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ENHANCING KEY ELEMENTS OF THE VALUE CHAIN FOR PLANTATION GROWN WOOD IN LAO PDR

Specification on finishes and finishing methods for various products and service conditions

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Date

VALTIP2

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1 Introduction

This report is one of the milestone reports within the Activity 3.2 of ACIAR funded project *"Enhancing key elements of the value chains for plantation-grown wood in Lao PDR"* which objective is to enhance the competitiveness and capacity of the Lao PDR wood processing industry through the development of an industry-led value-added timber market strategy.

This report provides a specification on most appropriate finishing methods and finishes for various high value wood products. The focus has been placed on appearance wood products used in indoor conditions but some products such as outdoor furniture have also been included.

- Furniture
- Joinery
- Flooring
- Panelling
- Decorative architectural products.

The review of literature indicates that various authors use the words "coatings" and "finishes" synonymously. According to Wikipedia, "a coating is a covering that is applied to the surface of an object, usually referred to as the substrate" (http://en.wikipedia.org/wiki/Coating).

It appears that the term "finish" is mainly referred specifically to coatings applied to wood while the term "coating" is used in general term, in application to any coating applied to various materials.

One of the definitions of the finishes is: "Finishes are coatings of paint, varnish, lacquer, wax, etc., applied to the wood surface to enhance their durability and appearance http://www.techitoutuk.com/knowledge/materials/woods/definitions.html.

In this report both terms, finishes and coatings have been used.

There are many finishing systems available for various wood products but it is important to find the system best suited for the product and its application.

Well made products often fail in service due to the selection of the unsuitable coating or improper finishing method. For example, many companies which manufacture furniture spend a lot of time and effort in designing and making beautiful items of furniture but they finally use incorrect finish or finishing system which significantly diminish the quality of the final products. Obviously, the final appearance of the finished item of furniture is its major selling point.

Producing a quality wood product and applying an unsuitable coating system or not following the specification for finishing procedure will reduce the appeal and overall durability of the product. The main objective of any manufacturer of wood products should be to ensure that the finished product withstands all of the requirements placed upon it.

High quality finish is one of the major elements of the selection criteria for high quality wood product and, as such, it increases the product marketability and eliminates the risk of complaints from the end consumers.

Achieving a good quality finish on wood involves a combination of three major factors:

1. Selection of coating system.

2. Wood surface condition.
3. Finishing treatment applied to wood.

All the three factors have an equally important role in obtaining high quality finish and they must be considered in the overall manufacturing process. These factors are discussed in details in the following chapters of this report.

2 Role of wood finishes

Wood finishes are mainly applied to protect the wood and enhance its appearance. It is essential to select the right coating system for a particular product to meet the overall product performance requirements.

2.1 Protection of wood surfaces

It is necessary to protect the wood surfaces from accumulating dust and to form a surface that can be easily cleaned. Finishes should also prevent colour changes due to UV light exposure, protect against abrasion, scratching or indentation and reduce the dimensional changes of wood due to variable atmospheric conditions (variation in relative humidity and temperature). It should be highlighted that a wood finish, even if several coats are applied, will reduce but won't eliminate the wood movement related to changes in moisture content resulting from variation in environment conditions. Given enough time, moisture will be absorbed into wood from a humid atmosphere or will escape to a dry atmosphere through any finish. Another important role of the finish is to retard the rate of moisture movement enough to buffer the temporary extremes of high and low ambient air humidity. Obviously, some finishes are better than others and the effectiveness of a particular finish is affected by the number of coats applied and the time of exposure to a different ambient air humidity level.

There are many performance requirements for coatings depending on their applications which need to be taken into account while selecting a coating for a particular wood product. For example, common problems seen are lacquer peeling or blotchy staining on kitchen cabinet doors or kitchen benches shortly after installation. A coating for a kitchen bench should be resistant to scraping, heat and moisture because it will be used as a heavy duty surface. Kitchen doors may be subjected to steam, water and frequent knocks whereas bathroom vanity units are exposed to very humid environment. Therefore the selection of an appropriate finish is critical to ensure long term performance of the product being coated.

In most cases, finish related problems are not caused by the failure of the finish itself, but rather by the poor selection of the type of finish, incorrect preparation of wood surface prior finishing and/or improper application of the finish.

2.2 Decorative role of wood finishes

Apart from its wood protective role, finishes also have a decorative role by enhancing the appearance and elegance of wood. The selection of a good finish must take into account the nature of the material onto which it is applied. In the case of wood, a wood finisher must have a basic working knowledge of the type of wood species used, its structure and properties. Texture, figure and colour are the main characteristics applicable to wood finishing.

> "*Wood is not metal. It is not inert. It once had life and even in the converted form it still has life. Wood is, above all, individualistic and even personable*"
>
> Oughton (1992)

It is important to point out that, in some cases, more than one coating systems should be used on a wood product, in particular on a piece of furniture. For example, very durable coating needs to be applied on the working surfaces of kitchen benches or sideboard tables, whilst the vertical surfaces can have a less durable, but just as attractive coating (Ozarska, 2013).

3 Types of wood finishes

3.1 Classification of wood finishes

Many different methods of classifying wood finishes can be found in the literature review, which are divided into various groups according to their formulations, general properties and applications. Therefore, it is difficult to select the classification most appropriate for particular products and applications.

An overview of potential classification categories of wood coatings is given in Table 1 (Bullian and Grayston, 2009).

Table 1: Potential classification categories for wood coatings.

Classification terms of coatings	Examples
Generic type	Paint, varnish
System function	Primer, basecoat, finish
Solids content	Low solids, high solids
Film build	Non-filming (e.g. impregnating stains, waxes); film forming (paints, varnishes)
Appearance	Colour, gloss, build
Chemistry	Alkyd, acrylic, polyurethane
Technology	Water-borne, solvent-borne, UV curing

Delivery	Air-drying, stoving, two-pack
Property	Flexible, permeable, fungal resistant
Market sector	DIY, industrial joinery, interior, exterior
End use	Furniture, joinery, flooring

3.2 Criteria for selection of wood finishes

The key factors which need to be considered in the selection of the suitable finishes are:

- The type of timber to be coated.
- The environment into which the coated product will be subjected in service.
- The intended use of the product.

Other factors which need to be considered are:

- The application equipment and environment.
- Skill and experience of the coating applicators.
- Health, safety and environmental requirements.
- Any special buyer/customer coating requirements (specification) that must be met.

Questions which need to be asked when selecting a coating system are:

Do we want to bring out the grain, enhance it or cover it up? Do we want the finish to be glossy and soft, or bright and colourful? Do we want the piece to blend in well with surrounding wood surfaces, or to offer a sharp contrast? Will the product be exposed to heat, moisture, liquid and chemicals spills, or to heavy use? Do we have appropriate equipment for applying the selected finish?

The type of wood species plays a very important role in the selection procedure. For example, open grained woods may require filling (see p. 25), especially if a high gloss finish is desired. Some wood species 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 (Ozarska, 2013).

Differences between heartwood and sapwood properties should also be considered. Tannins and other hot water soluble extractives are much more relevant in heartwoods of some species than in sapwoods. The colour of the heartwood is often much darker than the surrounding sapwood. Another important factor for coatings is the moisture content of

sapwood and heartwood. The difference in moisture content between the two zones may cause coating penetration problems.

It is important to ask lacquer manufacturers for advice on the most suitable coating system which would meet the desired selection criteria.

4 Types of wood finishes for appearance wood products

As explained above, the classification of wood finishes is a complex task as it depends on many different classification criteria. The two most common classifications of the finishes are based on their application and formulation.

4.1 Classification based on finishes applications

The classification of wood finishes based on their applications is provided below:

1. Transparent finishes
    a) Varnish
    b) Shellac
    c) Lacquer
2. Penetrating finishes
    a) Linseed oil
    b) Danish oil
    c) Tung oil
3. Opaque finishes
    a) Paint
    b) Enamel.

4.1.1 Transparent finishes

Transparent finishes, also named “surface finishes” are the finishes that can be seen through. These finishes will add depth and warmth to the appearance of the woodwork, while enhancing the colour and grain. They consist of resin dissolved in oil-based solvents. When the solvent evaporates, the resin hardens, or polymerizes, and remains firmly adhered to the wood surface. Examples of surface finishes are varnish, shellac and lacquer.

Varnish

Varnishes are a complex combination of oils combined with chemicals, resins and plasticizers. They usually have much higher solids content than lacquers, resulting in a much thicker dry film per coat. This allows the applicator to avoid using a separate sealer or finisher. The comparatively slow drying times of most varnishes allow airborne dust and dirt to settle onto the surface while drying. Therefore, cleaning, by fine sanding, is required to

produce ultimately acceptable clean surface. A varnished surface is highly resistant to water and alcohol.

There are varieties of varnish formulations including alkyds, polyurethane, phenolic, epoxy/polyester and water based latex.

Alkyd varnishes are for general interior use and the best for all purpose furniture work. They are known for a good adhesion and are flexible enough to accommodate a reasonable amount of wood expansion and contraction without failure.

Polyurethane varnishes for a film that is harder and more brittle than alkyd varnishes. However, they are also more wear and chemical resistant. Addition of oils has been known to decrease the brittleness. Polyurethane and alkyd varnish performance is quite similar but polyurethane varnish has poorer intercoat adhesion.

- Phenolic varnishes are extremely tough, stress and moisture resistant. They are not suited for interior finishing, but are superb for outside work or applications requiring maximum resistance to moisture penetration. Phenolic varnishes are also known to yellow and darken with time.
- Epoxy/polyester varnishes are extremely tough and durable two parts finishes. They are mainly used for highly specialised applications and markets.
- Latex varnishes exhibit good flow and brush ability, quick drying time and a high durability. Latex varnishes differ from the conventional varnishes as they use water instead of thinners as their base solvent. This allowed latex varnishes to become a highly acceptable environmentally friendly finishes.

Shellac

Shellac finishes are natural resins that result from exudation deposited by the lac bug, an insect found in South Asia. Shellacs are made by dissolving the solid resin in ethyl alcohol. When applied, the alcohol quickly evaporates, leaving a film of shellac.

Shellacs are quick drying, easily applied, adhere well, have good resistance to wear and impact, and although not as water-resistant as other varnishes they are appropriate for interior applications. As shellac will attach itself to virtually any surface, even glass, and practically any other finish can be used over it.

Shellacs are capable of producing a beautiful finish known as French polishing which is the art of producing a mirror smooth finish by hand rubbing countless thin coats of shellac into and onto the wood surface. However, French polished finish can easily be water or alcohol marked and is sensitive to any mistreatment.

Lacquer

Lacquers, which are commonly used furniture finishes, are transparent and bring out the beauty of wood grain when a natural finish is desired. They harden by loss of solvent but do not build layers as thick as most varnishes.

Lacquers offer hard, durable and waterproof surfaces able to withstand high heat and provide good resistance to abrasion, handling and water spotting. Some available lacquers are resistant to acids and alcohol, making them ideal for tabletops. Lacquers are fast drying (1 – 2 hours) and can dry within minutes for thin films. Because of their rapid drying it is better to apply them by spraying rather than brushing, which minimises brush-marks.

Alternatively, the speed of drying can be reduced by the addition of a solvent to thin the solution, which helps to prevent marking.

There are various types of lacquers available on the market. Lacquers most commonly used are:

- Nitrocellulose
- Pre-catalysed
- Acid-catalysed
- Polyurethane
- Water-based.

Table 2 provides a guideline for the selection of lacquers for appearance wood products (based on: Australian Furniture Research and Development Institute 2001).

Table 2: Guidelines for selection of lacquers systems for appearance wood products

Type of lacquer	Properties	Typical application area
Nitrocellulose	– Simple, easy to use – Fast drying – Economical	– General lounge and bedroom furniture – Furniture restoration – Wall panelling – Casket manufacture
Pre-catalysed	– Improved mar and scuff resistance – Fast drying – Medium water and solvent resistance	– Dining room tables – Wall panelling – Office furniture
Acid catalysed	– High build – Superior mar and scuff resistance	– Dining and office furniture – Utility furniture – High use areas
Polyurethane	– Excellent chemical solvent and water resistance – High build – Excellent mar and scuff resistance	– Vanity units – Kitchen cupboards, doors and kitchen units – Laboratory, hotel and office fittings and furniture – Bars and restaurants – Flooring
Water-based	– Ease of clean-up	– General lounge and

	– Quick drying times – Very scuff resistant – Non-yellowing – Non fire hazard – Less polluting – Good UV protection	bedroom furniture – Dining furniture – Wall panelling

Water-based finishes

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, new environmentally friendly finishes were developed. Clear water-based finishes are one of these new products 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.

Water-based finish contains some of the same ingredients as varnish and lacquer, notably urethane, alkyd and acrylic, but many flammable and polluting ingredients have been replaced with water. The chemistry in this product is complex. Because the resins don't have a natural affinity for water, they must be chemically modified or forced to combine with water. Water-based finish is usually made with either an acrylic resin (sold as water-based lacquer) or an acrylic urethane mixture (sold as water-based polyurethane). As with varnish, the addition of the urethane makes the resin tougher and more scratch resistant, but water-based urethane does not have the same solvent and heat resistance as its oil-based counterpart.

Choosing a transparent finish for wood involves trade-offs between appearance, protection, durability, safety, requirements for cleaning, and ease of application. The comparison between the characteristics of different transparent finishes is provided in Table 3.

4.1.2 Penetrating finishes

Penetrating finishes, as the name suggests, penetrate the wood grain rather than 'setting up' on the surface and leave no appreciable surface coating or film. They basically soak into the wood rather than just coat it. They may be applied in plan or mixed with colour. Similar to varnishes, oil finishes provide a beautiful protective film using natural oil that hardens by reacting with oxygen from the air.

Examples include linseed oil, Danish oil and tung oil. Oil will impart a beautiful low lustre finish, but requires more maintenance than the surface coating finish.

Linseed oil

Linseed oil films are relatively soft and often feel sticky in hot weather. They exhibit poor wear and handling resistance and allow moisture to penetrate easily into wood.

Danish oil

Danish oil is a wood finishing oil, made of either tung oil or polymerized linseed oil. The function of Danish oil is to provide a hard-wearing finish, rather than a particularly fine or high-gloss finish. Compared to oil, it is hard-wearing and compared to a varnish, it is simple to apply. As the finished coating is not glossy or slippery, it is a suitable finish for tool handles, giving some additional weather resistance. Danish oil is a hard drying oil which provides a tough, water-resistant finish. It can be used as a finish or as a primer or sealer on bare wood before applying paint or varnish.

Tung oil

Tung oil has found more application than other penetrating oils because of his good protection against moisture penetration and hardness. Two basis tung oils are available, plain and polymerised oils. Both are quick drying, hard and highly durable with good resistance to water and chemicals. Plain tung oil dries to a matt finish, whereas polymerised oil produces a lustrous finish.

4.1.3 Opaque finishes

cover the surface completely. They cannot be seen through. Examples include paint and enamel.

Paint

Paint is any liquid, liquefiable, or mastic composition which, after application to a substrate in a thin layer, is converted to a solid film. It is most commonly used to protect, colour or provide texture to wood surfaces. Paint can be used in many colours, and there are many different types of paint, such as watercolor, artificial, etc. Paint is typically stored, sold, and applied as a liquid, but then dries into a solid. Wood stain is a type of paint that is very "thin," that is, low in viscosity, and formulated so that the pigment penetrates the surface rather than remaining in a film on the surface. Stain is predominantly pigment or dye and solvent with little binder, designed primarily to add colour without providing a surface coating (http://en.wikipedia.org/wiki/Paint)

Enamel

Enamel paint is paint that air dries to a hard, usually glossy, finish, used for coating various surfaces, including wood, that are outdoors or otherwise subject to hard wear or variations in temperature. The term “enamel paint” is often used in reference to paint brands of higher quality, floor coatings of a high gloss finish, or spray paints. Most enamel paints are alkyd resin based. Some enamel paints have been made by adding varnish to oil-based paint.

Table 3. Comparison between the characteristics of different transparent (clear) finishes (http://en.wikipedia.org/wiki/Wood_finishing)

Type of clear finishes	Appearance	Protection	Durability	Safety	Ease of Application	Reversibility	Rubbing Qualities
Wax	Creates shine	Short Term	Needs frequent reapplication	Safe when solvents in paste wax evaporate	easy, needs sanding	Can easily be removed with solvents	Needs to be buffed
Shellac	Some yellow or orange tint, depending on grade used	Fair against water, good on solvents except alcohol	Durable	Safe when solvent evaporates, used as food and pill coating	French polishing technique difficult to master.	Completely reversible using alcohol	Excellent
Nitrocellulose lacquer	Transparent, good gloss	Decent protection	Soft and somewhat durable	Uses toxic solvents. Good protection is needed, especially if painted	Requires equipment.	Completely irreversible	Excellent soft finish
Conversion varnish	Transparent, good gloss	Excellent protection against many substances	Hard and durable	Uses toxic solvents, including toluene. Breathing protection is needed	Requires spray equipment. Used in professional shops only	Difficult to reverse	Excellent hard finish

Type of clear finishes	Appearance	Protection	Durability	Safety	Ease of Application	Reversibility	Rubbing Qualities
Linseed oil	Yellow warm glow, pops grain[1], darkens with age	Very little	Fairly durable, depending on number of coats	Relatively safe, metallic driers are poisonous, rags may spontaneously combust	Easy, apply with rags and wipe off. Takes relatively long time to dry	Needs sanding out as oil is absorbed	None
Tung oil	Warm glow, pops grain[1], lighter than linseed	Water resistant	Fairly durable, depending on number of coats	Relatively safe, metallic driers are poisonous	Easy, apply with rags and wipe off. Faster to dry than linseed oil	Needs sanding out as oil is absorbed	None
Alkyd varnish	Not as transparent as lacquer, yellowish/orange tint	Good protection	Durable	Relatively safe, uses petroleum based solvents	Brush or spray. Brushing needs good technique to avoid bubbles & streaks	Can be stripped using paint removers	Fair
Polyurethane varnish	Transparent, many coats can look like plastic	Excellent protection against many substances, tough finish	Durable after approx. 30 day curing period	Relatively safe, uses petroleum based solvents	Application requires some level of skill	Can be stripped using paint removers	Bad, coats do not meld leading to white rings if rubbing out cuts through coat
Water-based polyurethane	Transparent	Good protection. Newer products (2009) also UV stable	Durable after approx. 10 day curing period	Safer than oil-based, fewer volatile organic compounds	Brush or spray. Fast drying demands care in application techniques	Can be stripped using paint removers	Bad, coats do not meld leading to white rings if rubbing out cuts through coat

Type of clear finishes	Appearance	Protection	Durability	Safety	Ease of Application	Reversibility	Rubbing Qualities
2-Part polyurethane	Transparent	Stronger protection than regular polyurethane varnish	Durable once cured, generally less than an hour	low or free of VOCs, nonreactive when cured	generally sprayed, equipment must be cleaned of any mixed product immediately	Irreversible	Sands easily. Sanding not needed between coats
Oil-varnish mixes	Similar to oils unless many coats applied, then takes on characteristics of varnishes	Low, but more than pure oil finishes	Fairly durable, depending on number of coats (archaic product, rarely used due to availability of modern finishes)	Relatively safe, uses petroleum based solvents	Easy, apply with rags and wipe off. Faster to dry than linseed oil	Needs sanding out as oil is absorbed	None unless many coats applied
Epoxy resin	Thick, high-gloss, and transparent. Some formulations can cloud or yellow with UV exposure	High level of protection	Flexible and durable	Safe when cured	Easy pour-on application for flat surfaces, difficult to apply evenly on more complicated shapes	Cleanable with acetone when liquid. Irreversible once cured	flexibility makes sanding difficult but possible

4.2 Classification based on finishes formulation

The other common classification system used for wood finishes is based on their formulation consists of three types of finishes:

1. Evaporative finishes
2. Reactive finishes
3. Coalescing finishes

4.2.1 Evaporative finishes

Evaporative finishes consist of lacquers, waxes, shellacs and varnishes. They contain a solid film forming material suspended in a thinner or solvent. Wax is an example of evaporative finish because it is dissolved in turpentine or petroleum distillates to form a soft paste. After these distillates evaporate, a wax residue is left over.

4.2.2 Reactive finishes

Reactive finishes represent drying oils, penetrating oils and different types of traditional varnishes. The hardening process of reactive finishes, which contains little or no thinners, is different and much more complex that of evaporative type finishes. Reactive finishes use solvents such as white spirits and naphtha. Oil varnishes and linseed oil are reactive finishes, meaning they change chemically when they cure, unlike evaporative finishes. The solvent evaporates and a chemical reaction occurs causing the resins to undergo a change. This change prevents solvents from dissolving reactive finishes. Tung oil and linseed oil are reactive finishes that cure by reacting with oxygen, but do not form a film.

4.2.3 Coalescing finishes

Coalescing finishes are made up of reactive-cured finish droplets suspended in water and a very slow evaporating solvent. The water evaporates first. Then the solvent softens the outside of the droplets which become sticky and stick together when the solvent evaporates (Flexner, 2010). Coalescing coatings include water based coatings.

5 Finishing process

5.1 Preparation of wood surface for finishing

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

A very important aspect of surface preparation is the control of the moisture control of wood to be finished. As high moisture content is difficult to detect visually, therefore it should be checked with a moisture meter. The wood components or wood products to be finished

should be stored in a cool dry place; otherwise they will absorb moisture from the ambient air.

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

One of the worst contributors to poor quality finish is glue that has squeezed out. Glue will not take stain and it is essential that every spot of glue has been removed. Glue around joints can be removed with a scraper or sharp chisel once it has thickened.

The evenness and smoothness of the surfaces are also very important factors in wood preparation. Raised grain is a common problem related to machining and moisture problems.

A planer or jointer that is not properly adjusted can leave cutter markers or chip imprints on wood surfaces. These are difficult to see on unfinished wood but will be visible after the finish is applied, and therefore they must be removed.

Raised or sunken joints can also produce uneven surface as a complication of poor gluing procedures.

5.2 Sanding wood surfaces

5.2.1 Principles of wood sanding

Sanding is often the most overlooked surface preparation operation. The quality and uniformity of the sanding process directly affects the quality of the finished piece.

Sanding can be considered as the last operation in the manufacturing process of the uncoated product. It is done to remove the first wood layers, producing a smooth and uniform surface and also eliminating blemishes due to previous operations such as gluing (Bulian and Graystone, 2009). Sanding is usually carried out by several passes just before the application of the first coat. It is also carried out on applied coats after drying and just before the application of the finishing coatings. In this case the function of sanding is to smooth any raised grain and also improve the inter-coat adhesion of the following coats.

When sanding is performed correctly, it will ensure:

- an even, smooth surface finish
- an accurate thickness and flatness
- minimal problems due to fibre rising
- a better result due to less dust on the surface
- cost savings, both on sanding products, as well as coatings and lacquers.

It is essential to know the type of wood used for finishing before starting sanding. The type of wood to be sanded has a direct relationship to the grit of paper used for final sanding.

The grade, or grit, of sandpaper is based on the number of sand granules per square inch of paper. The higher the number; the finer the grade. Lower-numbered grades denote coarser sandpaper. The grit number is generally printed on the back of each sheet.

Guidance for sanding appearance wood products provided in Table 4.

Table 4: Guide for the use of sandpaper grit for various sanding operations (reproduced from http://www.nortonconsumer.com/bare-wood-sanding.aspx)

Grit Guide	
Very Fine (220)	For light sanding between stain and sealer.
Fine (150-180)	For final sanding or cleaning of wood surfaces.
Medium (100-120)	For moderate removal of surface imperfections.
Course (60-80)	For heavy removal of wood and coatings.

According to Norton Abrasives website (Norton Abrasives, 2013), softwoods can be finish sanded with 150 or 180 grit prior to the application of primer. Hardwoods used in furniture and other appearance wood products fall into two categories: closed grain and open grain. Open grained hardwoods can often be finish sanded with 220 grit. Since sanding actually scratches the surface, it is important to keep in mind that the coarser the final grit size the darker the finish when using stain. Conversely the finer the grit size the lighter the finished stain. The coarser the scratch pattern the deeper the stain "penetrates" the wood. To achieve the desired stain color, it is recommended to test the sanding steps on a scrap piece of wood to determine the correct sequence of sanding steps. Once the stain/colour has been applied to the workpiece the only way to remove it is to strip or sand it and start over. Using a test block saves time, money and frustration.

There are several steps which need to be followed to achieve a smooth finish (Norton Abrasives, 2013)

Step 1

Always sand in the direction of the grain; never perpendicular to it or at an angle (Figure 1). This also applies when working on edges and hard-to-reach corners. Scratches made by sanding against the grain will look unattractive on the finished piece and will be particularly noticeable after staining.

Be extra careful when sanding face frames or assembled pieces where the grain direction changes at the joint between the two pieces. Cross grain scratches are difficult to remove without extra sanding and will show through your final finish.

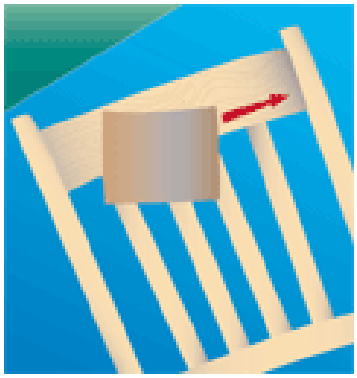


Figure 1: Sanding in the direction of the grain (drawing reproduced from http://www.nortonconsumer.com/bare-wood-sanding.aspx)

Step 2

Start with the finest grade (grit) of sandpaper that allows you to get the job done effectively. Starting too coarse only means extra sanding steps to achieve an acceptable finish. This is very important especially when sanding veneers. Since most veneers used today are very thin, extra sanding steps as a result of starting too coarse may result in sanding through the veneer.

Step 3

Scrape off any glue residue from the assembly steps and sand uniformly to remove any traces. Glue residue limits the ability of the stain to penetrate the wood surface. Clean all surfaces with a tack cloth to remove wood dust. Tack cloth is a specialized type of wiping cloth that is treated with a tacky material. It is designed to remove loose particles of dust, dirt and lint that would contaminate a surface that is to be painted, coated, laminated, or otherwise finished

Step 4

For sanding flat areas, use a sanding block to ensure an even and smooth surface. For larger areas, use an oscillating sander like a palm sander.

Step 5

Sand the entire surface of the workpiece. Do not sand only the area that may have contained a small surface defect. Sanding only a small area will result in an uneven and blotchy appearance.

Step 6

Sand with successively finer grades of sandpaper skipping one grade between sanding steps. Since you have pre-determined the final sanding grade for you project by using your test block determine your starting grade for sanding by testing to see if that final grit size effectively removes the surface defects. If it doesn't, then use the next coarsest grit in the grade sequence and start again. **Remember you are trying to minimize the number of sanding steps to achieve the desired result. The coarser you start, the more sanding you have to do between the coarse grade and finish grade to get an acceptable finish**. Do not skip more than one grade between sanding steps. For example if you started with

100 grit and that is not your last sanding grade then you can skip 120 grit and go to 150 grit to complete the job.

Step 7

Clean all surfaces with a tack cloth (Figure 2).

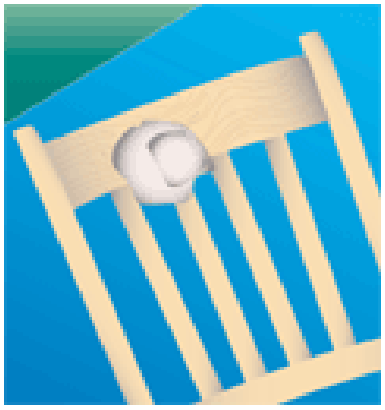


Figure 2: Cleaning the surfaces with a tack cloth (drawing reproduced from http://www.nortonconsumer.com/bare-wood-sanding.aspx)

5.2.2 Sanding equipment

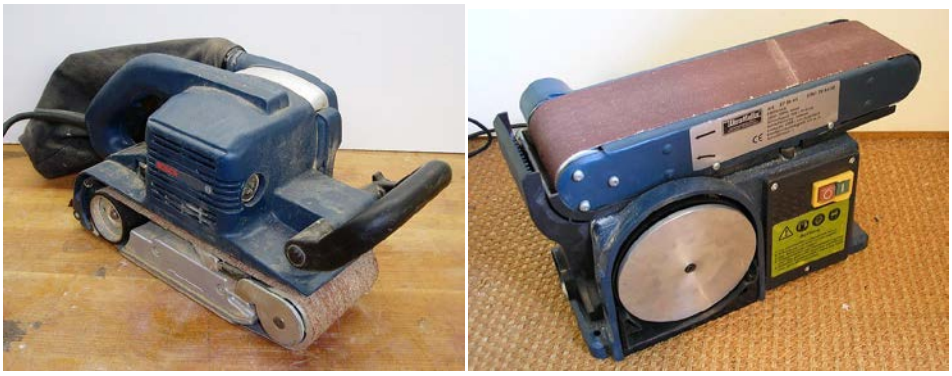
There are many different types of sanders on the market, and they come in many varieties. It is important for the buyers and users user to consider which features they require and the advantages and disadvantages of each type of sander. The choice of sander depends on the type of job and the type of power source that the sander uses.

Sanding can be done either by hand (typically using a sanding block or power sander), or by a sanding machine.

Hand sanding is preferable for fine finishes and delicate pieces. It is often essential on small jobs and may be required in some cases where a machine cannot reach.

Most common woodworking sanders include: (http://en.wikipedia.org/wiki/Sander)

1. ***Belt sander*** is one of the most commonly used sanders. It is used in shaping and finishing wood and other materials. It consists of an electric motor that turns a pair of drums on which a seamless loop of sandpaper is mounted. Belt sanders may be handheld and moved over the material, or stationary (fixed), where the material is moved to the sanding belt (Figure 3 a and b, respectively). Stationary belt sanders are sometimes mounted on a work bench, in which case they are called bench sanders. Stationary belt sanders are often combined with a disc sander. Belt sanders can have a very aggressive action on wood and are normally used only for the beginning stages of the sanding process, or used to rapidly remove material. Sometimes they are also used for removing paints or finishes from wood. Fitted with fine grit sand paper, a belt sander can be used to achieve a completely smooth surface.



(a) Hand-held belt sander (b) Stationery belt sander

Figure 3: Types of belt sanders (reproduced from http://en.wikipedia.org/wiki/Sander)

2. ***Disc sander*** consists of replaceable circular shaped sandpaper attached to a wheel turned by an electric motor or compressed air (Figure 4). The usually wooden work piece is sat on a front bench that can be adjusted to various angles. It can be used for rough or fine sanding depending on the sanding grit used.

Figure 4: Disc sander (reproduced from http://bbs.homeshopmachinist.net/threads/38608-Looking-for-plans-for-disc-sander-angle-table)

3. ***Oscillating spindle sander*****:** Good for sanding curves and contours that would be difficult with hand or orbital sanding (Figure 5).

Figure 5: Oscillating spindle sander (reproduced from http://www.grizzly.com/products/g0529/images/)

4. ***Orbital sander*****:** A hand-held sander that vibrates in small circles, or "orbits." Mostly used for fine sanding or where little material needs to be removed (Figure 6).

Figure 6: Orbital sander (reproduced from http://www.festool.com.au/Sanders/Orbital-Sanders)

5. ***Straight-line sander*****:** A sander that vibrates in a straight line, instead of in circles (Figure 7). Good for places where hand sanding is tedious or "blocking" is required.

Figure 7: Straight-line sander (reproduced from http://www.eastwood.com/straight-line-air-sander.html

6. ***Stroke sander*:** A large production sander that uses a hand-operated platen on a standard sanding belt to apply pressure. For large surfaces such as tabletops, doors, and cabinets (Figure 8).

Figure 8: Stroke sander
(reproduced from www.garyweeks.wordpress.com)

7. ***Table top drum sander*:** A bench top sander that uses a rotating drum (Figure 9). Can be used for surface sanding, edge sanding, stripping paint, cabinet doors, etc

Figure 9: Table top drum sander
(reproduced from http://www.krtwood.com/sander.html)

8. ***Drum sander*:** A large sander that uses a rotating sanding drum. Good for finishing large surfaces (Figure 10).

Figure 10: Drum sander
(reproduced from http://www.rockslide.org/drum%20sander.html)

9. ***Wide-belt sander:*** A large sander similar in concept to a planer, but much larger. Uses a large sanding belt head instead of a planer's knife cutterhead, and requires air from a separate source to tension the belt Figure 11). These sanders are produced as single, twin or triple head wide belt sanding machine for rough sanding large surfaces or finishing. Used mainly for manufacturing furniture and cabinets.

Figure 11: Wide-belt sander (reproduced from
http://gabbett.com/scm-wide-belt-sanders/)

Whatever sanding method is used, a lot of dust will be left on the wood surfaces. This dust must be cleaned off before applying a finish.

There are various ways to remove the dust:

- Brush it off.
- Wipe it off with a special “tack” cloth. Tack cloth is a specialized type of wiping cloth that is treated with a tacky material. It is designed to remove loose particles of dust, dirt and

lint that would contaminate a surface that is to be painted, coated, laminated, or otherwise finished.

- Vacuum it off.
- Blow it off with compressed air.

5.2.3 Safety procedures during sanding operation

Wood dust can be a serious hazard to both health and safety if not properly controlled. Breathing very small wood particles may cause allergic respiratory symptoms, mucosal and non-allergic respiratory symptoms, and cancer. Therefore it is critical that safety precautions are used during any sanding operation, with most important listed below:

- Wear respiratory protection (e.g., dust masks) where required, during sanding operations and clean up.
- Wear safety glasses or goggles, or a face shield (with safety glasses or goggles) when operating a sander.
- Wear hearing protection that is suitable for the level and frequency of the noise you are exposed to in the woodworking area.
- Wear protective footwear.
- Use sanders with the local exhaust ventilation turned on.
- Keep hands away from the abrasive surface, beware of loose fitting clothes, long hair or jewellery which could become entangled in moving parts.
- Hold small or thin pieces of stock in a jig or holding device to prevent injuries to the fingers or hands.
- Inspect abrasive belts before using them. Replace belts worn, frayed, or excessively worn in spots.
- Sand on the downward side of a disc sander so that the wood is driven onto the table by the machine's rotation.
- Enclose all drums, disk or belt sanding machines with an exhaust dust hood that covers all portions of the machine but the portion designed for the work feed.
- Have the dust extracting system turned on and connected to the sander. Because of the dust created when sanding wood, the fire and explosion hazard is considerable.
- Ensure that fire extinguishers are available and that persons working with the equipment know how to operate the extinguishers.

5.3 Finishing methods

Finishing methods vary according to desired finishes used for various products and service conditions. It is recommended that the products and methods used for coating be recorded for each type of product. This will provide useful information on the possible cause of problems if they arise.

Any wood imperfections on the surface or pores should be filled using wood putty or wood filler. The wood colour may be changed by staining, bleaching, or any of a number of other techniques.

Once the wood surface is prepared and stained, the finish is applied. Usually several coats of various finishes are applied, such as shellac, wax, lacquer, varnish, or paint. After each coat is applied, typically the surface is sanded. Finally, the surface may be polished depending on the shine desired.

Typical coating methods are described below.

Filling the pores: if the pores of open-pored wood such as mahogany, walnut, are to be filled, a wash-coat is applied first. On tight-grained wood such as maple or cherry and an open-pored wood that has not been filled a sealing process is applied. This is usually done with a sanding sealer for easy sanding. This coat is then sanded to remove any raised grained and other minor imperfections.

Paste wood fillers are used to produce a smooth, nonporous surface and accentuate the grain. They are usually thinned to a watery consistency and sprayed. The thinner is allowed to evaporate so the filler dulls, and then the filler is wiped, either across the grain or in circles, to push it deeper into the pores and to remove the excess. Large-pored woods are usually filled a second time. The filling step is followed by a sanding sealer, which is sanded smooth.

Waxing is the ultimate rich-looking and labour intensive finish that seals and protects the wood. It is used to rejuvenate and old finish or can be used as a finish itself. Surprising to most, a professionally applied wax finish requires little maintenance. It can also be applied over a penetrating finish, to reduce the amount of maintenance that would typically be required.

Staining is used to enhance the true colour of the woodwork or to achieve uniformity when the wood has an inconsistent appearance. It can also be used to change the natural colour of the wood to a colour required by the product customer.

Glazing and Toning are techniques used to highlight the details in the woodwork or to unify and add depth to the colour. These two techniques can also be used to give "age" to the finish. The process involves applying transparent pigmented liquid over or between coats of finish.

Pickling is a technique that refinishers use to lighten the natural colour of wood -- usually oak -- to give it a washed-out appearance. This is usually done by brushing on a white or light-coloured stain. Therefore, pickling is nothing more than a non-penetrating stain brushed onto the bare wood and covered with a clear finish.

Liming is a highly fashionable yet traditional method of decoration, liming both revitalizes the look of wood and gives it a comforting, time worn appearance (Peel, 2009).

Liming is a simple technique for bringing out the grain of the wood and giving it a whitened look, as if it has faded naturally over the years. It is ideal for both restoring old furniture and mellowing new. The soft, textured effect liming produces is especially pleasing in neutral colour schemes. Liming is most effective on prominently grained woods such as ash, pine and oak. Oak particularly benefits. It is a naturally pale wood that can look rather heavy and dull, all the more so when it is covered in dark varnish, as it often is. Traditionally, limewash

was used for liming wood. However, lime is very caustic so it is safer and just as effective to use liming wax or white eggshell paint, both of which are readily available, and easy to apply. Wax produces a particularly subtle effect, with a soft sheen.

Bleaching is used to lighten the natural colour of wood or to remove discoloration caused by moisture. Bleaching can also be used to achieve the base colour in preparation for pickling or liming. It is not used to remove stain or dyes.

Distressing is a technique that can be used to give age and interest to the finish. This can be done any number of ways, including:

- sanding the finish away from areas that would have been worn over the years
- rubbing the finish away with a chemical
- striking the surface with a mix of objects that will randomly dent the finish

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.

5.4 Finishing application techniques

Wood coating takes place in different sizes of facilities, from small handcraft shops up to large furniture production facilities. Different application technologies and equipment are used in rather different sizes of production facilities. Also, coated surfaces are of different shape, from large flat surfaces to very complex surfaces, which cause significant losses of coating in case of spraying (overspray). Therefore, it is difficult to give general recommendations on best suitable coating techniques.

Most commonly used methods are as follows:

- Brushing
- Spraying
- Roller coating
- Curtain coating
- Automated hangline system.

Brushing

The increasing popularity of spray equipment is making brushes less important but they are still used by finishers in small woodworking workshops and small furniture factorieswith good results. There are three types of brushes: natural bristle, synthetic bristle and foam. Brushing is very intuitive and requires a lot of knowledge based on experience.

Spraying

It is probably the most widely used application method in the furniture industry. In essence all spraying consists of breaking the coating material into a cloud of airborne droplets and transporting these droplets to the wood surface where they coalesce to form a continuous film.

There are five main categories of spray guns (Flexner, 2010):

- Conventional: traditional high-pressure spray guns, powered by compressed air and in common used for century but almost entirely replaced by HVLP (High Volume Low Pressure) spray guns.
- Turbine HVLP: this system uses a high volume of air supplied by a turbine blower instead of compressed air to atomize liquids. The finish is applied at a lower pressure but at high volume. The advantage of this system is that reducing the pressure creates a “soft” spray with much less bounce-back and waste than occurs with high-pressure, conventional spray guns. A much higher percentage is applied to the surface and is not lost in overspray.
- Compressor HVLP: compressed air is converted inside the gun to high volume and low pressure. Due to its sift-spray velocity, about tqo-third of the liquid material is deposited on the sprayed surface, while the conventional spray guns deposit only about one-third.
- Airless (hydraulic atomization): these spray guns are powered by a pump that pushes liquid material through a very small spray-nozzle orifice at up to 22 MPa. A very large volume of liquid material can be sprayed with this system.
- Air-assisted airless are powered by both a medium-pressure pump and compressed air. This system is expensive and therefore is used in large factories to speed production with no loss in spray quality.

Spray booths

Professionally equipped factories use commercially made spray booths to exhaust overspray. A spray booth is a pressure controlled closed environment, used to spray finish on various products. To ensure the ideal working conditions (temperature, air flow and humidity), the spray booths are equipped with one or more groups of ventilation, consisting of one or more motors and one or more burners to heat the air blown. In order to assist in the removal of the oversprayed paint from the air and to provide efficient operation of the down-draft, water-washed paint spray booths utilize paint detackifying chemical agents.

Roller Coating

Roller coating is used for finishing flat furniture panels which are passed through a roller coater in which the roller picks up a layer of lacquer from a tank and transfers it to the panel.

Curtain Coating

Curtain coating is a method of applying liquid finishing material to flat, or nearly flat, panels, which are moved horizontally through a falling curtain, or waterfall of the liquid. It is thus not applicable to complete items of furniture. It is often used for coating table tops. The greatest advantages of curtain coating are speed of application and economy in use.

Hangline approach

In the hangline approach, wood items being finished are hung by carriers or hangers that are attached to a conveyor system that moves the items overhead or above the floor space. The conveyor itself can be ceiling mounted, wall mounted or supported by floor mounts. A simple overhead conveyor system can be designed to move wood products through several wood finishing processes in a continuous loop. The hangline approach to automated wood finishing also allows the option of moving items up to warmer air at the ceiling level to speed up drying process.

New finishing methods and techniques are being developed all over the world in order to improve the efficiencies of the processes and shorten the finishing times. However, small companies will continue to use traditional methods, like brushing and simple spraying, and taking advantage of developments, where they are worthwhile. The main focus should be placed on achieving high quality finished wood products instead of high technology equipment.

5.5 Health and environmental concerns on wood finishing[1]

As organic materials in finishes evaporate during the drying/curing process, VOCs are released into the air, affecting indoor and outdoor air quality. The American Lung Association reported that VOCs and their byproducts can produce a number of physical problems, including eye and skin irritation, lung and breathing problems, headaches, nausea, muscle weakness, and liver and kidney damage. VOC levels can be ten times higher indoors than outdoors, with numbers rising up to 1,000 times higher immediately following application of a new coat of finish.

Outside, VOCs released into the atmosphere can combine with each other, or with other substances in the air, to create new chemical compounds, such as ground-level ozone. Ozone is a major component of smog, which causes negative health and environmental impacts when present in high concentrations at ground level. VOCs are considered air pollutants, and the amount that can be released for a given amount of solids is now regulated in many areas.

Wood finishes may also contain other toxic ingredients which are suspected carcinogens. And aromatic solvents such as toluene and xylene can cause a number of health problems if inhaled. All of these examples are currently reported as ingredients in some wood finishing

[1] This section was reproduced from http://www.healthyhouseinstitute.com/a-948-Wood-Finishes

products. Lead, a well-known toxic metal, had been used as a metallic drier in oil and resin varnishes; lead has since been replaced by other metals such as cobalt and zinc. Metals may still be problematic because of their environmental toxicity and persistence.

Phthalates, used as plasticizers, are of concern because they may potentially affect human and animal hormone systems. Ozone-depleting compounds have been phased out of most coating products.

Lower-VOC Finishes

Over the past few years, regulation under the Clean Air Act (USA) and consumer demand for low-VOC finishes have led to the creation of a variety of new products. Many penetrating finishes, such as semi-transparent stains, have low solids content (pigment, oils, polymers) and are being reformulated to meet low-VOC regulations. To meet the VOC requirements, these reformulated finishes may contain higher solids content, reactive diluents (dilutants or thinners), new types of solvents and/or cosolvents, or other non-traditional substitutes. These low-VOC requirements favour film-forming formulations over products that penetrate the wood surface, since traditional wood stains were formulated to penetrate the wood, and the new formulations that meet the VOC requirements may not penetrate as well.

Water-based Finishes

Another way to decrease air emissions from wood finishes is to change the formulation to a water-based coating. The new water-based products achieve a dramatic improvement over solvent-based finishes in terms of VOC emissions and human comfort and health. Companies that have successfully switched to water-based coatings have worked closely with their suppliers to determine the best water-based formula for their specific uses.

6 Performance of furniture finishes and surfaces

6.1 Introduction

The degradation factors affecting coated surfaces in indoor conditions are usually caused by people during their daily routine activities inside houses, offices or other living spaces. They can be either accidental events such as dropping a sharp object on the item of furniture or continuous stressing factors like surface cleaning, wear and tear on flooring, water spillage on the kitchen bench top, etc. There are several test methods simulating the degradation effects affecting coated surfaces during the real use.

Most suitable specification and test methods related to the performance of furniture finishes have been developed by Furniture Industry Research Association, FIRA, in UK. FIRA is an internationally recognised furniture research and testing institution with many branches established in various parts of the world. There are also several furniture research and testing organisations located in many other European countries (France, Italy, Germany, Sweden), America, Asia and Australia, with furniture testing facilities based on the FIRA model and using test methods developed by FIRA. In Australia, Australian Furniture Research and Development Institute (AFRDI) has been established in 1989 in Launceston, Tasmania, which has strong collaborative arrangements with FIRA.

The description of the test methods used to assess the performance of furniture finishes is provided below (reproduced from FIRA website (http://www.fira.co.uk/).

6.2 Test methods for furniture finishes

The performance of furniture finishes and surfaces is defined in FIRA Standard 6250, which has its origins in British Standard 6250: 1991 Part 3. BSI formerly withdrew this standard in 1999. The withdrawal of this standard came about as result of a review of test procedures and a move toward harmonisation of standards throughout Europe. Whilst common agreement was established for the test procedures the goal of a commonly agreed performance specification across Europe has yet to be established.

With the withdrawal of BS 6250, at that time, FIRA realised the UK furniture industry would be left without a vitally important performance standard and therefore published FIRA Standard 6250 1999 to fill the gap. This FIRA standard, based on the old BS 6250, adopted the new European test procedures and made certain that other appropriate changes were made. However six years have passed since its publication and an upgrade of standard was overdue. Therefore, the new standard FIRA Standard 6250: 2005 Specification: Furniture materials (interior applications) have been revised and now also incorporate a more extensive range of performance specifications for furniture. At the core of this standard remains the comprehensive finish performance specification. The tests and performance requirements within this new standard are described below.

Test procedures to assess the durability of finishes are divided into three main groups,

- Resistance to mechanical damage
- Resistance to dry and wet heat
- Resistance to cold liquids, oils and fats.

These tests are generally applicable to all types of furniture finishes including liquid based finishes, plastics laminate, melamine faced chipboard, paper foils, and PVC bonded to wood based substrates as well any other type of surface finish/substrate combination. Normally the surface finish is tested on the substrate on which it will be used, as the substrate can affect the results of some tests.

Performance requirements for the assessment of furniture finishes are specified in FIRA Standard 6250. The test methods referred to in this standard are, BS 3962 Part 6 1980, BS EN 12720, 12721 and 12722. Plastics laminates used for kitchen worktops are also required to comply with the relevant requirements of BS EN 438 (plastics laminate standard).

Assessment of surface resistance to mechanical damage (BS 3962 part 6: 1980)

Crosscut test

A template is used to guide knife cuts, to a depth of 0.3 mm, in a grid pattern into the surface finish of the sample (Figure 12). The test area is then brushed and examined with a hand lens. The appearance of the cuts and the degree of finish removed are then assessed on a scale ranging from rating 1-5.

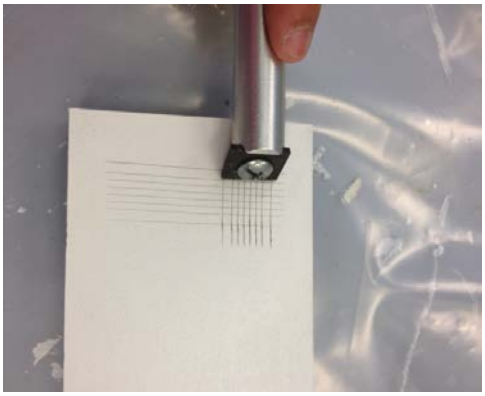


Figure 12: Crosscut tester

Impact test

This test gives an indication of the impact resistance of a surface finish to cracking. A steel ball (19.1 mm diameter, 28 grams) is dropped on to the test panel from a height of two metres ensuring the ball is caught to prevent multiple impacts (Figure 13). The test area is then examined with a hand lens. The degree of cracking of the finish is assessed on a scale ranging from rating 1-5.

Figure 13: Impact testing equipment

Scrape test

A scraper blade is traversed, approximately 200 mm, over the surface of the panel at a constant speed of 20 mm/sec, with a vertical force on the blade increasing from less than 1.5 N to more than 14 N (Figure 14). The scrape line is examined with a hand lens to determine the initial point at which the surface coating is penetrated and a second point where the blade penetrates into the substrate. The first visible signs of surface marking may also be recorded if required. The scrape force, in Newtons, is read from a calibration graph and the result converted into a rating ranging from 1 to 5.

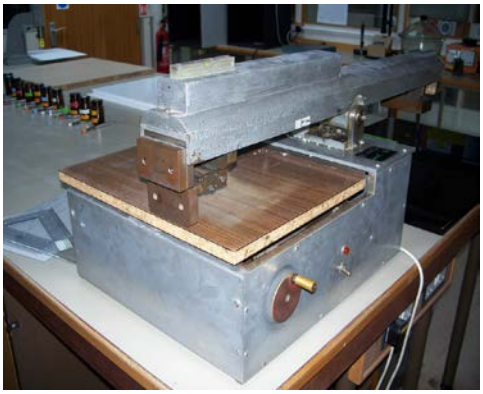


Figure 14: Scrape test

Assessment of abrasion resistance of coatings by the Taber Abraser (ASTM D4060 – 10)

Taber Abrasers are durable, precision-built instruments designed to perform accelerated wear tests on a variety of specimens. Materials are subjected to the wear action of two abrasive wheels at a known load (Figure 15). This wear action results when the abrasive wheels are rotated in opposite directions by a turntable on which the specimen material is mounted. The abrading wheels travel on the material about a horizontal axis displaced tangentially from the axis of the test material which results in a sliding action.

The Taber Abrasers are available with either a single test head or dual testing heads, which allows the user to test two different or identical materials simultaneously.

Figure 15: Taber abraser tester (reproduced from http://www.elcometer.com/en/laboratory/abrasion-and-washability/taber-abrasers/)

Assessment of surface resistance to wet heat (BS EN 12721:1997)

This test represents the conditions of hot liquid, trapped for example between a hot cup and tablecloth, in contact with a surface finish (Figure 16).

A wetted nylon cloth is placed on the surface of the test panel following which a standard aluminium alloy block, heated to a specified temperature, is then placed on the cloth for a period 20 minutes.

After test the area is wiped dry and left undisturbed for at least 16 hours. The test area is then examined in diffuse and direct light for signs of change in appearance. Damage to the surface is then assessed on a scale ranging from rating 1 to 5.

Assessment of surface resistance to dry heat (BS EN 12722:1997)

This test is intended to represent hot ovenware being placed directly onto a surface finish. The dry heat test is similar to the wet heat test, described above, except the wetted cloth is omitted.

Figure 16: Wet and dry heat test

Assessment of surface resistance to cold liquids (BS EN 12720:1997)

This test is intended to simulate spillage of common household liquids onto a surface finish. A 25 mm diameter absorbent paper disc is soaked in the test liquid and placed onto the surface of the test panel and then covered with a glass dish for a period of 1 hour. In the case of ‘cold oil and fats’ (e.g. butter) these are placed directly on the surface finish for a period of 24 hr (Figure 17). Absorbent paper is then used to soak up any remaining test liquid and the test area left undisturbed for period of at least a further 16 hours. Finally the test surface is cleaned with a standard cleaning solution and water, allowed to dry and then examined in diffuse and direct light for change in appearance. Damage top the surface is assessed on a scale ranging from rating 1 to 5.

The test liquids specified in FIRA Standard 6250 1999 are Acetone, Ethanol (96%), Ethanol (48%), Tea, Coffee, Disinfectant (Phenol), Disinfectant (Chloro), Paraffin Oil, Blackcurrant Juice, Ammonia Solution (10%), Acetic Acid (4.4%), Olive Oil, Cold Oils (margarine) and Cold Fats (butter).

Figure 17: Resistance to cold liquids test

7 Performance problems with finished wood products

7.1 Typical failures related to improper finishing

The majority of coating-related failures apparent on wood 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 (Ozarska, 2013).

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 (Figure 18).

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.

Figure 18: Crazing of finished surfaces (reproduced from http://www.furniture-refinishing-guide.com/articles/repairing-cracking-and-crazing-furniture-finishes/

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 (Figure 19).

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.

Figure 19: Orange peel (reproduced from http://hardwoodfloorsmag.com/forum/topic25-what-causes-this-finish-problem.aspx

Blushing

Blushing is a milky-white appearance in the finish caused by the condensation of airborne moisture in a finish cooled by evaporating solvents (Figure 20). 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.

Figure 20: Blushing problem (reproduced from http://www.wisnofurniturefinishing.com/2010/04/blushing-problem-in-furniture-finishing.html)

Blistering

Blisters are defects in finished wood products, usually visible as elevations on the finished surface that look like skin blisters (Figure 21). 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.

Figure 21: Blistering (reproduced from http://hardwoodfloorsmag.com)

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 (Figure 22). 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).

Figure 21: Overspray of finished surface (reproduced from http://www.mig-welding.co.uk/paint-faults/overspray.jpg)

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 (Figure 22). 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.

Figure 22: White-in-the-grain finish problem (reproduced from http://chiccalifornia.com)

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 (Figure 23). 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.

Figure 23: Cissing problem (reproduced from http://voices.yahoo.com/how-fix-common-paint-faults-11860425.html?cat=30

UV discolouration of coated wood surfaces

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 (Ozarska 2013).

The colour characteristics of wood depend mainly on the presence of extractives, complex organic compounds, such as polyphenolic compounds, and quinines. 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. Discolouration occurs in both indoor and outdoor applications.

Even very clear finishes will change the colour of wood considerably. Discolouration of wood by UV light occurs mainly 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 planning the surface. UV inhibitors should be added to finishes to reduce the yellowing effect on lighter timbers. Therefore it is highly recommended that appropriate UV protective coating should be used to eliminate the discolouration of wood surfaces.

It is important to highlight that generally; the application of protective clear coatings containing UV absorbing additives reduces, but does not completely eliminate, the detrimental wood discolouration caused by UV radiation originating from sunlight.

Clear UV protective coatings should always contain UV absorbing additives or a combination of a synergistic UV absorber and free radical scavenger additives to prolong the service life of the coating itself and that of wood.

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.

Research study results (Forest and Wood Products Australia 2008) revealed that high quality solvent-based acrylic-polyurethane coatings systems with UV blockers are the most effective protective systems which should be used to protect the veneers against sunlight discolouration.

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.

Improper handling of finished 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 products 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.

8 Summary recommendations on wood 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 wood products be coated to provide a protective seal against changes in humidity. Failure to do so will be detrimental to the stability of the products as moisture penetrates through the unsealed surface during any ambient change in relative humidity. The products not sealed may also bow or cup. The sealing of all surfaces is a critical factor in maintaining high quality wood products.

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 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 wood 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.

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