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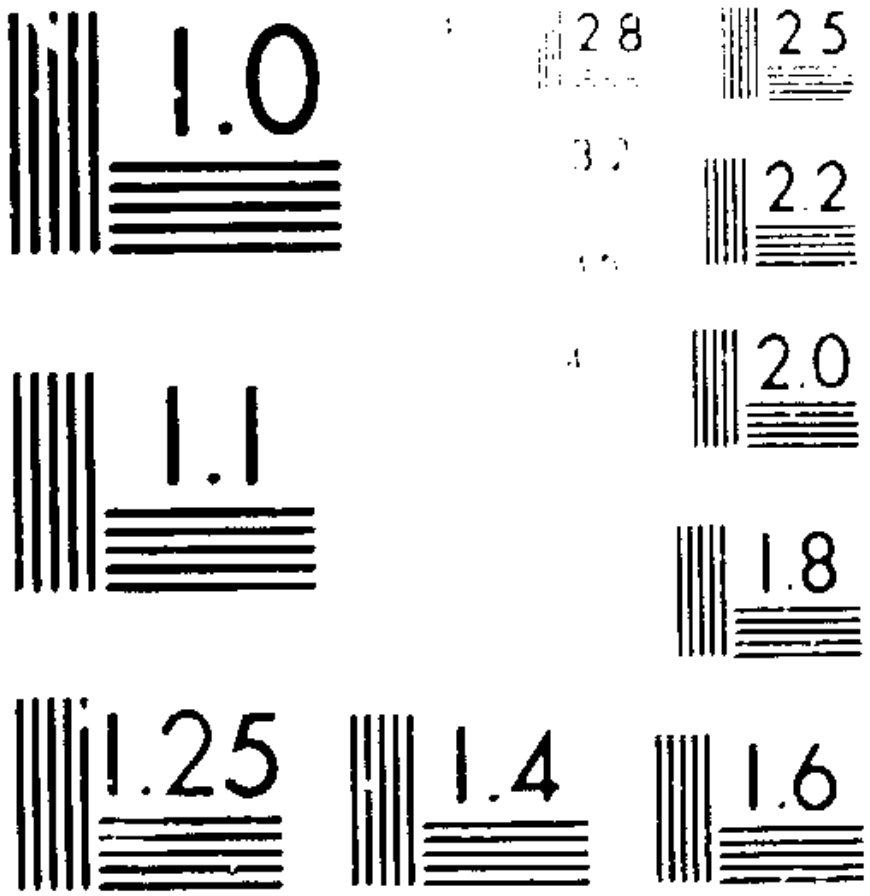
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United Nations Industrial Development Organization

Seminar on Wood Based Panels and Furniture Industries

Beijing, China, 20 March - 4 April 1981

DECORATIVE LAMINATES *

by

Xia Zhiyuan **

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DECORATIVE LAMINATES

Corrigendum

Page 7

After paragraph 1 insert table 2 printed overleaf.

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Table 2: Technical Properties of Various Types of Paper Used in the Production of Plastic Laminates.

(Reference is made to page 7 - Material of the Decorative Laminate, item "A").

Item	Unit	Overlay Paper	Ornamental Paper	Masking Paper	Base Paper
Material		Refined Wood Plup	Refined Wood or Cotton Pulp	Refined Wood or Cotton Pulp	Sulphate Wood Pulp
Dry Breakage Strength	mm	< 3500	< 2500	< 2500	< 5600
Whiteness	%	< 90	< 90	< 90	< 18
Water Absorption	mm/m	< 20	< 25	< 25	
Ash Content	%	> 1	< 15	< 15	
Moisture	%	> 7	> 7	> 7	> 7
pH Value		7 - 8	7 - 8	7 - 8	-
Dust Content	m^2	-	0.2 - 0.5 not exceeding 100	-	-
Paper Weight	g/m^2	21 - 32	120	120 - 90	80

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DECORATIVE LAMINATES

Corrigendum

Page 40, line 5 from bottom, right column

For 4500 tons read 2500 tons

Corrigendum 1

Page 2, table 2, water absorption entry

For mm/m read min.

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INTRODUCTION

Thermosetting paper decorative laminates hereafter referred to as decorative laminates save a modern decorative material in widely applied construction. This material has a smooth surface and bright-coloured lustre. Particularly, it is adaptable to many design conditions with its attractive printing patterns and many varieties of surface figures. In addition to its decorative value, it also has many valuable properties; it is wear-resistant, is chemically contamination-proof and has a good resistance to heat. Thus, it has been widely used in the production of furniture, different facilities, building construction, transportation equipment, etc.

Decorative laminates have developed rapidly in the period since World War II and it still maintains a relatively high rate of growth, meeting the demand of an ever-increasing scope of applications. According to the information available, the annual increase in production of decorative laminates is 12 to 15 per cent, and the percentage it occupies in the total production of laminated materials is ever-increasing, too. For instance, the production of decorative laminates in the United States has increased from 60 per cent in 1962 to 70 per cent in 1965 and to 85 per cent in 1969; in Japan, it has increased from 53 per cent in 1968 to 55 per cent in 1969; in Italy, the production of decorative laminates represented, in 1965, 85.5 per cent of the total laminates used. The world production of decorative laminates was 124 million square meters in 1964; 195 million square meters in 1968; 285 million square meters in 1972 and 420 million square meters in 1974 (see Fig. 1).

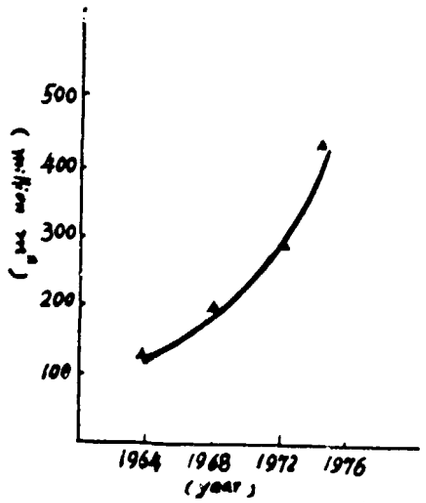


Fig. 1: World Production of Decorative laminates in 1964-1974.

Modern high pressure decorative laminates are mostly made of melamine-formaldehyde resin which is hard in texture, colorless, unaffected by light, wear-resistant, contamination-proof and resistant to cigarette burns. In western European countries, the melamine-formaldehyde resin used in the production of decorative laminates is about 40 per cent of the total production of melamine-formaldehyde resin, at the same time, while the average yearly increase of decorative laminate is 10 per cent, the yearly increase of melamine-formaldehyde resin required will be 13 per cent.

The main decorative laminate producing countries are: the United States of America, Italy, Japan, the Federal Republic of Germany, France and the United Kingdom; among which, the Federal Republic of Germany and Japan also export significant amounts of decorative laminates to other countries. Table 1 gives data on decorative laminate production of some principal countries.

Table 1.: Decorative laminate Production of Some Principal Countries in the world in 1972.

Country	Decorative Laminate Production	
	Total (in million m^2)	Per Capita (m^2)
Italy	80	1.75
Federal Republic of Germany	33	0.59
France	25	0.50
United Kingdom	18	0.33
Spain	14	0.41
Sweden	11	0.82
Austria	5	0.71

The earliest decorative laminates were made of phenol-formaldehyde resin, however, it lacked stability to light. It was therefore only used for the production of dark-coloured patterns with low contrasts. Later, colorless urea-formaldehyde resin came into being which can be used as a resin for surface decoration. When overlaid on the paper impregnated with phenol-formaldehyde resin, it possessed both good-looking lustre and

light-resistant capability. Though the thio-ureas made some improvements in the above-mentioned functions. their heat-resistance was barely enough to meet the requirements, the problem posed by them was not solved until the emergence of melamine-formaldehyde resin after 1930 (in the 1940s). This resin provides comprehensive functions which other resins do not have.

Other resins, such as polyester, particularly, diallyl phthalate (DAP) have already been used in the production of decorative laminates, however they have not yet been widely applied. Therefore, the discussion of decorative laminates in this study is limited to those which are made from melamine-formaldehyde resin.

Modern decorative laminate factories are comprehensive complexes of various types of facilities and technical processes comprising the following procedures: preparation of adhesives (phenol-formaldehyde and melamine resins), paper impregnating and drying, preparation of printing cylinders, printing pattern, polishing and hot-pressing of stainless bearing plate, post-processing of decorative laminates, etc.

The sizes of decorative laminate sheets are 3 x 7ft. (915 x 2135 mm), 4 x 8ft (1220 x 2440 mm) and also 5 x 12ft (1525 x 3660 mm) with thicknesses of 0.8 mm ($^1/_{32}$"), 1.6 mm $^1/_{16}$") or 2.0 mm ($^1/_{12}$"). There are many varieties in design and colour. There are several different levels of surface polish of decorative laminates: gloss finish (70 - 100 units), furniture finish (36 - 60 units), satin (15 - 34 units) and dull (2 - 5 units).

In the development of decorative laminate production, there is a trend toward lower pressures and a reduction in the thickness of the laminates. For instance, the demand of melamine resin for decorative laminate production in Japan increased 5 per cent in 1965, while the decorative laminate production increased 19 per cent. This could be achieved by reducing the thickness of the decorative laminate sheets. Extensive research work is being carried out on the increase of the plasticity of the melamine resin through its modification, the elimination of warping, the reduction of the pressing pressure, the manufacture of flexible and post-formed decorative panels. Attention has also been paid to the reduction of the combustability of decorative laminates.

The feature of the technical level of modern production is the high quality of products. This was achieved through high mechanization and automation of the production process.

Considering that the factors which play a decisive role in affecting the quality of decorative laminates are the quality of raw materials used, the facilities used and the technical standard of production reached. The conclusion which should be drawn is that the improvement of the quality of decorative laminates is a comprehensive issue which should be dealt with through joint participation of various industrial departments, including experts in the chemical, paper-making, printing, machinery and arts and crafts fields. Beyond all doubt, the tasks of improvement of quality and technical level confronting the producers of decorative laminates will, unceasingly, be solved.

II. Production of Decorative Laminates

Composition of the Decorative Laminate

A decorative laminate is composed of three parts: the surface, the decorative and the base layers. (Fig. 2). The surface alyer is a sheet of high quality cellulose paper impregnated with sufficient melamine resin, which is overlaid on top of the decorative paper mainly to form a wear-resistant layer to protect the decorative figures through its functions of resistance to contamination, wear, cigarette-fire and boiling water as well as to ordinary domestic solvents. The decorative layer is a sheet of high quality paper impregnated with dye-stuff, whose surface is processed with various designs through tri-colour chromatographic printing so as to display the effect of decorative laminates. The most welcome one among them is that which renders the true-to-life wood grains, though there are also designs imitating marble, leather and textile. Generally, the rotogravure press is used for printing figures. Screen printing, typography and even manual painting or drawing may however also be used to obtain special effects. The base layer is composed of several sheets of kraft paper whose main function is to act as a support to increase the strength of the decorative laminate.

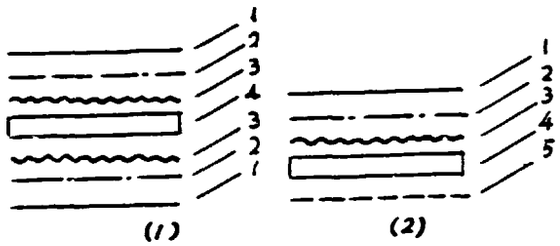


Fig. 2: Composition of the Decorative Laminate

(1) Composition of Double-face Decorative Laminate

(2) Composition of Single-face Decorative Laminate

1. Overlay Paper
2. Ornamental Paper
3. Masked Paper
4. Base Paper
5. Separating Paper

Varieties of Decorative Laminates

1.6mm ($^1/_{16}$") thick basic decorative laminate can be made into various types. Their principal types are:

(1) Decorative laminates of different thicknesses may be of either single-face or double-face decoration.

(2) The surface features of decorative laminates may be from high to low lustre and the surface can also be made into a suede, relief, fine or deep concave and convex grains.

(3) The base layer of decorative laminate can be a special sheet of paper and a plastified resin, thus, through heating, enabling the decorative lamiante to stick to the outline of the wall or follow closely the edge of the furniture after post-forming.

(4) The plain-coloured surface, without any pattern, which maintains the original function of decorative laminates, is also widely used.

(5) The surface layer may have metal chips incorporated into it to give an attractive effect.

(6) Small batches may be ordered by printing special patterns on decorative paper using the screen printing method.

(7) The surface layer may contain finely ground abrasive to increase greatly the wear-resistance for use under strictly required conditions, such as the counter in a dining hall or a special floor, etc. It can also be used with reduced thickness in places not requiring a high wear-resistance, such as walls or vertical surfaces of furniture etc.

(8) Special surfaces may be used on decorative laminates to make furniture in order to obtain a fine flexibility or even to make weather-proof outdoor products.

Material of the Decorative Laminate

There is a relatively strict requirement of products. If the material cannot meet these requirements, they would not be able to produce high-quality decorative laminates in spite of the use of the most modernized facilities and fully-developed techniques. Therefore, certain strict requirements of materials must be met, especially those concerning the purity and physical and chemical properties of the materials.

A) Paper

The paper used for the decorative laminates has two main functions: one is as a reinforced filler, to increase the mechanical strength of the decorative laminate and the other is to act as a carrier. The weight of paper represents approximately 65 per cent of the finished product of decorative laminates. The quality of the paper not only determines the quality of the decorative laminate, but also determines the productivity of the impregnating and the printing machines.

The technical properties of the paper vary with its different uses. The requirements of various types of paper are listed on the following page.

The original paper is divided into overlay paper, ornamental paper, masked paper and base paper. The technical properties of these various types of paper are shown as in Table 2 hereunder.

Overlay Paper

The principal function of the overlay paper is to protect the printed figure against external forces, mainly wear and chemical erosion. Of course, the application of overlay paper may also change or even improve the appearance of the patterns. Furthermore, the overlay paper also plays an important role in technology: it prevents the polishing steel plate against contamination by printing figures during pressing, as even the best quality colour will leave some traces on a mirror surface, particularly by a dark-coloured pattern. Such contamination may be cumulative and be transferred onto surfaces of products produced later, thus affecting their appearance.

The gram weight (per square meter) of the overlay paper affects the cost of the product. Due to the decrease of the paper weight, it is possible to reduce the risk of warping and the rpoduction costs. However, it also creates some problems, namely that the humidity must be maintained sufficiently high so as to assure an appropriate absorption of glue. The ash content, however, does not plav a role in this, since the absorption of glue is of particular importance, because if the ornamental paper absorbs 100 per cent of its weight of glue (calculated by the absolute dry weight of the paper), the overlay paper should, then, absorb 400 per cent its weight of glue. Hence it can be seen how important it is to identify the aeration, and the capillary and surface permeability of the overlay paper.

The weight per square meter of the overlay paper must be carefully selected. A paper that has a wieght of 35 - 45 g/m^2 is recommended for the product with strick plane surface requirements, and the 25 - 30 g/m^2 paper may be adopted for laminates used for the vertical surface and plane ones not subject to high abrasion.

Ornamental Paper

The ornamental paper has several functions which are closely interrelated, and they may affect the property of the finished products, impregnating technology and profitability. The required properties of the

ornamental paper are often contradictory: Namely an increase of one property may lead to the reduction of another, therefore, the co-ordination among the quality of the end product, the technological parameters and the cost is of great importance in choosing one of the properties.

The function of the ornamental paper first and foremost is to give the attractive aesthetic appearance of the decorative laminate and to maintain this appearance during the period of employment. Uniform colour and lustre, high artistic design, high light-resistance and stability during processing are all important factors to ensure a beautiful appearance.

The second important function of the ornamental paper is its capability of coverage. The ornamental paper should cover up the dark-coloured base paper impregnated with the reddish brown phenol-formaldehyde resin. The capability of coverage can be obtained by adding a proper amount of filler. Finally, the adhesive of the ornamental layer makes it become very brittle and the paper will make it stronger.

According to the development of the decorative laminate industry, the obvious tendency in the changes to the ornamental paper is mainly to reduce its thickness and weight while, at the same time maintain its capability of coverage. In this way, the quality of the end product can be improved, since the warping of decorative laminate is reduced while reducing the thickness of the ornamental layer; and though the cost of paper is increased, the cost per square meter is reduced, thus improving the competitiveness of this product. In addition, consumption of expensive adhesive is also reduced. The following figures will indicate this tendency: in the fifties the weight of ornamental paper used was 140-200g/m^2. it contained 10-15 per cent of filler (depending upon the colour), and two sheets were employed for almost all light-coloured paper. It was reduced to 130-160g/m^2 in the sixties and two sheets were employed for only extremely/light-colored paper. Today, the paper weight is further reduced to 80-130g/m^2 which contains 15-35 per cent filler, and two sheets of paper are employed (only for white laminate sheets). The employment of thin ornamental paper of high filler content is the trend of development, however, the minumum weight of paper per square meter is limited by the requirement of a particular wearability to maintain the ornamental layer.

Base Paper

The base paper is a special type of kraft paper. It is a kind of specially impregnated paper made from non-bleached or half-bleached sulphate pulp, which has several functions. It is impregnated with phenol-formaldehyde resin when used as the base layer of the decorative laminate. When decorative laminates are made into rolls, it is impregnated with polyester or diallyl phthalate. If it is used as the buffer or balance layer of the decorative laminate, then it is impregnated with amino or phenol-formaldehyde resin. The weight of this paper may be 80-200g/m^2, depending upon both the economic and technological factors. The weight presently considered to be the most suitable is 150-160 g/m^2. When the paper weight is increased to 200 g/m^2, it can hardly ensure good glue-absorption and uniform impregnation; while reducing the number of the paper layers, the physico-mechanical property of the decorative laminate may also be reduced. If the paper weight is reduced to 100-120 g/m^2, the number of impregnated paper sheets needs to increase greatly, thus, the productivity of the impregnating machine will drop. Although additives may be added into the paper to increase its wet strength, this is not generally done, for the fibre itself has already secured enough wet strength through impregnation. Sometimes, specially reinforced paper is used to achieve the forming of the decorative laminate.

B) Chemical Materials used in Decorative Laminates

Melamine

There are two approaches to produce melamine industrially. Before the sixties, most of the melamine was produced by the multi-stage power capacity method using calcium carbide as the raw material. However, the calcium carbide method has almost been replaced by the one-step method of producing melamine from urea. There are many different approaches in the technological process for producing melamine from urea. These have been classified into high (30-100 kg/cm^2) or low (1-10 kg/cm^2) pressure, with or without catalyst, in gaseous or liquid phase, etc. Some of these approaches may enable the cost of the melamine to drop and somewhat improve the quality.

The property of melamine is determined by its purity, which in turn affects greatly the property of the melamine resin, particularly when an impregnating composition without urea is employed. The impregnating solution must be a sufficiently stable one otherwise the plant (pipes and their accessories) will be plugged, or the paper may not be impregnated at all.

The technical properties of the melamine required are as follows:

Appearance	white fine crystallized powder
Melamine content	$\geq$ 99.5 %
Insoluble material in water	$\leq$ 0.06 %
Moisture	$\leq$ 0.5 %
Ash content	$\leq$ 0.03 %
Iron	$\leq$ 0.002%
Alkaline value	0.02 - 0.5 mgKOH/ g melamine

Formaldehyde

There are two processes for producing formaldehyde industrially: the methyl alcohol catalyzed oxidation process and the methane incomplete oxidation process. Most of the formaldehyde is produced by the first and comparatively old method, however, the second method is expected to develop in future because of its cheaper raw material.

The technical properties of formaldehyde required are as follows:

Appearance	white transparent liquid
Formaldehyde content	37.0 $\pm$ 0.5 %
Acid content	$\leq$ 0.04 %
Iron content	$\leq$ 0.0005 g/100ml

Five to eleven percent of methanol may be used as a stabilizer in the formaldehyde solution to prevent the generation of poly-formaldehyde.

Phenol

There are many different processes for producing phenol industrially, benzine, nevertheless, is the sole raw material used in all processes.

Under atmospheric temperature, pure phenol is white and crystalline with a particular odour, and it will turn into redish colour when it is kept in storage, particularly, under the effect of sunshine.

The technical properties of Phenol required are as follows:

Appearance	White or light-rosy crystalline
Crystallization temperature (C^{O})	$\geq$ 40.0
Phenol contents (%)	$\geq$ 98
Unvaporizable matter content(%)	$\leq$ 0.016
Solubility of phenol in 100 ml of water at 20°C (g)	$\leq$ 5

C) Synthetic Resin used in Decorative Laminates

Melamine-formaldehyde Resin

In the early thirties, the decorative laminate was made from impregnated urea-formaldehyde resin and thiourea-formaldehyde resin paper, but neither of them was widely employed because of their relatively low resistance to heat and water. The emergence and use of melamine-formaldehyde resin as an impregnating resin has brought about a significant improvement of the features of the decorative laminates and ensured the rapid development of the production. The malamine-formaldehyde resin is cured, through heating and pressing, to form a wear-resistant, water-tolerant and organic-solvent-resistant, transparent product. All these functions of the melamine-formaldehyde resin have made it a valuable material for producing decorative laminates. The characteristics of the surface of decorative laminate are heat-resistance, contamination-proof, cigarette-burn proof, resistance to wear, etc.

The technical properties of the Melamire Resin required are as follows:

Viscosity at 20° C	3 - 4 Engler degrees
Solid content	46 - 48 %
Free formaldehyde	$\leq$ 0.9 %

In addition, polyvinyl-alchol-modified melamine resin is also used to increase the tenacity and flexibility.

Phenol-formaldehyde resin

In order to increase the strength of the decorative panel and reduce the cost of production, phenol-formaldehyde resin is used for impregnating base paper. The following are very important considerations in the technical process of production of decorative laminates: Whether the phenol-formaldehyde resin can be fully cured or not under the selected pressing condition; whether the flowability of adhesives will generate spots or not; whether the phenol-formaldehyde resin will seep through the surface or not; and whether there is any stratification. If the phenol-formaldehyde resin is not entirely cured, it might result in poor stability of moisture-absorption of the decorative laminate, thus further decomposition of the product may occur and subsequently surface splitting, warping and other phenomena may result.

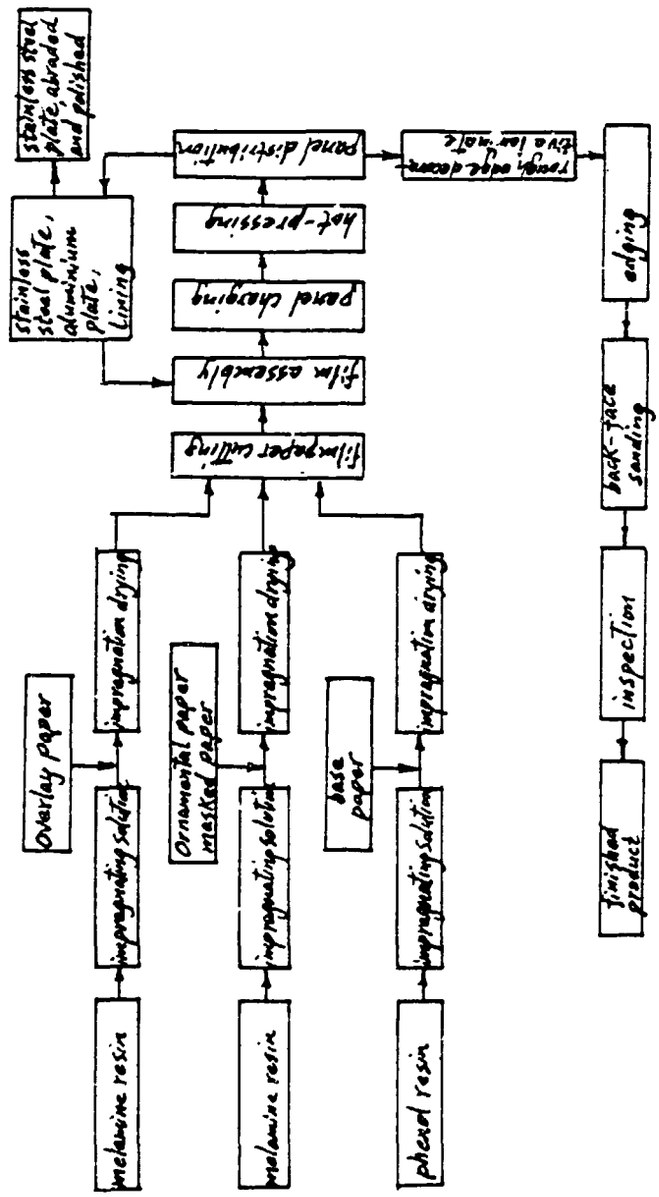
FQ-7 phenol-formaldehyde resin glue is employed for the decorative laminate production in China. This glue is of water-alchol mixed resin liquid condensed under low temperature and catalyzed by sodium hydroxide. The technical properties of the resin required are as follows:

Solid content	(%)	36 - 40
Viscosity (Engler degree)		6 - 9 at 20°C
Free phenol	(%)	2 - 4

The polyvinyl-alchol-modified phenol-formaldehyde resin impregnated paper is also sometimes used. The features of this GF-A resin are the increased tenacity and fine impregnatability of the resin, furthermore, there is also a reduction both of the free phenol content and the consumption of alcohol.

Figure 3 on the following page shows the process for the production of decorative laminates. The various stages are described and detailed.

Figure 3. Production process of melamine decorative laminates:



Impregnation

There are several methods of impregnation. One is to put the object to be impregnated into a water or organic solution of the resin, then remove the moisture or the solvent in the drying chamber; another method is to put the object to be impregnated into liquid or fused resin, in which it does not need to dry; the third method is to introduce directly the resin or its primary component during the preparation of the impregnated matter. The first method (that is, impregnating paper sheets with resin solution) is the one most widely used in producing these laminates. The method of impregnated paper sheets with fused and powder resin is seldom used. If the paper sheets were to be impregnated, the resin solution will not only seep into the pores among the fibres, but it will also seep into the fibres themselves. If the fibres are not well impregnated, this can be remedied through the use of high pressure and temperature, otherwise the quality of the product will be lower than that required. The extent of impregnating solution seepage into pores of the paper is determined by a series of factors. The most important ones are: the viscosity of the impregnating solution, the properties of the paper (water absorption capacity, density, etc.), the time the paper stayed in the impregnating solution, and the characteristics of the impregnation equipment. The diluted solution with low viscosity will easily seep into the pores of the paper, however, if the solution used is too diluted, the resin content of the paper will be too low and the energy consumption for drying will be increased. The water absorption capacity of the paper plays a decisive role in the impregnation process, therefore, it is one of its most important properties.

The retention time of the paper in the impregnating solution is determined by the speed of movement and the size of the impregnating tank. The most important thing during impregnation is that the air be removed from the paper as far as possible, since the air contained in the paper will hinder its proper impregnation when it is impregnated rapidly in the resin solution, thus, it will affect the uniformity and strength of the product. In order to remove the air, it is recommended that the paper should be put into the impregnating solution approximately parallel to the surface

of the solution, and the uniform distribution of the resin along the direction of the thickness is not considered as an ideal solution. If no overlay paper is employed, then, more resin must be applied on the front surface to form a top layer to protect the decorative laminate against abrasion. This can be achieved by utilizing properly designed and constructed impregnating facilities.

After the paper is impregnated with resin, it will be sent into the drier to pass through two processes: the physical porcess (vaporization of the solution) and the chemical process (to strengthen the condensation polymerization and solidification of the resin). The second process is the pre-curing of the resin. This is very important for producing laminates. Both the content of the solvable part and flowability of the resin are reduced during the process of solidification. In order to maintain the flowability, every effort must be made to keep the pre-curing at a minimum, however, if the resin will be cured through the dischsrge of vaporized matter generated by the condensation polymerization reaction, the material will have to be pressed after the component is vaporized, thus lower its physico-mechanical and ornamental features, result in a greater shrinkage and splitting, and reduce the lustre of the surface of the decorative laminate. Therefore, a certain degree of curing of the resin must be ensured during the drying process, and certain flowability must also be maintained. Consequently, the pre-curing should not be fully carried out and the resin should not lose its flowability, so that completely uniform resin film cannot be formed over the surface during pressing. The extent of condensation polymerization of the resin of the impregnated paper is the most important factor to determine the quality and appearance of the end product. The best set of conditions should be determined to ensure the co-ordination between the required flowability and the allowable amount of vaporized materials. This point is especially important for the amino resin, since the flowability of this resin is somewhat lower than that of the phenol-formaldehyde resin. The most effective method of improving the flowability of the amino-resin is its modification.

In order to produce high-quality products, attention must particularly be paid to the storage conditions of the impregnated film paper, especially

to ambient temperature and humidity. The room in which the film is kept paper must be ventilated. The recommended parameters are: temperature, 20-25°C; relative humidity, 35-45 per cent. The film paper or its stack may be covered with a polyvinyl film.

During the paper-impregnating process, attention should be mainly paid to provide such technological conditions as the temperature of the drying zone, the speed of paper movement, the steam pressure, the level, the temperature and the viscosity of resin solution in the impregnating tank, also the systematic control of the properties of the film paper itself.

All kinds of film paper must meet the requirements of the following quality properties: (Table 3)

Table 3: Property requirements for various types of film paper

Type of Film Paper	Resin Content (%)	Vaporization Content (%)
Overlay Paper		
for light-coloured ornamental paper	170 - 190	6.0 - 7.5
for dark-coloured ornamental paper	170 - 190	7.0 - 8.5
Ornamental paper	50 - 60	5.0 - 7.0
Masked paper	60 - 70	5.0 - 7.0
Base paper	38 - 45	7.0 - 9.0

Pressing

The technological process of pressing the decorative laminate comprises three steps: mould spreading, loading panels into the press and unloading panels from the press.

Mould spreading consists of making up the film paper into a group of paper assemblies according to pre-determined sequential order. The structure of the assembly varies with the production's conditions and requirements.

The most complete structure of a paper assembly is as follows: the overlay, the ornamental, the masking, the base and balancing paper. The structure of the mould spreading is shown in Figure 4 hereunder.

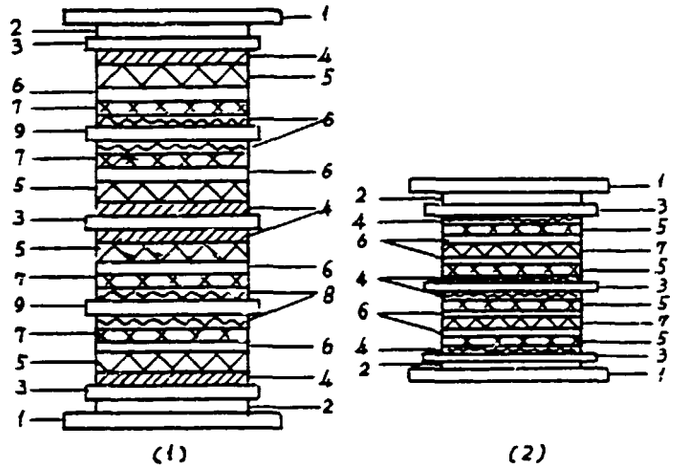


Fig. 4: Assembly preparation of the Decorative Laminate

(a) Spreading of the Single-face Decorative Laminate

1. aluminium plate
2. lining
3. aluminium plate
4. separating film paper
5. base film paper
6. masked film paper
7. ornamental film paper
8. overlay film paper
9. stainless steel plate

(b) Spreading of the Double-face Decorative Laminate

1. aluminium plate
2. lining
3. stainless steel plate
4. overlay film paper
5. ornamental film paper
6. masked film paper
7. base film paper

In spreading, the film paper must be checked to see if it meets the requirements with respect to the flowability, the resin and vaporization

contents, and all the film paper that has stuck together and is improperly sized, or with defects, fragments of resin, and refuse etc. are removed. Spreading is a very important operation, which has a decisive effect on the quality of the end products. Therefore, the work place where this spreading is done must always be kept neat and clean and well-lighted.

In China the spreading of the film paper in the decorative laminate production is still a manual operation. This is because on the one hand, strict control of the quality of each sheet of the film paper is required before inserting the paper assemblies in the press; and on the other hand, it is also due to the complicated technical problems which remain to be solved if the operation were to be mechanized. Since several different film papers are to be taken up, particularly, the very brittle overlay film paper, the operation can hardly be mechanized without damaging some of the film paper. In order to solve this problem, we have developed a kind of decorative laminate without overlay paper. This kind of decorative laminate has the same quality as the similar current product. In this way, favourable conditions are created for the mechanization of the spreading. It can be expected that the operation will be mechanized in the not too distant future.

One of the current methods for mechanized spreading is shown in Figure 5 hereunder.

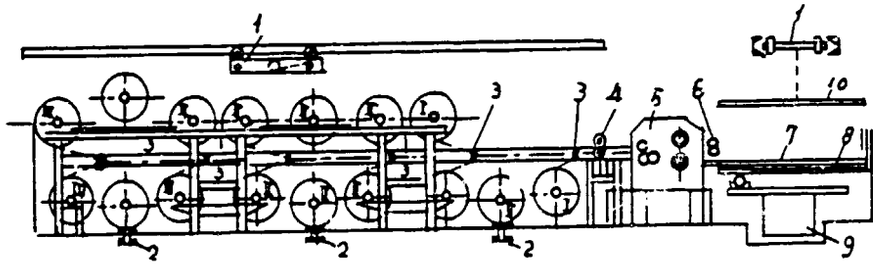


Fig 5.: Schematic Diagram of Mechanized Spreading

I. ornamental paper II. base paper III. balancing paper IV. separating paper (1) gantry crane (2) trolley (3) paper-clamping roller (4) tractive roller (5) paper-cutting device (6) paper-pulling roller (7) paper-supporting rack (8) trolley (9) hydraulic elevator (10) empty paper-supporting rack

Pressing the moulds is done at both high pressures and temperatures. Under the effect of the high temperature, the resin in the film paper melts and seeps more deeply into the paper; at the same time, the melamine resin on the overlay paper flows uniformly over the surface of the material to form a layer of glossy transparent film. Then the resin is finally cured under the high temperature and pressure, and the paper is fused into a compact decorative laminate.

A low resin content of the film paper leads to the reduction of the adhesive strength, and possibly the separation of the layers of the decorative laminate. The higher the resin content is, the quicker the cover-up of the surface of the decorative laminate with resin film and the better the quality of the surface will be. However, if the resin content is too high, the brittleness of the material will increase and the surface will likely be subject to cracking. The separation of the layers of the decorative laminate is possibly related to the over-cure of the resin during its drying in the drier. A high vaporization content will possibly cause blisters and also form moisture figures. There are many variables affecting the quality of the product during the process of pressing; the six principal ones are: the resin and vaporization contents of the film paper, the flowability, and the temperature, pressure and time of pressing. The first three factors are due to the properties of the film paper, while the last three determine the technological parameters of the pressing.

The pressing temperature is variable. After the panel assemblies are put into the press, the hot-press platens are closed to reach the required pressure and temperature in a certain time, and finally it is cooled. The temperature during pressing is mainly determined by the type of resin used: the temperature for phenol-formaldehyde resin is 155 - 165° C, and that for melamine resin is 145 - 155° C. The melamine decorative laminate is pressed at 145 - 150° C, however, if the melamine urea resin is used, the pressing temperature should be 135 - 140° C. The pressing time and the pressure required are mainly determined by the pressing temperature.

With the increase in the pressing temperature to a certain extent, the pressing time will be reduced, thus the physico-mechanical properties of the product will be improved. Nevertheless, if the intial heating temperature

chosen is too high, the resin will be cured very quickly, thus it won't be able to fill up the pores of the paper in time, resulting in the product not having the required compactness and good properties. One of the most common defects is the so called insufficient pressing, i.e. dark spots are formed on the glossy surface of the decorative laminate, and this is quite important for decorative laminates. This is because the resin has already begun to cure before the resin flowing along the panel surface is completed and part of the panel surface is not yet covered with resin film. This phenomenon often becomes even more serious due to the nonuniform heating of the pressing platens, since the part where the steam enters is heated first and then heat gradually reaches the centre of the platens, this causes insufficient pressing along the edge.

In order to eliminate insufficient pressing, the flowing of the resin film must take place before it cures. The flowing of the resin is determined by the extent and uniformity of the pressure and the rate of increase of the temperature. In order to ensure the sufficient and uniform melting and flowing of the resin on the panel surface, the material should be gradually heated to the pressing temperature and maintained for no less than 15 to 25 minutes. In selecting the proper pressure, it must be borne in mind that the greater the pressure, the higher then will be the compactness of the decorative laminate and its mechanical strength. Moreover, the flowability of the resin will be increased under high pressure, which makes it possible to use film paper with a low vaporization content, thus produce a decorative laminate with fine surface, small shrinkage, high wear-resistance and scratch-proof functions. Because of the internal pressure exerted by the by-products discharged from the vaporizing matter in the film paper and the cure of the resin, blisters and separation of the layers may appear in the material, therefore, the minimum pressure must always be maintained in the hot press, and the decorative laminates are mostly pressed at a pressure greater than 70 kg/cm^2 and in very few occasions at 100 to 120 kg/cm^2.

The material placed between the two hot press platens is not heated uniformly both along its surface and thickness. The pressing time is determined by the curing speed of the resin and also by that of the heating of the material. Considering that the heating speed of the inside layer

of the material is rather slow due to poor conduction of heat of the film. The pressing time is principally related to the thickness of the pressed material. Though the productivity can be raised through increasing the thickness of the pressed material, attention must be paid to the fact that the quality of decorative lamiantes may likely be reduced due to the lowering or varying of the pressing temperature. If the pressing time is too short, the decorative laminate will likely be subjected to warping, insufficient hardness, and increased moisture abosrption. For the same reason, the time of heating should not be too long, since this will cause the decomposition of the material and the reduction of its physico-mechanical properties.

The most common defects of decorative laminates due to one or the other deviation or mistake of the production operations are as follows:

(1) Warping: The cause of this comparatively common defect is that the homogeneity of the decorative laminate and its cooling under pressure are both insufficient. Most of the warping is the result of the differential expansion and shrinkage of the decorative laminate through the change of moisture of its melamine and phenol-formaldehyde resins. Because warping is a serious and common defect of the decorative laminate, the measures to eliminate it will be discussed separately.

(2) Glue-seepage of phenol-formaldehyde resin on the surface of decorative laminate: The seepage of phenol-formaldehyde resin to the surface of the laminate is probably related to a high resin content and flowability, or the low malamine resin content of the ornamental layer or insufficient covering capability of the ornamental paper.

(3) Panel sticking: Generally, it is due to incomplete curing of the melamine resin which is probably related to low pressing temperature and insufficient pressing time in the press. Repetitive sticking of the panel at the same place may indicate that the pipes in the heating plate of the press may be obstructed.

(4) Insufficient-pressing: "White flower" (dark spots on the glossy surface, no resin-film coverage, etc.) is a defect probably caused by low resin content and insufficient flowability and by the resin beginning to cure before it reaches the required flowability because the heating

of the press is too fast. One of its causes is probably a low pressing pressure, because the flowability of resin under such circumstances may not be sufficient.

(5) Insufficient lustre: The defect is probably caused by different reasons, such as high vaporization content of the film paper, low resin content, release of pressure when the temperature is too high during the cooling process, or using poorly polished cauls.

The feeding of assemblies into the hot press and their unloading from the press are either fully automatic or semi-automatic operations.

Continuous Pressing

The well known defects of the method of pressing described above are the periodic heating and cooling required, employing a great number of expensive stainless steel plates, the long pressing cycle, etc. This is the reason why the continuous production method must be studied and developed. The main difficulties that remain to be solved are the high pressure required and the long time for the complete cure of the resin. Research work conducted so far in the field of producing decorative laminates with melamine and phenol-formaldehyde resins is still in the laboratory stage and actual industrial production has not yet been achieved.

Post Processing

As the decorative laminates are unloaded from the hot press, those with broken and unpressed edges and edges not at right angles should be trimmed according to the required dimensions, and their backs should be sanded to give a rough surface needed to assure easy bonding to the underlaying panel on which they are applied. After inspection, grading, storing and packing, the decorative laminates are transported to the consumers.

Edging

In order to cut off the broken edge, longitudinal and transverse edgers are used concurrently. The main cutting tool is a 300 to 400 mm diameter circular saw blade operating at 3,000 to 4,000 r.p.m. Since this saw blade is very noisy, hobs and multi-cutter heads in which each cutter sequentially

cuts a certain depth on the decorative laminate have been developed. The rotary cutters are used for more precise and higher quality edging. There are both advantages and disadvantages to each method. Shears are also used to cut decorative laminates less than 2mm thick.

Sanding

Since the decorative laminate is a kind of ornamental structure material with insufficient rigidity, when employed, it is generally bonded to an underlaying panel having a certain strength so as to produce a kind of decorative laminate with the required performance, economic construction, and higher value than the basic material. After pressing, the decorative laminate has a glossy back surface which hinders its subsequent bonding. In order to improve the bonding strength, the back surface must be sanded into a rough surface which will increase the area of contact, thus improving the bonding strength.

The back surface of the decorative laminate is generally roughened on a three roller sander, whose abrasive varies between No. 30 and No. 60, the more appropriate being the No. 60.

Technical Properties and Function of Decorative Laminates

The improvement of the quality of the products and new varieties for special uses and functions, (such as the post-forming decorative laminates, curved decorative laminates, fire-resistant decorative laminates, polyester decorative laminates for edge bonding, etc.) have appeared with the rapid development of the production of decorative laminates. The currently effective standards can never reflect all new products. Decorative laminates are normally divided into several most common kinds by the general technical standards, which do not consider certain new types. Some of these standards only refer to one of the most common decorative laminates, i.e. the ordinary decorative laminate made with phenol-formaldehyde resin for the basic layer and amino-resin for the ornamental layer. A general description of the technical properties and functions of this type of decorative laminate is given hereunder:

(1) Classification: Decorative laminates are divided into four kinds by the American standards: decorative laminates for general use,

vertical surface finish, post-forming, and fibreboard as the base board. In Great Britain, they are divided into two kinds: one is the single-face decorative panel 1.5 mm thick, and the other is the double-face decorative laminate 3.0 mm thick. In France, they are also divided into two kinds: that for general use and the cigarette-burn-proof type. In the Federal Republic of Germany, besides the general use type, fire-resistant and after-shaping decorative laminates and the cigarette-burn-proof decorative laminates are also produced. In China, the standard divides decorative laminates into two grades by quality, i.e. Grade I and Grade II.

In the Soviet Union, three grades of decorative laminates are produced, classified according to physico-mechanical properties and surface quality requirements. To a certain extent, this classification is also related to the scope of application. Top class decorative laminates are used mainly for plane surfaces. They are applied where high wear-resistance is called for. The second class is applied to planes and vertical surfaces with lower requirements; while the third class is used as a material for repairs.

(2) Thickness and size: The most common thickness of decorative laminate used in the world is 1.3 to 1.5 mm. The range of thickness for the decorative laminate production according to the standard of the Federal Republic of Germany is 1.3 to 5.0 mm. It recommends that decorative laminates with smaller thicknesses, such as 1 mm, should be used for vertical surfaces and those 0.5 mm thick should be used for edge banding of furniture. The tolerance permitted in the thickness of decorative laminates is $\pm$ 6 - 10 per cent.

In China, there are two thicknesses for decorative laminates: 0.8 and 1.0 mm with a tolerance of $\pm$ 0.1 mm. The size of the decorative laminate is determined by the specification of the press used. Normally the length varies from 925 to 2,450 mm, and the width varies between 925 and 1,230 mm. The tolerance permitted is $\pm$ 5 mm in either direction.

(3) Right Angle Tolerance: The right angle tolerance of decorative laminate is determined by the accuracy of the edging machine used. The right

angle tolerance of decorative laminate should not exceed 6 mm when the length is over 1, 840 mm.

(4) Split-proof: The internal stress generated by the vaporization of the moisture contained in the decorative laminates under high temperature and low humidity may cause splitting of the material. Splitting is likely to occur if the decorative laminates with higher moisture content is bonded on a rigid underlay and if they are stored or used at high ambient moisture conditions.

This is tested as follows: a sample of size 120 x 50 mm, is placed in the splitting clamp and tightened. It is dried for 6 hours at a temperature of $80^{\circ} \pm 1^{\circ}C$, then taken out and put into the drier to cool to ambient temperature. Its surface is then observed to detect any blisters or splitting etc.

(5) Resistance to boiling water: Three test samples of 50 x 50 mm are put into the drier for 24 hours at the ambient temperature, then boiled for 2 hours. The surface is then wiped and their weight and thickness is measured. The increment of weight and thickness should be less than 10 per cent. The samples are observed to detect any blisters on the surface, separation of the layer, splitting, etc.

(6) Resistance to dry heat: The dry heat resistant test is conducted on a 200 x 200 mm sample which is heated for twenty minutes under a tank containing oil at 180° C. The oil tank is then removed and the sample is kept at ambient temperature for half an hour to observe if any blisters or splitting, etc. have developed.

(7) Wear-Resistance: The experiment is conducted on a Taber tester for 500 turns of wear-and-tear test under a load of 500 g. It is an inspection of the wearability of the product when applied to plane surface.

The research on the effect of the technological factors on decorative laminates proves that the effect of the pressure and temperature of the pressing is smaller than that of the resin content and its cure. The vaporization content of the film paper and the flowability of the resin have substantial effect also.

(8) Shock-resistance: The high surface hardness of melamine resin decorative laminates causes brittleness of the ornamental layer. This feature of the decorative laminates can be tested by the following method: One decorative laminate test sample of 200 x 200 mm is placed on the falling ball tester and tightly clamped in it. A steel ball (40 mm in diameter and 260 g in weight) is allowed to fall freely from a height of 1.75 m on to the surface of the sample which is then removed and checked for cracking and splitting of the surface.

(9) Contamination-proof: The surface of two sample pieces, 200 x 200 mm, are wiped with ethyl alcohol and let dry. Two drops of test solution are applied on each of the two samples with a small dropper and separated under glass carriers. The glass carriers are removed after 6 hours, the surface is washed with running water, wiped with ethyl alchol and dried to observe if there is any contamination, erosion, or traces on the surface where the solution was applied.

The test solutions employed are: vinegar, vegetable oil, red ink, blue ink, black ink, mercurochrome, gentian, iodine, strong tea, 10 per cent sulphuric acid, and 20 per cent caustic soda.

The test materials vary with the characteristics and customs of different countries, however, the most common ones used are: spirits (white spirit, port wine, beer), Coca-Cola, fruit and vegetable juices, lemon juice, milk, cocoa, tea, coffee, dairy products, meat and sausages, animal and plant grease, vinegar, 10 per cent citric acid, mustard, onion, lipstick, nail polish, 10 per cent ammonia spirit, iodine, alcohols (methyl alcohol, ethyl alcohol, isopropanol), ink, soap and washing powder, shoe polish, indigo powder, gasoline, petroleum, amly acetate, propanone, carbon tetrachloride, liquid naphthalene, sodium phosphate, sodium sulphate, paraffinum, 6.6 per cent urea solution, benzine, 5 per cent carboilic acid, etc.

(10) Resistance to Light: The experiment to test resistance to light is conducted with a gloss-meter and ageing-meter. The lustre of the surface of the sample is tested on the gloss-meter. The sample is placed in the ageing-meter to test it under operational conditions. The lustre is observed and measured after 24, 48, and 72 hours.

(11) Resistance to cigarette burns: Class A cigarette is used for this test, which is put in the drier for 24 hours before the test. The cigarette is lit and placed on the surface of the sample. After a couple of minutes, the cigarette is removed and the burned surface is carefully wiped with gauze wetted with a little ethyl alcohol, then dried to see if there is any dullness, yellow spots, black spots, breaking or splitting, blisters, etc.

(12) Tensile strength: The test is conducted with a general standard instrument and using the common method. Attention should be paid to the inequality of the longitudinal and transversal strength of the decorative laminate and the asymmetry of the sections and inequality of the strength of the decorative laminate which is composed of different kinds of paper and resin. The tensile strength should not be less than 900 kg/cm^2 longitudinally, and not less than 700 kg/cm^2 transversally.

The values of the physico-mechanical peoperties of melmamine resin decorative laminates are listed in table 4 on the following page.

Range of application of decorative laminates

Decorative laminates are a kind of beautiful ornamental material, whose surface is rich in aesthetic value, and bright in lustre and colour. It also gives a realistic feeling through imitation of various patterns including different surface grains of valuable timber, marble, textile, leather, etc. In addition, the high strength, wear-resistance, and resistance to chemical corrosion and high temperature further make decorative laminates a very valuable material with ideal effectiveness for decorating furniture, facilities, buildings and transportation vehicles. They are deeply welcomed by a broad range of consumers.

Table 4. Values of physico-mechanical properties of melamine resin decorative laminates:

Item of inspection	Requirements
Resistance to boiling water	1. Increase of weight < 10 % 2. Swelling < 10 % 3. No blisters and spearation of the layer.
Resistance to wear	1. Value of wear-and-tear < 0.08g/ 100 turns 2. Figures still remain after 500 turns on wear tester.
Resistance to dry heat	No separaration of the layer and blisters.
Resistance to shock	No breaking or splitting.
Resistance to contamination and erosion	No apparent traces of contamination or erosion.
Resistance to cigarette burns	No blisters, splitting, yellow spots or black spots.
Resistance to splitting	No splitting or blisters
Tensile strength	1. Longitudinally > 900 kg/cm^2 2. Transversally > 700 kg/cm^2
Resistance to light	1. No splitting 2. With slight cloudy watermark 3. With slight change of colour

In the furniture production industry, decorative laminates are heat resistant, contamination-proof and easy to wash and clean. This makes them eminently suited for making furniture for kitchens, restaurants, stores, schools, hospitals, etc.

They are widely used in the transport sector to decorate ocean-going vessels, airplanes, coaches, buses, tramcars, elevators, etc.

In building construction, they are used to decorate internal facilities, such as the front walls, partitions, doors, bathrooms and toilet enclosures, even floors of public and office buildings and hospitals. For instance, a kind of square tile for flooring made with decorative laminate was introduced in 1963 which led to a fundamental change in the maintenance of the frequently stepped-on floors. This kind of floor tile was selected for use in a computer room not only to keep the room neat and clean but also to eliminate any electro-static charges.

III. THE PRESENT SITUATION AND FUTURE DEVELOPMENT TRENDS OF THE PRODUCTION OF DECORATIVE LAMINATES IN CHINA

The earliest decorative laminates produced in China were of the melamine resin type. Production started in Beijing and Shanghai in 1958. Both the Guanghua Timber Mill in Beijing and Yanzi Timber Mill in Shanghai gradually built their factories in 1960-1961. Their yearly output have presently exceeded 2.5 million square metres. According to incomplete statistics, in 1979 there were already 11 provinces and municipalities producing decorative laminates. The production of decorative laminates varies in scope. The productive capacity of a medium mill with a high level of mechanization exceeds 2.5 million square metres yearly, and that of a small mill with semi-automated production is approximately 400,000 square metres. The production equipment can be manufactured entirely in China.

The production of decorative laminates in our country is increasing yearly, however, it is still very far from meeting the demands for the national economic construction and the well-being of the people. The research and development made in the field of decorative laminate production in recent years have further increased the quantity and improved the quality

of the products.

For instance, the success of the research on wear-resistant decorative laminate without overlay paper has not only saved on raw materials and reduced the production costs, but also created favourable conditions for the automation of the assembling of the film paper.

After repeated experiments, the Yangzi Timber Mill in Shanghai has achieved good results in substituting the oleic acid paper by poly-propylene film laminated on aluminium plates as the film release material. This system has been put into operation. Thus it has not only improved the quality of the products but also increased the utilization rate of the glue impregnating drier. Based on the production of one million square metres, 83 tons of impregnating paper, 70 tons of alcohol and 5 tons oleic acid can be saved, having a total value of 174,600 yuan (RMB) can be saved.

The use of a neutral compound resin aqueous solution, for the glue of basic paper of melamine decorative laminates can further save over 200 tons of alcohol per million square metres of decorative laminates, if compared with the alcohol and aqueous soluble phenol-formaldehyde resin presently used in China. This type of resin has many advantageous features, such a light colour, good stability for storage, rapid curing, low free-phenol content, good binding with the amino-resin ornamental layer, etc. The decorative laminate made with it has a very good durability, excellent water resistance and tenacity.

The future trends of development of decorative laminates' production in China are as follows:

(1) The medium size mills for decorative laminate production in China have basically realized mechanization except the film paper assembling and spreading process, thus reducing the labour require-

ments. The future development should be the mechanization of the assembling of the film paper process based on the promotion of the production of the decorative laminates without overlay paper, thus forming a complete technical system for the continuous production of decorative laminates.

(2) The research work on the major decorative laminates mills, on the systematic study of the technical problems of increasing the realistic feeling of the pattern concerning paper, plate making, printing, etc. should be strengthened so as to raise the quality of the decorative laminates.

(3) The present production of decorative laminates in China generally uses the high pressure formation, and cold-on and cold-off technique, i.e. cold pressure-on - hot pressing - cold pressure-off with high heat consumption and long productive cycle, therefore, in view of improving the productive technique and the resins used for decorative laminates, one of the objectives of the future development should be the study of low-pressure formation of the melamine, hot-on and hot-off, and shortening the cycle of the hot press.

(4) To develop the designs, colours and special varieties of decorative laminates. Presently, there are more than 4,000 varieties of decorative laminates produced in the world. The ever-increasing varieties of the designs and colours will promote a wider range of applications of the decorative laminates and various demands of consumers. Much remains to be done in this field such as:

a. Decorative laminates having low warping:

The warping of decorative laminates is an important problem not yet solved. Warping will cause many difficulties in the process of application. The relative humidity changes significantly in bathrooms, kitchens and laundries, therefore the internal stresses generated in the decorative laminates in such places will possible lead to their splitting or separating from their underlay.

Research has shown that such factors as the weight per square metre of the basic paper and the distribution of resin content have no direct substantial effect on the warping of the decorative laminates; as the resin impregnation is relatively homogeneous, modern glue-impregnating machines are used, and the weight and thickness of the paper are strictly formulated. Therefore, the main factors affecting warping are presumed to be: the variety of resin and its content, vaporization content, flowability, the relative thickness of the ornamental paper in the decorative laminate, etc.

The adoption of compensating paper impregnated with a resin similar to that used with the ornamental paper reduces warping. However, in order to eliminate warping completely, an ornamental layer with the same paper and resin should be placed at the back of the decorative laminate, but this will increase the cost of production.

Another possibility to reduce warping would be to prepare a kind of resin with the flowability that can ensure a fine quality of surface when its vaporization content is even lower than the pure melamine resin, for a deeper pre-curing will inevitably generate at this time. Therefore, a kind of material which can maintain the flowability must be used to modify the resin. Such materials may be ortho and para methyl benzine sulphonamide, sucrose, ethyl guaniamide, benzyl guaniamide and other polymers.

It is very important to reduce the relative thickness of the ornamental layer in the total thickness of the decorative laminate, since the greater the thickness, the greater the warping will be. The functions of performance and decoration of the decorative laminates must however both be maintained. This can be attained through using ornamental paper having high filling material and low gram weight. This is particularly feasible for the production of decorative laminates under 1 mm thick.

b. Post-forming decorative laminate:

In designing a structure which is made with decorative laminates, the decoration of non-planar surfaces and rimming of arcs, edges, columns, etc. is often required.

A film paper may be placed in a corresponding forming mould to be pressed into products having different appearances, but with this method, only certain kinds of components can be produced and the manufacture of the various moulds is not only expensive but also unreasonable. The demand for the so-called post-forming decorative laminates is increasing. Under certain conditions, it can be formed and bent to the required radius of curvature of as low as 15 - 20 mm. Considerations should be given to the fact that bending is possible in only two directions, i.e., a cylindrical body may be covered by a decorative laminate but not a spherical body.

If the material is not well cured during pressing, even the ordinary decorative laminate will have the character of post-forming. The decorative laminate will have a certain plasticity after heating for a limited time at a particular temperature, that is, the final shape should be formed during this time. But the incomplete curing of the decorative laminate may be further cured in the course of storage, therefore, it is reasonable to make post-forming decorative laminate with special paper or modified basic layer paper and overlay resin. As the result of the modification of the resin which will bring forth a certain plasticity to the decorative laminate, it is able to be formed through heating. Through this operation, the material will have similar functions as the ordinary decorative laminate. Because the decorative laminate will lose its capacity of post-forming if it is over cured during the process of impregnation and hot-pressing, particular attention should be paid to controlling the glue content of the film paper and the extent of its condensation while applying the modified resin so as to assure the possibility of post-forming.

The components (by weight) of the overlay paper impregnated for making post-forming decorative laminate are as follows:

Melamine resin at 50 percent concentration	100
Surface activator (alkyl benzyl sulfonic sodium)	0.05 - 0.25
Solidifier $MgCl_2 6H_2O$)	0.03 - 0.2

The following method has been adopted to make post-forming decorative laminates without using any modifier: Impregnate the ornamental paper with a melamine resin (gram molecular ratio: 1:2) without catalyzer, impregnate the overlay paper with the same resin plus 1 percent of catalyzer (glacial acetic acid to which ethyl diamine has been added), and rapidly press the assemblies at a decreased temperature. Now the overlay is cured, but not yet completely so, while the ornamental layer maintains its plasticity, the formability is attained. Before the overlay paper is impregnated with the melamine resin prepared with a low gram molecular ratio (from 1:1.1 to 1:1.8), it must first become acidic. Summing up, there are many different methods to make post-forming decorative laminate. A great number of decorative laminate mills and adhesive factories in foreign countries have done a lot of work in this respect.

Applying the method of post-forming to furnish the horizontal working plane of products has a broad prospect, because the edges and corners of most products are the places of the structure where breaking first begins.

c. Decorative laminates with special functions:

The research work conducted on the special functions of the overlay in order to improve its quality and its aesthetic and economic requirements, has led to the production of a great variety of decorative laminates.

One of the most important targets to determine the durability of the decorative laminate is its surface wearability and also the maintenance of a favourable appearance.

The addition of special wear-resistant material to the overlay layer may increase its wearability. In order not to use the overlay paper, we have developed a kind of wear-resistant coating which has obviously increased the wearability of the decorative laminate.

It must be strictly observed taht when choosing additives to increase the wearability, the refracting coefficient of the microsome must always be close to that of the adhesive, otherwise the figures will become vague; however, the appearance and the shape and size of the microsome will have no wearing effect on the polishing plate, impregrating press-roller, and all other parts of the equipment entering in contact with it.

d. Fire-resistant decorative laminates:

With the expansion of the range of application of decorative laminates, the question of decreasing their fire risks has been put forth. Special requirements for this material have been raised by such industrial departments as ship-building, aircraft production, transport manufacture and building construction. One of the main requirements is to reduce their combustibility.

Paper, a combustible material, which represents 60 to 65 per cent of the decorative laminate, induces the principal heat-release during burning. The ignition point of the phenol-formaldehyde resin employed in the decorative laminate is 448 to 458°C and its spontaneous combustion temperature is 510 to 545°C. The melamine resin, however, only burns at a temperature approaching 600°C. Although the resin may be a fire-retardant to a certain extent, it cannot meet the requirements for fire prevention. Therefore, the conditions required for the production of fire-resistant decorative laminates are to reduce the combustibility of the paper used in production and utilize phenol-formaldehyde resin which contains fire resisting agents.

Fire-resistant decorative laminates can be made with the same process of modified phenol-formaldehyde resin. For instance, in

Great Britain, kraft paper containing 18.6 percent of kaolin is used to make basic paper for the decorative laminate, which is initially impregnated with ammonium phosphate, then with the phenol-formaldehyde resin solution plus boric acid and sodium pentaborate. Another method being investigated is to add boric acid, melamine-formaldehyde condensation compound and sodium pentaborate into phenol-formaldehyde resin to impregnate paper as the interior layer of the decorative laminate. The decorative laminate made in this way is able to meet the requirements of class I fire-prevention standard.

The following chemicals are added to the phenol-formaldehyde resin for impregnating the basic paper: 0.05-0.15 gram molecule of H_3PO_4 or $(NH_4)_2HPO_4$ (per gram molecule of phenol), 3 gram molecules of NH_4OH (per gram-molecule of H_3PO_4) and 1 gram molecule of formaldehyde (per gram molecule of NH_4OH). The basic paper is impregnated with this composition and then dried to make the basic layer of the decorative laminate. Ammonium salt, sodium phosphate, aqeous soluble condensation of compound of phosphochloride and ammonia, and phosphamide liploids are recommended as the additives of the phenol-formaldehyde resin.

One method used in the Soviet Union is to apply a coating of a mixture of antimony oxide and perchloro-ethylene to the basic paper before pressing, and the paper coated with the mixture is placed alternately with the paper without the coating in order to prevent this paper from sliding in the assemblies. However, the cost of material for this method is rather high and the technical process is very complicated. In order to modify the phenol-formaldehyde resin, various phosphoric compounds were tried for the fire-resistants, such as nitrogen phosphorus chloride, triphenyl phosphates, phosphoric acid and pyrophosphoric acid etc. All the compounds tested can reduce the combustibility of the impregnated paper, but the physico-mechanical properties of the paper itself will decrease when nitrogen phosphorus chloride and triphenyl phosphate are used. The impregnated film paper

is somewhat brittle, so it is easy to be cracked and fall to pieces.

Through experiments, it appears that when phenol-formaldehyde resin plus phosphoric acid are used for the production of decorative laminates, the optimum proportion of phosphoric acid and pyrophosphoric acid is 15 percent. The combustion co-efficient of the decorative laminate is 0.36 which belongs to the category of materials whose combustion is difficult. However, the addition of phosphoric acid will increase the viscosity of the phenol-formaldehyde resin solution, thus causing the reduction of its viability and the precuring of the resin while drying the film paper. In order to prevent this phenomenon, it is better to prepare the impregnating resin solution before using it.

One of the trends in the development of modified phenol-formaldehyde resin is to add more effective phosphorated and nitrogenous compounds into the resin. The trial production of 1.5 to 1.6 mm thick fire-resistant decorative laminates with the phenol formaldehyde resin attained through the research work conducted in this field has proved that not only is its physico-mechanical property good but its fire-resistance is also improved.

Methyl alcohol added with antimony oxide and pentaboro-diphenol or pentachloro-diphenol or solutions with other solvents may be added during the paper-making process and the product may also be used to make fire-resistant decorative laminates in the same manner. Asbestos sheets may be used for the production of fire-resistant decorative laminate too.

ANNEX I

ANALYSIS OF COST OF PRODUCTION

Decorative laminates are produced in China in medium and small size factories. Taking the Yangzi Timber Mill in Shanghai as an example, the analysis of its cost of production of decorative laminates in 1979 is given in table 6 below.

Table 6. Analysis on the cost of production of decorative laminates:*

Item	Percentage of the cost
Raw materials:	93,0
a. Paper:	41,0
Overlay	3,06
Ornamental	16,15
Basic	21,4
b. Adhesive:	52,0
Melamine resin	29,2
Phenol-formaldehyde resin	22,8
Fuel and power	2,6
Wages	1,04
Factory expenses	2,41
Management expenses	1,04

* Based on the statistics for 1979 of the Yangzi Timber Mill in Shanghai.

ANNEX II

TECHNICAL SPECIFICATIONS OF A MILL WITH AN ANNUAL OUTPUT OF 1.5 MILLION SQUARE METRES OF MELAMINE DECORATIVE LAMINATES

General Description:

1.	Capacity	1.5 million m^2/year
2.	Dimension of finished product	4' x 8' (1220 x 2440 mm)
3.	Operation	3 shifs of 8 hours
4.	Total power	250 kw
5.	Labour	approximately 136 persons
6.	Factory building area	approximately 1900 m^2
7.	Raw materials used	a. melamine resin
		b. phenol-formaldehyde resin
		c. overlay paper
		d. ornamental paper
		e. basic paper
		f. polypropylene
		g. others

Machinery:

1.	Hot press	
	Capacity:	
	a. total pressure:	4500 tons
	b. maximum unit pressure	80 kg/cm^2
	c. hot press platen	65 mm x 1,370 mm x 2,590 mm
	d. number of daylights	15
	e. panel loader and unloader	push-and-pull type

Plate returning facility

Stainless steel plate:	200 sheets (3mm x 1,270 mm x 2,500 mm)
Aluminium plates:	70 sheets (2.5 mm x 1,275 mm x 2,505 mm)
Cover plates:	70 sheets (3.0 mm x 1,275 mm x 2,505 mm)

2. Horizontal impregnating and drying machines — 2 sets

	Impregnating with melamine resin	Impregnating with phenol-formaldehyde resin
a. rated speed	6-20 m/min	15-25 m/min
b. operational speed	10 m/min	20 m/min
c. working width	1,350 mm	1,350 mm
d. vaporization content(%)	5-7	7-9
e. resin content (%)	50-60	38-45
f. working temperature	120-145°C	140°C

3. Vertical impregnating and drying machines — 2 sets

a. rated speed	0.5 - 2.5 m/min
b. impregnating speed	2 - 2.5 m/min
c. vaporization content (%)	6-8
d. resin content (%)	170-190
e. drying temperature	max. 130°C

4. Vacuum sucker

5. Polishing machine

a. maximum specification work	1600mm x 2,000 mm
b. abrasive	chromoxide green

6. Longitudinal and Transverse edger

a. specification of processing	1230 x 2450
b. Speed of machining head	2800 rpm

7.	**Sander**	
	a. working width	max. 1,500 mm
	b. panel feeding speed	3 - 5 m/min
	c. sand paper grit used	60
8.	**Steam boiler**	
	a. maximum pressure	10 kg/cm^2
	b. working pressure	8 kg/cm^2
	c. output	4,800 kg/hour
9.	**Glue mixing tank**	
	a. Melamine resin glue-mixing tank with mixer: capacity	500 litres
	b. Phenol-formaldehyde resin glue-mixing tank (with mixer): capacity	500 litres
10.	Air compressor	
11.	Vacuum pump	
12.	Ventilator	
13.	Laboratory equipment	
	Viscometer	1
	Electric drying oven	1
	Analytical balance	1
	Hydrometer	10
	Micrometer, 0-25 mm	3
	Hygrometer	5
	Thermometer	10
	Enamel mug, 500 ml	10
	Enamel mug, 1000 ml	10
	Experimental hot press, 450 mm x 450 mm	1