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05286

Distr.
LIMITED
ID/WG.163/28
2 February 1974
ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Seminar on the Furniture Industry
Lahti, Finland, 6 - 25 August 1973

PROPERTIES AND USAGE OF PAPER BASED DECORATIVE PLASTIC LAMINATE BOARD 1/

by

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SUMMARY

Laminate boards are manufactured of resin impregnated paper by pressing together several layers under great pressure, and in raised temperature. The surface formed of melamine resin and paper is hard, and well resistant to abrasion and heat. Variations in relative humidity of the air have a disadvantageous effect upon the dimensions of the board, causing tensions in installed boards.

Decorative laminate is widely used for kitchen cabinets, furniture of cafés, hotels and hospitals, and interiors of ships, buses and trains.

The board is usually glued on wooden board, but it may also be fixed e.g. on walls with the aid of strips.

A surface covered with decorative laminate is easy to keep clean, it is hygienic, beautiful, and very durable.

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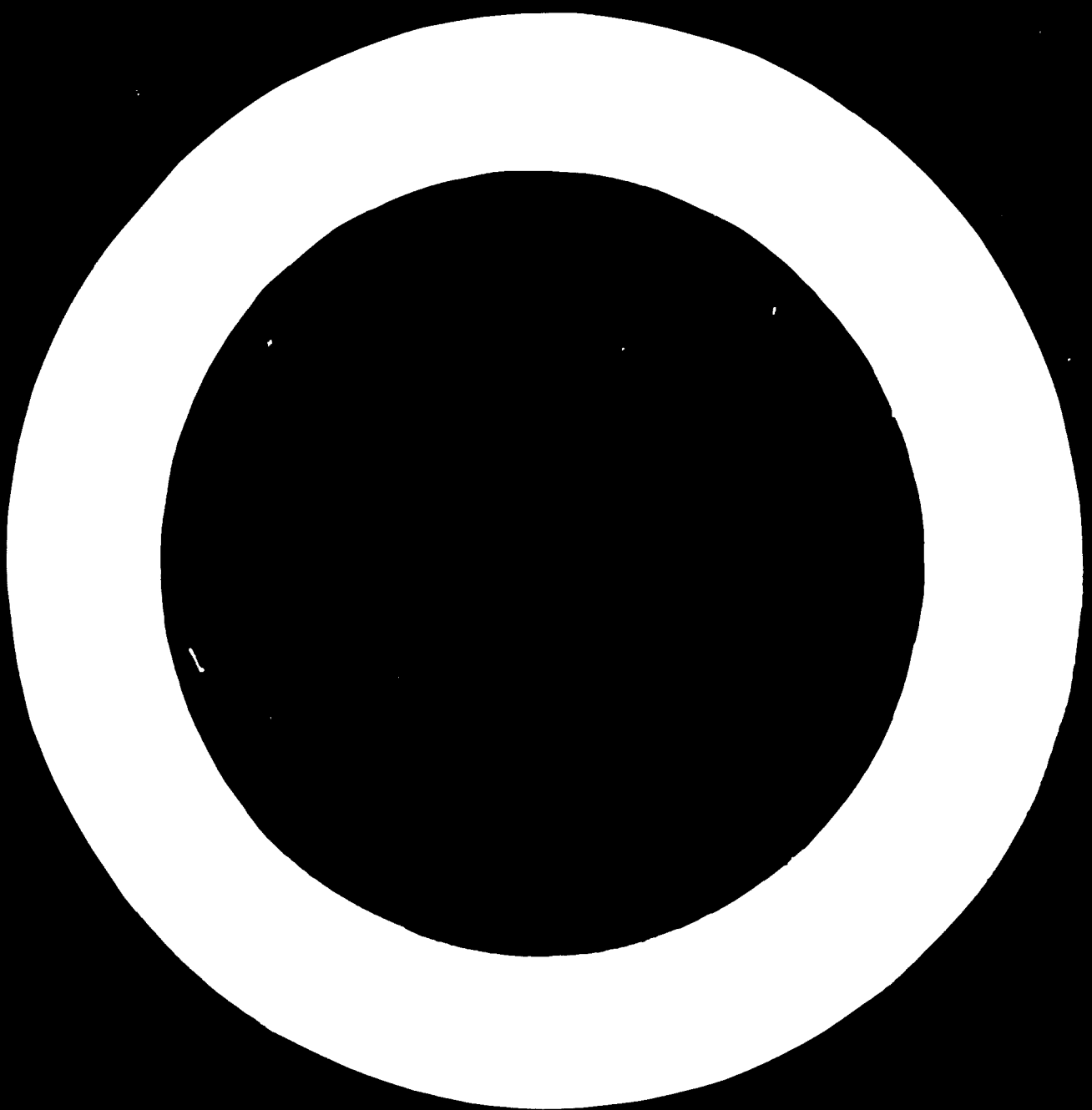

Nowadays many plastic materials are used as interior linings, such as imitiation leather, plastic covered textiles, plastic films, and to a very large extent, laminate boards.

Paper based decorative plastic laminate boards (in short decorative laminates or laminate boards) are manufactures, as the name suggests, from paper and plastic. Plastic impregnated papers are pressed at an elevated temperature under particularly high pressure (100 kp/cm^2, i.e. 1400 p.s.i.) between steel plates into a homogenous board. Decorative laminate contains two different types of plastic and three types of paper. The core part consists of a kraft paper and phenolic formaldehyde resin, and the visible surface part consist of decorative, printed or unicoloured paper and completely transparent overlay. Both of these papers have been impregnated with melamine formaldehyde resin, which is a hard clear substance highly resistant to heat. (Figure 1).

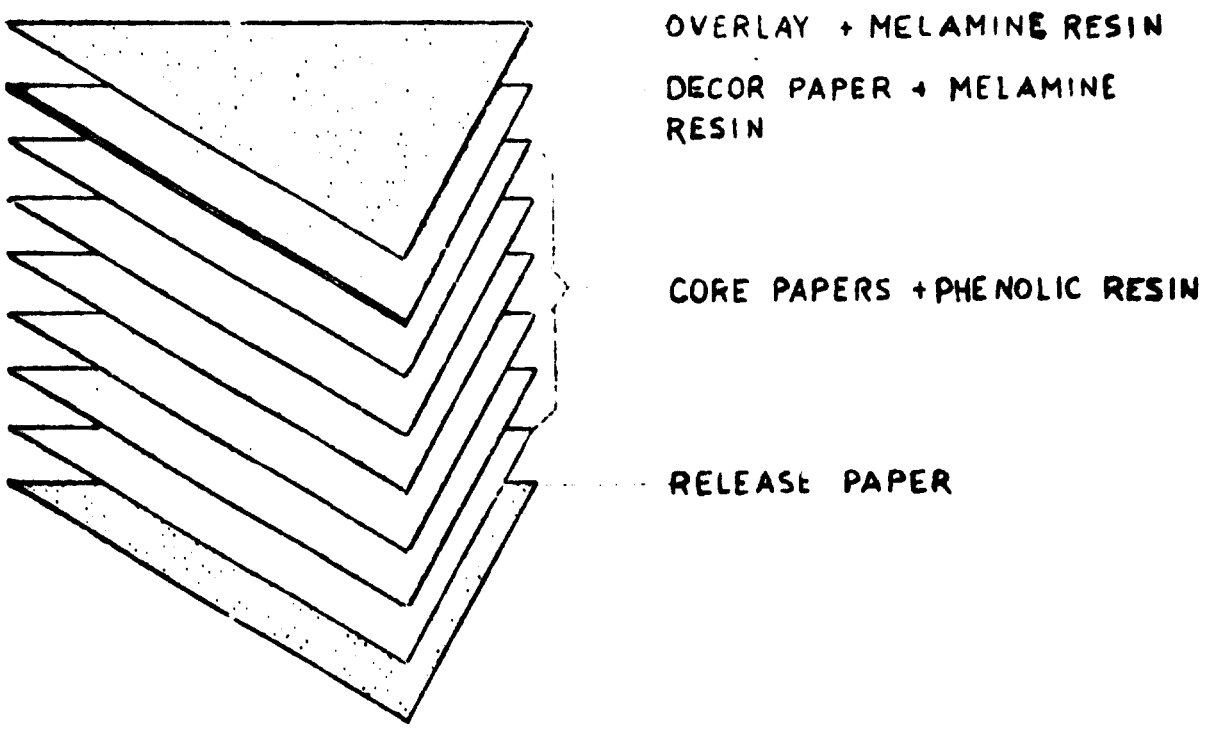

FIGURE 1. THE CONSTRUCTION OF LAMINATE BOARD

Decorative laminate boards with melamine resin surface have been industrially manufactured in several countries since the 1940's. The best known trade marks are Formica in Anglo-Saxon countries, Resopal in Western Germany, Perstorp in Sweden, and UKI-board in Finland, and several others in various countries. World production is over 200 million m^2 per year (2000 million sq. feet per year).

The main producer countries are the U.S.A., Italy, Japan, Western Germany, France, England, and Sweden. The largest factory units manufacture over 10 million m^2 a year, and the middle-sized units about 2 to 3 million m^2 a year. The minimum economic size of a laminate plant depends on local circumstances, but 1 million m^2 a year will in many cases be the smallest possible. This production is achieved by one machine line.

According to European statistics, decorative laminate is mostly used for kitchen furniture, about 42 per cent, for other furniture, about 35 per cent, for passenger transport vehicles, such as ships, buses and trains, 7 per cent, for doors and wall coverings, 12 per cent, and for other purposes, 4 per cent. The figures may vary noticeably in different countries, e.g. in Scandinavia, the proportion of vehicles has been 17 per cent. The most typical and oldest use of laminate is still for table tops in kitchens, shops, and cafés; the use has since been extended to vertical surfaces of kitchen cabinets, doors, bathrooms, hotel interiors, furniture and cabin walls of passenger ships, buses and trains. For example, about 50.000 m^2 of decorative laminate is needed for one de luxe cruiser. Decorative laminates have recently been introduced also for exterior wall coverings, but the experiences of their usability for this purpose are still insufficient. Great demands are made upon the resistance to light in these cases. Laminate for exterior walls has usually large patterns, and the thickness is about 3mm.

There are few modifications of laminate boards, of which three could be mentioned.

1. Postforming laminates
2. Fireproof laminates
3. Low pressure laminates, in other words, direct laminated chipboards.

In principle, postforming laminates are manufactured in the same way as ordinary laminates. The resin has been modified so that it is possible once more to soften it, and thus to bend the board two-dimensionally. As a result, curved corners can be made. For this, the user of the board must have equipment for heating the board up to 160°C, and bending it as desired.

Fireproof boards are used in ships. In these boards, certain substances have been added to the resin or paper, which prevent the board from burning. It is possible to make the board self-extinguishing, and unable to burn further. However, the laminate is charred to an extent depending on the circumstances of the fire. Direct laminated boards differ most from ordinary laminate. They are made by pressing decorative paper straight on the chipboard surface. Thus a pressure of only 15 kp/cm^2 can be used to avoid compressing the chipboard.

Direct laminated chipboard is used for inner surfaces of kitchen furniture, but not for table tops. It is of course, less durable than the actual laminate, but cheaper, because gluing is not needed at all, because lamination and "gluing" are carried out at the same stage. The use of laminate has continously increased in the whole world; in Western Europe the increase has been about 10 per cent a year. This is mainly because laminate makes it possible to obtain durable, beautiful and hygienic surfaces.

The appearance of laminate board depends on the decor paper and surface finish. As mentioned, the decorative paper may be decorative, printed or unicoloured. Printed patterns are divided into three main groups: woodgrain imitations, textile imitations and fantasy patterns. The printing cylinders are made by photogravure method; thus it is possible, for example, to make the woodgrain look genuine.

However, the diameter of the cylinder is usually only about 30 cm (1 foot), which means that the same pattern is repeated at spaces of one meter. The largest factories have their own printing machines and pattern collections, the middle-sized and small ones buy their printed papers from the same subcontractors. Thus exactly the same patterns are included in the collections of several different producers. It is also possible to buy sole rights for a certain cylinder and in this way

get an individual pattern in the collection.

Unicoloured decor papers are thoroughly coloured already in the paper machine of the paper factory. The result of this is that it is not worth while to manufacture very small quantities of some separately chosen colour.

Attemps must be made to explain - although it is very difficult - to architects that it is easier to harmonize the paints according to the laminate, than to find a laminate to match a certain shade of paint.

It is also possible to affect the appearance of the board by the surface finish, which is normally either glossy, semimatt or matt. Recently, the marketing of so called three-dimensional surfaces has been started. Perhaps the most popular of them is the woodgrain imitation with porous finish, which produces a surface more wood-like than before. The third dimension has also been employed in the textile imitations, in order to obtain textured surfaces.

If the decorative paper and overlay of the laminate are omitted, the product is called industrial laminate or technical laminate.

It is mainly used in machine parts, and in furniture, e.g. on the reverse side of table tops to give sufficient homogeneity to the construction.

By changing the amount of core paper in the laminate it is possible to vary the thickness considerably. As a curiosity, it is possible to make board of even 50 mm (2 inches) thickness. The thinnest qualities for sale are 0.5 mm. The most common thicknesses on the market are: 1.6, 1.4, 1.0, 0.8, and 0.7 mm. Generally, the manufacturers aim at thicknesses from 1.6 to 1.0 mm, because it is difficult to handle the thin qualities in large sheet sizes. They are inclined to break and crack, thus the result is no cheaper than if thicker boards were used. Boards between 1.6 and 1.0 mm are mainly used for horizontal surfaces and thin qualities (from 1.0 to 0.7 mm) for vertical surfaces. They do not require especially high resistance to abrasion, and the overlay can thus be omitted, especially when unicoloured boards are concerned. As a result, the hardness and simultaneous fragility of the board is decreased. The thickness tolerance is usually ± 10 per cent. The size of the boards varies considerably with different manufactures.

The length normally varies between 245 and 360 cm (8 feet and 12 feet), and the width between 125 and 245 cm (4feet and 6 feet); the usual dimensions are 125 x 245 cm (4' x 8') and 125 x 305 cm (4' x 10'). By far the most common width is between 122 and 127 cm, for two kitchen table widths can be obtained from it. Because the product is sold cut to certain sizes, and not for example in rolls, waste occurs both in longitudinal and transverse directions.

THE MOST COMMON TYPES OF LAMINATES AND THEIR PROPERTIES

Decorative laminate is very resistant to wear abrasion. Another important advantage is that it tolerates a temperature over 100 degrees Celsius (212°F). A kettle filled with boiling water can easily be placed on laminate board, and even a burning cigarette may remain on it for two minutes, without damaging the surface. These good properties are mainly due to the melamine resin which is hard and transparent. In boards for horizontal surfaces, this property is increased by an overlay with particularly high resin content.

Decorative laminate also has certain advantages because it contains three different materials: paper, phenolic resin, and melamine resin. All the substances have their own peculiar physical and chemical characteristics. When these materials are laminated, the core part and the surface behave in different ways. Variations in temperature and humidity cause tensions between the layers which may result in delamination and warping. The characteristics of the paper cause most of the negative effects, and because 60 per cent of the laminate consists of paper, the resins are unable to eliminate the effects completely. However, the paper fibres are able to absorb moisture from the air they expand, and in dry circumstances again give out water, and they shrink. The result of this is that the dimensions of the board change somewhat with the relative humidity of the air, i.e. when the laminate is kept in great humidity it expands, and in dry circumstances it shrinks (Figure 2). For example if the laminate is taken from cold and moist storage, glued on chipboard, and later kept in dry circumstances, it will shrink; however, when glued it only stretches and causes heavy tension. If the chipboard is not firmly fixed it will bend and in

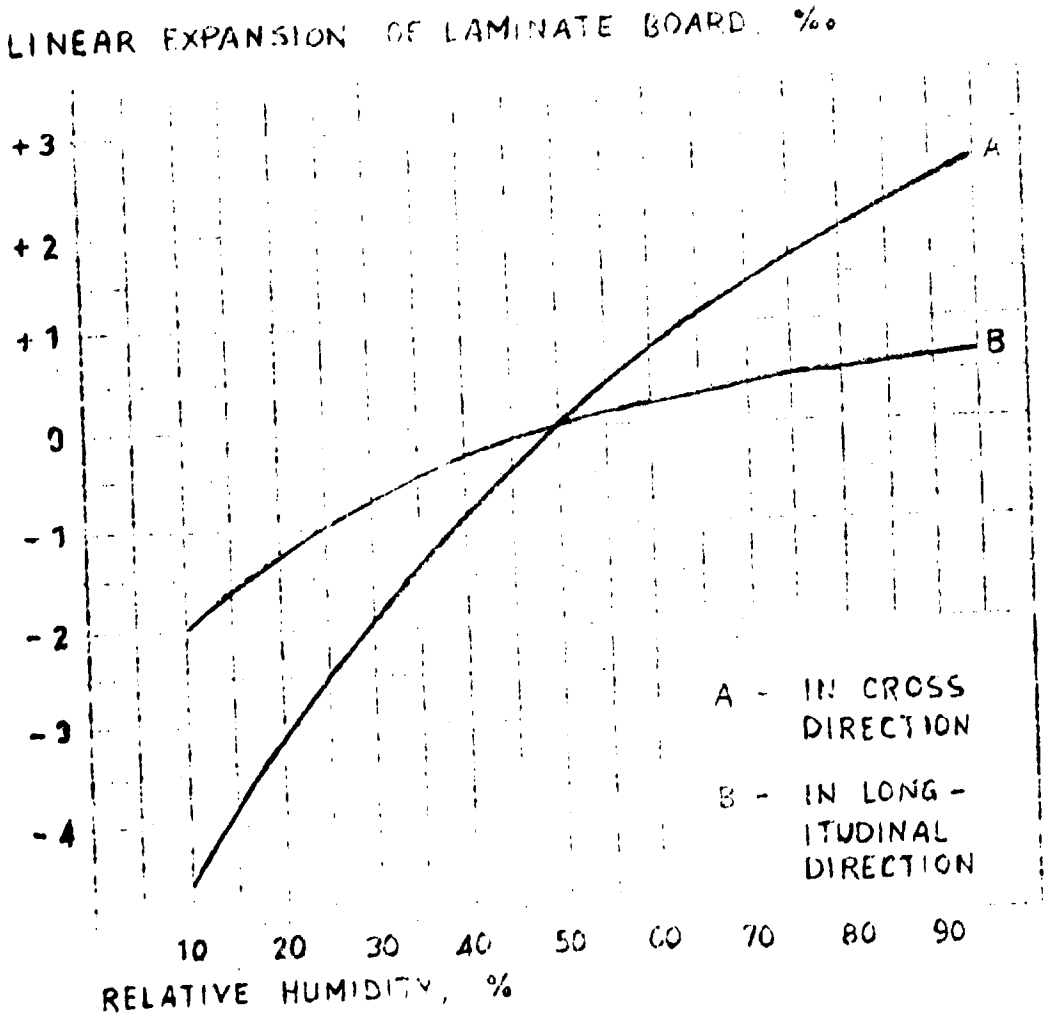

FIGURE 2. DIMENSIONAL STABILITY OF LAMINATE BOARD

extreme circumstances the laminate will crack. This danger is avoided by gluing the laminate in normal circumstances, not particularly moist or dry. The disadvantages are thus partly eliminated. Tha paper also causes the strength of the board, and the abovementioned dimensional stability, to be different in transverse and longitudinal directions. The paper fibres are more oriented in the longitudinal direction, the same characteristic is also apparent in the laminate. The result is that board swells and shrinks in the transverse direction more than in the longitudinal direction. Swelling from bone dry to tropical moist may be 0.8 per cent crosswise and 0.3 per cent in the longitudinal direction or the tension may correspond to this. The same difference also appears in tensile strength and modulus of elasticity, which are greater in the longitudinal than in the tranverse direction. Although paper causes the above disadvantage, it of course, on the other

hand, will reinforce the board. It is also very easy to print various imitation patterns on paper.

NEMA standards (National Electric Manufacturers' Association, N.Y.) are mostly used to control the quality of laminate boards. Some other standards could also be mentioned, such as DIN in Germany, British Standards, and SIS in Scandinavia.

Their code numbers and methods for measuring the most usual properties are given in table 1.

Most laminates is used for covering furniture or for covering walls which are exposed to wear and which easily get dirty, especially those in public buildings.

Normal decorative laminates with melamine surface are used for these purposes. In manufacture table tops e.g. so-called counterboard (a laminate board without melamine layer) has to be fixed under the table top. This prevents the warping of the board. These counterboards normally comprise about 30 per cent of the quantity of decorative laminates. If the board is long, and warping is fully prevented, both sides must have identical laminates with melamine surface glued to them. Finally so-called postforming laminates can be mentioned. These laminates can be bent to permanent form by warping the laminate board to about 135-140°C and bending it quickly against a mould. After the cooling of the laminate board the bending radius remains permanent. The postforming laminates generally comprise about 5-20 per cent of the total quantity of normal decorative laminates. The following technical characteristics can be considered as typical properties of decorative laminates:

Bending strength	in lengthwise direction	ca. 1800 kp/cm^2
Bending strength	in crosswise direction	ca. 1300 kp/cm^2
Tensile strength	in lengthwise direction	ca. 800 kp/cm^2
Tensile strength	in crosswise direction	ca. 600 kp/m^2
Modulus of elasticity	in lengthwise direction	ca. 143000 kp/cm^2
Modulus of elasticity	in crosswise direction	ca. 95000 kp/cm^2
Thermal expansion	in lengthwise direction	0.11 x 10^{-4}/°C
Thermal expansion	in crosswise direction	0.14 x 10^{-4}/°C
Heat conductivity	0.208 W/m°C s	

The mechanical characteristics of counterboards are a little bit lower for modulus of elasticity, but otherwise are of the same magnitude as the properties of decorative laminates.

Normal 1.0 - 1.4 mm laminates can be bent to a radius of about 30-40 cm without risk of damage in long-time use. When using so-called postforming laminates the best qualities can be bent to the radius of about 4-5 cm, but normally to a radius of about 10 cm.

Melamine plastics, so-called, are very resistant to all chemicals, and generally it can be said that the laminate surface resist all chemicals which are used in household, hospitals and institutions, with the exception of some easily staining organic colourants which may leave a spot difficult to clean on the surface.

MACHINING AND GLUING OF LAMINATES IN FURNITURE INDUSTRY

As a general rule, the majority of machines used in joinery production are suitable for the machining of laminate board. Nevertheless, for constant use it is advisable to provide machines with tungsten carbide bits, as their lasting sharpness improves the finishing of board edges, and speeds up the manufacturing process. When laminate boards are sawn into sizes corresponding to those of the base material the board must be placed against the saw blade so that it will cut the decor side first.

In factory processing, straight cuts are made by circular saws, and curved cuts by band-saws. (Figures 3 and 4).

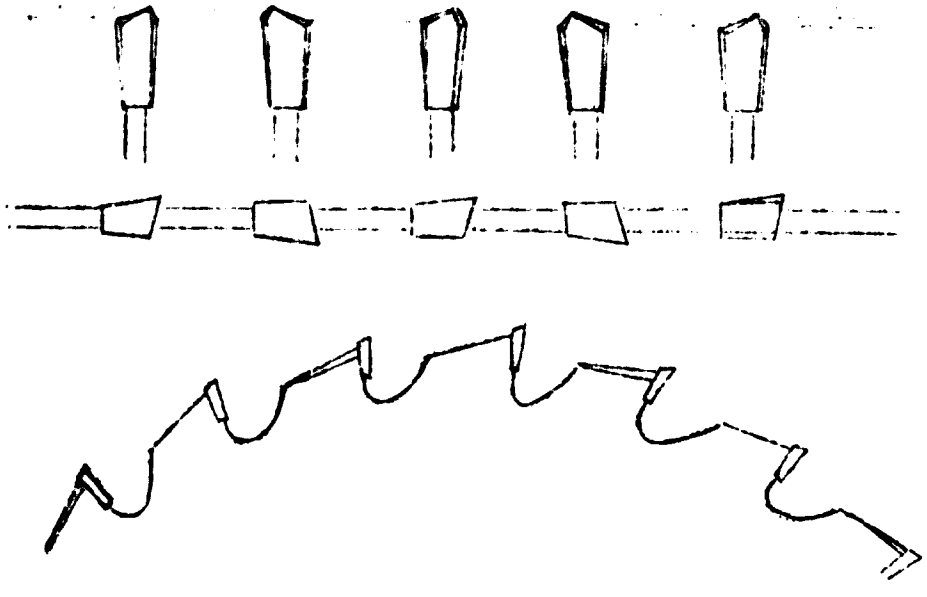

FIGURE 3. A CUTTING BLADE RECOMMENDED FOR CUTTING LAMINATE BOARD

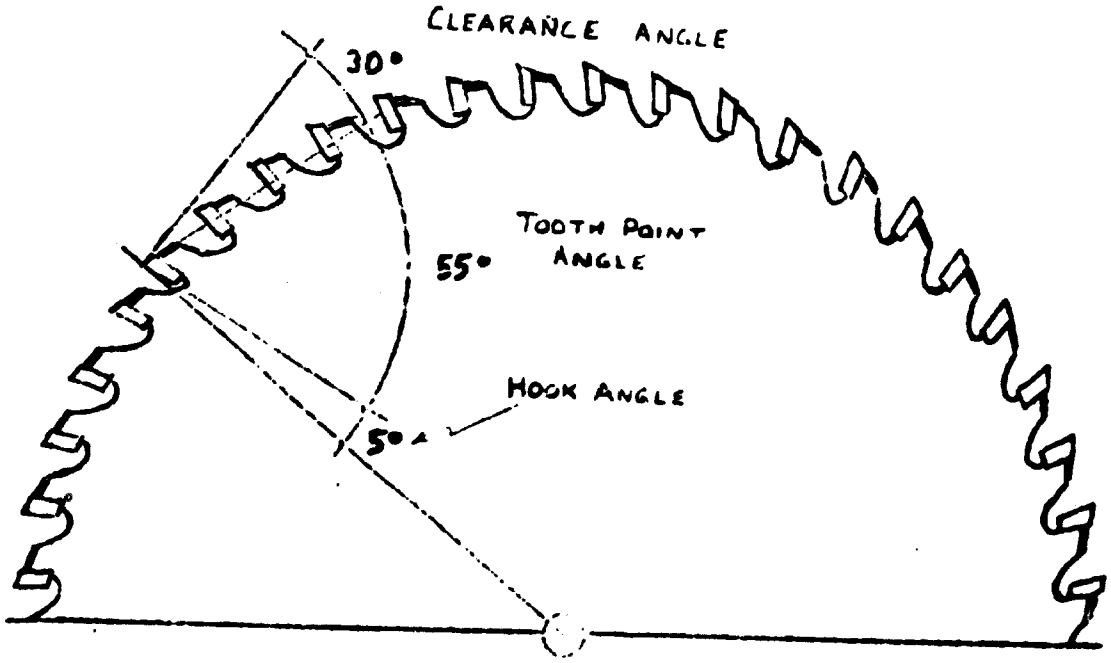

FIGURE 4. THE CHARACTERISTICS OF A CIRCULAR SAW BLADE FOR LAMINATES

The purpose of machining laminates before gluing is usually to cut them to suitable sizes for gluing and installation tungsten carbide bits with rim speed of 50 - 60 m/s are used for sawing, with a feed speed of 0.2 - 0.3 m/s. Laminate boards can also be cut in the same way as glass, by cutting up the decor side with a sharp cutting tip and by bending quickly towards a steep edge in which case the laminate breaks but the core part splits with about 0.2 mm tolerance. The above-mentioned method of working is much used when laminate boards are installed for coverings of walls with the help of installation strips to cover the edges. Often a normal guillotine is used for cutting laminate boards.

When the laminate is to be glued on to a base material, e.g. on chipboard, the finishing then usually must be final in order to avoid extra costs, and therefore a very good cutting edge is demanded. If a normal saw is available, laminate boards must be cut with 5-10 mm tolerance to the final size and then be planed to exact dimensions and a very good edge finish. A cutter with high revolutions (about 15000-18000 rpm), and a rim speed of ca. 80 m/s. should be used. In sawing the laminate board direct to the final size - the method followed

more and more nowadays, very fast tungsten carbide bits with quite closely spaced teeth should be used. The best tooth pitch is 10 - 12 mm. with a rim speed of up to 100 m/s. In this case one tooth cuts about 20 - 50 μm of the material.

When a decorative laminate is laminated on both sides of the core (e.g. particle board), and even finishing track is demanded on both the upper and the under side, the under side has to be opened with a separate blade before final sawing. This method is seen in Figure 5. When sawing several laminate boards at one time, 3 - 5 boards, only the undermost board need be opened, but then strong pressure has to be used to bind the boards firmly together during the sawing.

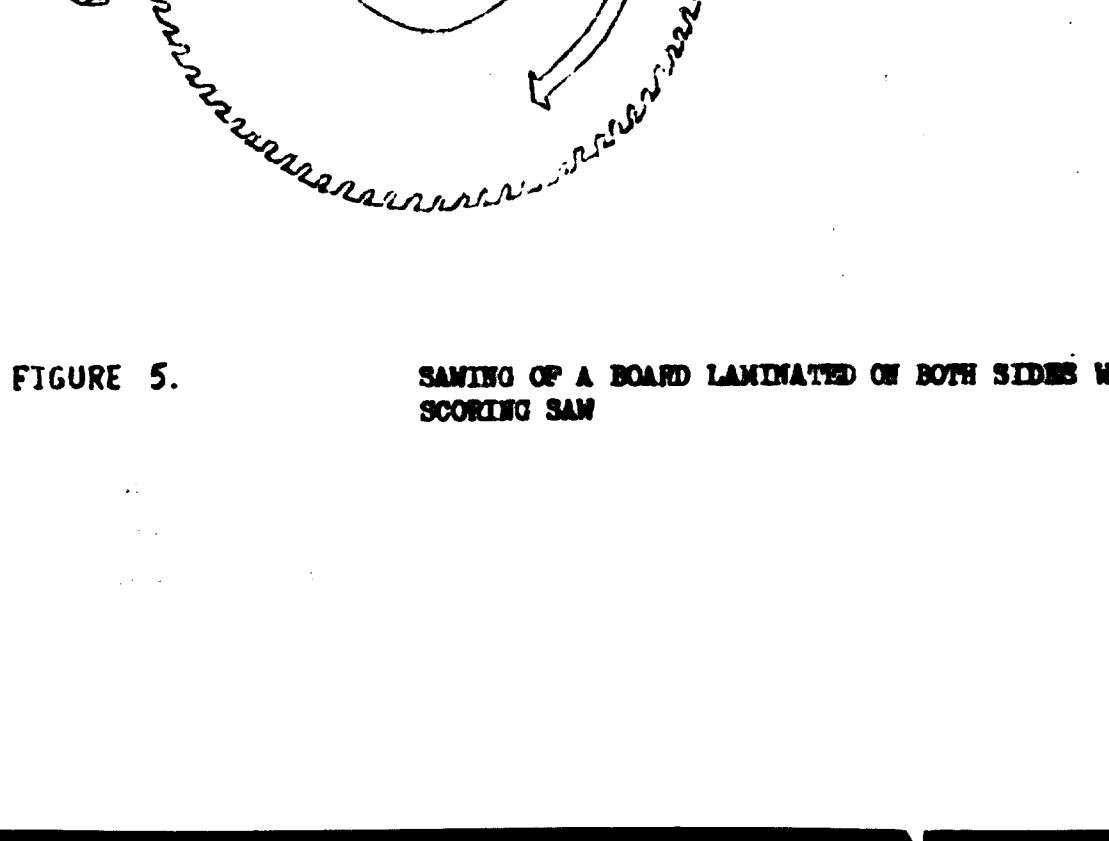

FIGURE 5. SAWING OF A BOARD LAMINATED ON BOTH SIDES WITH SCORING SAW

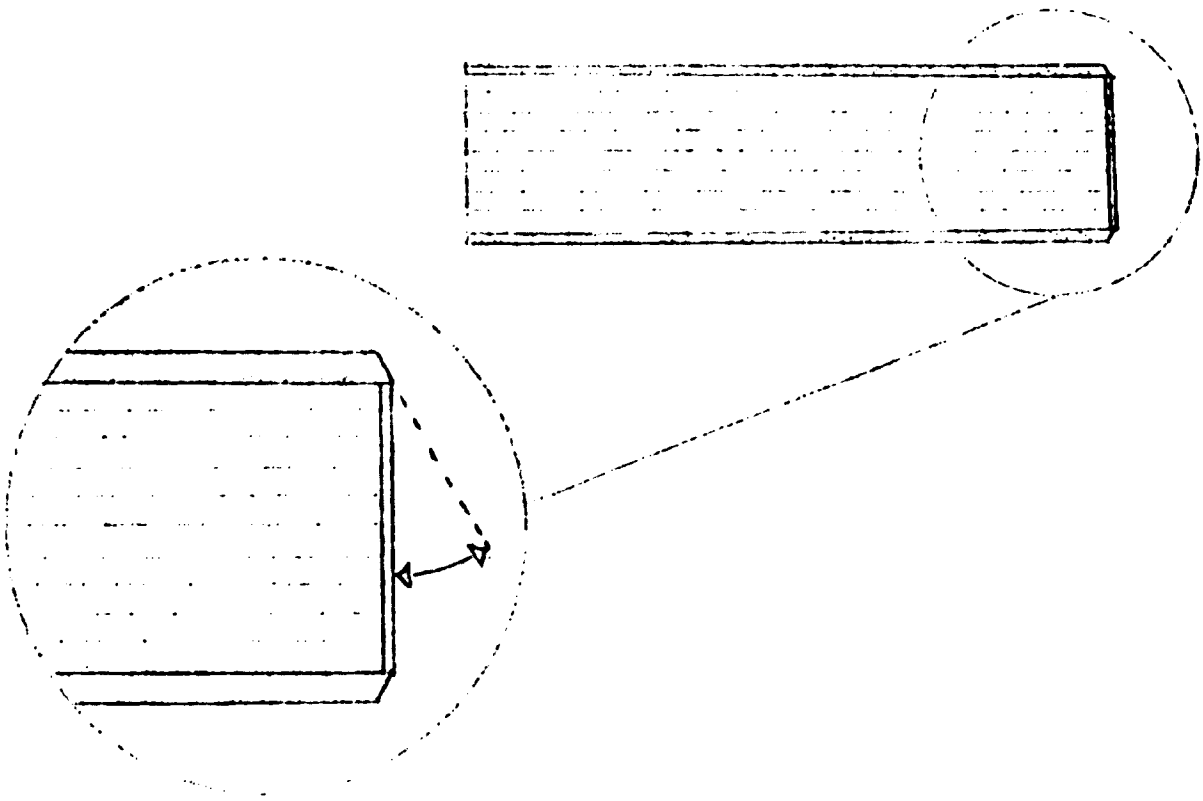

FIGURE 6. THE EDGES

THE EDGE OF LAMINATE BOARDS SHOULD ALWAYS BE MACHINED OR ROUNDED IN A MACHINE OR BY FILE

The edges of the boards are machined as in Figure 6 in order to avoid splitting. This is carried out either with a cutter or a file after the edging.

About 500 - 1000 rm[1/] of laminate boards can be cut with the present tungsten carbide bits before resharpening. In Figure 3 you can see the shape of a blade profile known to be very durable.

GLUING OF LAMINATES

Laminate board is fixed by gluing on the framework which is usually of wooden board, such as chipboard, block- or laminboard, plywood. Metal and stone base may also be considered (Figures 7 and 8).

There are general rules for the application of wood glues, such as urea glue, PVA, and those based on phenol, and in special cases, contact glues and hot-melting glues. The following rules can be applied depending upon both the particular circumstances and the available means for pressing.

1/ rm = running metre

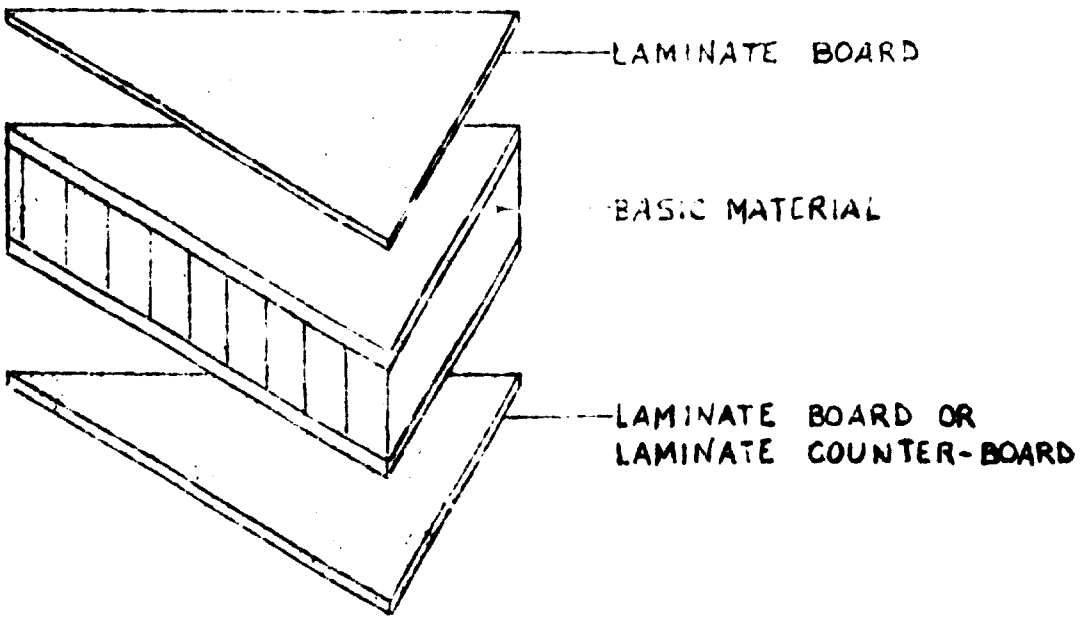

FIGURE 7. LAMINATE COUNTER-BOARD

WHEN PARTICLE OR BLOCKBOARD, PLYWOOD, DOOR FRAME STRUCTURES AND SIMILAR ITEMS ARE COVERED WITH LAMINATE BOARD, IT IS NECESSARY TO MAKE USE OF A COUNTER-BOARD.

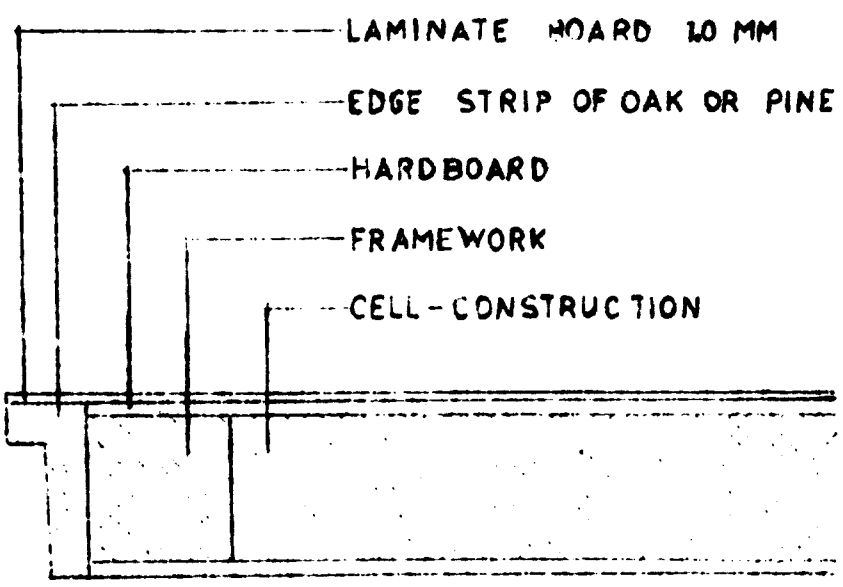

FIGURE 8. CROSS SECTION OF A DOOR.

1. Use PVA dispersion glue (cold cured) when good resistance to heat and moisture is not essential.
2. Use cold-curing glues if ample pressing capacity is available and there is no special need for moisture resistance.
3. Use hot-curing urea glues if the framework material is sufficiently sturdy to prelude the effects of tension resulting from thermal expansion. (30% PVA dispersion with urea glue.)
4. Use phenol and resorcine glues when special moisture resistance is required.
5. Use contact glues when a press is either not available or impractical to use.
6. Use epoxy glues or two-component-contact glue when laminate boards are to be fixed to metal surfaces.
7. Use hot-melting for edging table tops and other edged panels.

In any case, manufacturer's instructions should be observed during gluing.

The glue is generally spread on both sides of the core material at the same time e.g. chipboard, so that the amount of glue is about 120 - 140 g/m^2. On the even core material, as on a surfaced wood, a smaller amount of glue is enough. Rollers are used to spread the glue, the board being pushed between them. The amount of glue is regulated by adjusting the margin between the scrapers and rollers.

Chipboards, laminboards and fibreboards are considered as the best core materials for gluing. Plywood and wood are more difficult materials, because changes in moisture content on their surface causes unevenness.

After the glue spreading, laminates are placed on the core and set into the gluing press. As a rule up to 50 boards can be pressed at one time. Then, however, care should be taken that the compression strength is about 3 - 4 kp/cm^2 to compensate for warping etc. A sufficient pressing time is about 15 minutes. In this method, cold-curing PVA (polyvinyl-alcohol) or ureaformaldehyde glues are used.

When hot-curing glues are used, such as ureaformaldehyde or phenol glues, temperatures higher than 70°C are not recommended. Pressing time is generally about 5 - 15 minutes.

Suitable materials for edging strips are wood, metal or plastic.

Wood and plastic strips should be afixed by gluing. When metal strips are used, they should be firmly attached to the framework with screws set as closely together as is expedient (Figures 9 and 6).

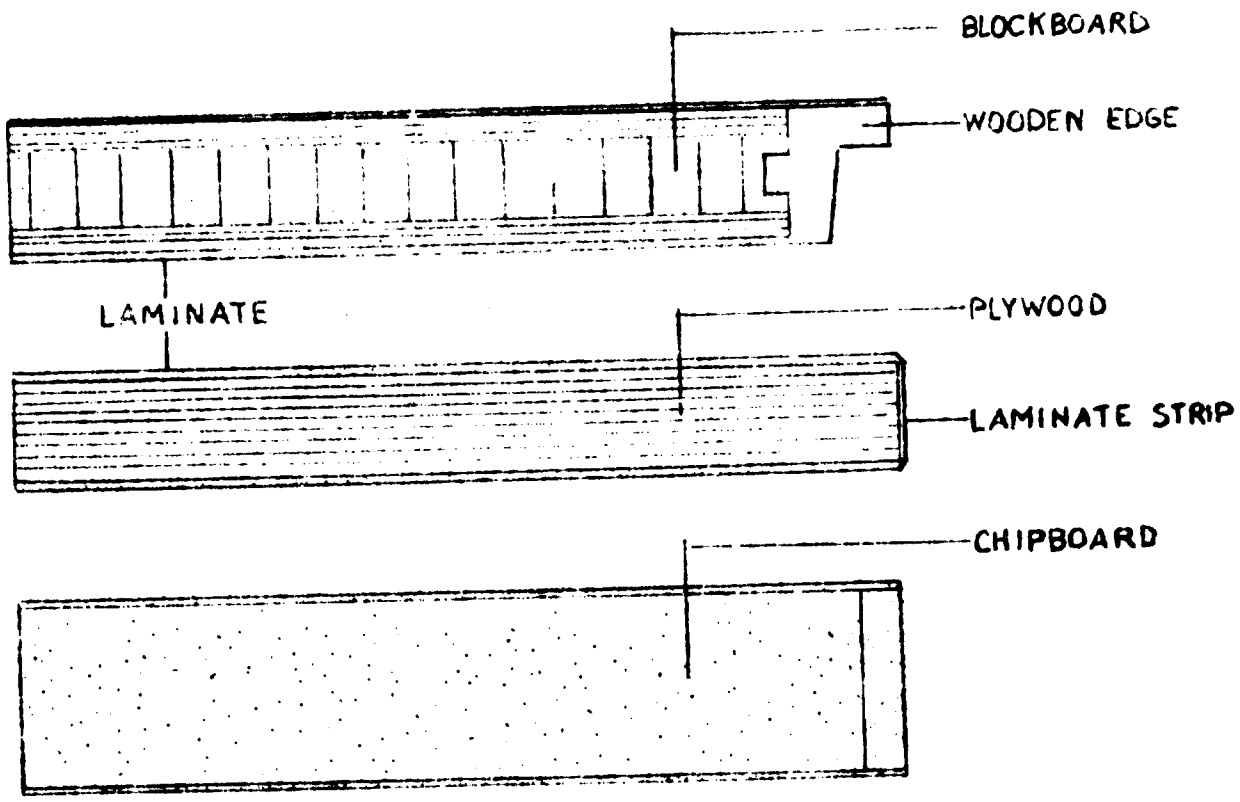

FIGURE 9. COREMATERIALS AND EDGE FORMS

Laminate board can be used as edging material simply by gluing it on the framework, and by rounding off or planing the joining edges.

On the vertical surfaces, laminate can also be attached with strips. Either link strips or capping strips, which may be of aluminium, plastic or wood, are used. In addition to strips, also elastic glue may be used in the middle part of the board. This installation method is used e.g. in kitchens for covering the wall between cupboards, in bathrooms and toilets, ships and trains.

In handling of laminates the most usual error is that care has not sufficiently been taken of the moisture content of laminates. In Figure 2 the dimensional changes of the laminate board can be seen as a function of the relative humidity of the air. If the laminate board is glued

when too moist on the core material, the board can split during drying. This depends on the fact that the core material cannot dry and shrink in the same way as the laminate, because the laminate is a good moisture barrier for the core material. It would be desirable for laminates to be kept for ca. 2 weeks at 50 per cent relative humidity or ca. 12 hours in a warm drying plant of 50°C where the relative humidity is quite low.

In the machining of laminates the most usual faults, characteristic of this material, are the splitting which begin from edges and holes. Therefore a small hole should always be drilled first at the corner before making acute openings. Similiarly, a wide hole ought to be drilled before fixing nails or screws to the board.

As a rule it can be said that laminates are recommended for use where surfaces of high quality which are highly resistant to wear and chemicals are desired, as for covering walls in kitchens hospitals, and public buildings, as well as theatres, schools, ships and busses.

Table 1. TESTING METHODS FOR DECORATIVE PLASTIC LAMINATE BOARDS

	NEMA	SIS	DIN	BS
Abrasion resistance	LD 1-2.01			
Resistance to boiling water	LD 1-2.02	R 70 50 02	53799	3794
Resistance to high temperature	LD 1-2.03	24 58 03	53799	
Resistance to burning cigarettes	LD 1-2.04	-	53799	
Stain resistance	LD 1-2.05	24 58 05	53799	
Resistance to light	LD 1-2.06	24 58 05	53799	
Wetting resistance	LD 1-2.07	24 58 01		2782
Dimensional stability	LD 1-2.08	24 58 06	53799	
Flexural strength	LD 1-2.09			3794
Modulus of elasticity	LD 1-2.09			3794
Deflection at rupture	LD 1-2.09			3794
Inspection for appearance	LD 1-2.10			3794
Tensile strength	LD 1-2.14		53455	
Impact strength	LD 1-2.15			
Scratch resistance by pencils	-	18 41 87		
Water vapour transmission	-		53122	
Thermal expansion	-			
Thermal conductivity	-			

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