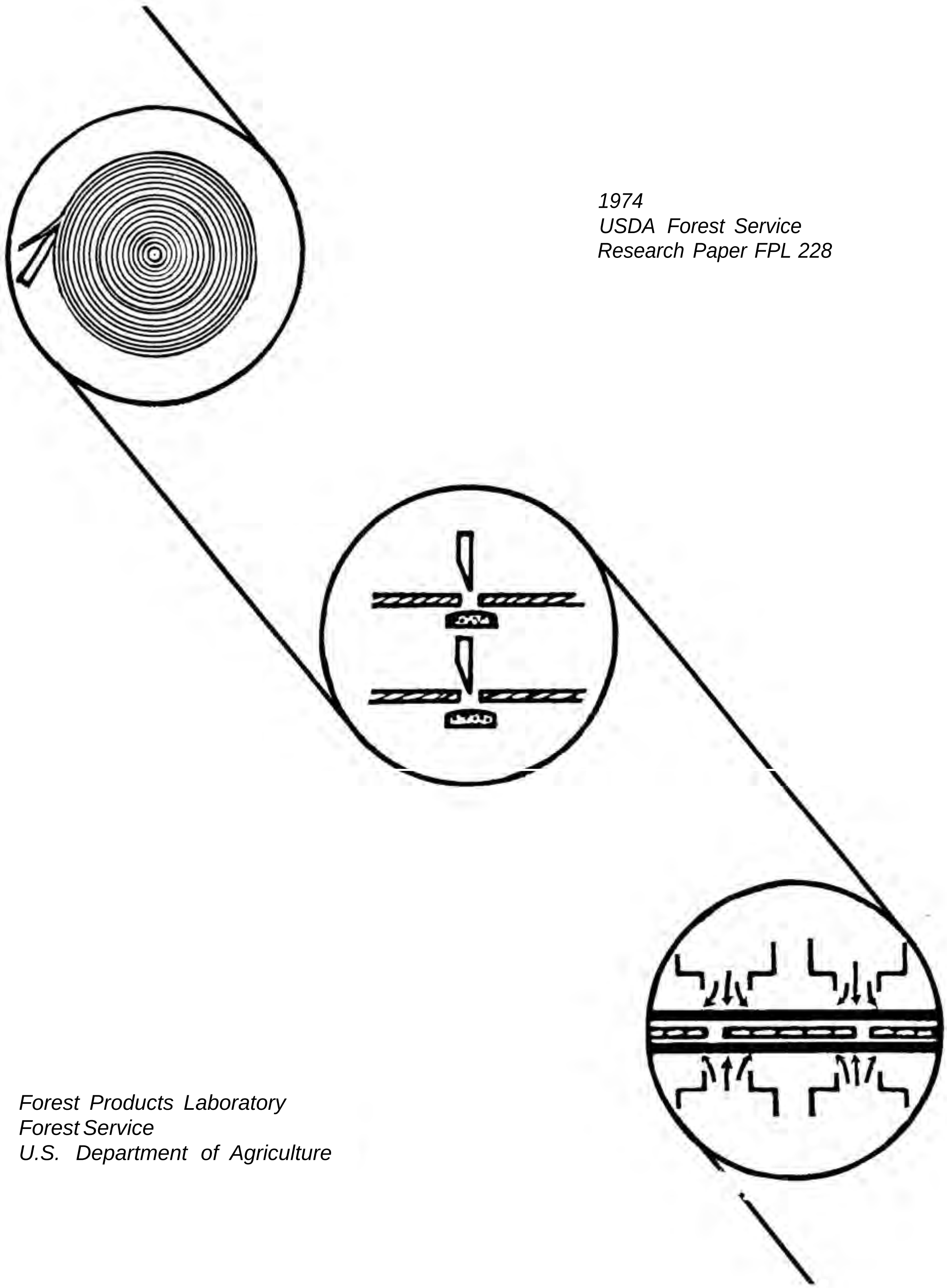
TECHNIQUES FOR PEELING SLICING, AND DRYING VENEER



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FOREWORD

The broad spectrum of veneer cutting and handling for a multitude of uses obviously covers a wide range of operations by many specialists and involves hard-learned secrets. No one individual can be an expert in all areas - yet his efforts should generally be in line with those of others. In days of material shortages and pressure on energy sources, it seems doubly important to summarize some of the principles and coordinate terminology.

This report is an overall view of the state of the art of veneer manufacture as seen by one who spent the last 25 years in research and industry contacts. It represents an attempt to tie together the experiences of many for the benefit of all.

This is the third in a series of Research Papers by John F. Lutz on aspects of veneer production. Previous papers were:

> "Wood and Log Characteristics Affecting Veneer Production," USDA Forest Service Research Paper FPL 150, 1971.
>
> "Veneer Species That Grow in the United States," USDA Forest Service Research Paper FPL 167, 1972.

Single copies of each report are available upon request from the Director, Forest Products Laboratory, Forest Service, USDA, Box 5130, Madison, Wis. 53705.

ACKNOWLEDGEMENT

This compilation represents the contributions of many people over a considerable period of time. The 75 references listed indicate this, but it is harder to document the thoughts that others shared informally with me over the years - many of which contribute to this publication. Memorable contributions by members of the Forest Products Laboratory staff were by Bob Hann, Curt Peters, Harry Panzer, Joe Clark, and John McMillen.

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J.F.L.

ABSTRACT

Procedures used to manufacture wood veneer are reviewed in detail. The process is followed step by step from the log to the dry veneer, including a section on quality control. In addition to current industrial practice, comments are made on research that may lead to changes in manufacturing techniques.

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TECHNIQUES FOR PEELING, SLICING, AND DRYING VENEER

By

JOHN F. LUTZ, Forest Products Technologist

Forest Products Laboratory,[1] Forest Service

U.S. Department of Agriculture

INTRODUCTION

Practically any wood species that grows in the United States can be cut and dried into useful veneer. To be sure, some species are easier to work than others. Many differences are described in the papers "Wood and Log Characteristics Affecting Veneer Production'' (51) and "Veneer Species That Grow in the United States" **(52)**.

The present report is concerned with the general techniques used in processing logs into dry veneer. Different viewpoints about veneer processing are discussed and reconciled as far as possible. More detail is given on some phases of veneer manufacture than others. When good information is published elsewhere, the descriptions are short and the reader referred to other published reports.

In addition to current commercial practice, the report also describes recent research that may some day find application in the industrial production of veneer.

Veneer in this report is defined as being produced by cutting wood with a knife into pieces 1/200 to 1/4 inch (0.13 to 6.35 mm.) in thickness. Properties that ma be affected by processing techniques include uniformity of thickness, surface roughness, sheet buckle, depth of checks into the veneer, color, and figure. Uniform thickness and relative smoothness and flatness are important for all veneer uses. Checks in the veneer, color, and figure are important for decorative face veneer.

An "ideal" piece of veneer may be defined as uniform in thickness, roughness not greater than the wood structure, flat, with no checks into either side, and having a pleasing color. Figure is desirable for decorative face veneer and straight grain for other uses.

From a given supply of logs, the processor can improve the quality of veneer in two general ways: Handle the wood so that variability is minimized, and carefully select and adequately maintain processing equipment.

Handling the wood to minimize variability involves such things as log storage, breaking logs into bolts or flitches, and heating or cooling the wood prior to cutting.

Processing equipment involves the basic design of debarkers, lathes, slicers, veneer conveyors, clippers, and dryers. All of this equipment must be properly maintained, set up, and operated to consistently produce good-quality veneer.

The veneer processing techniques described in this report follow the chronological steps in which they occur from log to dry veneer. This is followed by a section on quality control and troubleshooting to minimize veneer defects.

LOG STORAGE

Veneer logs can be kept in good condition for some time providing the storage conditions are suitable. With poor storage conditions, logs can deteriorate by drying and cracking of the log ends and other exposed wood, development of blue stain, decay, and oxidation stain, attack by insects, cracks and grain separation due to freezing and thawing, development of undesirable odor, and increased porosity due to attack by bacteria.

Log end drying and splits can occur with susceptible species like dense hardwoods in one hot, dry, windy day when the sunlight falls directly on the log end. End drying is less of a problem with a species like Douglas-fir stored in winter in the damp Northwest. Blue stain and mold can occur in a week to 10 days on the

[1] The Forest Products Laboratory, Forest Service, U.S. Department of Agriculture, is maintained at Madison, Wis., in cooperation with the University of Wisconsin.

sapwood of species like sweetgum and southern pine stored in humid summer weather in the South. Decay generally requires weeks or months to develop. Oxidation stain, which lowers the value of white sapwood of species like birch and maple, may occur through the ends of unprotected logs stored several weeks during summer. These and other stains are described in more detail in reference **(51).**

Insects like lyctus beetles may attack a log within hours after felling. To minimize insect attack, logs stored in warm weather should be used within 2 weeks after felling, treated with an approved chemical, or stored under water.

Freezing and thawing of logs of species such as sweetgum and claro walnut may fracture the wood so that it is useless for veneer. This is less of a problem with species grown in northern climates.

The sapwood of many species is subject to attack by anaerobic bacteria even though the wood is kept wet. This has caused objectionable odor, particularly in tropical hardwoods like ceiba and cativo. Bacteria may also cause excessive porosity in pines like ponderosa and the southern species. The best way to control bacterial action is processing felled trees within 1 month or by storing the wood below 40° F. Spraying with chemicals may help, providing the bacteria has not already entered the wood.

Given these many possible problems, what is the best procedure for log storage? In general, veneer log storage should be kept to a minimum. The first logs into storage should be the first ones out of storage for processing. Ideal storage conditions would be to end coat and keep the bark intact on tree-length logs that are either held at high humidity and a temperature just above freezing (34° F.) or completely submerged in cold water (34° to 40° F.). The next best system would be to keep the logs under a roof and all surfaces constantly wet by a water spray. This would be just as good as the first method, providing the temperature was between 34° and 40° F.

A common storage method that is generally satisfactory is to keep all log surfaces wet with a water spray but without using a roof. When water spray is not feasible, then a chemical spray and end coating may permit satisfactory storage. Less desirable methods which are sometimes suitable include floating the logs in a pond and cold-decking the logs. A much more complete discussion of log storage is given in a paper by Scheffer **(72).**

BARK REMOVAL

The subject of bark removal is one in which two people, both knowledgeable in the field, may disagree. The reason is the wide variability in difficulty of removing bark. Three factors that must be considered are: (1) Variability of bark adhesion within a given species, (2) variability of bark adhesion between different species, and (3) type of equipment used for debarking.

Variability Within a Given Species

Spring-cut logs are easier to debark than fall-cut logs of the same species. This general statement is true for all species. Actual measurements of the wood-to-bark bond on several species indicate that this increase of bond strength from spring to fall may be on the order of 100 to 200 percent.

A second factor is the temperature of the wood and bark at the time of bark removal. Heated wood is much easier to debark. When hand debarking of veneer logs was common, a main reason for heating the logs was to make it easier to remove the bark. Frozen logs are particularly difficult to debark. A plant may even put in a hot pond to get logs above freezing so they can be more readily debarked with a mechanical debarker.

Another factor in debarking is whether or not the bark has been allowed to dry on the log. Assuming no bacterial action has taken place, the bark generally adheres more tightly after it has partially dried.

A fourth factor is the action of bacteria. Logs stored in a warm pond or under a sprinkler during summer may be subject to attack by bacteria. Bacteria seem to prefer the inner bark as a food source. Consequently, logs stored in a pond and attacked by bacteria may have the bark loosened so that it will come off in one big sheet. If the bark falls off in one big piece, it may jamb the bark conveyor, Conversely, bacteria attack may make peeling of bark much easier when using hand tools.

As Related to Species Differences

Individual wood species differ in strength of the bond between the bark and the wood. In one study of fall-cut logs, the bark-to-wood bond of quaking aspen was more than 40 percent stronger than that of red spruce.

Some species like basswood and elm have stringy bark. This becomes a problem in conveying the material from a mechanical debarker, as bark may come off in large sheets.

In general, softwoods like pine are easier to debark than hardwoods like hickory, but there are many exceptions. For example, fall-cut eastern hemlock is reported to be more difficult to debark than northern hardwoods like maple and birch. Other examples of softwoods that are difficult to debark are cypress with a fluted base, western redcedar with stringy bark, and redwood with very thick bark. Table 5 of "Veneer Species That Grow in the United States" **(52)** rates the difficulty of bark removal of all species that grow in the United States.

Types of Equipment Used

A number of different systems have been used for debarking veneer logs. These include hand tools, bark saws, water under high pressure, flailing chains, and drum debarkers. Some mills have used an old lathe to debark and round bolts. At present, however, two methods are by far the most common for debarking veneer logs - the cambio-shear or ring debarker, and the rosser-head debarker. There are also combination machines which can use either cambio-shear or rosser-head or both.

Some factors to consider in choosing a debarker include cost, maintenance cost, species to be debarked, volume of wood to be debarked, maximum and minimum diameter of logs to be debarked, importance of fiber loss, pollution, ease of operation, and ease of maintenance.

In general, the rosser-head debarker has a lower initial cost, lower maintenance cost, is easier to adjust, and is more adaptable for logs of a wide range of diameters. The rosser-head is generally preferred for debarking rough logs of species like hickory, logs that vary widely in diameter, and logs that may be frozen.

The cambio-shear or ring debarkers are generally preferred by plants processing logs with relatively uniform diameters and where high production and low fiber loss are important. A typical installation would be in a large southern pine plywood plant.

Several manufacturers of cambio-shear debarkers state that, by proper adjustment of tool pressure and feed, their equipment can debark any species under any conditions, including frozen logs. Similarly, manufacturers of rosser-head debarkers state their equipment can be used to debark any species under any conditions.

SAWING INTO BOLTS OR FLITCHES

Some Sequences Used in Debarking, Buckling and Flitching

It is generally desirable to harvest logs in as long lengths as possible and to saw into bolts or flitches at the veneer-cutting plant. The reasons for doing this include less waste from end drying of the logs, a better opportunity to observe all sides of the log before cutting, availability of skilled labor trained to buck and saw flitches from the logs for the best use, and better mechanical equipment for handling and sawing the logs.

The sequences of debarking, bucking into bolts, and heating depends on type of logs, debarking and sawing equipment at the plant, and whether log end splitting is a factor during heating. In general, debarking reduces heating time, as bark is a good insulator. Heating in long lengths reduces waste due to log end splits. On the other hand, bark indicators of hidden defects in the logs may help the sawyer decide where to break the logs for best grade. The bark may also protect the logs during handling.

A method sometimes used with hardwoods that tend to end split is to debark in long log lengths, heat in long log lengths, and then buck into bolts just prior to cutting veneer. This method reduces the required heating time by eliminating insulation by the bark. Log end splits are confined largely to the ends of the long log and minimized at bolt ends exposed by crosscutting after heating. The process requires a continuous debarker, long heating vats, and equipment to handle long logs. Other disadvantages are that the bark indicators of defects are lost before bucking, and care must be used to prevent the debarked logs from picking up grit during handling.

A method used with softwoods like southern pine is to debark in long log lengths, crosscut bolts, and then heat prior to peeling. This requires a continuous debarker but permits heating vats and handling equipment which work with 8-foot and shorter blocks. It is a satisfactory method if end splitting is not a serious problem and the handling equipment is kept clean so the debarked logs do not pick up grit.

Large-diameter logs such as old-growth Douglas-fir are sometimes cut to bolt length in a pond, debarked in a machine designed for 8-

foot lengths, and then heated or cut at room temperature.

The debarking-sawing-heating sequence used for flitches is generally to buck to length, then saw the flitches, and finally heat the flitches. As flitches are generally a step in producing face veneer, bark indicators are important for cutting logs to length and for producing the flitches. Most or all of the bark is removed in sawing and so does not significantly retard heating. The heated flitches are cleaned and any remaining bark removed with a flitch planer just prior to slicing.

Types of Saw Used in Manufacturing Bolts and Flitches

Logs are cut to length of bolts or flitches primarily with large circular saws or with chain saws. In both cases it is important that the log and saw be positioned so the cut is at a right angle to the axis of the log.

Logs are generally sawn into flitches with a bandsaw or a circular saw. A recent innovation is a vertically movable circular saw that is mounted over the log carriage. This permits sawing logs into thirds as well as halves and quarters. In all cases it is important that the log can be accurately positioned with respect to the sawline and that the sawyer can see both ends of the log. If both lumber and veneer flitches are to be produced, the bandsaw may be advantageous, as generally a smaller saw kerf is produced.

What Does the Sawyer Look for?

Bolts

Factors to be considered in bolts are sweep in the log, end trim, presence of large defects like knots, and the length of the bolts required. If possible, sweep in the log should be minimized as it results in excessive roundup and short grain in the veneer. Thus, even though long bolts are generally more valuable than short bolts, a log with excessive sweep would probably be more valuable if cut into two or more bolts to minimize the sweep. Logs that have been end coated or that have dried and checked should be end trimmed. The cut should be at a right angle to the longitudinal axis of the bolt. Crosscutting with a hand-held saw can result in irregular bolt ends, which in turn can reduce the surface engaged by the lathe chucks and also cause the veneer to vary in length or require excess spurring at the lathe.

Flitches

A log with sweep should be sawn into flitches so the sweep is perpendicular to the plane of the knife used in slicing. This permits full-length veneers from the start of slicing. A large split or frost crack in a log may be minimized by dividing a log along this longitudinal plane. If possible, knots or other defects indicated in the bark should be trimmed out or be put at one edge or end of the flitch so the defect will occur at the edge or end of the veneer. In general, it is desirable to saw the flitch parallel to the bark and take the taper from the center of the log. This makes for straighter grain and a balanced design in the face veneer. The side of the flitch that is to be the exit side for the knife at the end of the cut should be sloped with the wide side next to the flitch table to minimize tear-off during slicing. The top and bottom of the back of the flitch should be squared so the slicer dogs can obtain a good grip. The recent developments of remotely controlled extension dogs and a fixture for holding the flitch by vacuum make this precaution less important.

Frequently the sawyer preparing flitches for face veneer has the option of sawing the log for lumber. This judgment is generally made after he has sawn through the pith and can see the quality and figure in the wood. If the log has some limitation for slicing, such as ring shake, it may still be possible to recover high-quality lumber.

Minimum Log Diameters

In general, logs for rotary cutting should have a minimum diameter of 10 to 12 inches, those for flat-slicing and half-round cutting a minimum diameter of 15 inches, and those for rift-cutting or quarter-slicing a minimum diameter of 21 inches.

Choice of Cutting Direction

Some of the ways bolts or flitches are prepared and cut into veneer on a lathe or a slicer are illustrated in figure 1.

There are two main directions in which veneer can be cut - parallel to the annual rings (rotary cut) or parallel to the wood rays (quarter sliced). The other methods fall between these two extremes. Half-round, flat-slicing, and back-cutting all result in cutting parallel to the rings in the center of the veneer and at angles to the rings at the two edges of the veneer sheets. Rift-slicing is a deliberate attempt to cut midway between parallel to the rays and perpendicular to them.

The lathe is used to cut practically all

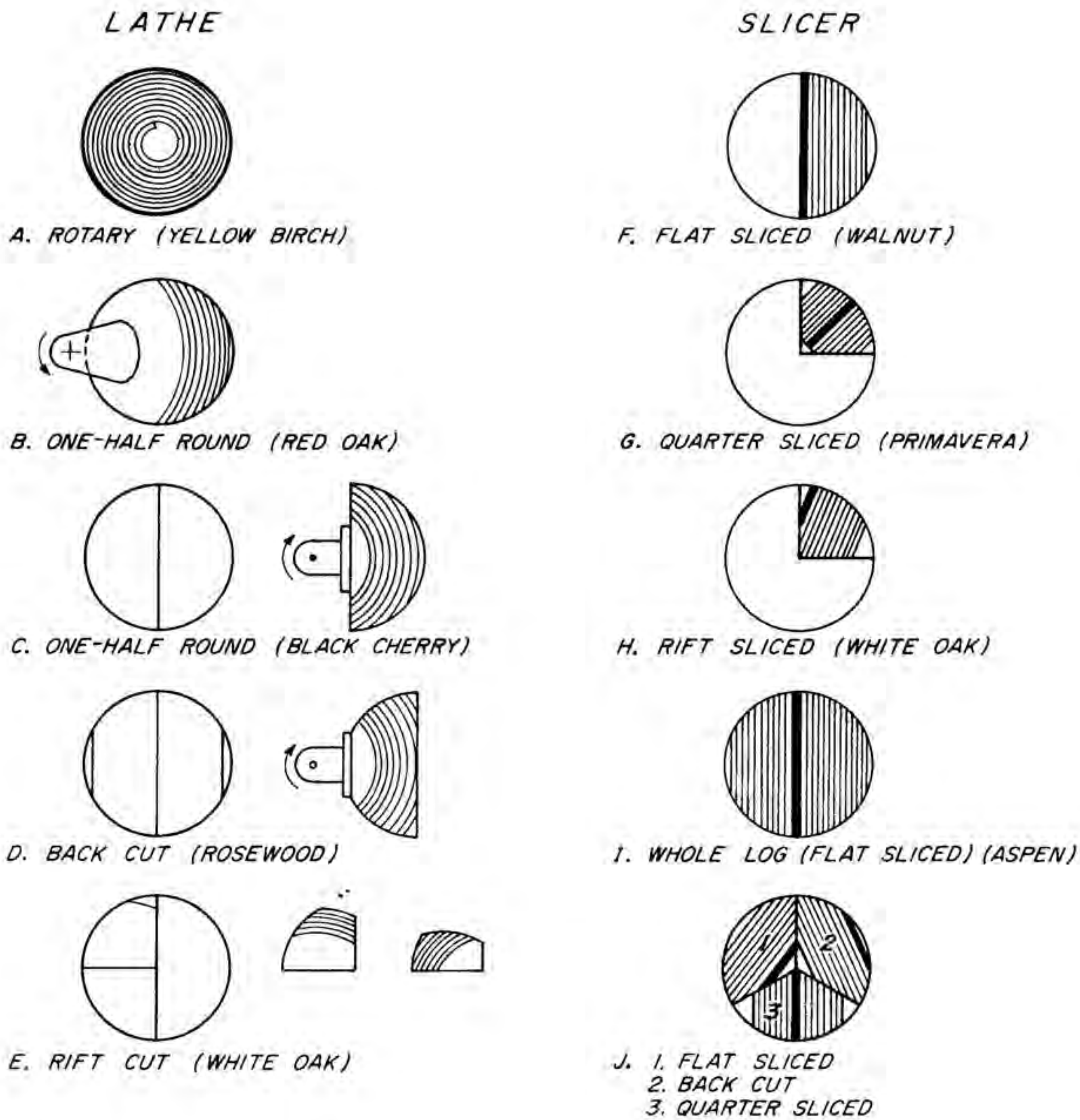


Figure 1. - Some of the cutting directions used to obtain different grain patterns in veneer. The species in parentheses are typical of those cut by the method diagramed. The wide dark lines under "slicer" represent the backboard left at the end of slicing.

(M 140 660)

veneer used in construction plywood, some decorative face veneer, and most container, core, and crossband veneer. Slicing and stay-log cutting is done primarily to produce decorative face veneer. A stay-log is an attachment for a veneer lathe on which flitches may be mounted for cutting into half-round, back-cut, or rift veneer (fig. 1-C, D, E). Very high-quality core and crossband veneer is occasionally produced by quarter-slicing. Small, fast slicers have been used to produce container veneer.

Rotary

Eighty to ninety percent of all veneer is cut by the rotary method (fig. 1-A). The rotary method gives the maximum yield; it results in the widest sheets; knots are cut to show the smallest cross-section; and most juvenile wood and splits are left in the core. Some rotary-cut veneer is used for the decorative effect of annual rings or irregular grain, such as that causing "blister" figure.

Flat Slicing and Half-Round Cutting

Flat slicing (fig. 1-F) is done on a slicer, and half-round (fig. 1-B, C) is done on a lathe. Half-round cutting may be done with flitches mounted on a stay-log (fig. 1-C), or by chucking a bolt at one edge rather than at the center, and by having the lathe chucks mounted eccentrically (fig. 1-B). Veneers produced by the flat slicing and by half-round cutting are similar in appearance. The centers of the sheets are essentially flat-grain while the edges are rift or even quartered material. The half-round method gives slightly wider sheets and a bigger area of flat cutting in the center of the sheet than the flat-slicing method. These two cutting methods show growth rings to advantage. When the grain dips in and out of the sheet, the figure is broadly termed "crossfire." Burls are generally cut by the half-round method and crotches by the flat-sliced method.

Rift Cut

A quarter section of a log is cut and mounted so that the knife cuts at about a 45° angle to the wood rays. This can be done with a stay-log on a lathe (fig. I-E) or on the slicer (fig. 1-H). The method is used primarily with white oak to produce a figure caused by the wood rays. When the veneer is coarse-textured and the annual rings are not exactly parallel to the edge of the veneer, the figure is called rift cut. A form of rift cut that is particularly desirable is comb grain. By contrast with the more familiar form, comb grain has fine texture, straight grain, and no broad flakes.

Quarter-Sliced

Quarter-slicing (fig. 1-G) produces straight, narrow stripes in straight-grained softwoods like Douglas-fir, redwood, and western redcedar or straight-grained hardwoods like oak and walnut. Quarter-slicing is also done with species having interlocked grain such as mahogany and primavera. This produces a plain stripe or ribbon-grain which reflects light in different directions depending upon the position of the viewer. Plain-stripe is a comparatively broad stripe and not too pronounced. A ribbon stripe has narrower bands and is more highly reflective. When the grain in the wood dips in and out of the sheet, the figure is called a broken stripe.

Back Cut

Back cutting (fig. 1-D) is done on a lathe with a stay-log, much like half-round cutting. However, instead of cutting from the sapwood side, the cut is from pith side of the flitch. Back-cutting is uncommon and is done where the heartwood is narrow and much more valuable than the sapwood. Rosewood is an example of this.

Sawn

At one time sawing was a common method of producing veneer, but it is almost obsolete because of the large volume of material lost as sawdust. Sawing does have the advantage that it is not necessary to heat the log or flitch prior to cutting, the two sides of the veneer are essentially the same in quality, and thicker veneers can be produced without developing cracks into the veneer. An example where these advantages are important would be the top or back of a musical instrument, such as the guitar. Species like spruce, oak, cypress, and eastern redcedar are occasionally sawn. Sawn material can be flat-cut, quarter-cut, or rift-cut much the same as when slicing with a knife.

Figure in Veneer

As briefly described under the different cutting directions, the appearance of veneer can be greatly affected by whether the veneer is cut tangential to the annual rings, at a right angle to the annual rings, or somewhere in-between. Figures 2, 3, 4, and 5 are examples of the appearance of face veneer. A further description of figure in wood and its relation to the cutting direction through the bolt or flitch is given in U.S.D.A. Miscellaneous Circular No. 66 **(40).** Another reference that illustrates figure in veneer is the Fine Hardwoods Selectorama **(33).**

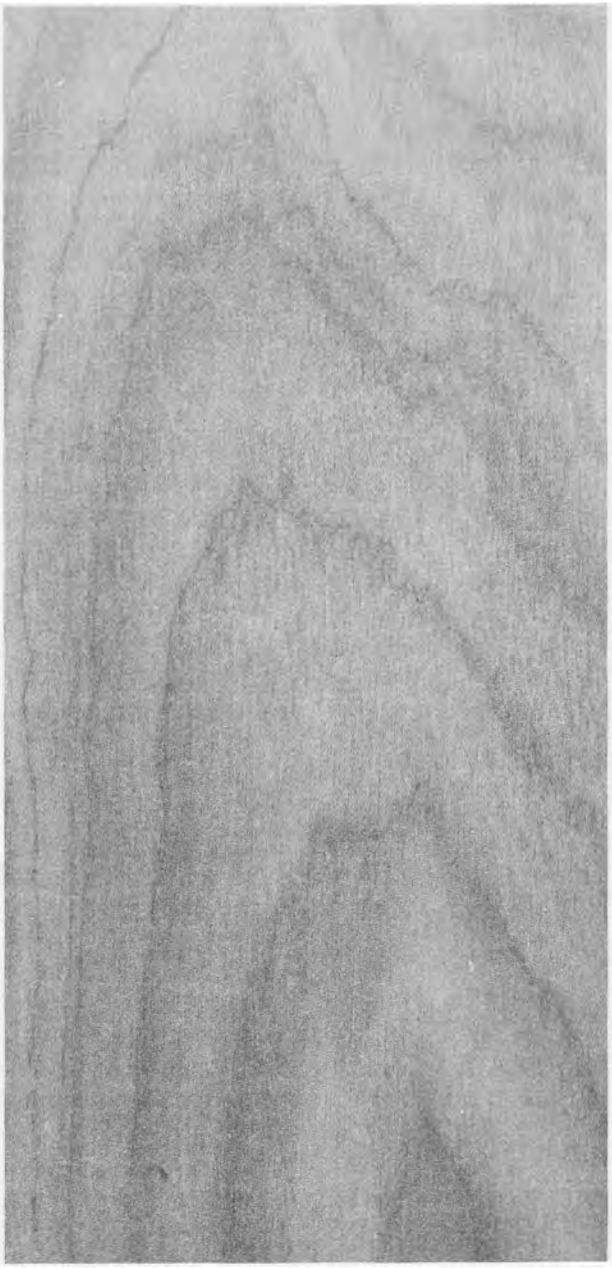


Figure 2. - Rotary-cut yellow birch with the figure caused by annual rings.

(M 139 946)

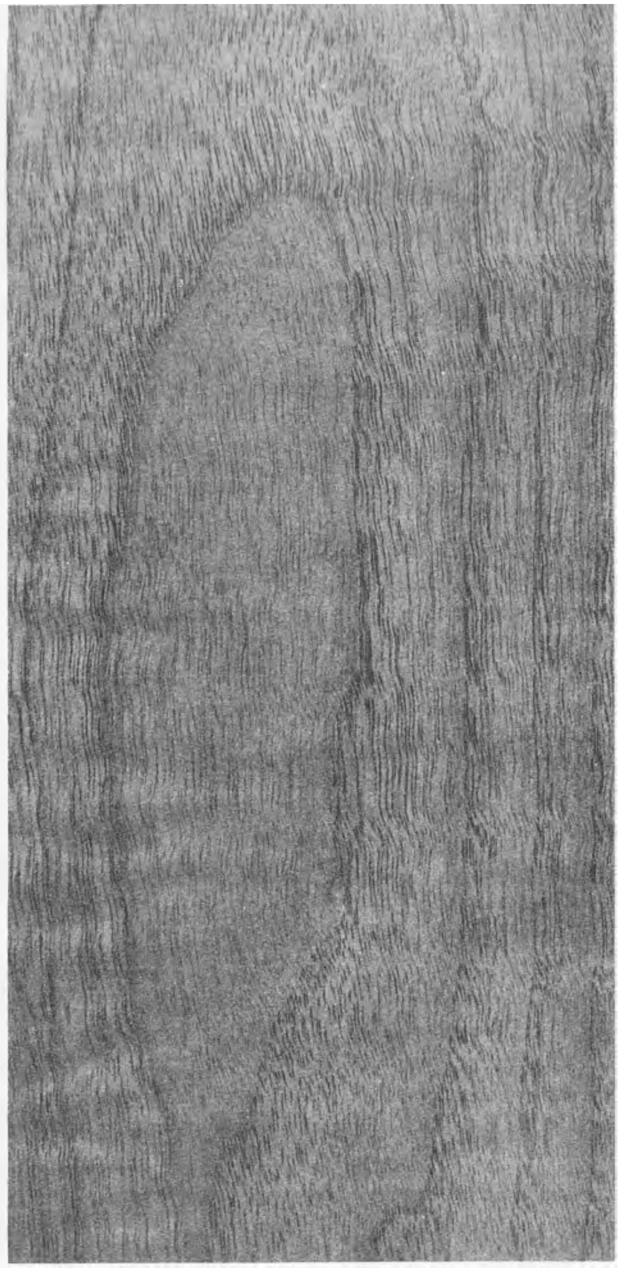


Figure 3. - Flat- or plain-sliced black walnut with figure from the annual rings and also a dip in the grain. The dip in the grain is sometimes called cross figures. (M 139 948)

Figure 4. - Rift-sliced white oak. The pencil stripe figure is caused by cutting the wood rays at an angle of about 45°. (M 139947)

Figure 5. - Quarter-sliced primavera. The broken stripe figure is caused by interlocked grain which dips in and out of the sheet. (M 139945)

CONDITIONING WOOD PRIOR TO CUTTING VENEER

The moisture content, permeability, and the temperature of wood can have a marked effect on veneer cutting.

Wood Moisture Content

Poor cutting results if nearly all cell cavities in the wood are filled with water or if the moisture content is below the fiber saturation point, about 30 percent for all species. This is discussed in FPL 150 **(51).** Unfortunately there is little the plant manager can do to drastically change the moisture content in a bolt or flitch. Rapid processing, storage under water, or a sprinkler system will prevent green logs from drying. Logs having very high moisture content cannot be partially dried quickly without developing degrade at the outer portions of the log. Steaming may slightly reduce the moisture content of such wood, and slightly reduce the time required to dry the veneer.

Wood Permeability

The more permeable wood is to water, the easier it is to cut. But permeability is also largely inherent in the species. Sapwood of some species can be made more permeable by storing in a warm, wet condition so bacteria will attack it. This may make it easier to cut into veneer **(53)** but it may also affect the odor of the wood and its gluing properties. These disadvantages make it unlikely industry will purposely induce bacterial attack to improve cutting.

Wood Temperature

The major factor under control of the plant manager is the temperature of the wood when it is cut. This is an area where strong differences of opinion exist among veneer plant managers. For example, a hardwood plant manager in Wisconsin stated that the entire quality control in his plant hinged on proper heating of bolts prior to cutting veneer. He stated that many things depend on whether or not the bolts were properly heated: Smoothness, tightness, and thickness control when cutting the veneer; buckle, splits, and uniform moisture content after drying; and quality of glue bonds.

In contrast, a softwood plant manager in Oregon stated that heating of veneer bolts was not worth the cost and he did not want log heating equipment in a plant that was to be built. Before commenting on these statements, let's examine some of the known effects of heating on green wood.

Some Effects of Heating on Green Wood

Plasticity

Heating green wood makes it more plastic. This fact is easily demonstrated with mechanical tests and is the basis of steam bending of wood. Within the limits used in veneer production, plasticity is not time dependent; as soon as green wood reaches a given temperature, it is as plastic as it will get at that temperature. Veneer cut from heated bolts or flitches can be bent with less fractures than veneer cut from unheated wood. This effect is more noticeable with dense species and when cutting thick veneer. If a plant is interested in cutting tight, thick veneer from dense species, then heating of the bolts or flitches is an important part of the process.

Hardness

Heating wet wood makes it softer. Hard knots, which if unheated may nick a sharp knife, will often be softened by heating so they can be cut. Heat also softens pitch but does not soften mineral deposits like calcium carbonate and silica.

While heating generally aids cutting of dense species, it may oversoften less dense species and result in tearing of fibers and a fuzzy surface on the veneer. This phenomenon occurs at different temperatures for different species. In general, if the wood cuts with a fuzzy surface, it is too hot.

Dimensional Changes in Wood Due to Heating

When green wood is heated, it expands tangentially and shrinks radially. This fact has been verified for both softwoods and hardwoods by a number of researchers. The amount of shrinking and swelling varies with the species. This thermal movement increases with temperature but the rate of increase is slow up to about 150° F. and then increases more rapidly. Consequently, if a species tends to develop splits through the pith and shake due to heating, a general recommendation is to not heat above 150° F.

Tangential expansion and radial shrinkage can occur in flitches without causing end checks or shake. It is therefore often possible to use higher heating temperatures with flitches that do not contain the pith than with bolts that do contain the pith.

Tree *Growth Stresses and Heating*

Most trees develop growth stresses. The

wood on the outside of a tree is in tension in the longitudinal direction and the wood near the pith is in compression in the longitudinal direction. Secondary stresses occur across the log with the wood in compression near the bark and in tension near the pith. This combination of stresses tends to cause the ends of a log to split as soon as it is crosscut. Whether it does or not depends on the magnitude of the stresses and the strength of the wood in tension perpendicular to the grain.

When bolts with large growth stresses are heated, the wood at the bolt ends is temporarily weakened in tension perpendicular to the grain; the growth stresses, together with dimensional changes discussed earlier, may cause star-shaped cracks radiating from the pith at the ends of the bolts.

The longitudinal growth stresses act primarily at the two log ends. When the wood is heated to a temperature of 180° F. or higher, 90 percent or more of the growth stresses are relieved. If the wood is heated in long log lengths and then crosscut to bolt lengths, the newly formed bolt ends will have less end splits than would develop if the bolts were cut to length prior to heating.

Longitudinal growth stresses tend to cause flitches to bow toward the bark side. This bow may become worse during heating. Bowing can be reduced by strapping the flitches together with the bark side out and allowing heating to relieve the growth stresses while the flitches are mechanically held flat. A wide, strong strap or heavy chains and bolts must be used as the forces involved are large.

Experimental strapping has also been tried to reduce end splits in bolts during heating. A I-inch-wide steel strap applied by a tool commonly used to strap containers was ineffective in preventing splits at the bolt ends during heating of Brazil nut about 2 feet in diameter. End splits were reduced in another bolt of Brazil nut heated to 160° F. by wrapping the ends with 1/2-inch cable and applying a tensile force of 40,000 pounds to the cable. Similar results have been obtained experimentally with red oak.

Steel strapping is used on the ends of flitches by some face veneer plants. Plant managers report this reduces splitting. As indicated earlier, the forces that tend to cause end splits during heating are less in flitches than in bolts of the same species.

Color Changes in Wood Due to Heating

Heating green logs may darken or lighten the wood. Heating in steam is reported to cause greater color changes than heating in water. The color changes may be desirable or undesirable. In general, heating tends to darken sapwood of all species. Similarly, the heartwood of oak, beech, and Port-Orford-cedar are darkened by heating. Minimum heating time and temperature are recommended for ash, oak, maple, and beech to keep the wood as light in color as possible.

Heating may also affect later color changes. Wet sapwood of yellow birch may develop orange streaks, thought to be an oxidation stain promoted by enzymes, Adequate log heating tends to inactivate the enzymes and reduce the likelihood of this undesirable orange stain occurring. Similarly, adequate heating of oak sapwood reduces the development of gray-brown oxidation stain.

Warm, wet walnut veneer is often held in storage until the sapwood becomes darker from oxidation stain and the heartwood reaches a desirable light gray-brown color. It is then dried to minimize further color changes.

Strength of Wood Related to Heating.

Occasionally a question is raised about whether heating bolts or flitches prior to cutting veneer weakens the dry veneer. As discussed earlier, heating wet wood plasticizes and softens it while it is hot. After drying, the wood cut from heated veneer bolts or flitches has much the same strength as wood cut from unheated controls.

Excessively long and high heating temperatures can reduce the strength permanently. For example, Douglas-fir and Sitka spruce heated for 50 days at 150° F. (66° C.) in water lost 10 percent of the modulus of rupture of unheated controls. When the same species were heated at 200° F. (93° C.), the modulus of rupture was reduced about 10 percent in approximately 10 to 12 days. Modulus of elasticity (stiffness) values were affected even less by heating.

Heating has a greater effect on hardwoods than on softwoods. Where softwoods Douglas-fir and Sitka spruce required 10 to 12 days' heating at 200° F. (93° C.) to lose 10 percent in modulus of rupture, a comparable loss for yellow birch occurred in 6 to 7 days' heating. Further information on strength of wood as affected by heating is given in reference **(61).**

Heating and Torque to Turn Bolts on the Lathe

The torque required to turn a bolt depends on the species, veneer thickness, bolt diameter, and setting of the knife and pressure bar - and is only slightly affected by heating. The heated wood is softer and more plastic so it bends readily, but the total work for peeling is only slightly less than for the more brittle, unheated wood. However, the heated bolt ends have less holding power than unheated wood. Consequently, spinout or turning of the chucks in the bolt ends is more likely to occur with heated bolts. Plant managers compensate for this by using retractable chucks, using lower bolt conditioning temperatures, or by spraying cold water on the bolt ends prior to chucking them in the lathe.

Shrinkage of Veneer Related to Heating Bolts or Flitches

Heating of softwood veneer bolts or flitches has no detectable effect on the shrinkage of veneer cut from them. In contrast, heating of bolts or flitches of some collapse-susceptible hardwoods may result in noticeably higher shrinkage of veneer cut from the preheated wood. In one trial, alpine ash veneer peeled at 60° F. (16° C) shrank 13.3 percent, while matched veneer peeled at 135° F. (57° C.) shrank 15.1 percent. The effect was greater the higher the conditioning temperature and the longer the heating time. Reference **(31)** gives more details. Whether this is important for some hardwoods grown in the United States is not known.

Drying Time For Veneer Related to Heating Bolts or Flitches

When sound, green logs with a high moisture content are heated in hot water or steam to 150° F (66° C.) or higher, they generally lose 1 to 10 percent of the moisture in the log. This is believed to be caused by air in cell cavities expanding and pushing out free water. Decayed logs may pick up water during heating in water.

It is sometimes thought that warm veneer cut from heated wood will dry faster than veneer cut from bolts or flitches that are not heated, Grantham and Atherton **(32)** report that Douglas-fir sapwood cut from bolts at about 140° F. (60° C.) dried 10 percent faster than sapwood from unheated bolts. They found the drying time for Douglas-fir heartwood was the same for veneer cut from heated and unheated bolts. Thin veneer cut from hardwoods generally requires the same drying time whether the bolts or flitches were heated or not. These results are to be expected from the relatively small amount of energy required to heat wood compared to the large amount of energy required to dry it.

Warp in Veneer Related to Heating Bolts or Flitches

Veneer cut from heated wood is generally tighter than veneer cut from unheated wood. Tightcut rotary veneer may tend to reassume the curvature of the bolt more than loosely cut veneer. The tendency of the veneer to curl is also related to the setting of the pressure bar during cutting.

If the logs or flitches are heated and then cooled in water, the end grain will pick up water. If the veneer is not spurred at the lathe, this extra water at the ends may affect drying at the ends of the sheets.

Effect of Heating on Decay Resistance of Naturally Durable Woods

The heartwood of green Douglas-fir, Alaska-cedar, white oak, and true mahogany were heated at 212° F. (100° C.) for various times from 1 to 48 hours. After 12 hours of heating, the white oak and mahogany were slightly less resistant to decay than the untreated controls. The Douglas-fir and Alaska-cedar were not noticeably affected. After 48 hours at 212° F. (100° C.), all of the woods were slightly less decay resistant than the unheated controls of the same species. The results indicate the heating of wood in normal veneer processing does not degrade decay resistance from a practical point of view.

Conclusions on Some Effects of Heating

Some benefits of heating. - The most obvious effect of heating is that it makes it possible to cut tighter veneer than can be cut from unheated wood. Tighter cutting means greater strength in tension perpendicular to the grain of the veneer and so less splitting of the veneer in handling and less checking of face veneer in service. A second effect of heating is that it softens knots, thereby reducing nicks in the lathe or slicer knife. The sharper knife in turn helps produce smooth veneer surfaces. Other possible benefits of heating include less power to cut equally tight veneer, improvement of color by decreasing oxidation stain in the sapwood, and reduced veneer drying time.

Frozen wood cannot be cut satisfactorily into veneer with a knife. Wood bolts or flitches yield veneer of varying quality with varying temperature. The changing temperature may adversely affect the lathe or slicer settings.

In general, heating is beneficial when slicing figured face veneer from dense species. Heating is also important if tight veneer is to be produced in thicknesses of $^1/_8$ inch or greater.

Some disadvantages of heating. - Most disadvantages of heating can be attributed to using too high a heating temperature or too long a heating time. Overheating may cause excessive end splits in bolts of species like oak, fuzzy surfaces on springwood and glossy surfaces on summerwood, shelling or separation of springwood and summerwood during cutting, unwanted darkening of the veneer, increased spinout of bolts by softening the end grain, or increased shrinkage. But the heating temperature must be very high and the heating time very long to affect the strength and durability of the wood.

Conclusions as Related to Wood Temperature

The improved veneer tightness, smoothness, and color are sufficiently beneficial so that almost all producers of hardwood face veneer heat bolts or flitches prior to cutting veneer. Whether heating has a significant effect on veneer thickness, moisture content after drying, and quality of glue bonds is not well documented. The Wisconsin plant manager was nevertheless correct when he stated that heating must be done properly in order to produce high-quality hardwood face veneer.

The softwood plant manager in Oregon who did not want heating equipment was producing a very different product. The panels from his plant were to be used mainly for construction such as sheathing. Here, properties of veneer tightness, smoothness, and color are less important. Many western softwood plywood plants make satisfactory construction plywood from unheated veneer bolts. However, research and plant experience indicates that heating pays even for manufacture of construction plywood. This is particularly true if there is any danger that the logs will freeze. Both researchers and industrial veneer producers have found that it is not possible to cut veneer from frozen logs. If the logs do freeze, then the plant without heating facilities will be shut down.

Another advantage of heating for this kind of product is that the veneer is tighter cut and as a result a higher percentage of 4-foot-wide and 2-foot-wide sheets is produced. That is, less splitting occurs during handling of the green, tightly cut veneer than when handling loosely cut veneer. In addition, heated knots are softer and result in less knife wear than cutting similar wood from unheated blocks. Grantham and Atherton **(32)** conclude that heating does pay when cutting veneer for plywood to be used in construction.

Time Required to Heat Veneer Bolts and Flitches

Most investigators agree upon some points about the time required to heat veneer bolts and flitches but other points are controversial. First, let's examine the points that are generally accepted.

Generally Accepted Factors About Time Required

Uniform final temperature. - The bolt or flitch should be heated long enough so that the temperature of the wood from the start of cutting to the end of cutting varies a maximum of about 10° F. (6° C.). To achieve this goal, the heating time must be sufficiently long and the heating medium (steam or hot water) must circulate freely to all surfaces of bolts and flitches.

Effect of bolt or flitch diameter. - The time required to heat a large-diameter bolt or flitch is much longer than the time required to heat one of small diameter. For example, while a bolt 1 foot (0.3 m.) in diameter might be heated in 14 hours, a bolt of the same species 2 feet (0.6 m.) in diameter would require about 60 hours. This example is from the report by Fleischer **(26)** for wood having a specific gravity of 0.50, an initial wood temperature of 60° F. (16° C.), a temperature of the water used to heat the bolt of 150° F. (66° C.) and the final temperature at a 6-inch (15-cm.) core of 140° F. (60° C.). Feihl **(16)** states that the time required to heat a log increases approximately as the square of the log diameter.

Effect of temperature gradient. - The greater the difference in temperature between the wood and the heating medium, the faster the heating rate. As the wood approaches the temperature of the heating medium, the rate of heating becomes very slow. As a result, when selecting heating schedules, it is generally desirable from a practical standpoint to aim for a core temperature of 10° F. (6° C.) lower than the temperature of the heating medium. Some veneer plants use an equalizing period at the end of the heating cycle to take advantage of the faster heating with a large temperature gradient and still end up with relatively uniform temperature throughout the block **(32).** A limitation to this practice is the bolt end splitting that may occur with the high initial temperature.

Total temperature change required for wood. - The colder the wood, the longer the heating time required to bring it to the desired cutting temperature. In other words, the heating capacity of a plant should be figured for the worst winter conditions rather than the average ambient temperature. This is particularly true if logs of high moisture content may be frozen at some part of the year. While ice conducts heat faster than water, the heat required to melt the ice can result in longer heating times. Feihl's tables **(16)** illustrate this effect. When heating frozen wood of species with a low moisture content like Douglas-fir heartwood, the heating times are shorter than for frozen logs with very high moisture content like western hemlock.

Effect of grain direction. - End grain heats two-and-one-half times as fast as side grain. The rate of heating in the tangential and radial directions is about the same. Because most flitches and bolts are long, compared to their cross sections, heating through side grain generally is the controlling factor. Faster end-grain heating probably means knots heat faster than surrounding clear wood. This is fortunate as one of the reasons for heating is to make the knots soft enough so they will not turn the edge of the lathe or slicer knife.

Variability of heating - Due to irregular shapes, differences in specific gravity and moisture content, and the presence of open defects like cracks, the rate of heating the logs or flitches of the same species is somewhat variable. It is therefore doubtful if heating schedules can be extremely precise. In general, the schedules should be developed for the largest bolts or flitches that are to be heated, starting from the lowest ambient temperatures in the log storage area. The most common problem in heating veneer logs is insufficient vat capacity to adequately heat the logs or flitches under all operating conditions.

Controversial Factors in Heating

Effect of heating medium. - MacLean **(60)** reports water heats wood 5 to 10 percent more slowly than steam. He found the slowest rate of heating in air at low humidities, but the rate was increased as the humidity was increased. In contrast, Feihl **(16)** reports that hot water heats as fast or faster than steam. Feihl points out that this apparent conflict may be due to the experimental conditions. MacLean was using steam at 212° F. (100° C.) and higher, while Feihl used a steam-air mix at a temperature generally below 200° F. (93° C.).

Some commercial plants inject steam into a vat and at the same time spray hot water over the bolts or flitches. In addition to adding heat to the wood, the hot water spray prevents drying and checking.

A commercial modification of the steaming hot-water spray method is to blow steam through an alkaline water solution. It is known that salts added to water will raise the boiling point slightly. These few degrees change in temperature would not seem to be important for conditioning veneer logs. Strong, alkali solutions will break down wood structure. However, in typical heating cycles, the alkali would not penetrate more than a fraction of an inch in most wood species.

Effect of differences in moisture content and specific gravity. - MacLean **(60)** found wood that is well below 30 percent moisture content heats more slowly than green wood. On the other hand, MacLean reported that differences in moisture content above about 30 percent had no important effect on the rate of heating. All veneer cutting, of course, is done with wood at a moisture content of 30 percent or higher. For practical purposes, MacLean is suggesting that green wood of any given species will heat at about the same rate at any moisture content above 30 percent.

In contrast, he found that the rate of heating of wood varied inversely with the specific gravity **(60).** Although the heat conductivity of wood increases with the increase in specific gravity, the diffusivity (a measure of the rate of temperature change) decreases with increases in specific gravity. In other words, the lighter woods will heat to a given temperature more rapidly than the heavier woods, although the heavier ones are better conductors of heat.

Feihl **(16)** found that the rate of heating is related to the specific gravity of the total log (that is, the wood and the water). He reports that sinker logs require longer heating time than logs that float one-third out of water, and that logs that float one-half out of water require less time to heat than logs that float one-third out of water.

Nakamichi and Konno **(64)** report that the variation due to species is not important for the time required to heat veneer logs.

Different researchers may have come to different conclusions about the effect of moisture content and specific gravity because these two properties vary within individual bolts and flitches, and because the effect of these two properties on required heating times are small when compared to the effect of log diameter, initial wood temperature, and the temperature of the heating medium. For example, as described under "Effect of Bolt or Flitch Diameter," the time required to heat a bolt 2 feet (0.6 m.) in diameter may be 400 percent greater than to heat a bolt 1 foot (0.3 m.) in diameter. In contrast, using MacLean's data **(60),** a wood species having a specific gravity of 0.38 has a diffusivity about 50 percent greater than a wood species with a specific gravity of 0.60. Similarly, Feihl reports **(16)** that a log which floats half out of water would require about 50 percent less time to heat than a log that is nearly submerged. In other words, the effect of bolt and flitch diameters on required heating times is much greater than the effect of differences in specific gravity and moisture con tent.

Log end splits. - In general, it is believed that rapid heating increases end splits. A few trials at the U.S. Forest Products Laboratory showed little difference between end splits in bolts heated slowly and matched bolts put directly into water at the desired final temperature. While slow heating may slightly reduce end splits, the maximum heating temperature seems to be more important. The higher the heating temperature, the larger the end splits.

Duration of heating at a given temperature. - Some researchers have reported that longtime heating using a low temperature has the same effect in conditioning wood for cutting veneer as short-time heating at a high temperature. Experiments at the Forest Products Laboratory in Madison indicate this is questionable. Duration of heating up to several days does not affect the plasticity and hardness of the wood. This in turn means excessively long heating periods do not improve the tightness or smoothness of the veneer compared to short-term heating to the same final temperature.

Heating longer than necessary to bring the wood to the desired cutting temperature may affect the color and shrinkage of veneer. More details are given in the paper "Processing Variables Affect Chestnut Oak Veneer Quality" **(54).**

Conclusions on Time Required to Heat Veneer Bolts and Flitches

The most common difficulty in heating veneer bolts and flitches is insufficient vat capacity.

The single largest factor in the required heating time is the diameter of the bolt or flitch to be heated. Good estimates of the required heating time for unfrozen logs can be made from Forest Products Laboratory Report No. 2149 **(26).** Feihl's report **(16)** can be used to estimate the heating time for frozen and unfrozen wood.

A special heating cycle may be appropriate if the color of the wood is important.

Construction of Steam and Hot Water Vats

Most heating vats or steam chambers are made from reinforced concrete. The vats should be constructed so that good circulation of the heating medium can be attained. The steam pipes should not be placed so live steam will impinge directly on the log ends. Steam blowing directly on the log ends overheats them and accentuates log end splits. If logs that float are to be heated in hot water, the tank should have hold-downs that will keep the logs under water during heating. The doors on steam chests or covers on water vats should be tight and preferably be insulated. In many commercial operations as much heat is lost to the atmosphere as is used to heat the wood.

Temperature-sensing devices should be placed in several locations in the vats or steam chambers. These in turn should automatically control the heating of the water vats or steam chambers. With a good system it is possible to keep the temperature in the vat to within 2° to 4° F. (1° or 2° C.) of the desired temperature.

A system that works well with hot water vats is to pump the water from one vat to another. After heating one vat, the hot water is pumped to a second vat which has just been loaded with unheated logs. The process is repeated and the hot water goes from tank to tank.

Some mills strap a number of bolts or flitches together so they can be handled as a bundle. This practice is all right provided the flitches are separated by stickers to allow for circulation of the hot water to all wood surfaces.

Another method that has been used commercially is to move the bolts or flitches progressively through a hot water or steam tunnel. This practice has the merit of straight-line production. To be successful, the bolts or flitches should be about the same diameter, the heating time should be long enough to ensure heating to the core of the bolts or center of the flitch, and the heating medium should circulate so that all surfaces of the bolts or flitches are heated the same amount.

Comparison of Hot Water and Steam Heating

Producers of hardwood face veneer generally prefer hot water vats while producers of softwood construction plywood generally prefer steam chambers.

The rate of heating in the two systems is about the same. The actual temperature throughout the vat can probably be controlled more accurately with water than with a steam-air mix. End drying is never a problem when heating in water vats, while it can be a problem in steam chambers if the relative humidity is not kept high. For workers, steam chambers are safer as a fall into a hot water vat is generally fatal. In terms of manpower, one man with a lift truck can load and unload steam chambers for a large plant while two or more men are generally needed to operate hot water vats.

Applied Heating Suggestions With Hot Water or Steam

Debark logs prior to heating.

Heat in tree lengths or the maximum length possible.

Segregate logs by diameter so the larger diameter logs can be given the needed longer heating time.

Heat United States species at the temperature suggested in Research Paper 167 **(52).**

For unfamiliar hardwoods, use the heating temperature indicated for the specific gravity of the wood as shown in figure 6.

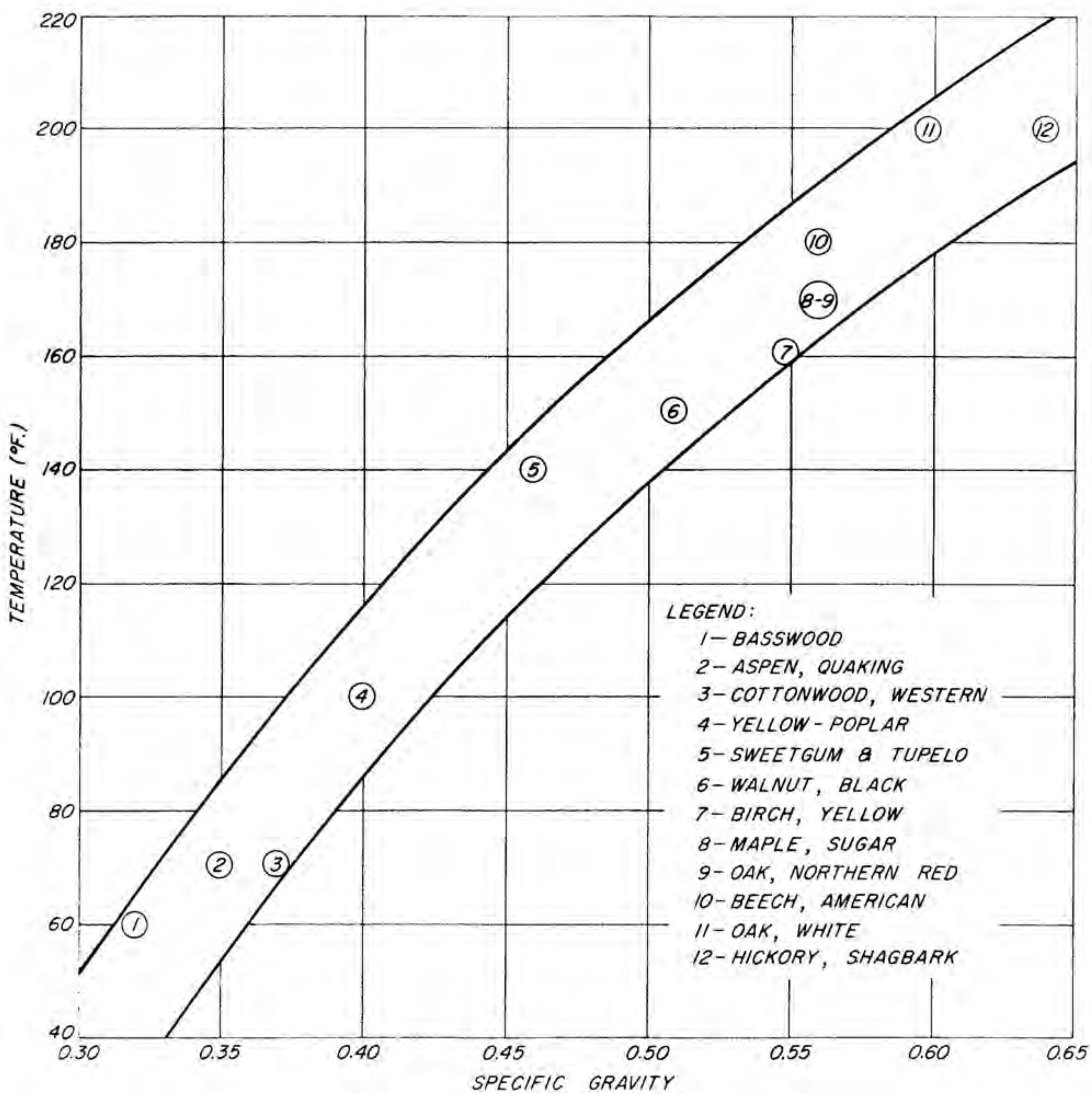


Figure 6. - Favorable temperature range (area between heavy lines) for cutting veneer of hardwood species of various specific gravities. Points show favorable temperatures for the individual hardwood species indicated. The data apply to the rotary cutting of veneer $^1/_8$-inch thick, of straight-grained wood, free of defects such as knots or tension wood ("soft streaks").

An example of the heating times required for bolts of different diameters is given below. More detailed information and tables are given in **(16)** and **(26).**

Examples:

Heating time as related to bolt diameter

(Green 8-ft.-long bolts with a specific gravity of 0.50, an initial temperature of 70° F. (21° C.), water or air-steam vat temperature of 150° F. (66° C.), and a final temperature at 6-in. (15 cm.) core of 140° F. (60° C.).)

Bolt Diameter		Required Heating Time
(In.)	(Cm.)	(Hr.)
12	31.5	14
24	63	60

Heating time as related to final core temperature

(Green 8-ft-long bolts with a specific gravity of 0.50, an initial temperature of 70° F. (21°C.), water or air-steam vat temperature of 150° F. (66° C.), and various final temperatures at a 6-in. (15 cm.) core.)

Bolt Diameter		Final Core Temperature		Required Heating Time
(In.)	(Cm.)	(°F.)	(°C.)	(Hr.)
24	63	140	60	60
24	63	120	49	34
24	63	100	38	22

Heating time as related to initial wood temperature

(Eight-ft.-long bolts with a specific gravity of 0.56, a green moisture content of 80 pct., various initial temperatures, water or air-steam vat temperature of 150° F. (66° C.), and final temperature at 4-in. (10 cm.) core of 140° F. (60° C.).)

Bolt Diameter		Initial Wood Temperature		Required Heating Time
(In.)	(Cm.)	(°F.)	(°C.)	(Hr.)
12	31.5	0	-18	27
12	31.5	40	4	21
12	31.5	70	21	16

The heating tanks should be arranged for circulation of steam or hot water so heat can flow easily to all sides of the bolts or flitches. Steam should not impinge directly on the ends of logs, bolts, or flitches.

The temperature in the vats should be recorded at half-hour or shorter intervals. Heating should preferably be controlled by automatic valves on the steam lines, regulated by heat sensors in the heating chamber.

The temperature at the core of larger bolts should be checked by drilling a hole in the middle of the core as it comes from the lathe. The hole should be 1 to 2 inches deep and just large enough to accept the thermometer. The thermometer should be inserted immediately and the temperature recorded.

If the cores of the large diameter bolts are within 10° F. (5° C.) of the temperature in the vat, the smaller bolts will also be adequately heated.

Proper heating will aid in producing tightly cut veneer of uniform thickness. Underheating will result in less tight veneer and may result in excessive handling splits and variation of veneer thicknesses. Overheating may cause large end splits in the bolts, spinout, fuzzy veneer, and shelling of the grain.

Some Other Methods of Heating Veneer Logs and Flitches

Some methods other than hot water or steam, or steam-air mixtures below 212° F., have been used on a small scale commercially or tried in the laboratory. These include heating in steam under pressure, electrically heating the wood, and forcing hot water or steam longitudinally through the wood.

Heating in Steam Under Pressure

A few veneer mills heat veneer bolts in steam under pressure. This does shorten the heating time as there is a bigger differential between the starting temperature of the wood and the temperature of the heating medium. However, there is nothing special about the change in temperature at 212° F. (100° C.). That is, the reduced heating time when going from 210° to 220° F. (99° to 104° C.) is comparable to the reduced heating time when going from 200° to 210° F. (94° to 99° C.). The disadvantages of a short heating cycle in steam under pressure include the very large temperature gradient from the surface to the core of the bolts and excessive bolt ends splits **(27).**

Electric Heating

Electrical methods have been used experimentally to heat bolts or flitches in an attempt to reduce the heating time required with water or steam **(47).**

In one set of experiments, electrodes were placed at each end of a bolt or flitch and as high as 5,000 volts sent an electrical current through the wood. Because the wood acted as a resistor, it was heated. This method is fast but has not been accepted commercially due to nonuniform heating. The electrical current follows the path of the least resistance, which may be wet streaks, cracks, or mineral streaks in the wood. These areas overheat and the other parts of the bolt or flitch are underheated.

High frequency has also been used experimentally to heat veneer bolts. High frequency tends to overheat the wetter parts of the wood, and is much more expensive than heating in steam or water.

Forcing Hot Water or Steam Longitudinally Through Wood

Short beech veneer bolts have been heated experimentally by forcing hot water longitudinally through the wood structure **(41)**. The experimenters report that heating time was reduced to minutes and that satisfactory veneer was cut from bolts heated this way. The method requires that the wood be permeable and that a cap be attached to each bolt.

VENEER CUTTING EQUIPMENT

In selecting veneer cutting equipment, it is important to remember the forces involved in cutting. In one rotary-cutting study **(57),** calculated loads were as high as 200 pounds per inch of knife and 500 pounds per inch of pressure bar. Pictures comparing early lathes and modern lathes indicate that experience has dictated the desirability of more rigid lathes. A lathe or slicer operator never has trouble because the equipment is too rigid, but excessive movement of machine parts is a common problem. If smooth, tight veneer of uniform thickness is to be produced, it is better to have a lathe or slicer that is stronger than necessary rather than to have one that is underdesigned.

Some face veneer slicers are made so excessive pressure cannot be applied to the flitch. The knife and bar carriage is not fastened on the ways of some horizontal slicers. Thus, if the total force against the flitch exceeds the weight of the knife and pressure bar carriage, the carriage is lifted from the ways. Similarly, on vertical slicers, the knife and bar assembly is not held on the half bearings that allow the knife to be offset on the upstroke of the flitch table. if there is excessive nosebar pressure, thin veneer sheets are produced and eventually the flitch will not clear on the upstroke. At this time, the knife and bar carriage will be lifted slightly from the half-bearing and the noise when the carriage falls back alerts the slicer operator that he has too much nosebar pressure.

There is no mechanism such as this for lathes. Excessive nosebar pressure can progressively build up until the bolt spins out of the chucks, the motor stalls, or some part of the lathe breaks.

Any moving part on a lathe or slicer is subject to wear. Consequently, preloaded antifriction bearings are a good investment as well as wear plates and mechanisms for taking up slack or play when it occurs.

Similarly, it is desirable to have hydraulically operated dogs on slicers and hydraulically operated chucks on a lathe. Any tendency of the wood work piece to come loose in cutting is automatically corrected as hydraulic pressure resets the dogs or chucks.

Another source of unwanted movement of the lathe or slicer is heat distortion. The use of A-frames with screw takeups on the nosebar casting is one method of correcting for this.

Another desirable feature is a means of keeping the lathe or slicer at a uniform temperature during setup of the knife and pressure bar and during cutting. An added benefit is the reduction of blue stain caused by the reaction of iron or steel with wet wood. Keeping the knife and pressure bar warm reduces condensation and so reduces the staining.

The heart of any lathe or slicer is the knife and pressure bar. The machine should permit rapid change of the knife and bar and easy adjustment of the clearance angle of the knife and the lead and gap between the knife and nosebar. If these adjustments are difficult to make, the operator will make as few adjustments as practical and so produce poorer quality veneer than would be produced on easily adjustable equipment.

Retractable dogs on slicers and retractable chucks on lathes permit secure holding of large wood flitches and bolts; when the dogs or chucks are retracted they permit continuous cutting to thin backboards or small-diameter cores.

Recent development of the vacuum table permits fast loading of flitches and cutting to a thin backboard. However, the flitch back should be wide, flat, and smooth to maximize the holding power of the vacuum table.

Cutting Action on Lathe and Slicer

Similarities of lathe and Slicer

The knife and pressure bar are very similar on both the lathe and slicer and perform the same function. Cross sections of a lathe (fig. 7) and slicer (fig. 8) illustrate the position of the knife and bar in the two machines. Terminology used to describe the knife and pressure bar on lathes and slicer is shown in figure 9.

The knife severs the veneer from the bolt or flitch. The included angle is about the same for knives on a lathe or slicer. The knife used on a lathe may be slightly more hollow ground.

The pressure bar on both the lathe and slicer cornpresses the wood, with maximum compression ideally occurring just ahead of the knife edge. This compression reduces splitting of the wood ahead of the knife, reduces breaks into the veneer from the knife side, and forces the knife bar assembly against the feed mechanism, thereby helping control veneer thickness. For both the lathe and slicer, the pressure bar is therefore important in controlling the roughness, depth of checks, and thickness of the veneer. The slicer has a fixed nosebar while the lathe may have a fixed nosebar or a rotating roller bar.

Advantages of Lathe

Logs to be cut into veneer on a lathe need to be crosscut to the desired bolt length, but they do not need to be processed through a sawmill prior to cutting veneer. After roundup of the bolt, the lathe cuts a continuous strip of veneer. Continuous cutting is advantageous because it means more production with a given cutting velocity, wider sheets of veneer, and a more uniform cutting condition. Full rotary cutting is approximately tangential to the annual rings and knots are exposed at their smallest cross section. in full rotary cutting, there is no impact at the start of cutting or tearoff at the end of cutting as may occur when slicing or cutting with a stay-log.

Advantages of Slicer

A main advantage of the slicer is that it permits sawing the log into flitches to present the most decorative grain pattern. As the veneer sheets are kept in consecutive order, this permits ready matching of figured veneer. Flitches can be heated with less danger of end splits developing than in comparable bolts being heated for rotary cutting. Sliced veneer is always cut from a flat surface while rotary veneer is cut from a curved surface. Since most veneer is used on a flat surface, the sliced veneer is used as it is cut while rotary veneer cut from a curved surface must be flattened for most uses. The disadvantage of cutting from a curved surface becomes more pronounced with thicker veneers cut from small-diameter bolts.

Sliced veneer is cut with a draw motion across the knife, while rotary veneer is cut with no draw motion. Theoretically, the draw cut should aid cutting. However, recent experiments at the U.S. Forest Products Laboraboratory indicate that the effect of the draw cut on smoothness, tightness, and veneer thickness is relatively unimportant.

Veneer as long as 16 feet is produced on a slicer while most rotary-cut veneer is 10 feet or shorter. The flitch on a slicer is backed by the flitch table while support for a veneer bolt may be provided by a backup roll.

Advantages of Cutting with Stay-Log on Lathe

The stay-log makes it possible to produce veneer, on a lathe, similar in appearance to sliced face veneer (fig. 1C). The advantages of stay-log cutting on the lathe are very similar to the advantages of slicing. The flitches can be selected for appearance of the grain and consecutive sheets can be matched for decorative faces. Sheets cut with the stay-log are generally wider than sheets cut on the slicer. For example, half-round veneer cut with a stay-log would probably be slightly wider than flat-sliced veneer cut from the same log. Veneer cut with a stay-log is taken from a curved surface in comparison with veneer that is sliced from a flat surface. Veneer cut with a stay-log may be up to 10 feet in length.

Advantages of Back-Roll Lathe

A modification of the rotary lathe is the back-roll lathe (fig. 10). This special type of lathe has ways that carry the knife-bar headblocks extended out on the log side of the lathe. On the extended ways, a frame is mounted to carry the back-roll. The entire mounting is fed toward the log by feed screws at the same rate at which the knife is fed. Knives mounted radially in the back-roll make an impression into the veneer bolt slightly deeper than the thickness of the veneer being cut. Then as the veneer is cut, it separates into pieces the same width as the spacing of the knives on the back-roll.

All lathes are generally equipped with spur knives so veneer can be cut to one or more lengths while it is being peeled.

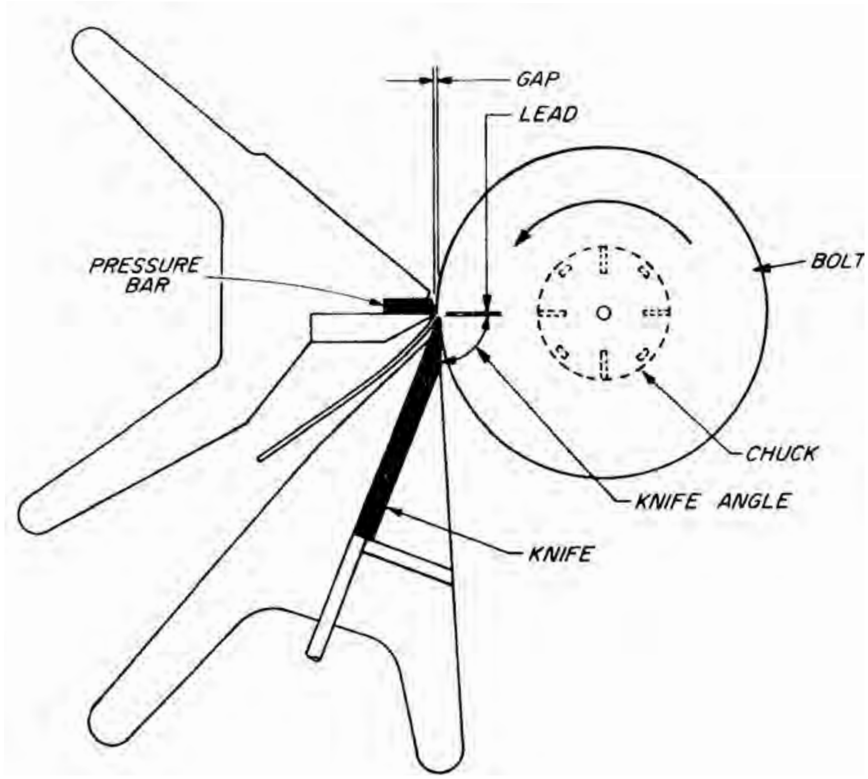


Figure 7. - Cross section of a veneer lathe having a fixed pressure bar.
(M 140 657)

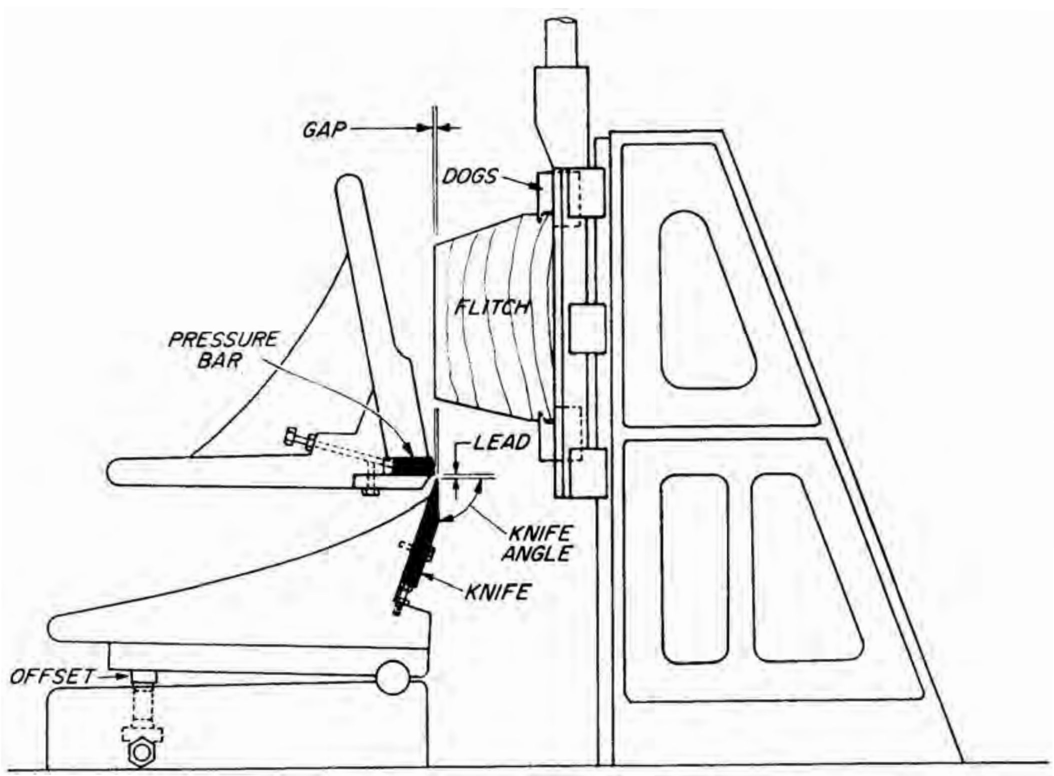
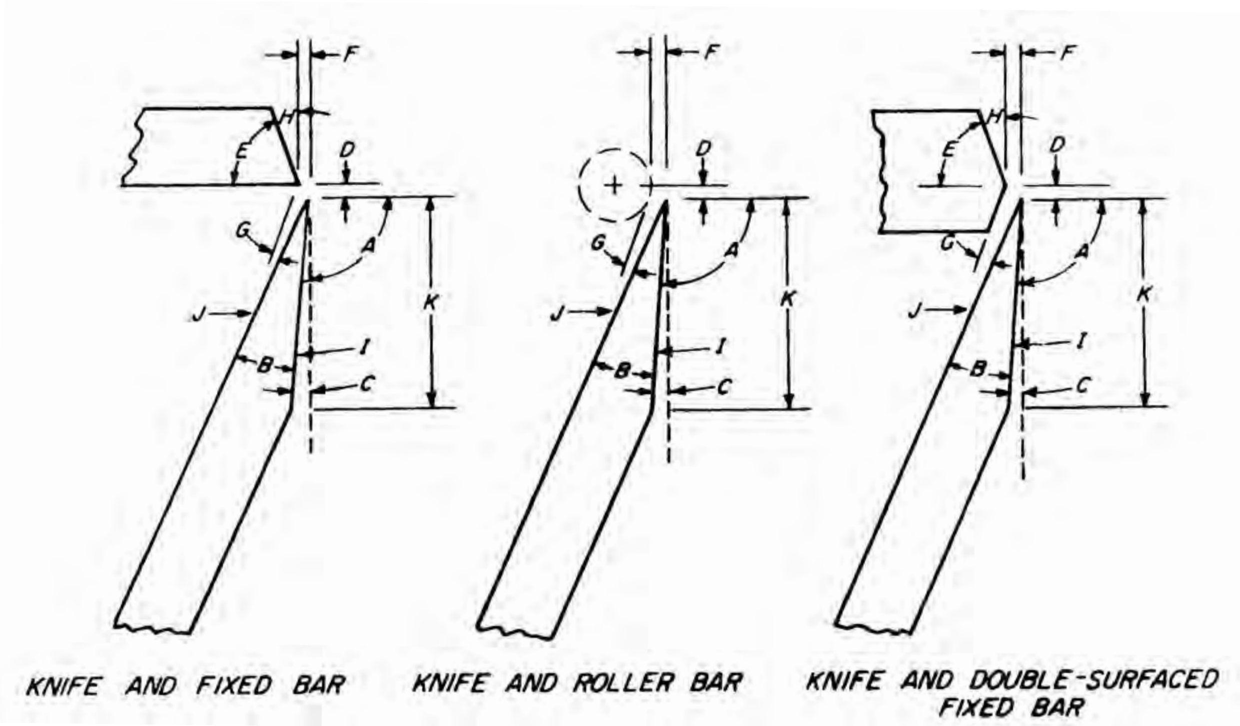


Figure 8. - Cross section of a vertically operating veneer slicer.
(M 140 656)



M 141 892

Figure 9. - Knife and pressure-bar terminology.

Symbol	Preferred Term	Alternate Term
A	Knife angle	Knife pitch
B	Knife bevel angle	Knife sharpness angle
C	Clearance angle	– –
D	Lead	Vertical opening*
E	Pressure bar bevel	Pressure bar sharpness angle
F	Gap	Horizontal opening*
G	Exit gap	Restraint
H	Nosebar compression angle	Bar angle
I	Knife surface next to wood work piece**	– –
J	Knife surface next to wood veneer**	– –
K	Length of knife bevel	– –

*Satisfactory for vertically operating lathe or slicer but is misleading for horizontally operating slicers.

**The term knife face is sometimes applied to J by knife manufacturers and to I by lathe operators. To reduce ambiguity, this terminology is suggested.

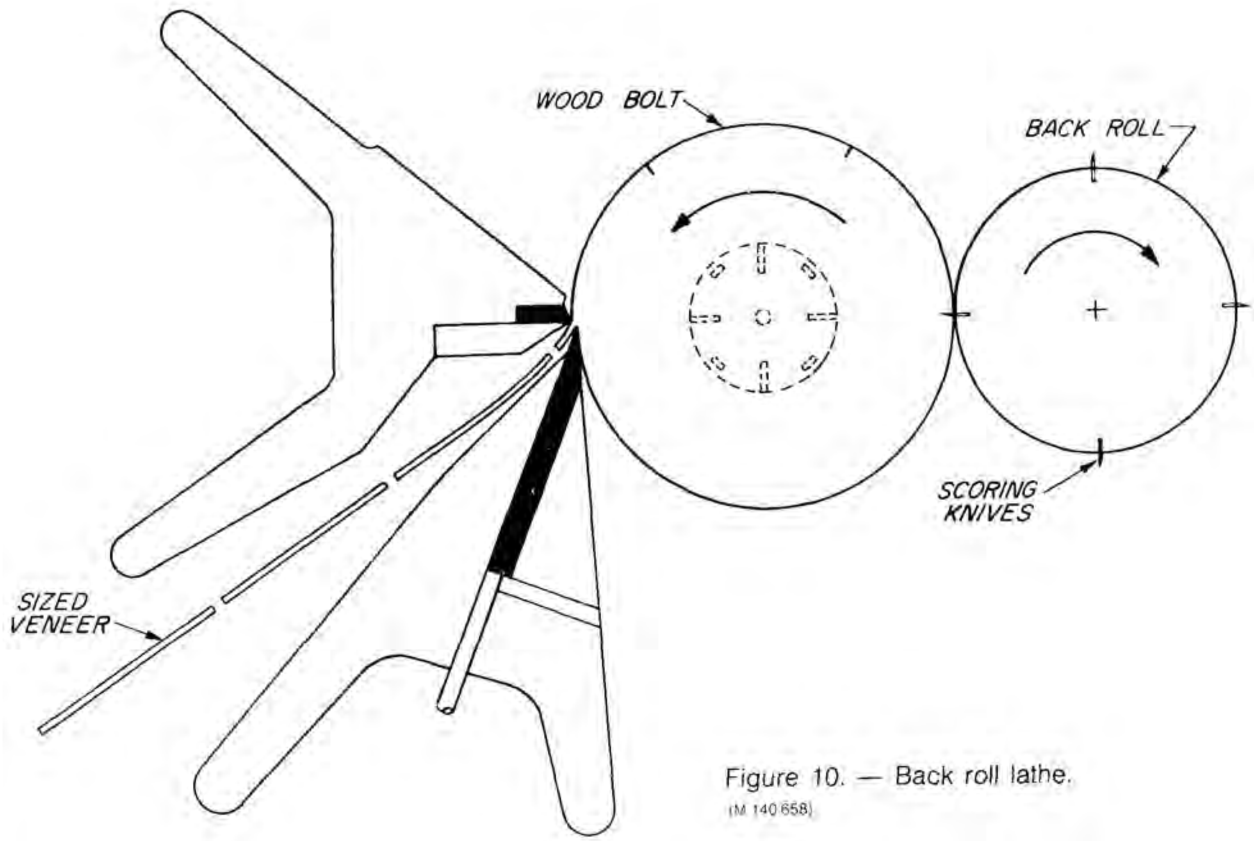


Figure 10. — Back roll lathe.
(M 140 658)

Some General Comparisons of Veneer Cut on the lathe and Slicer

In general, the greatest yield is obtained by rotary cutting followed by half-round, flat-slicing, or back cutting; the least yield is obtained by quarter- or rift-slicing. The smoothest and tightest veneer can be produced by quarter- or rift-slicing, followed by rotary cutting; the roughest and loosest veneer is produced by flat slicing, half-round, or back-cutting. The reasons for the differences in roughness are due to the effect of wood structure orientation **(46).**

While there are some differences and inherent advantages in slicing and in rotary cutting, good-quality veneer can generally be produced by either method. The quality of the end product is determined more by the log quality, the heating of the bolts or flitches, and the setting of the knife and pressure bar, than by differences in the cutting method.

Undesirable Movement of Wood and Machine Parts on lathe and Slicer

Knife and pressure bar settings are meaningful only if the wood is held securely in the lathe or slicer and if the machine parts have a minimum of play.

Undesirable Movement of Wood on Lathe

Bolts are held by chucks in a lathe. In general, the larger the chucks the more securely the bolt is held. The chucks transmit the torque needed to cut the veneer and also must resist the tendency of the bolts to ride up on the knife. The spurs on the chucks should therefore be designed not only to transmit power to turn the bolt but also to keep it from shifting from the spindle center. The best spur configuration is not well established. Some mills prefer one-half circles and others star-shaped spurs and a ring around the circumference of the chuck. In practice, the spurs sometimes become battered and bent and may collect wood debris. For best performance, they should be in their original shape and clean. The chucks and spindle ends should be tapered for a positive secure fit.

The pressure used to set the chucks in the bolt ends depends on the wood species, heating, and chuck size. Generally, enough pressure is used to indent the spurs at least three-fourths their length into the bolt ends. Square-cut bolt ends allow for a more uniform grip than bolts that are end trimmed at a bias.

The wood in contact with the spurs receives fluctuating loads during cutting, which may cause the bolt to become loose in the chucks. On older lathes, the operator must watch for this and further indent the spurs if any looseness of the bolt is observed. Newer lathes have hydraulic chucking. A relatively high pressure is used to set the chucks and then a lower pressure is continually exerted by hydraulic pressure to make sure the spurs remain seated during cutting. If too high hydraulic end pressure is continued during cutting, the wood bolt may bend when it reaches a small diameter.

Another modern solution to holding the bolts more securely is the use of retractable chucks. Larger chucks and spindles hold the bolt at the start of peeling; they are retracted during peeling, allowing smaller inner chucks and spindles to hold and drive the bolt until the final core diameter is reached. A modification of this is sequentially retractable chucks such as 5-inch (13-cm.) inner chucks, one 8-inch (20-cm.) outer chuck on one end, and one 12-inch (30-cm.) outer chuck at the other end. The bolt is first driven with the 12- and 8-inch chucks. At a bolt diameter of about 14 inches (35 cm.), the 12-inch chuck is withdrawn and the bolt is then driven with one 8- and one 5-inch chuck. At a diameter of about 10 inches (25 cm.), the 8-inch chuck is withdrawn and cutting is continued with the two 5-inch chucks driving the bolt to the final core diameter.

In an effort to obtain maximum recovery, bolts are turned to as small a diameter as practical. The bolt is loaded as a beam by the knife and pressure bar. Its resistance to bending is directly related to the cube of the radius of the bolt. At small bolt diameters, an unsupported bolt bends in the middle away from the knife. The bolt becomes barrel-shaped and the veneer ribbon wrinkles in the middle. To overcome this problem, backup rolls have been built to support the bolt during cutting. When properly made and operated, they permit cutting 8-foot- (2.44-m.) long bolts to a final core diameter of about 4 inches (10 cm.)

Undesirable Movement or Play in Lathe Machine Parts

All movable parts must have some clearance. Wear tends to make this clearance become greater. Many lathes have built-in methods of taking up slack as wear progresses. However, it is not uncommon to find that production lathes have been permitted to develop excessive wear and looseness or play in the mechanism. Some specific areas to check are spindle sleeves and bearings, feed screws, head-block or knife-angle trunnions, nosebar eccentric, and blocks under screws used to change the lead (vertical adjustment) of the pressure bar. The greatest wear is likely to be in the spindle sleeves and bearings, followed by the feed screws and movable parts of the nosebar assembly. Some modern lathes minimize these problems by using preloaded roller bearings for the spindles and an air cylinder to keep the knife bar always against one side of the feed screw. In addition, some lathes have replaceable wear surfaces for the ways.

Most production lathes develop some play between the knife frame and the bar frame. The amount of movement depends on the looseness in the lathe and the amount of pressure exerted against the bar during cutting. To detect and correct for this play, dial gages should be mounted at each end of the lathe with the gage on the knife frame and the sensing tip against a bracket on the bar frame. These gages should be zeroed after setting the gap or horizontal opening. Any play will show on the gages as a reading other than zero and the original gap or horizontal opening restored by adjusting the nosebar until the gages read zero.

Play can also affect the lead or vertical opening. This is less common than play in the gap or horizontal opening. Again, dial gages can be mounted to detect and guide correction of the play.

Spindle overhang. - Other things being equal, the greater the overhang of the spindles the more spring in the cutting system. This is most noticeable when short bolts are cut on a long lathe. If both short and long bolts are to be cut on the same lathe, the lathe should be equipped with spindle steady rests.

Heat Distortion of Lathe

Bolts that have been heat-conditioned prior to cutting may cause the knife and pressure bar to distort. It is generally agreed that heating causes the knife to rise in the middle, decreasing the lead. Heat may cause the pressure bar to drop or move in a horizontal plane, depending on the lathe. On some lathes, one method of correcting for these changes is to adjust the pull screws on the A-frame built over the pressure bars for this purpose. A better solution is to heat the knife and pressure bar to the expected operating condition prior to the final fitting (setting) of the knife and bar. Some lathes have had heating elements built in them to prevent heat distortion.

Another good practice is to store sharpened knives in a warm area so they are at the same temperature they attain during cutting. Feihl and Godin **(19)** suggest heat distortion can also be controlled by continuous cooling of the knife bed and the pressure bar bed. However, they and others indicate heating the knife and bar works better than cooling, particularly for long lathes.

Undesirable Movement of Wood on Slicer

The wood flitch is generally held against the bed on a vertical or horizontal slicer with dogs. In some vertical and all horizontal slicers, gravity helps hold the back of the flitch against the flitch bed. However, in the most common vertically operating face veneer slicers, the flitch is cantilevered from the bed and dogging is very important.

Heated flitches may be bowed or twisted. Very often this bow or twist can be removed by forcing the flitch flat against the flitch table and dogging it securely. Here oversized dogs are useful at the start of the cutting. A recent development has been retractable dogs, which are extended for maximum holding power at the start of slicing and then automatically retracted when the slicing cut approaches the dogs.

Older slicers had the dogs set by screws. After intermittent cutting, the flitch would often become loose, so the slicer would have to be stopped and the dogs reset in the wood. Modern slicers have hydraulic dogs which maintain good contact with the flitch throughout cutting. The hydraulic cylinders actuating the dogs have check valves to prevent the flitch from shifting during slicing.

A recent practice is to glue valuable flitches such as walnut to an inexpensive backboard and then slice to the glueline. Special glues and gluing techniques are used to bond the hot wet flitches to the backboards. Another innovation is to hold the flitch against the table with a pattern of vacuum cups. The flitch back should be wide, smooth, and flat or the flitch may break loose from the table during cutting.

Undesirable Movement or Play in Slicer Machine Parts

Play can develop in all moving parts such as feed screws, offset mechanism, flitch table ways, and knife-bar carriage ways. Most modern slicers have means of taking up slack in these parts. A regular maintenance schedule should be followed.

Feed by pawl and ratchet. - Some slicers advance the knife by a pawl and ratchet for each stroke. This is highly accurate providing the same number of teeth are advanced each stroke, there is little play in the feed mechanism, and there is no overtravel of the carriage. The number of teeth advanced each stroke should be checked several times before and during actual cutting. The brake on the shaft which advances the knife each stroke should be adjusted so there is no overtravel.

Feed to a stop plate. - Some slicers feed by moving the previously cut surface against a stop plate. The surface of the flitch and of the stop plate must be free of splinters or other debris and the flitch must be advanced flush to the stop to produce veneer of uniform thickness.

Offset on vertical face-veneer slicers. - The offset mechanism on modern slicers is hydraulically operated and does not generally require attention once the cam is set to retract the knife at the bottom of the stroke. The amount of offset is adjustable and should be large enough to insure clearance of the flitch on the upstroke. Excess offset should not be used as it may induce slight vibration to the knife. The knife and bar carriage pivot on half bearings for the offset. Since the half bearings are not held at the top, if the flitch fails to clear on the upstroke, the knife bar carriage may be lifted from the half bearings. Similarly, high nosebar pressure cannot be used without danger of unwanted movement of the knife carriage on the half bearings.

As with the lathe, it is desirable to have dial gages mounted at each end of the slicer with the gage on the knife frame and the sensing tip against a bracket on the bar frame. The gages are particularly useful for returning to the previous setting after the bar has been retracted to hone the knife.

Heat Distortion of Slicer

Since face veneer slicers are generally longer than lathes, heat distortion of the knife and bar may be more of a problem. As on the lathe, the heated knife rises in the middle and the pressure bar drops. The pull screws on the A-frame on the casting holding the bar can be used to compensate for movement due to heat. A better solution, and one that is built into modern slicers, is a means of heating the knife and bar prior to fitting them and then keeping these parts continually warm. This not only greatly reduces any change in the knife-bar setting due to cutting hot flitches, but also reduces condensate and the iron-tannate stain that results when iron or steel particles come in contact with wet wood.

Dynamic Equilibrium on Lathe and Slicer

Many have observed that the first sheets from a flitch on the slicer and the first few revolutions of veneer from a bolt on the lathe are thinner than the nominal knife feed. Hoadley **(34)** studied this phenomenon with a knife and pressure bar mounted on a pendulum dynamometer. He attributed the thin first cuts primarily to compression of the wood beyond the thickness of cut, followed by springback after the cut. With the same advance, both the compression and springback became progressively larger until a full thickness chip was produced. Hoadley called this dynamic equilibrium.

Later studies on both an experimental and commercial lathe at the Forest Products Laboratory **(56)** indicated that the thin first cuts were due mainly to takeup of slackness in the lathe. Veneer cut from a small, more rigid experimental lathe reached full thickness quicker than veneer cut on a 4-foot-long commercial lathe. The study also showed that when the pressure bar was against the wood, it tended to force the bolt and knife in opposite directions. When the bar was retracted and the knife alone engaged the bolt, the knife and bolt were drawn together. As a result, opening the bar (for example, to clear a splinter) during cutting results in large changes of veneer thickness on a lathe that has slackness. In contrast, if the pressure bar is kept closed from the start of cutting, then much of the slackness in the lathe will be taken out by the time the veneer is wide enough to use. This veneer will be more uniform in thickness than veneer cut just after the pressure bar has been closed.

Some slicer operators set to cut tight veneer and run into a gradual buildup of the flitch face with respect to the knife due to cutting veneer thinner than the feed. Eventually, the knife carriage will vibrate due to excessive pressure against the knife and pressure bar. The operator will then throw off the feed for one stroke, cutting a thick shim and continue to cut. This is poor practice as consecutive sheets cut after each shim are gradually changing in thickness. Better practice is to change the pressure bar setting (larger lead or gap) so that a constant full thickness veneer will be cut.

Effect of Speed of Cutting on Veneer Quality

When Knospe **(39)** reviewed some of the veneer cutting literature in 1964, he concluded that cutting speed has a minimal influence on the quality of veneer. Other studies since then indicate that for practical purposes this is essentially true within the speeds of about 100 to 500 feet (30 to 150 m.) per minute. However, at least two studies **(7, 55)** have shown that the strength of the veneer in tension perpendicular to the grain decreases with an increase in cutting speed. Lower strength in tension perpendicular to the grain is generally caused by deeper checks into the veneer. In addition, high cutting speed with wood species having a very high moisture content may increase the incidence of mashed grain and shelling. In summary then, the cutting speed does not seem to be a critical controlling factor for most veneer production. However, if optimum veneer tightness and smoothness are important, it may pay to use a moderately slow cutting speed.

When slicing 1/8-inch and thicker veneer, there may be a slight vibration of the slicer due to the impact at the start of the cut. Inclining the length of the flitch 3° to 5° from the long direction of the knife lessens this impact as the cutting starts at one corner of the flitch rather than across the entire length of the flitch. A slower speed also reduces the impact at the start of each cut.

KNIFE AND PRESSURE BAR ON LATHE AND SLICER

Knife

Selecting the Knife

The knife represents the largest maintenance cost in cutting veneer and consequently it is worthwhile to use good purchasing specifications and take care in grinding and setting the knives in the lathe or slicer.

What should be specified when ordering a knife for the lathe or slicer? The length of the knife and presence or absence of slots and their spacing will be determined by the equipment on which the knife will be used. Other factors such as depth, thickness, hardness, insert or solid, and the grind can be specified. In addition, the percent carbon and other components of the steel could be specified. However, the exact components of the knife steel are generally not published by knife manufacturers. As a result, most veneer plant managers deal with a reputable knife manufacturer and specify only the size, shape, hardness, and whether they want an insert or solid blade. An ideal knife should have maximum stiffness, toughness, corrosion resistance, and wear resistance.

The most common knife thickness for lathes is 5/8 inch (16 mm.), and for face veneer slicers, 3/4 inch (19 mm.). Thinner knives such as 1/2 inch (13 mm.) are sometimes used on the lathe; they are less expensive but also less stiff. The European horizontal slicers may use a knife 19/32 inch (15 mm.) in thickness, supported with a blade holder. In general, the veneer knife should be thicker when cutting thick veneer. When cutting thin veneer, thinner knives can be used if they are properly supported.

The choice of an inlaid knife or one hardened throughout may depend on the end product. Hardwood face veneer is generally cut with an inlaid knife. The mild steel used for backing is stable and easy to grind. It can be readily drilled so that the knife can be held firmly when back grinding. The highly refined hardened tool steel insert is generally of highest quality for cutting wood.

Knives that are hardened throughout reportedly may stand up better when cutting hard knots. They are sometimes but not always used in plants producing construction plywood.

Most veneer knives are supplied the full length of the lathe or slicer. However, two- and three-piece knives are sometimes used with a special clamping arrangement so they can be ground and set as a unit. If one section is damaged, it can be replaced without replacing the entire knife.

The hardness of the knife should be specified and can readily be tested. A soft knife can be easily honed and is tough but also wears rapidly. A hard knife is difficult to hone, is more likely to chip if it hits something hard, but holds a sharp edge much better. Most rotary veneer plants prefer a knife with a Rockwell hardness on the C scale of 56 to 58. Knives for face veneer slicers are often 58 to 60 on the Rockwell C scale. To keep as sharp an edge as possible when cutting low-density woods like basswood, a knife with a Rockwell hardness of 60 to 62 may even be used.

Bevel angle, wedge angle, and sharpness angle all refer to the angle that results from the intersection of the two surfaces which form the knife edge. This and other terminology used with the knife and pressure bar are shown in figure 9. The knife bevel angle may vary from about 18° to 23°. The smaller the angle, the less the veneer is bent as it is cut and hence the tighter the veneer. In contrast, the larger the bevel angle the stiffer the blade and the better the edge can withstand impact. More care must be taken when grinding the smaller bevel angles as the knife tip is more likely to heat than when grinding a knife to a large bevel angle.

An 18° bevel angle may be used to slice properly heated flitches of eastern redcedar while a 23° bevel angle is often used to rotary cut bolts of unheated softwoods. Many veneer knives are ground to a bevel angle of 20° or 21°.

Some lathe and slicer operators prefer to measure the length of the knife bevel rather than the knife bevel angle (fig. 9). Some relations of knife thickness, knife bevel angle, and knife bevel length follow.

Knife Thickness	Knife Bevel Angle	Knife Bevel Length
Inch	*Degrees*	*Inch*
½ (0.500)	18	1.618
	19	1.536
	20	1.462
	21	1.395
	22	1.335
	23	1.280
5/8 (0.625)	18	2.023
	19	1.920
	20	1.827
	21	1.744
	22	1.668
	23	1.600
3/4 (0.750)	18	2.427
	19	2.304
	20	2.193
	21	2.093
	22	2.002
	23	1.919

The ground surface is generally slightly concave to make the knife easier to hone. For the lathe, the recommended hollow grind is 0.002 to 0.004 inch (0.05 to 0.10 mm.) while slicer knives generally have a hollow of 0.001 to 0.002 inch (0.025 to 0.05 mm.). The flatter grind for a slicer knife means less chance for the flitch to rub against the heel of the knife and stain the wood. More hollow can be used on a lathe knife as the bolt surface curves away from the ground surface of the knife. However, the hollow should not exceed 0.004 inch (0.10 mm.) as this weakens the knife edge. While the details of the knife bevel can be changed by grinding at the veneer-producing plant, the knife should be ordered as it will be used to eliminate an extra grinding.

Knife Wear

Knife wear apparently takes place by three methods: Impact, abrasion, and corrosion. Impact and abrasion are mechanical phenomena while corrosion is chemical in nature.

Mechanical impact is most obvious when a hard object as a small piece of gravel makes a chip in the knife edge. Damage due to mechanical impact may also occur when the knife hits hard, unheated knots. Such knots may turn the extreme edge of the knife. Woods containing 1 percent or more of silica or calcium carbonate are abrasive and rapidly wear a rough edge on a veneer knife. Use of a tough tool steel rather than a brittle steel may help reduce the damage due to mechanical impact. Use of a microbevel (15) or back bevel reduces the chance of damage due to impact and may make it possible to cut abrasive wood longer between honings. A microbevel about 0.015 inch wide is often applied at the edge of the knife to make the included angle about 30° **(15).** If a tough knife could be made from tungsten carbide ground to a 20° included angle, this should be a good material for cutting wood containing silica or calcium carbonate crystals.

The third method of knife wear is corrosion as described by Kivimaa **(36)** and by McKenzie and McCombe **(63).** Acetic acid and polyphenols in some woods react with the steel knife and corrode it. This reaction makes the common blue iron stain that is so objectionable on face veneer as well as causing wear of the knife. Kivimaa **(36)** found that knife wear was greatly retarded by putting a positive potential on the wood work piece and a negative potential of 1,500 volts on a planer knife.

Later at Madison we put a positive charge of 300 volts on a rigid pressure bar on a 4-foot- (1.2-m.) long lathe and a negative charge on the knife. The charge greatly retarded blue stain from the knife as compared to the stain that developed on oak veneer when the lathe was stopped momentarily without a charge to the pressure bar. However, a shallow brown stain occurred on the veneer next to the knife. In addition, blue stain from the tool steel pressure bar became worse. When a stainless steel pressure bar was used, the blue stain was nearly stopped next to the bar but the shallow brown stain again occurred on the wood next to the tool steel knife. Ralph Scott, a research chemist at the U.S. Forest Products Laboratory, checked the wood next to the knife (negative terminal) and found it to be a strong base (pH 10 to 12). Apparently hydroxyl ions were released at the negative terminal and formed a base that turned the wood brown.

Another difficulty with running 300 volts direct current from the pressure bar to the knife was that sap forced from the bolt ends made a short and the arc caused a big crater in the knife at this point. A third problem was that the stain was spotty over the 4-foot (1.2-m.) length of veneer, indicating the electric current took the path of least resistance and so was not acting uniformly to reduce stain and knife wear.

McKenzie and McCombe **(63)** successfully rotary-cut 4$^{3}/_{4}$-inch- (12-cm.) long bolts with the knife held at a negative potential of 60 volts with respect to the nosebar. They report that knife wear was reduced 60 percent.

In spite of the difficulties in applying a positive electrical potential to the bolt or flitch and a negative potential to possibly both the knife and pressure bar, the method does look technically interesting. An alternative would be development of stainless knives that can hold an edge sharp enough for good veneer cutting.

Grinding Veneer Knives

The purpose of grinding is to restore a straight, sharp, tough edge. If these three requirements are kept in mind, they may help guide good grinding practice.

In order to grind a straight edge, it is necessary to start with a rigid level grinder. The most satisfactory veneer knife grinders have a fixed bed for mounting the knife and a traveling grinding wheel.

The abrasive may be a solid cup wheel or may be segmented. Some operators prefer the segmented wheel because it requires less dressing and replacement segments are less expensive than a new cup wheel.

A magnetic chuck makes it faster to set the knife for grinding. A V-belt drive in place of gears reportedly reduces chatter marks on the knife.

The knife bed as well as the ways on which the grinder moves must be rigid, straight, and parallel to one another. The ways are generally hand scraped for accuracy when the grinder is made. The ways should have wipers to keep them clean in use. The accuracy of the ways can be measured in the veneer plant by traversing them with a dolly holding a gage. A special telescope with a measuring crosshair is leveled like a transit and then sighted on the gage on the dolly. The dolly is moved along the ways and any deviation from a straight line can be recorded. If the ways are not straight, they must be straightened at the factory. After the ways have been determined to be straight, they are used as a reference to determine if the knife bed is straight and parallel to the ways. This can be readily done in the veneer plant by indexing with a surface gage such as a dial indicator from the grinding wheel carrier which moves on the ways.

If the knife bed is not parallel to the ways on which the grinding wheel traverses, the knife bed should be adjusted until it is parallel to the ways.

To maintain even wear of the ways, the grinding wheel should traverse the entire length of the grinder even when grinding short knives.

The surface of the knife that goes against the grinder bed must be checked for bumps or other rough spots that will prevent the knife from lying perfectly flat. If necessary, the back of the knife should also be ground to restore a plane surface. (See “Back Grinding.”)

Heat can cause metal to expand and deform. The grinder and knife should therefore be kept at as uniform a temperature as possible during grinding. An example of poor practice was a grinder set near a radiator. During summer the knife bed was straight. However, in winter with the radiator on, the grinder bed was heated on one side and warped enough to result in unsatisfactory grinding. Similarly, the water used to cool the grinding wheel and knife should be at room temperature and be recirculated. A stream of water with synthetic coolant should be directed against the grinding stone 1/2 inch ahead of where the stone contacts the knife edge during grinding.

Godin **(30)** considers overheating of the knife tip the most serious problem in grinding and lists four main causes: (1) Too heavy a cut, (2) inadequate cooling, (3) clogged grinding wheel, and **(4)** too hard a grade of grinding wheel. Heating is less likely to occur if the knife edge is pointed up and engages the grinding wheel first during grinding. A feed of 0.0003 to 0.0005 inch (0.008 to 0.012 mm.) is suggested for each complete traverse of the wheel. We like to dress the wheel and use a very fine feed for the last one or two traverses of the sharpening. This helps give a fine surface. Some manufacturers polish the knife by multiple passes without feeding. The smooth edge reportedly aids good veneer cutting. Care must be used with this technique or the grinding wheel may rub, heat, and weaken the knife tip.

Another cause of an irregular edge is dubbing at the two ends of the knife. The most likely causes are looseness in the grinding wheel spindle bearings, excessive end play, and slack in the feeding mechanism. However, even a grinder in good mechanical condition may slightly round the ends of the knife. This may not be a problem as the end inch or two of the knife generally does not engage the wood when cutting veneer on a commercial lathe or slicer. If it is important to have the knife straight to the extreme ends, then dummy knife sections 4 to 6 inches (10 to 15 cm.) can be attached to the knife bed at the two ends and in line with the knife being ground. Sections of a discarded knife can be used for this. The dummy sections absorb the heavier cut at the start of each traverse of the wheel and the main knife is not dubbed at the ends.

Back grinding. - After a knife is used, it may wear unevenly on the side where the veneer passes through the throat between the pressure bar and the knife. It may also be bent by excessive local pressure as from a knot or chip buildup. This can be detected by placing a straight edge at a right angle to the cutting edge. If this surface is not flat, then grinding the side of the knife that goes next to the bolt or flitch will not result in a straight edge. The solution is to grind a flat surface on the veneer side of the knife. It is not necessary to grind the full surface of the knife. The grinder bed is tilted ½° to 3° toward the knife and the knife is ground to produce a bevel ½ to 1¼ inches long. A magnetic chuck on the grinder facilitates this grinding. Otherwise, the knife body must be drilled and tapped not more than 12 inches apart so the knife can be mounted securely for back grinding.

Some modern grinders are equipped with

two grinding wheels so the face and back of the knife can be ground at the same time.

Honing knife. - The knife should be ground only enough to obtain a thin wire edge the length of the knife. The wire edge is removed by careful honing with a stone on one side of the knife, then the other. The stone should be medium grain and medium to soft in hardness. The stone should be saturated with kerosene. Some operators use one stone and others use two stones, one on each side of the knife simultaneously. In either case, each pass of the stone cuts at the base of the wire edge and bends it away from the stone. After several passes, most of the wire edge will fall off. Honing is continued until all of the wire edge is removed. If a badly nicked knife develops a heavy wire edge, the grinding wheel can be stopped and the wire edge removed while the knife is still clamped in the grinder. A few more passes of the wheel will create a new fine wire edge that can be easily removed by honing. After the wire edge is removed, the edge is finished by lightly honing with a fine-textured stone that has been stored in kerosene.

More detailed suggestions for grinding and honing veneer knives are contained in Canadian Forestry Service Publication No. 1236 **(30).**

Secondary knife bevels. - When a sharp knife ground to a bevel angle of about 21° is first put in the lathe or slicer, it is easily nicked by a knot or other hard substance. These nicks are removed by honing the knife in place on the lathe or slicer. After several bolts or flitches are cut, the knife edge wears slightly and this, plus the honing, makes the extreme edge more resistant to damage. This condition is sometimes called a work-sharp knife. When examined under a microscope, the edge is seen to be slightly rounded so it is probably closer to 30° to 35° than to 21° at the extreme tip. Such a knife will remain sharp and do a good job of cutting for several hours if no very hard material is hit.

Other steel knives used to cut wood, such as planer knives, wear faster the smaller the bevel or sharpness angle. The rate of wear goes up much faster if the bevel angle or sharpness angle is less than 30° to 35°. This wear phenomenon is apparently the same for veneer knives. Realizing this, the veneer industry has long had a practice of putting a back bevel on the knife. This strengthens the knife edge and is commonly used with knives installed on core lathes for peeling unheated softwoods.

Kivimaa and Kovanen **(38),** Feihl **(15),** and others have studied the use of a precision microbevel put on either side of the knife. They report that a second bevel can be honed on either or both sides of the knife and that the final included angle of 30° or 35° with a microbevel 0.010 to 0.020 inch in width greatly improves the strength of the knife edge. At least one commercial grinder has a separate grinding wheel that can grind a microbevel at the same time the main bevel is being ground.

Veneer manufacturer consultant "Jake" Ross reported **(71)** that some slicer operators use a two-bevel knife. The main bevel is 19° and the second bevel is 21°. He reports grinding of the second bevel is continued until the length of the second bevel is about ½ inch. When cutting, this is the only part of the knife that rubs against the flitch, and so the two-bevel knife reduces stain. Mr. Ross went on to say some operators like the two-bevel knife and others do not.

Setting Knife

Information on setting the knife and bar in a lathe assumes that the knife frame and bar frame of the machine are in proper alinement with the center of rotation of the spindles. Similarly, it is assumed that the knife and bar ways on the slicer are level and perpendicular to the flitch ways. It is further assumed that there is a minimum of play in the moving parts of the lathe or slicer and that the machine parts are at the same temperature they attain in use. If these conditions are not met, the careful setting of the knife and bar on the static machine may be changed so much in the dynamic cutting condition that poor quality veneer will be produced. Feihl and Godin **(20)** describe methods of checking the basic alinement of lathes.

Setting the Knife in the Lathe and Slicer

A correctly ground flat knife with a straight cutting edge is the first requirement. If a knife holder is used, it must also be clean and flat. A clean, flat bed on the lathe or slicer is the second requirement. (If these conditions are not met, it is difficult or impossible to correctly set the knife.) The knife or knife and knife holder is then set on the two end adjusting screws. The clamping screws are tightened by hand and so the knife is flat against the bed but free to move. To this point, the procedure is the same for the lathe and the slicer.

Setting the lathe knife. - After the knife is resting on the two end adjusting screws on the lathe, the knife edge is raised until it is level with the center of the spindles. This can be facilitated by using a template consisting of an accurately machined wood block cut out at one end to one-half the diameter of the spindle. The cutout end rests on the spindle and the other end on the knife edge. The height of the knife is then adjusted until a spirit level on the back of the template indicates level. The same adjustment is then made at the other end of the knife. If the span is short and the knife deep and stiff, the knife height should be the same across the lathe. However, with longer knives, particularly those that have been ground so they are not so deep, the knife may sag in the middle. One way of checking this is to level a special transit with a telescope about 20 feet (6 m.) from the lathe and swing it from one end of the knife to the other. The knife edge should be in line with the crosshairs along its length. If the knife sags in the middle, it should be raised with the leveling screws near the center of the knife. Once the knife edge is true, some operators make scribe marks on the lathe so they can reposition knives with precision. Another method is to measure the extension of the knife from the top of the knife bed.

To speed up knife changes, some lathes have knife holders. After grinding the knife is preset to the desired height in the holder, and the holder quickly bolted in place in the lathe. Some plants in effect pre-set the knife by pouring babbit metal at the bottom edge of the knife after each grind. The depth of the knife is thus kept constant and the knife can then be placed on the height-adjusting screws without changing them.

Sag in the knife can also be checked with a tautly stretched fine wire.

If there is wear in the spindle bearings, the bolt will ride up during cutting, taking up the play. To compensate for this, the knife edge is sometimes set above the spindle centers the same amount as the play in the spindles. This results in the knife edge being at the spindle centers during cutting.

After the knife is set to the spindle centers, the knife angle is adjusted. In general, the side of the knife that contacts the bolt is approximately vertical (tangent to the surface of the bolt). Such a knife is said to have an angle of 90°. If the knife leads into the bolt 2°, the knife angle is 92° and the clearance angle 2°. A lathe knife can also be set with a negative clearance. A knife angle of 89° means the knife has 1° negative clearance.

Most lathes are built so the knife angle can be made to change automatically with the bolt diameter. The objective is to keep the width of the knife surface that rubs against the bolt about the same when cutting a bolt of a large diameter as at a small diameter. For example, when cutting at a bolt diameter of 3 feet (91 cm.), the knife angle may be 91°; at a diameter of 6 inches (15 cm.) the angle may be 89° 30'. The means of changing the knife pitch varies with different lathes. Feihl and Godin **(20)** describe several methods that can be used to properly set the pitch ways. The lathe manufacturers should be consulted for recommended procedure for use with their lathes.

In general, lathe operators use less lead into the bolt (lower knife angles) when cutting low-density woods and when cutting thick veneer. For example, Fleischer **(22)** suggests a knife setting of 90° 30' when cutting 1/32-inch (0.8 mm.) yellow-poplar (low-density wood) and 90° 45' when cutting 1/32-inch (0.8 mm.) yellow birch (high-density wood). Fleischer **(22)** shows a more pronounced effect of veneer thickness on the best knife setting. For 1/100-inch (0.25-mm.) birch, he recommends a knife setting of 92°, for 1/32-inch (0.8-mm.) 90° 45', for 1/16-inch (1.6-mm.) 90° 15', and for 1/8-inch (3.2-mm.) veneer 90°. These settings are for log diameter from 20 to 12 inches (50 to 30 cm.).

When the correct knife angle is being used, the knife side next to the bolt will show 1/16 to 1/8 inch (1.6 to 3.2 mm.) of bright rub below the knife edge.

If the correct knife angle is not used the veneer may show this. Too high an angle causes the knife or bolt to chatter and results in a corrugation on the veneer and the bolt surfaces. The waves are closely spaced with three or more waves per inch of veneer width. Too low a knife angle results in too much bearing on the knife, forcing it out of the ideal spiral cutting line. When the force on the knife builds up, it may then plunge into the bolt, resulting in thick and thin veneer with waves a foot or more apart.

Some lathe operators use low knife angles, as the heavy bearing of the knife against the bolt tends to smooth the surface of the veneer. Lathe and knife manufacturers do not like this practice because the pressures on the face of the knife may become so great that the knife will be bent and the knife failure blamed on the knife manufacturer. Low knife angles also require more power for turning the bolt and cause more strain and wear to the lathe.

To prevent these problems, some lathe operators increase the angle of the knife until a corrugated veneer surface results. They then reduce the knife angle gradually until the corrugations disappear and use this knife angle for cutting.

For best results, we recommend knowing the knife angles that are satisfactory and use of an instrument for measuring this angle when the knife is set.

instruments for measuring the knife angle are described by Fleischer **(25),** Feihl and Godin **(20),** and Fondronnier and Guillerm **(28).** While all are suitable, the French design **(28)** is the easiest to use (fig. 11).

If the knives are all ground the same, they can be interchanged on a lathe or slicer without changing the knife angle or clearance angle. However, if the knives are ground so the bevel or sharpness angle is as little as ½° different, it can alter the cutting significantly. Consequently, we recommend the knife angle be checked with an instrument after each knife change.

Setting the slicer knife. - Setting the knife in the slicer is similar to setting the knife in a lathe except that the position of the knife edge in a slicer is set by the extension of the knife from the bed. The slicer knife edge should extend above the knife bed just enough so the ground face of the knife clears the bolts that hold it against the knife bed. In other words, the knife should extend as little as possible and still make certain the flitch will clear. On vertical face veneer slicers, this distance is about 2 inches.

Like the lathe knife, the slicer knife should rest on the two end adjusting screws. The knife is then brought against the bed and any sag in the middle is removed with the height-adjusting screws near the middle of the slicer. Since slicer knives are often longer than lathe knives, this adjustment is more critical on the slicer. A taut fine wire can be used as a guide to determine sag in the knife or, if the pressure bar bed is known to be straight, it can be used

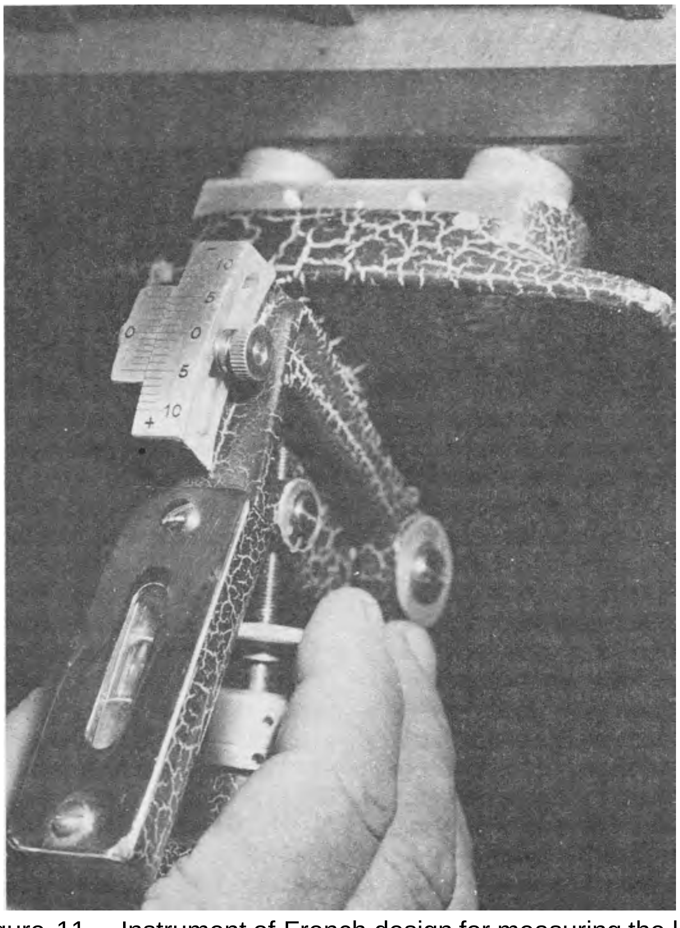


Figure 11. - Instrument of French design for measuring the knife angle It is held by magnets to the face of the knife, the bubble is centered, and the knife angle IS read on the vernier

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as a guide. A pressure bar that has been ground uniform in thickness is brought up against the pressure bar bed. The bottom of the pressure bar can then be used as a reference to determine if there is a sag in the slicer knife.

Once the knife edge is determined to be straight, the knife is bolted firmly in place and all of the adjusting screws are brought in contact with the bottom of the knife.

The knife angle of the slicer is relatively easy to set compared to the lathe knife. Since all cutting is from a flat surface, the knife angle does not change with flitch diameter. Further, the knife must lead into the flitch so the heel of the knife does not rub hard against the flitch. Experimentally, we have found that a slicer knife angle from 90° 20' to 90° 30' (about ½° clearance angle) can be used to slice wood 1/100 to 1/4 inch (0.25 to 6.3 mm.) in thickness from both low-density and high-density woods.

Like the lathe knife, the angle of the slicer knife should be checked with an instrument each time a knife is replaced.

Pressure Bar

The pressure bar is important for controlling thickness, smoothness, and depth of checks into the veneer. It compresses the wood just ahead of the knife and so allows the knife to cut rather than split the veneer from the bolt or flitch. This helps control rough surfaces and checks into the veneer. By keeping a force between the knife carriage and the flitch or bolt, the pressure bar takes up slack in the machinery always in the same direction and so aids control of the veneer thickness.

There are two common types of pressure bars - the fixed pressure bar and the roller pressure bar.

Fixed Pressure Bar

Two factors to consider when selecting a fixed pressure bar are its stability and wear resistance. The most common metals are tool steel, stellite, and stainless steel. The tool steel bar is relatively stable, machines easily, and is relatively inexpensive. A stellite bar is more expensive, harder to grind, and less stable. However, the stellite bar will wear many times longer than the tool steel. Stainless steel is easier to grind than stellite and like stellite does not stain the veneer.

The fixed bar is generally ground to a bevel angle of about 74° to 78°. As the wood bolt or flitch aproaches the fixed bar in the lathe or slicer, the wood is compressed along a plane 12° to 16° from the motion of the wood. When cutting 1/28 inch (0.9 mm.) or thinner veneer from dense hardwoods, the bar should be ground to a sharp edge. When cutting thicker veneer from low-density woods or woods subject to rupture on the tight side of the veneer due to rubbing against the bar, the edge of the bar is generally eased. The amount the bar is eased or rounded is small. Various researchers recommend an edge radius of about 0.015 inch (0.3 mm.). But Fleischer **(22)** reports rounding the bar to 1/8-inch (3.2-mm.) radius did not improve the smoothness of western hemlock veneer and may be disadvantageous.

Roller Pressure Bar

The second major type of pressure bar is the roller bar. In United States practice, it is commonly of bronze, generally 5/8 inch (15.9 mm.) in diameter if it is a single bar and 1/2 inch (12.7 mm.) in diameter if it is a double roller bar. The single roller bar is driven directly while the double roller bar is driven with a backup roll. Advantages of the double roller type include: (1) The drive roller can be larger so there is less breakage of the rollers and (2) the knife and pressure bar can advance very close to the chucks, permitting peeling to smaller diameter cores than with a single roller bar. The drive chain for a single roller bar may protrude up to 1 inch beyond the surface of the roller bar. Roller bars are generally lubricated with 1 percent vegetable oil mixed in water and introduced through holes in the cap that holds the bar.

Comparison of Fixed Bar and Roller Bar

The fixed bar is the simplest and most commonly used pressure bar. It is used exclusively on slicers and is by far the most common bar used to cut hardwoods on a lathe. The roller bar is more common in the United States for cutting West Coast softwoods and has occasionally been used to cut eastern softwoods and hardwoods. The fixed bar can be used to cut veneer of any thickness. The 5/8-inch-(15.9-mm.) diameter roller bar cannot be set to cut veneer much thinner than 1/16 inch (1.6 mm.). Most veneer peeled with the aid of a roller bar is used in construction plywood and is 1/12 inch (2.1 mm.) or thicker. In general, it is easier to set a fixed bar precisely than a roller bar.

A major advantage of the driven roller bar is that it requires less torque to turn a bolt and this in turn means less spinout of the bolts at the chucks and less breakage at shake and splits in these bolts. Another advantage of the roller bar is that it pushes through small splinters that may jam between a fixed bar and the bolt and degrade the veneer.

Double-Surfaced Fixed Bar

A number of researchers have tried double-surfaced fixed bars with the second surface nearly parallel to the surface of the knife (fig 9). This keeps bending of the veneer to a minimum and may help restrict breaks into the veneer. It seems to work best with veneer 1/4 inch (6.3 mm.) or thicker. The disadvantage of the double-surfaced bar is that it requires more power to cut and so causes more spinout from lathe chucks or breakout from dogs used to hold flitches. The extra force required to move the wood past the bar may also cause cracks to develop into the wood work piece. This is due to the restraint on the veneer as it moves through the exit gap between the knife and the bar. Setting the double-surfaced bar is critical when cutting thin veneer. If too much restraint results, the veneer is pushed rather than cut from the work piece. As far as is known, the double-surfaced bar is not used commercially.

Setting Pressure Bar

The information on setting the pressure bar, like the information on setting the knife, assumes the lathe or slicer is in good mechanical condition with a minimum of looseness in moving parts. The knife, pressure bar, and surrounding metal parts on the lathe or slicer should be at the approximate temperature they will attain during cutting.

Figure 9 shows cross sections of the knife with a conventional fixed bar, a roller bar and a fixed bar with a second surface that bears on the wood to cause restraint. Three openings between the knife and the bar are indicated on each of the three figures. These are the lead, gap, and exit gap. With any knife-bar combination, the position of the bar with respect to the knife is fixed if any two of the three openings are fixed. In other words, if the lead and gap are set, this also automatically sets the exit gap. Similarly, if the gap and exit gap are set, this fixes the lead. If the lead and exit gap are set, this fixes the gap. Since these three openings are important for setting the knife and bar and since setting any two fixes the third, it follows that the two chosen for setting the knife and bar should depend on the ease with which the openings can be measured and on how the knife and bar can be adjusted on a specific lathe or slicer. Tables 1,2,3, and 4 list examples of how these three openings are interrelated for different veneer thicknesses and different settings.

Setting Fixed Pressure Bar on Lathe (by Lead and Gap)

When the knife edge and the pressure bar edge are ground straight, the setting of the bar is greatly facilitated. These two edges must be straight and in as near perfect alinement as possible for precision veneer cutting. All the precautions suggested under knife grinding should also be used when grinding a new edge on a fixed pressure bar.

The bed for the bar and the nosebar cap should be clean and straight. The bar is inserted between the bed and the cap and the nosebar locking screw tightened just enough to hold the bar against the bed but loose enough so the bar can be moved without bending it. The bar should extend from the supporting casting only a minimum amount so it is as rigid as practical.

After the knife is set, the bar is moved toward the knife with adjusting screws at the two ends of the bar until the bar is about 1/32 inch (0.8 mm.) behind the knife edge.

Setting lead. - The nosebar bed on most lathes has adjusting screws at the two ends that allow the entire bed to be raised or lowered, increasing or decreasing the lead of the nosebar edge with respect to the knife edge. The amount of lead (vertical opening) is adjusted primarily for the thickness of veneer being cut. Some lathe operators set the lead one-third of the thickness of veneer being cut. Fleischer **(22)** suggests there is a straight-line relationship with a lead of 0.005 inch (0.12 mm.) when cutting 1/100-inch (0.25 mm.) to 0.030 inch (0.8 mm.) when cutting 1/8-inch (3.2 mm.) veneer. Table 2 shows some settings using a variable lead depending on veneer thickness. Some lathes made in Germany do not have a lead or vertical-opening adjustment. This distance is built in the lathe to be about 0.020 inch (0.5 mm.). It coincides with the lead suggested by Fleischer for cutting veneer about 1/14 inch (2 mm.) thick.

All agree that the bar edge should be set above rather than at or below the knife edge. It is also generally agreed that the distance the bar is set to lead the knife must be the same at all points along the knife edge.

The common method of checking this opening is to insert a feeler gage of the proper thickness in the lead (fig. 12) between the

Table 1. - *Lathe settings with a fixed bar and a constant lead*[1]

Feed (veneer thickness)		**Lead**		**Gap**		**Exit gap**	
In.	*Mm.*	*In.*	*Mm.*	*In.*	*Mm.*	*In.*	*Mm.*
0.010	0.25	0.030	0.76	0.009	0.23	0.019	0.48
.032	.81	.030	.76	.029	.74	.038	.97
.042	1.07	.030	.76	.038	.97	.046	1.17
.0625	1.59	.030	.76	.056	1.42	.063	1.60
.100	2.54	.030	.76	.090	2.29	.095	2.41
.125	3.17	.030	.76	.112	2.84	.115	2.92
.1875	4.76	.030	.76	.169	4.29	.168	4.27
.250	6.35	.030	.76	.225	5.71	.221	5.61

[1]Fixed bar, knife bevel 20°, knife angle 90° (0° clearance), lead 0.030 in. (0.76 mm.), and gap 10 pct. less than feed.

Table 2. - *Lathe settings with a fixed bar and a variable lead*[1]

Feed (veneer thickness)		**Lead**		**Gap**		**Exit gap**	
In.	*Mm.*	*In.*	*Mm.*	*In.*	*Mm.*	*In.*	*Mm.*
0.010	0.25	0.005	0.13	0.009	0.23	0.010	0.25
.032	.81	.010	.25	.029	.74	.031	.79
.042	1.07	.012	.30	.038	.97	.040	1.02
.0625	1.59	.017	.43	.056	1.42	.058	1.47
.100	2.54	.024	.51	.090	2.29	.093	2.36
.125	3.17	.030	.76	.112	2.84	.115	2.92
.1875	4.76	.043	1.09	.169	4.29	.173	4.39
.250	6.35	.056	1.42	.225	5.71	.230	5.84

[1]Fixed bar, knife bevel 21°, knife angle 90° (0° clearance), lead changing with veneer thickness **(20)**, and gap 10 pct. less than feed.

Table 3. - *Lathe settings with a roller bar and a fixed lead*[1]

Feed (veneer thickness)		Lead		Gap		Exit gap	
In.	*Mm.*	*In.*	*Mm.*	*In.*	*Mm.*	*In.*	*Mm.*
0.0625	1.59	0.085	2.16	0.056	1.42	0.062	1.57
.100	2.54	.085	2.16	.090	2.29	.094	2.39
.125	3.17	.085	2.16	.112	2.84	.114	2.90
.1875	4.76	.085	2.16	.169	4.29	.167	4.24
.250	6.35	.085	2.16	.225	5.71	.220	5.59

[1] ⅝-in.-diameter roller bar, knife bevel 20°, knife angle 90° (0° clearance), lead 0.085 in. (2.16 mm.), and gap 10 pct. less than feed.

Table 4. - *Lathe settings with a roller bar and a variable lead*[1]

Feed (veneer thickness)		Lead		Gap		Exit gap	
In.	*Mm.*	*In.*	*Mm.*	*In.*	*Mm.*	*In.*	*Mm.*
0.0625	1.59	0.068	1.73	0.056	1.42	0.056	1.42
.100	2.54	.075	1.90	.090	2.29	.090	2.29
.125	3.17	.079	2.01	.112	2.84	.112	2.84
.1875	4.76	.089	2.26	.169	4.29	.169	4.29
.250	6.35	.100	2.54	.225	5.71	.225	5.71

[1] ⅝-in.-diameter roller bar, knife bevel 21°, knife angle 90° (0° clearance), gap equal exit gap equal 10 pct. less than feed.

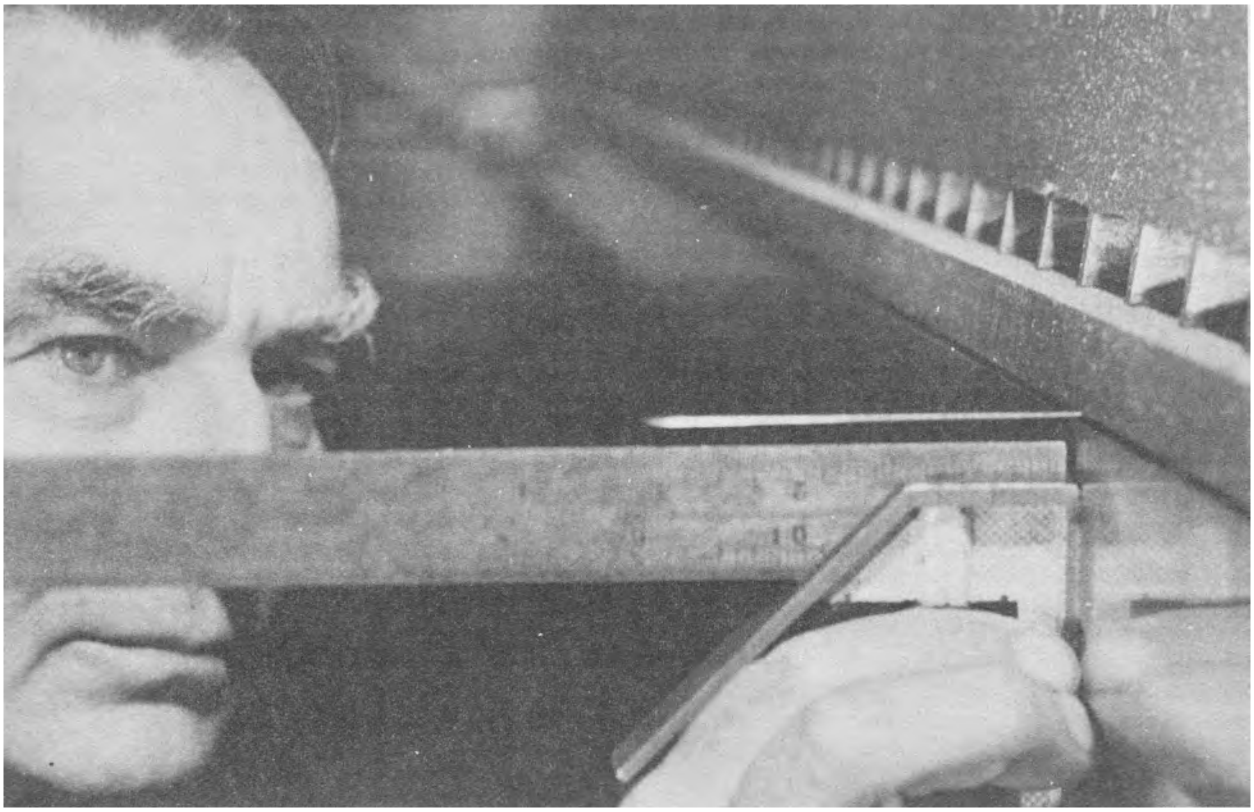

Figure 12. - Adjusting the lead of the pressure bar with a feeler gage. The lead of the bar is moved until a feeler gage of the desired thickness is at a right angle to the face of the knife when the gage is inserted in the opening between the knife and the bar.

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knife edge and the bar. When the feeler gage is perpendicular to the ground face of the knife, the opening is the same as the thickness of the gage. After the bar is set this way at both ends, it should also be checked at other intervals along the knife. Some lathes have push-pulls so the bar can be warped locally to make the lead or vertical opening uniform across the lathe. However, if the knife and bar are ground straight and the knife bed and bar bed are also straight, any local adjustment of the lead should be minimal. Use of a feeler gage may slightly nick the knife. It is therefore good practice to lightly hone the knife after setting the lead.

Setting the gap. - The second bar adjustment is the gap or horizontal opening. This is the distance from the leading edge of the pressure bar to a plane extended from the ground surface of the knife. Some experienced operators like to bring the edge of the bar to the same plane as the knife edge. Then by feeling with the thumb, they can tell if there are any spots where the bar is ahead or behind the knife edge. These local spots are brought in line with the push-pull screws at the back of the bar. Once the bar is "fit" to the knife, it is retracted to give the desired opening or gap and clamped.

We prefer to use instruments to help make this critical setting. Two such instruments are described by Fleischer **(25)** and Feihl and Godin **(20).** Both are essentially dial-micrometer depth gages that use the ground surface of the knife as a reference and measure to the edge of the bar. To automatically position the measuring pin, Fleischer **(25)** suggests that the instrument rest on the top of the pressure bar and on the ground face of the knife (fig. 13).

While one man holds the instrument in contact with the knife and with the movable sensing pin against the leading nosebar edge, a second man advances the bar until the correct

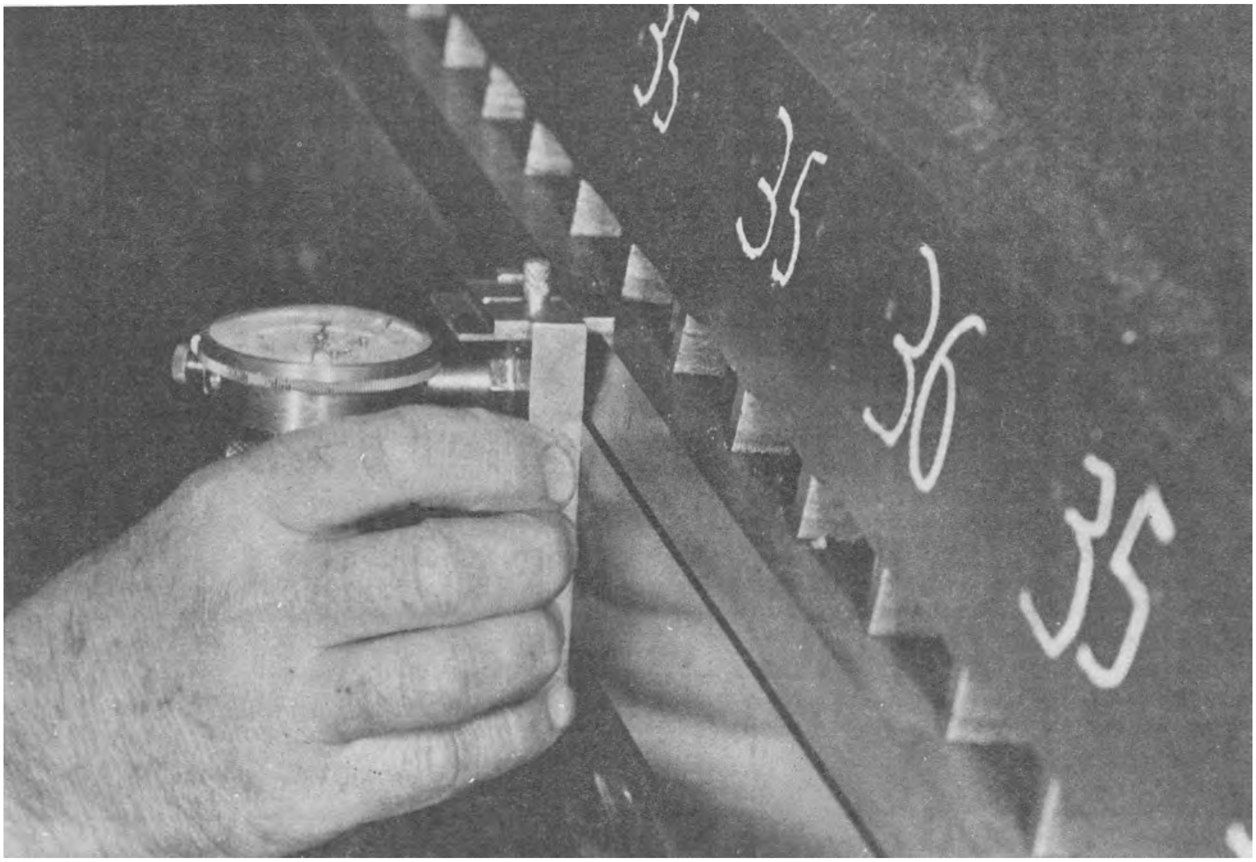

Figure 13. - Measuring the gap between the knife and pressure bar edge. Measurements are chalked on the nosebar casting and any deviations greater than 0.001 inch removed with the push-pull adjustment of the bar.

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gap or horizontal opening is indicated. The adjustment should always be made when advancing the bar to take the play out of the adjusting screws. First the two ends are checked. If they do not indicate the same opening, then they must be brought to the same position with the adjusting screws at each end of the pressure bar bed. Assuming the knife and bar were ground straight and were not warped when mounted on the lathe, the gap should now be the same across the lathe. However, since this is one of the critical lathe settings, we routinely check the opening or gap at 4-inch intervals along the bar. The value of each reading is chalked on the casting holding the pressure bar. Any gradual bends or humps in the bar are then plainly visible. Local deviations are corrected by the push-pull screws at the back of the bar. For accurate cutting, the gap should be within ±0.001 inch (0.025 mm.) at all positions.

The actual value of the gap will depend on the thickness of veneer and somewhat on the species being cut. A figure commonly quoted is for the gap to be 20 percent smaller than the thickness of veneer being cut. Experiments at the U.S. Forest Products Laboratory indicate this results in high compression of the wood by the nosebar. It would only be used when cutting thin veneer from an easily compressible species that is resistant to damage by scraping the nosebar over the wood surface. As Fleischer points out **(22),** 20 percent compression when cutting 1/8-inch- (3.2-mm.) thick veneer means the bar is indented into the wood four times as much as when cutting 1/32-inch (0.8-mm.) veneer with 20 percent compression.

We suspect the 20 percent figure may also be partly due to making measurements on lathes that had some looseness or play and not correcting for the looseness.

When the pressure bar is set as described earlier in this section, we have found a compression of 10 to 15 percent to be good for cutting veneer from 1/16 to 1/8 inch (1/6 to 3.2 mm.) thick. Twenty percent compression may be satisfactory when cutting thinner veneer. Higher compression (smaller gap or horizontal opening) may result in tighter veneer but it may also cause the veneer to be thinner than the knife feed and cause damage to the tight side, such as shelling of the grain on susceptible species like western redcedar and redwood.

The advantage of using instruments to measure the knife angle and pressure bar settings is that the setup can be readily duplicated. When experience shows that a certain setting is good for cutting a given thickness of veneer from a given species at a given temperature, then the information is recorded and the exact processing conditions duplicated when this item is produced again.

Setting Fixed Pressure Bar on Slicer (by Lead and Cap)

The slicer bar is ground and set by the same method as described for setting the fixed bar on the lathe. The difference comes in the actual value of the settings. On the lathe, the lead or vertical opening may be set at various openings such as 0.010 inch (0.25 mm.) for 1/50-inch (0.5-mm.) veneer to 0.030 inch (0.75 mm.) for 1/8-inch- (3.2-mm.) thick veneer. On the slicer, the lead or vertical opening is generally set at about 0.030 inch (0.75 mm.). We have cut veneer of satisfactory quality from 1/100 to 1/4 inch (0.25 to 6.3 mm.) in thickness with this lead. A smaller lead such as 0.020 inch (0.5 mm.) can be used when cutting 1/28-inch (0.9-mm.) and thinner veneer. However, this smaller lead may result in more splinters breaking off at the end of the cut and more chance that splinters will become jammed between the knife and bar, causing rub marks on the veneer.

Not as much pressure can be applied with the nosebar on a vertical operating face veneer slicer as can be applied on a lathe. The knife and pressure bar rest on half bearings, permitting the knife and bar to be offset to clear the flitch on the upstroke. If the pressure bar is set for excessive pressure against the flitch, it will cause the knife and bar carriage to rock on the half bearing and result in poor veneer and possibly to damage of the slicer.

When slicing 1/28-inch (0.036-in.) (0.9-mm.) veneer, we have found the range of satisfatory gap or horizontal openings between the knife and bar to be between 0.029 and 0.032 inch (0.725 and 0.800 mm.). In effect, the bar is then compressing the wood just ahead of the knife edge 0.004 to 0.007 inch (0.1 to 0.175 mm.). Face veneer producers sometimes set the bar to compress the wood only 0.001 or 0.002 inch. When slicing thicker veneer such as 1/8 (0.125) inch (3.25 mm.), the bar may be set to leave a gap of 0.115 inch (2.95 mm.), or 0.010 inch (0.25 mm.) less than the feed.

As with the lathe, more compression (slightly smaller openings) can be used when cutting low-density woods than when cutting high-density woods.

Setting Roller Pressure Bar on Lathe (by Lead and Cap)

The roller bar is most commonly used when rotary cutting western softwoods 1/12 to 3/16 inch (2.1 to 4.8 mm.) in thickness. It is not suitable for use when cutting veneer thinner than 1/16 inch (1.6 mm.). The reason for this is that the pressure should be applied against the bolt just ahead of the knife edge. If the roller bar is set with a lead such as is used with a fixed bar when cutting veneer thinner than 1/16 inch (1.6 mm.), then the roller bar overcompresses the veneer after it is cut by restricting the throat between the roller bar and the knife. This restraint may cause the veneer to jam and break.

In industry practice, 5/8-inch- (15.9-mm.) diameter roller bars are generally set with a lead of 1/16 (0.062) inch (1.6 mm.) or more. From theoretical considerations and laboratory experiments, Feihl, Colbeck, and Godin **(18)** recommended a roller bar lead or vertical gap of 0.085 inch (2.16 mm.) when cutting Douglas-fir 1/10 to 1/4 inch (2.54 to 6.35 mm.) in thickness. In this same paper, they describe an instrument for measuring the lead of a roller bar. Table 3 shows settings for several veneer thicknesses using a fixed lead.

The gap is set much the same as with a fixed bar. That is, good results are obtained by compressing the wood ahead of the knife about 10 to 15 percent of the veneer thickness. This varies with species, wood density, and veneer thickness as discussed under the fixed pressure bar. The gap or horizontal opening can be set and checked with the aid of a depth gage reading to 0.001 inch (0.025 mm.), much the same as with a fixed bar.

Setting Roller Pressure Bar (by Gap and Exit Cap)

Collett, Brackley, and Cumming **(12)** suggest that lathes having a roller bar be set by gap and exit gap. They comment that for veneer thicknesses from 1\10 to 1/4 inch (2.54

to 6.35 mm.), the literature indicates that the gap and exit gap can be the same. This simplifies the record keepng as only one value needs to be recorded for each veneer thickness of each species. They recommend use of a depth gage to measure the gap and a feeler gage to measure the exit gap. The amount of compression they suggest at both the gap and exit gap is 10 to 20 percent of the veneer thickness. Table 4 shows some settings where the gap and exit gap are the same.

Setting Fixed Pressure Bar (by Lead and Exit Gap)

Lead and exit gap are suggested by Fondronnier and Guillerm **(28)** as the openings to be measured when setting a lathe with a fixed bar. They list the lead changing in a regular manner with veneer thickness as follows:

Veneer Thickness		Lead or Vertical Opening	
(In.)	(Mm.)	(In.)	(Mm.)
0.039	1	0.020	0.5
.078	2	.024	.6
.118	3	.028	.7
.157	4	.031	.8
.197	5	.035	.9
.236	6	.039	1.0

They suggest the exit gap should be 10 to 20 percent less than the veneer thickness. Further they recommend that feeler gages be used to measure both the lead and exit gap.

Setting Gap by Pressure Rather Than to Fixed Stops

During rotary cutting of veneer, the force against the pressure bar may vary as much as from 10 to 500 pounds per lineal inch (178 to 8,900 kg. per m.) of contact with the wood **(57).** Feihl and Carroll **(17)** adapted a research lathe to allow the bar to float and maintain the gap by pressure delivered by a cylinder and piston acting against the bar frame. In other words, they set the lead to stops but allowed the gap to be determined by the force against the bar. They report that the method eliminates play in the horizontal mechanism; provides a direct measure of pressure against the bar and so gives the operator good control of the setting; and finally that the veneer produced was equal in quality to veneer produced with a bar set to fixed stops. The method is being tried commercially.

Possible Ways to Generalize Setting of Lathe and Slicer

The section on setting the lathe goes into the details of possible modifications of knife bevel, pressure bar bevel, knife angle, and position of pressure bar with respect to the knife. Different settings have been suggested by different researchers, depending on block diameter, wood density, veneer species, heating of blocks, and thickness of veneer being cut.

Optimization of veneer peeling or slicing may require different knife and pressure bar settings for each specific cutting situation. However, it would be convenient to have one knife setting that could be used to cut veneer of any species into any thickness from 1/32 to 1/4 inch (0.8 to 6.3 mm.). Similarly, it would simplify pressure bar settings if one lead could be used for cutting all veneer. From an examination of the literature and our own experience, it is possible to do this.

Generalized Knife Setting (fig. 14)

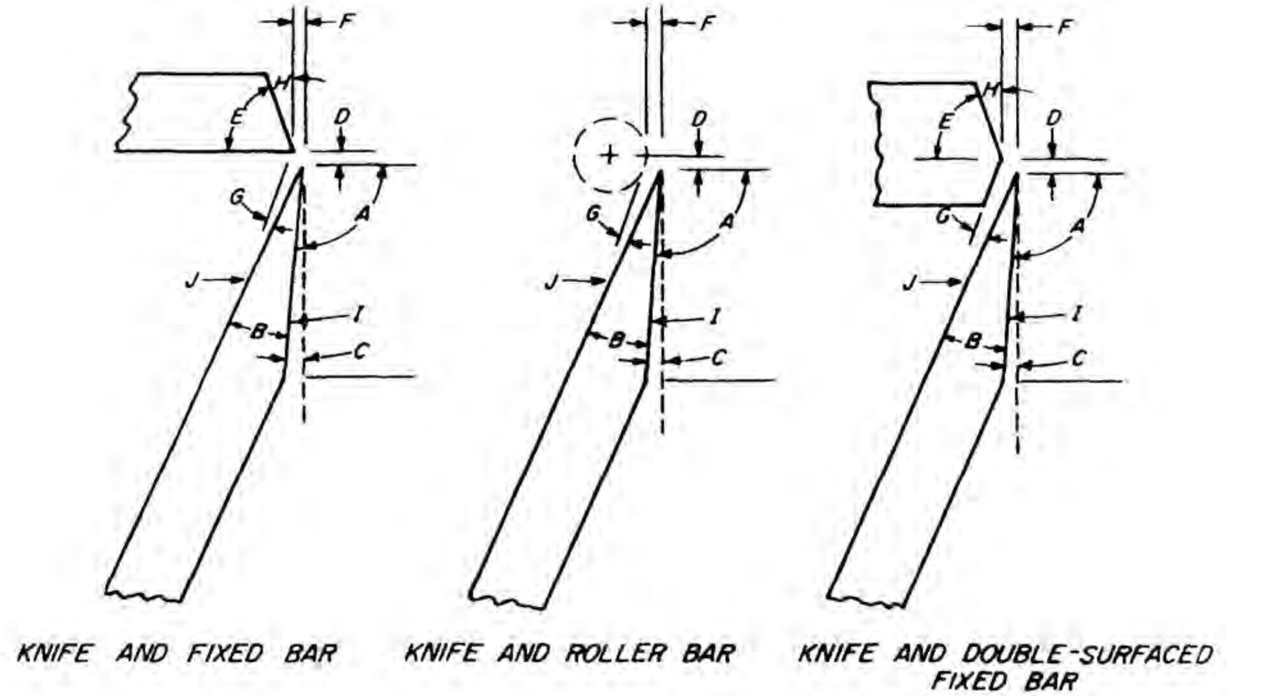
The knife should be ground to a 21° bevel with 0.002-inch (0.05 mm.) hollow grind. The knife angle can be set to 90° 30° or, stated another way, with ½° clearance angle. For lathes having an automatic change of knife angle with change in bolt diameter the knife can be set at 90° 30' when it is 12 inches (30 mm.) from the spindle center. This knife setting can be used to cut veneer 1/32 to 1/4 inch (0.8 to 6.3 mm.) in thickness from any species on the slicer or on the lathe from bolt diameters of 24 inches (60 cm.) to a 6-inch (15-cm.) core.

Generalized Setting of a Fixed Pressure Bar

The pressure bar should be ground to have an included angle to 75°. This results in the wood work piece being compressed along a plane approximately 15° from the cutting direction. The edge of the bar that contacts the wood should be rounded to an edge having a radius of about 0.015 inch (0.3 mm.).

The lead of the fixed pressure bar ahead of the knife edge can be 0.03 inch (0.75 mm.) for both the lathe and the slicer.

The gap from the edge of the pressure bar to the plane of the ground face of the knife can be 90 percent of the thickness of the veneer being cut. Veneer 1/32 to 1/4 inch (0.8 to 6.3 mm.) in thickness and of various species can be cut with these fixed pressure bar settings (fig. 14).



Symbol	Generalized Settings	Symbol	Generalized Settings M 141 893
A'	Knife angle = 90° 30'	E	Pressure bar bevel = 75°
B	Knife bevel = 21° with 0.002-inch hollow grind	F	Gap = 90 percent of veneer thickness
C	Clearance angle = 30' (½°)	G	Exit gap = Gap = 90 percent of veneer thickness (roller bar)
D	Lead = 0.030 inch for fixed bar or 0.085 inch for 5/8-inch-diarneter roller bar	H	Nosebar compression angle = 15° (fixed bar)

Figure 14. - Settings that might be used to cut veneer from 1/32 to 1/4 inch in thickness. They may be particularly valuable as a starting point for cutting unfamiliar species.

Generalizing Setting of Roller Pressure Bar

The generalized settings for lathes with a roller pressure bar are for cutting veneer 1/16 to 1/4 inch (1.6 to 6.3 mm.) in thickness. The lead of the roller bar should be 0.085 inch (2.16 mm.). That is, the center of the 5/8-inch- (15.9-mm.) diameter roller bar should lead the knife edge by 0.085 inch (2.16 mm.). The comparable figure for the fixed bar is 0.030 inch (0.75 mm.) (fig. 14 and tables 1 and 3).

An Alternate Generalized Setting of Roller Pressure Bar

Collett, Brackley, and Cumming **(12)** describe setting a roller bar with the gap and exit gap equal. As with the rigid-bar, a generalized setting would be to have the gap and exit gap both 90 percent of the thickness of the veneer being cut (fig. 14 and table 4).

Generalized Setting of the Gap by Pressure

Feihl and Carroll **(17)** report that 1/10- to 1/6-inch- (2.5- to 4.2-mm.) thick pine veneer can be cut satisfactorily with the pressure on a floating roller bar of about 60 pounds per linear inch (1,070 kg. per m.) of bar contacting the wood bolt. They further conclude: "It is not impossible that in some mills (when all species are fairly similar and veneer thicknesses are in the same range) it would be practical to use only one pressure setting."

Summary of Generalized Lathe and Slicer Settings

Suggested "universal" lathe and slicer settings are listed in figure 14. These are not optimum settings, but they should permit cutting veneer of moderate quality from any species into any thickness from 1/32 to 1/4 inch (0.8 to 6.3 mm.).(The roller bar is not satisfactory for use when cutting veneer thinner than 1/16 in. (1.6 mm.).)

In general, excluding the extreme ranges of specific gravity, one species of wood acts much like another and the veneer cutting process does not change abruptly within the range of thickness from 1/32 to 1/4 inch (0.8 to 6.3 mm.).

The settings listed with figure 14 will generally result in a moderately tight cut. if tighter and smoother veneer is desired, smaller openings between the knife and pressure bar may be used. Lathes having automatic pitch adjustment could be set to have a knife angle of 91° at a bolt diameter of 36 inches (91 cm.) and a knife angle of 89° 30' at a bolt diameter of 6 inches (15 cm.). Ideally, the rate of change of the knife pitch should be greater at the smaller diameters. A smaller fixed pressure bar lead such as 0.020 or 0.015 inch (0.5 to 0.4 mm.) can be used for cutting 1/16-inch (1.6-mm.) and thinner veneer.

Positioning Bolts and Flitches

For maximum yield of rotary veneer, it is essential that bolts be chucked in the geometric center. If the bolts are chucked eccentrically as little as 1/2 inch, the recovery of veneer can be reduced significantly. An industry consultant, H. C. Mason, reported in 1972 that use of bolt-diameter-measuring instruments and a minicomputer controlling a lathe charger to precisely center the bolt in the chucks, will result in at least a 7 percent increase in recovery of veneer for a typical Douglas-fir veneer plant.

The way a flitch is mounted on the slicer table has little effect on yield, but it can affect the smoothness of the veneer **(46).** An eccentric flat-cut flitch should be dogged with the pith toward the start of the knife cut. A quartered flitch should be turned 180° when the cut approaches the true quarter. These and related phenomena are discussed in detail in **(46).**

CONVEYING AND CLIPPING VENEER

Conveying Veneer from Lathe

As veneer comes from the lathe, it may be manually pulled out on a table, but more generally is moved to long trays in line with the clippers or is reeled.

The tray system is most common in both softwood and hardwood plants. As the veneer comes from the lathe, a short tipple directs unusable veneer to a waste conveyor. When usable veneer is produced, the veneer is directed into one of the trays with belts synchronized to the lathe speed. After one tray is full, the veneer is broken, or cut and the veneer directed to another tray. If this is not done carefully, the veneer ribbon may be folded and split.

The second mechanical means of conveying veneer from the lathe is with a reel. The reel system works best with 1/8-inch (3.2-mm.) and thinner hardwoods cut from sound bolts. Like the tray system, the first unusable veneer is directed to a waste conveyor. Then the usable roundup is collected on a short tray or table. Finally, when a sound ribbon of veneer comes from the lathe, it is tacked to a reel and the veneer is wound on the reel as it is peeled. The speed of the reel is synchronized with the lathe. The veneer is reeled with the loose side out.

Combination tray and reeling is popular with some plants peeling species like lauan. The better grades are cut into thin, face stock and reeled. Lower grades are cut into thicker core stock and conveyed on trays.

Conveying Veneer from Slicer

It is important to keep the sliced veneer sheets in consecutive order. In many plants, two men turn the veneer over as the sheets come from the slicer and stack them consecutively with the loose side up. In some cases, a short conveyor takes the veneer from the slicer to a position where it is more convenient to stack it. Some European plants automatically convey the sliced veneer to a veneer dryer. Dryer capacity should be sized for the wood veneer species, thickness, and production rate of the slicer.

Clipping Green Veneer

Veneer stored on trays is fed to one or more clippers. In a typical installation, with six trays from a lathe, three trays would feed to one clipper and the other three to a second clipper. A modern clipper has some sensing and measuring device so veneer can be clipped to nominal 4-foot (1.2-m.), 2-foot (0.6-m.), or random widths. Random widths may be generated when defects such as knots and splits are clipped from the veneer ribbon. An accurate sensing device coupled with the clipper soon pays for itself by greater yields of usable veneer. The green veneer is then sorted by widths, grade, and possibly by sapwood and heartwood in preparation for drying.

Reeled veneer is stored in racks and unreeled just ahead of the clipper. The clipping operation is much the same as that described for veneer stored on trays. One limitation of reeled veneer is that if it is cut from hot bolts, it should be clipped before the veneer cools and sets in a curved shape.

Flitches of green sliced veneer sometimes havedefects clipped out or are trimmed before drying. Packs about 1/4 inch (6.3 mm.) deep are clipped together as a book. The green clipping saves drying of material that will not be used.

Clipping Dry Veneer

Veneer on trays or on reels is sometimes fed to the dryer in a continuous ribbon. As the veneer comes from the dryer, it is clipped to size. This system reportedly results in less waste and split veneer. One dryer manufacturer states that drying of a continuous ribbon will result in at least a 4 percent increase in recovery of dry veneer.

VENEER DRYING

An essential part of the veneer-producing process is to dry the veneer. This varies from a minimum of drying of products - such as bushel baskets and fruit containers - to bring the veneer below a moisture content at which it will mold (about 20 pct.) to drying of softwood veneers that are to be glued with a phenolic hot-press glue, in which case the veneer must be 5 percent or lower in moisture content. In between are such products as decorative face veneer, which is generally dried to a moisture content of about 8 to 10 percent, and commercial hardwood veneers that are to be glued with a urea glue, in which case the desired moisture content in the veneer is 6 to 8 percent. In all cases, a major criterion is to dry the veneer at the lowest total cost.

Since most veneer operations are set up in a straight-line production system and since the production from the lathe and slicer is very high, it is generally necessary to have a fast drying system. Some desirable characteristics of the dried veneer are that (1) it have a uniform moisture content; (2) it be dried without buckle or end waviness; (3) it be free of splits; (4) the surface be in good condition for gluing; (5) the veneer have a desirable color; (6) shrinkage be kept to a minimum; (7) collapse and honeycomb be avoided; and (8) veneer has a minimum of casehardening. Veneer is casehardened when the outer layers are in compression and the center or core is in tension.

Some Veneer Properties That Affect Drying

Factors that affect drying of veneer include both the wood itself and the drying conditions.

An obvious factor is the thickness of the veneer. Thicker veneers dry more slowly than thin veneers. A modification of this is variation in veneer thickness from the nominal thickness. Commercial 1/8-inch (3.2-mm.) veneer will often vary ±0.008 inch (0.2 mm.) or more in thickness. The thicker portions of the veneer take longer to dry than the thinner portions and contribute to a nonuniform final moisture content.

A second factor is the grain direction on the surface of the veneer. End grain dries several times faster than tangential (flat) grain. End-grain drying is significant at the ends of all veneer sheets, which tend to dry faster than the bulk of the sheet. It may also be a factor in curly grained or other figured veneer where at least partial end grain is exposed on the broad surface of the veneer. As these areas dry faster than surrounding straight-grain areas, they can cause stresses and buckling in the veneer sheet. The difference in drying rates between radial and tangential surfaces is small but may show up in that quarter-sliced veneer will take slightly longer to dry than rotary-cut veneer of the same thickness and flat-sliced veneer may dry slower on the near-quarter edges than in the flat-grain area at the center of the sheet.

The moisture in the veneer affects the total drying time. The moisture content of butt logs may be higher than the moisture content of top logs. For example, the difference in moisture content of the heartwood of redwood from different logs may be as much as 2 to 1. The wetter heartwood veneer requires significantly longer drying time than drier heartwood of the same species. Recent studies by Walters **(74)** indicate that the actual water content in the veneer rather than the percent moisture content is the important factor.

Similarly, recent studies by Comstock **(13)** and Walters **(74)** indicate that density of the veneer may be a factor in total drying time. The denser wood has a slower rate of heating and requires more total calories to heat and dry than less dense wood.

The differences between the sapwood and heartwood may be factors with some species and not with others. Bethel and Hader (1) report that the sapwood of sweetgum will dry 25 to 50 percent faster than the heartwood of sweetgum. The difference is attributed to the difference in permeability of the sapwood and the heartwood. This same phenomenon has been observed at the U.S. Forest Products Laboratory when drying veneer of tupelo and other hardwoods like overcup oak. In contrast, Comstock (13) reports that drying time in a jet dryer does not depend on whether the veneer is heartwood or sapwood.

Similarly, there is a lack of agreement on the effect of species on veneer drying. Fleischer **(23)** found that redwood and sweetgum heartwood dried at a slower rate than yellow-poplar heartwood. Bethel and Hader **(1)** also found differences in the drying of different species. Carruthers and Paxton **(11)** confirm the observation that some species dry faster than others. Comstock **(13)** and Fleischer **(23)** indicate that drying of veneer is controlled to a large extent by the rate of heat transfer to the veneer. Fleischer qualifies this by saying that this controlling factor is a function of veneer thickness and also to some degree of veneer species. Comstock **(13)** states that differences between species and between heartwood and sapwood are not important independent variables aside from their effect on the veneer density and moisture content. He developed a general equation for the time required to dry veneer in a jet dryer. He was, therefore, interested in generalities that could be used for predicting the jet dryer capacity needed for any given species. Bethel and Hader **(1)** and Carruthers and Paxton **(11)** concluded that the drying rate of veneer may be controlled by moisture diffusion.

From the literature then, it appears that the rate of heat transfer to veneer is an important factor in the rate of veneer drying. However, 1/8 inch (3.2 mm.) and thicker veneer of the more impermeable species such as sweetgum heartwood have the rate of drying controlled at least in part by diffusion.

Reaction wood - tension wood in hardwoods and compression wood in softwoods - shrinks more longitudinally than typical wood of the same species. As a result, sheets of veneer containing streaks of tension wood or compression wood tend to buckle during drying.

Do breaks (knife checks) in the veneer caused during cutting have any effect on the drying? Experiments at the Forest Products Lab do not show any difference in the drying rate of 1/16- or 1/8-inch (1.6- or 3.2-mm.) loosely cut and tightly cut sapwood veneer of sweetgum and yellow birch dried at 200° to 350° F. (93° to 177° C.) with an air velocity of 600 feet (180 m.) per minute. The loosely cut veneer was easier to flatten after drying.

Some Dryer Conditions That Can Affect Veneer Drying

In general, dryers are operated to hold the veneer as flat as possible during drying and to transfer as much heat as possible to the veneer.

The importance of holding the veneer flat during drying can be judged by comparing matched sheets of veneer dried with various amounts of restraint. In general, buckle will be greatest in the veneer hung from the ends and allowed to dry at ambient room conditions. Next will be veneer restrained by stickers and dried in a kiln. Veneer dried in a mechanical dryer with a roller or wire-mesh conveyor will buckle less than matched material dried in a kiln. The least buckled will be veneer dried between flat hotplates.

Factors in the dryer that can affect the rate of drying include temperature, air velocity across the surface of the veneer, the relative humidity, and the related equalized moisture condition for wood.

All investigators report a direct relationship of drying temperature and drying time. For example, from the literature, 1/8-inch (3.2-mm.) heartwood of Douglas-fir dried at 250° F. (121° C.) will require 20 minutes in the dryer. The same kind of veneer dried at 320° F. (160° C.) will dry in 10 minutes. Increasing the drying temperature to 400° F. (204° C.) will further reduce this drying time to about 6 minutes. Douglas-fir heartwood veneer has reportedly been dried in 2½ minutes by using a drying temperature of 550° F. (288° C.).

The second factor which is universally agreed to affect the drying rate is the air velocity across the veneer surface. In loft drying, air movement is very slow and due only to convection currents. Veneer dried in a kiln might be subject to air velocities of several hundred feet per minute. This higher air velocity, together with the higher temperatures used in the kiln, greatly accelerates the drying. Prior to 1960, most mechanical veneer dryers had air circulation either in the longitudinal direction of the dryer or across the width of the dryer. Typical air velocities in such dryers were about 600 feet per minute (180 m. per min.). Most mechanical dryers made after 1960 have the air impinging directly onto the face of the veneer through slots or orifices. The air velocity is in the range of 2,000 to 10,000 feet per minute (600 to 3,000 m. per min.). This very high air velocity tends to break up any boundary layer at the veneer surface and greatly improves heat transfer. As a result, with a given dryer temperature, thin veneer will dry about one-third faster in a jet dryer than in a mechanical dryer having longitudinal or cross circulation air movement.

The fastest heat transfer is by conduction. In general, with a given dryer temperature, veneer dried between heated platens requires less drying time than veneer in a dryer that depends on air circulation to transfer the heat **(59).** The drying occurs fastest when the metal cauls are perforated to allow moisture to escape while maintaining high heat transfer from the hot plates. Carruthers **(11)** reports that platen dryers that open periodically to advance the veneer, dry the veneer at about the same rate as jet dryers operating at the same temperature.

The roller conveyor or wire-mesh conveyor in conventional mechanical veneer dryers aids in the drying by transferring heat by conduction to the veneer surface. Some investigators have reported that the heat transfer from the rolls may be as much as 20 percent of the total heat transferred to the veneer. This heat transfer from the rolls is very obvious when comparing the drying rates of veneer through an essentially empty dryer and one in which the conveyor is full of veneer. In the full dryer, the rolls are cooled by the wet veneer and the required drying time for a given final moisture content increases. This means the first veneer through an empty dryer will emerge much drier than veneer coming from a full dryer. If the drying time is set according to the first veneer through the dryer, the time will be too short and veneer coming from a full dryer will be much higher in moisture content.

The relative humidity in a kiln can be used to control the final moisture content of the veneer. The relationship of wet-bulb and dry-bulb temperatures to the final equilibrium moisture content of the wood is shown in figure 15. The ability to control the final moisture content of the veneer is one of the main advantages of the dry kiln.

Most veneer is dried in mechanical dryers at temperatures above 250° F. At these higher temperatures, Fleischer reports that relative humidity has no effect on the drying rate **(23).** As a matter of interest, the calculated equilibrium moisture content of wood in saturated steam at 220° F. (104° C.) is about 11 percent. At 240° F. (116° C.) it is about 5 percent. Recent experiments show that veneer steamed at 220° to 240° F. in a kiln **(73)** or in a hot press **(59)** will come to the desired final moisture content. Drying veneer to a controlled final moisture content should reduce degrade, reduce shrinkage, and provide a superior surface for gluing.

Types of Veneer Dryers

By far the most common veneer dryer is the direct-fired or steam- or hot water-heated progressive conveyor type. The roller conveyor is used most commonly with rotary-cut veneer. A wire-mesh conveyor is used for drying continuous ribbons of rotary-cut veneer and for sliced and half-round veneer. It permits feeding the veneer sidewise so that the sheets can be kept in sequence for matching, in contrast to the roller dryer where the sheets are fed endwise. The wire-mesh conveyor is reported to work most satisfactorily with a restraint weight of about 5 pounds per square foot (24 kg. per sq. m.) when drying thin face veneer. In a roller dryer the rollers are generally hollow tubes which rest directly on the veneer. As reported earlier, both the roller conveyor and the wire-mesh conveyor can contribute to drying by conduction of heat directly to the surface of the veneer. Longitudinal, cross-circulation, and impingement air movement are used in these progressive dryers. The method most commonly used in new veneer plants today is the jet dryer with the air impinging on the veneer surface at velocities of 2,000 to 10,000 feet per minute (600 to 3,000 m. per min.).

Some veneer is dried in progressive kilns. These kilns are operated at temperatures below 212° F. (100° C.) and, consequently, the relative humidity and equilibrium moisture content of the veneer can be controlled. Control of the final moisture content and production of veneer that is easily glued are two of the main advantages of the progressive kiln.

Heated tunnels with conveyors to carry products like baskets are used to dry veneer to about 20 percent moisture content to prevent mold.

A few veneer plants use progressive platen dryers. Many users of face veneer redry their veneer in a plate dryer.

A rather unique face dryer made in Germany consists of perforated drums, with a partial vacuum inside the drums. The vacuum holds the veneer against the heated drum and reportedly works satisfactorily with relatively thin veneer. The dryer does not seem well adapted for veneer thicker than 1/28 inch (0.9 mm.).

An infrared dryer has been used commercially on the West Coast, but its use has been discontinued because of high drying costs. With the development of more efficient gas-fired infrared heat the method is being reconsidered for drying veneer.

Similarly, high-frequency and microwave energy have been used as a part of drying systems to equalize the moisture content at the end of the drying cycle. These methods have not been generally used because of high equipment and power costs **(70).**

Researchers have worked with direct

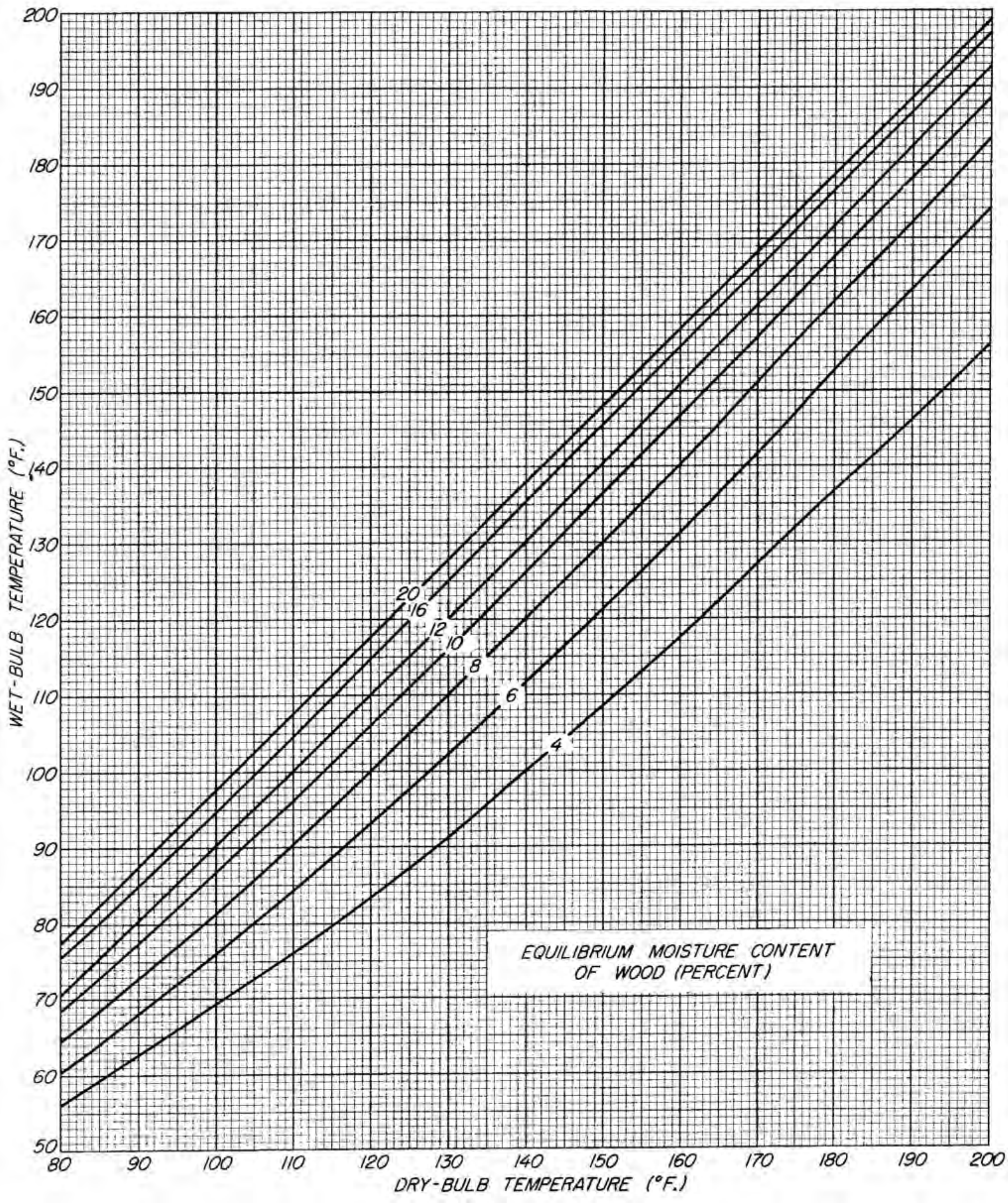


Figure 15. - Lines of constant equilibrium moisture content.
(M 74591 F)

electric current to partially dry veneer **(35)** and with fluidized beds **(9, 43);** but as far as we know, these methods have never been used commercially to dry veneer.

Drying veneer between perforated cauls in a hot press has been shown experimentally **(5, 58, 59)** to be a fast way to dry flat veneer.

Veneer Dryer Emissions

A factor of current interest is veneer dryer emissions and whether they contribute to air pollution. Recent studies **(2)** indicate the opacity of the plume from veneer dryers ranged up to 82 percent with an average of 21 percent.

Opacity is judged visually by qualified raters. Rating is in 20 percent increments similar to the Ringelmann Smoke Scale where 0 is clear and 5 is opaque.

The State of Oregon passed a law in 1972 limiting opacity of plumes from existing veneer dryers to 20 percent and from new dryers to 10 percent.

The opacity of the plume can be reduced by using stack velocities over 2,000 feet (600 m.) a minute. While this may pass the opacity limitation, it is costly because it results in a large heat loss. Also, it does not cut down on pollution.

Another approach is to filter the stack gases at high velocity through a fiberglass mat. This system can reportedly reduce the average opacity to 5 percent or less **(6).**

Still another approach is to recirculate the air in direct-fired dryers through a heated duct at 1200° F. In one-half second the hydrocarbons are incinerated and visibility of stack emissions reduced accordingly **(6).** Heat of combustion of the hydrocarbons is recovered by a heat exchanger to lower the total fuel needed to operate the system.

Applied Drying Suggestions for Mechanical Dryers

Dry the veneer as soon as practical after cutting to minimize end splits, oxidation stain, mold, and blue stain. This is particularly important for light-colored wood.

To minimize drying time, operate the dryer at the maximum temperature consistent with good glue bonds and wood color. In general, this will be about 400° F. (204° C.) at the green end and 360° F. (182° C.) at the dry end of the dryer. If gluing or veneer color are problems, lower the dryer temperature. Changing the dryer temperature by 100° F. (38° C.) [for example, from 350° to 250° F. (177° to 121° C.)] will approximately double the drying time.

Keep the dryer vents as nearly closed as practical. If condensation and haze in the building become troublesome, open the vents the minimum amount needed to correct the problem.

In general, operate the dryer with maximum air circulation possible. It may sometimes be necessary to reduce the air velocity to prevent overdrying and splitting of very thin veneer.

Keep the dryer full of veneer as much as possible. A partially full dryer or one into which veneer is just starting to be fed will dry veneer faster than a full dryer. Dryer schedules should be based on a full dryer operating at a steady temperature and air movement.

Segregate green veneer by required drying time. The green veneer sorts should be by veneer thickness, species, and for many softwoods by sapwood and heartwood. Doubling the veneer thickness will more than double the drying time. Sapwood of species like Douglas-fir requires about twice as much drying time as heartwood veneer. Heartwood and sapwood of many hardwoods dry in about the same time. Veneer containing both sapwood and heartwood or wet streaks in the heartwood should be dried on the sapwood schedule.

The veneer drying time should be regulated by the kind of veneer being fed in the green end. it is tempting for the dryer operator to change the drying time from the dry end depending on whether the emerging veneer seems too wet or too dry. If he does, there may be a constant shifting of drying times and a corresponding shifting in the average moisture content of the veneer out of the dryer. A better method is to carefully determine the proper time to dry veneer of a given thickness, species, and sapwood or heartwood and use this schedule when similar veneer is dried again.

Even when the best dryer schedules are maintained, there will be a range of moisture content in the emerging veneer. Consequently, it is very desirable to have a constant electronic check of the moisture content in the veneer. Veneer having wet spots can be pulled separately. After standing overnight or longer, the veneer can be rechecked for high moisture content and wet pieces redried.

If automatic moisture-detection equipment is not available, then the veneer out of the dryer should be checked regularly with a hand-operated moisture meter. When such meters are calibrated for a given species and make firm contact on cool veneer, they are quite accurate from about 6 to 15 percent moisture content.

An experienced dryer operator can sometimes tell in general how the veneer is drying by subjective methods. When veneer is being overdried, static electricity makes the dryer snap and pop. Overdried veneer may be hotter to touch and in extremes cases may be darkened. Underdried veneer will be cool to touch, there will be less noise from static electricity, and the veneer may be more free of end waviness and buckle.

All veneer should be cooled and held flat as it comes from the dryer. Cool veneer is less likely to buckle and will not contribute to precure of gluelines.

The dried veneer should be neatly stacked on flat skids and the top of the pile weighted. Flitches of sliced veneer should be promptly strapped in flat crates.

QUALITY CONTROL

Green Veneer

The quality of green veneer is affected by log quality, by the care used in storing the logs or flitches, by heating the wood prior to cutting, and by the mechanical condition, setup, and operation of the lathe or slicer.

Quantitatively five factors of green veneer should be checked at regular intervals: Stain, uniformity of thickness, roughness of the veneer surface, breaks into the veneer, and buckle or other distortions of the veneer **(21, 62, 75).**

Control of Stain

Stain on green veneer may be due to fungus, oxidation, or contact of the wet wood with iron or steel.

Blue stain is the most common fungus stain that occurs readily in the sapwood of most species if unprotected logs are stored during warm weather. The best control is rapid processing of the logs or storage of the logs under water or under a water spray. If water or water spray is not available, end coating the logs is beneficial.

Oxidation stain is generally a yellow or tan stain that may penetrate from the ends of unprotected logs during summer storage. Like fungus stain, it can be prevented by rapid processing of the logs or by storing logs under water or under a water spray. End coatings are also helpful.

Oxidation stain may also occur on the surface of green veneer sheets between the time they are cut and dried. A common example is the yellow stain that may develop on birch or maple sapwood. The stain is sometimes compared to the browning of a freshly cut surface of an apple. Enzymes, moisture, favorable temperatures, and air are factors in this color change.

Probably the best way to control this stain is to dry the veneer promptly after cutting so the surface is dried before oxidation takes place. Holding wet veneer over a weekend is likely to cause stain on susceptible wood species.

Another control method is to heat the logs sufficiently to inactivate the enzymes present in the wood. This generally means heating the logs for 2 days at 160° F. or higher rather than limiting heating to overnight. We have been told that running the veneer through boiling water as soon as it is cut may prevent the stain.

When wet wood comes in contact with iron or steel, it reacts to form a blue-black stain. The stain becomes worse the longer the contact and the hotter the wood. It may be particularly prevalent on woods like oak that have a high tannin content, and is very noticeable on lightcolored wood like the sapwood of maple. Such stain is not particularly important for uses like construction plywood but is very objectionable on decorative face veneer.

Control methods include keeping the knife and pressure bar as clean as possible; heating the knife and pressure bar to reduce condensation; lacquering the knife and pressure bar so that only the extreme edges have exposed steel that can stain the wood; using stainless metals for the pressure bar and knife; using a double bevel on the slicer knife so the heel of the slicer knife cannot rub against the flitch; using a greater knife angle (more clearance) so the heel of the slicer knife does not contact the flitch; and using less nosebar pressure. All are self-explanatory except the use of a stainless pressure bar and knife.

Both stellite and stainless steel may be used to make pressure bars. Stellite wears longer but stainless steel is easier to machine. A stainless knife has long been sought for cutting face veneer. Some knife manufacturers have sold knives that are reportedly of a less staining character than high-speed tool steel. However, to date no true stainless steel knife has been satisfactory as they do not take and hold an edge like tool steel.

Control of Veneer Thickness

Uniform veneer thickness is desirable for production of high-quality glue bonds in plywood, for minimizing show-through of the core, and for producing panels to a specified thickness. In 1958 French **(29)** pointed out that a veneer savings of I percent, that is, 0.001 inch (0.025 mm.) for 0.1-inch (2.54-mm.) veneer is worth at least $10,000 a year to a typical softwood plywood plant.

Since uniform veneer thickness is so important, it should be checked on a regular basis. As a minimum, at the green end, the foreman and the lathe or slicer operators should have hand micrometers that read to 0.001 inch (0.025 mm.) (fig. 16). They should be encouraged to check veneer thickness at the start of each shift, at each knife change, after any change in thickness being cut, and randomly at other times.

For quality-control purposes, it would probably pay to have a comparator such as described by Bryant, Peters, and Hoerber **(3).** The size of the anvil or contacting surface should be about 1/2 inch (12.7 mm.) in diameter and the weight on the top anvil about 0.66 pound (300 g.). When checking thickness of heavy veneer, we have found an air-operated cylinder with adjustable contact pressure and anvils about 2 inches (5 cm.) in diameter to be fast and accurate (fig. 17).

The tolerance permitted in green veneer will depend in part on the end use. For exacting end uses, this tabulation may be a guide.

Veneer Thickness		Tolerance	
(In.)	(Mm.)	(In.)	(Mm.)
1/4 (0.250)	6.3	±0.005	±0.127
1/8 (.125)	3.2	±.004	±.102
1/16 (.062)	1.6	±.003	±.076
1/32 (.031)	.8	±.002	±.051
1/64 (.016)	.4	±.001	±.025

The lathe or slicer will need to be in very good condition and set up and operated with care in order to produce veneer that will consistently meet the preceding specifications. Many commercial operations run with tolerances approximately double those listed.

Control of thickness of veneer cut on lathe. - The most common fault in veneer thickness is thin veneer for the first few revolutions of veneer cut on the lathe. The major cause of this thin veneer is looseness in the moving parts of the lathe. A second cause is deflection of the wood by the pressure bar beyond the knife edge **(34).** Further, when the knife alone is contacting the wood, the knife carriage and the wood work piece are pulled together. In contrast, when the pressure bar is contacting the wood, the knife carriage and the wood work piece are forced apart. To minimize the production of thin veneer at the start of cutting, the lathe should have tight-fitting parts; the pressure bar should be closed from the start of cutting and throughout the cutting; and moderate nosebar pressure should be used. This is discussed in more detail in reference **(56).**

Another cause of variable veneer thickness is an improper setting of the knife angle or knife pitch. If the pitch is too low, the veneer is thick and thin in waves, the crest of which may be 1 or more feet apart. Feihl and Godin **(21)** report, "This defect is particularly pronounced in winter when veneer is cut from logs that are not adequately heated and contain some frozen wood. When such logs are peeled with a low knife angle, the frozen parts tend to produce thin veneer and the thawed parts thick veneer." The corrective measures are to heat the logs to a uniform temperature and to change to a higher knife angle (greater clearance angle).

A number of investigators **(3)** have found that wood having high moisture content is more susceptible than drier wood to being cut thinner than the knife feed. An example is the tendency of Douglas-fir sapwood veneer to be thinner than heartwood veneer when cut with the same lathe settings. One solution is to use less nosebar pressure when cutting sapwood of conifers than when cutting heartwood.

In what is probably a related phenomenon, it has been shown **(55)** that wood having high moisture content, such as southern pine sapwood, tends to be thinner than would be expected from the knife feed when cut at fast speed and with high nosebar pressure. Slower cutting speed or less nosebar pressure should result in better thickness control.

Shake, heart checks, or splits in the log and soft centers that allow the bolt to move in the chucks can cause irregular veneer thickness. These unwanted thickness variations are related to specific bolts and do not occur on sound bolts. Use of larger chucks and continuous end pressure helps when cutting bolts with soft centers or with large end splits.

Misalinement of the pressure bar and knife may cause a thickness variation from one end to the other end of the veneer sheet. If the bar moves back at one end of the lathe, the gap or horizontal opening is wedge-shaped. As a result, the emerging sheet of veneer is thick and short at the edge cut with the large gap, and thin and long at the edge cut at the smaller gap. The veneer coming from the lathe runs in the direction of the thicker veneer and the bolt takes a conical shape. The corrective

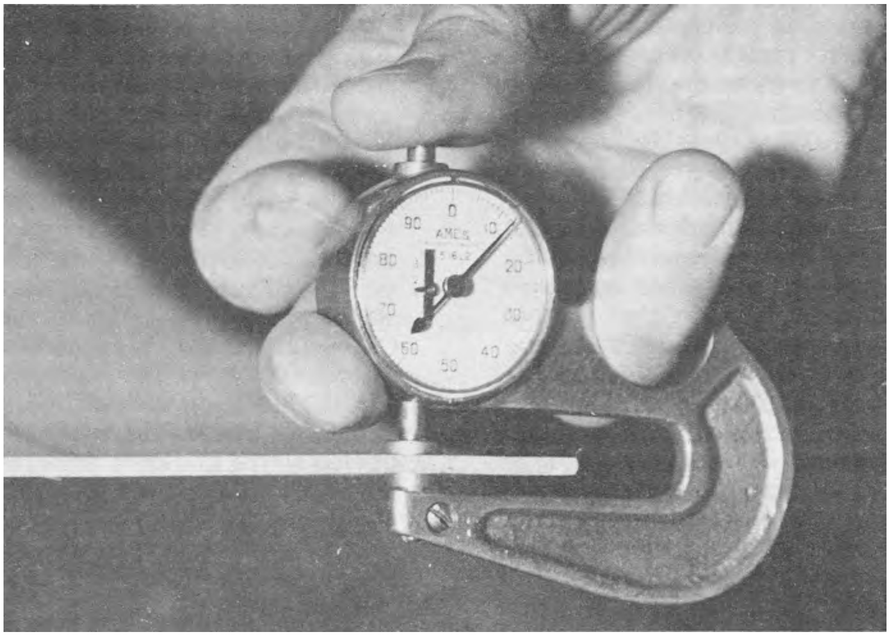


Figure 16. - Micrometer for measuring veneer thickness to 0.001 inch.

(M 139 943)

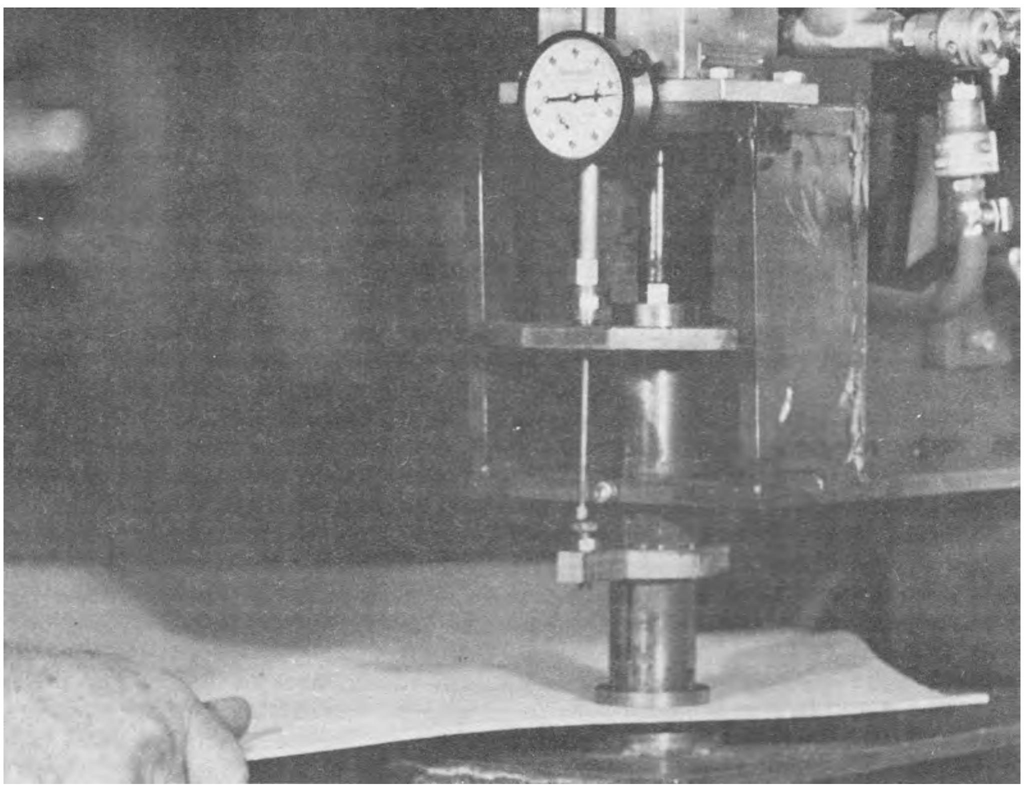


Figure 17. - An air-operated device for measuring veneer thickness. The pressure on the anvils can be easily changed to suit the species and thickness being measured.

(M 139 941)

measure is to aline the bar parallel to the knife. Then check for play in the nosebar assembly. Movement of the pressure bar during cutting may be greater at one end than the other and so cause misalinement **(21).**

Misalinement of the lead of the pressure bar with respect to the knife may also cause this phenomenon but it is less likely to occur and relatively less important than misalinement of the gap.

A conical-shaped bolt may also be caused by a much larger overhang of one spindle than the other. The remedy is to center the bolt endwise with respect to the knife.

Similarly, if the knife edge is not parallel to the axis of the spindle, a conical bolt will be generated. The correction is to adjust the nut of one of the feed screws of the lathe carriage until the knife frame is parallel to the axis of the spindles **(20).**

Misalinement of the knife and bar may cause barrel-shaped bolts and veneer that is thicker at the edges than in the middle. This may be caused by closing of the bar lead and gap at the center of the lathe due to heat expansion when cutting hot bolts. It can best be corrected by heating the knife and bar prior to setting up the lathe. Alternately, the lathe can be equipped with a cooling system or the nosebar frame may have a yoke and pull screw.

A barrel-shaped bolt may also be caused by bending of the bolt in the lathe. This is most likely to occur when cutting long bolts to a small diameter. Use of a backup roll can prevent bending of the bolt during peeling.

Control of thickness of veneer cut on the slicer. - The pressure bar is generally bolted into position on the slicer and the flitch is backed up with a steel table. Consequently, the veneer cut on the slicer may be more uniform in thickness than veneer cut on the lathe. Since most veneer cut on a slicer is 1/16 inch (1.6 mm.) or thinner, this also makes thickness control less of a problem than with thicker rotary-cut veneer.

The first few sheets cut on a slicer may be thinner than nominal thickness. The cause is primarily due to play in the feed mechanism and the flitch table. As with the lathe, it may also be due to compression of the wood beyond the knife edge by the pressure bar **(34).**

A warped flitch that is not held securely against the flitch table by the dogs may also cause thin veneer. Having all slicer parts close fitting and the flitch securely held against the flitch table as well as using moderate nosebar pressure should minimize these sources of nonuniform sliced veneer.

Heat distortion of the knife and pressure bar can cause veneer cut from near the center of the slicer to be thin. Heating the knife and pressure bar prior to setting up the slicer is the best way to overcome this problem. Yokes and pull screws on the pressure bar holder can also be used to help correct the alinement of the pressure bar to the knife edge. A nonuniformly heated flitch may also result in nonuniform veneer thickness.

A slicer that indexes the previously cut surface against a stop plate may produce uneven veneer if splinters or other debris come between the flitch face and the stop plate.

Slicers having a pawl and ratchet feed must have the same number of teeth advanced every stroke. If the mechanism is not set carefully, an incorrect thickness may be produced. Similarly, if the feed index train is not braked, momentum may carry the knife carriage beyond the desired index.

Splits or shake in flitches can cause uneven veneer thickness. These thickness variations of course do not occur with sound flitches.

Control of Veneer Roughness

Like nonuniform veneer thickness, veneer roughness is undesirable for all end uses. Rough veneer can cause gluing problems, require excessive sanding, and cause finishing problems.

Measuring the roughness of wood surfaces is a complex problem. Peters and Cumming **(67)** have reviewed the problem and discussed methods that have been developed and used by various researchers. Peters and Mergen **(68)** later described a stylus trace method they developed for measuring wood surfaces (fig. 18). Earlier Lutz **(44)** described a light-sectioning method for measuring roughness of rotary-cut veneer (fig. 19). Northcott and Walser **(66)** have published a visual veneer roughness scale which in turn was obtained by measuring depressions on the surface of the veneer samples with a dial micrometer. For research the stylus trace method, the light-sectioning method, and the dial micrometer give quantitative numbers for comparing surfaces. For mill use, a visual veneer roughness scale is probably more useful. Actual veneer samples that have been measured for surface roughness in the laboratory could be kept near the lathe or slicer for visual comparision with the veneer being produced.

The orientation of the wood structure **(46)** and the growth rate of softwood trees **(48)** affect the smoothness of knife-cut veneers.

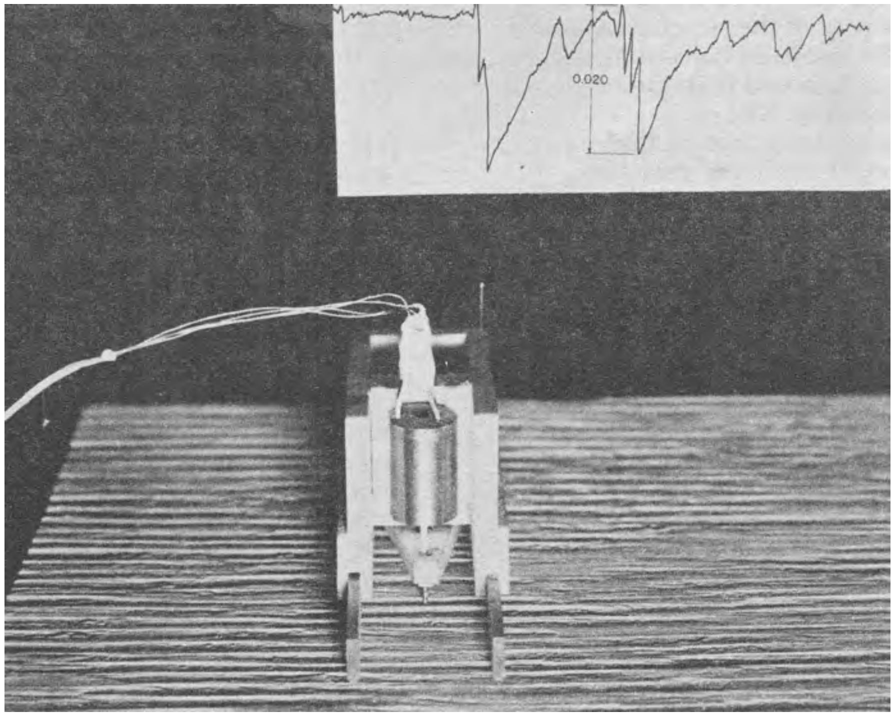


Figure 18. - An instrument for measuring roughness of wood surfaces by moving a stylus across the rough surface. The insert shows the type of trace the instrument records.
(M 139 938)

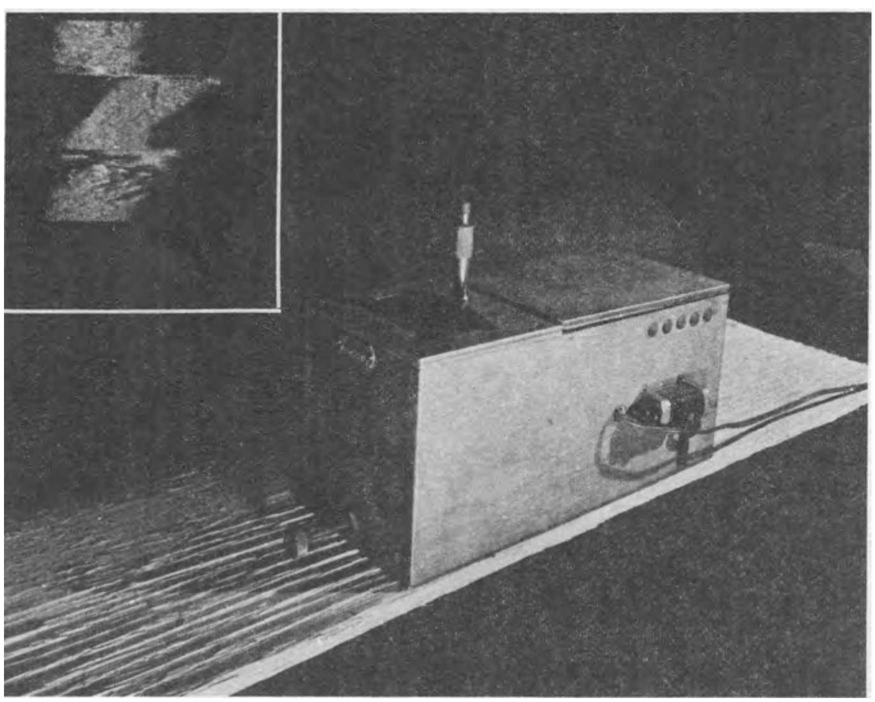


Figure 19. - An instrument for measuring veneer surfaces by light sectioning. The insert shows what is seen through the magnifying glass of the instrument.
(M 139 937; M 87901 F)

When cutting against the grain of the wood fibers, annual rings, or wood rays, the wood tends to split ahead of the knife and into the wood work piece causing depressions on the tight side of the veneer. The annual ring effect is most pronounced when rotary cutting fast-grown softwoods at small core diameters. The ray effect is pronounced when quarter-slicing goes beyond the true quarter. Cutting against the fibers occurs around knots, with curly grain and with interlocked grain. The thicker the veneer, the more likely the veneer will be rough. As pointed out in reference **(46),** it is sometimes possible to mount the flitch or bolt to minimize cutting against the grain. Probably the best control is to adjust the nosebar to increase the pressure just ahead of the knife tip and so reduce splitting ahead of the knife. Proper heating of the wood and use of a sharp knife also help reduce this roughness.

Another type of roughness is a fuzzy surface. It is most common on low-density hardwoods like cottonwood that contain tension wood. Overheating of any species may also cause fuzzy surfaces. Control may include log selection to avoid bad tension wood **(69),** cutting the wood at as low a temperature as is practical, and keeping the knife sharp by honing when necessary. An extra hard knife will keep a sharp edge longer than a soft knife and can be used with low-density woods. Use of a slightly eased fixed nosebar edge and continuous flushing of the surface between the wood and the nosebar with cold water may also help.

Shelling or separation of the springwood from the summerwood may occur when rotary-cutting or when flat-slicing some softwoods and hardwoods that have a relatively weak zone between the springwood and summerwood. Hemlock, true firs, western redcedar, and angelique are some species that may develop shelling. Overheating of the wood, too much nosebar pressure, too sharp a nosebar, or a dull knife may contribute to shelling.

Shattering of the veneer surface is somewhat like shelling and may occur with wood having a high moisture content and low permeability. For example, Douglas-fir sapwood and sinker redwood bolts may develop shattered veneer surfaces if cut at high speed and with high nosebar pressure. Apparently water in the wood is compressed so fast that it ruptures the wood structure to escape. Less nosebar pressure and slower cutting speed reduce the occurrence of shattered veneer surfaces.

Nicks on the knife edge or pressure-bar edge may cause scratches on the veneer. Scratches from the knife occur on both the tight and loose side of the veneer while scratches from the pressure bar occur only on the tight side of the veneer. These scratch marks are so common that they can often be used to distinguish one-half-round from flat-sliced veneer. The scratches on the half-round veneer are at a right angle to the length of the sheet while those on flat-sliced veneer are at some acute angle corresponding to the draw of the slicer. Careful examination of the veneer followed by honing the knife and pressure bar when necessary minimizes these scratch marks. This is particularly important for decorative face veneer. The scratches may take stain more than surrounding wood even if the sanded wood appears to be free of scratches.

A defect occasionally seen on softwood veneer cut from wood having a dense summerwood and much less dense springwood is grain raising. Excessive pressure from the nosebar overcompresses the springwood. After the veneer is cut, the springwood recovers, resulting in raised grain. The corrective measure is to reduce the nosebar pressure. Feihl and Codin **(21)** report that bulging of knots in the core is related to raised grain and they suggest increasing the knife angle as well as decreasing the nosebar pressure as means of correcting this fault.

Corrugated veneer with three or four waves per inch of veneer is generally associated with too high a knife angle. Feihl and Godin **(21)** report corrugated veneer can also be caused by cold or dry wood and by setting the knife edge too low. Other causes are too much overhang on the spindles, cutting to a small core without adequate support for the core, and wood bolts that become loose in the chucks. Corrective measures are obvious from the stated causes.

Control of Cracks or Breaks into the Veneer

Breaks into the veneer may be on the side of the veneer that is next to the knife or on the side next to the pressure bar during cutting. By far the most common are small cracks that develop on the side of the veneer next to the knife. They may be caused by splitting ahead of the knife edge or by bending the veneer as it passes the knife after it is cut. The terms tight and loose side of the veneer refer to this phenomenon, with the loose side being the side that has the checks. These small breaks are also known as knife checks, lathe checks, or slicer checks.

Less prevalent but perhaps more serious are breaks on the bar side or tight side of the veneer. Three examples are grain separation, lifted grain, and cracks approximately normal to the veneer surface.

Loosely cut veneer is weak in tension perpendicular to the grain. As a result, it may develop splits or break readily during handling, thus lowering the grade of the veneer. Deep checks in face veneer may also contribute to surface checking in furniture or other finished panels. On the other hand, loosely cut veneer may develop more wood failure than tightly cut veneer when both are evaluated by the standard plywood shear test.

Three methods have been used to measure looseness of veneer. One method is to pull 1-inch-(2.54-cm.) long veneer samples apart in tension perpendicular to the grain on a suitable test machine (37) (fig. 20). Because of variability, a minimum of about 30 samples should be tested to obtain a value for a given cutting condition. The values obtained can be compared with values for matched sawn and planed pieces of the same size. As shown in reference **(54),** quarter-sliced oak veneer may

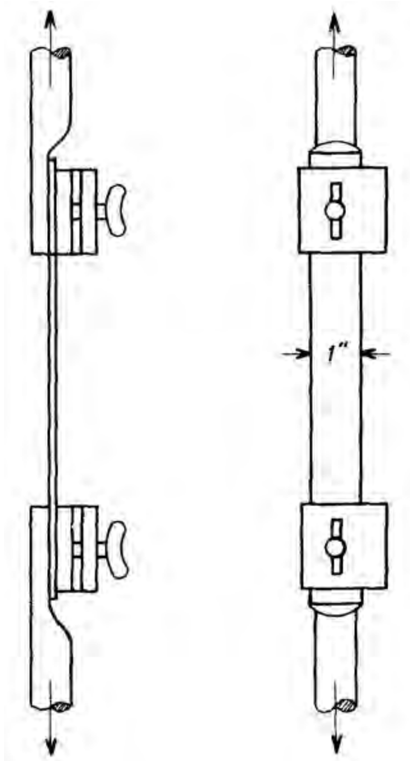


Figure 20. - A veneer specimen in the grips of a tension testing machine. (M 108 074)

be stronger in tension perpendicular to the grain than matched flat-sliced or rotary-cut veneer.

A second method of evaluating veneer checks is to apply an alcohol-soluble dye to the checks by brushing it on the dry veneer surfaces or by dipping the end of the dry veneer in the dye. The dye penetrates into the checks. The depth of checks as a percentage of the veneer thickness can be estimated from scarfed sections of the samples (fig. 21). The method works very well with relatively impermeable veneer such as Douglas-fir heartwood where the dye is generally confined to the checks; it is less satisfactory with permeable veneer such as southern pine sapwood due to overall penetration of the dye into the wood.

A third method is to flex the veneer across the grain. Tightly cut veneer is stiffer than loosely cut veneer.

Two factors are most important in minimizing depth of checks on the loose side of the veneer. They are adequate heating of the wood **(49)** and use of adequate nosebar pressure **(75).** Factors that may increase checking are logs that have partially dried and use of a knife bevel much greater than is commonly used.

Assuming proper heating schedules are being used as described earlier, the temperature through the flitch or bolts should be relatively uniform. One way to check the bolt temperature is to drill a ¼-inch- (6.3-mm.) diameter hole radially an inch or two (2.5 to 5 cm.) deep at the center of the cores remaining after cutting veneer from large- and small-diameter bolts. A thermometer should immediately be inserted in the hole and the temperature recorded. This temperature should be within 10° F. (5° C.) of the desired temperature for good cutting. This method is recommended over measuring the temperature at the surface of the bolt, as the surface temperature of a heated block changes very fast when it is exposed to air.

If the measured temperature is not satisfactory, the heating schedules should be rechecked and the actual temperatures in various positions in the heating vat should be monitored with thermocouples throughout the heating cycle.

Nosebar pressure was described in detail earlier. For quality control, perhaps the most useful procedure is to be certain that the lathe or slicer settings are made with instruments and that gages are mounted on the equipment to show any unwanted movement of the

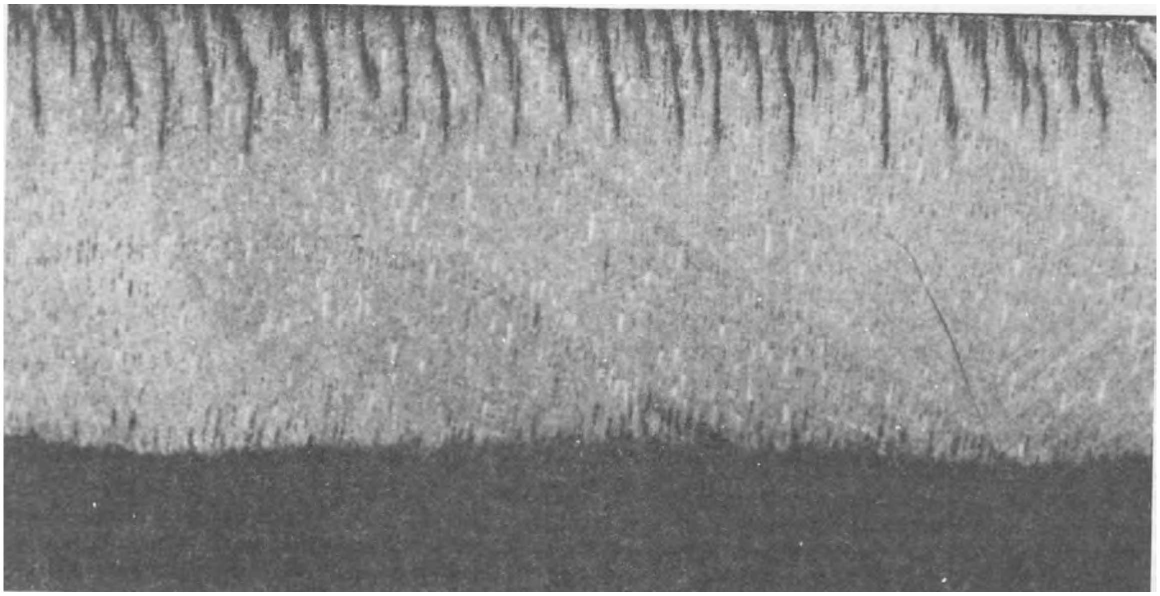


Figure 21. - A scarfed sample of birch veneer to show checks about one-third of the thickness of the veneer. A dye was applied prior to scarfing to make the checks stand out.
(M 107 770)

nosebar with respect to the knife edge during cutting.

With good veneer species like yellow birch and yellow-poplar, it is possible to cut veneer as thick as 1/8 inch (3.2 mm.) with no visible checks on the knife side of the veneer.

Grain separation is similar to shelling and is a failure of wood between annual rings. The defect may not be noticed in the green veneer but later cause trouble when the plywood made from the veneer is bent as for a boat hull. Two species that have developed the defect are okoume and lauan. The cause is related to relatively weak zones in the wood and is generally considered to be due to setting the bar with too much lead and too small a gap. If suspected, it may be detected in dry veneer or plywood by tapping with a coin or stroking with a stiff brush. The void causes a different noise than the noise that comes when tapping or brushing sound veneer.

Lifted grain is a separation of large groups of fibers in figured veneer like curly birch **(21).** It is serious because such areas cannot be sanded to a smooth surface. Careful setting of the knife and pressure bar may minimize this defect in thin face veneer such as 1/24 inch (1 mm.). Extreme curly grain should not be cut into thicker veneer if lifted grain is to be avoided.

The last type of cracks to be discussed is breaks normal to the tight side. They may occur if excessive nosebar pressure is used or if the nosebar lead is such that excessive restraint is put on the veneer as it passes between the knife and the pressure bar. This is one reason setting of the double-surfaced fixed pressure bar is so critical for cutting veneer. Breaks on the tight side of the veneer can be detected by the tension test and by the alcohol soluble dye test the same as breaks into the loose side of the veneer. Careful setting of the pressure bar will eliminate this problem.

Control of Buckle in Green Veneer

Buckle is undesirable as it interferes with edge gluing, glue spreading, and panel layup. When it is severe it may cause overlaps or splits in the plywood. Buckled veneer caused by reaction wood may also cause warped panels in service.

Buckle, like end waviness, may be measured by deviation from a plane surface by placing the buckled veneer between two flat parallel surfaces and recording the spacing **(45).** Commonly, buckle is rated visually as mild, moderate, or severe.

Buckle in green veneer may be caused by reaction wood or by uneven pressure against the bolt or flitch during cutting.

Compression wood in softwoods and tension wood in hardwoods has different longitudinal stresses than normal wood. When sheets of veneer containing both reaction wood and normal wood are cut, the veneer may buckle as it comes from the lathe or slicer. Drying accentuates this buckle. Logs from species known to be prone to develop reaction wood should be examined prior to cutting and not be cut into veneer if the reaction wood is pronounced.

Uneven pressure against the bolt or flitch may be due to heat distortion of the knife and pressure bar setting on the lathe or slicer; bowing of small-diameter bolts on the lathe; jamming of a chip or splinter between the pressure bar and the bolt or flitch; a tight spot due to a local deviation of the knife or pressure bar edges from a straight line. As discussed earlier, heat distortion can be minimized by heating the knife and pressure bar prior to setting them. Bowing of the bolt may be minimized by reducing the nosebar pressure and by using a backup roll. Some lathe operators judge the correct nosebar pressure by whether the veneer buckles in the center of the sheet. If the center of the veneer ribbon is buckled, the pressure is too high and the nosebar gap is widened.

A splinter or chip jammed between the knife and bar in effect puts very high local pressure on the wood and causes the veneer to be thin. A bump builds on the bolt or flitch. If it is pronounced, the veneer may develop a hole at this area and the knife may be bent. The correction is to stop cutting, open the pressure bar, remove the chip or splinter, close the bar, and resume cutting. Use of a roller bar helps reduce this defect as the chips are more readily pushed past the opening between the knife and pressure bar. Setting a fixed bar with more lead may help reduce this problem. Having the bolt or flitches clear of bark and loose splinters is good practice and will reduce jamming of particles between the surface of the bolt or flitch and the pressure bar.

Finally, if the knife and pressure bar are not ground straight, there may be a local tight spot that will result in buckled veneer. The correction is to grind the knife and bar straight. Both surfaces of the knife edge should be examined and if necessary both should be ground to straighten the edge **(30).**

Quality Control of Dry Veneer

Most veneer is readily dried satisfactorily for the intended end use. But since veneer is easy to dry, potential problems are sometimes overlooked.

Some veneer drying problems are nonuniform moisture content in the veneer as it emerges from the dryer, buckle and end waviness of veneer sheets, splits and checks in the veneer, a veneer surface that is difficult to glue, scorched veneer surfaces, veneer that shows signs of collapse, honeycomb, or casehardening, excessive veneer shrinkage, and undesirable color. A recent evaluation of veneer drying problems has been made by Carroll and Dokken **(8).**

Contral of Final Moisture Content

Probably the most universal problem in drying veneer in a progressive mechanical veneer-type dryer operating at temperatures above 220° F. (104° C.) is the nonuniform moisture content in the veneer as it comes from the dryer. This is true of a dryer having longitudinal circulation, cross circulation, or jet impingement circulation. It is similarly true for a progressive platen-type dryer **(10).** For example, veneer dried to an average moisture content of 8 percent will generally have a range in moisture content from about 2 to 20 percent. This is because the equilibrium moisture conditions in the dryer are for all practical purposes 2 percent or less. When drying to an average moisture content of 8 percent, the faster drying veneer may come to 2 percent and the slower drying to 20 percent moisture content. In other words, any difference in the drying rates of different areas of the same sheet of veneer then results in a wide range in final moisture content in the veneer as it comes from the dryer.

To keep this problem to a minimum, the green veneer should be sorted for thickness, moisture content, and density. Better control will probably result if the green veneer is also sorted for sapwood and heartwood and by species. Assuming the veneer is being sorted as well as possible to have veneer of one type being dried at the same time, the next point to check is the uniformity of drying conditions in different parts of the dryer.

Modern veneer dryers are generally designed to have uniform temperature and air movement throughout the dryer. However, it may be worthwhile to check these factors. Is the temperature at the top conveyor the same as it is at the bottom conveyor? Is the air speed approximately the same in all parts of the dryer? One method of checking this is to run matched samples of veneer through different portions of the dryer. For example, one sample can be run through the left side of the upper conveyor, another through the right side of the upper conveyor, another through the left side of a lower conveyor, and so on. Then carefully check these samples for moisture content immediately out of the dryer. If this -est shows that one portion of the dryer is consistently drying veneer faster than another, drying rates can sometimes be equalized by adding steam coils, baffles, or fans where needed in the dryer.

Another way of controlling the final moisture content is to dry all of the veneer to 5 percent moisture content or less. This may result in overdrying of some of the veneer, but it will result in a narrower range of veneer moisture.

A very common method of reducing the spread of moisture in the veneer is to electronically measure the moisture content in each piece of veneer as it comes from the dryer. Veneer that has a moisture content higher than the desired maximum is marked and pulled separately for further drying. Leaving this wet veneer in a solid stack overnight will help to equalize the moisture content. A resort through the moisture detector the next day will reduce the number of pieces that need to be redried.

Another method that is sometimes used when nonuniform moisture content is a serious problem is to dry in two stages. In the first pass, the veneer is brought to an average moisture content of about 20 percent. It is then stacked overnight to allow some equalization and rerun the next day to the average moisture content desired.

High-frequency or microwave units have been used experimentally at the dry end of the dryer to equalize the moisture content of the veneer. Both of these methods work on the principle that the higher moisture areas in the veneer absorb more energy. Heating and drying are proportional to this absorption of energy. Both of these methods do equalize moisture content in the veneer, but they have not been generally adopted because of cost **(70).**

It is also possible to dry veneer to controlled moisture contents in superheated steam at atmospheric pressure **(59,73).** To date this method has not been used commercially.

Control of Buckle

Buckle in veneer may be caused by stresses in the wood, by reaction wood, by irregular grain with resulting irregular drying rates and irregular shrinkage, and possibly also by improper setting of the lathe or slicer. As mentioned earlier, use of the maximum restraint that will hold the veneer flat without causing it to split due to shrinkage stresses will help to minimize buckle. Similarly, anything that can be done to dry the veneer to as uniform a moisture content as possible will reduce buckling. In most cases, buckling can be minimized by redrying in a plate dryer. The redrying temperature and time will depend on the moisture content of the veneer. This is described in some detail in reference **(50).**

Control of Splits

Splits in veneer that has been dried in a progressive mechanical dryer are generally related to splits that were in the green veneer or are due to rough handling. If stacks of green veneer must be held prior to drying, the ends should be protected from end drying by covering them with a plastic sheet (such as polyethylene) or if necessary by spraying them with water.

A recent development for controlling handling splits is green veneer taping. Dokken (14) points out that tape is applied at the lathe primarily to veneer thinner than 1/26 inch (1 mm.). Taping reportedly improves the veneer grade, and reduces the need to splice and repair veneer. Forest Products Laboratory experiments **(45)** showed that 1/2-inch- (12.7-mm.) wide flexible tape applied to the spurred ends of the green veneer reduces end waviness.

Another method of reducing handling splits is to dry rotary-cut veneer in a continuous ribbon using a wire-mesh conveyor in a mechanical dryer. The method was used as early as 1950 with birch veneer which was reeled as it came from the lathe and then unreeled into the dryer. The dry veneer was then clipped for grade. More recently a system has been developed where softwood veneer is stored on long trays and then fed in line to the dryer. In addition to reducing splits, recovery is reportedly improved because the veneer is clipped dry and it is not necessary to oversize to compensate for variability in shrinkage.

Control of Veneer Surfaces for Gluability

Poor glue bonds have been reported with veneer dried in direct oil-fired dryers operating at temperatures as high as 550° F. (288° C.). This is less of a problem with direct gas-fired dryers and less yet with steam-heated dryers. Dropping the temperature to 400° F. (208° C.) or lower improved the gluability of the veneer. The cause of glue interference has been described as weakening of the surfaces by Bryant and Stensrud **(4),** and others. Resch **(70)** states that glue interference is caused by extractives brought to the wood surface during high-temperature drying. At any rate, use of a lower drying temperature and prevention of overdrying the veneer are the common means of overcoming veneer gluing problems.

Control of Dryer Fires and Scorched Veneer

High drying temperatures may cause scorched veneer and possibly fires in the dryer. At temperatures from 200° to 300° F. (93° to 149° C.), there is a volatilization of extraneous materials in the wood. From 300° to 400° F. (149° to 204° C.), there is scorching and slow evolution of flammable gases from the wood. This progressively becomes more rapid until at about 600° to 650° F. (316° to 346° C.) the wood will ignite spontaneously.

While wood itself does not ignite spontaneously until the temperature at its surface reaches about 650° F. (346° C.), if the surface becomes charred, charcoal gases may ignite at a temperature as low as 450° F. (232° C.). Extraneous materials such as turpentine also ignite at a temperature of about 450° F. (232° C.).

Veneer being dried on the West Coast in dryers operating at 400° F. (204° C.) or less sometimes ignites in the dryer. These fires may be caused by a static spark that ignited flammable gases of volatile extraneous materials.

Avoiding overdrying and use of controlled lower drying temperatures are the primary means of preventing dryer fires and scorched veneer.

Control of Collapse, Honeycomb, and Casehardening

Collapse and honeycomb may occur in species that are relatively nonporous. Typical examples would be 1/8 inch (3.2 mm.) and thicker heartwood of sweetgum and overcup oak. Bethel and Hader **(1)** indicate that collapse in sweetgum heartwood is likely to occur in early stages of the drying. Fleischer **(24)** found that sweetgum dried at 350° F. (177° C.) had much more honeycomb than sweetgum heartwood dried at 150° F. (66° C.). Experiments at Madison showed that 1/8-inch (3.2-mm.) overcup oak dried at 320° F. (160° C.) might shrink as much as 20 percent in thickness. The solution to these drying problems in all cases appears to be to use a lower drying temperature.

Casehardening was found to be at a maximum in 1/8-inch (3.2-mm.) heartwood of sweetgum when dried at temperatures of 120° to 160° F. (49° to 71° C.). Kuebler **(42)** described in some detail how casehardening can be removed by use of high temperature, particularly if the veneer has a high moisture content.

Control of Shrinkage

Widthwise shrinkage of flat-grain veneer generally decreases with increasing drying temperature. For example, 1/8-inch (3.2-mm.) yellow-poplar dried at 150° F. (66° C.) shrank 6 percent; when dried at 250° F.(121° C.) it shrank 5½ percent; and when dried at 350° F. (177° C.) it shrank 4½ percent. In contrast, the shrinkage in thickness tends to increase with an increase in drying temperature. Gottstein **(31)** reports that collapse-susceptible alpine ash grown in Australia tends to increase in shrinkage if the warm veneer is held in a stack for some time prior to drying. This point should be checked with collapse-susceptible U.S. hardwoods.

Control of Color

Color in face veneer can often be controlled to some degree by varying the time that the green veneer is held in a stack prior to drying. In general, the wet veneer tends to oxidize and darken in storage. Consequently, if a light color is desired, as with the sapwood of hard maple, the veneer should be dried as quickly as possible after cutting. In other cases, it may be desirable to have some color change take place in the green veneer stack. An example is black walnut. The color of the sapwood and heartwood changes gradually in the warm green stack. When the desired color is reached, the veneer is sent through the veneer dryer.

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APPENDIX
IDENTIFICATION OF CONTINENTAL U.S. WOODS AND OTHERS MENTIONED IN THIS REPORT[1]

Commercial name of veneer	Common name	Botanical name
	Continental U. S. Hardwoods[2]	
Ash	Ash	*Fraxinus* sp.
Aspen	Aspen	*Populus* sp.
	Quaking aspen	*P. tremuloides*
Basswood	American basswood	*Tilia americana*
Beech	Beech	*Fagus grandifolia*
Birch	Birch	*Betula* sp.
	Yellow birch	*B. alleghaniensis*
Cherry	Black cherry	*Prunus serotina*
Cottonwood	Cottonwood	*Populus* sp.
Elm	Elm	*Ulmus* sp.
Gum	Sweetgum	*Liquidambar styraciflua*
Hickory	Hickory	*Carya* sp.
	Shagbark hickory	*C. ovata*
Maple	Maple	*Acer* sp.
	Sugar maple	*A. saccharum*
Oak	Oak	*Quercus* sp.
Red oak	Northern red oak	*Q. rubra*
White oak	Oak	*Q.* sp.
	Overcup oak	*Q. lyrata*
Poplar	Yellow-poplar	*Liriodendron tulipifera*
Tupelo	Tupelo	*Nyssa* sp.
Walnut	Black walnut	*Juglans nigra*
	Claro walnut	*J. hindsii*
	Continental U. S. Softwoods[2]	
Alaska cedar	Alaska-cedar	*Chamaecyparis nootkatensis*
Port Orford cedar	Port-Orford-cedar	*C. lawsoniana*
Eastern red cedar	Eastern redcedar	*Juniperus virginiana*
Western red cedar	Western redcedar	*Thuja plicata*
Cypress	Baldcypress	*Taxodium distichum*
Douglas-fir	Douglas-fir	*Pseudotsuga* sp.
Eastern hemlock	Eastern hemlock	*Tsuga canadensis*
Ponderosa pine	Ponderosa pine	*Pinus ponderosa*
Southern Pine	Southern Pines	*P.* sp.
Redwood	Redwood	*Sequoia sempervirens*
Spruce	Spruce	*Picea* sp.
	Red spruce	*P. rubens*
Sitka spruce	Sitka spruce	*P. sitchensis*

Commercial name of veneer	Common name	Botanical name
	***Other Species*[3]**	
Alpine ash	Alpine ash	*Eucalyptus gigantea*
Angelique	Angelique	*Dicorynia guianensis*
Brazil nut	Brazil nut	*Bertholletia excelsa*
Cativo	Cativo	*Prioria copaifera*
Ceiba	Ceiba	*Ceiba pentandra*
Lauan	Philippine mahogany	*Shorea, parashorea, pentacme* sp.
Mahogany	Honduras mahogany	*Swietenia macrophylla*
Okoume	Okoume	*Aucoumea klaineana*
Primavera	Primavera	*Cybistax donnell-smithii*
Rosewood	Rosewood	*Dalbergia* sp.

[1] All species listed are used for veneer.

[2] Names of wood from continental United States are taken from "Check List of Trees of the United States," by Elbert L. Little, Jr. USDA Agriculture Handbook 41, 1953.

[3] Names of wood from outside the United States taken mostly from "Properties of Imported Tropical Woods," USDA Forest Service Research Paper FPL 125, 1970, Forest Products Laboratory, Madison, Wis.

*U.S. Government Printing Office: 1974 -754-553/58

Note

Mention of a chemical in this publication does not constitute a recommendation; only chemicals registered by the U. S. Environmental Protection Agency may be recommended, and then only for uses as prescribed in the registration and in the manner and at the concentration prescribed.

The list of registered chemicals varies from time to time; prospective users, therefore, should get current information on registration states from the Environmental Protection Agency, Washington, D.C.