and door veneer (which are within 5 percent of each other). Prices for furniture, dimension, and flooring veneer are only 50 to 70 percent the price of panel and door veneer.

In general, lower quality veneer can be used to cover the surfaces of consumer products that are less visible and/or smaller in size; veneer for smaller products such as flooring and furniture can be more easily recovered from clear areas located between blemishes that are found on sheets of lower quality veneer. Higher quality veneer is used to cover surfaces that will be highly visible and have a large surface area (thus the length of the clear area between blemishes and consistency of appearance are of paramount importance).

Highly figured logs and flitches that will produce distinctive veneer usually are sliced for the architectural veneer market (Appendix III B). Terms used to describe some of these figures include: "fiddleback," "quilted," "curly," "ropey," "tiger stripe," etc. Key quality requirements for architectural, door, and panel veneers are: large, blemish-free areas; consistent and desirable coloration; and tight growth ring patterns (e.g., more than 8 rings per inch). The door market tends to have more stringent color requirements than does the panel market. Conversely, the panel market demands greater overall consistency of appearance since panels will be placed side-by-side around a room so that many square feet are visible. Lower quality veneer markets permit smaller, blemish-free clear areas, less color consistency, lower growth-ring density, and occasionally, sound defects/blemishes of various types. Rotary veneer often allows some mineral (Appendix III F) and sound defects but cannot be produced from logs with seams or multiple frost cracks.

In addition to internal and external log-quality attribute requirements, the higher value veneer markets (architectural, door, and panel) have diameter and length requirements. The range of veneer lengths accepted by the architectural veneer markets is from 8 feet 6 inches to 17 feet. Panel veneer lengths span a similar range, but 8- to 9-foot lengths are usually preferred. Door veneer typically is 7 to 8 feet long. The minimum acceptable length of veneer for the domestic furniture/dimension industry is 30 inches (clipped).

The Relationship between Slicing Methods and Veneer Characteristics Quality

High-quality veneer logs are typically manufactured into high-value veneer products using either vertical or stay-log slicing methods (Table 2). Vertical slicing is performed by passing a log section (or flitch) that is mounted (or chucked) on a table, up and down against a stationary knife. Flat- and quarter-sliced veneer patterns are produced using the vertical slicing method (Table 2). Stay-log slicing is performed by passing a log section against a stationary knife in an arc or circular motion rather than a straight line. *Rift* and half-round veneer patterns are produced using the stay-log slicing method (Table 2). Horizontal slicing is performed by repetitively feeding a board (rather than a flitch) lengthwise over a stationary knife to produce high-quality veneer, but this slicing method is rarely used and considerably slower than the other production methods. This veneer processing method is referred to as rotary cutting, slicing, or peeling. There are a few high-value veneer markets that utilize rotary peeled veneer (Table 2). One such market is veneer for woven baskets. Another is the birds-eye maple market. This is probably the highest value veneer produced in North America and rotary slicing is required to produce the most desirable birds-eye figure (Appendix III B).

Lower quality veneer logs are used for lower value products, such as cores, backing, and flooring. These lower quality logs usually are produced on a rotary lathe (or full-round machine). Rotary-cut veneer (Fig. 2) is

Table 2.—Veneer production equipment, slicing patterns, and factors considered in determining how a veneer log will be sliced.

Type of slicer	Slicing pattern	Selection factors
Vertical	Flat	1) Slicing larger diameter logs 2) Producing veneer to maximize cathedral pattern 3) Producing veneer for book-matching into wall panels and wider furniture panels
	Quartered	1) Slicing larger diameter logs 2) Producing straighter grained veneer 3) Producing white oak veneer with flake 4) Slicing mahogany, teak, and walnut
Stay-log	Half-round	1) Slicing smaller diameter logs 2) Species for which maximizing the recovery of sapwood is important 3) Accentuating the grain pattern on highly figured woods such as burl
	Rift	1) Slicing red and white oak to minimize ray flake 2) Producing veneer to minimize cathedral pattern
Horizontal	Lengthwise	1) Slicing boards rather than flitches 2) Producing veneer with a highly variable grain pattern 3) Achieving optimal veneer recovery because entire workpiece is sliced into veneer
Rotary lathe	Rotary	1) Accentuating the grain in birds-eye maple 2) Producing veneer for basket strips 3) Producing lower grade veneer for flooring, stock panels, and kitchen cabinets

more efficient to produce (less handling and greater production speed) than vertically- or stay-log-sliced veneer, but the grain pattern produced by this cutting method can be unspectacular. The tangential surface of the wood that is exposed when a log is rotary cut often has a flat appearance with wide wood grain bands. Rotary-cut veneer is more difficult to *pattern match* than is the veneer produced using the other slicing methods. Rotary-cut veneer is commonly used for stock panels, kitchen cabinets (thinner rotary-cut veneers), and flooring (thicker rotary-cut veneers) (Table 2).

Slicing Patterns

Flat (Fig. 2C), half-round, rift (Fig. 2B), and quarter-sliced veneers are preferred for many appearance applications since these slicing patterns yield more distinctive grain patterns than does rotary-cut veneer. The method of veneer slicing used depends not only on the veneer product, but also on the species, size, and quality of the veneer log.

Flat-sliced (or plain) veneer is produced by slicing log halves on the vertical slicer. In *flat slicing*, the slicer's knife is oriented so that it runs at a right angle to the wood rays (tangential to the annual rings, Fig. 3). This slicing method produces veneer with a "cathedral" pattern in which the growth rings form V- or U-shaped patterns that result from annual rings that barely intersect the cutting plane (i.e., the veneer face, Fig. 2). Flat slicing is the most common method used for producing face- or appearance-grade hardwood veneer. Because flat-sliced veneer is easy to *book match*, it is commonly used in manufacturing wall panels and wider furniture panels such as table and dresser tops. Larger diameter logs (16 inches or larger) tend to be flat- rather than half-round sliced since they yield more veneer sheets with a pronounced "cathedral" grain pattern (Fig. 2B) than do smaller diameter logs.

Figure 2.—Pictures of red oak veneer produced using the different slicing methods: A–spliced together pieces of veneer produced on the rotary peeler; B–the classic look of rift-cut red oak veneer; C–flat-sliced veneer with cathedral grain pattern; D–thicker veneer cut on stay-log lathe for flooring – note how similar this grain pattern is to the flat sliced veneer.

Half-round veneer (Fig. 3B) is produced by slicing log halves on a stay-log machine. The orientation of the knife in half-round slicing is approximately parallel with the growth rings. The pattern produced off the half-round machine is in-between that produced by flat slicing (Fig. 3C) and *rotary peeling* (Fig. 3A); many consumers have a hard time distinguishing between half-round and flat-sliced veneer. This method of veneer slicing tends to be used more for smaller logs (e.g., less than 16 inches), for species in which the recovery of a maximum amount of *sapwood* is important (e.g., maple), and for accentuating the grain pattern on a piece of highly figured wood, such as a burl.

Rift-sliced veneer is produced by slicing log quarters on the stay-log machine. The orientation of the knife in rift slicing is such that it crosses the rays at a slight angle (approximately 15 degrees) so that the intersection of the rays and the veneer surface are reduced in size. Rift slicing is used predominantly on red and white oak, which have especially large rays, in order to maximize the production of straight-grained veneer and minimize the appearance of ray flake. Rift slicing (Fig. 2B) produces a veneer that lacks the "cathedral" pattern produced when veneer is flat, half-round, or rotary sliced.

Quarter-sliced veneer is produced by slicing log quarters on the vertical slicer (Fig. 3). In quarter slicing, the veneer knife is oriented so that it runs nearly parallel with the wood rays. Like rift-sliced veneer, quarter-sliced veneer (Fig. 2) is straighter grained and less variable in appearance than rotary, half-round, and flat-sliced veneer. However, when red oak or white oak is quarter sliced, the ray flake may be very prominent (Fig. 2). This occurs when the veneer slice intersects a large ray at a very small angle. While many veneer customers do not want ray flake in their veneer, others find this distinctive look to be highly desirable. Mahogany, teak, and walnut are other species that frequently are typically quarter sliced. Quarter slicing requires larger diameter logs than other slicing methods.

There also are some quality considerations related to how thick the veneer is sliced. Handling of very thin veneer can lead to cracking and tearing of the sheets. Some manufacturers minimize the damage risk by using new equipment that allows hands-off stacking of veneer sheets. In addition, thinner veneer is more subject to *buckling* than thicker veneer since there is insufficient wood thickness to stabilize or balance stressed regions.

Veneer Log Quality Evaluation

Appearance-grade veneer logs are evaluated at least two times prior to entering a veneer plant's sawmill operation. The first evaluation is by the buyer in the field who commits to the price that will be paid for the tree or log. The second evaluation is by the grader in the veneer plant's log yard who usually is evaluating the log to decide how it should be sawn and sliced. While the buyer often needs to be skilled in recognizing defects in standing timber, the log grader at the plant has more information (e.g., log ends are visible and ends can be freshly cut to reveal wood character) and time for making his/her quality judgment. However, the log grader must understand fully the veneer log processing options (sawing and slicing) and customer/market requirements to determine the log breakdown approach that will optimize the quality and value of the veneer.

An experienced veneer log grader/buyer who possesses a keen eye and good knowledge of veneer processing and markets is "worth his weight in gold", or perhaps "worth his weight in cherry veneer." Proficient log buyers can make amazingly accurate inferences about the internal characteristics of a log since features seen on log surfaces are usually indicators of what can be found on the inside. Some of these features, such as limbs, forks, holes, bulges, bumps, burls, seams, and scars, are obvious; others are very subtle (e.g., bark patterns that indicate overgrown defects). Some of the subtle defect indicators can be missed or inaccurately evaluated by even an experienced grader.

Some veneer log defects are more evident when the bark is on the log (in the winter) while others are easier to spot on bark-free logs. For example, pin knots in cherry and walnut and worm track in ash can be easier to spot when the bark is off the log, but *overgrown knots* and *bird peck* (Appendix III E) are easier to evaluate when the bark is on the log.

Figure 3.—A series of pictures of veneer slicing methods: A–log chucked for rotary peeling; B–half-log rotating on stay log lathe with next half log in position for being mounted; C–backing board is all that remains after slicing of flitch on flat slicer.

External evaluation of logs includes not only bark or outer-wood evaluation, but also evaluation of log ends. Some log defects, such as *gum* in cherry, sugar streak in maple, and worm holes in several species, are seen only on the freshly cut ends of logs. Log buyers will spray log ends with water to enhance the visibility of the hardest to see defects (e.g., sugar streak and *mineral stains*/ streaks; Appendix III F). Growth ring consistency (or texture), density, and wood color also are judged by viewing log ends. The location of the pith (centered or off-centered) and evidence of tension wood (which can buckle and tear in the manufacturing process; Appendix III C) are evaluated here too. Finally, the heartwood and sapwood content of logs is assessed by looking at the two log-end cross-sections.

The hardest-to-see veneer log defects, according to the veneer log buyers we spoke with, are bird peck, T-shaped scars, pin knots, *ingrown bark* (especially in cherry), and insect induced localized defects, such as *glassworm* in ash and sugar streaks in maple. Most log buyers surveyed indicated that sugar maple is the most difficult species for which to predict veneer log quality. White oak also was cited by multiple sources as being particularly difficult to evaluate. Red oak, ash, and walnut are considered easy species in which to judge quality. Cherry is easy in many regards except that pin knots and gum pockets are important defects in this species that can be difficult to detect. Also, some cherry logs have extremely flaky bark, which is much more difficult to read.

Logs with excellent size, shape, and clear-wood characteristics sometimes yield poor quality veneer. In white ash, for example, it is common for heartwood to be large on both ends of a log but to be small between the two ends (hourglass shaped). This characteristic creates problems for the log grader since color is critical but uncertain for this species. This tendency for the size and shape of the heartwood to vary dramatically along the length of the tree also is seen in hackberry.

Several Forest Service research publications pictorially document the relationships between difficult-to-evaluate external indicators and their associated internal defects in red oak (Rast 1982), white oak (Rast et al. 1989), black cherry (Rast and Beaton 1985), black walnut (Rast et al. 1988), yellow birch (Rast et al. 1991b), yellow-poplar (Rast et al. 1991c), and sugar maple (Rast et al. 1991a). These publications show *external defect indicators*, such as *epicormic branch scars* and bird peck, followed by a series of pictures of the wood veneers cut from the same log section, to demonstrate how the defect plays out as veneer slices are taken at greater depths in the log. Defect descriptions accompany the pictures.

Two other publications specifically address defects affecting the quality of appearance-grade veneer (Cassens 1992, Harrar 1954). These publications are unique in that they discuss and show pictures of log-end defects as well as *log face* defects.

Though research has been conducted to determine if internal defects can be detected using scanning technology while a log is still intact, scanning systems using x-rays (Hodges et al. 1990; Schmoldt et al. 1996, 2000; Guddanti and Chang 1998), gamma rays (Taylor et al. 1984), microwaves (Choffel and Martin 1996), nuclear magnetic resonance (Chang et al. 1989), or ultrasound (Birkeland and Han 1991, Sandoz 1996) are expensive and currently are used almost exclusively in research. Since these technologies are not readily moved from site to site, their most feasible future application would be for sorting/merchandizing logs at a large log yard (e.g., a log broker's yard). Consequently, tree and log graders/buyers continue to rely on external attributes that distinguish veneer logs from high-grade sawlogs.

Veneer Log Sourcing

While most veneer logs are purchased directly from sawmills, some are obtained from log brokers who can provide sorted and graded logs, and some are bought at the log landings of harvest operations. A few are purchased as standing timber and occasionally veneer logs will be traded between veneer mills. Veneer procurement methods may be quite variable between mills. For instance, some veneer mills buy up to 20 percent of their raw material as standing timber, but many mills buy no standing timber. The veneer manufacturers we spoke with reported procuring between 20 and 90 percent of their logs from sawmills, 5 to 25 percent from *concentration yards*/log brokers, 0 to 25 percent as standing timber, and 5 to 50 percent from independent loggers (either at the landing or at the mill's gate). Other, less important log sources that were cited included veneer company-owned timberland and other veneer companies.

A disadvantage of purchasing standing trees is that many of the most important log attributes may not be seen by the veneer log buyer if he/she is not present during the harvesting operation. These attributes include growth rate, wood color, and other log characteristics that can only be judged by looking at log ends. A problem with purchasing logs from sawmills or concentration yards, however, is that they may have suffered storage degrade in the form of end splits, insect attack, or fungal stain. One advantage of purchasing standing timber is the 100 percent certainty of the source of veneer logs. It can be difficult to determine the origin of logs purchased from sawmills and concentration yards.

Table 3.— Prices paid for figured hard maple veneer logs.

Type of figure	Log prices U.S. dollars per board foot
Heavy birdseye	8.20
Burl	6.60
Fiddleback	2.80
Curl	2.90
Unfigured	1.25

Almost all veneer logs are barcoded at the time of purchase, allowing for accurate inventory control and yield tracking. This allows veneer plants to track logs through processing so that the veneer yield, quality, and value recovered can be associated with specific logs. With this information, relationships between log sizes, grades, prices, and origins (when known) and veneer recovery can be established. Knowing these relationships, buyers will be more informed when making future purchase decisions. This information also helps veneer producers determine whether their system for log grading and pricing is optimizing return on investment.

Veneer Log Pricing

There is general agreement about the most important veneer log characteristics (discussed in the next section), but there is no broadly accepted system for grading and pricing veneer logs. Each veneer mill establishes grading guidelines based on specific product markets and customers. A clearly defined log-price structure based on industry-accepted log grade specifications does not suit the veneer industry with its highly variable markets. For unique uses, such as office paneling, irreproducible figure may be highly desirable. Other uses, such as a line of office furniture, may require large quantities with consistent appearance. While no unique grading system exists, knowledge of the effects of log attributes on quality and yield can help determine the prices that veneer producers can afford to pay. Table 1 gives price ranges paid for veneer logs in 2001 and 2002.

The large range in prices paid, especially for cherry, hard maple, and white oak, reflect the wide range in quality attributes and markets for these species. The degree to which buyers are willing to adjust their quality guidelines and prices depends on market conditions. In one company's procurement system, maple and black cherry logs are bought in three grades: A, B, and C. Grade A is the commonly accepted veneer log, whereas grades B and C are accepted only when demand is high, as reflected in the price of grade A logs. Another survey respondent indicated that when a species is in "hot" demand, more log grade classes will be used (e.g., nine log grades for sugar maple).

In some cases, bark distortions indicate underlying wood with attractive figure that increases veneer value. See Table 3 for an example of one company's 2000 veneer log price list for flat sliced, figured hard maple.

Generalized Veneer Log Quality Requirements

The veneer log quality attributes that are common (but not absolute) among species and uses are:

- *butt logs*
- freshly cut
- round, sound, and straight
- straight-grained
- free of knots, bark distortions, decay, seams, worm holes, and bird peck on each of the four log faces
- *centered heart*
- uniform color
- uniformly spaced rings
- free of metal contamination

These generalized quality standards for veneer logs may be more or less important depending on the veneer market segment, species, and manufacturing system. For instance, logs above the butt log are acceptable when large trees with high crowns produce second logs of large diameter that do not have any branches. However, due to pin knots, the closeness to the surface of overgrown knots and smaller bole diameter, the majority of high quality veneer logs are butt logs – from 60 to 98 percent depending on species. Species that grow straighter with less taper, such as cherry and yellow-poplar, will yield more veneer logs from upper portions of the tree than will white oak, walnut, and hard maple.

Veneer logs must be sliced soon after harvest to minimize discolorations caused by fungal and bacterial infections. This is especially important during the hotter months of the year. It is more important with lighter colored species, such as maple, white oak, birch, and ash, than it is with darker colored woods since color variations in the lighter woods are easier to discern.

Tapered or *elliptically shaped logs* can be a problem for some veneer products, but can be an asset if veneer with cathedral pattern is desired. Even severe butt taper is usually not a serious problem because it is removed with "butt reducers" during log preparation prior to peeling or slicing. A butt reducer grinds off buttresses and swollen bases and usually is accompanied by debarking. However, grain deviations associated with taper may be a problem if the veneer will be bent for furniture parts or woven into baskets.

Sweep is a defect that reduces the usable volume of a veneer log and affects the grain pattern of the veneer. The altered grain pattern can decrease the grade and value of the veneer. In addition, sometimes the change in grain direction characteristic of sweep causes buckling in flat-sliced or half-round veneers. Logs with significant sweep often will be sawn into three sections before slicing with one of the cuts running from the log's pith to the concave surface of the log (Fig. 4). *Crook* is similar to sweep but usually is caused by deflection of the main stem caused by a major branch. Thus, in sectioning logs with crook prior to slicing, the position of the branch knot also must be considered.

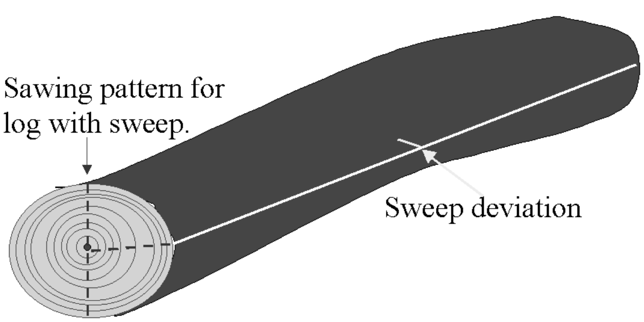

Figure 4.—A common sawing (flitching) pattern for veneer logs with significant sweep.

Although centered heart and uniformly spaced rings are important for production of sliced veneer with symmetrical appearance, some cutting methods can avoid this requirement. Veneer manufacturers report a tendency for logs with off-centered piths to be more prone to splitting. Off-centered heart is addressed when the log is flitched (cut into sections) (Fig. 5) in the sawmill — the log is flitched so that the edge of the log sections goes through the pith. By doing this, the pith is contained in the part of the flitch that is not recoverable as veneer (called the *backing board*).

Nonuniform rings (or *double texture*) are less of a problem in the furniture-grade veneer market since this market segment generally cuts the veneer into smaller face sections than do manufacturers of doors and panels.

Sapwood is desirable in maple, ash, yellow-poplar, hackberry, sycamore and sometimes in birch and hickory, whereas heartwood is desired in walnut and cherry. Sapwood color may be critical, such as in architectural panels and high-value furniture, or it may be less important when used in strips that will be dyed or given clear but darkening stains, such as basket-weaving strips. In white oak, red oak, hickory, and sometimes yellow-poplar, the heartwood-sapwood distinction is less important due to the color consistency between the two wood regions and less intense product color requirements.

Company-Specific Veneer Log Quality Requirements

Table 4 demonstrates the complexity associated with most company-specific veneer log grading and valuation systems. The data contained in this table were provided by a company that purchases veneer logs from private landowners and peels them to produce furniture grade veneer. Table 4 gives the grading criteria for six species used in the production of 1/32-inch veneer. Five of the six species are manufactured into appearance grade veneer, and one, yellow- poplar, is used for inner plies or hidden parts. Each species has a different set of grades (eight grades for maple, six for birch, five for red oak, three for black oak, and two each for ash and yellow-poplar). These grades are related to the particular species characteristics that affect veneer quality. For example, the two highest grades of black oak specify butt logs only, whereas red oak does not impose this restriction for any grade. The highest grades of black oak must be butt logs because of the abundance of limbs in this species; red oak, in contrast, will have fewer buried branches and therefore second logs are acceptable in all grades. As previously discussed, there are no standard grading rules for veneer logs. This illustrates one company's attempt at providing detailed guidelines for its log buyers based on current markets and customers.

For this company, heartwood size is very important in all grades of maple and ash, important in the highest grade of birch, but unimportant in oak. Because heartwood may be wound initiated in maple, ash, and birch, and is

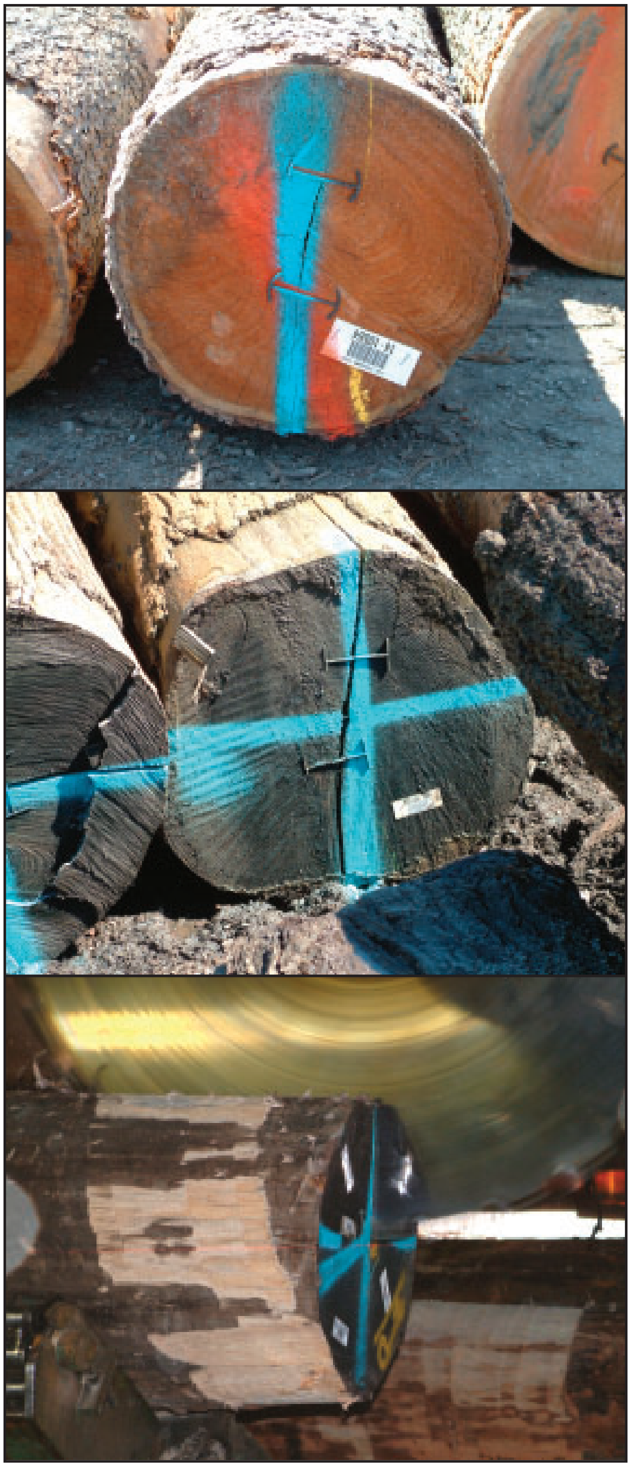

Figure 5.—Pictures of veneer flitching marks that indicate the location (marked with blue paint) where the log should be split into the log sections that will yield the highest value lumber. Note that the marks correspond with major splits in the log ends.

therefore not necessarily centered on the pith, off-centered heartwood can affect more of the higher quality outer wood. Therefore, centeredness is important in the company's highest grade (Prime Plus) of maple and birch. Heartwood centeredness also is required in Prime Plus red oak, but in this case its importance is as an indicator of the location of the pith within the log.

The requirement that the Prime and Prime Plus logs of all species have large diameters reflects the fact that wood near the center of a tree is of lower quality than the outer wood of large stems. However, relatively small diameter (10 inches) maple and birch are acceptable (in the lowest grades) because they are likely to have small heartwood. Diameter requirements sometimes are eased slightly for logs bought from northern sources. Since northern timber typically grows more slowly, larger diameters are harder to obtain but the smaller diameters are offset by tighter growth rings (a desirable veneer trait) and smaller diameter pith-affected zones (*juvenile wood* regions).

Only two grades of ash and yellow-poplar are listed. It is common for more grades to be defined for species that are in high demand in multiple-product markets. Small diameter ash is acceptable if enough white wood can be produced from the logs, but yellow-poplar requires somewhat larger diameters to meet yield-per-log requirements.

This company also shared its veneer log pricing guidelines with us. Price ranges for different grades within a species are a good indicator of the variability of the species' markets. In this instance, Prime Plus hard maple and birch logs commanded a price that was 80 percent higher than Select grade logs of the same species. For red oak and white oak, the price paid for the highest quality veneer logs was only 45 percent higher than for Select grade logs.

Log Buyers' Observations on Regional Variations in Veneer Tree Quality

The geographic source of logs frequently affects their quality. Not only is growth rate affected, but other characteristics, such as color and insect damage, vary with soil type, climate, length of growing season, topography, and silvicultural practices. Our survey respondents offered a plethora of anecdotal information on regional variations in veneer tree quality. Many reported that maple and birch from colder climates with slower growth have larger hearts but whiter sapwood. One buyer reports that hard maple from Maine can be counted on to have both good color and minimal incidence of the blemish known as sugar track whereas hard maple from neighboring states may have good color

Table 4.—Example of one company's grading criteria for hardwood veneer logs.

Species	Grade	Lengths	Minimum Diameter (inches)	Allowable Defects	Heartwood Proportion	Additional Requirements
Hard maple	Prime Plus	8 feet 9 inches, 9 feet 5 inches, 10 feet 5 inches, 11 feet 5 inches	16	0	1/3; Centered	
	Prime		14	0	1/3	
	Select		11	0	1/3	
	No. 1 Special		14	1	1/3	
	No. 1		11	1	1/3	
			11	0	40%	Butt cut only
	No. 2		11	0	50%	
	No. 3		11	2	1/3	
	No. 4		10	0	1/3	Butt cut only; no sweep
Birch	Prime Plus	8 feet 9 inches, 9 feet 5 inches, 10 feet 5 inches, 11 feet 5 inches	14	0	Centered	
			12		1/3; Centered	
	Prime		14	0		
	Select		11	0		
			14	1		
	No. 1		11	1-surface 1-end		
	No. 2		11	2		
	No. 4	8 feet 9 inches, 9 feet 5 inches	10	0		Straight logs only
Red oak	Prime Plus	9 feet 5 inches, 10 feet 5 inches	16	0	Centered	
	Prime		14	0		
	Select		12	0		
			14	1		
	No. 1		12	1-surface 1-end		
	No. 2		12	2-surface 1-end		
			11	0		
Black oak	Prime	9 feet 5 inches, 10 feet 5 inches	14	0		Butt cut only
	Select		12	0		Butt cut only
			14	1		Butt cut only
	No. 1		12	1		
White ash	Select	9 feet 5 inches, 10 feet 5 inches	11	0	1/3	
	No. 1		11	0	1/2	
Yellow –poplar	Select	8 feet 9 inches, 9 feet 5 inches	12	0		
	No. 1		12	1		

but inconsistent sugar track (Fig. 5). Another veneer log buyer cites New York, Ontario, New Brunswick, and Michigan's Upper Peninsula as the preferred procurement regions for sugar maple. Yet another buyer reports that in maple from Ontario, the sugar track is minimal but the color may not be as white as is required by some veneer manufacturers. There is general agreement that as you move farther south, the color of maple and birch becomes more inconsistent within a stand of trees. One respondent suggested the warmer climate may be responsible for yellowing of the wood due to oxidation during log storage. Sugar maple from the southern part of its range also is reported to have more sugar/worm track.

Red oak quality differences are thought to be more a function of soils than latitude. Log buyers indicate that grub holes in red oak are more of a problem in logs from higher, drier sites than they are in logs from lower, wetter sites. An increased incidence of mineral stain (Appendix III F), a major problem in red oak, has been linked by some procurement experts to trees grown on slopes and on soils with high coal content.

The wood color of white oak, like that of red oak, seems to be influenced by soils. Oaks grown on slate soils are said to have particularly good (light) color. In contrast, oaks grown on red clay soils seem to be more red (black and white oak) and brown (red oak) than is preferred. Observations on regional differences in white oak quality were conflicting. One respondent indicated that white oak logs from Ohio have excellent color (light in color) but often have a higher concentration of pin knots than do white oak logs from other regions. Another respondent reported that white oak logs from West Virginia seemed to be darker in color than desired. A third respondent disagreed saying that white oak from West Virginia is desirable "because of its color consistency."

The regional variation in the color of walnut heartwood is thought to be more extreme than for most other species. Walnut from Missouri and Illinois can have red color streaks, according to our sources. Also, increased occurrence of worm holes and tracks may be correlated with walnut growth on wetter sites.

Some veneer log buyers report that hickory from northwestern Pennsylvania is mostly brown, whereas hickory from the higher elevations of the Appalachian Mountains is much whiter, even though both regions include the same mixture of species. Other log buyers contend that the color variation in hickory is so strongly influenced by species that all other color factors are inconsequential. Glassworm (a *cambium miner* caused by the larval stage of the fly, *Phytobia* spp.) is a difficult problem in ash veneer, however ash from the Shenandoah Valley region of Virginia seems to be less affected (Appendix III I).

Gum in cherry is reported to be a much more common problem in West Virginia than it is in the Allegheny region of Pennsylvania due to the abundance of bark and engraver beetles and cambium miners (Rexrode and Baumgras 1984). Therefore, within-tree color variability is a problem for West Virginia cherry. Cherry from North Carolina is tall, round, and high quality except for the presence of gum pockets (Appendix III J). One cherry log buyer has proposed that a relationship exists between wind exposure and the occurrence of cherry gum with more exposed trees having higher amounts of gum. There is general agreement among veneer producers that Allegheny cherry is the highest quality in the country, while Allegheny maple is relatively poor in quality.

In the absence of external indicators of internal characteristics, internal quality is sometimes inferred from knowledge of a log's origin. This leads some veneer companies to avoid buying stumpage or logs from certain regions. Other companies report that they occasionally find high-end veneer logs that are undervalued by putting some procurement efforts into these less highly rated regions. In order to circumvent the effect of regional reputation on price, logs are sometimes shipped and offered for sale far from their point of harvest.

Species Related Requirements and Characteristics for Furniture Grade and Better Veneer

The information contained in the following section was gleaned from discussions with several veneer log buyers during 2000 and 2001 (Appendix 1). Additional information on species characteristics important to veneer production can be found in Cassens (1992).

White oak

In general, the tree must be true white oak (*Quercus alba* L.), though bur oak and chestnut oak are occasionally accepted (they tend to have more variation in wood color). The minimum small-end diameter is typically in the 14- to 16-inch range and some users only are interested in 9- or 10- foot lengths or multiples thereof. Door length white oak veneer can be cut from 7-foot long logs. Growth rings should be at least $^{1}/_{8}$-inch wide and concentric and the wood should have a light, uniform color without mineral stain (mineral is generally not a problem in white oak). Pin knots and bird peck are sometimes a problem. Though knots would ordinarily be unacceptable, at least one company is marketing knotty white oak veneer for use in "character-marked" furniture. White oak tends to have more taper than red oak. Variations in the width and color of growth rings seem to be less of a problem (due to a more consistent rate of growth) with white oak than for other species such as maple and cherry. White oak from timber stands that have been released (having received an intermediate or thinning cut) will exhibit variable texture however. White oak bark is relatively easy to read for indications of internal defects, such as overgrown knots and bird peck. Approximately 80 to 90 percent of white oak veneer logs are butt logs.

Red oak

Northern red oak (*Quercus rubra* L.) produces the best veneer logs, but shumard oak is sometimes acceptable. Because the tree typically has good form, 15 to 30 percent of the veneer logs are second logs. Diameter must be at least 14 inches at the small end. Usable lengths of 8 to 12 feet are typical. Growth rings should be at least $^{1}/_{8}$ inch wide (under current market pressures $^{1}/_{6}$-inch growth-ring widths are sometimes accepted), and ring width should be uniform around the log. Light colored heartwood is best, however, the heartwood/sapwood distinction is less important for red oak than for some other species. The wood should be relatively free of mineral stain (Appendix III H). Defects that are difficult to identify on logs are *adventitious buds*, insect borer damage, ingrown bark (Appendix III K), and deeply buried knots and wounds. In general, red oak is considered an easy-to-read species. Red oak veneer can be prone to buckling (Appendix III C).

White ash

Minimum log diameter requirements for white ash (*Fraxinus americana* L.) range from 12 to 14 inches at the small end. Usable lengths must be multiples of 8, 9, or 10 feet for some companies. Other companies accept log lengths ranging from 8 to 12 feet. Color is particularly important in ash since the wound-initiated heartwood is of no value as veneer. Heartwood should be no more than 30 percent of the diameter. Heartwood proportions are difficult to estimate in ash because heartwood diameter is not uniform through the log like it is in most other species. Even more serious is a feathered or irregular heart where darker heartwood *flares* into the sapwood. These color irregularities prevent long strips of clear veneer from being clipped from a sheet. Stress cracks also are important in this species since ash is brittle (brash). The grain must be straight and logs should be free of the insect damage known as glassworm tracks caused by a cambium miner (*Phytobia* sp.). Defect indicators are relatively easy to read on ash bark, but since glassworm does not cause bark distortions, some log buyers rate ash as one of the most difficult species to evaluate (Appendix III I top).

Sugar maple

In addition to sliced and half-round veneer for architectural, panel, door, and furniture manufacture, sugar maple (*Acer saccharum* Marsh.) also is peeled for basket weaving strips, plywood flooring, or specialty items such as laminated skateboards and handles. Thus, there is a very large range in acceptable log quality attributes. The highest grades require butt logs that are at least 13 inches in diameter at the small end; only 2 to 5 percent of the sliced or half-round production comes from second logs. Log lengths for sliced or half-round production must be in multiples of 8 to 12 feet to satisfy the high-end veneer markets (architectural paneling and doors). Like ash, maple heartwood is wound-initiated and of limited value as veneer.

The sapwood exhibits a range in color, from the most valuable pure white (required for architectural grade veneer) to various shades of yellow. High-value logs usually are sliced using the half-round pattern on the stay-log slicer in order to isolate the heartwood, which must be less than one-third of the log diameter. Sapwood thickness must be at least 5 inches. Veneer log buyers believe that regional differences in the color of sugar maple sapwood may be attributed to variations in the sugar content of the sap. The less highly demanded creamy yellow color becomes obvious after the logs are "*cooked*" in hot water vats prior to slicing.

Trees from northern parts of the species' range usually have less sugar than those from farther south. The terms sugar streak, sugar fleck, sugar track, and worm track all refer to what is more generally referred to as *pith fleck* (Appendix III I), which is caused by a cambium miner. This insect-induced defect can be a serious problem, especially since it is often undetectable until after the veneer is dried. It can sometimes be detected in logs by cutting a 3-inch disk from a log end and splitting the disk tangentially to reveal the insect tracks. Other hidden defects include ingrown bark, bird peck, T-shaped scars, and the grain deviations known as flares and *bars*. Moisture pockets also can be difficult to detect in sugar maple logs. They are more common in trees from the southern part of the range and cause the veneer to buckle upon drying (Appendix III C). Growth rate must be uniform (even textured), with an optimum growth rate of six to eight rings per inch. Growth must be uniform around the circumference of the log, since nonuniform growth indicates the presence of tension wood that will cause splitting or buckling of the veneer. Buckling also can be caused by *cross-grain* and even minor deviations. For this reason, grain deviations are particularly troublesome when they occur in raw material to be used in basket-weaving strips. Because there is often little contrast between wood color, growth rings, and defects, it is necessary to make fresh cuts and to wet log ends to evaluate a log. Defect indicators are more difficult to read on the bark of sugar maple compared to many other species.

Birch

Some veneer log buyers stated that white birch (*Betula papyrifera* Marsh.) is worth more than black birch (*Betula lenta* L.) or yellow birch (*Betula alleghaniensis* Britton). Others indicate that white birch is more valuable than darker or more variably colored birch, but they do not distinguish between species in their log pricing. Birch is frequently rotary cut, sometimes as short bolts for the production of specialty items. Birch heartwood is wound-initiated, but is less of a defect than in ash or hard maple. Nevertheless, the best veneer logs contain less than one-third heartwood. Recently, a market has developed for "natural color" birch veneer. Veneer mills (typically rotary mills) cutting this grade of veneer buy logs containing approximately 50 percent heartwood. Worm track is a defect that is more common in white birch than in black or yellow birch. One company, however, has successfully marketed specialty products that include worm track as "character."

Black cherry

Black cherry (*Prunus serotina* Ehrh.) is probably the most valuable domestic veneer species and most cherry veneer production is in sliced veneer. Minimum log diameter specifications (small end, inside bark) for veneer quality cherry logs range between 14 and 17 inches for the companies we surveyed. Log lengths for cherry must be at least 9 feet for panel grade and up to 16 feet for architectural grade. Second logs comprise 10 to 20 percent of the supply of top-grade veneer logs. Color must be uniform since variable color is a defect in this species. Fast-grown cherry is thought to have more within-tree color variation. The preferred color for cherry veneer is pink rather than olive or dark red. Bands of color, referred to as target when seen on the log ends, are serious defects.

Other serious veneer-log defects in black cherry are the presence of pin knots (which often occur in clusters), ingrown bark (Appendix III K), and bird peck (Appendix III G). The most notorious defects in black cherry veneer logs are *gum spots* and *gum rings*, which are caused predominantly by bark and engraver beetles (perhaps the peach bark beetle *Phloeotribus liminaris*) (Rexrode and Baumgras 1984). When gum is heavy, it is readily visible on log ends, but pin knots, ingrown bark, and bird peck may be difficult to find. Heavy ingrown bark can reduce veneer grade, whereas mild ingrown bark (known as *rice pattern*) is a less serious defect. Bird peck, if recent, may be detectable on log surfaces. The width of the annual growth rings is not as critical in cherry as in maple. Cherry is considered a difficult species to buy because so many of the more critical cherry defects are ones that may only be detected on the freshly cut log ends. Cherry logs with flaky bark are more difficult to read for defects than are cherry logs with tighter scaly bark.

Walnut

Although walnut (*Juglans nigra* L.) used to be the most valuable North American veneer species (Cassens 1992), this is no longer the case. The highest quality walnut comes from butt logs; only about 1 to 7 percent of the sliced production comes from second logs. Defects that are sometimes difficult to identify include overgrown knots, pin knots, worm holes, and bird peck (Appendix III G). Sapwood is of no value, and wide sapwood is often an unwanted consequence of the vigorous growth that usually produces desirable characteristics (e.g., greater wood volume). Uneven color (streaks) greatly reduces the value of walnut veneer; color problems may be the result of poor growing site or insect attack. There are large regional variations in walnut color. Walnut veneer logs must have at least 10 inches of dark heartwood. Moderate growth rate (eight rings per inch) is better than slow or fast growth; slow growth indicates lack of vigor, and fast growth results in wide sapwood and coarse texture. Walnut slices easily but is typically soaked in the steam vat two to three times longer than most other species to reduce heartwood color variability. Defect indicators are comparatively easy to read on walnut bark.

Yellow-poplar

Because yellow-poplar (*Liriodendron tulipifera* L.) veneer is usually used as core stock, the standards by which the species is judged are not as rigorous. The primary defect is dark-colored (blue-stained) heartwood because color can show through thin face veneers if these are of light-colored species. Some veneer manufacturers specify that heartwood should be less than one-third of the log diameter. There is some demand for yellow-poplar whitewood. Other color problems, such as dark "tobacco-stain", are common and can seriously devalue veneer, especially when the tobacco goes the whole length of a log. Mineral stain is an important characteristic in yellow-poplar logs selected for slicing. Other important defects are related to grain deviation, since these can cause warping. Yellow-poplar bark is relatively easy to evaluate for the presence of underlying defects.

Summary and Conclusions

Based on knowledge we gained from a series of visits with veneer log procurement and production personnel, it is evident that subtle appearance factors are critically important determinants of veneer value in both domestic and foreign high-end veneer markets (architectural, door, and panel). Therefore, these subtle factors are of keen importance to log buyers/graders when purchasing and sorting/selecting logs for processing to supply these high-end markets. The basic color (shade) of the wood is important for all species, but especially so for maple, walnut, ash, and white oak in today's veneer markets. Minor color variations and blemishes are considered defects in these three high-end veneer market sectors since these sectors require large veneer sections of consistent appearance. Thus the color variations caused by insect pests are a concern. These include gum pockets and rings in cherry (Appendix III J), sugar flecks in maple (Appendix III I), and glassworm in ash. Mineral streaks in oak and maple also are important since they, too, cause color variations that are defects in high-grade veneer (Appendix III H). Next to color consistency, grain pattern consistency is almost as important. The texture of the growth-ring pattern must be uniform (i.e., consistent rate of growth) and the grain must be relatively straight. Veneer having wild grain or figure can command a high price for some species in the architectural woodworking market only if it is consistently wild along the length and throughout the thickness of the veneer flitch.

Acknowledgments

Appendix 1 lists the individuals and companies that shared their time and knowledge with us for this study. These individuals are the underpinning of this information compendium and their contributions are greatly appreciated. Two individuals deserve special recognition. Mr. Tom Richards of The Freeman Corporation and Mr. Joe Sankow of Wescor Forest Products provided very thorough and thoughtful reviews of earlier versions of this manuscript. Their suggestions led to substantial improvements.

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Appendix I. Information sources

The companies and personnel listed below were interviewed for this study.

Company Name	Location	Participating Personnel
Veneer producers:		
The Dean Co.	Princeton, WV	Mike Lefever, Chuck Fulcher, Dan McCracken
Spencer Veneer	Spencer, WV	Charlie Moss
Columbia Forest Products	Newport City, VT	David Ogden
Rutland Plywood Corp.	Rutland, VT	Mike Rawson
Interforest Corp.	Darlington, PA	Bill Pruitt
Keystone Veneers, Inc.	Williamsport, PA	Vijay Reddy, Michael Folmar, Terry Capuyto
The Longaberger Co.	Hartville, OH	Jim Wills, Todd Kunzman
Universal Veneer	Newark, OH	Robert Baldwin, John Lanning
The Freeman Corp.	Winchester, KY	Tom Richards
Amos-Hill Associates	Edinburgh, IN	John Chiarotti, Richard Wertz
David R. Webb Co.	Edinburgh, IN	Bill Costoplos, Larry Leonard
B.L. Curry	New Albany, IN	Robert Streepey
Stemwood	New Albany, IN	David Wunderlin
Besse Veneers	Trafalgar, IN	Paul McHone
Norstam Veneers	Mauckport, IN	Rick Coffey, George Bowlin
Veneer log brokers:		
Seiling and Jones	New Freedom, PA	Biff Jones, Wayne Benjamin
Edward F. Kocjancic, Inc.	Kane, PA	Edward S. Kocjancic
Payne Enterprises	Kane, PA	Donald E. Payne
Highland Forest Resources	Marienville, PA	David W. Kiehl, Joseph D. Plummer
Wescor Forest Products	Clarksburg, WV	Joe Sankow
Log buyers:		
No company affiliation	West Virginia	Scott Allen
No company affiliation	New Hampshire	David Ogden
No company affiliation	New Hampshire	Greg Saulnier

Appendix II. Glossary

Adventitious buds: Buds that arise in mature tissues, usually from dormant buds, without connection with an apical meristem.

Backing board: The board that remains after flat and half-round slicing on a flitch is completed. This board is the "wasted" part of the veneer flitch. It varies in thickness for different types of veneer slicers but averages about 7/8 inch. The backing board comes from the poorer face of the flitch since this is the face that is mounted on and held (dogged) by the veneer slicing machine during flat and half-round slicing operations.

Bars: (also known as cross-bars): Localized grain deviations, up to 2 cm wide and up to several centimeters long, whose length is perpendicular to the overall grain direction of a sheet of veneer.

Bird peck: It is believed that birds peck holes to cause the flow of sap, and insects are attracted to the sap, upon which the bird feeds. Holes result in aesthetically unappealing flitches; moreover, before the tree is harvested, bird peck holes are a pathway for insects and bacterial damage. The severity of bird peck is judged as follows: (1) if the hole remains open, the peck may not have reached the cambium layer and wood damage is unlikely, and (2) if callus tissue is located in the peck hole, the hole is termed "occluded," and a peck mark will show up in the wood beneath the surface. Bird peck can lead to wood discoloration.

Book match: See pattern match.

Boule log: A log that is of lower quality than a veneer log. Boule logs typically are live sawn into lumber; the unedged lumber is reassembled in sequential order and shipped as unit or "boule".

Buckling: A veneer defect caused by differential shrinkage of the fibers in the veneer sheet. Buckling appears as a rippled or wavy surface on the veneer. It often is associated with wood sections having cross grain or tension wood (e.g., proximal to knots).

Bundle: A veneer bundle typically consists of 32 sheets of veneer stacked in the order from which they were sliced out of the log. Veneer logs produce multiple bundles of veneer. The bundles, like the sheets themselves, are numbered and stacked in the order in which they were produced from the veneer log. This packaging method has traditionally been used for veneer that is to be exported.

Butt log: A log that is cut from the bottom of the main stem of a tree. A high percentage of veneer logs are butt logs rather than "upper" logs. Butt logs typically are higher in quality than logs that originate from higher up the tree stem because the lower section of the tree stem in hardwoods typically has fewer limbs, thus fewer knots than the upper sections. However, the end of the butt log that was nearest the ground often has a swollen form and is more prone to rot /decay than other parts of the tree stem.

Cambium miner: An insect whose larvae bore through the cambial region causing longitudinal channels that may be referred to as pith fleck or worm track.

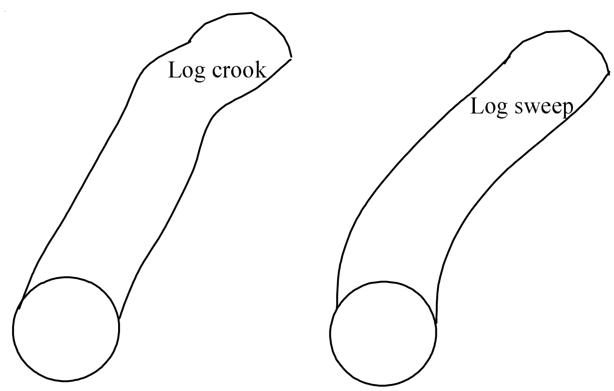
Centered heart: When the pith and associated heartwood is located very near the center of the log's cross section, the log end is said to have a centered heart. This area around the heart is the low value core section of the tree/log. Pith may be displaced from the center of the log in cases where limbs are present in that vertical section of the tree or in cases where the tree has grown abnormally to overcome a growth stress, such as is caused by growing on a mountain slope.

Clipped: Veneer may be end and edge clipped before it is packaged for show and sale. Until recently, veneer for domestic sales was seldom clipped while veneer for export sales was usually clipped. Veneer clipping is performed on veneer after the veneer has been dried. One edge of an entire bundle (32 sheets) is clipped in a single operation. Veneer loss at the clippers ranges from 20 to 30 percent of total veneer surface area.

Concentration yard: A concentration yard is a collection point for logs. The logs that come into a concentration yard usually come from multiple harvesting operations. At the yard, the logs may be sorted by species, size, and/or grade. This enables the concentration yard owner to identify groups of logs that are best suited for their different customers.

Cooked: Veneer logs are "cooked" in a vat of hot water for different lengths of time depending on species. Lighter colored and less dense woods typically are cooked for shorter periods than darker colored and denser woods. Cooking times range from 20 hours to 3 days. The cooking process softens the wood fibers making them easier to slice.

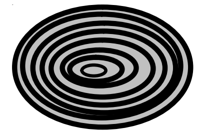
Crook: Crook is a shape deviation that occurs in both logs and lumber. In logs, crook refers to logs which are relatively straight along part of their length before they bend abruptly. Sweep is a log form distortion in which the bend occurs gradually along the entire length of the log. Crook typically is associated with a tree fork or limb while sweep occurs when a tree that is growing on a hillside or in the shade develops lean to adjust to its growth conditions.



Cross-grain: Deviation of the fiber alignment from the direction of longitudinal growth or orientation. Cross-grain frequently causes veneer to buckle.

Double texture: Texture is related to a tree's growth rate. A fast growth rate results in a coarse-textured and less dense wood, while a slow growth rate results in a finer texture and somewhat denser wood. Texture is particularly important in veneer quality trees where a growth rate of eight to nine rings per inch is typically preferred. Texture may be categorized as follows: fine (10-12 rings/inch), medium (8-9 rings/inch), loose (< 6 rings/inch). "Double textured" wood, where both fast and slow growth rates occur in the same tree, is not a desirable feature in veneer. Double textured logs also may result in yield losses, as during drying the sheets separate at the point where fast and slow growth rings abut each other. Texture is species specific, and very fine texture may result in slicing difficulty (the knives are not able to separate between rings, resulting in aesthetically unappealing flitches). Loose texture is not preferred due to aesthetic and problems associated with drying.

Elliptically shaped log: An elliptically shaped log is a log having a log end cross section that is noticeably nonround. For example:



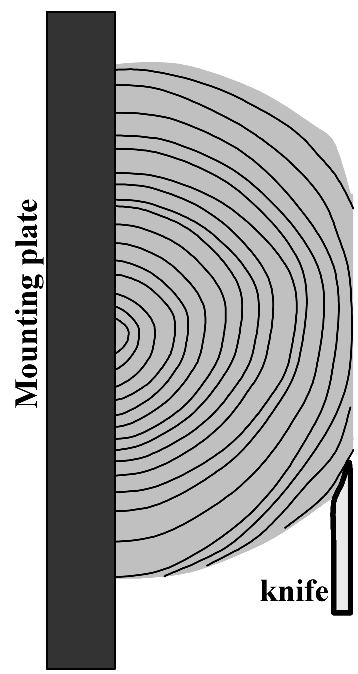
Epicormic branch scars: Marks left by branches that form on tree stems from buds, previously dormant, that become active due to sudden change in crown exposure.

External defect indicators: Indicators of a defect inside the log or tree that are noticeable when looking at the outer surface of the log or tree. Interrupted bark patterns often provide indications that a defect such as an overgrown knot exists inside the log section.

Figure: Traditionally refers to distinctive wood grain patterns, such as "birdseye", "crotch", "fiddleback", etc. (Appendix III B). More recently the term has been used in a broader sense to include other distinctive wood appearance factors, such as color variations.

Flares: Irregular markings caused by sprouts.

Flat slicing: Also known as plain slicing. Flat slicing is performed using a slicer that moves up and down but does not rotate as does the half-round lathe. With each downward stroke a veneer sheet is produced. After each full up and down stroke cycle, the mounting plate and log are indexed forward incrementally toward the knife so another thin sheet will be removed with the next down stroke. Flat slicing is used more often on larger diameter logs than is half-round slicing. The veneer sheet produced from this slicing method typically contains "cathedral" shaped ring patterns, also known as cathedral figure.



Flat slicing

Flitch: The section of a veneer log that is created by splitting a log's cross section into two, three, or four parts, which will subsequently be processed individually on the veneer slicer (Fig. 5). The sheets of veneer that are cut from a flitch are kept together through all processing steps and the veneer buyer ultimately will buy the entire flitch. Thus, the term "flitch" is used when referring to both the unsliced and the sliced and reassembled veneer log section.

Glassworm: (also known as worm track): A zig-zag pattern of light-colored wood which follows the tracks of a cambium miner; accompanied by cambial damage and grain distortion.

Gum: Nonvolatile, viscous plant exudates that swell or dissolve in water and appear as dark spots or patches; also known as pitch pocket. Gum is common in cherry.

Gum rings: Large quantity of gum deposited in numerous adjacent gum spots and occupying most or all of a growth ring; produced in response to damage or stress throughout the cambium.

Gum spots: Small quantity of gum, usually confined to the areas between wood rays, produced in response to localized, usually insect-caused damage to the cambium.

Half-round slicing: In half-round slicing, a half-log flitch is mounted on a half-round lathe (also called a stay-log lathe) and rotated in a series of rounded downward strokes against the veneer knife. Because the lathe carries the flitch in a curved path, the cut achieved with half-round slicing very nearly parallels the curve of the annual growth ring. The veneer produced by this method has a similar look to that produced in flat slicing. Logs with diameters smaller than 16 inches usually are sliced on the half-round lathe while larger diameter logs are flat sliced.

Heartwood: The portion of wood extending from the true center (pith) of the tree to the sapwood and these cells no longer participate in life processes (i.e., deceased). Heartwood color and the uniformity of color (especially in veneer-quality trees) are especially important in most veneer markets . Heartwood color varies greatly based on species, geographic location, soil type, aspect, slope, and elevation. Heartwood may contain phenolic compounds, gums, resins, and other materials that usually make it darker and more decay resistant than sapwood. It is generally darker in color than sapwood, though not always clearly differentiated.

Ingrown bark: Bark which has been enclosed by wood.

Juvenile wood: Wood formed near the pith, characterized by a progressive increase in dimensions and changes in cell characteristics, and in the pattern of cell arrangement (also termed 'core wood'.) Two problems with juvenile wood are: (1) it shrinks and swells along the grain as moisture content changes and (2) strength is lower, and in some cases, much lower than mature wood of the same tree.

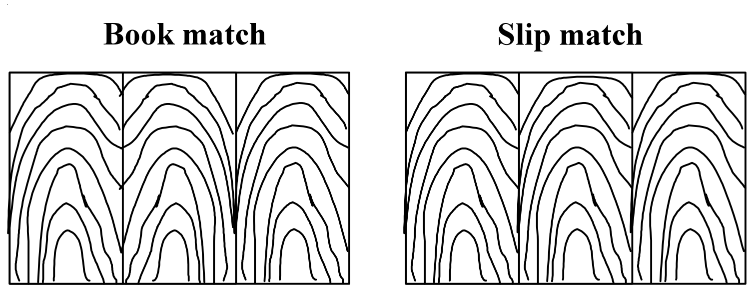
Log broker: A person or company who buys, sorts, and sells logs (including sawlogs, veneer logs, and roundwood). Log brokers can provide custom veneer log sorts based on individual requirements for size, color, texture, and defect. Saw log sorts also can be made available to meet individual specifications. Brokers typically know the hardwood log sourcing areas that yield logs with exceptional quality (color, grain, and lack of certain defects) for a given species. Log brokers can purchase stumpage fee simple or act as a commercial agent to negotiate the buying and selling of logs, which can include export payment terms and international banking.

Log face: A log is considered to have four faces with each face running along the length of the log and occupying one-quarter of the circumference of the log. The location of log faces is determined by the log grader so that as many defects as possible are contained within one face so that the other faces might contain fewer grade-lowering defects. To accurately grade or otherwise evaluate a log you must be able to roll it so that you can see all four log faces.

Mineral stain: Greenish-black or greenish-brown discoloration of the wood caused by inclusions in cell cavities and usually accompanied by elevated mineral content; the term is often used to refer to similar discolorations of undetermined causes.

Overgrown knots: Portion of a branch that is completely covered by non-branch stem wood.

Pattern match: Pattern matched veneer is commonly specified for paneling, door, and large furniture products. There are several pattern matches but the two most common are book match and slip match. Book matched veneer surfaces are created by taking every second piece of veneer in a reassembled flitch and flipping it over. So that adjoining leaves of veneer are symmetrical about their glue joint. Slip matched surfaces are created by joining the edges of adjacent veneer leaves without flipping any leaves.



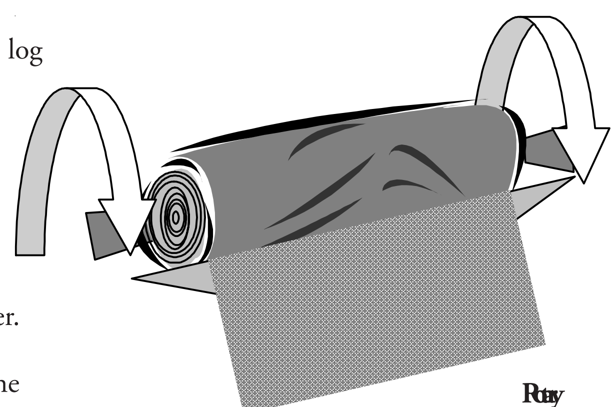
Pith Fleck: Small area of wound tissue caused by damage to the cambium by insect larvae, appearing on a longitudinal surface as a narrow, usually brownish streak several centimeters long.

Procurement: To supply raw material (generally logs) to a company's processing facility. Procurement occurs when logs or stumpage are bought directly from public or private landowners. In addition, material needs are met by purchasing logs from sawmills, other wood products' processors, log brokers, or by barter. Typically, procurement personnel arrange for standing timber to be harvested, either by logging crews or by contract crews, once the timber has been purchased. Not all procurement personnel (e.g., timber buyers and log brokers) are professional foresters.

Rice pattern: Small pockets of ingrown bark (see Appendix III-K).

Rift cut: Rift cut or rift sliced veneer is a type of sliced veneer in which the cut of the veneer knife crosses the wood rays at an angle of approximately 15 degrees. Red and white oak are the two species that are most frequently cut in this way. Because the oaks have very large rays, rift cutting is used so that the grain pattern of the veneer does not include large ray flakes, which result when the plane of the cut intersects with the ray cells for an extended distance. Rift cut veneer is very straight grained (similar to quarter-sliced veneer), appearing as a series of parallel lines (the growth rings). It is cut by mounting a quarter-log flitch onto the veneer lathe, called a stay-log or half-round lathe. The lathe rotates the flitch through the knife in a series of short, fast strokes.

Rotary peeling: A method for producing veneer in which the whole log (usually a 4- to 6-foot-long bolt) is mounted on the rotary lathe by attaching the two ends of the log to spindles. The spindles rotate the log against a long veneer knife which gradually moves into the log's face. Once the log has been rounded by the knife a continuous sheet of veneer is produced. It is as if the log was a roll of toilet tissue unraveling as it spins quickly and continuously along its central axis. After peeling is completed, an unpeeled central core remains; this core section is only 2 to 3 inches in diameter.



Rotary peeling

Rotary slicing: Synonymous to rotary peeling, however, peeling is the more appropriate term.

Rotary veneer: Veneer produced by peeling/cutting/slicing logs on a rotary lathe. All rotary veneer faces have a tangential orientation. Rotary veneer often is mistaken for flat-sliced veneer.

Sapwood: Sapwood is typically the light-colored band of wood on the outside of the cross section of the bole. This is the latest growth area of the tree and in most cases is lighter in color and softer, and the portion of the tree that contains living cells and reserve materials (e.g., starch). Faster-grown trees tend to have a wider sapwood zone than slow growth trees and under most conditions, sapwood is more susceptible to decay than heartwood. It is considered a defect in veneer because most of it must be clipped off and discarded.

Sawlogs: The formal Forest Service definition of a hardwood sawlog is a log that is at least 8 feet log and has a diameter of at least 8 inches measured inside the bark on the small end of the log. Many sawmills have their own criteria for minimum log length and diameter that may vary slightly from the Forest Service minimums. The Forest Service definition is particularly relevant since it is used in log pricing reports and in a variety of timber products output and trade reports.

Sliced veneer: Veneer that is produced using flat, quarter, rift, and half-round slicing methods. Veneer that is produced on a rotary lathe is not considered to be sliced veneer.

Sweep: See crook.

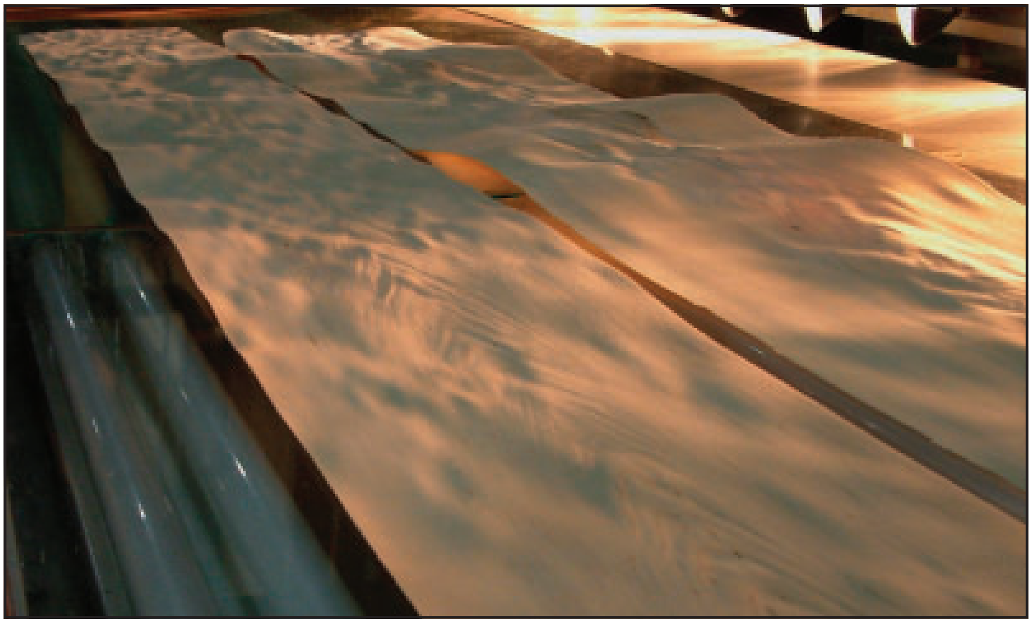
Whitewood: Most commonly refers to sapwood (as opposed to heartwood) for any species that has relatively white colored sapwood. However, the term sometimes is used more specifically to refer to yellow-poplar and American basswood.

Appendix III. Photos of Defects

This appendix of log and veneer defects are important but not easily recognized.

A.—Figured cherry veneer – not in high demand.

B.—Figured maple veneer called "birdseye maple" – high demand.



C.—Buckled sheets of veneer

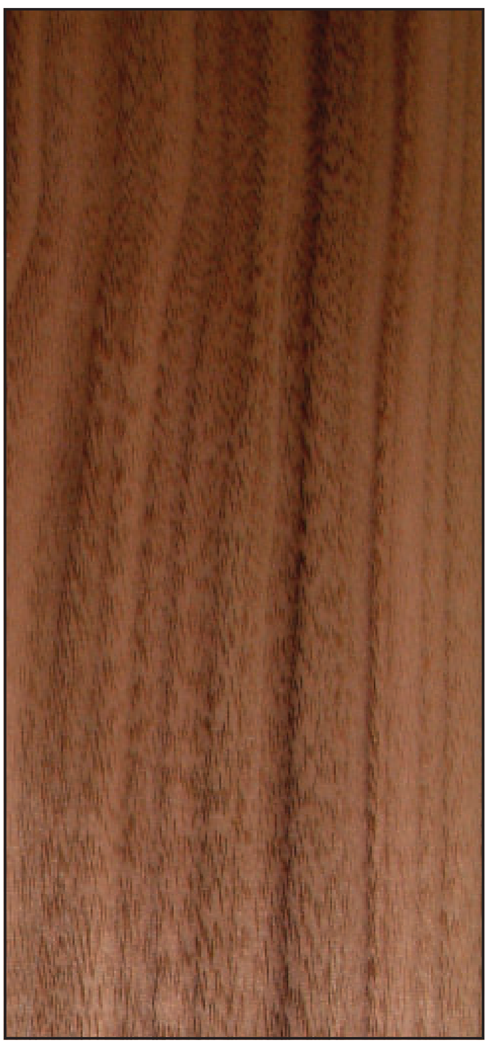
D.—An undesirable figure called "catspaw" that is common in cherry and is caused by a cluster of adventitious buds.

E.—Bird peck damage that occurred several years earlier as seen on the end of a walnut log.

F.—Bands of mineral stain as seen on the end of an red oak log.

G.—Bird peck in walnut (upper left), cherry (upper right), and maple (below) with associated amounts of mineral stain and ingrown bark.

H.—Mineral streaks in veneer sheets takes many forms as seen in this set of pictures: above – red oak; below-left – walnut; below-right – sugar maple.



I.—Cambium miner damage in three species: above – glassworm in ash; below-left – sugar streak in maple; below-right – cambium miner damage in hickory.

J.—Gum ring in cherry: above - as observed on the end of the log, below – as it appears in a slice of veneer.

K.—Ingrown bark: top – on the log surface (only visible with the bark off); bottom-left – in a "rice pattern" arrangement in cherry; below-right – in a more common form in cherry.

L.—A defect referred to as "bone" or "tension streak": above – as seen on the end of a white oak log; below – as seen in a hickory veneer sheet.

Wiedenbeck, Jan; Wiemann, Michael; Alderman, Delton; Baumgras, John; Luppold, William. 2004. **Defining Hardwood Veneer Log Quality Attributes.** Gen. Tech. Rep. NE-313. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 36 p.

This publication provides a broad spectrum of information on the hardwood veneer industry in North America. Veneer manufacturers and their customers impose guidelines in specifying wood quality attributes that are very discriminating but poorly defined (e.g., exceptional color, texture, and/or figure characteristics). To better understand and begin to define the most important attributes that distinguish veneer logs from sawlogs, and high-end from low-end veneer logs, we visited and interviewed veneer log buyers and sellers, veneer manufacturers, and veneer sales personnel. The first section of this report provides information on the demographics of the hardwood veneer industry and domestic and export market influences on veneer manufacturing. This is followed by a discussion of: 1) veneer quality requirements for different product markets, 2) veneer log quality evaluation procedures, 3) veneer log procurement systems, 4) regional variations in veneer log quality characteristics, and 5) species-specific quality requirements and issues.

Keywords: veneer; quality; hardwood; slicing; appearance-grade; flitch

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