Forest&Wood Products Australia
Knowledge for a sustainable Australia

MARKET ACCESS

PROJECT NUMBER: PRA295-1213 JULY 2013

A Manual for Decorative Wood Veneering Technology

2nd Edition

This report can also be viewed on the FWPA website
www.fwpa.com.au
FWPA Level 4, 10-16 Queen Street,
Melbourne VIC 3000, Australia
T +61 (0)3 9927 3200 F +61 (0)3 9927 3288
E info@fwpa.com.au W www.fwpa.com.au

Publication: A Manual for Decorative Wood Veneering Technology 2nd Edition

Project No: PRA295-1213

This work is supported by funding provided to FWPA by the Department of Agriculture, Fisheries and Forestry (DAFF).

ISBN: 978-1-921763-77-9

Researcher:
Dr Barbara Ozarska
Melbourne University

Forest & Wood Products Australia Limited
Level 4, 10-16 Queen St, Melbourne, Victoria, 3000
T +61 3 9416 7544 F +61 3 9416 6822
E info@fwpa.com.au
W www.fwpa.com.au

LIST OF CONTENTS

Contents

GLOSSARY

BALANCED CONSTRUCTION – A construction such that forces induced by uniformly distributed changes in moisture will not cause warpage. In a veneered panel, a construction in which back and face veneers are essentially equal in thickness, grain direction and properties is considered balanced construction.

BALANCE MATCH – One or more pieces of uniform size used in a single face.

BIRD'S EYE – A figure created by local sharp depressions in the annual rings accompanied by considerable fibre distortions.

BLISTER – Spot or area where veneer does not adhere. Blisters are considered a bond line failure.

BOOK MATCH – Adjacent sheets from a flitch are opened like a book with the figure on the back of the first sheet matched to the figure on the face of the next sheet. The fibres of the wood, slanting in opposite directions on the two sheets, create a characteristic light and dark effect when the surface is seen from an angle.

BURL (BURR) – A hard woody abnormal growth or excrescence on either trunk or branch formed by the local development of numerous dormant buds, often caused by some injury to the tree.

BURL FIGURE – In veneer, a localised distortion of the grain generally rounded in outline. Frequently includes one or more clusters of several small adjoining conical protuberances, each usually having a core or pith but no appreciable end grain.

CENTRE MATCH – An even number of pieces of equal size are matched with a joint in the centre of the panel.

CHECKS

- **SEASONING CHECKS –** Small slits running parallel to the grain of wood, caused chiefly by strains produced during seasoning.
- **PEELER or SLICER CHECKS –** Closely spaced checks originating from one side of a veneer, usually the surface nearest the pith of the tree. Caused by stressing during veneer cutting (peeling or slicing).

COMPRESSION WOOD – Abnormal wood that may occur in non-pored timbers, characterised anatomically by short thick-walled cells showing spiral markings, the wood being denser, more brittle and prone to greater longitudinal shrinkage than normal wood.

CONTINUOUS MATCH – Each panel face is arranged from as many veneer sheets as necessary for the specified panel width; if a portion of a veneer is left over, it becomes the start of the next panel face.

CORE – The inner part of veneered panel or plywood between face and back. Particleboard, medium density fibreboard, sawn timber, hardboard, veneers or other material can be used as cores.

CROSS-BANDED – A veneered panel in which the veneer grain directions are parallel to the shorter panel dimension.

CROTCHWOOD – Crotchwood comes from the portion of a tree just below the point where it forks into two limbs. The grain is crushed and twisted, creating a variety of plume and flame figures, often resembling a well-formed feather. The outside of the block produces a swirl figure that changes to full crotch figure as the cutting approaches the centre of the block.

CROWN CUT – Sliced from a billet with successive veneers parallel to the axis of the billet and kept in sequence as cutting progresses across the diameter. This method is also known as flat cut. In Australia, an equivalent term "back-sawn" is used for solid timber cut in such a way that the wide surface of the board is a tangential plane to the growth rings.

CURLY – Figure that occurs when the fibres are distorted, producing a wavy or curly effect in the veneer. Primarily found in North American maple and birch.

DEFECT, OPEN – Open checks, splits, joints, knotholes, cracks, loose knots, gaps, voids or other openings interrupting the smooth continuity of the wood surface.

DISCOLOURATION – Stains in wood substances. Common veneer stains are sap stains, blue stains, stains produced by chemical action caused by the iron in the cutting knife coming into contact with the tannic acid of the wood, chemical reaction between extractives in wood and glue or finish discolourations.

EDGEBAND – Thin strips of veneer used to cover the exposed edges of panel substrates. This veneer is usually available in rolls of various lengths and comes either pre-glued or unglued.

END MATCH or BUTT – The veneers as described for book matched, but the ends of the sheets are also matched.

EXTRACTIVES – Many species have high tannin contents that react with iron to form black and insoluble iron tannates if the wood is in wet or humid conditions. Any contact with iron may cause problems. Therefore it is essential that special care is taken during the storage and manufacturing of these types of veneers, veneered panels and products. All external fixings and metal joints should be heavily galvanised steel or of non-ferrous metals.

FACE VENEER – A term used to describe better quality veneers that are used to cover the visible surfaces of a panel.

FIGURE – The pattern produced in a wood surface by annual growth rings, rays, knots, deviations from natural grain, such as interlocked and wavy grain, and irregular colouration.

FIDDLE-BACK FIGURE – A fine, strong, even, ripple figure in veneers. The figure is often found in red gum, myrtle, mahogany and maple, but also occurs in other species.

FLEXIBLE VENEER – Wood veneer that is jointed, processed, sanded and backed with paper or other material to create a fully ready-to-use dimensional sheet of real wood veneer.

FLITCH – A section of log made ready for slicing into veneers, or the bundle of sliced veneers.

GRADING – Classifying veneers according to quality standards for each species. This greatly affects the price and end use of the veneer.

GRAIN – The direction, size, arrangement and appearance of the fibres in timber and veneer.

GRAIN SLOPE – Expression of the angle of the grain to the long edges or the length of the veneer.

GUM POCKETS – Well-defined openings between rings of annual growth containing gum or evidence of prior gum accumulations.

GUM VEINS – A ribbon of resin between growth rings, a common feature of most eucalypts. The gum is formed as a protective response to some injury to the tree, such as from insect attack, fire or mechanical damage.

HALF-ROUND VENEER – Veneer produced in the same manner as rotary cutting, except that the piece being cut is secured to a "stay log", a device that permits the cutting of the log on a wider sweep than when mounted with its centre secured in the lathe. A type of half-round cutting may be used to achieve "flat cut" veneer.

HARDWOOD – General term used to designate lumber or veneer produced from broad-leafed or deciduous trees in contrast to softwood, which is produced from evergreen or coniferous trees.

HEARTWOOD – The non-active centre of a tree generally distinguishable from the outer portion (sapwood) by its darker colour.

INTERLOCKED GRAIN – Where the angle of the fibres periodically changes or reverses in successive layers.

JOINT – The line between the edges or ends of two adjacent sheets of veneer in the same plane.

JOINT, EDGE – Joint running parallel to the grain of the veneer or lumber.

JOINT, OPEN – Joint in which two adjacent pieces of veneer do not fit tightly together.

KNIFE MARKS – A raised or hollowed cross grain cut caused generally by a nick in the peeling or slicing knife.

KNOT – A portion of a branch that is enclosed by the natural growth of the tree, with grains usually running at right angles to that of the piece of wood in which it occurs.

KNOT, OPEN – Opening produced when a portion of the wood substance of a knot has dropped out, or where cross checks have occurred to produce an opening.

LOOSE SIDE OF VENEER – In knife-cut veneer, the side of the sheet that was in contact with the knife as the sheet was being cut. It contains cutting checks (lathe checks) because of the bending of the wood at the knife edge.

MOISTURE CONTENT – The weight of the moisture in wood, expressed as a percentage of its oven dry weight.

OVERLAP – A condition where one piece of veneer in the same ply overlaps an adjacent piece.

QUARTER CUT – A method of slicing veneers whereby the average inclination of the growth rings to the wide surface is greater than 45 degrees.

QUILTED FIGURE – Although greatly resembling a larger and exaggerated version of pommele or blister figure, quilted figure has bulges that are elongated and closely crowded. Quilted grain looks three-dimensional when seen at its best. It's most commonly found in mahogany, maple, sapele and myrtle, and occurs only rarely in other species.

POMMELE – This figure resembles a puddle surface during a light rain – a dense pattern of small rings enveloping one another. Some say this has a "suede" or "furry" look. It's usually found in extremely large trees of African species like sapele, bubinga and makore. Some domestic species with a sparser, larger figure are referred to as "blistered".

PSA VENEER – Pressure sensitive adhesive, often referred to as peel and stick veneer. This is a self-adhesive veneer that doesn't require the application of glue and is used much the same way as contact paper.

RIBBON GRAIN – The ribbon effect produced by quarter slicing woods with interlocking grain.

RIFT CUT VENEER – A variation on the quarter cut appearance specifically used to eliminate medullary rays in white oak, which results in a broader stripe. Veneer is produced by centring the entire log in a lathe and turning it against a broad cutting knife, which is set into the log at a slight angle.

ROTARY VENEER – A veneer produced when a log mounted in a lathe is rotated against a cutting blade. This method of peeling is used to produce veneers for plywood manufacture.

ROUGH CUT – Irregular shaped areas of generally uneven corrugation on the surface of veneer, differing from surrounding smooth veneer and occurring as the veneer is cut by the lathe or slicer.

RUBBER MARKS – A raised or hollowed cross grain cut caused by a sliver between the knife and pressure bar.

SAPWOOD – The living wood occurring in the outer portion of a tree immediately under the bark. Sometimes is referred to as "sap". Generally it is lighter in colour than the heartwood, which is the part of the tree that is used for veneer.

SEQUENCE MATCHING – A method of arranging veneer faces such that each face is in order relative to its original position in the tree and, therefore, contains features of grain and figures similar to adjacent faces.

SLICED VENEER – Veneer produced by thrusting a log or sawn flitch into a slicing machine that shears off the veneer in sheets.

SLIP MATCH – The top sheet of veneer is slid into position with the sheet beneath it, and the face of both sheets exposed, instead of the back of one sheet and the face of another sheet as in book matching.

SMOOTH, TIGHT CUT – Veneer carefully cut to minimise peeler or slicer checks.

SOFTWOOD – General term used to describe lumber or veneer produced from evergreen or coniferous (needle and/or cone bearing) trees.

SPECIES – A distinct kind of wood.

SPIRAL GRAIN – The fibres form a spiral around the circumference of the tree.

SPLITS – Separation of wood fibres running parallel to the grain.

TELEGRAPHING – Visible irregularities in the surface of the face of the veneered panel or plywood caused by corresponding irregularities in the underlying core such as voids or zigzag stitches.

TENSION WOOD – Reaction wood formed typically on the upper sides of branches and leaning or crooked boles of hardwood trees. Characterised anatomically by little or no lignification and by presence of an internal gelatinous layer in the fibres. It has an abnormally high longitudinal shrinkage, tending to cause warping and splitting, and the machined surface tends to be fibrous or woolly especially when green.

TIGHT SIDE – In knife-cut veneer, that side of the sheet that was farthest from the knife as the sheet was being cut and containing no cutting checks (lathe checks).

WAVY GRAIN – Where the fibres form short undulating waves in a regular sequence.

1 INTRODUCTION

A growing use of decorative veneers and veneered panels in high value appearance wood products creates a need for an extensive technology transfer program related to veneering manufacturing procedures and product performance in various service conditions. However, limited information is available in Australia and overseas on the production of decorative veneer panels and product requirements.

In 2003, the decorative wood veneer industry in Australia recognised a need to develop a "Veneer Bible", a technical manual that would specify the best veneering procedures to ensure the production of top quality veneered products. Therefore, *A manual for decorative wood veneering technology* was developed by the University of Melbourne and funded by the Forest and Wood Products Research and Development Corporation (current name Forest and Wood Products Australia, FWPA). The Manual has been widely used both in Australia and overseas by veneer and veneered panel producers, furniture and joinery manufacturers, designers and architects, seeking to avoid product failures.

As significant developments in decorative veneers and veneering technology have been made since 2003, the FWPA commissioned the University of Melbourne to write the second edition of the Manual by updating and adding information on latest developments in veneer production, specifications, performance requirements, as well as applications and production of various veneered products.

The updated Manual covers all aspects of the veneering process, including the requirements for decorative veneers, substrate materials, glues and finishes, manufacturing procedures, storage and handling, the environmental benefits of natural timber veneers, typical problems related to veneered products and their prevention, and quality control in the production of decorative veneered products.

2 THE USE OF VENEER IN WOOD PRODUCTS

2.1 Types of veneers and their uses

A shortage of high grade decorative timber available for processing and manufacturing makes veneering technology extremely important from an environmental point of view. This method of manufacturing allows a small amount of resource to be extended substantially and enables furniture, cabinet and joinery manufacturers to accomplish designs that would be impossible or very expensive and difficult to create with solid wood.

A veneer is a thin slice of wood cut from a log using peeling, slicing or sawing methods, with its thickness determined by the end use. A veneer is used to make plywood, fine furniture and laminated shapes for construction, decorative and architectural purposes.

There are two major classifications of veneers:

- constructional
- decorative.

Constructional veneers are peeled veneers used mainly for production of plywood and laminated veneer lumber (LVL).

- Plywood consists of an odd number of laminations of veneer bonded at right angles to each other to equalise shrinkage and improve engineering properties.
- LVL is made up of parallel laminations of veneer, which are glued and processed together to form a timber material of a thickness similar to sawn timber.

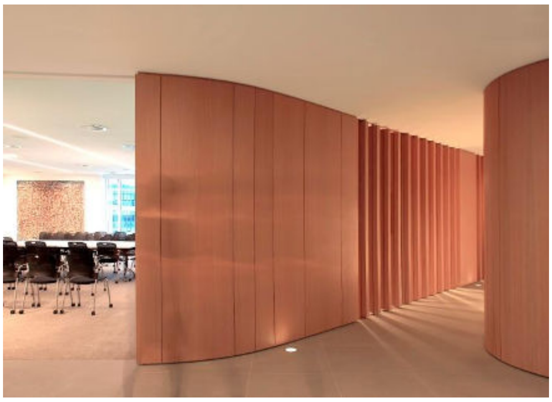
The distinguishing difference between LVL and plywood is the orientation of the veneer layers.

Decorative veneers are produced to display aesthetic surface appeal. There are four major types of markets or uses for decorative veneers:

- architectural
- secondary manufacturing such as furniture, joinery and cabinets
- profile-wrapped mouldings
- panelling.

Examples of different uses of decorative veneers are provided in Figure 1.

(a) (b)



(c) (d)

(e) (f)

Figure 1(a – f): Examples of wood veneer products

Photos:

(a) http://www.horizon-custom-homes.com/Veneer.html
(b) http://www.fitoutfurniture.com.au/index.php/
(c) http://www.trendium.net.au/
(d) http://www.timberawards.com.au/winners/timber-inspiration# - (Winner: Tobias Partners with Davenport Campbell for Gadens Lawyers)
(e) https://pinterest.com/wisewoodveneer/wood-veneer-and-products/
(f) http://www.glenholst.com.au/

2.2 Advantages of the use of veneered panels in wood products

The advantages of veneered construction may be summarised as follows:

- Veneer maximises the use of harvested wood. Less wood is used for the production of a wood product made with veneer in comparison with the same product made with solid wood. The majority of solid boards used for furniture tabletops are 25 mm thick. As veneer is usually 0.6 mm thick, about 40 slices of veneer can be obtained in comparison to one solid board of the same thickness. This results in the more economical use of wood by enabling the maximum surface area to be obtained from suitable materials.
- It permits the utilisation of highly figured timber showing unusual and beautiful effects due to grain irregularities. In many cases such timber cannot be seasoned economically in the form of boards.
- The uses of veneers opens great opportunities for designers. Most beautiful furniture can be designed through creating various patterns, which wouldn't be possible using solid wood. This can be done by combining veneers of several species of wood for contrasting borders and inlays or by using highly figured wood such fiddle-back, bird's eye and flame wood. It also enables the use marquetry in furniture design to create beautiful pictures and patterns.
- Some parts of trees, such as burls and stumps or distorted logs that provide highly figured and coloured wood, can be utilised for decorative purposes when sliced into veneer but are structurally unsound in the solid wood.
- Veneered panels are less prone than solid figured timber to shrink, check and warp.
- The cores of veneered panels (medium density fibreboard (MDF), particleboard or plywood) are used to provide stability and strength, and to provide the most suitable foundation for displaying the veneers to the best advantage. It should be pointed out that these panels are made from low quality trees and wood waste.
- Bent and curved panels are readily fabricated by the gluing up of veneer between shaped forms, often using accelerated curing methods such as radiofrequency or electrical resistance heating.
- Using modern veneering techniques, such as a vacuum system, allows for pressing the veneer into a substrate of various shapes.
- Veneer provides a unique opportunity to work with some of the most extraordinary and exotic woods in the world by creating beautiful designs.

3 PRODUCTION OF DECORATIVE VENEERS

3.1 Selecting veneer quality trees and logs

Veneer and veneered products are produced from both hardwood and softwood tree species.

The raw material requirements for logs used for veneer production are different for peeled and sliced veneers. The criteria for log selection mainly relate to log size, shape, quality and grades, but also include log transport and handling requirements.

- Rotary cut or peeled veneer – in the past only logs of large diameter, cylindrical in shape and with minimum defects were used, but due to developments in recent manufacturing techniques and modern equipment, very small diameter logs can now be economically utilised for plywood products.
- Sliced veneers – requirements are more specific regarding the log quality, diameter and shape, as a greater emphasis is placed on decorative effects and value of the end product.

The manufacturing of quality decorative veneer is an exacting and expensive process. If a log ends up being lower in quality than anticipated, it can often cost more to manufacture the veneer than what it can be sold for. As a result, veneer companies are usually very selective in what logs they can use. However, each company has its own specialised markets, and therefore, the quality of logs that are acceptable will vary from one company to another.

Determining the value of veneer trees is extremely difficult because a judgement decision has to be made on the quality of the wood without actually seeing it. The site, soil type, overall condition of the timber stand and its history are of major significance. Also of importance are tree form (straightness and taper) and visible defects.

It is difficult to select the highest quality logs because many internal defects are difficult to detect from the outside of the log.

The following factors need to be assessed in the round log form:

- end splits
- visible faults (knots, pin-knots, gum veins, decay and insect damage)
- dimension
- colour
- texture
- shape.

To meet present day quality standards, a veneer surface should, as far as possible, be free of defects, uniformly coloured and evenly textured. This means that a great deal of experience and knowledge of veneer is required to ensure correct, optimal conversion.

3.2 Production of flitches

Logs selected for veneer production are usually inspected with a metal detector. They are debarked and cut to the desired length into flitches (in Australia they are usually 2.4 m to 3.9 m long). The flitches may be squared up with a saw. The method of "shaping" the flitch depends on the log quality and size, which then determine the method of slicing. The shaping also eliminates the need to trim the veneers to manageable sizes and shapes.

The flitches are heated in water vats or steamed to soften the wood, making it easier to slice or cut and to improve the quality of the veneer produced.

Schedules, in terms of temperature and of time, depend on species, size, density and figure variation.

Heating or cooking schedules vary greatly, depending on the species and the size of flitches and the manufacturer. The temperature usually varies between 50°C and 90°C. The heating time is between 24 to 36 hours, however some high density species require heating for many days.

Undercooked logs will not slice smoothly. Overcooked logs can become fuzzy and "hot cut". How a log is cooked will determine its colour in veneer form.

It is important to note that lighter woods such as maple (*Acer* spp.), sycamore (*Platanus* spp.) and ash (*Fraxinus* spp.) can easily turn brown if they are left to cook for too long. Therefore, these timbers are not heated or only heated for a short time because the light colour of these timbers is highly desired. On other hand, walnut (*Juglans* spp.) is heated for extended periods to even the colour. After slicing, the walnut veneer is allowed to set overnight. This process is called "sweating" and it allows the colour to darken before drying.

3.3 Veneer cutting methods

The method used to cut veneers is an important factor in producing the various visual effects. Two logs of the same species, but with their veneers cut differently, will have entirely different visual characteristics.

Generally there are three major methods of veneer cutting: rotary peeling, slicing and half-round slicing. These methods produce different grain patterns regardless of the wood species involved.

3.3.1 Rotary peeling

The log is mounted centrally in the lathe and turned continuously against a knife (Figure 2). The veneer is "unrolled", much like a ribbon. Since the cut follows the log’s annual growth rings, a bold variegated grain marking is produced. Rotary peeled veneer is exceptionally wide. The veneer is then clipped to width and objectionable defects are removed.

This is the common procedure for manufacture of commercial veneers for construction-grade plywood from softwood species. This method is also used for producing veneer from some hardwood species.

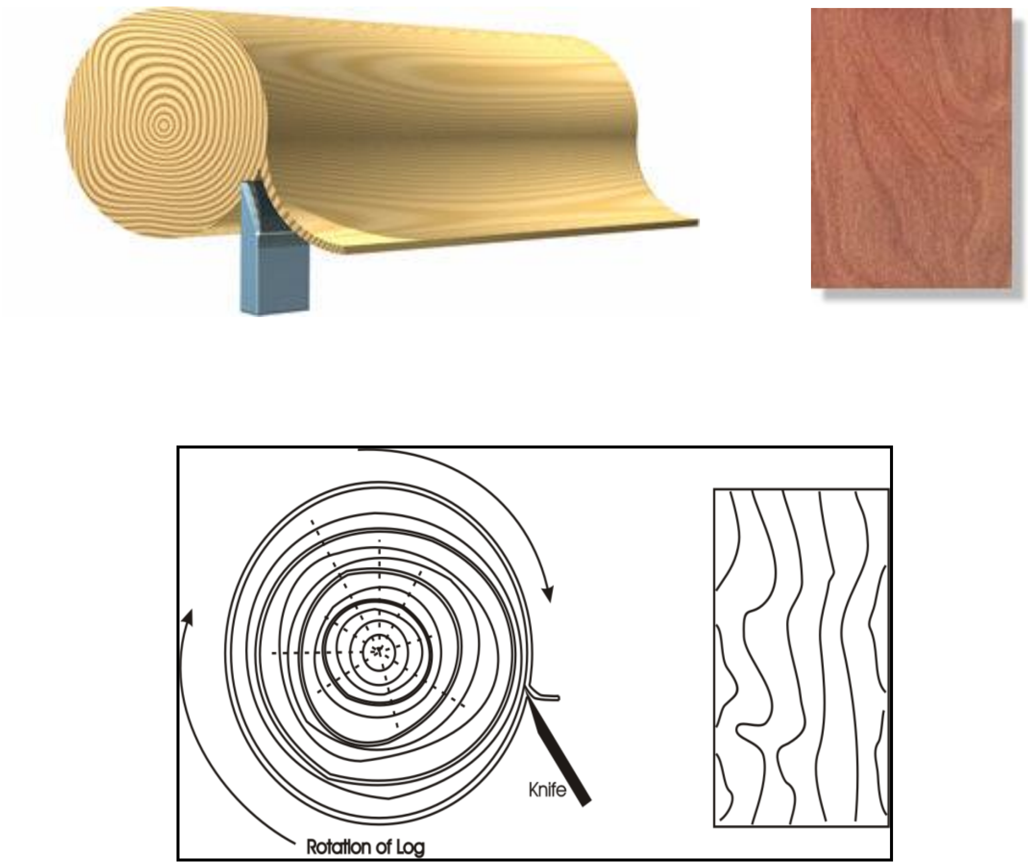


Figure 2: Rotary peeling of veneers

Peeling large diameter, good quality logs is commonly done using a spindle veneer lathe. However, for peeling small diameter plantation logs, a spindleless lathe is widely used. Originally developed by the Meinan and the Durand-Raute companies, these peeling machines are now produced by many companies, particularly in China.

The principle of the spindleless lathe is the rotation of the log using three rolls: the top roll functions as a roller nose bar while the two bottom rolls move in a linear direction, which is controlled by a servo-cylinder (Figure 3). The cutting knife is in a close parallel position with the top roll. The spindleless lathe can also peel peeler cores left from a spindle lathe, which allows for maximum veneer recovery in the veneer mill.

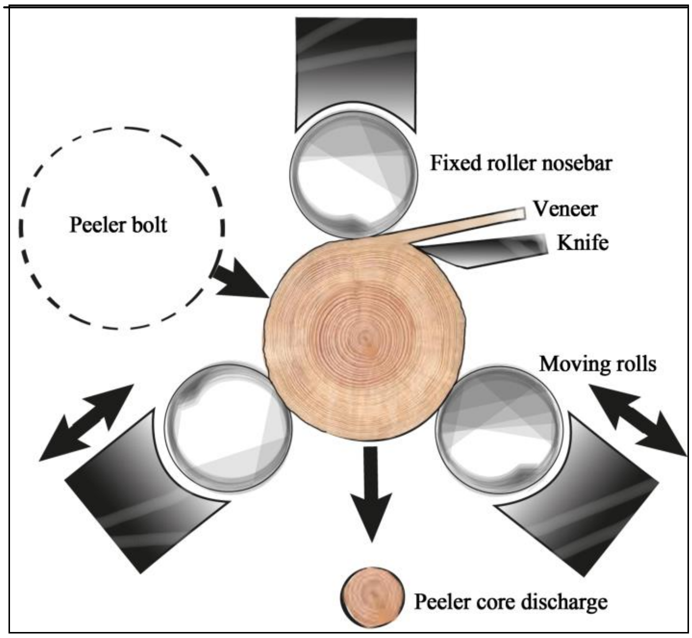


Figure 3: Principles of peeling with a spindleless lathe

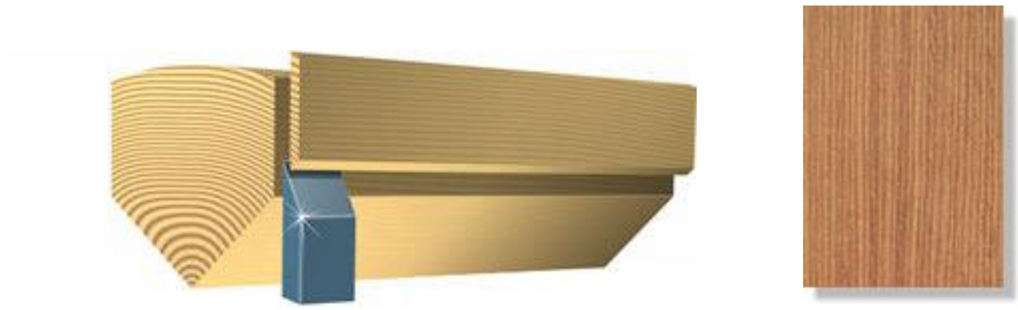
3.3.2 Slicing

Slicing is used to produce decorative veneers. There are various methods of veneer slicing such as quarter cut, crown cut, half-round and rift cut.

3.3.2.1 Quarter cut

The quarter log or flitch is mounted on a metal frame so that the growth rings of the flitch strike the knife at approximately right angles, producing a series of stripes, straight in some timbers or varied in others (Figure 4). This cut requires the largest diameter logs, usually from tropical species.

In this method, the average inclination of the growth rings to the wide surface is greater than 45 degrees.



(Source: http://www.oakwoodveneer.com/index.html)

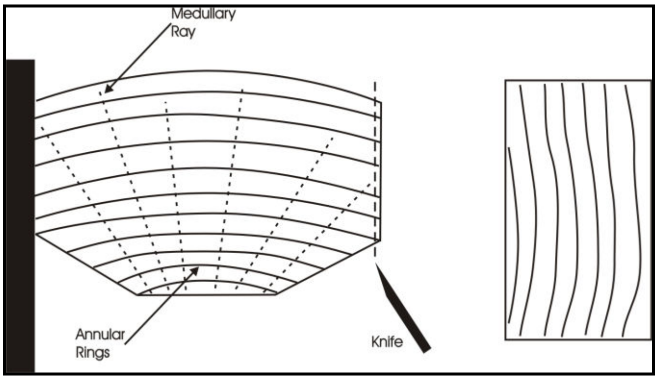


Figure 4: Quarter slicing of veneer

3.3.2.2 Crown cut or flat slicing

The half log, or flitch, is mounted on a metal frame with the heart side flat against the guide plate. The frame moves up and down against a knife in a straight plane parallel to a line through the centre of the flitch (Figure 5).

As each slice of veneer is removed from the flitch, the knife moves forward the same distance as the thickness of the veneer that is removed. This is repeated until the entire flitch is converted into veneer. As the veneer is removed from the flitch, it is kept in the same sequence, and the flitch is literally re-built in veneer form. This is important for its future use.

The grain pattern gradually changes from one piece to the next and follows the grain of the log as it too changes.

This cut of veneer is ideally suited for wall panels and furniture because of the consistency in its grain and the ability to match sequences of leaves in "bookmatched and endmatched" patterns.

In Australia, an equivalent term "back-sawn" is used for solid timber cut in such a way that the wide surface of the board is a tangential plane to the growth rings.

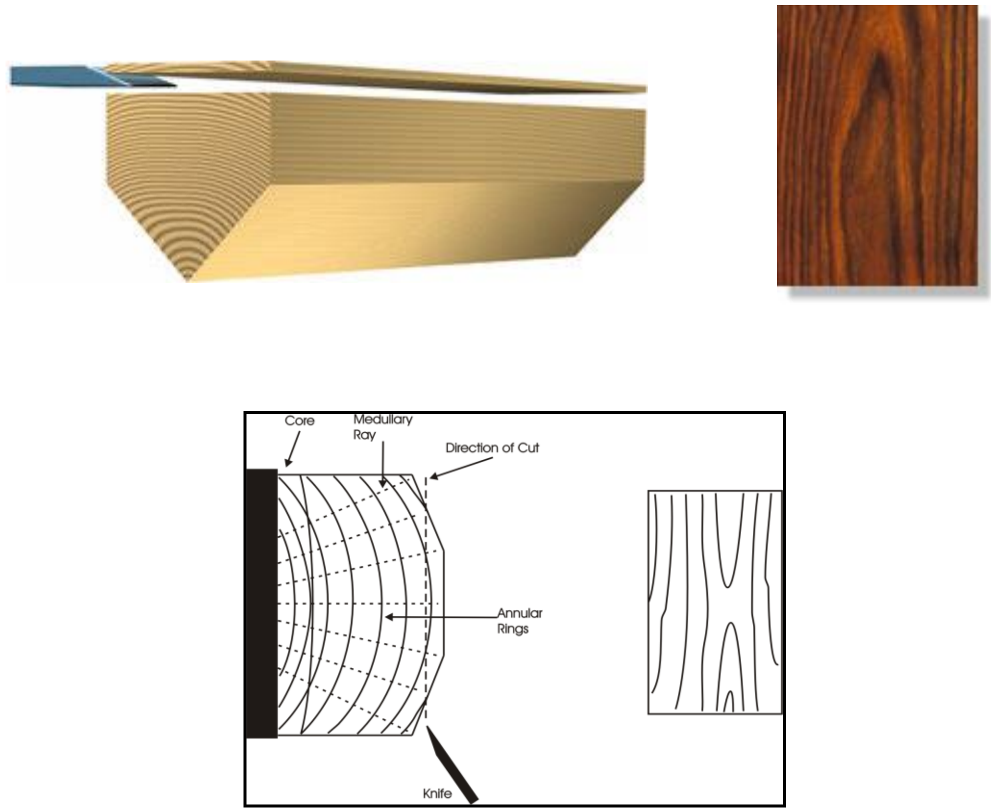


Figure 5: Crown cut or flat slicing of veneer

A slight variation of flat slicing is “lengthwise slicing” where the veneer is sliced lengthwise from a board of flat or quarter sawn lumber rather than from a flitch (Figure 6).

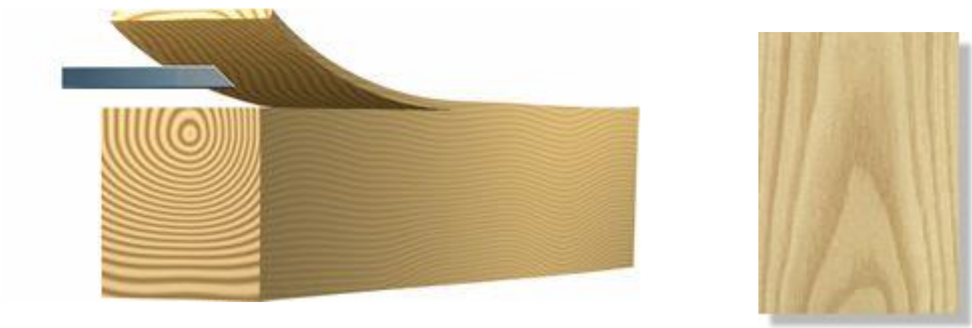


Figure 6: Lengthwise slicing of veneer

3.3.2.3 Half-round slicing

This method is a variation of rotary cutting. Segments or flitches of the log are mounted off centre in the lathe and then rotated against a knife and a pressure bar (Figure 7). This results in the veneer being cut in a curved manner slightly across the annual growth rings. The veneer visually shows modified characteristics of both rotary and flat sliced methods.

This method produces a wider sheet of veneer from a given size of log as compared to a flat slicing method. As a result, smaller logs can be used for veneer production. This technique is ideally suited for the production of veneer from plantation logs of a relatively young age and smaller diameter.

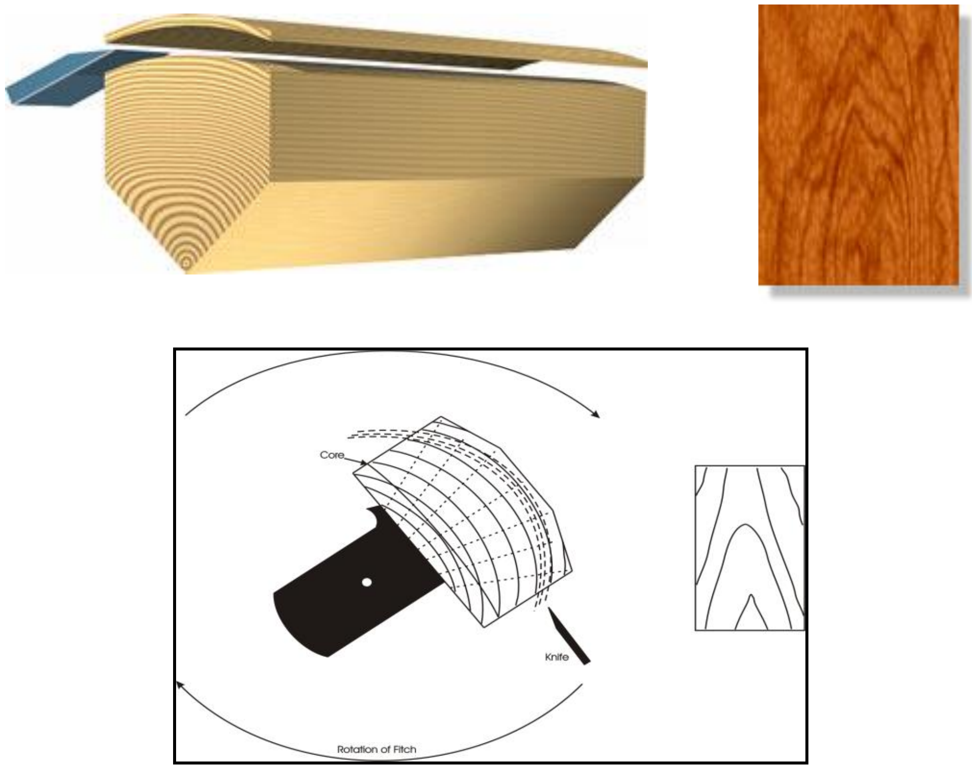


Figure 7: Half-round slicing of veneer

3.3.2.4 Rift cut slicing

Rift cut veneer is produced in the various species of oak (*Quercus* spp.). Oak has medullary ray cells, which radiate from the centre of the log like curved spokes of a wheel. The rift or comb grain effect is obtained by cutting at an angle of about 15 degrees off the quartered position to avoid the flake figure of the medullary rays (Figure 8).

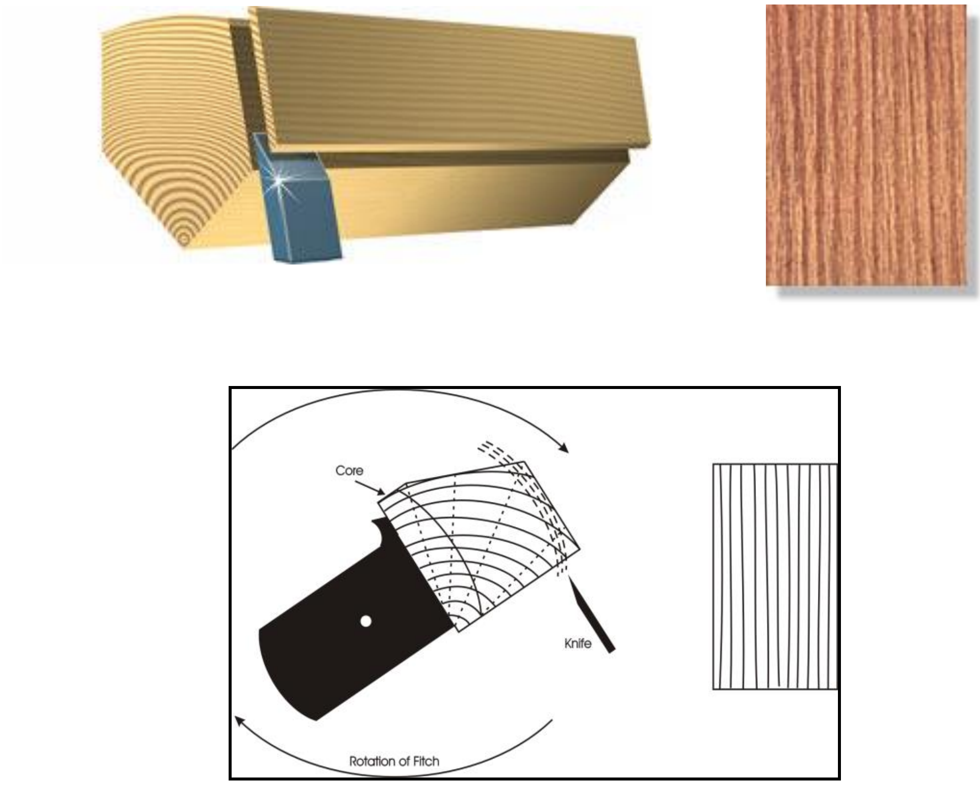


Figure 8: Rift cut slicing of veneer

The selection of a slicing method depends mainly on the log diameter, log quality and the veneer pattern desired for the wood product that will be manufactured.

The relationship between slicing method, slicing pattern and log quality was investigated by Wiedenbeck et al. (2004). The study, based on interviews with veneer log buyers and sellers, veneer manufacturers and veneer sellers in United States, provided valuable information on the criteria used for selecting veneer production methods for various veneer applications. The results of the Wiedenbeck et al. study are presented in Table 1.

Table 1: Veneer production equipment, slicing patterns and factors considered in determining how a veneer log will be sliced. Reproduced from Wiedenbeck et al. (2004).

Type of slicer	Slicing pattern	Selection factors
Vertical	Flat	1) Slicing larger diameter logs
		2) Producing veneer to maximise cathedral pattern
		3) Producing veneer for bookmatching into wall panels and wider furniture panels
	Quartered	1) Slicing larger diameter logs
		2) Producing straighter grained veneer
		3) Producing white oak veneer with flake
		4) Slicing mahogany, teak, and walnut
Stay-log	Half-round	1) Slicing smaller diameter logs
		2) Species for which maximising the recovery of sapwood is important
		3) Accentuating the grain pattern on highly figured woods such as burl
	Rift	1) Slicing red and white oak to minimise ray flake
		2) Producing veneer to minimise cathedral pattern
Horizontal	Lengthwise	1) Slicing boards rather than flitches
		2) Producing veneer with a highly variable grain pattern
		3) Achieving optimal veneer recovery because entire workpiece is sliced into veneers

3.3.3 Reconstructed veneer

More than 30 years ago Alpi, an Italian wood products company, developed a novel natural wood veneer product whose colours and grain can be manipulated according to a designed pattern. The veneer, known as reconstructed or multilaminar veneer, uses sustainable plantation wood to reproduce decorative effects typical of quality wood species (often protected and rare).

The manufacturing process consists of several stages: log selection and peeling, dying, gluing and pressing, slicing and final inspection (Figure 9).

REMARK

Permission was provided by Greenline Industries to use the description of the process provided on the company website http://www.greenlineforest.com.

1) Log peeling

Logs are carefully selected, cut to required sizes and debarked. The logs are then peeled into thin sheets of veneers. The thickness depends on the manufacturer's production methods used in subsequent processing and type of reconstructed veneer produced. The veneers are segregated according to quality and various characteristics.

2) Veneer dying

The dying process is used to dye the veneer sheets to the required colour shades. The veneers are placed in stainless steel tanks that contain water soluble dyes at controlled temperatures. The composition of the dyes and the dying parameters are usually treated as confidential information by the veneer producing companies. The soluble organic dyes are free of chromium and other heavy metals. The veneers are left in the tanks until the dye completely penetrates each individual leaf of veneer. Once the desired color has been achieved, the leaves are unloaded from the tanks and dried. The veneers are then inspected to ensure that they are coloured evenly throughout their thicknesses.

3) Veneer gluing and pressing

Before gluing, the dyed sheets of veneer are selected and stacked with the fibres in the same direction in a particular sequence according to the design pattern of the reconstructed veneer that is being produced. There are numerous formulas for veneer stacking sequences used by various companies, depending on the final pattern of the reconstructed veneer. In a more advanced production process, a computer-automated system is used to mix veneers from different coloured tanks in a systematic manner.

The veneers are passed through a roller glue spreading machine, which smears glue on each sheet. Dyed glue is used to create the contrast as part of the grain definition. Special aesthetic patterns can be obtained, depending on the colour of the glues used. Once the stack of bonded sheets has been laid up to the exact specifications in the formula, it is then sent to flat or specially shaped presses, depending on the required design, to bond the leaves together and create a large, rectangular block. This block is now ready to be sliced into sheets of veneer.

4) Slicing of the block into multilaminar veneer

The block is mounted to the flitch table of the slicing unit and runs across a large blade that slices thickness controlled leaves of veneer. The process of creating reconstructed veneer is complete. The veneer is now ready to be further processed into spliced faces for lamination onto different substrate materials.

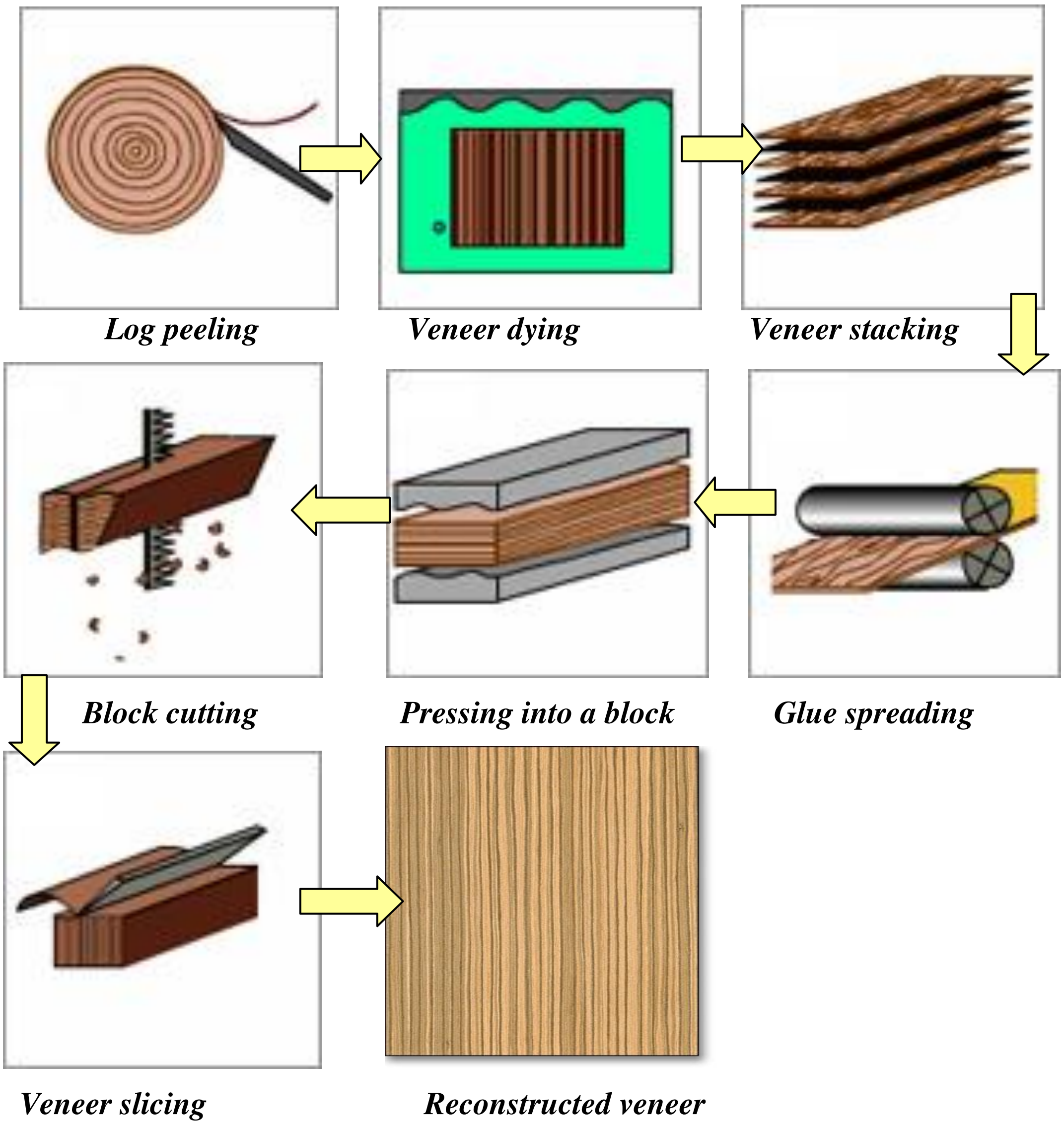


Figure 9: Production of reconstructed veneer

The manufacturing process is fully automated and often involves the use of computer software developed specifically for different veneer figures and patterns. A wide range of veneers of different colours and grain patterns can be produced (Figure 10).

Figure 10. Examples of reconstructed veneers (Source: http://www.greenlineforest.com)

3.4 Veneer figure

The pattern seen on the surface of a veneer is known as the “figure”. It results from two main factors:

- interaction of several natural features e.g. the frequency of growth rings, the colour tone variations between earlywood and latewood, type of grain (wavy or curly grain, interlocked grain), markings and pigments in the wood structure, burls or curls
- the way the flitch is cut to achieve the desired figure.

There are several types of figures that are desirable in decorative veneers. Examples are provided below.

3.4.1 Burl or burr

This is a large abnormal growth or excrescence on either trunk or branch, and is formed by the local development of numerous dormant buds, often caused by some injury to the tree. The interwoven mass of wood elements gives an attractive and unusual figure, whichever way it is cut (Figure 11).

Figure 11: Walnut burl (Source: http://www.27estore.com/walnut-burl)

3.4.2 Crotches and buttresses

In the crotch of a forked tree or at the base of a buttresses tree, the folding or wrinkling of the wood elements is quite marked. These parts of trees of certain species are in demand for veneer (Figure 12).

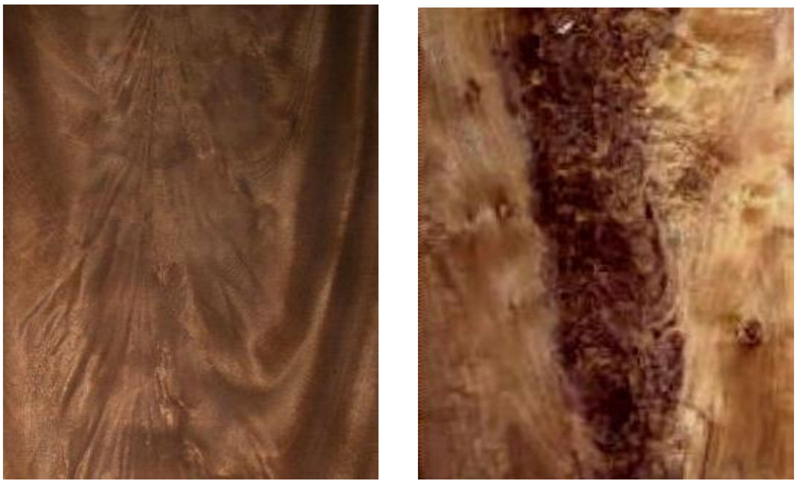


Figure 12: Mahogany (*Swietenia* spp.) and walnut crotch (Source: http://wood-veneer.com)

3.4.3 Wavy figure and fiddle-back

Logs with wavy grains, when quarter cut

, produce beautiful veneer with wavy patterns. Light is reflected at varying angles from quarter cut surfaces because the individual elements are cut across at varying angles. When the wave is fine and regular, the markings on quarter cut surfaces are also regular and appear as lustrous bars across the veneer leaf (Figure 13). Such grain is termed “fiddle-back” and is commonly found in such species as redgum (*Eucalyptus camaldulensis*), blackwood (*Acacia melanoxylon*), mountain ash (*Eucalyptus regnans*), alpine ash (*E. delegatensis*), jarrah (*E. marginata*) and others.

(a) Anegre (*Pouteria* sp.) veneer (Source: http://specialprojectsdivision.wordpress.com)

(b) Tasmanian blackwood (Source: http://tasmaniantonewoods.com)

Figure 13: Examples of fiddle-back veneers

3.4.4 Curl

Veneer from the junction of a branch and the main trunk gives the attractive curl figure. Beautiful curl veneers are also cut from the main root members of some trees (Figure 14).

Figure 14: Sycamore curl and mahogany curl veneers (Source: http://www.relianceveneer.com)

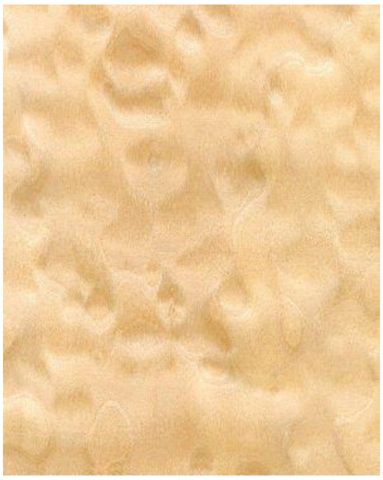
3.4.5 Bird's eye

This figure may be seen on back-sawn surfaces of certain species as numerous rounded areas resembling small eyes (Figure 15). Bird's eye is caused by small conical depressions of the fibres. It is common in maple and is also found in the Australian species, musk (*Olearia argophylla*), which as a result is highly prized. Radiata pine (*Pinus radiata*) sometimes exhibits a similar effect, but such material is not segregated commercially.

Figure 15: Bird's eye maple veneer (Source: http://www.woodworksuk.com/wood.html)

3.4.6 Quilted figure

Although greatly resembling a larger and exaggerated version of pommele or blister figure, quilted figure has bulges that are elongated and closely crowded. Quilted grain looks veritably three-dimensional when seen at its billowy best (Figure 16). It is most commonly found in mahogany, maple, sapele and myrtle, and occurs only rarely in other species.



(a) Maple quilted veneer (Source: http://www.winwood-products.com)

(b) Honduras mahogany (*Swietenia macrophylla*) (Source: http://www.exotichardwood.com)

Figure 16: Examples of quilted veneers

3.4.7 Pommele

This figure resembles a puddle surface during a light rain: a dense pattern of small rings enveloping one another (Figure 17). Some say this has a "suede" or "furry" look. It is usually found in extremely large trees of African species like sapele (*Entandrophragma* sp.), bubinga (*Guibourtia* spp.) and makore (*Tieghemella heckelii*). Some domestic species with a sparser, larger figure are referred to as "blistered". The veneer is always peeled to maximise the figured effect.

Figure 17: Sapele pommele veneer (Source: http://www.relianceveneer.com)

3.4.8 Pecky and Masur birch

This figure, as the name implies, appears to have been pecked by a bird, leaving darkened marks over the surface (Figure 18). It is much like the bird's-eye figure and is also caused by an infection of the annular growth ring. When one species, the Scandinavian birch (*Betula* sp.), exhibits this figure, it is called Karelian or Masur birch. It is a pinkish white veneer with dark brown peck marks over the entire surface. Another North American veneer that often displays this figure is pecan (*Carya illinoinensis*).

Figure 18: European Masur birch and pecky pecan veneer (Source: http://www.hobbithouseinc.com/personal/woodpics/_pecky.htm)

4 VENEER GRADING AND TECHNICAL REQUIREMENTS

4.1 Grading rules

The development of grading rules for decorative veneers is a very difficult task because each flitch of the veneer provides a unique pattern of figure and grain.

In Australia, a large number of veneer species, both native and imported, are being used. As all these veneers have different characteristics; they vary in colour, grain pattern and features. Therefore, one set of grading rules for decorative veneers, if such were to be developed, would not fit all sliced veneer for all applications.

4.1.1 Grading rules in Australia

In Australia, there are two standards related to decorative peeled and sliced veneers, which are used by veneer producers, specifiers and manufacturers of veneered panels:

- Australian/New Zealand Standard AS/NZS 1859.3: 2005 *Reconstructed wood-based panels – Specifications. Part 3: Decorative overlaid wood panels*
- Australian/New Zealand Standard AS/NZS 2270: 2006 *Plywood and blockboard for interior use*.

AS/NZS 1859.3: 2005 ***Reconstructed wood-based panels – Specifications. Part 3: Decorative overlaid wood panels***

This standard provides performance requirements and specifications for the manufacture and application of decorative overlaid wood panels. It includes four types of decorative overlay applied to wood panel substrates: termed low pressure melamine, polyvinyl chloride (PVC) film, paper foils and wood veneers.

According to this standard, wood veneer used as the overlay on decorative wood panels should comply with the following requirements:

Face grade veneers

Face grade veneers should exclude the following:

- open joints
- overlapping joints
- splits
- non-natural discolouration
- Any other faults detrimental to the finish and appearance of the surface.

REMARK

Natural cracks and holes are permitted in some exotic veneers and burls. These may require attention during finishing.

Backing grade veneers

Backing grade veneers may be of lower quality than face grade veneers. The following imperfections are permitted:

- minor open joints, overlaps, knots, knotholes, splits and mismatching
- mild discolouration
- natural blemishes such as gum veins and knots
- other minor faults that do not impair the integrity of the veneer.

REMARK

Patching of open defects with a suitable filler of matching colour can be arranged subject to agreement between supplier and purchaser.

Grading rules described in this standard have been adopted by the Australian veneer industry and are widely used when specifying veneered boards.

The requirements for decorative wood veneer panels specified in the above standard, such as types of adhesives; performance and durability of veneer bond; construction of veneered panels; finishing, storage and handling of panels; are described in the relevant chapters of the Manual.

AS/NZS 2270: 2006 *Plywood and blockboard for interior use*

The objective of this standard is to provide minimum performance requirements and specifications for appearance and non-appearance grades of plywood and blockboard acceptable for use in fully protected interior applications in Australia and New Zealand. All veneers in a finished sheet of plywood or blockboard for interior use may be rotary peeled or sliced.

The standard specifies veneer and core strip qualities, bond quality, joints, panel construction, dimensional tolerances, moisture content (MC), finishing and branding.

Five veneer qualities, i.e. A, S, B, C and D, are prescribed. Veneer qualities A, S and B are suitable for use in plywood and blockboard face veneers intended for use in aesthetic applications while veneer qualities C and D are suitable for veneers intended for non-aesthetic applications and back veneers. The specifics of these qualities are as follows.

1. Plywood and blockboard intended for aesthetic applications:

a) Face veneer qualities:

- Quality A – a high quality appearance grade, suitable for clear finishing

- Quality S – an appearance grade that permits natural characteristics as a decorative feature
- Quality B – an appearance grade suitable for high quality paint finishing

b) Back veneer qualities:

- Quality C – a non-appearance grade with a solid surface
- Quality D – a non-appearance grade with permitted open imperfections

2. ***Plywood and blockboard intended for non-aesthetic applications – face and back veneer qualities:***

- Quality C – a non-appearance grade with a solid surface
- Quality D – a non-appearance grade with permitted open imperfections.

The grade of the plywood is determined by the quality of the face and back veneers.

4.1.2 Overseas grading rules

In the United States, the grading of timber and veneer is done according to the ANSI/HPVA HP-1-2009 standard from the Hardwood Plywood and Veneer Association (HPVA). It is voluntary consensus standard, meaning compliance is voluntary, and the contents are a result of a consensus of those involved in its development. This is done because of the natural differences between timber boards or veneer sheets, even from the same tree: every grade includes a range of appearance from the low end of the grade to the high end. The standards provide tables with most commonly used timbers in North America and the differentiation between grades (depending on the species) from AA to C for the face of the veneer (http://columbiaforestproducts.com/GradingGuide/Standards).

The tables in the ANSI/HPVA HP-1 standard establish a minimum appearance for each grade. In other words, the tables essentially say that if a given attribute such as a small burl is present, it can’t exceed the size and quantity restrictions listed in the table.

While the standard consists of numerous sections and complete tables for every grade of face and back by species category, it also includes sections and tables relating to core requirements, glue performance, formaldehyde emissions, dimensions and tolerances, and testing methodology.

Similar to the United States, countries like Chile grade veneer from AA to D standards, depending on the quality of the surface and the percentage of anomalies, such as knots, burls or bark pockets.

In Europe the grading system is performance based i.e. panels are classified in terms of their intended end use conditions. European standard BS EN 635: *Plywood – Classification by surface appearance*, establishes general rules for the classification of plywood by its surface appearance. The classification is made according to the number and the extent of certain natural characteristics of wood and the defects that arise from the manufacturing process. Five appearance classes are distinguished – E, I, II, III and IV. The grading can be compared to the one used in the United States.

4.2 Dimensional tolerances of veneer

Decorative veneers are produced in Australia at a nominal thickness of 0.6 mm (AS/NZS 1859.3: 2005).

- Each piece of veneer leaf shall be of sound timber, smoothly and tightly cut to a uniform thickness. Veneer thickness shall be 0.5 mm to 0.7 mm or as agreed between purchaser and supplier.
- Veneer leaf shall be cut such that the long edges or edges parallel to the grain are parallel and clean cut. Leaf shall be edge butt jointed by suitable means to form a lay-on of the required grain pattern and dimensions.

REMARK

A veneer lay-on is made up of a number of pieces of veneer leaf, suitably matched for figure and colour according to purchaser requirements.

In North America the standard thickness of veneer demanded by the domestic market is 0.8 mm (it may vary between 0.7 and 0.9 mm) while in Europe and Asia the thickness generally varies between 0.3 and 0.7 mm. New veneer applications and modern sanding technologies in Europe and Japan enable super-thin veneer of between 0.1 and 0.3 mm thickness to be used (Wiedenbeck et al. 2004).

4.3 Veneer moisture content

Veneer, as a very thin material, responds quickly to humidity changes. Therefore, it is critical that the value of the veneer MC is as close as possible to the average value of the equilibrium moisture content (EMC) for the intended service conditions.

According to the Australian/New Zealand standard (AS/NZS 1859.3: 2005), veneer leaf MC should be in the range of 6% to 12% prior to making up into lay-on and also prior to pressing onto the substrate. However, it should be pointed out that according to the standard requirements (AS/NZS 1859.1, 1859.2 and 1859.4) the MC of the substrate should be in the range of 8% and 12%. From the author's experience, the use of such a wide range of MC for the veneer and substrate could result in a high moisture gradient between two types of laminated materials. For example, the use of veneer of 6% MC and MDF of 12% MC would certainly cause severe veneer checking in service. Therefore, to avoid any possible failure, it is recommended that the MC of veneer and substrate be between 8% and 10%. However, some brittle veneers are difficult to handle when their MC is below 11%. In such cases, the MC can be increased to 11% or 12%.

Severe problems may occur if the MC of veneer is too high or too low. If veneer with too high a MC is used for production of furniture panels and then the furniture is used in a dry environment (such as an air-conditioned or centrally heated building) it will dry out and shrink significantly, resulting in splitting and cracking.

The MC of the veneer should be measured with a moisture meter. There are special moisture meters available for measuring MC of veneers. It is important to use correction factors for various veneer species. These can be obtained from any supplier of moisture meters.

If the MC of veneers is too high they should be re-dried. There are various methods that can be used for re-drying veneers whilst keeping them flat. One method is to put a stack of veneers in a warm press (slightly above room temperature) and leave them overnight. Another method is to put a few sheets of veneer in a hot press (about 60°C) for two to three hours, between two pieces of dry, absorbent board, which will remove excess moisture.

REMARK

The correct MC of veneers and substrate is a critical factor in the manufacture of high quality and high performance veneered products.

4.4 Flattening of veneers

4.4.1 General requirements

One of the main prerequisites for good veneering work is that the veneer must be flat. However, veneers often buckle or warp in various ways. The primary causes of general buckling of veneer are tension wood in hardwoods, compression wood in softwoods, irregular grain and non-uniform drying. In all cases, buckle is caused by unequal stresses across or parallel to the grain of a sheet of veneer.

Buckled veneer can be flattened by various methods, which are based on the application of moisture, heat and pressure. The most commonly used method involves the application of a mixture of water with glycerine to the veneer to dampen the wood. Various proportions of the two liquids are recommended. Usually a solution of 10% glycerine to 90% water is used. A sheet of dry absorbent material (e.g. particleboard, brown kraft paper) is inserted between every six to ten sheets of veneer (depending on the species and its density) to absorb excess moisture. The veneer is then kept flat in a warm press. The time in the press can be varied, but two hours at 60°C is thought to be adequate provided sufficient absorbent material is included within the stack in the press.

4.4.2 Flattening burl veneers

Laying burls and curl veneers may cause difficulties because their surface usually is not flat but presents a mass of brittle knots and short fibres. These veneers are often dried with a slightly higher MC than ordinary veneers, which makes them less liable to crack or break in handling.

However, it is almost impossible to prepare and handle burl veneer with low MC. To overcome this problem, the veneers need to be dampened to make them more flexible prior to flattening and, unless they are dried carefully, this treatment can increase the risk of cracking in later stages.

There are methods of flattening burls whilst minimising the risk of cracking. The most effective procedure is as follows (FIRA 1991b).

- Dampen every third or fourth veneer in a stack of ten to twelve with a sponge or rag dipped in water.
- Wrap stack in a plastic film for 24 hours to enable all veneers to reach an equilibrium.
- After removing veneers from plastic film, place a panel of a dry particleboard in the centre of the stack.
- Lightly press the stack in a heated press at 80°C for two hours.
- After removing the stack from the press, remove dampened particleboard from the centre and replace with a similar dry panel.
- Place stack under a light pressure between two panels of dry particleboard or plywood in a dry atmosphere for one or two days.

The above method can be used for flattening not only burl veneers but also other buckled and wavy veneers.

5 REQUIREMENTS FOR SUBSTRATES USED IN VENEERED PANELS

5.1 Types of substrates

Various types of substrates can be used for the production of veneered panels, such as particleboard, MDF, plywood, blockboard and lightweight panels. Requirements for most commonly used substrate materials are provided below.

5.1.1 Particleboard

Particleboard is an engineered wood product manufactured from lignocellulosic materials (usually wood) primarily in the form of particles, flakes or strands bonded together with synthetic resin, or other binder, under heat and pressure until cured.

The advantages of using particleboard in veneered panels are smoothness, surface integrity, uniform thickness, uniform properties, machinability, good dimensional stability and ability to stay flat. However, as the edges are not suitable for coating, the panels have to be finished with veneer or solid wood edgings.

Both standard and moisture resistant particleboard panels are available for the production of veneered panels.

1) ***Standard particleboard*** is suitable only for interior applications. It is not suitable for exterior use or in interior areas where wetting or prolonged high humidity conditions are likely to occur. It is used mainly for furniture and general fit outs.

   Standard particleboard uses a urea formaldehyde (UF) resin, with paraffin wax added to the surface layers to protect against accidental water spillage.

2) ***Moisture resistant (MR) particleboard*** is manufactured using melamine-urea formaldehyde (MUF) resin (plus other additives), with a substantial melamine content. In order to distinguish MR particleboard from standard particleboard, a green dye is added to the resin mixture. MR particleboard is also manufactured from other MR resins (such as phenol formaldehyde, tannin formaldehyde or co-condensates of these with UF). In such cases it is dark brown in colour and so readily distinguished from the UF bonded product. The green colouration is only necessary if MUF resin is used. Wax emulsion is also added to the resin system for MR particleboard. Wax imparts resistance to the penetration of liquid water by providing water repellent properties to board surfaces.

   As per standard particleboard, MR particleboard should only be used for interior applications. It is suitable for areas with high humidity and occasional wetting such as bathrooms, kitchens, laundries and for furniture in tropical areas. It is important to remember that moisture resistant does not mean waterproof.

5.1.2 Medium density fibreboard (MDF)

MDF is an engineered wood product manufactured from wood fibres, as opposed to veneers or particles, bonded together with synthetic resins or other binders under heat and pressure until cured. MDF has an even density throughout and is smooth on both sides. Paraffin wax is added to assist with water repellency, while other chemicals can be added during manufacturing for more specific protection.

MDF is primarily used for internal use applications as a substrate material due its smooth surface and edge-finishing qualities. Other advantages include good dimensional stability, flatness, close tolerances, impact resistance, good machining characteristics, low glue usage and lack of grain-telegraphing, high bond strength and screw holding characteristics.

Both standard and MR MDF panels are available.

a) ***Standard MDF*** is suitable only for interior applications such as furniture and general fit outs. It is not suitable for exterior use or in interior areas where wetting or prolonged high humidity conditions are likely to occur.

b) ***Moisture resistant (MR) MDF*** should only be used for interior applications. Being “moisture resistant” means it is suitable for areas of high humidity and occasional wetting; such as bathrooms, kitchens and laundries and for furniture in tropical areas. While standard MDF uses a formaldehyde-based resin, which is thermosetting, MR MDF uses MUF to provide moisture resistant properties and increase dimensional stability.

5.1.3 Plywood

Plywood is used sometimes as a core material but not as widely as particleboard and MDF. It is a very stable product with a very little risk of warping. Decorative veneers are laid with grains at right angles to that of the plywood surface in order to maintain the alternating grain direction in the structure of the substrate.

5.1.4 Blockboard

Blockboard is usually made of strips of wood about 25 mm wide, glued together with the heartwood facing in alternate directions.

In Australia, blockboard is rarely used in the production of decorative veneered products. In Europe, it is often used in joinery and architectural products.

5.1.5 Lightweight panels

Modern lightweight wood panels, which are based on sandwich structures, are well established on the market with a great variety of size and material combinations. They are used for decorative purposes and for load bearing applications

Suitable lightweight panels have already made their mark in furniture construction where there is a cost advantage or added value for the end customer, retail or logistics.

There are a variety of concepts in lightweight panels. Dr Olaf Plümer listed a number of these in a recent article: various sandwich constructions with a solid top and a variety of fillings for the inner layer, honeycomb panels, frameless boards, board-on frame constructions, light solid wood boards and the like (Plümer no date).

There are many applications for lightweight panels (Stosch and Lihra 2008). These include:

- household furniture
- office furniture
- cabinets, counters and other work surfaces
- shelving
- components and fixtures for exhibition stands
- office space dividers
- tables (especially tabletops)
- miscellaneous office furnishings
- doors
- thick contemporary design pieces
- displays for department stores and other retail establishments.

There has been significant progress in technological development of lightweight panels and the group of users continues to expand.

Examples:

DendroLight® panel, created in Latvia, is a 3-layer lightweight solid wood panel with a unique DendroLight® middle layer sandwiched between two deck layers (Figure 19) (http://dendrolight.lv/en/products/).

The key feature of the panel lies in the manufacturing process of the middle layer that secures reduced weight, extra homogeneous panel dimensions and superior strength. DendroLight® 3-layer panels are available with plywood and MDF deck layers and are widely applied in furniture and interior design industries.

DendroLight® 3-layer panel can be used for furniture, work surfaces, modular kitchen cabinets, shelving systems and wide range of interior design elements.

Veneering or laminating DendroLight® 3-layer panels is possible with all conventional bonding systems.

(a) (b)

Figure 19: DendroLight® 3-layer furniture panels with (a) MDF faces and (b) plywood faces (Source: http://dendrolight.lv/en/products/furniture-panel/)

Honeycomb panels are a sandwich-type assembly comprised of an expanded paper honeycomb core layer of lightweight material and two thin layers glued onto both sides of the core layer (Stosch and Lihra 2008). The layers can be made of thin wood, plywood, particleboard, high-density fibreboard (HDF) or MDF, asbestos, aluminium or even laminated plastic.

There are two types of lightweight panels based on an expanded paper honeycomb core: framed panels and frameless panels.

One of the examples of honeycomb panels is Eurolight® which is made from 8 mm high-density chipboard top and bottom layers, combined with a light, yet robust recycled cardboard honeycomb core (Figure 20).

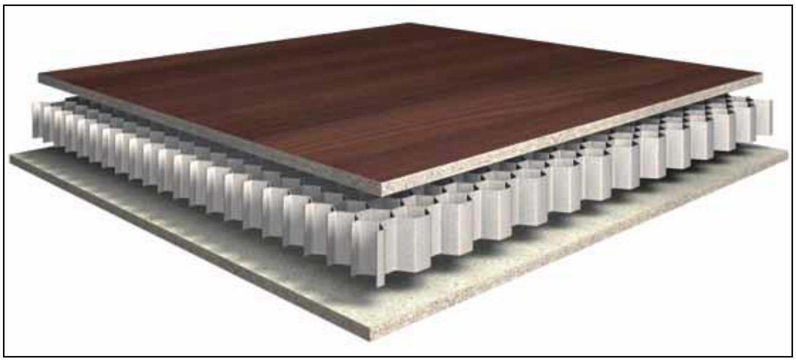


Figure 20: Eurolight®, an example of a honeycomb panel (Source http://www.egger.com)

Dascanova panels were developed by the Dascanova company, based in Austria, with a wave-like internal structure, resulting in an improved internal bond strength (Figure 21).

Dascanova panels (international patent applications pending) redistributes density inside the particleboard, fibreboard or insulation boards before or during compression. This leads to a higher concentration of particles in the areas subjected to compression and less concentration of particles in the remaining areas. The result is improved mechanical properties compared to standard wood-based panels with only a horizontal density profile. The use of these panels can save up to 30% on raw materials (wood particles, resin and other chemical components) as well as save on the energy required for production processes e.g. fibre drying.

Figure 21. Dascanova panel (Source: http://www.dascanova.com/en/Home.html)

<u>REMARK</u>

The information provided above for DendroLight®, Eurolight® and Dascanova panels was reproduced from their respective websites.

5.1.6 Other substrate materials

As alternatives to wood substrates, other substrate materials have been used in the industry such as aluminium, used mainly in applications where product weight may present an issue; steel, used sometimes in interior car parts (door panel inserts or dashes); fibreglass windows or door components; and cardboard panels made out of recycled food and beverage cartons. Some of the substrates, especially fibreglass and steel, are used in combination with decorative veneers, but it is not as widespread as wood-based materials.

5.2 Technical requirements for substrate materials

Requirements for particleboard and MDF used as substrate materials are specified in several Australian and New Zealand standards:

- AS/NZS 1859.1: 2004 *Reconstructed wood-based panels – Specifications. Part 1: Particleboard*
- AS/NZS 1859.2: 2004 *Reconstructed wood-based panels – Specifications. Part 2: Dry-processed fibreboard*
- AS/NZS 4266: 2004 *Reconstructed wood-based panels – Methods of test.*

5.2.1 Thickness tolerances

The successful outcome of veneering and finishing operations is dependent upon the use of boards with close thickness tolerance. Therefore, a close thickness tolerance of supplied boards is desirable.

The Australian/New Zealand standards AS/NZ 1859.1: 2004 and AS/NZ 1859.2: 2004 specify the thickness tolerances for particleboard and MDF used as decorative boards (Table 2).

Table 2: Tolerances on nominal thicknesses for particleboard and MDF.

Application	Test method AS/NZS	Nominal thickness range (mm)		
		<12	>12 to 22	>22
Non-sanded board	4266.2	±0.5	±1.0	±1.5
Sanded board		±0.2	±0.3	±0.3
Decorative board		±0.4	±0.6	±0.6

Significant changes in MC during transportation or storage can adversely affect the thickness tolerance of boards reaching the end user. Attention to correct storage conditions of the boards at all stages of the supply chain is recommended.

5.2.2 Moisture resistance requirements

From the point of view of resistance to moisture there are two types of MDF and particleboard – “standard” and “moisture resistant (MR)”. Selection of one type or the other should follow guidelines based on the service environment.

- **Standard board** should be used for dry interior applications. It is not suitable for exposure to high humidity for extended periods of time. It can be used in a dry climate having no significant changes in relative humidity, or in fully air-conditioned buildings. If exposed to high humidity and fluctuating humidity, standard board will suffer a significant thickness swelling and loss of strength and stiffness.
- **Moisture resistant board (MR board)** should be used for interior applications where resistance is required to high moisture conditions or where there is occasional risk of wetting (e.g. in kitchens and bathrooms and in tropical areas).

MR board exhibits a much slower response rate to humidity changes, much lower thickness swelling and minimal residual swelling after drying out (although the board cannot be expected to perform satisfactory in continuously wet conditions). If the board is left in such conditions, degradation will occur through glue failure or fungal attack (or both).

MR plywood, such as marine plywood, is also an option in damp applications.

Wood-based materials and solid wood also respond to changes in relative humidity and consequently the dimensions are closely related to MC. The advantage of wood-based products over solid wood is that they have only two-directional movements (in the plane of the panel and in the thickness). This property makes particleboard and MDF excellent core materials (Figure 21).

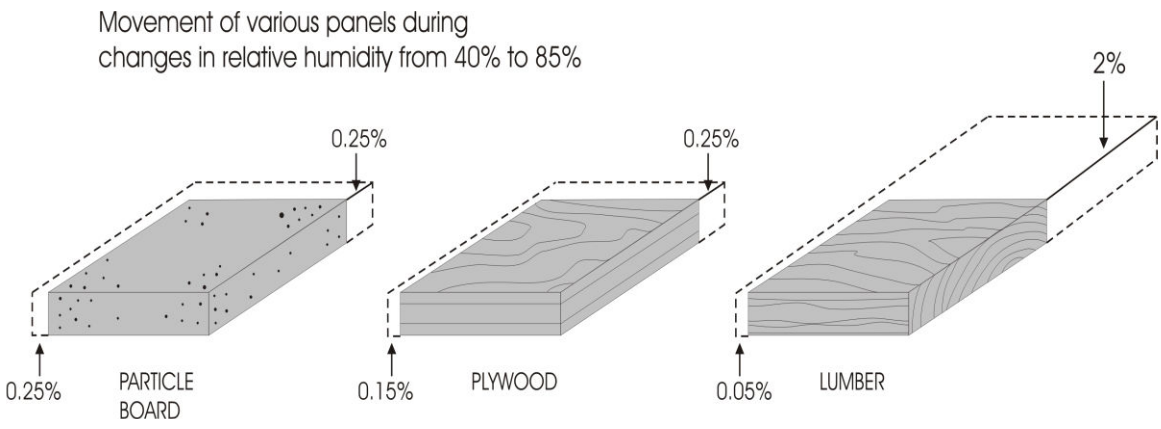


Figure 21: In-plane movement of various panels (Source: NPA Technical Bulletin 1993)

5.2.3 Moisture content requirements for substrate materials

According to AS/NZS 1859 Part 1 and Part 2, the MC of the substrate material should be from 5% to 13% (advisory only). The MC should be tested according to AS/NZS 4266: 2004.

In the author's opinion, in order to minimise the differential movement of the substrate and veneer it is recommended that the MC of the substrate should be between 8% and 10%. Extreme environmental conditions that would result in significant changes of MC above the specified range could cause a significant deterioration of final products.

5.2.4 Other requirements for substrate materials

Particleboard and MDF should comply with the general requirements for physical and mechanical properties as well some performance requirements listed in AS/NZS 1859: 2004, Part 1 and Part 2. The tests methods for these properties are described in AS/NZS 4266: 2004. The list of tests required is provided below:

Method 2: Dimensions, squareness, flatness and edge straightness of whole panel

Method 3: Moisture content

Method 4: Density

Method 5: Modulus of elasticity in bending and bending strength

Method 6: Tensile strength perpendicular to plane (internal bond strength)

Method 7: Surface soundness

Method 8: Swelling in thickness after immersion in water

Method 10: Wet bending strength after immersion in water at 70°C or boiling temperature

Method 11: Moisture resistance under cyclic test conditions

Method 13: Resistance to axial withdrawal of screws

Method 14: Dimensional changes associated with changes in relative humidity

Method 16: Formaldehyde emission – Desiccator method

EN 120 Wood-based panels – Determination of formaldehyde content – Extraction method (called perforator method).

6 CONSTRUCTION OF A VENEERED PANEL

6.1 Panel forms

As specified in the Australian/New Zealand standard (AS/NZS 2270: 2006), plywood and blockboard for interior use may be manufactured in various forms based on veneer grades and end use requirements, as specified in Table 3.

Table 3: Wood veneer panel forms.

Ordering code	Face veneer	Backing veneer
SSB	Face grade	Backing grade of same species
F2S	Face grade	Face grade
MOB	Face grade	Backing grade at manufacturer's option
CNB	Face grade	Grade and species nominated by the customer

Legend:

SSB *same species on back sides (sometimes called "Down Grade Back" – DGB)*

F2S *face two sides (sometimes called "Good Two Sides" – G2S)*

MOB *manufacturer's option on back (sometimes called "Backs at Manufacturers Option" – BAMO)*

CNB *customer nominated veneer on back.*

6.2 Veneered panel construction

Veneered panels should be balanced, that is, generally the same species and thickness of veneer should be applied to both sides (AS/NZS 1859.3: 2005). An unbalanced panel would warp upon moisture gain (Figure 22). There may be occasions where a purchaser requires differing species of veneer on the face and back sides. These cases must be subject to consultation and agreement between purchaser and supplier. However, to avoid warping it is essential to ensure that if different species are used, both veneers have similar strength properties and dimensional behaviour characteristics.

The grain of the veneer should be generally parallel to the long edges of the panel. There will be exceptions to this according to purchaser's requirements, e.g. diagonal and cross grain panels. In these cases, grain direction should be the same on both sides where possible.

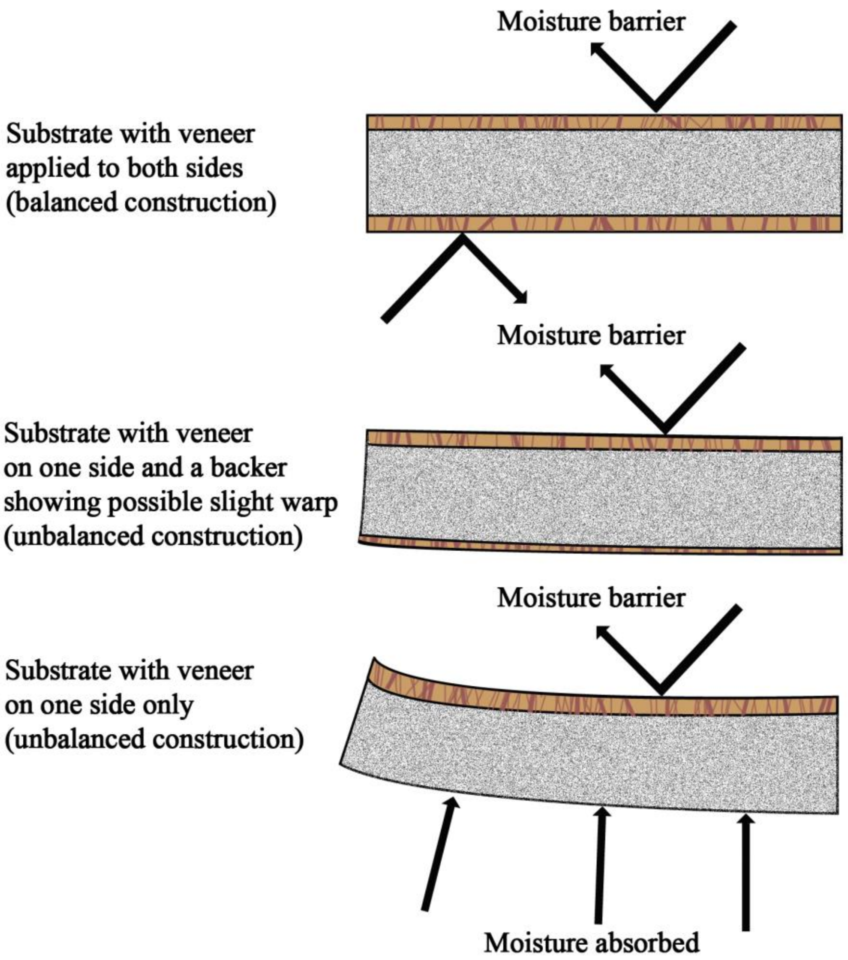


Figure 22: Balanced and unbalanced construction of veneered panel

6.3 Performance requirements for wood veneered panels

In addition to the requirements for substrate materials specified in AS 1859, wood veneer panels should meet the requirements for veneer bond strength and veneer bond durability specified in AS/NZS 1859.3:2005. These requirements are listed in Chapter 10.6.

7 PRODUCTION OF DECORATIVE VENEERED PRODUCTS

The production of veneered products consists of two manufacturing stages:

- manufacture of raw veneered panels
- manufacture of final products.

The production of veneered panels involves the following processes:

- veneer and board storage and handling
- jointing veneers into lay-ons
- gluing and pressing
- panel conditioning
- sanding.

The manufacture of final products involves:

- finishing of veneered panels
- machining, jointing and assembly.

The whole production process is presented in Figure 23.

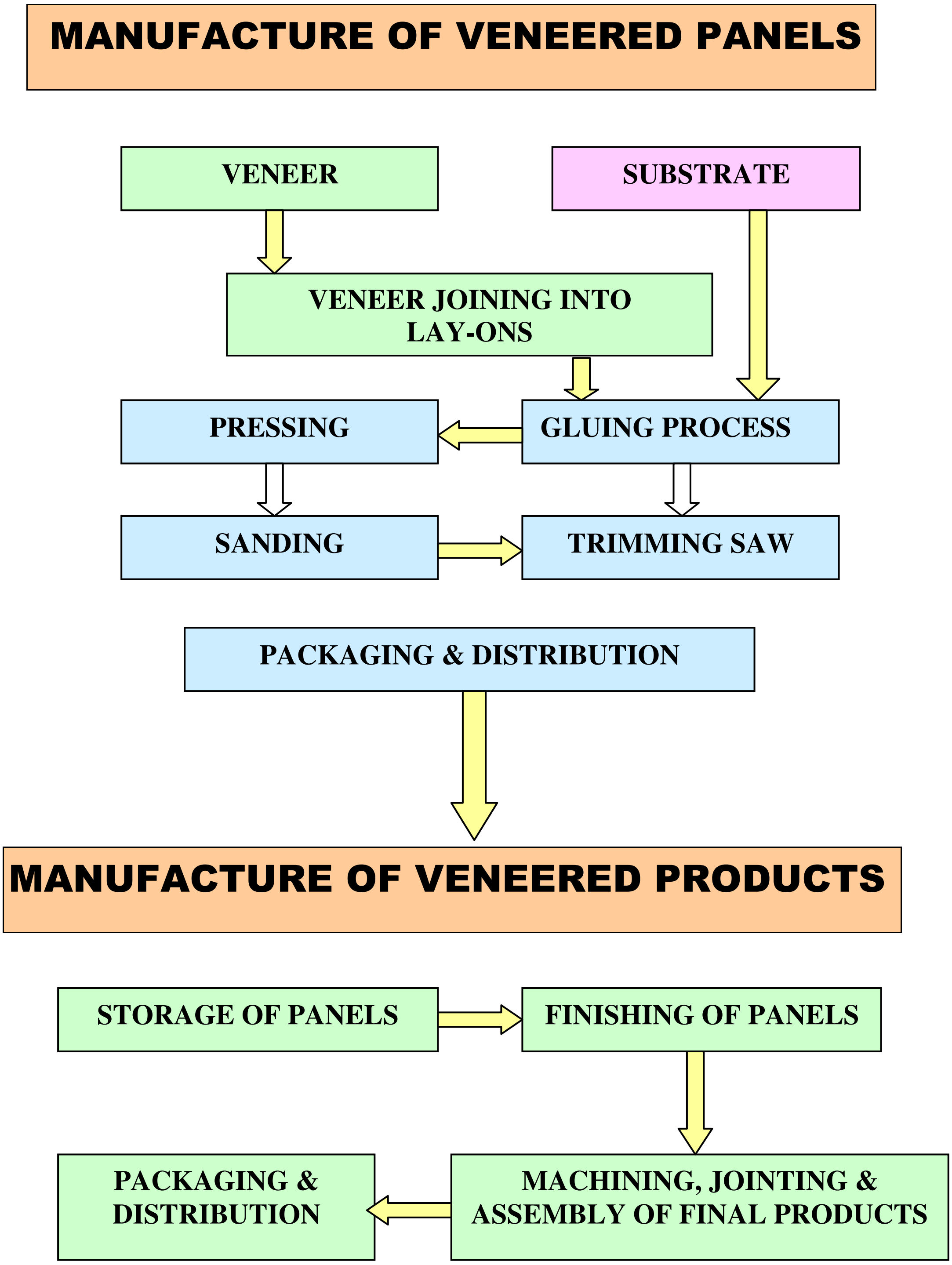


Figure 23: Manufacturing stages in the production of veneered products

The manufacturing stages are usually undertaken by separate companies. The first manufacturing stage is generally undertaken by companies with specialised veneering machinery who concentrate on the production of veneered panels. The second manufacturing stage is often undertaken by furniture or joinery companies. Occasionally a subcontracting company performs the finishing process outside the furniture/joinery factory.

The involvement of many companies in the production of veneered products makes the manufacturing process complex and can create difficulties in maintaining quality control during the production process. In case of dispute about product failure, it is often difficult to establish which company is responsible for the problem. Therefore, it is critical that each company involved in the production strictly follows technical requirements and quality control procedures.

Requirements and recommendations for each step of the manufacturing process are provided in detail in Chapters 8 – 13.

8 STORAGE AND HANDLING REQUIREMENTS

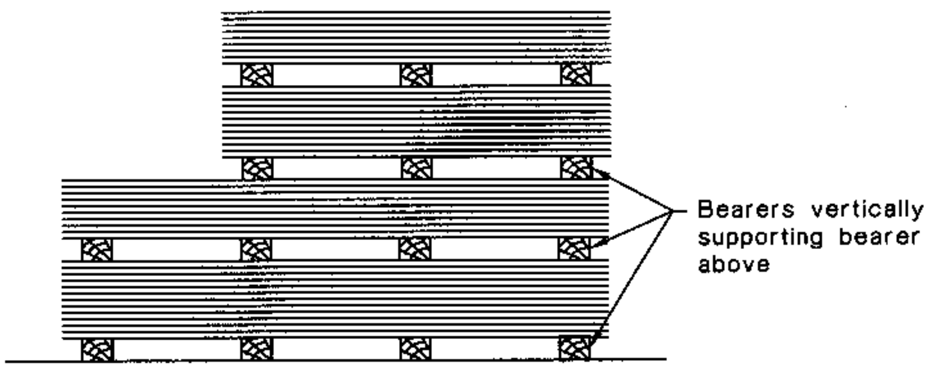
Appropriate storage and handling of veneers, substrates and veneered panels is a critical factor in producing quality products.

Requirements for storage and handling of veneer, substrates and veneered panels are provided in the AS/NZ 1859 series dealing with reconstructed wood-based panels.

The following recommendations for storage and handling are essential in order to maintain veneers and panels in good order and condition.

- The storage area should be located in an enclosed dry building, which should minimise rapid changes in temperature and humidity. The area should be well ventilated with good air circulation. Open-sided sheds should not be regarded as dry stores. It is recommended that the humidity and temperature in the storage area be recorded.
- All packs should be evenly supported at each end and at intervals of not more than 600 mm. Where packs are stacked, all supports should be vertically aligned (Figure 24). This will reduce the potential for colour change of exposed edges if exposed to ultraviolet light.
- Should it be necessary to store in the open, veneers, lay-ons and decorative overlaid wood panels should be covered with waterproof sheets, supported on battens laid on top of the pack allowing air to circulate around and over the pack. The cover sheet should protect both sides and ends to floor level and be tied to prevent lifting.
- The stack should be kept dry and clear of the ground, and be placed so that it will not be exposed to mechanical damage.
- Where packs are supported on bearers manufactured from decorative overlaid wood panels, care should be taken to ensure water does not make contact with the bearers. Added care can be taken by supporting each bearer on natural timber packing (or other impervious material). The minimum thickness of packing should be 38 mm.
- To avoid staining and fading, the sheets should not be exposed to the weather while awaiting installation.
- The surface should be kept free of contaminants, e.g. dust, oil and adhesives, which will affect the overlaying of veneer, plastic laminate and other surface finishes.
- Sheets should be installed in accordance with the manufacturer's instructions.
- Small quantities of formaldehyde may be emitted from wood-based panels. Under normal conditions, atmospheric concentrations of formaldehyde will be well below recommended threshold levels. If large quantities of panels are stored together there may be risk of formaldehyde build up. Provisions for ventilation in storage areas should prevent formaldehyde build up.

(a) Correct storage method



(b) Temporary cover

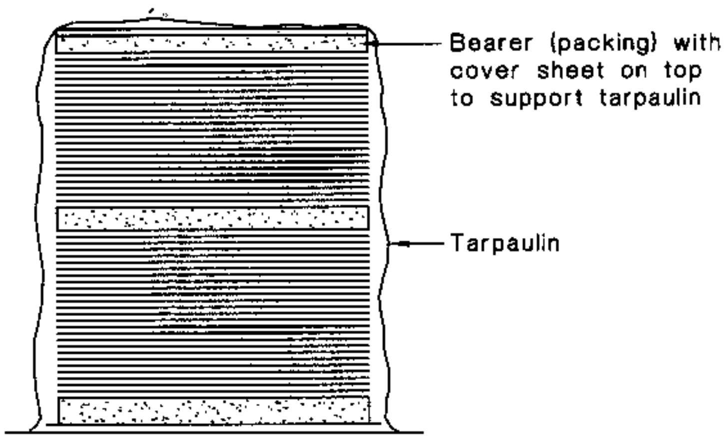


Figure 24: Recommended storage and handling of decorative veneered panels (Source: AS/NZS 1859.3: 2005)

Storage conditions are often not satisfactory, with veneer and boards often stored unwrapped in a large warehouse with open doors where the products are subjected to significant changes in relative humidity and temperature depending on outdoor environmental conditions. This may result in significant variation in the MC of the very thin veneers, thus this parameter should be measured.

9 VENEER JOINTING

Veneer leaves need to be jointed together to form a “lay-on” in order to create the width necessary to cover the surface of the substrate material to be veneered.

Jointed veneer leaves should be suitably matched for figure and colour according to purchaser requirements.

9.1 Veneer matching

Matching is the term used to describe the method by which the individual leaves are jointed edge to edge into a lay-on. The method of match determines the final appearance of the panel. Careful choice of veneer colour and grain pattern may produce highly decorative effects.

There are several methods of veneer matching described below.

9.1.1 Book matching

The book match method is the most common in the industry. It is based on the mirror image principle. To produce this image, successive veneer leaves in a flitch are turned over like the pages in a book and edge-jointed in this manner. Since the reverse side of one leaf is the mirror image of the succeeding leaf, the result is a series of pairs (Figure 25).

Book matching may be used with plain, quarter or rift sliced veneers.

It is important to note that when two sheets of veneer are book matched, the “tight” and “loose” faces alternate in adjacent leaves. They reflect light and accept stain differently, and this may result in a noticeable colour variation in some species, which is often called a “picket fence” effect in Australia or a “barber pole” effect in America. This effect can be minimised by proper sanding and finishing techniques.

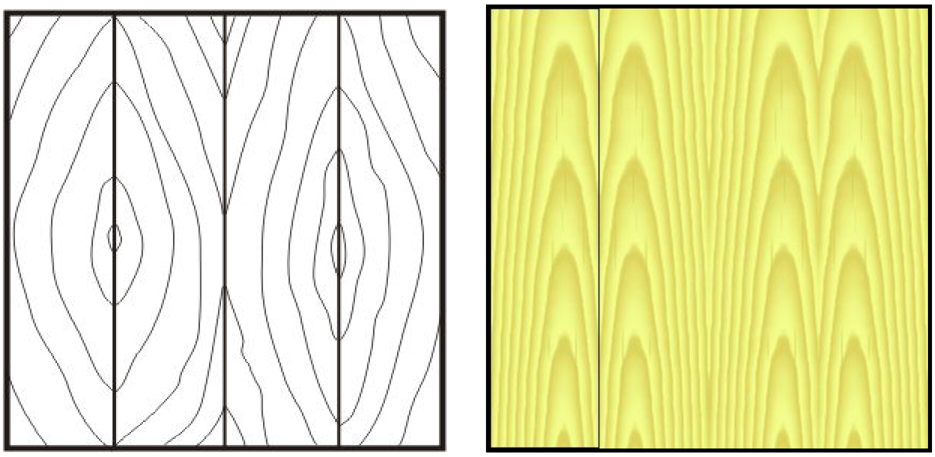


Figure 25: Veneer book matching

A book match is commonly seen on furniture where veneer with a strong figure, like swirl mahogany or walnut, is used. This creates a dramatic visual effect on a cupboard door or tabletop.

9.1.2 Slip matching

Successive veneer leaves in a flitch are "slipped" one alongside the other and edge-glued in this manner (Figure 26). The result is a series of grain repeats, but no pairs. The danger with this method derives from the fact that grain patterns are rarely perfectly straight. Where a particular grain pattern "runs off" the edge of the leaf, a series of leaves with this condition could visually make a panel "lean". This method gives the veneer lay-on uniformity of colour because all faces have the same light refraction. This is in contrast to book matching where alternating leaves are turned over.

This method is often used with quarter sliced and rift sliced veneers. The visual effect shows a grain figure repeating, but joints do not show grain match. The lack of grain match at the joints with slip matching can be desirable.

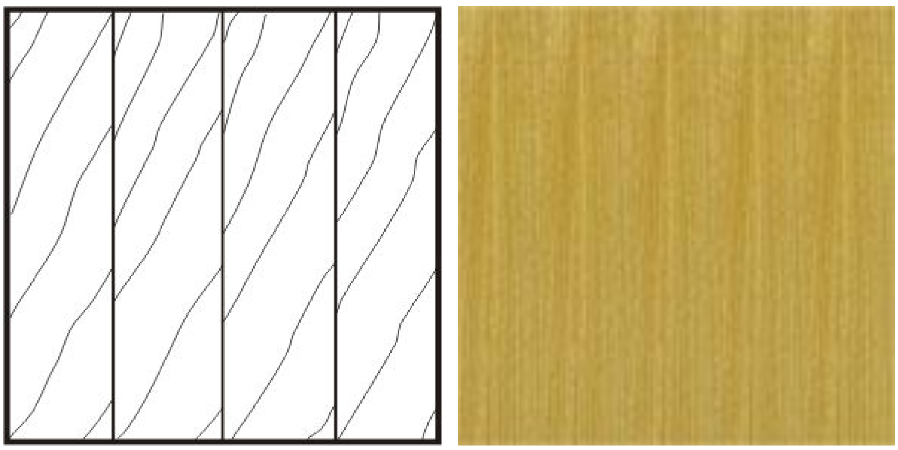


Figure 26: Veneer slip matching

9.1.3 Reverse slip matching

This method is generally used with crown cut veneers. Veneer leaves are slip matched, and then every second leaf is turned end to end (Figure 27). The method is used to balance crowns in the leaves so that all the crowns do not appear at one end.

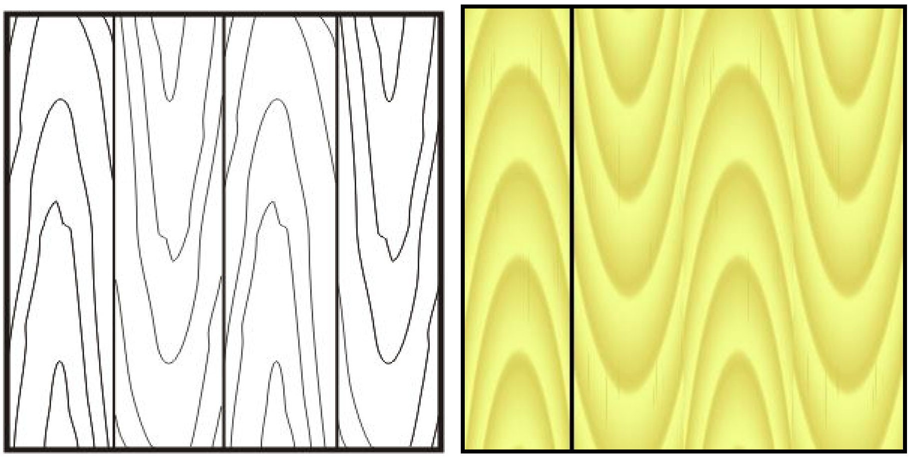


Figure 27: Reverse slip matching

9.1.4 Random matching

In this method, individual leaves are random matched with the intention of dispersing characteristics such as knots or gum veins more evenly across the sheet (Figure 28). The advantage of random matching is that veneers from several logs may be used in the manufacture of a set of panels.

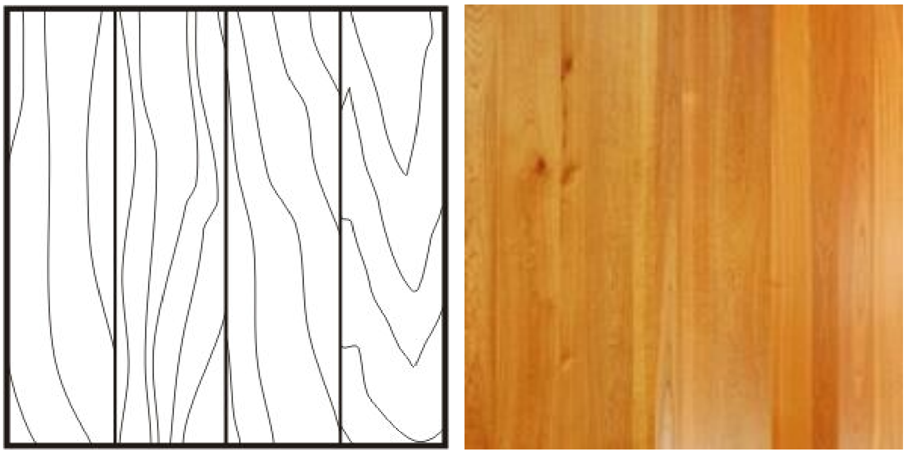


Figure 28: Veneer random matching

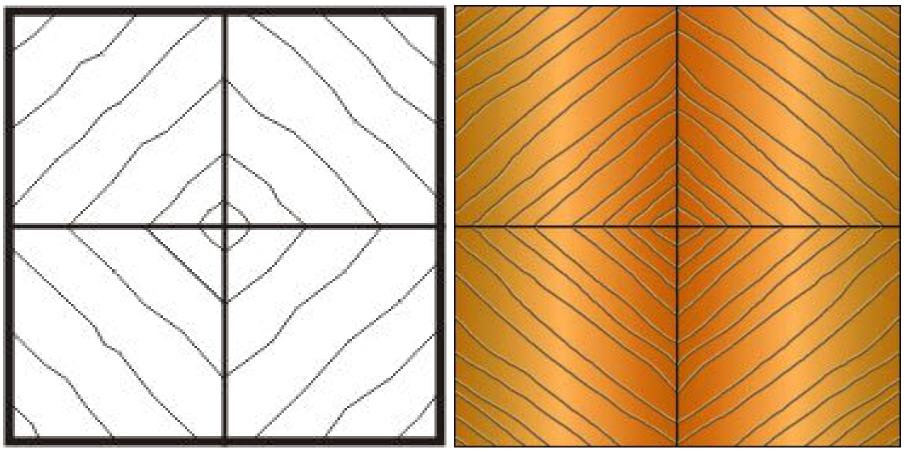
9.1.5 Herringbone matching

Veneer strips are used and matched to both sides of a centre line, at an angle to it. The resulting appearance is reminiscent of the bones in a fish as they are attached to the backbone (Figure 29).

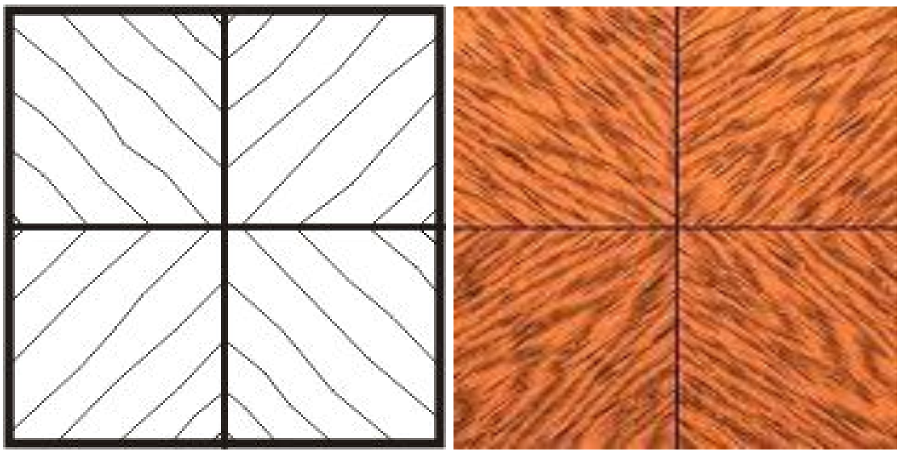
Figure 29: Herringbone matching

9.1.6 Diamond and reverse diamond matching

Diamond matching is a variation of quarter matching that can be used to advantage when the veneer is straight grained and without much figure. The sheets are cut on an angle and quarter matched to produce a diamond figure (Figure 30). Reverse diamond matching uses the same principle with the same kind of veneers, but the grains are matched to produce an "X" pattern rather than a closed diamond.



(a) Diamond matching



(b) Reverse diamond matching

Figure 30: Diamond and reverse diamond matching

The above methods are frequently used for matching veneers, However, other individually designed matching methods can be used to develop beautiful, unique patterns by utilising exquisite patterns and colours of veneers.

9.1.7 Inlay and marquetry

Inlay or Intarsia is a woodworking technique that uses varied shapes, sizes, and species of wood fitted together to create a mosaic-like picture with an illusion of depth. Intarsia is created through the selection of different types of wood veneers, using their natural grain pattern and colour (but can involve the use of stains and dyes) to create variations in the pattern. After selecting the specific woods to be used within the pattern, each piece is then individually cut, shaped, and finished. Sometimes areas of the pattern are raised to create more depth. Once the individual pieces are complete, they are fitted together like a jigsaw puzzle and glued to wood backing, which is sometimes cut to the outline shape of the image (Figure 31).

Inlay in wood furniture differs from marquetry, a similar technique that largely replaced marquetry in high-style European furniture during the 17th century, in that marquetry is an assembly of veneers applied over the entire surface of an object, whereas inlay consists of small pieces inserted on the bed of cut spaces in the base material, of which most remains visible.

Lutherie inlays are frequently used as decoration and marking on musical instruments, particularly the smaller strings.

Figure 31. Examples of inlays (Source: http://www.heritageinlay.com/)

Marquetry is the art and craft of applying pieces of veneer to a structure to form decorative patterns, designs or pictures (Figure 32).

Veneer faces of various kinds are made up with small segments of veneer cut into patterns and fitted together. Often many different species and grain patterns, including many of the most exotic grains, are used in marquetry work.

Beautiful effects can be obtained using the marquetry technique, which is generally applied in furniture manufacture and can be quite ornate.

(a) Cabinet made with exotic veneers inlays (Source: http://www.heritageinlay.com/)

(b) Modern marquetry cabinet made from Tasmanian timbers (Source: http://en.wikipedia.org/wiki/Marquetry)

Figure 32: Examples of marquetry furniture

9.2 Methods of veneer jointing

Veneer jointing, also called veneer splicing, is a very important veneering process that has a significant contribution to the quality of the final product.

Before jointing veneer leaves into lay-ons, veneer bundles must be trimmed. In the industrial situation specialised guillotines are used for trimming. It is essential that the joint lines are straight, parallel and square with minimal tear-out. Joints that are not straight create gap problems. If the joint line is bowed in just one millimeter, the result is a two millimeters gap when two sheets are laid-on. If the joint is bowed out one millimeter, the result is a two millimeters gap at either end, which will affect the joint quality.

There are various methods of veneer splicing.

- **Zigzag stitching** – a special hot melt glue thread is passed through a heated tube in a zigzag pattern to the underside of the veneer to produce a tight joint. Immediately after the thread is applied, it is compressed flat by compression rollers. The glue thread is buried in the glue line, against the core, so that removing the glue thread with a sander becomes unnecessary. Tight joints, high adhesion and tear resistance are guaranteed even on wavy veneers. A variety of zigzag glue thread splicing machines are available on the market.
- **Butt joining (splicing)** – veneer leaves are spliced with polyvinyl acetate (PVA) or UF glues applied to the veneer edges. The veneer sheets are automatically aligned to allow a precise application of the glue. This glue application can be done with the pre-gluing machine (e.g. Kuper KLM or with the pre-gluing device integrated in veneer splicer (e.g. Kuper FLI 500).
- **Veneer finger jointing** – the veneers are jointed with irregular fingers using special punching dies to provide the perfectly tightened finger jointing connection.
- **Paper tape** – this method is used for specialist segmented or intricate veneer work.

In the industrial situation, veneer jointing is undertaken by using specialised splicing machines. A wide range of veneer splicing machines are available on the market.

- **Longitudinal veneer splicer** with zigzag glue thread or glued butt joints is usually used for the furniture industry and when automatic production is required. This type of splicer often contains a specially designated gluing device between the feeding rollers and transporting conveyors to enable feeding of veneers after the veneer edges are cut straight, thus eliminating the gluing process. Rollers inside the machine align the veneer to the gluing unit and transport the glued veneers to a heating section.
- **Cross feed splicer veneer splicer** with zigzag glue thread or glued butt joints is used to glue spliced joints for long or panel-sized veneer faces. The strips are usually pre-glued and are fed into the machine manually. Some of the machines cut the glued sheets to the required sizes. A combination of veneer splicing machines, glue applicators and fanning machines are needed to finish the new panel.
- **Veneer finger jointing and jointing machines** are used for the production of veneer fixed lengths or veneer roll material with glued finger jointing. The veneer strips are trimmed lengthwise and then the finger jointing is created by cutting with a purpose-shaped knife and counter-knife. Glue is applied to the finger joint and lengthwise strips are obtained.

9.3 Recommendations for jointing veneers

It is essential that the MC of veneer leaves are checked before jointing them into lay-ons. It is recommended that the MC difference between adjacent leaves less than 2%. Otherwise, the movement of veneers due to changes in environmental conditions will result in veneer splitting and checking. As specified in Chapter 4.3, the recommended MC of veneers is between 8% and 10%.

The thickness of veneers should be measured to eliminate any problems due to thickness variation. If the thickness of the veneer leaves varies more than 0.1 mm they should not be jointed as the difference may give rise to problems during further manufacturing stages.

The parameters of the jointing machine should be checked prior to jointing. Machine instruction/specifications should provide recommended parameters (usually temperature and pressure applied to the joint) which should be applied for jointing different types of veneers). When using zigzag stitching machines the grade of thread should also be checked against the machine specifications.

9.4 Effects of poorly jointed veneer

9.4.1 Unparallel joints

Joints that are not straight create gap problems. If the joint line is bowed by just one mm, the result is a two mm gap when two sheets are laid up. If the joint is bowed out one mm, the result is a two mm gap at either end.

9.4.2 Unsquared veneer edges

Jointing with a dull knife or jointing the veneer improperly can leave a rounded edge on the leaf being cut. When two leaves are placed together, a groove will be formed. This is either filled with putty or worse yet, glue and the poor joint is clearly visible when the panel is finished.

9.4.3 Zigzag telegraphing through the veneer

Zigzag telegraphing through the veneer may be caused by many factors involved in the veneer production process. In the majority of cases this problem cannot be detected by the manufacturer until after the veneer panel has been finished or when in service. Therefore it is critical that all recommendations provided by the machine supplier are strictly followed.

The problem is recognised by the visual thread line on the face of the veneer panel. It is caused by one, or a combination, of the following factors:

- thickness of veneer
- species
- glue thread thickness/density
- machine temperature setting
- pressure of the compression rollers
- press pressure
- sanding.

Various grades of threads are used depending on the type of veneer and type of machine used. If an improper grade of thread is used, the glue thread may be transferred through the veneer all the way to the face. The area where the glue is transferred is then impenetrable to finishes. This often happens in a thin, soft or open pore veneer.

The temperature on the zigzag splicer must be properly set according to the supplier's instructions. If the temperature is too high, the glue thread is overheated and can be easily "transferred" through the veneer. On the other hand, if the thread is not heated enough it is not completely melted and it may show through.

The veneer structure can be deformed around the thread when pressed in a hydraulic hot press at too high a pressure. During sanding operations, a small amount of veneer surface is sanded off, which can take the surface down, or very near, the thread. The veneer around the thread is structurally denser because it has been compressed and deformed. During the finishing process it will absorb finishes differently, thus causing a visual blemish.

If zigzag problems occur and it is difficult to define its cause, the following experiment may be help to eliminate the problem.

- Run the stitcher at a lower temperature so the glue thread adhesive does not thin out too much.
- Use a lower density glue thread.
- Use a lower pressure on the zigzag compression roller.
- Size the veneer.
- Check the sanding operation (the amount of sanded veneer).

9.4.4 Discolouration of glue line in spliced veneers

Occasionally problems with dark lines occurring along the spliced veneer joints are encountered. This occurs in particular in light colour veneers. This problem usually occurs due to the use of improper glue for splicing. There are special types of glues available for veneer splicing, depending on the type of splicing machine.

The used of different type of glues for gluing veneer to the substrate (e.g. PVA) and for veneer splicing (e.g. UF) may cause problems with veneer joints.

9.4.5 Overlapping in veneer joints

Generally the veneer butt jointing process is so highly developed in Australia, Europe and America that it is virtually impossible to detect the joints in the finished veneer board. However, with some lesser-quality imported veneer products, the joints are noticeable because an overlapping technique is used (Figure 33).

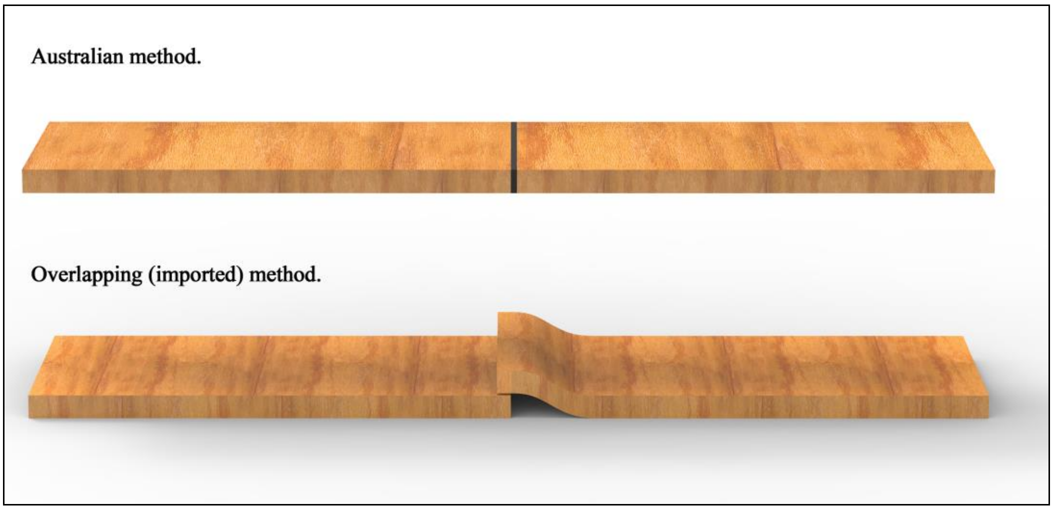


Figure 33: Differences between the veneer splicing butt jointing techniques

9.4.6 Troubleshooting with veneer splicing

A wide range of problems may occur due to improper procedures applied during veneer splicing. The list of problems, their possible causes and solutions are presented in Table 4.

Table 4: Troubleshooting with veneer splicing. Reproduced from http://www.diehlmachines.com/troubleshooting-overlapping-on-a-veneer-splicer/.

Overlapping on a veneer splicer		
Type of problem	Possible causes	Solutions
The edge of one piece of veneer is on top of the other. The veneer is not being held flat.	The pressure bar may be too high.	Check the float gauge. Lower the pressure bar.
	The front suspension bolt is too tight. This lifts the infeed end of the upper heater bar.	Loosen the suspension bolt.
	Upper heater bar is too high.	Reset the upper heater bar.
	The front end of the heater strip is not against the lower heater bar.	Place a slight bend in the heater strip ~10 cm (4 inches) from the infeed end.
	The heater strip will not “float” up and down at the infeed end.	Check the lower heater bar for level. The feed chains are pulling on the heater strip.
	The pressure setting is too light. Check for pressure marks, the	Increase the pressure setting.

	shine, on the veneer.	
The veneer overlaps before entering the feed chains.	The holddown springs on the matching roll are not holding the veneer flat.	Lower the holddown assembly.
		Replace the holddown split springs.
	The matching rolls pull the veneer into the machine at angles.	Readjust the cant on the matching rolls.
		Reduce the pressure on the matching rolls.
	The edge of the veneer curls up against the infeed guide.	Readjust the cant on the matching rolls.
		If the veneer is curled at the edge set the holddown block as close to the matching roll and as low as is possible.
	The jointed edges of the veneer are not square.	Check the jointer blade for sharpness. Only use the veneer edge from the flat side of the guillotine.
The veneer overlaps on one or both ends only.	The edges of the veneer are not straight or parallel.	Check the jointer.
Troubleshooting with mismatching		
The ends of the spliced veneers are offset.	Improper feeding. The veneer is fed into the machine unevenly.	Align edges and use only one hand to feed both sheets of veneer.
	Mismatches under the matching rolls.	Too much or too little spring pressure on the matching rolls.
		Large lower idle roll not turning with feed chains. Replace bushing.
		Matching rolls and/or lower feed rolls worn. Replace parts.
		Burr on the infeed guide or table catching the veneer. Repair.

	Mismatching at the beginning of feed chains.	Heater strip not "floating" up and down. Check adjustments of lower heater bar. Reset machine.
		Pressure bar is too low. Check the float gauge.
		The suspension bolt is too loose. Tighten the suspension bolt.
		Upper heater bar is too low.
Burning of veneer		
Dark brown scorch lines on either side of the glue line. Usually dominant on the bottom side from the lower heater bar.	Excessive heat from either the upper or lower heater bar. Also crystallises the glue.	Lower the temperature setting.
		Increase the feed rate.
Burnishing of veneer		
Crushed and shiny surface along the glue line.	Too much pressure.	Check the pressure setting.
Crimping of veneer		
The veneer is crimped within ~2.5 cm (1 inch) of either side of the glue line.	The inside edges of the feed chains are worn.	Replace the feed chains.
		Reduce the pressure.
Marking of stock		
Indentations left by the serrations in the lower feed chains.	Improper pressure setting.	Reduce the pressure setting.
	Incorrect adjustment of the splicer.	Check the adjustment of the lower heater bar, upper heater bar, and the pressure shoes.
Grooving along the glue line		
Gouges or indents in the veneer next and parallel to the glue line. Can be either top or bottom face.	Build up of crystallised glue on either the upper heater strip or lower heater bar.	Excessive glue on the veneer is the source of the problem. Clean the upper strip and lower bar. If scraping is necessary use only soft materials such as wood, brass, or bronze.

		Running a heavy piece of veneer crossways through the splicer will usually clean them.
	Nicks or burrs on the upper strip or lower heater bar.	Repair or replace.
	Incomplete glue joint	
The leading end of the veneer is spliced but the trailing end is open.	The edges of the veneer are not parallel.	Check the jointer.
	Poor jointing	
The sections of the veneer are spliced but sections open. Slight openings found along the glue line.	Inconsistent or insufficient glue spread. Sections of the veneer received too little glue or none.	Check the method of applying glue to the veneer.
	Small slivers of the veneer were torn out along the edge.	Check the jointer.
	Excessive glue spread	
A build up of glue on the surface of the veneer.	Too heavy of a glue spread on the veneer.	Check the method of applying glue.
Tear-out of the veneer along the glue line.	Build up of crystallised glue on either the upper heater strip or lower heater bar.	Check the method of applying glue.
	Crimbing	
The leading edge of the glue line is pushed back along the glue line.	Build up of crystallised glue on either the upper heater strip or lower heater bar.	Check the method of applying glue.
	Lower heater bar is high.	Readjust the lower and upper heater bars.
	Blue staining on veneer	
Metallic stain marks on either side of the glue line caused by condensation and moisture. More common on high humidity days. Generally exist in coarse-grained oak. On veneer already	Moisture content of veneer is too high.	Dry veneer to lower moisture content. Store in humidity controlled area.
	Glue is wet when veneer is spliced.	Allow the glue to dry completely before splicing.
	Humidity in area is high.	Reduce the temperature setting as much as possible and increase the feed rate.

stained, the ink can be removed by applying a 10% oxalic solution to the stain.		Install a compressed air jet blowing on each pressure chain in the pressure bar. Install a hot air gun in the centre hole in top of the pressure bar.

10 LAMINATING PROCESS

10.1 Veneer laminating requirements

10.1.1 Loose and tight sides of veneer

Face veneers should be laid with the tight side outwards, if it is possible to detect. The difference between the tight and loose sides of veneer sheet results from the slicing of flitches. When veneer is sliced from the flitch, the veneer side closest to the centre of the flitch usually has more fissures and checks than the other side. This side is often identified as the "loose" or inner side of the veneer leaf.

The outer side is known as the "tight" side. It is much smoother and gives a better surface for finishing than the loose side.

The easiest way to distinguish the loose side of the veneer is to hold the sheet in both hands and flex it back and forth (Figure 34). The loose side will flex outward more easily as the knife checks open. When it is flexed inward, and the checks close, the sheet will feel stiffer. However, in the last 20 years, veneer slicing technology has improved significantly and knife checking has been greatly reduced.

When two sheets of veneer are book matched, the tight and loose faces alternate in adjacent leaves.

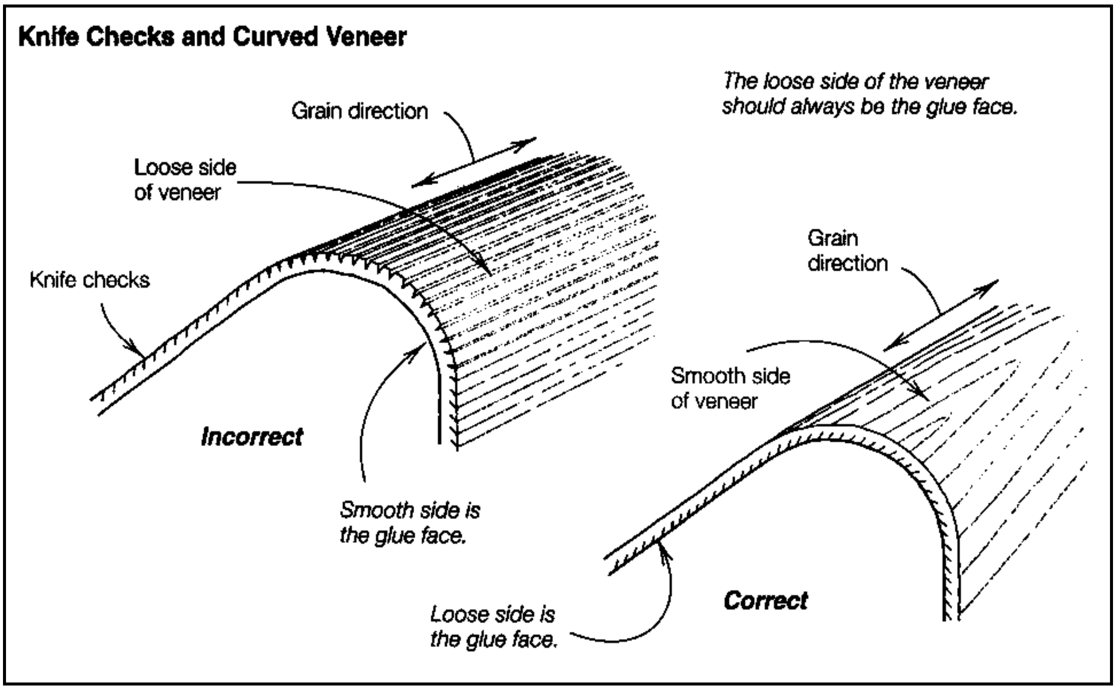


Figure 34: Loose and tight side of veneer (Source: Square 1995)

For some species, the difference between the tight side and the loose side is significant and easy to detect. However, there are species in which such identification is very difficult.

When the decorative veneer sheet is laid-on a plywood core, its grain should always be at right angles to that of the outermost veneer of the plywood, otherwise cracking and checking may result.

10.1.2 Moisture content of veneers and substrates prior to laminating

Moisture content of veneer and substrates at the time of gluing and pressing is the one of the most important factors in achieving high quality panels.

Veneer panel producers must check the MC values of veneers and boards prior to gluing to ensure confidence in the veneered board. In particular, it should be noted that the majority of veneers are imported from overseas and are produced under different environmental conditions and their MC could also change during their transport in shipping containers.

The MC of both veneers and substrate should be checked shortly before gluing. It is essential that the MC of the two materials be held at about the same level in order to eliminate high stresses due to differential movement.

In Australia, the recommended MC is:

- for veneers: between 8% and 10% (see Chapter 4.3)
- for substrate: between 8% and 10% (see Chapter 5.2.3).

In other countries, in particular in the United States, lower MC of 6% to 8% are used for both veneer and solid wood.

It is important to recognise that in the majority of cases, the species of veneer and the substrate material have different hygroscopicity and resulting dimensional stability characteristics. In particular, the hygroscopicity of particleboard and MDF, the EMC is lower than that of wood veneer at the same atmospheric conditions (temperature and relative humidity) and their shrinkage and swelling rates and values are different in most cases.

REMARK

The above recommendations should also be applied by veneer merchants.

10.2 Types of glues used for veneering

In Australia, two major types of glues are used for the veneering process:

- PVA
- UF.

MUF glue is also used for moisture resistant bonding applications.

The majority of companies use PVA glue as its application is easier and faster. UF is probably a more effective and reliable bonding agent but it has the disadvantage that its curing time is temperature dependent. Therefore, a hardener needs to be selected that is consistent with the ambient temperature and relative humidity in the factory.

10.2.1 Polyvinyl acetate (PVA) adhesive

PVA glue is one of the most common glues available for the woodworking industry. PVA glue is moderate in cost, offers good strength properties in dry conditions and is a gap-filler. The glue line is virtually colourless, and it cures rapidly at room temperature. It tends to creep under continued load. The glue is not resistant to moisture and tends to soften at elevated temperatures. For this reason, PVA glues are suitable only for interior applications for solid wood and veneered products (Forest Products Laboratory 1974).

Two types of PVA glues are available: PVA and cross linking PVA. Cross linking PVA is a single pack PVA that provides superior bonding properties to normal PVA. It provides excellent bond strength, high heat and humidity resistance.

Nowadays the gluing and pressing procedures for natural timber veneer are done on an automated flowthrough line. As the speed of these lines is usually fast, a quick setting glue such as crosslink PVA is required. A typical press time is 30 to 60 seconds at a press temperature of 100°C to 120°C. To press at this speed the press has to be self-loading and unloading. These press lines are very quick, efficient and by using PVA do not require a mixing station with a mixer, wheat flour, shell flour and water. There is also no need to keep checking viscosity and the clean-up time is greatly reduced. With PVA, a single pack or a two pack crosslink grade can be used.

When using PVA glues the following precautions should be taken to avoid veneering problems.

- If the MC of the veneer is slightly high one can get open joints in the veneer as the hot boards cool down and the adhesive is still soft.
- If the veneer and the board vary more than 1% – 2% in MC at the time of pressing one can also get open joints after the furniture is in service, particularly if heating is used in the room containing the furniture.
- Bonds with single pack PVA can be unstuck with heavy coats of lacquer or stain.

- Excessive bleed-through can clog sander belts and can discolour the veneer when polished. The PVA also does not accept stain well and the finished panel can be uneven in colour and finish.

10.2.2 Urea formaldehyde (UF) adhesive

UF resin is a thermoset resin produced by heating urea and formaldehyde in a solution of ammonia or pyridine. It is widely used as component of adhesives and protective finishes. UF adhesives are usually two-part systems, consisting of resin and hardener agent in liquid or powder form. They are also available as spray-dried powders with included hardener which is activated by mixing with water. Fillers and extenders are added to the resin to control flow, viscosity, resin penetration into the wood and to lower glue line costs. A typical mix of urea for a veneering line is urea resin, shell flour, wheat flour and hardener. The mix varies with manufacturers and applications. UF adhesive has high strength in both wet and dry conditions but will not withstand continuous cycles of wetting and drying. It will begin to degrade at about 60 ^{0}C and 60% relative humidity (Sellers et al. 19880).

Despite its many positive attributes UF adhesive can release formaldehyde gas under certain conditions.

A typical mix of urea for a veneering line is urea resin, shell flour, wheat flour and hardener. The mix varies with manufacturers and applications.

The following are a number of typical tips applicable to the urea mix.

Why do you need a mix in urea glue?

The wheat flour is an extender of the glue and a 25% – 40% extension is recommended.

Why do you need to extend the mix?

UF is a very strong but brittle glue, which can cause bowing of panels as they cool down. This bowing is mainly caused by pre-curing of the glue on the bottom side of the board as it sits on very hot platens while the press is manually loaded.

The wheat flour holds more water and retards the glue long enough to close the press before any curing occurs.

The flour used for extending is always a low protein flour, which is the same as that used for making biscuits. When using flour to extend the glue, water should be added to keep the correct viscosity (this should be monitored throughout the batch).

After the glue is mixed in the glue mixer, large volume users pipe it directly to the glue spreader. Smaller volume users would take it off in 20 litre drums and add hardener to each drum as it is being used. This cuts down on waste and means that there is fresh glue in the glue spreader every 30 minutes or so. Any of the mix not catalysed can be saved for the next day.

One of the reasons that urea has lost favour in the flat pressing of veneer to particleboard and MDF is that it is too slow for the majority of automated flow through press lines. However, some modern machines can operate on higher speeds.

The main disadvantage of using this resin is the potential health risks involved with exposure to the formaldehyde vapours released during its curing and decomposition.

A summary of performance characteristics of PVA and UF glues is provided in Table 5.

Table 5: Performance characteristics of PVA and UF glues.

Type of adhesive		
PVA	Crosslink PVA	UF
– Fast setting – High solid content – Wide range of viscosities – Ready-to-use – Gap filling ability – Bleed-through protection for thin veneers	– Hot, cold or RF curable – Water resistant – One or two part composition – Fast cure cycles – Low temp settings – Good bleed-through protection	– Very rigid bonding – Two part (mixing required) – Hot press and RF curable – High heat resistance – Heat accelerates bonding process

10.2.3 Development of new veneer adhesives

As formaldehyde was recently designated as a known carcinogen by a number of government and regulatory agencies around the world, regulations have been endorsed globally to reduce formaldehyde emissions from interior wood products. Introduction of strict requirements motivated adhesive producers to develop environmentally friendly adhesives.

Although UF adhesive is still used in wood products, the formaldehyde emissions from UF resin and its bonded products is a major issue, which limits its application. Many efforts have been made to reduce formaldehyde content of UF resin and the formaldehyde emissions of its bonded products as well as develop formaldehyde-free adhesives as a substitute for UF adhesives. Examples are provided below.

Modification of UF adhesive

UF resins have been modified to lower their emissions when used in wood-based products. For example, Zhang et al. (2011) used a new type of modifier, which was employed as a resource to substitute formaldehyde partly and synthesise the urea-formaldehyde-modifier (UFM) co-condensed resins to reduce the free formaldehyde content of UF resin and lower formaldehyde emissions of its bonded plywood. The results indicated that it could significantly reduce the free formaldehyde content of urea formaldehyde resin and the formaldehyde emissions of plywood.

There have also been studies using hyperbranched polymers to modify commercial UF resin during the glue mix preparation, such as polyglycerols and polyesters. It was demonstrated that the use of those products reduced the formaldehyde emissions, but it also lowered significantly the bondline strength after water soaking (Maminski et al. 2009).

Properzi et al. (2010) also researched dimethoxyethanal (DME) resins to test them as new adhesive formulations. The investigated adhesives were evaluated on a laboratory scale in order to study their technical performances, their gluing parameters, their reactivity as well as their formaldehyde emissions. It was found that all formulations met the requirements of current European standards (EN 319: 1993-08). From the technical point of view, major advantages of the tested systems were found to be: colourless, low toxicity, easy handling and high stability at room temperature (long shelf-life, pot-life and open-time). The formaldehyde emissions of the boards produced were found to be comparable with those of solid untreated wood (F**** according to JIS A 1460:2001 standard).

A study determined the effect of corn flour content of UF resin on the panel properties of particleboard. Corn flour was added to UF resin to decrease the free formaldehyde content of particleboard panels. Some physical and mechanical properties and formaldehyde emissions of particleboard panels were evaluated. The results showed that the introduction of small proportions of corn flour (7% by weight) in UF resins contributed to the improvement of mechanical and physical properties of the boards and reduced their formaldehyde emissions. Hazardous UF could be partially substituted in industrial applications by the addition of corn flour (Moubarik et al. 2012).

Soy-based adhesives

A soy-based formaldehyde-free adhesive consisting of soy flour (SF) and a curing agent (CA) has been successfully used for the production of plywood. However, this adhesive cannot be easily sprayed onto wood particles for making particleboard because of its high viscosity. With changes in the composition of the soy-based formaldehyde, mixing it with water to dilute it and form a soy slurry, improvements in the spread capabilities of the adhesive were achieved. The process still requires an additional mixing step and drying step. The extra cost for performing those additional procedures has not been confirmed, as it has not yet been used at a commercial production scale (Prasittisopin and Li 2010).

PureBond, a soy-based adhesive, was developed by Columbia Forest Products (http://columbiaforestproducts.com/PureBond). It is intended as a replacement for traditional UF, as it is formaldehyde free, thus avoiding the issue of the emissions levels.

Soyad™ adhesives were developed by the Ashland company (United States), which offers cost-competitive, formaldehyde-free adhesives. These patented, water-based products are formulated with soy flour and a proprietary cross-linking resin. When blended together, the resin reacts with the protein in the soy flour to form a durable and water-resistant thermoset adhesive. Ashland's line of Soyad™

adhesives contains no formaldehyde and low volatile organic compounds (VOCs) (http://www.ashland.com/products/soyad-adhesives).

10.3 Gluing procedures

10.3.1 General requirements

Major factors that affect the quality of the adhesive bond are:

- adhesive characteristics
- adhesive preparation
- moisture content
- gluing surface preparation
- gluing and pressing conditions.

Before any adhesive is used for gluing, it should be checked that it complies with the glue manufacturer's specifications.

It is essential that all glue components are mixed strictly according to the specifications provided by the glue supplier/producer. The actual quantities of glue mix ingredients should be recorded for each batch of glue in case of any future dispute. Ideally, the viscosity of the glue mix should also be measured and recorded to ensure compliance with the glue manufacturer's recommendations.

The MC of the veneer and the substrate must be check prior to gluing.

Gluing and pressing conditions are critical to achieving a good quality glue bond. The factors that need to be considered are:

- temperature
- glue spread
- pressure
- press time.

The temperature of the wood, adhesive and room in which gluing and pressing are performed, affect the temperature at the glue line. However, the wood temperature is most important because of its mass at the glue line. An adhesive glued below its minimum curing temperature will experience "chalking", which prevents the glue line from forming a continuous interlocked film. A "chalked" glue has a whitewashed appearance and will result in a permanently weakened joint.

Various types of glue spreaders are available for the application of glue on the substrate. The most common type is a double sided glue spreader that applies glue on both surfaces of the substrate panel.

The amount of glue spread on the contact surfaces is a very important parameter of the veneer laminating process. Therefore, glue spread must be controlled within the limits set by the glue manufacturer. Spreader operators should measure and record glue spreads at least once per day. Particular care should be taken to obtain even spread on both top and bottom spreader rolls. Excessive glue spread will increase the MC of veneer and/or will cause steam blows because the water will turn into steam during the pressing operation. Too small an amount of glue will result in lack of bonding and will cause delamination of veneer.

Variables that affect the glue spread rate are porosity and surface characteristics of wood veneer, viscosity of the adhesive, assembly time and pressing conditions.

Total assembly time (the time that elapses between glue spreading and assembly of components, and pressing) should be controlled within the glue manufacturer's recommendations.

Pressure and pressing time recommendations depend on many factors of which the type of wood species plays an important role.

- **Temperature** – Elevated temperature can reduce cure time. Low temperature can lengthen cure time.
- **Moisture content** – High MC will slow the drying and curing process. Low MC can result in the glue pre-curing.
- **Wood species** – Ring porous species (e.g. ash, oak) will typically require longer cure cycles than diffuse porous species (e.g. birch).

REMARK

Veneer adhesives available in Australia are known to have excellent properties and performance characteristics. However, it is essential that all instructions provided by the adhesive manufacturer/supplier are followed precisely if the full benefits are to be realised.

10.3.2 Adhesive handling

Reactive glues like UF and crosslink PVA, both one and two pack, have limited storage lives due to their reactive nature. This storage life should be checked to ensure that excess glue is not purchased that will then exceed its storage life prior to use.

All reactive glues should be stored away from direct sunlight or heat and kept in a cool area of the warehouse or factory.

Ensure glue is not stored or handled in metal containers, particularly iron or steel, and that the glue does not come into contact with anything containing iron. Crosslink PVA in particular will contaminate easily from metal (even metal taps) and give black or grey iron stain on the finished veneered article.

Two pack glues have fast and slow hardeners. Select the hardener that suits ambient conditions for pot-life and the press cycle required.

Seal all containers, glue and hardener after use. Most liquid hardeners are acidic and safety instructions for handling and mixing should be closely followed. Always wear goggles and gloves when handling.

Always clean up containers, spreaders and equipment prior to the glue setting. Cured or set glue is difficult to clean.

10.4 Veneer pressing

10.4.1 Pressing veneer panels

Hot presses are predominantly used for veneer gluing in industrial situations. When heat pressing, the following important factors need to be considered: the temperature setting of the press, pressure applied and the pressing time. The species of wood veneer should also be considered. Different densities require different pressing times and application techniques. As discussed in Chapter 10.3.1, these factors are critical and should be controlled and monitored on regular basis.

There are many different types of presses available. Therefore, when purchasing a press it is important to select the type appropriate for the specific application.

The following criteria should be used for selecting a press.

- To determine the size of press: W*hat is the largest sized panel that will be pressed?*
- To determine the press capacity: *How often will the press be used? What volume of panels will be produced?*
- To determine heating medium: *What type of overlay will be mainly pressed? (e.g. veneers, laminates).*
- To determine pressure and temperature: *What adhesives will be used for pressing? What cycle time is needed? (Cycle time is dependent on the thickness of the veneer, adhesive, core dimension and temperature).*

10.5 Other veneer laminating methods

10.5.1 Veneer profile wrapping

Profile wrapping is a process by which a decorative surface is laminated onto a substrate in lineal form. This is done using profile wrapping machines, which laminate wood, aluminium, steel or vinyl substrates to wood veneer or a paper/vinyl foil (Figure 35).

For moulding and furniture manufacturers, profile wrapping success depends on three factors: correct choice of machine, adhesive and lamination material. The failure of one of these factors will result in failure of the final product. Therefore, it is important that manufacturers have a good understanding of the equipment, the glues and the laminating materials.

Profile wrapping is most commonly used in two major areas: upgrading low cost lumber with a quality veneer wrap and applying veneer onto MDF or particleboard moulding. The same basic machine may be used for laminating all different substrates.

The substrates that can be used for veneer wrapping are:

- finger joint wood

- MDF
- particleboard
- PVC or vinyl
- aluminium
- fibreglass
- steel.

Figure 35: Veneer wrapped profiles (Source: http://www.winsfordsawmills.co.uk/veneer_wrapping.html)

Typical adhesives used for profile wrapping are:

- interior hot melts
- exterior hot melts. This adhesive is waterproof, not water resistant.

Profile wrapping veneers can be delivered as finger jointed veneer rolls, sheets with core tape from rolls or as single veneer sheets.

10.5.2 Veneer edgebanding

Edgebanding can be made of different materials (PVC, acrylic, melamine, wood or wood veneer). Edgebanding is used in carpentry and furniture-making to cover the exposed sides of materials such as plywood, particleboard, MDF or other substrate materials, giving the appearance of a solid (or more valuable) material. Edgebanding materials typically come with a primer, which acts like a bonding agent between the adhesive and the substrate. Thicker edgebanding requires a slight concavity to provide a tight glue line. The thickness can vary from 0.2 mm to 5 mm or even more. Edgebanding can be applied to the substrate by using hot melt adhesives, which can be water- or solvent-based. The machine that applies the edgebanding is called an edgebander. An edgebander bonds the edgebanding to the substrate, trims leading and trailing edge, trims top and bottom flush, scraps any surplus and buffs the edge.

Figure 36: Examples of edgebanded veneers (Source: http://www.fengshuowood.com)

10.5.3 Adhesive- and paper-backed veneers

1) **Paper-backed veneer** is a wood veneer that is permanently bonded to a resin saturated paper backing to minimise possible imperfections and to minimise seasonal expansion and contraction of the wood caused by changes in ambient humidity The backing is applied to keep intact the individual wood veneers that can be used to make up the full width of a sheet.

   The manufacture of paper-backed veneers typically involves the application of an adhesive resin to at least one surface of the paper backing sheet, followed by adhering the paper backing sheet to the inner facing surface to the veneer. Then, the paper-backed veneer can be stacked and pressed to base substrate(s) to produce a laminated veneer product. The pressing is generally accompanied by heating of the treated veneers in order to accelerate curing of the adhesive, although cold pressing has also been used.

   The veneer is available in large sizes, or sheets, as smaller pieces are jointed together prior to adding the backing. This is one of the advantages of this veneer; the user does not need to joint small pieces together. It is also helpful when veneering curves and columns because the veneer is less likely to crack. The backing also minimises seasonal expansion and contraction of the wood caused by changes in ambient humidity.

   Paper-backed veneers are usually available in 10 mm and 20 mm thicknesses. This measurement is a reference to the thickness of the backing, not the wood face. In most professional shops, the 10 mm backed veneer is used on vertical applications and the 20 mm is used for horizontal projects. Paper-backed veneers are typically available in 120 mm x 240 mm sheets and consist of several veneers matched side by side to make up the full width.

   The manufacture of paper-backed veneers typically involves the application of an adhesive resin, in most cases formaldehyde based, to at least one surface of the paper backing sheet followed by adhering the paper backing sheet to the inner facing surface of the veneer. The paper-backed veneer can be stacked and pressed to the base substrate to produce a laminated veneer product. The pressing is generally accompanied by heating of the treated veneers in order to accelerate curing of the adhesive, although cold pressing may also be used.

The adhesives used are predominantly thermosetting adhesives, such as formaldehyde-based resins. Polyisocyanates such as methylene diphenyl diisocyanate and ethyl urethane resins are formaldehyde-free adhesive alternatives; however, these adhesives are expensive and undesirable for many practical uses of veneer. There are alternatives, such as curable latex polymers with carboxyl groups to aid curing with additional epoxy resin resins as the crosslinking agents (http://www.joewoodworker.com/veneering/backed-veneer.htm).

2) **Fleece-backed veneer** has a fleece that is glued on to the back of the veneer under high pressure, resulting in a durable, high quality material composite. The weight of the fleece and the type of adhesive determines the veneer's stability, strength and resistance to heat and moisture.

   The fleece is a base material that has a wet laid non-woven mat of cellulose fibres, which is reinforced with polyester fibres, and an acrylic binder to give increased strength and good dimensional stability. This fibrous mat is then further impregnated with PVA adhesive, giving it good flexibility and internal bond strength. It is also compatible with most of the adhesives used in woodworking. This fleece version is also used in the automotive industry. In the field of profile wrapping, this fleece type offers the best preconditions for aluminium-plastic profiles and also for extreme requirements.

   Fleece-backed veneers are perfect for projects with curves and rounded surfaces. Even burl veneers are made completely smooth and easy to handle by the addition of fleece. Simplified processing and improved process reliability ensure that the slightly greater investment in fleeced spliced veneer is quickly amortised in most cases.

   A German company, Schorn and Groh, has vast experience in the production of veneer-reinforcing materials (http://www.sg-veneers.com). Two types of fleece-backed veneer are available from this company: Fleece'n'flex and Easiwood veneers. The basis of these products is a non-woven mat of cellulose fibres reinforced with polyester and an acrylic binder. The non-woven mat is then generally impregnated with PVA adhesives. In the pressing grade products, a second coating of adhesive is applied, which then works as a dry film. The fleece for pressing is eminently suitable for reinforcing face veneers, micro veneers and as a backer for flexible veneer sheets.

   Easiwood is claimed to be easier to use than other fleeced veneers because during its manufacture, the wood fibres are "pre-fractured", yielding an especially flexible material composite.

3) **Phenolic-backed** veneer is less common and is used for composite, or manmade wood veneers. Due to concern for the natural resource, this is becoming more popular. It too has the advantage of being available in sheets, and is also less likely to crack when used on curves.

10.5.4 Laminated bent components

Laminated bent components are produced by pressing laminations of veneers glued together, with the grain approximately parallel, over a bending form. No restraint is imposed on the ends of any one lamination, which is free to slide over a contiguous piece during the bending process (Stevens and Turner 1970). The final product consists of a series of individually bent laminations that are glued together with a wood adhesive (Figure 37).

Laminated bent components are widely used in the making of mass produced chair components (Figure 38).

In laminated bending, the thin layer is chosen so that it is easy to bend (between 1 mm to 5 mm) depending on its curvature.

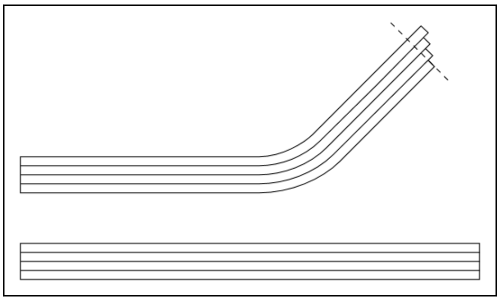


Figure 37: Laminated bent component

Figure 38: Chairs made of laminated bent components designed by a famous Finish designer lvar Hendrik Aalto

Moulded (or curved) plywood is made of layers of veneer bonded together to the desired thickness, placed into a male and female mould and pressed under a predetermined amount of pressure and heat. The glue used in the process of radio frequency (RF) curing of moulded plywood is UF. Moulded plywood is widely used in the production of chair seats and backs, club chairs and architectural products (Figure 39).

(a) (b)

Figure 39: Examples of the use of moulded plywood in chairs (a) chair by Cherner Chair in red gum wood (Source http://www.trendir.com/) and (b) LCW – Low Chair Wood by Charles and Ray Eames (Source: http://nikkiikkin.com/2011/06/24/eames-lcw/)

10.6 Requirements for bond quality

Veneer bond should be evaluated using test methods described in the Australian/New Zealand standard AS/NZS 4266: 2004. The standard specifies two methods for evaluation of the bond quality:

- Method 32: Veneer bond strength
- Method 33: Veneer bond durability.

The criteria for satisfactory veneer bond strength and durability are described in AS/NZS 1859.3: 2005. According to this standard, **veneer bond strength** shall be considered satisfactory provided that:

- failure occurs in the veneer
- failure load exceeds requirements of substrate surface soundness in AS/NZS 1859.1 for particleboard or AS/NZS 1859.2 for dry-processed (Table 6).

Veneer bond durability is considered satisfactory if, on visual examination, there is no separation of the veneer from the substrate (Table 6).

Table 6: Requirements for glue bond properties for wood veneer panels.

Property	Parameter examined	Test method	Requirements
Veneer bond strength	Visual and failure load	AS/NZS 4266.32	Pass and 1,300 N
Veneer bond durability	Visual	AS/NZS 4266.33	No separation

Simple testing equipment can be used for everyday quality control processes but it is recommended that tests be undertaken by a specialist accredited testing laboratory on a quarterly basis to validate and calibrate in-house testing.

For a regular testing of the bond quality the chisel test can be used "in-house" for quality control record purposes. The test, which is described in AS/NZS 2098.2: 2012 *Methods of test for veneer and plywood*, is commonly used for determining the quality of bond in plywood. The test involves the removal of the surface veneer of the veneered panel by forcing the chisel along the glue line and evaluating the percentage wood failure. Although this method is not directly developed for the evaluation of veneered panels, it will give a good indication of bond quality.

10.7 Typical problems related to gluing and pressing

10.7.1 Glue bleed-through

Bleed-through, or the penetration of glue through a veneer during pressing, depends upon veneer porosity, glue characteristics and pressing parameters.

In veneers cut from interlocked grain timbers, such as sapele and makore, the pores run at an angle to the plane of the veneer, which gives a clear channel for the glue to penetrate from one surface to other. This may cause the glue to bleed through the veneer surface.

Bleed-through may be minimised by:

- adding an extender to the glue (e.g. wood flour or starches), which will increase viscosity and lower penetration)
- reducing glue spread and pressing temperature.

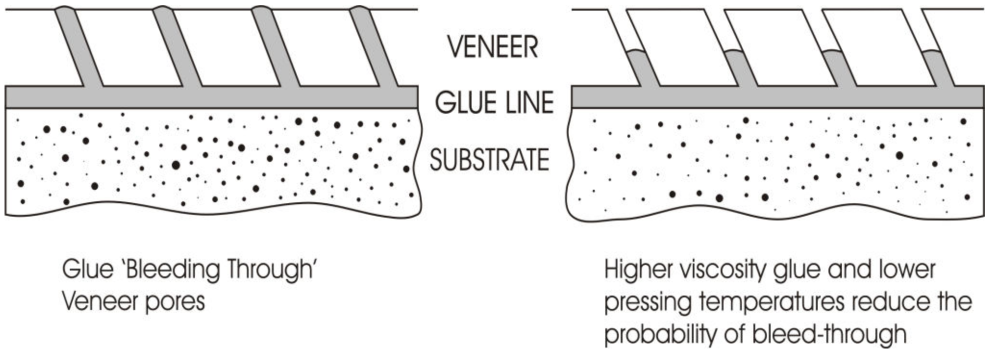


Figure 40: Glue bleed-through (Source: Ozarska 1991)

10.7.2 Veneer delamination

Several factors can lead to the veneer delamination in hot pressing, including steam blows, spotty bonds, complete glue failure and glue bleed-through to the surface of the face veneer. All these factors may be caused by the use of inadequate gluing and pressing procedures as described below (Jowat Corp 1983).

- **Improperly mixed glue**

  If preparation of glue requires mixing of several components (e.g. UF) it is essential that the mixing instruction is strictly followed to avoid veneer delamination.

- **Excessive glue spread**

  If glue spread is excessive, water will turn into steam. Recommendations provided by the glue supplier should be strictly followed.

- **Insufficient glue spread on veneer**

  If the spread is insufficient, there will be bonds in some areas and failures in others.

- **Too high a MC of veneer and/or substrate**

  Too high MC will contribute water to that already in the glue line and will lead to problems with steam blows.

- **Too high a temperature of pressing platen**

  The temperature of the platen and the pressure should be set according the press specifications.

- **Worn glue spreader rolls**

  Spreader rolls may be worn or the grooves may have a glue buildup. The only solution in this case is to re-groove the spreader rolls.

- **Assembly time too long**

  In this case, the glue lines may pre-cure (set-up) before pressure and heat is applied. A longer assembly time catalyst should be used if required by specific manufacturing conditions.

- **Variation in veneer thickness**

Veneers should be checked with a micrometer for differences in thickness. Any difference over 0.1 mm can cause problems.

- **Too short pressing time**

  If too short a press time is used, the glue line will not cure sufficiently. Panels should be checked immediately after they are removed from the press.

REMARK

If the proper steps are taken in the process of veneer laminating and delamination is still a problem, one should assume that the wrong adhesive is being used or that something is wrong with the adhesive. In the latter case, the adhesive must be checked in the laboratory to pinpoint the problem.

10.8 Conditioning of veneered panels after pressing

After pressing, veneered panels should be stored in relatively dry conditions to allow the moisture from the adhesive to dissipate. If the ambient conditions in the factory are not considered to be dry, it is recommended that the completed veneered panels be stored in a purpose built area with controlled temperature and relative humidity. In particular, as the MC of veneer is related directly to relative humidity, control of humidity in isolation is known to be effective and less expensive to operate.

Panels should be allowed to condition to an EMC of 8% – 10% in Australia, or 6% – 8% in the United States and Europe. If excess moisture is present, a hot conditioning area may be required. On the other hand, excessively dry panels may well have to be humidified. All stock should then be maintained at this MC until sanded and finished.

11 SANDING OF VENEERED PANELS

11.1 General requirements for sanding

Sanding can be considered the last operation in the manufacturing process of the uncoated veneered panel. Sanding is carried out to remove the surface wood layers, producing a smooth and uniform surface and eliminating blemishes due to previous operations such as gluing. Sanding is also carried out on applied coats after drying and just before the application of the final finishing coatings. In this case, the function of sanding is to smooth any raised grain and also to improve the inner coat adhesion of subsequent finishing coatings.

Proper sanding is imperative to the final appearance of the veneer surface. Sanding dramatically affects the staining process as well as the appearance of the top coat. A stain will appear dark and blotchy if the surface is not sanded adequately to remove machining imperfections, raised grain and handling marks.

Sanding requires considerable care to avoid over sanding the panel edges and ends, and sanding through of the thin sliced face veneers.

If the panels are sanded down too much, the veneer is not able to withstand even small stresses and will be prone to checking.

The sanding operation is performed for the following reasons (Saunders 1993):

- to produce a clean finish suitable for subsequent polishing or painting
- to produce a panel of a required thickness and having thickness uniformity within specified limits. This is called thicknessing
- to remove veneer repair tapes, to clean up filled splits or holes and to remove dust, finger marks and dirt.

The quality of sanding should be checked regularly. This should involve:

- the visual evaluation of the surface to ensure that there is no sanding through the veneer
- the measurement of thickness of the panels to ensure uniformity of the sanding operation.

Due to economic reasons, veneers have become thinner and thinner. For this reason, innovative sanding technology solutions must maintain a high degree of flexibility for industrially manufactured veneered parts. Various types of sanders are available for sanding veneered panels. The most common, wide-belt sanders, are where the abrasive belt is wider than the panel to be sanded. The sanding machines can be equipped with two or three heads. The sanders are often equipped with brushing systems that remove wood dust from the surface. It should be noted that wood dust presents health and fire hazards and that proper precautions should be taken for dust extraction.

11.2 Sanding maintenance guide

As sanders vary considerably, it is important that the instructions of the manufacturer are followed in the initial set-up of the machine and during the sanding process.

Sanding machines should be well maintained. A sanding maintenance guide is provided in Table 7.

Table 7: Problems related to lack of maintenance of sanding machines. Reproduced from Koenig (1991).

Sanding problem	Cause of the problem
Thickness of sanded panel not constant	– Clamp not sufficiently tight – Dust under clamp – Feed belt not parallel – Roller wear not uniform
Thickness sanding with flatness difference	– Residues under the feed belt – Roller wear not uniform
Traverse mark	– Belt joint defective – Roller eccentric
Longitudinal sinusoidal mark	– Belt gummed – Belt joint defective – Belt grain not proper or defective
Straight longitudinal mark	– Material clots on pressure shoes
Relief longitudinal line	– Roller to rectify
Relief longitudinal sinusoidal line	– Bely gummed – Belt engraved – Belt worn

Developing surface smoothness by sanding is best done using a progression of grit sizes, each of which produces as scratch pattern at least to the depth of the previous pattern. The selection of sanding paper grit is important because finer or coarser grains will result in greater or lesser absorption of the varnishing products and, respectively, in a more or less intense colour of the veneer. Worn sanding paper can cause burn marks on the veneer because of excessive friction. The burn marks will cause colour variation.

Excessive sanding causes over-reduction of the veneer’s thickness, which reveals the part of the veneer in contact with the glue, causing the undesirable phenomenon of pore whitening or sanding through. For these reasons it is advisable to harmonise perfectly the action of the abrasive, pressure and sander speed, according to the veneer’s characteristics.

After sanding, the veneered panels should be stored in controlled storage conditions (see Chapter 8).

12 FINISHING OF VENEERED PANELS

12.1 General requirements

The panels that are produced by veneered panel companies leave the factory as raw, unfinished products. This means that even if they meet all standard requirements, their performance and quality as final veneered products depends on the further handling and manufacturing process, which is usually undertaken by furniture or joinery companies. The veneered panel producer does not have any control over how the panels will be handled and what production procedures will be applied. Therefore it is critical that a manufacturer of veneered products, who receives the raw panels, understands and strictly follows the requirements and guidance developed for the veneer and veneered panels.

The first stage in the manufacture of veneered products is the finishing process. It is usually undertaken by furniture or joinery companies or by a specialised finishing factory.

The finishing of veneered panels is a very important process during which time special care should be taken in order to eliminate any problems that could affect product quality and performance.

There are many different finishing systems, methods and equipment used on veneered products. This information is readily available in various finishing manuals, handbooks and training materials and is not within the scope of this Manual. However, typical problems and faults related to finishing systems are described and information on how to prevent them is provided. Recommendations on proper finishing procedures are also outlined.

There are many claims related to poor performance and quality of veneered panels and products due to problems with finishes. Such claims are often difficult to investigate due to the many potential causes of the problem and lack of quality control records. Each problem should be traced individually by enquiring into every detail of application in as methodical a manner as possible. The problem is very complicated when the fault is caused by more than one factor.

It is often difficult to get accurate and detailed information from a manufacturer or user of the product. In such a case, finding the facts becomes almost impossible.

12.2 Selection of coatings

Wood veneer is a beautiful material. To retain its beauty, the veneer surface should be protected from the harshness of day-to-day usage because as an absorbent material, it is can be easily stained and can readily pick up dirt. Skilful finishing can considerably enhance the natural beauty of the wood veneer. The finishing not only adds a lustre to the wood but it also “brings up the grain”. This is an optical effect changing the contrast between light and dark sections of the wood, resulting in more pronounced grain.

The finishes for wood are normally transparent to reveal the grain, and these are commonly called lacquers. Sometimes, however, opaque coloured materials are used, hiding the underlying surface, and these, whatever their chemical composition, are referred to as paints.

Achieving a good-looking finish on wood involves a combination of two elements, the surface condition of the wood and the finishing treatment applied to it (Hoadley 2000). Although done separately, they are interrelated and must be planned with respect to one another. It is important to protect wood surfaces from any dirt or dust and to make sure that a surface can be cleaned easily. Finishes prevent changes in colour due to UV-light radiation or atmospheric pollutants but their most important function is to reduce the exchange of moisture with the atmosphere, thus reducing the consequences of wood dimensional movement. However, it is important to understand that even a high quality finish will not totally eliminate moisture changes in wood veneer or in solid wood. Given enough time, moisture will be absorbed into wood from a humid atmosphere or will escape to a dry atmosphere through any finish. However, the important role of the properly selected finish is to reduce the rate of exchange enough to buffer the humidity changes. Obviously, some finishes are better than others in this respect. The effectiveness of a particular finish may also be affected by the number of coats applied and the time of exposure to a different humidity level.

It is essential that the selection of finish is suitable for the end use application of the finished product. For example, a highly decorative display cabinet does not need the same durable coating as a kitchen table or a laboratory bench.

Recommendations for the selection of coatings for finishing of veneered panels have been developed by the Australian Furniture Research and Development Institute (AFRDI) with assistance from Mirotone and the author of the Manual while employed at CSIRO (Australian Furniture Research and Development Institute 2001). The information provided in this Section is based on these recommendations.

Inspection and preparation of veneer surface before finishing

The most critical aspect of surface preparation is the control of the MC of veneered boards. High MC is difficult to detect visually and therefore it should be checked with a moisture meter. The boards should be stored in a cool dry place, otherwise they will absorb moisture from the air.

The boards must be free from marks, dust, grit, indentations, oil, wax and other contaminants.

Coating methods

Coating methods vary, with desired finishes used for various products and service conditions. It is recommended that the products and methods used be recorded for each job. This will provide useful information on the possible cause of problems if they arise.

Environmental fluctuations in temperature and humidity can affect the finish. Therefore, finishing should be performed in controlled environmental conditions, out of droughts and away from dust, moisture and other contaminants.

The back or reverse side of all panels should be sealed to slow and equalise the ingress of moisture. Panels not sealed in his manner may bow or cup.

Selection of coating

There are many factors that contribute to the selection of a finish. The wood species plays a very important role in the selection procedure. For example, open grained veneers may require filling, especially if a high gloss finish is desired. Some species of veneers have a high content of phenols, tannins and other extractives. These species should be sealed with a specially formulated "isolator" coating that provides a barrier to stop the chemicals in the wood reacting with the chemicals in the top coat.

It is important to ask lacquer manufacturers for advice on the most suitable coating system for a particular species.

<u>REMARK</u>

Under no circumstances should two pack products be put over single pack coatings.

It may be necessary to use two or more coating systems on a piece of furniture. For example, a dresser or sideboard needs a very durable serving surface, whilst the vertical surfaces can have a less durable, but just as attractive coating.

A comprehensive guideline for the selection of coatings for a wide range of veneered products has been provided in Veneer Product Information Manual "Veneer" developed by Timber Veneer Association of Australia (2012). The author obtained an approval to reproduce the guideline in this Manual (Table 8).

Table 8: Timber finishes guide.

Reproduced from Timber Veneer Association of Australia (http://www.timberveneer.asn.au) *(These are guidelines only)*

Generic Type	General Properties	Typical Application	Hardness/wear & tear	Heat resistance, hot coffee	Water & yellowing resistance
Acrylic polyurethane, solvent base	The best product for re-con veneer & natural veneer	– Kitchen, bathroom vanity, doors & panels – High quality commercial & domestic projects / fit out – Window furnishing (venetian blinds & shutters) – High quality furniture – Table & bar tops – Hotel and office fittings	Excellent	Excellent	Excellent to both
Polyurethane	Very good product for re-con & natural veneer	– Kitchen, bathroom vanity, doors & panels – High quality commercial & domestic projects / fit out – High quality furniture – Table & bar tops – Laboratory, hotel and office fittings – Stairs & handrails	Excellent	Excellent	Water resistance excellent. Do yellow, degree of yellowing varies between brands.

Water base two pack	Excellent product for re-con & natural veneer. Perform similar to acrylic polyurethane, but more environmentally friendly	– Kitchen, bathroom vanity, doors & panels – High quality commercial & domestic projects / fit out – Window furnishing (venetian blinds & shutters) – High quality furniture – Table & bar tops – Hotel and office fittings – Stairs & handrails – Children's toys & furniture	Very good	Excellent	Excellent to both
Low VOC polyurethane	Very good product for re-con & natural veneer	– Kitchen, bathroom vanity, doors & panels – High quality commercial & domestic projects / fit out – Window furnishing (venetian blinds & shutters) – High quality furniture – Table & bar tops – Hotel and office fittings – Stairs & handrails – Children's toys & furniture	Excellent	Excellent	As per polyurethane

It should be pointed out that new type of polyurethane coatings, acrylic urethane coatings, have been developed with a remarkably high light fastness. The coatings have an excellent natural UV resistance, are highly non yellowing and have very good chemical and scuff resistance. Acrylic urethane coatings are used in a variety of applications due to their versatility, durability, appearance and superior weatherability compared to other resin systems. The coatings are particularly recommended for use on reconstructed veneers.

In recent years, concerns about environmental air quality have prompted legislation in many states to limit the VOCs released by finishing materials. As a result, chemists have reformulated old recipes and developed new finishes altogether. Clear water-based finishes are one of this class and, while relatively new to the market, they are growing in popularity. When first marketed, water-based finishes were embraced by woodworkers for their ease of clean-up and quick drying times, even though they were not as durable as the old oil-based finishes. New formulations of water-based finishes are tougher and more UV resistant, and are beginning to rival the old standbys for suitability in a wide variety of conditions.

12.3 Typical problems with finished veneered panels

The majority of coating-related failures apparent on veneered surfaces can be attributed to the causes below (Bayer and Zamanzadeh 2004).

- Inadequate preparation of surfaces (sanding) – the substrate surface is not adequately prepared for the coating that is applied.
- Improper selection and application of finishes (including incorrect mixing) – either the paint or coating selected is not suitable for the intended service conditions, or it is not compatible with the substrate surface.
- Inappropriate or wrongly adjusted equipment and improper application – problem may occur when the required specifications or parameters for the application are not met.
- Improper drying, curing and over coating times – again, this problem relates to a lack of conformance to the required specifications and parameters.
- Lack of protection against water and aqueous systems – this is a particularly serious problem with aqueous systems containing corrosive compounds, such as chlorides.
- Poor environmental and service conditions – exposure of the coated veneered product to wet and humid conditions during its service.
- Mechanical damage – which results from improper handling of the painted or coated substrate, resulting in a breach in the paint or coating.

Most common faults with finishes are described in the following sections.

12.3.1 Crazing of the surface

Crazing, also named “cracking”, is a common problem and gives a visual appearance like fine random crack lines, which are apparent both along and across the grain of the veneer.

On surfaces that have received numerous coats of paint, the underlying layers lose their elasticity and are unable to expand and contract with the surface as it responds to temperature and humidity changes. As the wood swells, stress breaks the bond between layers to form checks. Additional swelling widens the breaks to form cracks. Because wood expands to a greater extent between grain lines, more force is exerted across the grain. Cracks are therefore more likely to form with the grain.

There are many forms and degrees of crazing and there are a number of immediate causes.

Usually the crazing is caused by one of the following faults.

- The formulation of the lacquer being too brittle. A properly formulated lacquer should include a plasticiser, which will allow flexibility of the coating, therefore reducing the risk of cracking.
- Each subsequent coating has been applied too thickly, particularly if the successive coatings are applied over too short a time, leading to excessive solvent retention and consequential movement underneath the top surface when it is dry.
- The use of a hard finish over a soft one or of a fast drying material over a slow drying one.
- The mixing of incompatible materials.
- Rapid and/or large changes of temperature and relative humidity
- Undercoats that are thinned excessively and applied to inert fillers.

Crazing is more likely to occur as the “build” of the lacquer increases. The lacquer applied to a tabletop or sideboard top may craze within a few months while the same lacquer applied to vertical surfaces remains free from cracks. This difference in performance can be attributed to the heavier coating of the tops.

As lacquer crazing may develop over a period of many months, identification of the cause of the crazing after it has occurred may be difficult, particularly if the details of the complete finishing system are no longer available. The control of lacquer crazing is in the hands of the formulator. Potential weakness of the lacquer can be identified by the cold check test, which involves exposure of a lacquered panel for one hour at 60°C followed by one hour at 20°C. This cycle is repeated up to 30 times.

The remedy is to ensure a thinner initial application coat and to allow ample time for drying between coats.

Cracking down to the wood usually requires the complete removal of the coating and repainting. In cases where cracking occurs over veneer or plywood, there is not much that can be done to remedy the cracking besides periodic sanding and recoating.

12.3.2 Orange peel

"Orange peel" is the name given to an uneven, rippled lacquer surface. It is so named because the pattern resembles the texture of the outside surface of an orange.

It is usually associated with improper spraying technique. For example:

- spraying too thick a liquid with too little air pressure. The remedies are, therefore, to increase air pressure, to thin the liquid, or both
- holding a spray gun too close or too far from the surface
- spraying too slowly
- improper evaporation of solvents preventing flow out of the material during the drying cycle.

Orange peel may also occur in curtain coating and is then due to physical properties of the material coupled with the drying parameters.

12.3.3 Blushing

Blushing is a milky-white appearance in the finish caused by the condensation of airborne moisture in a finish cooled by evaporating solvents. On warm, humid days, moisture in the air condenses onto the surface of the finish because of cooling brought about by the rapid evaporation of the solvent. If the finish then cures before the moisture has time to evaporate off the surface, the moisture interferes with the proper curing, causing a milky-white appearance of the finish.

The remedy is firstly to ensure that the spray shop is as dry as possible. A slower evaporating lacquer thinner can be also added to the finish to slow the solvent evaporation and the curing of the finish.

Once blushing occurs, it can be removed by spraying a retardant onto the surface or by rubbing with an abrasive, such as steel wool. As blushing almost always occurs right at the surface, rubbing usually removes the problem with little risk of cutting through. Note that water-based finishes do not blush as they already contain significant amounts of water.

12.3.4 Blistering

Blisters are defects in finished wood products, usually visible as elevations on the finished surface that look like skin blisters. There are two main types of blisters – those caused by heat and those caused by moisture.

Painting in direct sunlight on a surface that is too warm can cause heat blistering. The film dries too rapidly and traps solvents, which are later vaporised, bringing pressure against the top coat and creating blistering. This is more common when using a dark colour coating, since darker colours absorb the heat more readily than light ones.

Blistering can be caused by moisture, particularly in winter months. Interior moisture in tightly constructed homes is a major cause of exterior paint blistering. Moisture bubbling up inside the house escapes through the walls because there is no place else for it to go. In the summer, the sun heats the siding, and the water trapped behind the paint film is vaporised. The resulting pressures cause blistering.

12.3.5 Aeration

Too heavy a coat may cause aeration with nearly all rapid drying materials, particularly if allied with high spraying pressures. In such cases the fault arises from trapping of solvents, which then burst through the virtually dry top skin of the coating. In extreme cases the aeration, which is not visible to the naked eye, gives the appearance of milkiness.

Another form of aeration is caused by the trapping of air in the film. This frequently arises where a heavy coating is applied to open grain timber.

12.3.6 Overspray

Overspray, or dry spray, is a sandy appearance and feel on the finished surface caused by the spray drying too much before it hits the surface. Causes include:

- too much air pressure or bounce back from spraying too close to the surface
- excessive air flow pre-dries the atomised lacquer before it can reach the surface (such as when spraying outdoors on a windy day).

12.3.7 White-in-the-grain

This problem usually occurs due to trapped filler solvent, which is a non-solvent for the lacquer, thus precipitating the lacquer solids. The condition is aggravated by the use of inferior lacquers with weak solvent mixtures and the consequent low tolerance for excess non-solvent.

Prevention is simply a matter of using faster drying filler or allowing a longer drying time. A better quality lacquer will reduce the possibility of the failure.

Bleed-through of glue used in the veneering process can give a similar looking effect and so can the silica inclusions which occur in some timbers, but these are not finishing faults.

12.3.8 Cissing or “fish-eye”

Cissing, also called “fish-eye” or cratering, is the appearance of small, crater like holes or indentations in the finish, resembling craters on the moon. Small impurities are often visible in the centre of the crater.

Cissing is caused by a difference in surface tension between an oily substance in the wood and the finish. The most common reasons for this are:

- silicone in the environment or on the surface of the substrate – even minute traces are sufficient to cause cissing
- contamination by other sources, such as grease, dried soap, detergent, spray dust, wax, or oil from the spray gun
- incompatible elements in the primer
- saturation by fumes in the spray booth.

There are a number of remedies that may assist in avoiding cissing.

- Thoroughly clean any silicone polishes from the surface to be painted and avoid using silicone polishes in the vicinity of the paint shop. Prepare the surface using the same preparation procedure as that set out below.
- Thoroughly clean the surface with wax and grease remover. Do not allow cleaning solvents to dry on the surface but remove with a clean dry cloth, using the cloth only once.
- Clean surfaces prior to sanding and always ensure that all sanding dust is removed. Prepare bare metal surfaces with metal conditioner. Repeat the solvent cleaning operation prior to commencing spraying. Ensure that the spray gun and compressed air equipment are properly maintained.
- Always use the recommended materials.
- Ensure that the spraying area is properly ventilated.
- Remove the paint completely from the affected area, and repaint, following the recommended preparation procedure
- In extreme circumstances it may be necessary to use an anti-cissing additive. Always consult the paint manufacturer before using such additives.

12.3.9 Incorrect choice of lacquers

The choice of sealer and lacquer is very important. Problems often occur if components of the finishing system are incompatible with each other. In such cases it is difficult to solve a dispute between the user and the suppliers of these various finishing components.

It is essential that all the components of a finish are compatible and come from one supplier/producer.

12.3.10 Veneer movement on the substrate

Cracks seen along the veneer grain usually indicate cracking of veneer. This can be caused by improper bonding of veneer to the substrate or incorrect MC of veneer.

12.3.11 Discolouration

Discolouration of the finished veneered products may be caused by change in colour of the substrate or the clear coating, mainly due to incompatibility between the glue, veneer and coating systems, or by fungal attack. There are several potential problems that may cause veneer staining or discolouration. These are discussed in detail in Chapter 15.2.

12.3.12 Improper handling of finished panels and products

When a satisfactory finish has been obtained it is essential to ensure that proper handling procedures are applied in order to maintain the quality of the finish. The following precautions should be undertaken.

- Allow ample time for lacquers to cure thoroughly before handling and packaging. Otherwise damage to the lacquer will occur.
- The finished panels should not be placed into enclosed boxes too soon after lacquering, as there will not be sufficient air circulation to cure the lacquer.
- Panels should not be stored in damp, draughty or hot warehouses or factories.
- Maintenance instructions should be provided by the supplier of the finished product and should be strictly followed by the users of the veneered products. In particular, if an inappropriate cleaning agent is used regularly it will damage the coating and allow moisture ingress. This will lead to the loss of gloss, whitening, embrittlement and veneer checking.

12.4 Summary recommendations on finishing procedures

- Veneered panels should be stored according to standard requirements in order to eliminate any factor that could affect the quality of the panels. The storage and handling requirements are described in Chapter 8. In particular, it is important that veneered panels are not exposed to damp and humid conditions. Several veneer cracking problems have been attributed to exposure of furniture or veneered panels to such conditions for several weeks.
- It is essential to check the MC of panels before the finishing process. This requirement is particularly important if the finishing is done by a subcontractor in another factory because the MC of veneered panels can easily increase while in transit. Finishing materials should not be viewed as

barriers to MC changes – they really only slow the process due to their low moisture vapour transmission characteristics.

- The panels should be free from marks or indentations that will detract from the panel's final appearance. They should be clean – dust and grit will adversely affect the finish. Oil, wax and other contaminants should also be removed before a lacquer is applied. If necessary a grease remover should be used.
- It is essential that the type of finish selected for a piece of furniture or other products is suitable for the end use application (domestic or commercial, damp or dry conditions, light, general or heavy use).
- Finishes should be applied under controlled environmental conditions, away from draughts, dust, moisture and other contaminants.
- It is absolutely essential that the manufacturer's instructions be carefully followed and that finishing products from different suppliers not be mixed or used on the same board.
- It is essential that all surfaces in veneered furniture/products be coated to provide a protective seal against changes in humidity. Failure to do so will be detrimental to the stability of the veneered products as moisture penetrates through the unsealed surface during any ambient change in relative humidity. This effect predisposes the panel to veneer cracking. Panels not sealed may also bow or cup. The sealing of all surfaces is a critical factor in maintaining high quality veneered wood products.

  Acrylic-urethane and polyurethane lacquers are generally considered to be the best moisture barriers amongst the commonly used wood finishes. However, in reality, the type of finish is usually determined by customer preference and therefore the manufacturer has little choice. But if the veneered product is destined for long-term use it is important to take care that all edges and surfaces of the panels are sealed to prevent rapid MC variations.
- It is strongly recommended that the finish's material data sheet and the finishing process be recorded.
- Manufacturers of veneered products should provide instructions as to the ongoing, "in service" care of the finished article. As these instructions largely apply to the treatment and protection of the surface finish, they should be formulated in conjunction with the lacquer supplier.

REMARK

Even if the veneer panel producer supplies high quality panels, the elimination of veneer problems is also dependent on the quality controls applied by the furniture or other product manufacturer.

13 MANUFACTURING AND MAINTENANCE OF VENEERED PRODUCTS

Generally the manufacturing process using veneered panels involves machining, jointing and assembly of various components. However, the production methods and procedures depend on the type of products, their design and the machinery available at particular manufacturing premises.

The description of various production methods is not within the scope of this Manual. However, it is important to highlight that manufacturing companies have responsibility for the quality of final veneered products. High quality, properly manufactured veneered panels may be seriously affected if further manufacturing procedures and maintenance of the final products do not meet the requirements specific to veneered products. Therefore, it is essential that all parties involved in the production of the products and their users strictly follow recommendations and requirements developed for the veneered products.

The following are general recommendations for packing, storage and cleaning of veneered products.

- Finished veneered panels are not stored in warehouses/factories that are damp, draughty or hot. Standard requirements for storage of veneered products should be strictly followed (Chapter 8). The same requirements apply to the conditions in the factory in which the manufacturing process takes place.
- Final veneered products should be carefully packed to protect against mechanical and/or environmental damage during transport and storage. Particular care should be taken of veneered products that are being shipped, as the MC of veneer in a shipping container may be as high as 20%. In addition, temperature may be high, not only permitting rapid diffusion of moisture into the veneer but also providing the most suitable conditions for checking when the veneers dry out. One suitable method of protection of furniture in transit is to seal it in polythene, which is cheap and a nearly ideal moisture seal that also provides some protection against surface markings.
- Products should not be placed or installed in wet, damp or very hot rooms/buildings. These extreme conditions may cause serious damage to the veneered products. Early installation of the products in newly constructed buildings may be particularly devastating. There have been instances of severe deterioration of the products (such as desks, tables and panelling) delivered to a site before contractors have finished internal work.
- It is essential that a proper cleaning agent is used on veneered products. If an inappropriate cleaning agent is used regularly it will damage the coating and allowing the ingress of moisture. This will lead to the loss of gloss, whitening, embrittlement and veneer checking.

14 FORMALDEHYDE REGULATIONS FOR VENEERED PRODUCTS

14.1 General information on formaldehyde emissions

Formaldehyde is produced on a large scale worldwide. One major use includes the production of wood binding adhesives and resins. The Air Resources Board (ARB) evaluated formaldehyde exposure in California and found that one of the major sources of exposure is from inhalation of formaldehyde emitted from composite wood products containing UF resins. The International Agency for Research on Cancer (IARC) reclassified formaldehyde from "probably carcinogenic to humans" to "carcinogenic to humans" in 2004, based on the increased risk of nasopharyngeal cancer. Formaldehyde was also designated as a toxic air contaminant (TAC) in California in 1992 with no safe level of exposure. State law requires the ARB to take action to reduce human exposure to all TACs (http://www.epa.gov/oppt/chemtest/formaldehyde/).

It must be highlighted that the cancer causing properties of formaldehyde are only evident at very high concentrations, hundreds of times greater than levels emitted from plywood and LVL products.

The IARC has established that at concentrations of less than 0.1 ppm, formaldehyde is undetectable by smell. At concentrations from 0.1 ppm to 0.5 ppm, formaldehyde is detectable by smell, with some sensitive individuals experiencing a slight irritation to the eyes, nose and throat. At levels from 0.5 ppm to 1.0 ppm, formaldehyde will produce irritation to the eyes, nose and throat of most people. At concentrations above 1.0 ppm, exposure to formaldehyde will produce extreme discomfort.

The acceptable level of formaldehyde emissions from wood panel products has been continuously reduced over the last decade. The consumer demand for environmental friendly and non-hazardous products and a public awareness of the dangers of exposure to high levels of formaldehyde are the driving forces of change in the emissions requirements. The formaldehyde regulations vary between countries.

The US Department of Housing and Urban Development has specified limitations for formaldehyde emitting products with underlayment and decking materials limited to emissions of 0.2 ppm and panelling and other products limited to 0.3 ppm. Europe has adopted the E1 regulation, which limits formaldehyde emissions from products to a level that produces a maximum indoor air concentration of 0.1 ppm.

Japan currently has the most stringent regulations under their "Sick House Legislation" (http://www.ipsnews.net/2003/10/environment-japan-sick-house-syndrome-leads-to-safer-buildings/). For all indoor environments, products must meet the F**** classification, which restricts emissions to 0.03 ppm. This is equivalent to background levels and is effectively a zero emission limit. Internationally, the generally accepted emissions limit is 0.1 ppm (EWPAA 2010).

14.2 International regulations on formaldehyde emissions

14.2.1 Australia and New Zealand

Worksafe Australia has established 1.0 ppm TWA (time weighted average) over an eight-hour period with a 2.0 ppm STEL (short-term exposure limit) of 15 minutes as the safe level for occupational exposure. New Zealand has an OEL (Occupational Exposure Limit) of 1.0 ppm that cannot be exceeded at any time (Engineered Wood Products Association of Australasia 2010).

The Engineered Wood Products Association of Australasia (EWPAA) and Timber Veneer Association of Australia (TVAA) have for a number of years monitored formaldehyde emissions from its members' products through testing conducted at their NATA National Testing Laboratory for compliance with Australian standards and Japanese regulations. The following standards are used for testing formaldehyde emissions from veneer, plywood, LVL and reconstructed wood-based products.

- AS/NZS 2098.11: 2005 *Methods of test for veneer and plywood – Determination of formaldehyde emissions for plywood*
- AS/NZS 4357.4: 2005 *Structural laminated veneer lumber – Determination of formaldehyde emissions*
- AS/NZS 4266.16: 2004 *Reconstructed wood-based panels – Methods of test – Formaldehyde emission – Desiccator method.*

Members of the TVAA use E0 and E1 boards as substrates for decorative wood veneers, and so comply with the lowest emitted levels of formaldehyde emissions.

Most TVAA members use non-formaldehyde glues when laying up veneers, but even when formaldehyde glue was used to bond veneers to wood panels it did not affect the rating of the substrate.

The Australian standards governing the manufacture of reconstructed wood-based panels provide for three levels of formaldehyde emissions from newly-manufactured boards, namely E0, E1 and E2. Products manufactured to Australian standards are required to be branded to show their formaldehyde classification.

The formaldehyde emissions classes in the Australian/New Zealand standards are detailed in Table 9.

Table 9: Formaldehyde emissions classes in Australia and New Zealand.

Emission class	Formaldehyde emissions limit (mg/L)	Formaldehyde emissions limit (ppm)*
E0	Less than or equal to 0.5	Less than or equal to 0.041
E1	Less than or equal to 1.0	Less than or equal to 0.08
E2	Less than or equal to 2.0	Less than or equal to 0.16
E3	Greater than 2.0	Greater than 0.16

** Based on a test chamber volume of 10 L, zero airflow during the 24 hour test cycle, molecular weight of formaldehyde 30.03 and the number of microlitres of formaldehyde gas in 1 micromole at 101 KPa and 298 K.*

Formaldehyde emissions from the Australian products, EWPAA certified, are well below acceptable exposure limits specified by Workplace Australia and do not constitute a health risk.

14.2.2 United States

In 2008, the California Air Resources Board (CARB) introduced new regulations on the emissions of formaldehyde from composite wood products, such as particleboards, hardwood plywood or MDF, that were going to be sold in the state. The new regulations started in 2009 as Phase 1, and by the end of July 2012 reach Phase 2, which has more stringent emissions standards. All manufacturers are required to be at those levels, which is the minimum requirement to be able to take part in the market of wood composite products.

In 2010, President Obama signed the *Formaldehyde Standards for Composite Wood Products Act* into law. This legislation establishes limits for formaldehyde emissions from composite wood products: hardwood plywood, MDF and particleboard. The national emissions standards in the act mirror standards previously established by the California Air Resources Board for products sold, offered for sale, supplied, used or manufactured for sale in California (Table 10).

The new standards apply to domestic products and foreign imports, and the emissions levels are aligned to the ones in Phase 2 of the regulations imposed by the CARB. This new law was made obligatory for all wood composited products in the United States by 1 January 2013.

In addition to establishing national standards, this law requires third-party testing and certification to ensure that products with formaldehyde comply with the national standards and directs the Environmental Protection Agency to work with Customs and Border Protection and other relevant federal agencies to enforce the standards for imported wood products. It also has broad support from the wood products industry as well as environmental, health, and labour organisations.

Table 10: Regulation on formaldehyde emissions from wood composite products for the United States, based on California's emissions requirements.

Hardwood plywood: veneer core	Hardwood plywood: composite core	Particleboard	Medium density fibreboard	Thin medium density fibreboard
0.05 ppm	0.05 ppm	0.09 ppm	0.11 ppm	0.13 ppm

Note: All testing must be conducted in accordance to ASTM E1333 (Large chamber test method).

To meet these standards, manufacturers need to use modified UF resin systems, no-added formaldehyde (NAF) or ultra-low-emitting formaldehyde (ULEF) resin systems.

Distributors, importers, fabricators and retailers are required to purchase and sell panels and finished goods that comply with applicable formaldehyde emissions standards. They are required to take "reasonable prudent precautions" (such as communicating with their suppliers) to ensure that the products they purchase are in compliance with applicable formaldehyde emissions standards. In addition, distributors and importers must keep records showing the date of purchase and the supplier of the product(s), and document what precautions were taken to ensure that the products comply with applicable formaldehyde emissions standards. Fabricators are also required to label their finished goods to denote that they comply the required emissions standards, if the finished good contains hardwood plywood, particleboard or MDF and will be sold, offered for sale or supplied for use in the United States. If the finished good is made exclusively from hardwood plywood, particleboard or MDF made with NAF or ULEF resins, then the finished good must be labelled accordingly.

14.2.3 European standards

The European standards are differentiated by the Board Class, with E1 being the top quality and E2 more suitable for secondary uses and not decorative veneers.

As of the summer of 2011, the European chamber test equivalent to the CARB system Phase 2 defined limits of 0.065 ppm for particleboard and 0.03 ppm for plywood (Table 11). Also, the European Panel Federation (EPF) agreed on a reduction of formaldehyde emissions to a maximum of 0.065 ppm (test chamber method EN 717-1) for CE-labelled, uncoated wood-based materials for use in the building trade (EN 13986). The recommended limit is to be implemented through European standardisation. This was proposed to attempt to match the requirements from the CARB and JAS emissions requirements and make it easier to trade between the countries (http://www.chimarhellas.com/wp-content/uploads/2008/07/formaldehyde_2008.pdf).

14.2.4 Japanese standards

In 2002, the Japanese Industry Standards (JIS) Committee amended the Japanese Building Standard Code in response to public health concerns over poor indoor air quality. Under the revised standard, all new habitable building construction in Japan requires that there be technical standards in place to regulate the air quality. One of the restrictions placed on building materials is the allowable level of formaldehyde emissions. As of July 2003, testing and certification requirements have been established for composite wood products, such as plywood, wood flooring, structural panels and LVL. Because it is very difficult, if not impossible, to eliminate formaldehyde from a building completely, the standard employs a tiered rating system based on the amount of formaldehyde emissions a building material gives off. These are from "one-star" to "four-star" ratings, with the four-star rating representing the lowest amount of formaldehyde emission. All testing must be done in accordance to either JIS A 1460-2001 *Building boards determination of formaldehyde emission – Desiccator method* or JIS A 1901-2003 *Determination of the emission of volatile organic compounds and aldehydes for building products – Small chamber method*. The values are presented in Table 11. Usually, only a three- to four-star grading is accepted for buildings.

Table 11: Japanese Formaldehyde Emissions Grades (mg/L). Reproduced from http://www.towood.com/news_detail.php?id=671.

Grades (rating)	Min. value	Max. value
F****	0.3 mg/L	0.4 mg/L
F***	0.5 mg/L	0.7 mg/L
F**	1.5 mg/L	2.1 mg/L
F*	5.0 mg/L	7.0 mg/L

14.2.5 Alternatives for emitting less formaldehyde

There are four major approaches when it comes to replacing or lowering formaldehyde emissions (Healthy Building Network Production 2008). These are:

- modified UF resins with scavenger additives, such as melamine
- alternate formaldehyde resins, such as PF, which cure at the factory during manufacture and hence have much lower formaldehyde emissions in use than UF
- alternate fossil fuel-based binders containing no added formaldehyde, such as methylene diphenyl diisocyanate (MDI)
- alternate binders based on renewable resource materials, such as soy flour.

15 COMPLEX PROBLEMS IN VENEERED PANELS

Problems may occur in veneered panels/products at any stage of the process if the manufacturing procedures are not strictly followed.

Examples of typical failures related to each of the manufacturing stages have been described in the earlier chapters. However, in some cases, several factors can contribute to the failure of the final product. Therefore it is often very difficult to trace back through all the stages of the manufacturing process in order to determine the cause of the failure. Typical examples of such a failure are veneer checking and discolouration of veneered products. These are complex problems that often occur in veneered products and it is usually very difficult to track down their likely causes, as they could be associated with almost every stage of the manufacturing process. Possible causes of these problems and their prevention methods are described in the following sections.

15.1 Causes of veneer checking and its prevention

Veneer checks (also called cracks) are formed when stress failures occur in the face veneer, caused by differential shrinkage or swelling between the face veneer and the panel substrate to which it is applied (Forbes 1997, Ozarska 1991). As the relative humidity of the environment (in which a panel is used) changes, so does the MC of the panel. With wood, changes in MC mean shrinkage and swelling. Unfortunately, when a veneered panel shrinks or swells, the veneer does not “move” at the same rate as the substrate. This creates considerable stresses within the panel that, if great enough, result in wood failure. Failure will occur at the weakest part of the wood, which is generally over deep lathe checks, large pores or other weakened areas on the face veneer. Such failures in the face veneer then create stress concentrations in the finish, which results in the visible cracks called veneer checks (Figure 41).

There are many causes of veneer checking and they can be eliminated or significantly reduced if proper manufacturing and quality control procedures are in place.

The factors that influence the formation and the severity of veneer checking are the selection of veneer species, type of core material and construction methods, MC of veneer and the core, adhesives and the gluing process, conditioning and storage, finishing process and the maintenance of the final products. These factors are discussed in the following sections.

Figure 41: Example of checks developed on veneer surface (Photo: Barbara Ozarska)

Cause 1: Veneer species and quality

Species that are highly porous or “ring porous” such as oak and walnut are very susceptible to checking. Generally, species with fine pores tend to be more resistant to checking than wood with large pores (Forbes 1997). This is because deep checks formed during veneer peeling/slicing and large pores create weak spots on the face veneer, which provide less resistance to failure when the face veneer is under stress. This creates stress concentrations in the finish, which results in cracks in the finish (Figure 42).

Veneers with a high degree of figure and of greater density are most prone to checking (Gilmore and Hannover 1990).

Quality of veneer used is extremely important as defects greatly enhance the possibility of surface checking by providing weak zones. Checking of the more popular straight grain veneers rarely occurs although exceptions have been noted when items have been stored in a humid area for some weeks before finishing.

Checking of the so-called “exotic veneers” is more common. The main difficulty here is that these veneers are brittle and, at the recommended MC of 10%, probably too distorted for any preparation to be carried out without severe splitting of the veneers. These brittle veneers have to be wetted to improve their handling characteristics. The excess water is then removed by the “flattening” process.

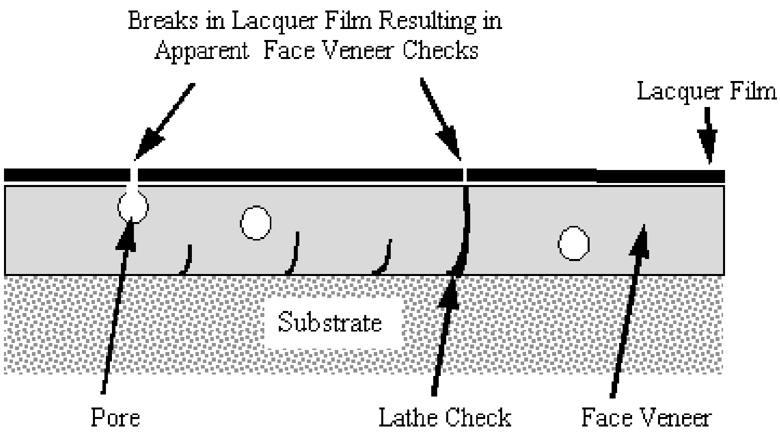


Figure 42: Veneer checks as the result of wood failure in the face veneer (Forbes 1997)

Cause 2: Moisture content changes

Veneer checking mainly occurs as a result of the movement of veneer or the substrate due to the changes in MC. As the dimensions change, stresses between the veneer and the core occur. When these stresses reach the point where they exceed the structural strength of the veneer, a rupture of the fibres takes place, which shows up as a check or minute split on the surface. The checks closely follow the grain direction of the decorative veneer.

Veneer checking due to the dimensional changes is related to the type of the veneer cut and type of substrate used. Quarter cut veneer will check less that crown cut veneer. The reason is related to differential shrinkage of wood in radial and tangential directions; tangential shrinkage is much greater than the radial shrinkage. Therefore, peeled or crown cut veneer is subject to high swelling and shrinkage. When laminated to a more dimensionally stable surface like fibreboard or particleboard, the veneer swells and may buckle as moisture is absorbed. In drying the veneer shrinks, which may result in the opening of checks (Christiansen and Knaebe 2004).

Figure 43 shows the formation of checks caused by differences in swelling and shrinkage characteristics.

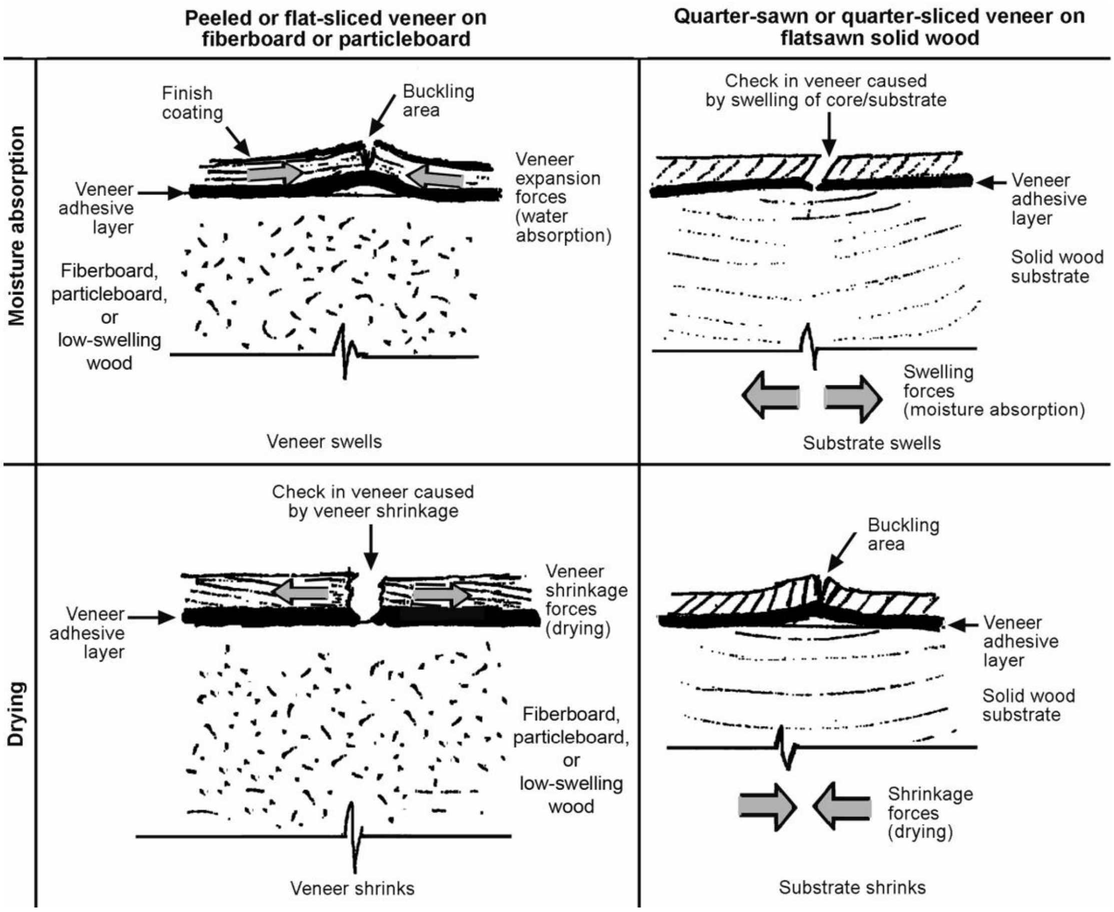


Figure 43: The formation of checks caused by differences in swelling and shrinkage characteristics. Reproduced from Christiansen and Knaebe (2004) with the authors' kind permissions.

The changes in MC may occur if:

- the MC of veneer or/and the substrate prior to the manufacturing process commencing is too low or too high
- the ambient conditions in the storage area do not meet requirements (too humid or too dry)
- the ambient conditions in the veneering factory do not meet requirements (too humid or too dry)
- veneered panels are not protected against the moisture changes during transport and storage prior to the finishing process
- an inappropriate coating system is used and the veneered panels are not sealed and coated on all surfaces
- the maintenance of the veneered surfaces while in service does not comply with the lacquer manufacturer's recommendations
- veneered products (e.g. furniture) are exposed to extreme environmental conditions while in service.

Manufacturers attempting to carefully control MC often overlook certain practices that adversely alter the MC of properly dried panel components. For instance, veneer and panels are often stored in areas with no environmental control. In uncontrolled conditions, this veneer changes MC at a surprising rate. Even in environmentally controlled plants, certain areas may be inadequate for wood storage. For example, veneer stored next to hot presses may lose moisture driven off by the radiating heat. The manufacturer often does not realise that MC has changed and assembles the panel, only to have problems later. The solution is to store wood components in an environmentally controlled atmosphere and check MC before panel assembly (Forbes 1997).

Another consideration often overlooked by manufacturers is the effect of the glue on veneer MC. If a high water content adhesive is applied to the veneer, especially with a long assembly time, the veneer can pick up considerable moisture before pressing. Avoiding high water content adhesives, thick spreads and long assembly times will reduce the likelihood of veneer checks. Manufacturers should consult with their adhesive suppliers, however, before making such alterations (Forbes 1997).

Once panels have been assembled, it is important that they be conditioned in an environmentally controlled area to allow for the temperature and moisture balances to reach equilibrium. Two days is a common minimum conditioning time.

Finally, the finished product must be stored in an environmentally controlled area. Very often, properly manufactured furniture is stored in a warehouse with no environmental controls. Some believe that the finish protects the furniture from moisture changes and storage conditions are not important. However, as discussed in Chapter 12.2, this is not correct because, although the finish helps to slow moisture movement, it does not prevent it. Furniture stored in adverse environments will surely check. Plastic wrap around the finished product prior to warehousing will help to prevent moisture from damaging the furniture. Manufactures should realise that veneer checks may also occur if the final product is used by the consumer in a different or harsh environment, even if checks were not visible when the furniture left the plant (Forbes 1997, Ozarska 2003a).

REMARK

Contrary to some manufacturers' expectations, lacquers do not stabilise the MC of the underlying veneer: they merely delay the first appearance of any cracks. Whilst a more flexible lacquer will absorb some of the movement of the veneer, a lacquer with good performance in other respects cannot be expected to bridge over open cracks in the veneer.

Cause 3: Improper gluing and pressing procedures

A controlled veneer gluing and pressing procedure is very important in preventing the formation of checks in veneered products. The following factors may contribute to veneer checking.

- Too much water in the glue mix. Moisture in the adhesive will result in swelling of both the veneer and the substrate and consequently the veneer will check along the grain as the substrate re-dries to its original MC.

Therefore, high solids content adhesives with proper spread rates and short assembly times should be used (Cassens et al. 2003).

- Varying thicknesses of adhesive spread, which may result in different veneer thicknesses after sanding. There will be localised areas of veneer sanded through or made thinner than the rest of the veneer. This veneer will be less resistant to any stresses caused by moisture changes in the panel and is likely to check. Therefore, a uniform glue spread is very important.
- Poorly bonded areas are much more prone to checking. Areas with poor adhesion will shrink/swell more easily as they are less restrained than the adjacent areas with a strong bond. This will result in stress concentration and consequently veneer checking (Zavala and Humphrey 1996).
- Assembly time is too long. Assembly time has been shown to have a significant effect on veneer checking – the longer the assembly time the more checking will subsequently occur. It is important to keep the assembly time to a minimum – within minutes of spreading. This will prevent swelling of the face veneer before pressing has been carried out.

Cause 4: Improper conditioning and finishing of panels

Immediately after the pressing operation, panels should be conditioned to the required MC of 8% – 10% (see Chapter 10.1.2). Hot-pressed panels may be stickered, to allow them to cool down and lose excessive moisture, or bulk stacked for curing to occur. Cold-pressed panels should be stickered as they absorbed a considerable amount of moisture during curing and require a sufficient time to reach EMC (Cassens et al. 2003).

Excessive sanding may reduce the veneer thickness so that the knife checks on the loose side of the veneer are exposed. This will result in the veneer checking if even small dimensional changes occur.

Checking of veneer often occurs when panels have been exposed to damp conditions for several weeks before finishing (transport or storage). Therefore, it is essential that the factory in which the finish is applied has a special conditioning room to store the panels. The MC of panels before finishing should be in the middle of the range that they will experience in service (between 8% and 10%). It is important to check the MC of panels before finishing to reduce the potential for veneer checking.

Furniture manufacturers should be aware that reasonable temperature and humidity requirements should be provided for storing completed furniture. If humidity rises substantially during storage, the manufacturers will encounter not only sticking drawers and doors, but the possibility of creating veneer checking if that furniture is subsequently placed in a dry ambient environment.

Cause 5: Improper maintenance of veneered products

The final product may be exposed to extreme conditions of environment (too dry or too humid) or to changing conditions (dry-humid-dry-humid) during its service. For example, there are areas in Australia where, during the winter period, the EMC of furniture in centrally heated rooms may be as low as 5% – 6%. However, in northern states during humid months the MC of timber products may be as high as 15%. Therefore, users of veneered products should be advised that the veneered products should to be placed in rooms with controlled environmental conditions.

Checking of veneered products may also occur if improper cleaning procedures (frequent wetting of veneered surface) and improper cleaning agents (e.g. heavy duty detergent or abrasives) are used (see Chapter 13).

15.2 Discolouration of veneered products

15.2.1 Changes in colour of wood

The variation of colour within species is a natural and valuable characteristic of wood, which makes solid wood and veneers much more attractive materials than the products that imitate wood's appearance.

The colour characteristics of wood depend mainly on the presence of extractives, complex organic compounds, such as polyphenolic compounds, and quinines. It is impossible to maintain the colour exactly as it appears on the freshly dressed wood surface. When subject to long-term exposure to sunlight or moderate to strong interior lighting, heat or chemicals, these compounds undergo chemical changes, which result in the change of wood colour. Discolouration occurs in both indoor and outdoor applications.

Even very clear finishes will change the colour of wood considerably. These finishes fill the air spaces among the wood fibres, which have a higher refractive index than air, resulting in a darkening of the colour. To obtain an indication of the effect of a clear finish on the wood, wetting a small area with water will give a good indication of colour.

15.2.2 Discolouration and staining of veneers

Veneer products are susceptible to discolouration and staining, which may be caused by various factors, such as those listed below.

- The effect of strongly acidic adhesives and/or coatings on the natural extractives in the wood, or from the reaction between extractives and strong alkalis.
- The reaction between tannin in timber and iron particles resulting in dark iron tannates. Many species have a high tannin content, which reacts with iron to form black/grey and insoluble iron tannates if the wood is in a wet condition. Such stain is limited to the surface. Spotty iron tannate staining may even result from the atmospheric fallout of particles produced in tool sharpening. Aluminum, monel metal and galvanised steel do not cause staining but in the latter case it is important that the galvanising remains undamaged during the driving of the nail (Bootle 1983).
- Degradation by UV light can occur due to exposure to sunlight. The exposure to sunlight results in a gradual bleaching of red/dark woods and a

yellowing of blonde woods. Such changes are limited to the surface layers of wood and the original colour can be regained by sanding or planing the surface. UV inhibitors can be added to finishes to reduce the yellowing effect on lighter timbers.

A literature review and a survey of the veneer panel producers and the users of the veneered products was carried out in Australia to identify the most common problems related to veneer discolouration (Ozarska and McNair 2001). The results of the survey and literature review on veneer discolouration enabled the researchers to summarise the most common and most typical examples of veneer discolouration as follows.

- ***Red/pinkish staining of blackwood, American cherry and European beech***

  The discolouration occurs on veneered products made of blackwood, American cherry *(Prunus serotina)* and European beech *(Fagus sylvatica)* panels in the form of red blotchy stains. This is caused by the reaction between extractives in the timber and an acid from the glue system or the finish used in the panels (Ozarska and McNair 2001, Sparkes 1991). It was also found that the reddening associated with the use of acid catalysed lacquers is generally less intense and more uniform in distribution than adhesive induced reddening. The reddening of these veneers can be largely controlled by using low spreads of low acidity adhesives and finishes with low acidity (Sparkes 1991).

- ***White staining of steamed European beech veneers***

  This discolouration problem was serious in Australia in the past but the occurrence of white staining has been eliminated after the results of an experimental research project were published in 1998 (Ozarska and McNair 1998). The project recommended that only polyurethane lacquer should be used on beech veneers to avoid white staining and the moisture resistant substrates be used with beech veneer in wet areas (kitchen and bathrooms).

- ***Iron contamination of veneers***

  Iron stain, which appears as a dark bluish to black colour, is usually caused by a chemical reaction between extractives in the wood and iron in steel products, such as nails, screws and other fasteners and appendages.

  Iron stain can occur on nearly all woods but oak, redwood (*Sequoia sempervirens*), cypress (*Cupressus* spp.), and cedar (*Cedrus* spp.) are particularly prone to iron stain because these woods contain large amounts of tannin-like extractives (Knaebe 2011). If the wood is kept dry (indoors), no discolouration will occur. Steel used in contact with wood must not corrode. This can be accomplished by using stainless steel or by coating the steel. A simple test can determine if wood discolouration is caused by iron: apply a saturated solution of oxalic acid or sodium hydrogen fluoride ($NaHF_2$, sodium bifluoride) in water to the stained wood surface. If the solution removes the stain, then iron is present on the wood. If the solution does not remove the stain, apply bleach to the stained area. If bleach removes the stain, the discolouration was probably caused by mildew. The appearances of discolourations caused by iron and mildew are distinctly different. After looking at examples of both, many people can identify them by sight (Knaebe 2011).

Discolouration can occur long after finishing if the finish repels water. When water reaches the iron (possibly from the back side), discolouration appears. In this instance, the finish must be removed to access the discolouration, to test it, and to treat it.

Iron staining can be removed, at least temporarily. Oxalic acid reacts with iron tannates to form a colourless chemical complex. After treating wood with oxalic acid, thoroughly wash the surface with fresh, warm water to remove excess acid. If all sources of iron are not removed or protected from corrosion, staining will occur again. In other words, oxalic acid treatment is only a temporary solution if iron remains on the wood. In time, oxalic acid breaks down with exposure to sunlight, and if wetted, discolouration occurs.

Grey or black discolouration of glues due to contact with iron has been reported (Ozarska and McNair 2001). Both PVA and urea glues may be affected by iron contamination if stored in steel containers. Low pH acidic PVA is most susceptible to this problem. Sometimes the glue does not change its colour while in the container but the discolouration is visible after the veneer is laminated on the substrate. Therefore no steel component should be used in the glue container, even in the tap. This recommendation applies to both the glue suppliers and the glue users who often pour the glue into smaller containers after purchasing.

- ***Dark staining of Tasmanian oak eucalypt veneer***

  Tasmanian oak is a common name for three eucalyptus species: *Eucalyptus delegatensis, E. regnans* and *E. obliqua*, which are usually sold under this name as a mixture of the three species.

  Staining of Tasmanian oak veneers is caused by the reaction between tannin in veneer and iron particles, in wet and/or humid conditions, resulting in dark iron tannates that cause brown staining of the veneered products (Figure 44). Many species have a high tannin content that reacts with iron. (Ozarska and McNair 2001).

Figure 44: Brown staining of Tasmanian oak veneers (Source: Barbara Ozarska)

In the case of Tasmanian oak, it has been proven that high humidity or water contamination of the veneer is essential for the process of staining to occur (Ozarska and McNair 2001). Therefore it is recommended that a durable coating system is used on Tasmanian oak veneers, all surfaces are carefully coated and the veneer is not exposed to wet or humid conditions.

The staining of Tasmanian oak veneer is not related to the type of substrate used in the construction of veneered panels. There has been much evidence of the staining problem occurring on panels with different types of substrates such as MDF, particleboard and plywood.

So far there has been no scientific understanding of the causes of the staining and no authoritative reference material available.

- ***Pink discolouration of American maple, silver ash and beech***

  Individual cases of pink discolouration have been reported on the surfaces of American maple *(Acer saccharum)*, silvertop ash *(Eucalyptus sieberi)* and European beach. According to the information provided, only a small proportion of the total number of veneered products were affected, although they were manufactured by the same company at the same time (Ozarska and McNair 2001).

- ***Discolouration of reconstructed and dyed veneers due to exposure to ultraviolet (UV) light***

  There is an increasing use in Australia, and other parts of the world, of reconstructed and dyed veneers imported from Europe. These veneers are particularly used in joinery, furniture and interior architectural applications.

  Colour change of the dyed wood veneer upon UV exposure is a complex process, which involves a photo-initiated reaction, subsequent chemical oxidation, decomposition of lignin and extractives from the wood and the dye and other chemicals introduced during the dyeing process. Furthermore, the discolouration caused by sunlight depends on the UV intensity and specific wavelength, photochemical reaction rate of lignin and the chemical nature of the extractive and dyes. Protective coatings containing UV absorbers and UV stabilisers have been developed and are used to seal the wood veneer and reduce UV oxidation and discolouration.

Recommendations on the selection of clear UV protective coatings for wood veneers are provided in Chapter 15.2.4.

15.2.3 Investigation of causes of veneer staining and discolouration

The University of Melbourne and the AFRDI undertook a research study in order to investigate causes of veneer discolouration in decorative veneered panels and develop guidelines on the prevention of veneer staining and discolouration (Ozarska 2003b). The project was initiated and developed by the Timber Veneer Association of Australia (formerly the Decorative Wood Veneer Association), and financially supported by FWPA.

The discolouration of four of the most "problematic" species, selected by the industry, was investigated:

- blackwood – *Acacia melanoxylon*
- European beech – *Fagus sylvatica*
- American maple – *Acer saccharum*
- Tasmanian oak – (sold as a mix of either *Eucalyptus delegatensis*, *E. regnans* or *E. obliqua*).

The project involved experimental trials with the objective of analysing the possible causes of the discolouration and then to reproduce the discolouration of these veneers under laboratory conditions. The following experiments were undertaken.

1. **The investigation of the effect of acidification on discolouration of selected veneers.**

   The study aimed to determine the effect of pH of various formulations on the veneer colour.

2. **Accelerated environmental exposure of veneered panels constructed according to the above findings.**

   Veneered panels were manufactured using four veneer species, four types of substrates commonly used by the furniture and joinery industry, two types of adhesives with two values of pH and three types of lacquers (at various levels of acidity). The samples were subjected to accelerated environmental exposure using high humidity and high UV radiation, which are known to be significant factors contributing to the discolouration of veneered products.

3. **The effect of various acid catalysts in relation to pink staining.**

In addition, an experimental study was undertaken with the objective of investigating the effect of various acid catalysts in relation to staining, in particular the pink stain, in European beech and blackwood veneers.

The details of the studies are provided in the project report (Ozarska et al. 2003b). Summary recommendations on the prevention of veneer discolouration are presented below.

Summary recommendations on the prevention of veneer staining and discolouration

Pink discolouration of veneers

- The results of the study described in the previous chapter indicated that the three veneers are susceptible to pink dicolouration from acidic products. Therefore, the recommendation to the industry is that for these veneers, the pH of lacquers and adhesives should be close to the natural pH of the veneers in order to prevent such discolouration occurring.
- When purchasing adhesives for "problematic" veneers, the veneer panel producers should specify the pH of the glues.
- Similarly, the users of veneer panels should ensure that the panels they purchase meet the required specifications in regards to the pH of the adhesives. They should also ensure that the coating systems they purchase meet the required specifications with respect to the pH range of the veneers.
- The following pH ranges are recommended for "problematic" veneers:
  - blackwood: pH range between 3.6 and 5.2
  - European beech: pH range between 3.6 and 6.3
  - American maple: pH range between 3.8 and 4.6.

Dark staining of Tasmanian oak veneers

1) The results of the research study described in Chapter 15.2.3 and findings of the industry survey (Ozarska and McNair 2001) revealed that when handling Tasmanian oak, particular care must be taken to minimise contamination with iron-containing fragments or solutions from such sources as:
   - saw blades
   - veneer slicing blades
   - surface sanding and smoothing (e.g. steel wool)
   - nails, screws and metal joints
   - contaminated water
   - contamination of glues and lacquers due to storage in metal containers that have an iron component.

2) High humidity or water contamination of the veneer is essential for the process of staining to occur. The use of lacquer inhibits the progression of the staining. Therefore, it is recommended that:

   - a durable coating system, such as polyurethane lacquer, be used on Tasmanian oak veneers
   - all surfaces are carefully coated
   - sharp edges, which allow moisture to readily penetrate to the veneer, should be avoided
   - when cutting and slicing Tasmanian oak veneers, stainless steel blades should be used
   - the MC of veneer and substrate should be within the specified range of between 8% and 10%.

3) Although there was only a slight pink tinge in the veneers coated with acid catalysed lacquer, it would be prudent to use glues and lacquers that are within the pH range of Tasmanian oak, which is between 3.6 and 5.2.

4) Iron stains may also occur in other species if veneers are severely contaminated with iron.

Practical guidance has been developed for the industry on the prevention of veneer discolouration and staining, which is provided in Table 12. The recommendations are based on the results of the research study (Chapter 15.2.3), industry experience and an extensive literature review.

<u>REMARK</u>

Although the above recommendations have been developed for the veneer species selected by the TVAA, the discolouration problems may also occur in other species. Therefore, the recommendations should be also applied to any species not mentioned in this Manual.

Table 12: Practical guidance on the prevention of veneer discolouration.

Veneer species	Type of discolouration	Methods of prevention
Blackwood, American maple, European beech, American cherry	Red or pink discolouration or staining of the surface of veneered products. May occur along the veneer glue line.	• The pH of lacquers and adhesives should be close to the natural pH of the veneers. • When purchasing adhesives, the veneer panel producers should specify the pH of the glues. Acidic glues should not be used. • The users of veneer panels should ensure that the panels they purchase meet the required specifications in regards to the pH of the adhesives. They should also ensure that the coating systems they purchase meet the required specifications with respect to the pH range of the veneers. Acidic catalyst lacquers should not be used. • The following pH ranges are recommended for the veneers: blackwood: pH between 3.6 and 5.2 American maple: pH between 3.8 and 4.6 European beech: pH between 3.6 and 6.3 American cherry: no data on pH available, but low acidity lacquers and adhesives should not be used.
European beech	Whiting effect on the veneer surface and around edges of accessory holes, in particularly in bathroom and kitchen installations.	• Polyurethane sealer and top coat should be used on the veneered products. • Only moisture resistant particleboard and MDF should be used as the substrate. • Sharp edges should be avoided.
Tasmanian oak	Dark brown/grey discolouration of veneers, particularly along the panel edges, holes, hinges and fittings, sometimes with a blotching effect on the veneer surface.	• When handling Tasmanian oak it is critical to minimise contamination with iron containing fragments or solutions from such sources as saw blades, veneer slicing blades, surface sanding and smoothing (e.g. steel wool), nails, screws and metal joints, contaminated water andcontamination of glues and lacquers due to storage in metal containers which have an iron component. • A durable coating system such as polyurethane lacquer should be used on Tasmanian oak veneers.

Tasmanian oak (continued)		• All surfaces should be carefully coated. • Sharp edges that allow moisture to readily penetrate to the veneer should be avoided. • When cutting and slicing Tasmanian oak veneers, stainless steel blades should be used. • The moisture content of veneer and substrate should be within the specified range of between 8% and 10%.

15.2.4 UV discolouration of natural, reconstructed and dyed veneers

A collaborative research study was undertaken by the TVAA, CSIRO Manufacturing and Materials Technology and the University of Melbourne, with the aim of investigating discolouration of selected natural, reconstructed and dyed wood veneers exposed to UV light and effectiveness of various coatings currently used by the industry in maintaining colour stability. The project was funded by FWPA.

The study developed a test protocol on recommended practice for accelerated determination of the UV durability of natural, reconstructed and dyed wood veneers and general recommendations on the selection of clear UV protective coatings for wood veneers (Forest and Wood Products Australia 2008a). This protocol has been reproduced below with the permission of the project funding organisation and the authors of the study.

It should be pointed out that UV protective coatings or proprietary treatments are a commercial secret and hence, no formulation details are available from either technical data sheets or technical representatives or suppliers of these materials. Therefore, no advice on the optimum composition of UV coatings or UV protective treatments, or the formulation ingredients, could be provided by the research team involved in this study.

15.2.4.1 Recommended practice for accelerated determination of the UV durability of natural, reconstructed and dyed veneers

The following information provides general guidelines for the accelerated assessment of relative suitability of wood-based veneers (natural, reconstructed and dyed) and surface coatings in applications where UV and/or natural light may cause discolouration, and hence the loss of decorative attributes of the original surface finish on furniture or wood panels.

It is anticipated that the use of the proposed protocol will provide the Australian veneer industry with a tool helpful in rapid screening of veneers and coatings to be directly or indirectly (through window glass) exposed to UV and/or visible light radiation at ambient or elevated temperatures up to 60°C. The protocol will facilitate better selection of suitable materials exhibiting a more acceptable level of colour retention and stability and durability during their intended use in areas exposed to UV and/or visible radiation.

Recommended test protocol

1. Accelerated UV weathering equipment and procedure

Both uncoated veneers and veneers coated with any clear or transparent/translucent coatings, including UV protective coatings, should be examined for colour change using the proposed accelerated UV exposure protocol involving a certified UV light source that allows for reproducible performance assessments.

The use of such a protocol facilitates assessment of the relative performance of materials in a much shorter time frame than is possible using natural weathering.

The recommended accelerated UV exposure method for the assessment of durability of colour retention of veneers or wood panels, as well as surface coatings and dyes used for indoor applications, involves the use of the following equipment and procedures:

a) QUV Accelerated Weathering tester (QUV-meter). Supplier: Q-Panel Lab Products, 800 Canterbury Road, Cleveland, Ohio/USA)
b) UV-A 351 nm lamps (these simulate the short and middle wavelength region of daylight which has been filtered through glass)
c) A recommended level of solar irradiance: 1.2 $W/m^2/nm$
d) Chamber temperature: 60°C.

The duration of the test is dependent on the degree of colour change observed throughout the test period. It is recommended, however, that the following time intervals be considered as a preliminary guide:

- reference point (unexposed samples)
- 6, 24, 72 hours; 1 week; and 2 weeks (if no plateau reached such as colour shift and other colour-related parameters e.g. fading or darkening).

The ASTM standards G154-12 and G151-10 provide further information on operating procedures for using fluorescent UV light. It is recommended that at least duplicate samples of veneer are exposed and the results averaged.

The user of the accelerated protocol needs to bear in mind that, as with any form of accelerated exposure, the proposed accelerated UV weathering protocol should be considered as comparative data only, **which cannot be converted into equivalent hours of natural exposure**.

2. Sample preparation

2.1 Veneer samples preparation

a) <u>Uncoated veneer samples</u>

- All veneers selected for the intended testing (e.g. 0.6 mm thick, which is a typical thickness for currently produced decorative veneers both in Australia and overseas) are mounted or laminated onto a 16 mm section of MDF board.
- Veneers are preferably glued onto large pieces of MDF board (1200 mm long x 1200 mm wide x 16 mm thick) using a recommended type of adhesive e.g. a sprayable contact adhesive (such as Laminex). Both the MDF board and loose side of the veneer are sprayed and allowed to become touch dry for approximately 10 minutes before adhering both

surfaces together. Veneer samples are then pressed onto the board using a rolling pin.

- After adequate drying, the laminated board is cut into specific specimen sizes that fit into the QUV-meter specimen holders (78 mm x 152 mm) used for accelerated UV exposure.
- As a final step, the veneers are machine sanded using 240 grit paper just prior to the UV exposure, and are adequately labelled.

b) Sample coating

The coating's manufacturer recommendations must be followed in the preparation of all coated specimens.

As a general rule, however, the following spraying procedure may be used for all coating formulations, assuring application consistency.

- The veneer samples are machine sanded just before coating by using 240 grit paper. All sanding dust is removed using an air gun.
- Two coating applications are applied, following the manufacturer's recommendations.
- The wet film thickness can be measured using a wet film thickness gauge or by weighing the sample and determining the weight per area (g/m^2) before each coating application, and may be adjusted accordingly by using a dummy sample (e.g. paper covered sample).
- A light sanding between intermediate coats may be carried out manually or by a mechanical sander for all samples by using 320 grit paper. The surface should be sanded until the gloss and roughness are removed. The amount of materials sanded away should be kept to a minimum. All sanding dust should be removed using an air gun.

Brushing may also be employed in the cases where the coating supplier considered it among the preferable application methods (i.e. some external, high-viscosity coatings). The coating is then brushed along the full length of the surface of the sample in the grain direction using a foam brush. Each sample is weighed and brushed until the manufacturer's recommended wet film weight is achieved.

3. Assessment of veneer discolouration

A suitable instrument for measurement of colour is a BYK-Gardiner digital colour meter.

Colour difference measurements (ΔE_{L*a*b*}, ΔL^*, Δa^* and Δb^*) should be made before UV exposure and at regular time intervals throughout the UV exposure in accordance with the Commission Internationale de l'Éclairage or CIE Lab colour system.

Recommended operating conditions are:

- light source type D65
- observation angle of 10 degrees

- calibration with ceramic standard
- sample averaging n = 8.

The colour measurements should be taken in at least eight different points on the UV exposed surface of each sample due to the high level of variability possible within the same range colour displayed by the wood grain and because of the narrow sampling area of the colour meter. To ensure that all of the colour readings throughout the different stages of UV exposure are taken in exactly the same spots, it is recommended that a colour measurement template is built (Figure 45).

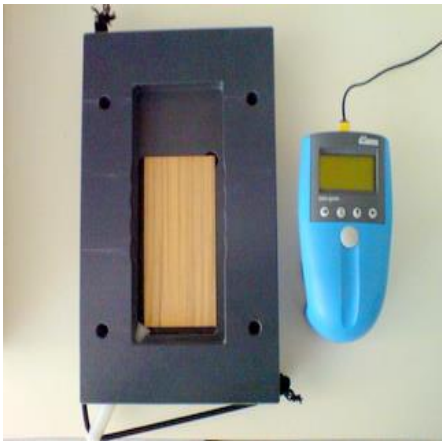


Figure 45: Colour measurement set-up

L*, a* and b* colour coordinates for each sample should be recorded before and after UV exposure. The overall colour change $\Delta E_{L^*a^*b^*}$ as a function of the UV irradiation period is then calculated according to the following equations:

$$\Delta L^* = L_f^* - L_i^*$$

$$\Delta a^* = a_f^* - a_i^*$$

$$\Delta b^* = b_f^* - b_i^*$$

$$\Delta E_{L^*,a^*,b^*} = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

where ΔL*, Δa*, and Δb* are the changes between the initial and several interval values.

+ ΔL* means that the sample is **lighter** than the standard

- ΔL* means that the sample is **darker** than the standard

+ Δa* means that the sample is **redder** than the standard

- Δa* means that the sample is **greener** than the standard

+Δ b* means that the sample is **yellower** than the standard

- Δb* means that the sample is **bluer** than the standard.

A low $\Delta E_{L^*a^*b^*}$ corresponds to a low colour change or a stable colour.

It is generally considered that a colour change of around five is the limiting value that can be distinguished by the naked eye.

4. Selection of clear UV protective coating

It is recommended that the clear UV protective coating should contain UV absorbing additives or a combination of synergistic UV absorber and free radical scavenger additives such as hindered amine light stabilisers (HALS) to elongate the service life of the coating itself and the veneer.

Coatings that do not contain UV additives may not offer optimal protection against UV discolouration and it is likely that yellowing and degradation of the coating itself can occur, resulting in higher discolouration compared to the uncoated veneer.

Regardless of the above general recommendations, all candidate coatings should be subjected to the accelerated UV weathering exposure according to protocols outlined above.

The user of the accelerated protocol needs to bear in mind that, as with any form of accelerated exposure, the proposed accelerated UV weathering protocol should be considered as comparative data only, **which cannot be converted into equivalent hours of natural exposure**.

15.2.4.2 General recommendations on the selection of clear UV protective coatings for wood veneers

Based on the outcomes of a research project carried out under the auspices of FWPA, the following recommendations are offered regarding the effectiveness of protection of wood veneers against UV driven discolouration.

- Generally, the application of protective clear coatings containing UV absorbing additives reduces, but does not completely eliminate, the detrimental veneer discolouration caused by UV radiation originating from sunlight exposure.
- Although a number of UV protective coatings drastically reduce UV driven discolouration of veneers, some veneers (natural, dyed and reconstructed) may still exhibit unsatisfactory levels of discolouration exceeding acceptable performance thresholds regardless of the use of currently available UV protective coatings.
- All candidate UV protective coatings and veneers must be subjected to accelerated UV weathering exposure according to the “Recommended Test Protocol” outlined in the Information Sheet *UV discolouration of natural, reconstructed and dyed veneers* (Forest and Wood Products Australia 2008b). This protocol allows rapid screening of candidate products and facilitates elimination of underperforming coatings and veneers. The effectiveness of

nominated coatings for UV protection of specified wood veneers should be obtained from the coating's manufacturer or from an independent laboratory prior to job commencement.

- Clear UV protective coatings or veneer impregnating dispersions or solutions for use with wood veneers exposed to UV radiation should always contain UV absorbing additives or a combination of a synergistic UV absorber and free radical scavenger additives such as HALS, and/or other additives to prolong the service life of the coating itself and that of veneer.
- Coatings that do not contain the above additives may not offer optimal protection against UV discolouration and it is likely that yellowing and degradation of the coating itself may occur, resulting in higher discolouration compared to the uncoated veneer.
- The user of the accelerated protocol needs to bear in mind that, as with any form of accelerated exposure, the performance data gathered through the proposed accelerated UV weathering protocol should be considered indicative and cannot be converted into equivalent hours of natural exposure.

15.3 Summary of typical problems in veneered products

Typical problems that occur in veneered products and their possible causes have been summarised in Table 13.

Analysis of the table shows that some types of the product failures can be caused by multiple factors. Therefore, it is important to keep quality control records at each stage of the manufacturing process.

Table 13: Summary – Typical problems occurring in veneered products and their causes.

Possible causes of the Problem	Typical problems occurring in veneered products							
	Veneer checking	Veneer discolouration	Zigzag telegraphing	Discolouration of glue line	Glue bleed-through	Veneer delamination	Lacquer crazing	Lacquer blushing
Veneer species	✓	✓	✓	✓	✓	✓		
Veneer quality	✓	✓	✓		✓	✓	✓	
MC of veneers	✓	✓		✓	✓	✓	✓	
MC of substrate	✓	✓		✓	✓	✓	✓	
Improper selection of substrate	✓	✓				✓		
Thickness variation (veneer and/or core)	✓					✓		
Veneer jointing		✓	✓	✓		✓		
Glue selection and preparation	✓	✓		✓	✓	✓		
Gluing process	✓	✓			✓	✓		
Pressing process	✓		✓		✓	✓		
Sanding of panels	✓		✓		✓			
Conditioning and storage by veneer producer	✓	✓					✓	
Storage before finishing	✓	✓					✓	
Selection and preparation of finish	✓	✓		✓			✓	✓
Finishing process	✓	✓					✓	✓

Conditioning and storage after finishing	✓	✓					✓	✓
Manufacturing of veneered products	✓							
Service conditions	✓	✓					✓	
Maintenance of veneered products	✓	✓				✓	✓	

16 QUALITY CONTROL IN PRODUCTION OF WOOD VENEERED PRODUCTS

16.1 Requirements for quality control process

The production of veneered products is a complex process that consists of many variables and parameters. Various problems may occur if even one of these variables or parameters fails to meet the process requirements.

Although a particular operation may be correct, the quality of the final product will be directly affected by what takes place in the plant before this operation commences. For example, when veneer delamination occurs, assuming all instructions provided by the adhesive supplier are followed properly, one must ask questions and explore possibilities to discover where the process could have gone wrong.

The best method of tracking the cause or causes of the product failure is to backtrack through all steps of the veneer manufacturing process and to examine the all of the plant procedures, from veneer production to the finished product. Therefore it is imperative to maintain a high standard of quality control with regular sampling and testing, monitoring and comprehensive record keeping of production parameters so that if there is a failure of the product there is documented evidence on which to base a defence of the product.

It has been shown in legal cases related to other manufacturing industry sectors that, unless the producer can show that the company has undertaken the manufacturing process within strict parameters and standard requirements, there is no basis to be able to defend a claim against the company's products. Therefore, the industry is vulnerable to claims being made against an individual company when a veneered product fails in service even though it may have nothing to do with the veneer manufacturing process. For example, there are many examples of the failures of veneered products due to the wrong lacquer being used or inappropriate care after the product leaves the company. A fully documented quality control system would be of great benefit to all the companies.

Adverse publicity about veneer failures impacts across the whole industry leading to customer distrust of veneers and veneered products.

REMARK

In order to be able to defend any claim it is critical that a documented quality control process is in place and correct procedures can be shown to have been undertaken.

16.2 Quality control procedures – checklist

In order to ensure that veneered products are of a high quality and high performance standard, the quality control process should cover:

- materials used in the manufacturing process (veneer, substrate, glue, finish)
- storage and manufacturing processes
- maintenance of final products.

In order to assist the industry in setting up quality control procedures a simple checklist has been developed, which may be used as the guidance for ensuring that all stages of the production process are tested in monitored (Tables 14 and 15).

It is recommended that the quality control procedures be undertaken on a daily basis and records kept. Every change to the manufacturing process (new species of veneer, substrate, new glue, coating system) should be recorded and the quality control process applied.

REMARK

The quality control checklist provides only recommendations of "best practice procedures". This is not equivalent to the formal accredited quality control system, which is a complex process of accreditation and frequent auditing.

Table 14: Quality control checklist for manufacture of veneered panels.

Production Stage	Requirements for testing and monitoring of manufacturing procedures	Reference to Manual
STORAGE OF VENEERS AND SUBSTRATE		
Storage conditions	• Check ambient conditions daily inside the storage room (temperature and relative humidity). • Ensure that storage conditions meet standard requirements (recommended every month). • At the time of delivery check if the veneer and substrate meet specifications. (e.g. check the moisture content of veneers and substrate, grade of veneers, type of substrate: standard or moisture resistant)	Chapter 8
PRODUCTION OF VENEERED PANELS		
Factory conditions	• Check ambient conditions daily in the factory (temperature and relative humidity).	Chapter 8
Veneer trimming (guillotine)	• Check that the edges are straight, parallel and square with minimal tear-out.	Chapter 9.4
Veneer jointing	• Check that the quality and grades of veneers meet specifications. • Check the moisture content of veneers (recommended MC = 8% to 10%). Do not joint veneer leaves if the moisture content difference between adjacent leaves is more than 2%. • Check the veneer thickness for any variation. Any difference over 0.1 mm can	Chapter 4.1 Chapter 4.3 Chapters 4.2 & 9.3

Veneer jointing (continued)	cause problems. • Check parameters of the jointing machine (usually temperature and pressure but it depends on the type of the machine). Check the machine instruction/specifications on what parameters are required for various types of veneers. Make sure that an appropriate glue is used for jointing according to the machine requirements. • In case of using a zigzag stiching machine, make sure that you use an appropriate grade of the thread to avoid problems. • After jointing check the quality of joints (glue bond quality, any delamination, straightness of joints, zigzag quality).	Chapters 9.3 & 9.4 Chapter 9.4.3 Chapter 9.4
Gluing process 1. Preparation of substrate	• Check the moisture content of substrate using moisture meter (recommended MC = 8% to 10%). • Check the thickness of the substrate and record any variation (permitted variation = +/-0.2 mm).	Chapter 5.2.3 Chapter 5.2.1
2. Preparation of veneer for gluing	• Identify loose and tight side of veneer to ensure that the face veneer is laid with tight side outwards. • If veneer lay-ons have been stored in uncontrolled environmental conditions for more than three days after jointing, check the moisture content of the veneer again just before the gluing process.	Chapter 10.1.1 Chapter 10.1.2
3. Gluing process	• Ensure that the glue mixture is prepared according to the glue supplier's specifications. • Measure the amount of glue spread on a daily basis. Adjust the glue spread to	Chapters 10.2 & 10.3 Chapter 10.3

	various types of veneers (according to the glue supplier's instruction). • Regularly check the glue spreader rolls. Adjust the gap between the rolls if required. Check that the grooves are not worn. • Always conduct a trial gluing and test the results when working with new adhesives or different species of wood.	
4. Pressing process	• Check whether pressing parameters (pressure, temperature of platens and pressing time) are set according to the press specifications. Adjust the parameters if required.	Chapter 10.4
5. Glue bond quality	• Check the quality of the glue bond: ➢ regular visual assessment to identify any sign of delamination and glue bleed-through ➢ occasional testing of the bond quality using the chisel test ➢ testing the bond strength and durability by an accredited laboratory according to the Australian standard.	Chapter 10.6
Sanding process	• Check sanding parameters according to the supplier's specifications. Monitor the parameters and grid of sanding paper applied. • After sanding, check the quality of the sanding operation, in particular whether the veneer is sanded excessively. • Check the uniformity of sanding (thickness variation within the panel and the amount of veneer removed).	Chapter 11
Storing and packing of	• Check ambient conditions inside the storage room (temperature and relative	Chapter 8

veneered panels	humidity). • Ensure that the packaging material does not allow any wetting and that it protect the panels against rapid moisture content changes and any mechanical damage during transport. • Provide instructions on quality control during finishing and further manufacturing of veneered panels. In particular, provide information on possible discolouration of various types of veneers and recommendations on types of finish to be applied on these veneers.	Chapters 12.1 & 12.4

REMARK

Immediate action must be undertaken if even one measured factor does not meet the requirements provided in the Manual and/or the relevant standard.

Table 15: Quality control checklist for finishing and manufacturing of veneered products.

Production Stage	Requirements for testing and monitoring of manufacturing procedures	Reference to Manual
Storage before finishing	• Make sure that storage conditions meet standard requirements. • Check ambient conditions daily inside the storage room (temperature and relative humidity).	Chapters 8 & 12.1
Finishing process	• Measure the moisture content of veneered panels (recommended 8% – 11%). • Check that surfaces of veneered panels are clean and free of contaminants. • Check that the selected coating system meets the requirements for the end use application. • Check whether any special precautions should be taken for the type of veneer used on the panel. • Check that the coating system is prepared and applied according to the supplier's specifications. Ensure that all surfaces are coated to protect the panels against moisture changes. • Ensure that the coated panels are conditioned in controlled environmental conditions before any further manufacturing process starts. • If the coated panels are transported to another company for the final manufacturing process, ensure that the coated panels are properly packed to eliminate any moisture changes or mechanical damage during transport. • Prepare information on the type of coating system used and instructions on	Chapter 12 Chapter 14.2.4 Chapter 12.4

	the cleaning of the panels (according to the information provided by the coating supplier).	Chapter 13
Manufacture of veneered products	• Check ambient conditions daily inside the storage room and factory (temperature and relative humidity). • Check the moisture content upon arrival to the factory. • Handle the veneered panels with special care during the production of final products.	Chapter 13
Maintenance of veneered products	• Ensure that the instructions on cleaning of the final product are provided to the user of the product.	Chapter 13

17 DIAGNOSTIC GUIDE FOR EVALUATING CAUSES OF FAILURES IN VENEERED PRODUCTS

This chapter provides a checklist of diagnostic questions, which were developed to help veneer producers and manufactures of veneered products in tracking down likely causes of problems (failures) that may occur in veneer and veneered products. The checklist may be also used to anticipate possible problems.

The checklist was developed by Christiansen and Knaebe (2004) at the Forest Products Laboratory, Madison, Wisconsin, United States. The authors approved of reproduction of this checklist in this Manual. The checklist is provided in Table 16.

To help to analyse problems that may arise later, it is suggested that the manufacturer or installer keep records of relevant construction details, multiple sales or installations of similar production runs to different customers or in different manufacturing locations. If the problem is not encountered at other locations, perhaps it is attributable to something specific at that site.

As this diagnostic guide indicates, moisture change is the predominant variable that affects wood surface quality in veneered cabinetry or furniture, once appropriate materials and processes have been put into place. Changes in MC need not be extreme to have a visible negative effect on fine woodwork.

Table 16: Diagnostic guide for evaluating failures in veneer and veneered products. Reproduced with permission from Christiansen and Knaebe (2004).

Diagnostic question	Comment
Preliminary questions	
• Where in the process (manufacturing to customer) was the problem discovered or brought to attention?	Pinpointing the stage at which the problem occurred will indicate where to examine the process for problems.
• If the problem occurred after installation, how much time had elapsed between manufacture and installation?	If the problem only occurred after a delay of a few months, environmental factors at the installation site may have changed the moisture content, promoting wood expansion or contraction, which produced the visual problem.
Parallel experience	
• Did the problem occur while using this process in the past? Has the problem occurred in other facilities?	Can the problem be localised to a particular plant or facility, rather than to the process or the materials in general?
• Have any of the components (substrate or core stock, veneer, paper backing, adhesives, finish) been changed recently?	If the process was operating adequately before the change, then the change should be evaluated to determine if it might be part of the problem.
• Is the same substrate (core material) and varnish or finish used on other wood veneer laminates without problem?	The substrate or finish may be incompatible with the veneer. Some veneer species, such as American beech and some tropical species, "move" (expand perpendicular to the grain) to a great extent with increasing moisture content (relative humidity).
• Has the problem occurred with other items from the same lot or other lots from the laminator, cabinet or furniture maker, or installer?	If the problem has not occurred in other lots, then the specific lot, or its last environment before the problem was noticed, is implicated in the problem. Association with a single lot may indicate the problem occurred after shipping.
• Has the problem occurred in other installations (rooms or buildings) of the same type of components?	If other installations are all right, the problem may be the environment in which the item has been placed.
• What differences in environment (moisture or temperature) are there between problem and non-problem situations?	The answer to these questions might help narrow down the cause of the problem.
• Have any other instances of this	

type of failure occurred? • If so, are there any parallels in experience?	
Inspections • Was a quality control (QC) inspection conducted by the veneer manufacturer? By the laminator? • Was a QC inspection conducted by the cabinet-maker or furniture manufacturer and/or the finisher? • Was a QC inspection conducted by the installer of cabinetry or the furniture retailer? • Was a QC inspection conducted by the consumer at the time of purchase or just after installation?	General quality, diving grain, thickness uniformity, moisture content. Cracks in or delamination of veneer, checks or blisters in the finish, uneven flat surfaces. Cracks or blisters in the finish, uneven surfaces, delamination of veneer. Cracks or blisters in the finish, uneven surfaces.
Materials • What is the type of core stock or substrate (solid wood, plywood, particleboard, MDF)? If the core stock is solid wood or plywood, what is the wood species?	Solid wood shrinks and swells less uniformly than does reconstructed wood. Species with high swelling and shrinking coefficients are more likely to experience problems; these are often the harder (denser) hardwoods. Some exotic species are not only dense but have other problems; for example, Santos rosewood (*Machaerium scleroxylon*) has a tendency to have drying checks, interlocked grain (makes machining difficult), high oil content (complicates gluing), occasional trees with high silica content (dulls blades quickly), and sawdust that can be highly irritating and cause dermatitis. A few low-density domestic species (e.g. cottonwood (*Populus* spp.)) tend to warp.
• Is the finish buckling away from the veneer?	Buckling of the finish indicates the veneer may have dried and shrunk since the finish was applied.
• Is the veneer buckling away from the substrate?	Buckling of the veneer indicates that it may have swelled (absorbed moisture) or that the moisture content of the core was higher than that of the veneer when the veneer was applied. Since then, the core may have dried and shrunk.
• If the substrate is a reconstructed panel, what adhesive was used to make it? Is the panel uncommon in some way?	Some adhesives adhere to wood surfaces better than others. Panels made with unconventional

• How thick is the substrate or core stock?	materials or complex shapes can be difficult to bond with some adhesives. A thin core stock is more likely to bend if the dimensions of the veneer change. On the other hand, if the substrate is thick, the affected veneer is more likely to crack or buckle.
• Is the construction balanced through the thickness of the finished piece? That is, equal thickness of face layers, same species or materials arranged in the same order from the surfaces, equal moisture content on both sides during bonding, same finishing on both sides. • In the application, is there restraint on one face (e.g. the face is fastened to something) but not on the other face (e.g. decorative molding around a door panel or a cleat on the bottom of a table)? Is moisture content frequently higher on one side than on the other (e.g. bathroom vanity panel, exterior door)?	Unbalanced constructions are more likely to deform if moisture conditions change. Moisture-impervious coatings on one side mean the other side can swell to a greater extent as humidity rises, causing it to cup around the non-swelling side. Stiffer wood (higher density, thicker pieces) will cup around less stiff pieces as humidity falls. Unbalanced construction causes problems.
• How far is the defect from the edge? Is the edge finished or covered (laminated)?	Edges are less restrained than is the rest of a surface, so that this region swells or shrinks more easily. In addition, moisture often can move in or out of the edges of wood more easily than in or out of the larger faces of the material. However, the problem can be reduced by covering the edges with an impervious plastic layer.
Veneer	
• Is the veneer made of wood?	Unlike plastic, wood shrinks and swells with moisture changes. Plastic laminates, commonly called Formica, are resin treated laminated paper. These laminates also shrink and swell with changes in moisture content, quite often more than does particleboard or MDF.
• Is the veneer simple (raw)? Or is the veneer complicated, e.g. twice-sliced (peeled or sliced, glued in stacks and re-sliced)?	In general, paper-backed veneer does not bond strongly to the substrate. Twice-sliced veneer is more stable than veneer that has only been peeled or is plane sliced, because it is glued and randomised.
• What is the wood species?	Specific gravity, tendency to swell, anatomy, and pH (acidity) vary with species.
• How was the veneer cut (peeled, sliced)?	Cutting affects wood grain orientation, which in turn affects resistance to deformation, particularly with changes in moisture.

• If the veneer is peeled, do the checks (small cracks along grain produced during peeling) face the core or the surface?	If the checks face the core, they are less likely to open the surface as the core or veneer changes dimension with changes in moisture.
• How thick is the veneer? Is the thickness uniform?	Thin veneer has less strength to resist changes in the substrate layer. However, checks will be larger in thick peeled veneer than in thin veneer.
• Is the defect parallel to veneer grain or wood rays?	Wood swells and shrinks perpendicular to the grain. Rays can initiate problems during wood expansion and contraction, especially in oaks.
• Was the veneer sanded after bonding? • How much wood was removed? • What grit size of abrasive paper or belt was used?	Sanding removes material, making the veneer thinner and less resistant to dimensional changes; it may expose checks on the glued face. Large grits for sanding cause more damage to the veneer, especially crushing of surface wood cells. An increase in moisture may raise these cells, which have less strength for good bonding. The raising of cells crushed by various processing steps can lead to telegraphing. (small bumps) on the surface.
• If the core material is solid wood, in which direction is its grain oriented relative to the grain direction in the veneer?	If the grain of the veneer and substrate run perpendicular to each other, then swelling and shrinking could play a factor in surface problems. Reconstructed wood panels usually have low dimensional movement in both directions of the plane, whereas veneer and solid wood tend to move perpendicular to the grain direction.
o Does the veneer have a paper backing?	Paper has more uniform dimensional change than does a solid wood substrate. Consequently, paper backing may reduce surface distortion if the veneer and substrate have different grain orientations. Paper is often used to hold thinly cut veneer together during handling and preparation of the piece for bonding.
o What adhesive was used to bond the veneer to the paper backing? Contact adhesive (solvent or water-based), hot melt (type), PVA or UF (plastic) resin?	Solvents and heat can drive moisture from wood, and water-based adhesives add moisture to wood. Some adhesives are weaker or more forgiving than others when stresses are created by wood swelling or shrinking. Solvents and heat can drive moisture from wood, and water-based adhesives add moisture to wood. Some adhesives are weaker or more forgiving than others when stresses are created by wood swelling or shrinking.
• Has the veneer been filled (to fill	

pores and gaps) before finishing?	Unfilled cracks in the surface are aggravated by dimensional changes.
Veneer laminating process • What is the climate where (city, country) the veneer was made? • How much time elapsed between shipping and application? • In what form (sheet, roll) was the veneer supplied to the plant? • What were the storage conditions? Was the veneer exposed to moisture and/or cold? • Where was the woody core material made? What were the storage conditions? • In what region (or climate) was the veneer bonded to the substrate (core stock)? • What are the conditions (especially humidity) in the veneering facility? Do the conditions vary by season? • How was the veneer layer laid onto the core (manually, press process, automated process)? • Was the laminating adhesive applied to one or both surfaces? If to both surfaces, which surface was the adhesive applied to first? • For the failed piece, did the adhesive adhere well to one surface but not the other (delaminated) in all cases? • What kind of adhesive was used to bond the veneer to the core (e.g. contact adhesive, hot melt, PVA, polyurethane, UF (or plastic) resin)? • Was any hot pressing used? What were the pressing conditions (temperature, pressure, time)? • How were the veneered pieces stored? • For shipment, was the material wrapped or sealed to protect against	It may be necessary to recondition the veneer or substrate before bonding. For veneer that can be exposed on both sides, conditioning time could be as short as a day. If the product will be shipped to a dry climate, consider conditioning all wood to lower moisture content. An important variable is the kind of force used to press the veneer flat against the substrate for good contact. More contact means a better bond, although excessive pressure can also be a problem. This may influence whether the veneer or substrate has insufficient bonding. Compare this to the previous answer to determine a possible correlation. Adhesives vary in strength and compliance (flexibility). The example adhesives are listed in approximate order of flexibility; however, greater flexibility means less resistance to difficult environments. Heating reduces moisture content overall, but more so at the surfaces. The issue is moisture control.

moisture changes? Was protective wrapping in good condition when the item was received?	
Veneered product manufacture • Under what conditions (moisture and temperature) were the panels stored before manufacture into cabinets or furniture? After manufacture? • What finishes were applied to the surface? Were both a primer and top coat applied? • Was the finish water-, gel-, or solvent-based? • Were the veneer and substrate at an appropriate moisture content before the first finish was applied? • How long was each layer of finish allowed to dry before the next layer was applied? • How thick was the applied finish? • Were the finished pieces shipped long distances (or long times) between manufacture and installation or final delivery, during which moisture content of the pieces could change?	Low quality primers and lacquer frequently cause problems. Water-based finishes will supply some moisture to the veneer, which may promote short-term swelling perpendicular to the grain and promote buckling. Manufacturing procedures may fail to take into account unanticipated climate conditions in product application. If excess moisture is not allowed to dissipate, dimensional changes will be greater. If too much finish is applied, then the finish may be unable to move with the natural expansion and contraction of the wood.
Product installation • At what time during the year were the products installed? Was humidity controlled? • Is the state or region where the problem occurred a new market or use area for this product? • If the problem occurred in a new region, is the humidity in this region different from that in the previous use region? • Was the product (e.g. cabinet)	Humidity usually dictates to what moisture content level the piece will equilibrate. The manufacturing moisture equilibration procedures may not have taken into account unanticipated climate conditions. There is a large difference between climatic conditions various states or regions, which will result in different equilibrium wood moisture content of wood. A difference of only a few percentage points in moisture content can significantly affect dimensional change. Continual interior climate control reduces such changes.

installed or brought to the job site in cool or cold weather before the permanent heating system of the building was operational? • If so, were unvented job site heaters used in the structure after the wood units were delivered? • What strategy (if any) was followed to dissipate construction moisture in a new building? • Was the problem piece a door or a lid?	The relative humidity of a cool unheated area may have been high before the heating was turned on, so the product may have absorbed moisture and expanded significantly. A job-site heater raises air temperature and thus lowers humidity and moisture content near it; areas farther from the heater, which are cooler, gain moisture content and swell. The largest source of construction moisture is usually a poured concrete foundation. Humidity conditions in the first year after construction can be significantly higher than those in subsequent years. The door or lid of a product may be thinner than other sides of the piece and are less restrained from warping. The construction of a door or lid may not be balanced if the exposed face is contoured. In cabinetry, the door may separate areas that differ greatly in humidity.
Conditions after installation (service conditions) • Were products in a room that might be cooler or more humid (bathroom, kitchen, unventilated basement) than the rest of the building, in front of a humidifier, or near an unvented gas fireplace? • To what extent has condensation occurred on the inside surfaces of windows? • Was the cabinet or furniture cleaned with water or ammonia cleaning solution? • In warm humid and hot humid climates, does the air conditioning compressor run fairly steadily or does it cycle on and off repeatedly? • Were the products stored in a room that might be hotter or drier than others? • Is the product situated in direct	See “Product installation” for comments on effects of job site heater. Condensation on inside surfaces could indicate a humid room (although in a cold climate condensation can occur with relatively low humidity if the windows are not insulating well). Absorption of water or ammonia could cause swelling of veneer. Cycling suggests that the equipment is oversized, a common occurrence that results in poor humidity control. Steady running of the air handler fan does not necessarily indicate that the compressor is running steadily. Sunlight shining on a surface within a room may raise the surface temperature by 11°C or more, which decreases relative humidity and moisture content and can cause shrinkage at the surface.

sunlight or heat (vent, radiator, fireplace, wood burning stove)? • After the product was installed, did the air conditioning or heating system of the building fail? Was it shut off for any significant time? • In what season did the problem occur? • If cabinetry units were built in place, were they allowed to come to moisture equilibrium before the finish was applied but after the building was enclosed? • Did the finished pieces gain or lose moisture? • To what extent have the problem units been exposed to temperature extremes?	Failure of electrical, ventilation, and air conditioning systems can affect humidity. Clear line of sight to an east- or west-facing window or to a skylight can result in solar-induced surface temperatures appreciably higher than the indoor air temperature. This is also true if the sunlight falls on wood with a dark surface. Localised heat sources can also cause temperature extremes. Heating duct surface temperatures usually range from about 43°C to 71°C. Furnace limit switches are not uncommonly set at around 82°C, which can lead to extensive localised overheating should mechanical malfunction occur. Radiant heat for wood flooring is set to a relatively low temperature, such as 26°C, to prevent a great reduction in moisture content.

18 FINAL REMARKS

Recommendations provided in the Manual should be strictly followed by both the producers and the users of decorative veneered panels to minimise any product failure and to enhance market confidence in veneered products.

The Manual should be used by the veneer and veneered panel producers, furniture and joinery manufacturers, designers and architects interested in producing and promoting high quality and high performance veneered products. However, it is essential to highlight that:

1. The manual does not claim to provide all of the issues or all of the solutions to using veneer and veneered products;
2. The manual provides suggested guidelines, processes and solutions only which may or may not be of assistance to veneer manufacturers or veneer users;
3. The information is of a general nature only and users should consult experts in the field when seeking specific assistance;
4. Some information in the form of figures, tables and text have been taken from other sources and, where possible, specific permission has been sought in order to reproduce the figures, tables and text in the Manual.

<u>REMARK</u>

Although this Manual has been written for the Australian industry, its principles and practices are applicable worldwide.

19 REFERENCES

ANSI/HPVA HP-1-2009. *Standard for Hardwood and Decorative Plywood.*

AS/NZS 1859.1: 2004. *Reconstructed wood-based panels. Part 1: Particleboard.*

AS/NZ 1859.2: 2004. *Reconstructed wood-based panels. Part 2. Dry-processed fibreboard.*

AS/NZS 1859.3: 2005. *Reconstructed wood-based panels. Part 3: Decorative overlaid wood panels.*

AS/NZS 1859.4: 2004. *Reconstructed wood-based panels. Part 4: Wet-processed fibreboard.*

AS/NZS 2270: 2006. *Plywood and blockboard for interior use.*

AS/NZS 4266: 2004. *Reconstructed wood-based panels – Methods of test.*

AS/NZS 4266.16: 2004 *Reconstructed wood-based panels – Methods of test – Formaldehyde emission – Desiccator method.*

AS/NZS 2098.2: 2012. *Methods of test for veneer and plywood. Method 2: Bond quality of plywood (Chisel test).*

AS/NZS 2098.11: 2005. *Methods of test for veneer and plywood. Determination of formaldehyde emissions for plywood.*

AS/NZS 4357.4: 2005. *Structural laminated veneer lumber. Determination of formaldehyde emissions.*

ASTM G154 – 12. *Standard practice for operating fluorescent ultraviolet (UV) lamp apparatus for exposure of nonmetallic materials.*

ASTM G151 – 10. *Standard practice for exposing nonmetallic materials in accelerated test devices that use laboratory light sources.*

ASTM 1333-10. *Standard test method for determining formaldehyde concentrations in air and emission rates from wood products using a large chamber.*

Australian Furniture Research and Development Institute. 2001. *Technical notes for finishing timber veneers.*

Bayer, G.T. & Zamanzadeh, M. 2004. *Failure analysis of paints and coatings*, Matco Associates Inc., Pittsburgh, PA, USA.

Bootle, K.R. 1983. *Wood in Australia: types, properties and uses*, McGraw-Hill, Sydney, Australia.

BS EN 635: *Plywood – Classification by surface appearance*. Retrieved from http://www.apa-europe.org/Languages/English/Plywood/Standards/eurostandards9.php.

Cassens, D., Leng, Y. & McCabe, G.M. 2003. Face check development in veneered furniture panels. Forest Products Journal, 53(10): 79-86.

Christiansen, A.W. & Knaebe, M. *Diagnostic guide for evaluating surface distortions in veneered furniture and cabinetry*, United States Department of

Agriculture, Forest Service, Forest Products Laboratory General Technical Report FPL-GTR-143.

EN 120: 1992. *Wood-based panels: Determination of formaldehyde content: Extraction method called the perforator method.*

EN 319: 1993-08. *Particleboards and fibreboards: Determination of tensile strength perpendicular to the plane of the board.*

Engineered Wood Products Association of Australasia. 2010. *Formaldehyde emissions from plywood and laminated veneer lumber*, Technical Note. Retrieved from http://www.ewp.asn.au/library/downloads/ewpaa_formaldehyde_emmisions.pdf.

FIRA. 1991a. "Veneer cracking", *Furniture Manufacturer*, no. 1: 45.

FIRA. 1991b. "Wood veneering problems", Fact Sheet No 5.

Forbes, C.L. 1997. *Understanding and minimizing veneer checking on furniture panels*, Wood Products Notes. Dept. of Wood and Paper Science, College of Forest Resources, North Carolina State University, Raleigh, NC, USA.

Forest Products Laboratory. 1974. *Wood handbook: Wood as an engineering material.* Agriculture Handbook 72 (revised 2010). Washington, D.C: U.S. Deaprt,ment of Agriculture, Forest Service. 415 p.

Forest and Wood Products Australia. 2008a. *General recommendations on the selection of clear UV-protective coatings for wood veneers*, Information Sheet.

Forest and Wood Products Australia. 2008b. *UV discolouration of natural, reconstructed and dyed veneers*, Information Sheet.

Gilmore, R.C. & Hanover, S.J. 1990. *Suggestions for preventing or minimizing veneer checking*, Wood Products Notes, Dept. of Wood and Paper Science, College of Forest Resources, North Carolina State University, Raleigh, NC, USA.

Healthy Building Network Production. 2008. *Alternative resin binders for particleboard, medium density fiberboard (MDF), and wheatboard.* Retrieved from http://www.healthybuilding.net/healthcare/2008-04-10_alt_resin_binders_particleboard.pdf.

Hoadley, R.B. 2000. *Understanding wood*, The Taunton Press. Retrieved from http://www.taunton.com/.

JIS A 1460: 2001. *Building boards. Determination of formaldehyde emission – Desiccator method.*

JIS A 1901: 2003. *Determination of the emission of volatile organic compounds and aldehydes for building products – Small chamber method.*

Jowat Corp. 1983. "Solving the problem of veneer delamination", *Furniture Design and Manufacturing*, no. 11: 32 – 33.

Knaebe, M. 2011. *Iron stain in wood, Finish line – Technical Note*, USDA Forest Service, Forest Products Laboratory, Madison, WI, USA. Retrieved from http://www.fpl.fs.fed.us/.

Koening, K.M. 1991. *'Thin is in' for veneer sanding,* Wood & Wood Products Journal, no.1: 82.

Maminski, M., Parzuchowski, P., Borysiuk, P. & Bouszewski, P. 2009. *Hyperbranched macromolecules as modifiers of urea-formaldehyde resins*, Wood Adhesives 2009, Technical Forum (Poster) Session.

Moubarik, M., Allal, A., Pizzi, A., Charrier, F. & Charrier, B. 2010. *Characterization of a formaldehyde-free cornstarch-tannin wood adhesive for interior plywood*, European Journal of Wood and Wood Products, 68 (4): 427 – 433.

NPA Technical Bulletin. 1993. *Dimensional stability in particleboard and MDF*, National Particleboard Association, USA.

Ozarska, B. 1991. *Veneers: Delamination, checking and how to prevent them*, AFRDI News. No 6.

Ozarska, B. & McNair, B. 1998. *Beech veneer – Research project*, Report for Decorative Wood Veneer Association.

Ozarska, B. & McNair, B. 2001. *State of the art report – Project scoping study*, Research report for Forest and Wood Products Australia and Decorative Wood Veneer Association.

Ozarska, B. 2003a. *A manual for decorative wood veneering technology*, Research report for Forest and Wood Products Research and Development Corporation.

Ozarska, B. 2003b. *Causes of discolouration in decorative veneered panels*, Research report for Forest and Wood Products Australia and Decorative Wood Veneer Association.

Ozarska, B. 2003a. *A manual for decorative wood veneering technology*, Research report for Forest and Wood Products Research and Development Corporation.

Plümer, O. no date. Wood and Panel Europe (online). Retrieved from http://www.woodandpanel.com/professionals/olaf_plumer.asp.

Prasittisopin, L. & Li, K. 2010. "A new method of making particleboard with a formaldehyde-free soy-based adhesive", *Composites Part A*, 41: 1447 – 1453.

Properzi, M., Wieland, S., Pichelin, F., Pizzi, A. & Despres, A. 2010. "Formaldehyde-free dimethoxyethanal-derived resins for wood-based panels", *Journal of Adhesion Science and Technology*, 24 (9/10): 1787 – 1799.

Saunders, J.P. 1993. "Sanding of plywood". Plywood and LVL Production Course, Lecture Notes Vol. 2, Part 9. Engineered Wood Products Association of Australasia.

Sellers, T., MCSween, J.R. & Neam, W.T. 1988. *Gluing of eastern hardwoods: a review.* General technical report SO-71. U.S. Department of Agriculture, Forest Service, Southern Forest Experimental Station. 30 p.

Sparkes, T. 1991. "Concerning cherry", *Furniture Manufacturer*, No 12.

Square, D.S. 1995. *The veneering book*, Taunton Press, Newtown, CT, USA.

Stevens, W.C., & Turner, N. 1970. *Wood bending handbook*, Forest Products Research Laboratory, Her Majesty's Stationary Office, London, England.

Stosch, M. & Lihra, T. 2008. *Think light – Innovative lightweight panels*, FPInnovations – Forintek Division.

Timber Veneer Association of Australia. 2012. *Veneer.* Veneer Product Information Manual. Retrieved from http://www.timberveneer.asn.au.

Wiedenbeck, J., Wiemann, M., Alderman, D., Baumgras, J. & Luppold, W. 2004. *Defining hardwood veneer log quality attributes*, United States Department of Agriculture, Forest Service, Northeastern Research Station, General Technical Report NE-313.

Zavala, D. & Humphrey, P.E. 1996. "Hot pressing veneer-based products: The interaction of physical processes", *Forest Prod. Journal*, 46(1): 69 – 77.

Zhang, J., Liu, X., Qiu, Y. & Wang, X. 2011. "Performance of modified urea-formaldehyde resins for bonding plywood", *Applied Mechanics and Materials*, Vol. 71 – 78: 3170 – 3173.

<u>REMARK</u>

At the time of publication, all of the URLs cited in the Manual were current.