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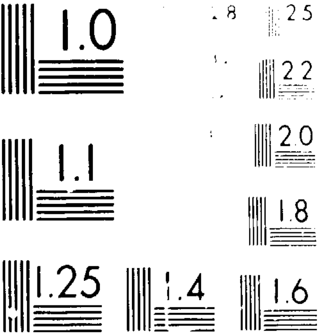
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THE PROCESSES OF PLYWOOD MANUFACTURE *

by

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I. INTRODUCTION

The two problems generally considered as being of major importance in contemporary plywood industry are: 1) plywood yield (per cubic content of logs peeled, e.g. m^3) i.e. "more plywood with fewer logs"; and 2) labour productivity (output per worker) i.e. "more panels with less labour". The concept of "high yield management" put forth by F. Baldwin also covers these two aspects. In fact, the whole evolution of plywood processing technology has been the industry's unceasing efforts towards the solution of these two aspects or problems.

The plywood processing technology has come down to us from great antiquity, dating back to 1500 B.C. when our forerunners made their preliminary or primitive contributions. This evolution has been very slow considering the lengthy period of time that has elapsed ever since. For instance the technology of hot pressing is quite recent with the first hot press equipment being installed almost half a century ago, and yet with no essential alterations having been made so far. Technical innovations in the plywood industry started slowly in the 1950's then quickened in the 1960's, quite a number of new processing techniques were introduced and then, again, with an accelerated pace in the 1970's, culminating in the development of jet drying of veneers, wide-belt sanding, veneer composing and automatic lay-up, which are generally accepted as the three major technological innovations of the modern plywood industry. Their application has served to raise production efficiency to a great extent.

The ever-decreasing availability of forest resources, especially of peeler logs, the cost of which has drastically increased as to render the conversion into plywood almost uneconomical, has made imperative the pursuit of both plywood yield and labour productivity. Consequently, many innovations have taken place in plywood processing technology. Among these are the improvement in the pre-conditioning of veneer blocks prior to peeling, more accurate veneer cutting, thereby reducing the thickness of the face veneers as well as their thickness allowances, the research undertaken to utilize small diameter logs, high efficiency precision veneer clipping equipment which **tends** to lessen the waste of this process and tremendously increase the speed, the wide-belt sanding which serves to minimize material removal from the panel surfaces and the like. The concurrent introduction of computer systems into the technology of plywood processing, moreover, marks the coming of the new era of computerization of the plywood industry, resulting in further notable increments in plywood yield and labour productivity.

The rigid control over processing techniques and the accurate adjustment of the equipment in operation have an important bearing, on the outcome of production. For instance, losses may be incurred due to inadequate treatment of logs before peeling, while any fault in the installation and adjustment of the peeling knife may render the best equipment liable to turn out poor products. The same is true of gluing or pressing, and heavy losses would also be likely to occur, without proper control. Hence, in order to maintain high production levels, regular analysis of the various processes must be resorted to, with a view of not letting a single mistake or faulty performance pass unnoticed.

The production activities of the plywood industry, like any other branch of industry should culminate in an outcome expressed in the form of economic effects. Under the prevailing conditions of world shortage of wood resources, the role of plywood yield has predominated over labour productivity.

But, whatever may be the ultimate object, whether it be the elevation of plywood yield or labour productivity, the first and foremost prerequisite is to find out the link that has the greatest potential for improvement. The nucleus of this link may be termed the "key point" leading to the solution of the problem. This key point may vary under different circumstances, but once identified, large benefits may be reaped with a modest amount of effort, and the production processes as a whole may thereby be rationalized. The said key point is identical with the "leverage point" as described in the concept of "high yield management".

Notwithstanding the relatively simple technology of plywood manufacturing, the difficulty lies in how such a panel could be produced more economically. The production of a high quality plywood panel was said to be an art; but the production of a low cost plywood panel is now regarded more as a science. Now, in respect of plywood production, the era of art seems to be ending, while on the other hand scientific influences in this industry are ever-increasing. It is in line with such a trend that the discussions in the present paper will be oriented.

II. CONDITIONING VENEER BLOCKS

The purpose of conditioning veneer blocks is to make them suitable for peeling or slicing by softening or plasticizing. This is done generally by cooking or steaming. Veneers obtained from blocks that have been pre-conditioned are of better quality, higher strength and less energy-consuming in cutting on the rotary lathe or slicer. Some of the advantages of conditioning veneer blocks prior to peeling or slicing follow.

1. It increases veneer yield. The veneer blocks after conditioning will have a more even distribution of moisture content, producing veneers with fewer lathe checks and a higher tranverse strength, less liable to split, and a higher ratio of full-sized sheets -- all of these contributing to elevate the veneer yield by more than three per cent.

2. It upgrades the veneers turned out. The veneers obtained from conditioned blocks are relatively flatter and smoother, even where the grain is irregular. Lathe checks and splits being reduced, the veneers are upgraded. Records in a certain plywood plant indicate that the amounts of second quality and up veneers can be increased by four to seven per cent.

3. It saves labour and wood raw material. The reduction in waste due to veneer breakage and the increase in the ratio of full-sized sheets, necessarily result in a saving of labour in drying and glue application, besides, giving a smoother surface of the panel product with fewer lathe checks, a higher bond quality and lower glue consumption. High surface smoothness reduces sanding requirements, making it possible to make a saving, in turn, in wood raw material by reducing the thickness of veneers. Also a reduction in lathe checks is helpful in improving the weather proofing of the panel products as they do not produce surface cracks during service as readily.

Dry wood is practically a non-conductor of heat, and so the heating of wood must be accompanied by elevating its moisture content by one or other of several methods.

1. Cooking Vat

The veneer blocks are put into a cooking vat. Hot water is poured in to submerge the blocks; steam is turned to a temperature at a rate suitable for the quality and diameter of the blocks; and the predetermined temperature is maintained. When the blocks are heated to the required temperature, the process of conditioning is ended.

The maximum temperature limits for hydro-thermic treatment of various categories of wood species are as follows:

For soft broad-leaved wood species (under 0.45 in sp. gr.)	25-45°C
For hard broad-leaved wood species (under 0.70 in sp. gr.)	50-70°C
For extra hard wood species (above 0.70 in sp. gr.)	80-90°C
For coniferous wood species	70-80°C

The duration of time required for conditioning depends on the mass of substances involved in the process (including the total mass of wood, and the water contained therein). The former is, in turn, determined by the diameter of the block (or sizes of the flitch) and its specific gravity in the green state.

The times differ according to their specific gravities, and are:

For soft broad-leaved wood species	24-30 hours
For hard broad-leaved wood species	36-40 hours
For extra hard wood species	40-70 hours
For coniferous wood species	36-40 hours

The speed of temperature elevation of veneer blocks in hot water treatment is faster longitudinally by 2 1/2 times than radially. However, the conduction coefficient of wood is relatively low, so that if the temperature is raised too fast end checking and ring shakes will inevitably result due to the big difference in temperature between the surface layer and interior of the veneer block. The rates of temperature rise commonly used are:

Broad-leaved wood species	2-3°C/hour
Coniferous wood species	5-6°C/hour

The above holds good for blocks under 40 cm in diameter. For larger blocks, the temperature rise can be faster.

The term "peeling temperature" of a veneer block refers to the surface temperature of the remaining core (the wood core expected to be left after veneer peeling). Generally, these are:

Broad-leaved wood species	25-45°C
Extra hard wood species	45-55°C
Coniferous wood species	40-45°C

Certain knotty and hard coniferous wood species like Pinus massoniana should be heated to a temperature of 80-90°C to soften the knots and allowed to cool down to 40-45°C prior to rotary **peeling.** Some further precautions that must be borne in mind are:

1. Frozen blocks must first be thawed out at a temperature of 30-40°C for eight hours;
2. **Blocks** should be sorted by diameter, and those falling within a range of diameters must be treated in the same vat.

3. Blocks cut from logs stored on land and in water should be treated separately. As a rule, the former require lower temperatures and slower rates of temperature rise.

2. Progressive Heating Tunnel

This is a tunnel-shaped piece of heating equipment, using a mixture of steam and water as heating medium. Veneer blocks are transported to the tunnel by a chain conveyor system and move progressively towards the out-feed end to provide a steady flow of veneer blocks to the rotary lathe. This method is suitable for treating small blocks with short cycles.

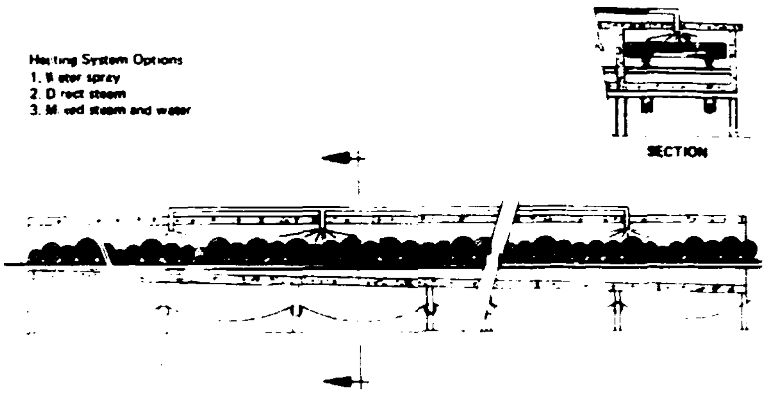


Fig. 1 - Continous-flow preheating tunnel often used for small blocks and operation with short heating cycles.

3. Hot Water Tub

A concrete tub of rectangular cross-section is used for this purpose, and there are two different kinds: 1) the floating type and 2) the sinking type.

The floating type hot water tub is suitable for use with blocks that float on water, with the loading of the blocks done by an inclined chain conveyor. At the top the tub conveyor chain equipped with a pushing rod is installed which drives the blocks close to each other on entering the tub so that they move towards the out-feed end, where they are lifted out by a chain elevator. The blocks on leaving the tub are carried away by a mechanical lifting hoist.

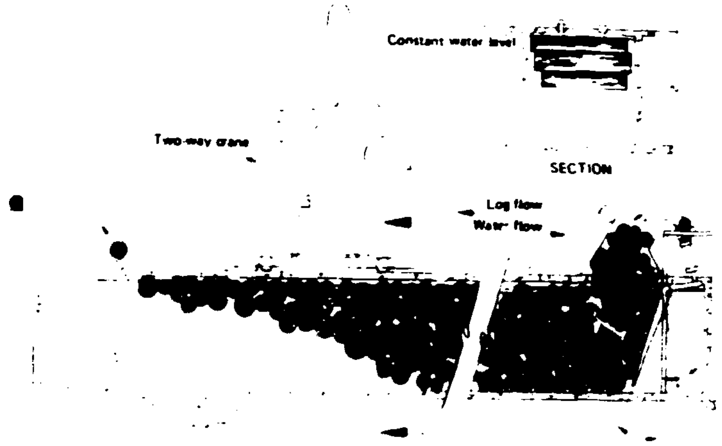


Fig. 2 - Hot-water heating tub for high-floating species.

The sinking type hot water tub is suitable for the treatment of veneer blocks of higher specific gravity that sink in water. The loading and unloading is done by a chain conveyor at the bottom of the tub.

Heating is done by either steam coils or steam plates. The water level in the tub should be kept constant.

The advantages of this method are safety in operation and relatively low heat loss, the disadvantage being high investment cost.

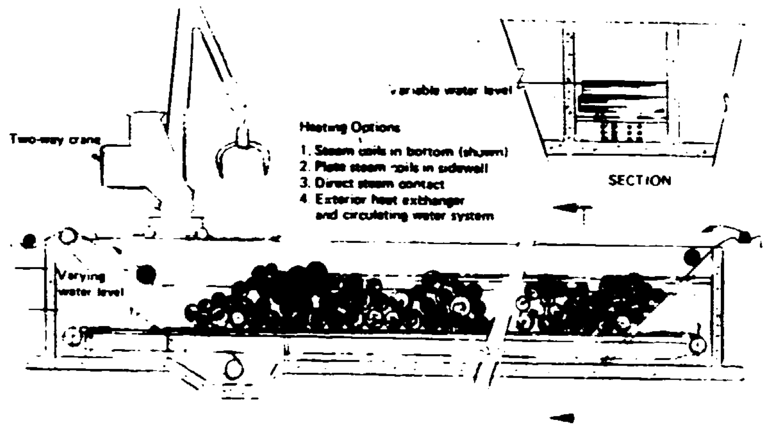


Fig. 3 - Hot water tubs for sinking species.

An important problem in hot water treatment of veneer blocks is the acidity of water. Most wood species being acidic, the pH value of water in the cooking vat after prolonged use may be reduced to as low as 3.5. Under such conditions, the wood fibers of the veneer block become brittle, making the veneers liable to breakage and a deepening of the lathe checks. These adversely affect the veneer yield as well as the corrosion of steam piping and conveyor mechanisms.

Some plywood plants adjust the acidity of water by means of an alkaline additive, raising the pH value from 3.5 to 8-11. This not only increases veneer yield by some seven per cent, but also quickens the rate of heat conduction by nearly fifty per cent, thus hastening the veneer drying speed due to the solution of resinous substances in the hot alkaline water.

The dual purpose of making acidic vat water more alkaline is further manifested in another aspect. Wood is composed of cellulose, hemi-cellulose and lignin. The hemi-cellulose and lignin, being thermo-plastic, soften or plasticize in hot water. The cellulose which comprises more than fifty per cent of the wood substances being acidic, however, is difficult to soften. It is easier to soften cellulose in hot alkaline water.

4. Steaming

The treatment by steaming has a low efficiency. Heat consumption is high and the heating effect uneven, causing a superficial drying of the block which handicaps heat transmission. End splitting develops very rapidly in blocks exceeding 50 cm in diameter in high temperatures. However, owing to the darkening of light coloured wood species in cooking vats, which does not happen in the treatment by steaming, the spraying of hot water or a mixture of water and steam has generally been used instead to increase veneer yield and to reduce end splitting. It also speeds up the heating cycle.

In this method, a drive-in vat, built of concrete, is used. On the top of the vat the steam pipes and nozzles which inject steam, hot water or steam/water mixture are installed. Loading and unloading is done by a fork lifter. The veneer blocks should be sorted according to size. Heating by using steam and hot water simultaneously or a mixture of steam and water increases production efficiency, and what is more important, end splits and heart shakes are reduced.

The choice of treatment method depends on the diameter range of the veneer blocks to be conditioned, safety in operation, economics of energy consumption and other factors. Hot-water treatment in a cooking vat is generally used in China.

For the conditioning c bauks and flitches for slicing, the maximum water temperature range is 80 to 90°C. The lining of heating equipment is sometimes made of stainless steel to avoid the contamination of wood by concrete.

An appropriate working schedule for heat treatment of veneer blocks should be prepared by the plywood plant based on the aforesaid ranges of temperature, duration of treatment and the rate of temperature rise correlated with the varieties of wood species used and the condition of the equipment. The following is a simple method to perform such an experiment.

Bore a series of holes lengthwise in the mid-length of a veneer block, with the depths of the holes increasing by equal increments, until it reaches the surface of the core. Insert thermoccuples, and heat. From the data obtained, prepare the working schedule. The following is an example of a schedule for hot water treatment formulated from such an experiment:

Wood species	Apitong (Dipterocerpus spp.)
Diameter of veneer blocks	80 cm
Temperature of hot water	80 - 90 °C
Speed of temperature elevation	8°C/hour
Duration of heating cycle	60 hours (including time for temperature rise).

III. VENEER PEELING

A. Lathe Setting

Veneer lathe setting comprises: the preparation and proper setting of the veneer knife, the preparation and proper setting of nosebar and the adjustment of the pitch rail with a view to obtaining quantitatively as much veneer as possible and qualitatively as much high quality veneer as possible from a given volume of logs. This is the so-called 'high yield principle of peeling technique".

B. Preparation of Veneer Knife

The veneer knife for rotary lathes should be made of steel of appropriate hardness within 56-58°Rc. The bevel angle of the veneer knife has an important bearing on the performance of peeling and should be determined within a range of 17-23° according to the conditions of raw material as well as veneer thickness desired. Generally, from the point of veneer quality, the smaller the bevel angle, the better will be the quality of veneer turned out. However, too small a bevel angle is apt to incur damages to the knife blade. As a rule, small bevel angles are to be preferred for working with soft woods; while for harder species, bigger angles should be used instead. Besides, smaller angles are more advantageous for peeling thin veneers irrespective of whether the raw material used is soft or hard wood; while for knotty soft woods, bigger angles are more advisable.

Finland, in the early 50's, undertook research work and adapted the technique of micro-bevelling. This is to back-bevel the knife edge with a piece of whetstone so as to form a slight bevel angle of 20°, thereby strengthening the knife edge. The width of micro-bevel is 0.25 - 0.50 mm.

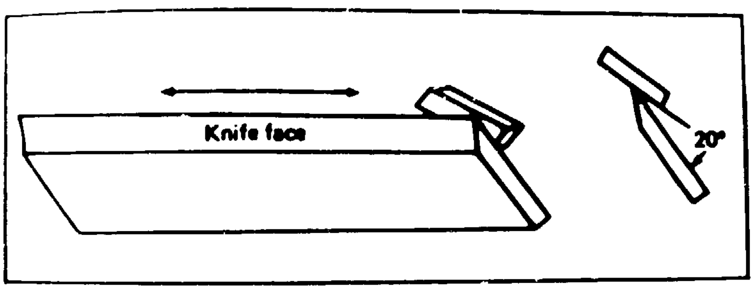


Fig. 4 - Applying the microbevel on a veneer knife, draw oil stone along back of knife

C. Knife Setting and Adjusting

This is done on the basis of two technological parameters: 1) height of knife tip h, and 2) knife setting angle k. These two parameters are of prime importance concerning veneer quality.

1) The height of knife tip h.

The tip of the veneer knife should preferably be located on or near to the axis of the chuck spindle. If the knife is above the axis, the knife setting angle will rapidly decrease with the decrease of the diameter of the log. On the contrary, if the knife tip is below the axis, the cutting angle will increase with the decrease of the diameter of the log. In either case, when the knife setting angle goes beyond the range of limits permitted by the conditions of technology, the quality of veneer would deteriorate, even to such an extent that peeling could no longer be carried on.

The adjustment of the height of knife tip may be performed according to the following process:

1. Set the veneer knife on the knife frame, secure it temporarily, and then remove the knife frame to within a distance of 25 - 30 mm from the axis of the chuck spindle (i.e., to a distance so that measurement could be made by means of a height gauge).

2. Stretch out both ends of the chuck spindle so that they extend beyond the respective ends of the veneer knife by more than 10 cm. Adjust the height of knife tip at ends of the knife with the help of a height gauge. Adjustments should be made at a distance of 10 cm from the ends of the knife.

3. The knife tip having been properly adjusted, fix the pressure plate and tighten the screw.

4. On completion of the above steps, fix a reference point on the knife frame, for example, on the top of the knife supporting plate. Find out the distance from the said point to the knife tip. This distance can be taken as a guide for the next setting.

It must be noticed that the knife tip must be slightly above or otherwise below the axis of the chuck spindle. For instance, when the diameter of the chuck spindles is relatively small or when the chuck spindles are slightly slanted, the knife tips should be set a little bit higher. On the other hand, if back-up rolls are used, the knife tip should then be set a little bit lower (about 0.7 - 0.8 mm) to allow for the compensation of strain due to force exerted during peeling operation.

2) Knife setting angle K

The knife setting angle is the angle between the bevel face of the knife and a horizontal line extended through the knife tip.

The magnitude of the knife setting angle has an important bearing on the extent of cutting checks and the smoothness and evenness of veneer thickness. Too big a setting angle would develop a "cutting into" effect on the log, causing the veneer produced to become too thick at the beginning of the peeling process and too thin when it comes near to the core. Too small a setting angle would develop an effect of "cutting away" from the log, causing the veneer ribbon to appear "dish-like", thicker on the edges and thinner at the middle. The lathe checks would also deepen with the increase of the setting angle, affecting the smoothness of the veneer produced.

Moreover, the magnitude of the knife setting angle K is correlated with wood species of the logs, and the thickness of veneer to be produced. Knife setting angles should be relatively smaller for the hard woods and bigger for the soft woods. Knife setting angles for thick veneers should be relatively smaller and vice versa.

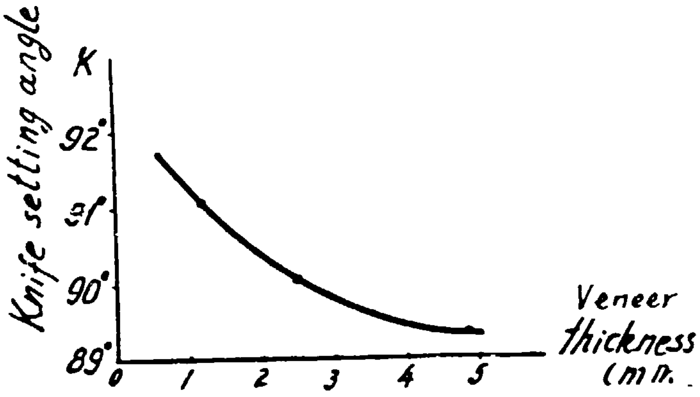


Fig. 5 - Relationship between the setting angle and the veneer thickness.

The change of the knife setting angles, especially for logs of smaller diameter, should be restricted only within the limits of a very narrow range, generally 89° to 90°. This is a very important condition to warrant for the evenness of thickness of the veneer ribbon. The determination of setting angle in practice is as follows:

1. Determine the optimum knife setting angle in terms of the factors of log quality, log diameter and the thickness of veneers to be turned out by a trial-and-error method.

2. The veneer knife and the knife tip having been set up, keep the knife frame at a position to correspond with the periphery of the average wood core. Measure with a protractor for optimum value to adjust the setting angle.

3. If the log to be peeled is relatively large, the knife carriage should be retraced to a position corresponding with the periphery of the biggest log diameter, and then the setting angle determined once more. Check whether the setting angle in both circumstances respectively, the peripheries of the biggest log diameter and that of the wood core, fall within the permitted range for the change of angle.

4. Should the result of the checking of the change of the angle be not in compliance with the requirements of technology, the slope of the pitch rail should be adjusted as described here under.

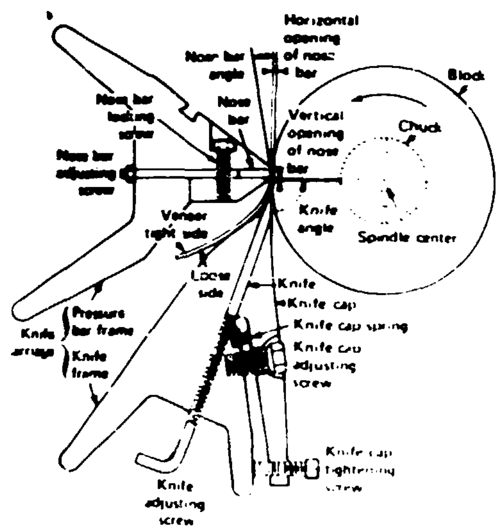


Fig. 6 - Veneer knife and nosebar setting.

In the peeling process, the control of the range of limits of the knife setting angle is brought about by adjusting the slope of the pitch rail.

First of all, to determine the adjustment of the slope of the pitch rail needed to change the knife setting angle 1°:

1. Adjust the elevation of pitch rail to level (slope = 0°), the adjust successively until the setting **angle** is just 90°.

2. To find out a reference point on the rotary lathe, measure and note down the plumb distance d_1 from the reference point to the top of the pitch rail.

3. Lower the pitch rail until the setting angle is equal to 89^{o}. Keep the pitch rail at level. Again measure and note down the distance d_2 from the reference point to the top of the pitch rail.

The value of $d_1 - d_2$ is the amount of modification of the elevation of pitch rail required corresponding to 1^{o} setting angle modification. Let $d_1 - d_2 = D_o$

4. To calculate the slope of the pitch rail.

$D/A = tg\theta$

where $D = D_o$ x amount of the change of setting angle required during peeling process.

A = distance of movement of knife carriage required from the periphery of the log to the surface of the wood core.

θ = the appropriate slope angle of pitch rail.

For example: Given log diameter = 50 cm, diameter of wood care = 15 cm, empirically determined the change of setting angle = 0^{o} 25', D_o = 1.2 cm.

$A = (50 - 15) \times 1/2 = 17.5$ cm

$D = D_o \times 0.417^{o}$ (=25') $= 1.2 \times 0.417 = 0.5$

$D/A = 0.029$

$\theta = tg^{-1}\ 0.029 = 1.66^{o} = 1^{o}39'36''$.

5. Adjust the slope angle of the pitch rail according to the solution of the above calcualtions, then remove the knife frame to the respective peripheries of maximum and minimum diameters, check if the degrees of setting angle do coincide with the specified.

The above procedure would appear to be rather complicated to start with, though it will soon become quite simple with practical experience.

The bearing area of knife on the block surface during cutting is the refernce for checking the correctness of knife setting.

After 5-10 revolutions of peeling, a clear and bright zone forms near the tip and along the whole length of knife bevel face, called "bearing area". The proper adjusting of angle K and the slope angle of pitch rail makes the bearing area 2 - 4mm, in this case, the angle K will change within the range of 1^{o} during the cutting process.

Too small a bearing area results in corrugated veneer with waves spaced 6 - 9 mm from crest to crest on the surface: too large a bearing area results in a wavy veneer with uneven thickness, the wave length of which may be 300 mm more.

D. Setting up of Nosebar

The functions of the nosebar is to exert appropriate pressure on the logs at the cutting edge of the veneer knife during peeling, so as to increase the smoothness of the surface of veneers turned out, as well as to mitigate the extent of cutting checks on the loose side and to render the thickness of veneers more uniform.

The setting up and adjusting of nosebar is carried out on the basis of the following two parameters: 1) the horizontal gap between nosebar and knife tip H and 2) the vertical gap V between them.

1) Adjusting horizontal gap (H)

The nosebar having been set up,first of all adjust the horizontal gap.

1. Make the edge of the pressure bar prallel to the edge of veneer knife by determining it at several points at regular intervals along the knife edge.

2. Adjust horizontal gap to 80 - 95 per cent of the thickness of veneer according to various species and veneer thicknesses. Generally, the compressibility for softwoods is relatively big, whilst that for hard woods is relatively small. Take a smaller degree of compression for thinner veneers and a bigger one for the thicker veneers.

3. Observe the smoothness and extent of lathe checks as peeling goes on, and make accurate adjustments. The phenomena of chipped or torn grain or perceivable ductility appearing on the

surface of the veneer ribbon are symptoms of excessive compression. Coarse surface and deep cutting checks on the loose side of the veneer ribbon symbolize inadequate compression. In either of these two cases, compression needs to be adjusted.

4. Localized tight and loose spots on the veneer ribbon suggest the necessity of local adjustment of compression by means of adjusting bolts of nosebar.

2) Adjusting vertical gap (V)

1. The parallelism of the edges of the nosebar and the veneer knife having been checked, measure V at both ends and at the middle of the knife with a mechanist's ruler. Raise or lower the nosebar to the predetermined value of V.

2. Adjust the vertical gap V to 40 - 50 per cent of veneer thicknesses according to the quality of log and thickness of veneer.

In peeling logs which have been cooked, the warmth of the log would cause the veneer knife to expand, resulting in an elevation of the height of knife tip. This modifies the gap already adjusted between the knife and the nosebar.

The proper degree of compression must be kept during veneer cutting. Over compression causes the veneer thickness to be slightly reduced, and insufficient compression results in slack veneer produced.

The critical value of compression for reference is as follows:

Thickness of veneer (mm)	Critical value of compression (%)
0.80	10 - 15
0.80 - 1.50	15 - 20
1.50 - 2.50	20 - 25

In addition, excessive compression applied on some species of softwood may produce "shelling" or slivering due to a separation between springwood and summerwood.

It must be noticed that in respect of the parameters of the technology of veneer peeling, the discriptions given above are merely generalized principles. Manufacturing plants should correlate the principles with the actual conditions of production i.e., log species, veneer thickness and the degree of technological precision of the rotary lathe used, to formulate their own technological specifications in actual practice.

The following is the instance of an actual experiment (Scientia Sinica Silvae Vo. II., No. 2)

1. Conditions of production:

Species:	Dipterocarpus Spp.
Thickness of veneer:	3 mm
Technological precision of the rotary lathe	$S^2 = 0.002$ (expressed in terms of variance)

2. Results of experiments:

$K = 90^\circ \sim 90^\circ 30'$ $(h > 0)$

$K = 89^\circ \sim 89^\circ 30'$ $(h < 0)$

$V = 0.8 \sim 1.5$ mm

3. **Empirical** formula of the principal technological parameters deduced from the experiment:

The relation of clearance angle α with the roughness of veneer R:

$R\ (\mu) = 192.77 + 48.60\alpha + 20.8\alpha^2$

The relation of clearance angle α with the extent of lathe checks L:

$L\ (\%) = 65.40 + 11.40\alpha + 3.14\alpha^2$

$(\alpha = K - 90^\circ)$

Likewise, the effect among the various technological parameters should also be taken into consideration.

The optimum results having been arrived at through experiments, observe and measure the width of the bright zone bearing area brought about due to the friciton of the veneer knife with the log. This maybe used as a simplified device for checking up the correctness of setting angle.

E. Effective Use of Backing-up Rolls

Back-up rolls have to be used for peeling logs under 250 mm in diameter, as otherwise, the veneers turned out, may have portions near to the edges thicker than at the middle, with surface of the veneer ribbon perceptively concaved or convexed, due to the lack of stiffness of smaller logs during peeling operation.

If not functioning adequately, back-up rolls not only would not contribute to the increase of veneer yield, but would also result in a drop in veneer quality.

The adequacy of the application of back-up rolls may be judged by the following phenomena:

1. Warping, dish-like appearance and breakage of the veneer ribbon.
2. Thicker veneer near the edges of the veneer ribbon than at the middle.
3. Barrel-shaped wood cores, the middle part having a corrugated surface.

In addition, the nominal thickness indicated for peeling will mainly depend on three factors: 1) the density of wood, 2) the surface quality of the veneer, and 3) the variables in hot pressing. When these factors are closely controlled, a yield increase of five per cent is possible.

The above mentioned conditions are evidence of inadequacy in the application of back-up rolls. The following are some of the points which have to be taken notice of when using back-up rolls:

1. The rotary lathe needs to be properly maintained. Loose machine assembly joints, wobbly or misaligned chuck spindles, worn out pitch rail and other deficiencies in maintenance work could render back-up rolls entirely useless.
2. Cutting knife and nosebar need to be accurately set up and properly adjusted. Otherwise, the backing-up effect would be seriously nullified.
3. The setting of cutting knife, when using back-up rolls, should preferably be such that the veneer ribbon produced would be slightly "dish-shaped" at the middle (to such an extent that the veneer ribbon would still nearly lie flat on the tray). For this purpose, the following directions may be followed:

a. Insert a filler piece of say 0.4 mm at the mid-length of the veneer knife so as to project the middle of the knife against the axis of the chuck spindle; or

b. Hone or grind the veneer knife so that the middle part is higher by about 0.8 mm than both ends.

4. As the pressure to be exerted on the log by back-up rolls varies with different wood species, so proper pressure for a particular wood specie must be ascertained by experiments, raising the pressure gradually, when the rolls are applied to the log, until a flat, straight veneer ribbon is obtained which is warp free.

5. Test the gap between a pair of wood cores. Hold them tightly together to see if the gap is about 2 - 3 mm in order to prove that the adjustments of cutting mechanism and the pressure of back-up rolls are appropriate.

The application of back-up rolls decreases the diameter of peeler cores, and increases veneer yield due to the increases of veneer from the heartwood in particular, the latter being easier to dry, also helps to increase the efficiency of veneer dyring.

Certain wood species, like Mahogany are rather difficult to peel due to the looseness of heartwood, large annual rings and heart eccentricity. As a rule, heartwood having 4 - 6 annual rings to the inch produces good veneers.

IV. VENEER SLICING

Sliced veneers are radially cut thin lumber usually under 1 mm in thickness, though thicker veneers of 1.0 - 1.2 mm are also sliced for specialty purposes. The surface of sliced veneer is generally straight grained, suitable for use as decorative material for panelling, furniture and other wood products.

The preparation of logs for manufacture of sliced veneer is similar to rotary cutting. The other processes involved are flitching, hydrothermic treatment of flitches, slicing, drying and matching for figure, etc.

Slicing is usually done on a slicer, but "rotary cut" sliced veneer may also be made on a rotary lathe equipped with a staylog.

1. <u>Preparation of Flitch</u>

Flitching, that is sawing flitches from a log, is usually performed on bandmills, though circular saws are also used instead or as a subsidiary equipment.

Good figure and yield are the two main factors which should be taken into consideration in flitching, which may be done in various ways. The more usual ones are balking with waney corners, breaking down the log into halves and sectoring. The last device is most advantageously done on a carriage circular sawmill. Flitches must be free from shakes, cracks and other defects. The average yield of flitch from a log is usually 50 to 65 percent, though logs of larger diameters (70 cm and up) may have a yield of up to 70 percent.

2. <u>Hydro-thermic Treatment</u>

Most of the raw materials used for slicing are of high quality dense hardwoods, so particular care should be taken in their hydrothermic treatment by rigidly adhering to the relevant technological specifications to prevent splitting.

Either steam or hot water may be used. The equipment for such treatment is similar to that for rotary cutting, with the exception of using stainless steel instead of concrete in the inner lining to prevent contamination of the wood.

Cooking of the logs not only softens the wood, but it also removes rosin and other extractives which are detrimental to the drying and gluing of the veneers. Cooking is apt to discolor wood from species containing an excess of tannin or of light color and in this case, steaming should be resorted to instead.

Temperature of treatment: 70-90^{0}C, too high a temperature is apt to injure the mechanical properties of the wood. Time of treatment: 40-80 hours, depending on the species and size of wood.

Rate of temperature rise: for species liable to split, e.g., Chinese Ash and Mahogany, 5 - 6°C/hour. For species of average hardwoods, e.g., Walnut and Camphorwood, 7 - 8°C/hour. For species having an excess of medullary rays conducting heat more easily in the radial direction, e.g., Oak and Beech, 10°C/hour.

Temperature of wood core required: 40 - 50°C. For species of low specific gravity, 30 - 35°C may be adopted.

3. Slicing

Slicing is a relative motion taking place between the knife and the flitch. The techniques of slicing are various; the slicer performing the reciprocating movement with the flitch fixed in position, or vice versa, horizontal slicing and vertical slicing, the slicer knives moving above or underneath the flitch stock.

The prevailing types used in practice are the horizontal and vertical slicers.

In the horizontal slicer, the flitch is secured on the slicer bed with the knife frame reciprocating in a horizontal direction. The flitch is elevated by a predetermined distance with each stroke, equal to the thickness of the veneer desired. On the contrary, in the vertical slicer, the flitch is secured on a slicer bed, and slicing is done by vertical movement of the flitch which advances by a distance equivalent to the thickness of veneer to be turned out.

The vertical slicer, has the advantage of faster slicing speeds, but for high class dense hardwoods, this has to be reduced.

Disadvantages of vertical slicers:

1. vertical slicers are less versatile the size of flitch capable of being sliced is smaller than the horizontal type.
2. Flitch holding mechanism is less rigid, and the flitch is less secured, and there is the risk of unsafe handling.
3. Loading the flitch and removing the veneer is difficult. In vertical slicing, bigger working crews are needed than with the horizontal type.

Hence, horizontal slicers are far more popular than the vertical type.

The technological conditions of slicing:

Bevel angle of slicing knife (β) = 16 - 20°.

Clearance angle (α) = $0^{\circ}15' - 1^{\circ}30'$

The gap between pressure bar and slicing knife (b_1) = (0.6 - 0.9)S

where S is the nominal thickness of veneer.

The clearance angle of pressure bar (λ) = 10 - 30°

Radius of the edge of pressure bar (r) = 0.5 - 1.0 mm

4. <u>The Flattening of Sliced Veneer</u>

Sliced veneers being of dense hardwoods, are apt to warp and so need flattening by moistening and pressing.

Veneer sliced from stumps or burls to produce special grain and figure effects is more liable to breakage and so must be soaked in softening solutions for several minutes, dripped dry and then flattened.

Preparation of softening solution:

Water	63 (parts by weight)
Glycerin	5
Alcohol	16
Animal glue	16

For specialty purpose, the sliced veneer may be dyed.

V. VENEER DRYING

The purpose of veneer drying is to reduce the moisture content of veneers to the required standard for gluing.

The quality requirements of dried veneers are:

1. Moisture content shall be acceptable for gluing.
2. Moisture content should be evenly distributed.

3. Veneer should remain flat after leaving the dryer.

There are various types of veneer dryers, differing from each other in the manner of air circulation and the heating medium used.

1) Classification by the manner of air circulation -- lengthwise, corsswise or by jet air impingement.
2) Classification by the heating medium and the heating source - steam, hot water, hot oil, coal gas, liquified petroleum gas, natural gas, propane. Recently, infra-red and microwave techniques have also been used for subsidiary heating.

Furthermore, dryers differ in the manner of veneer conveying, two main categories being recognized - roller type and mesh-belt type.

1. <u>Factors Influencing the Drying Rate of Veneer</u>

The drying rate of veneer depends on the temperature of drying medium, the velocity of air circulation, wood species and veneer thickness.

1. Temperature of the heating medium.

The higher the temperature of heating medium, the faster the drying rate will be.

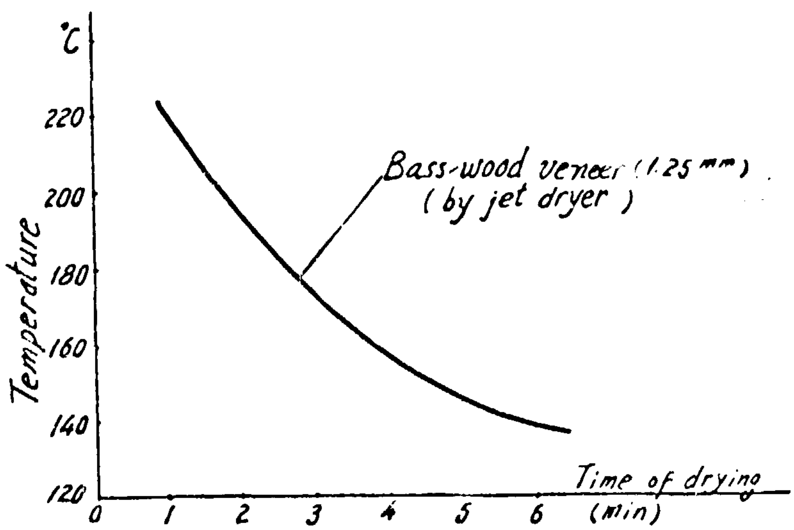


Fig. 7: **Effect of temperature on drying time of basswood veneer.**

However, should the temperature of drying be too high, the veneers would be adversely affected. (a) Case-hardening of the veneers occurs when the wood cells are sealed due to high temperature and dispersion of moisture is restricted thereby. (b) Gluability is affected. (c) The contamination of ambient atmosphere due to emissions of volatiles contained in the wood. That is why until quite recently, it has been held that the temperature of veneer dryers should not exceed 200°C. However,

such a limit could be disregarded, by using high temperature at the stage of high moisture content and reducing the temperature of the heating medium at the stage of lower moisture content, thereby making it possible to raise the drying temperature at the stage of high moisture content even to above 400°C.

2. Velocity of circulating air.

Under a given drying temperature, the higher the velocity of circulating air, the faster will be the speed of drying. The velocity of both the lengthwise and the cross wise air circulating systems are relatively low (2 - 4 m/sec). This is because of the fact in the case of either the lengthwise or crosswise system, when the air stream gets in touch with the veneer surface, it produces friction, forming a laminar flow which handicaps heat transmission. Even if the speed of air circulation is increased, a laminar flow would still be developed, and therefore, little improvement could be made. So, the more efficient device of drying by jet impingement has to be resorted to. This is to impinge a hot air flow perpendicularly forming a turbulent flow onto the veneer surface to rapidly break the boundary layer. It not only serves to drive away the film of saturated steam, thereby increasing the drying rate.

3. Wood species and veneer thickness

The coefficient of conductivity and specific heat vary with different species, and hence cause differences in drying speeds. The drying of Chinese Ash veneers of 1.25 mm thickness is 20 per cent faster than Chinese Basswood veneers of the same thickness. Obviously, the thicker the veneers, the slower the drying speed.

2. Improving the Efficiency of Jet Dryers

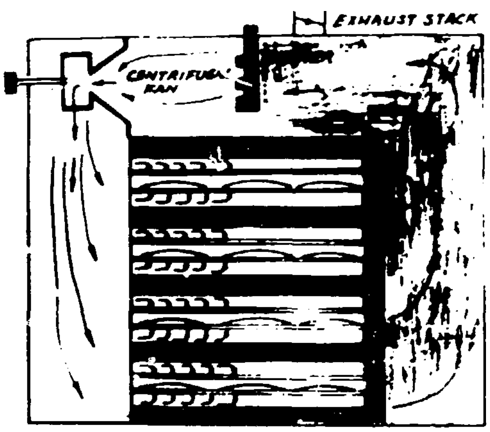
1. Increasing dryer production.

The drying rate of veneer may be speeded up by (a) increasing the volume of impinging air at the same air velocity, (b) increasing both velocity and volume of impinging air.

The velocity of air flow is a function of its static pressure. The higher velocity of air requires high static pressure. But it is impossible to develop a higher static pressure by an axial flow fan. Hence, a centrifugal fan has to be used instead.

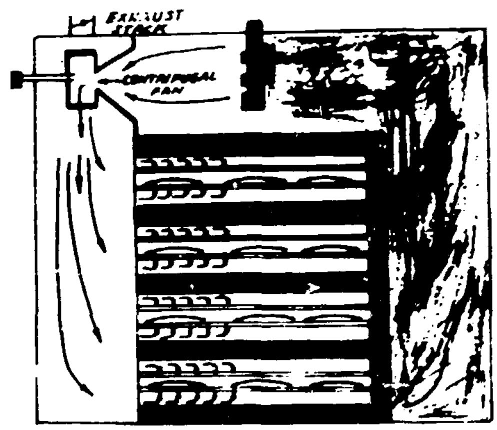
When the volume of air flow is increased by the use of centrifugal fans, it is possible to triple the air flow volume at higher velocities by increasing the rows of jets from one to three for each jet tube, thereby increasing the rate of production by at least ten per cent.

Fig. 8: Circulation of hot air in a veneer dryer (conventional exhaust stack location).



Centrifugal fans located downstream from the burner increase static pressure. If conventional exhaust stack location is maintained, exhaust blower must be in stack to overcome negative pressure.

Fig. 9: Circulation of air in a veneer dryer (exhaust stack is moved).



If exhaust stack is moved to positive pressure side of fan and damper exhaust valves are used to control - some heated air is lost however.

2. Additional Aids to Drying.

To increase the drying temperature at the stage of high moisture content, some plants have used infrared energy with a temperature of as high as 1,000 °C upwards, which raises the temperature of green veneer very rapidly. Production increases of 10-20 per cent are thereby possible.

Experiments with coniferous veneers in various thickness show that the speed of drying can be increased by at least ten per cent by using micro waves for subsidiary heating, the characteristics of which being: the higher the moisture content of veneer, the faster the veneer will be heated. An even veneer moisture content can be achieved, eliminating wet spots and reducing the difference in moisture content between the upper and lower decks, thereby minimizing the amount of re-drying and avoiding at the same time the development of over-dyring.

4. Moisture Exhaust

The exhaust of the large amount of vapor during the drying process carries away with it large amount of heating energy, too. Then, the fresh air taken in needs to be heated again. Early research work pointed out that at drying temperatures above 150°C, no replacement of fresh air whatever is needed by the dryer, for at that temperature, the equilibrium moisture content of veneer being only one per cent, it will still be able to dry the veneer to the moisture content required, even if the drying medium is entirely water vapor (fig. 10). Plant practice has proved that the consumption of heat energy could be drastically reduced. Super-heated steam exceeding 150°C could accelerate drying rate by 15 - 25 per cent. There is controversy among plant technicians regarding this proposition, however, it has been proved to be true by a number of experiments and practices.

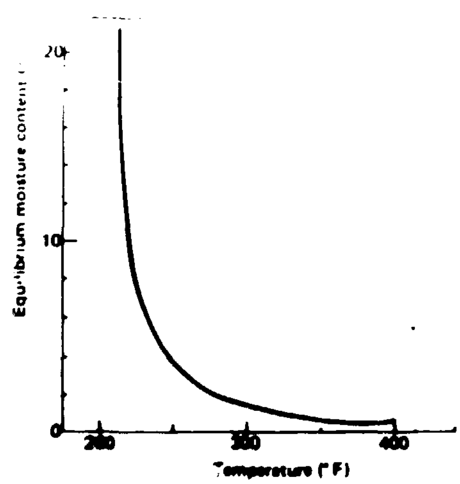


Fig. 10 - Equilibrium moisture content of softwood in superheated steam at atmospheric pressure

VI. VENEER CLIPPING

Though veneer clipping is quite a simple process it still involves some degree of complication in that it concerns the yield and grading of plywood turned out, and yet these two targets - yield and grading - are contradictory. The solution of this contradiction can only be found in efficient management.

1) Operation Management

The clipperman should clip the veneer with precision, making adequate allowances. Clippings should be made as little as possible at the leading and trailing edges of veneer strips. Care must be taken to avoid over-clipping when cutting out defects from the veneers.

Accuracy of the clipping machine should be carefully maintained. A default or delay of the pneumatic valve or a slip of the conveyor in-feed belt would cause waste of wood.

An appropriately prepared work instruction manual serves to raise the average grade of plywood panels produced. These work instructions, being characteristic of the production of an individual plywood plant, are seldom alike between different plants.

The most difficult problem encountered in veneer clipping is that when the clipperman has to make an instantaneous optimum decision in a contradictory choice between yield and grading, taking into consideration, as well, the diversity of end products of or end-uses in the plant. For instance, for plants producing high grade panels, the clipping into first class veneer strips of random widths should be preferred to full-sized sheets of lower grade; while for those producing panels for packaging purposes, clippings for the maximum amount of full-sized sheets of lower grades should be the rule. However, in most cases, the situation is not so obvious whether it is advantageous to clip into strips of random widths for higher grade or to give the priority to full-sized sheets or wider strips with a view to increased plywood yield. A decision under circumstances like this should be made on the basis of profitability as a primary consideration.

The specified dimensions of veneers required and the equilibrium among face, back, core (crossband) veneers is a pre-requisite condition for the proper running of plywood production, and therefore, these factors should be taken into consideration, too.

2. Process Control

The mathematical statistics used in veneer quality control are applicable also to veneer clipping process. For details, please refer to the section on veneer quality control

VII. SPLICING OF CORES AND CROSSBANDS

The splicing of cores (crossbands) is a pre-requisite for mechanized lay-up, and it was not until the advent of the techniques of splicing of veneer strips that the systems of mechanized lay-up were formally adopted in plywood manufacture.

By splicing of cores (crossbands) is meant the joining or edge jointing of veneer strips of random widths into an integrated full-sized sheet, generally using either one of the following two methods: 1) sewing or stitching: and 2) stringing.

1. Sewing or Stitching

This was originated by the Coe Manufacturing Co. of US in 1963. These veneer stitchers sew or stitch up five to eight nylon or polyester strands of 0.20 - 0.25 mm in diameter across the grain of the veneer strips. For veneers over 3 mm in thickness, perforation prior to stitching is necessary, and these two operations are done in succession by the same head. The veneer strips are then spliced into continuous ribbons. The technique of stitching green veneer strips was developed in 1972, and put into operation in the next year. Heretofore, stitching was practiced on dried veneers.

A veneer stitching machine has recently be developed in Shanghai, comprising the functions of feeding, edge-to-edge crowding, stitching up, clipping to required dimensions and mechanized stacking. The machine operates on green veneers at a feeding speed of 12 m/min with 5 and 7 stitch lines on 3' and 4' wide cores respectively. The tensile strength of a single strand is 27 kg. Performances in drying, glue application and hot-pressing are satisfactory.

Compared with splicing dried veneers, the technique of splicing green veneers has the obvious advantage of increasing the rate of veneer recovery. A considerable amount of irregular veneer strips developed in rounding up the bolts and many very narrow strips (so-called "fish tails") can be salvaged which, in all, may comprise some 15 to 35 per cent of the total green veneer yield. Certainly, less damage such as end splitting occurs to the spliced core veneers during drying or in transit, and hence less wastage from re-clipping. Normally, the average waste of drying non-spliced veneer strips is about ten per cent, while that of the spliced full-sized sheet is nearly zero. The damage incurred in transit may likewise be reduced to a minimum. As a result, the rate of veneer recovery could be raised by four to seven per cent.

2. Stringing

This is done by pressing hot-melt resin coated glass fibers across the grain on the surface of veneer strips so as to splice them into a continuous ribbon, to be clipped into full-sized core sheets. This kind of equipment is called a stringing machine or core veneer composer which involves the functions of feeding, edge-to-edge crowding of veneer strips, pressing of hot melt string, clipping and mechanized stacking. Three pairs or six strings are distributed across the grain of the veneer of which two pairs are pressed at a distance of 20 - 25 mm from the edges. The remaining pair is located at the middle with a space of 2.5 cm between the two strings. Otherwise, 5 single strings may be used instead of 3 strings pressed on the face side, and the other 2, near the respective edges on the reverse side in order to obtain an equillibrium of strains between the two sides.

The application of hot-melt resin or the strings may be done in either of two ways: precoating or on-site. While pre-coating facilitates application, it requires a heating element to melt the adhesive before the string could be pressed on the veneer by means of a cold roll. The on-site coater comprises a hot glue pot and weighing device. Though it is difficult to obtain an even glue spread by this latter method, nevertheless, it is lower in cost and its application is more easily accomplished by a mere cold roll pressing. Hence, its use is comparatively conventional.

As the quality of peeler logs continues to decline and their diameter decreases, the amount of veneers in the form of narrow strips developed in peeling is bound to increase, and consequently splicing technique should become more and more important. As a principle, it is always advantageous to minimize the handling of veneer in the form of narrow strips to avoid or to lessen damage. Hence, the best way to do the job is to splice the veneer strips into full-size sheets.

However, the techniques and relevant equipment of splicing core (crossband) veneers have yet to be further improved. For instance, the side-to-side crowding mechanism is a very important component part for which further research should be directed toward the elimination of any possible overlaps or gaps at a faster feed speed, and also towards the automatic compensation for the deviation of slanted veneer strips to a fan-shaped course. At present, when such a deviation does occur during side-to-side crowding of the veneer strips, the usual remedy is a manual insertion of a compensatory veneer strip. Obviously, this is not a good practice.

In the stringing method, the hot-melt adhesives now being used are of different types respectively for summer and winter climates and so research work, in particular, has to be carried on for the formulation of an adhesive that will serve all the year round.

Moreover, the shelf life of hot melt adhesive for stringing is too short. When the stitching expands on absorbing ambient moisture, it loosens and warping may result. Therefore, it would be of interest to the plywood industry that these deficiencies be remedied soon for the benefit of the plywood manufacture.

VIII. GLUE APPLICATION

The application of glue in plywood manufacture has long since been done by spreading adhesives on both surfaces of the veneer by means of hard rubber rolls. Not until the 60's, were improvements in the techniques of glue application gradually made which would permit development of automated or mechanized lay-up of glue-coated veneer packages.

In addition to the traditional method of applying glue by means of hard rolls, there are four methods of glue application:

1) Applying Glue by Soft Rubber Rolls

These rolls are made of close-celled sponge rubber, and are usually used on automated lay-up lines. They are sub-divided into two different types:

1. Insulation Type. The rolls are made of soft sponge rubber, and having a short working life, require frequent replacement.

2. Neoprene Type. Used in ordinary lay-up systems, and have a long working life. An even and thin glue line can be obtained by using soft rubber rolls of this type.

2) Curtain-coating

This is transplanted from a similar practice used in paint-on techniques, and has two different types:

1. Pressure Type. In this type, adhesives are transferred from storage tank by means of a positive displacement pump. The adhesives form a glue film through an orifice and spread on the veneer sheet. The rpm of the glue pump and the feed speed of veneer control the amount of glue deposited onto the veneer sheet. Surplus adhesive

is returned to the storage tank, and so there is very little wastage. This type of curtain-coating is usually used for spreading phenol formaldehyde resin adhesive.

2. Gravity Type. This was much used before the appearance of the pressure type. It has the disadvantage of being difficult to control the speed of curtain-coating and involves a higher investment cost.

Compared with traditional glue spreading it is insensitive to thickness variation of veneer, being incapable of discriminating and hence rejecting the veneer strips which exceed the range of thickness variation permitted. On the other hand, however, some advocators of curtain-coating hold that this should be an advantage since with curtain-coating the spra.line "can tolerate a reasonable amount of thick-and-thin veneer with no detrimental effect on the plywood panel", contributing to a reduction of glue waste, besides a saving in man power requirement and a better bond quality.

3) The Spray Line

This is also transplanted from the technology of spray painting. The adhesives are sprayed by an atomizing nozzle under a pressure of about 20 kg/cm^2.

1. Air-blast Spraying. The adhesive being mixed with air is forced out through a nozzle to form a mist spray.

2. Airless Spraying. The adhesives are forced out under pressure through an orifice, forming a mist spray much like the air-blast spraying. But, being air-free, it is not so diffused as to result in an over-spray.

In both of the above mentioned forms of spray lines, the amount of glue spread is controlled by adjusting the feeding speed of veneer or by modifying the size of the nozzle, but neither of these two methods are reliable since the main cause of trouble is the choking of the spraying nozzle itself.

4) Glue Application by Extrusion

In this type of glue application, the adhesive is conveyed by a constant displacement pump to foaming equipment which expands the adhesive to five times its original volume, and then applied on the veneer surface by an extrusion mechanism. The extruded adhesive cords are rod-like, and hence, are called "spaghetti" (slender and solid maccaroni), about 2.5 mm in diameter, and applied on the veneer surface, spacing by 5 mm. The adhesives applied in this form has a very good water-holding ability, and so, even if applied on hot veneers, it will not dry out. Consequently, there is a saving in the glue spread. However, the slowness of the process, is an apparent disadvantage affecting production efficiency.

The glue spreading equipment now generally used in China are the traditional roll spreaders, double-rolled and quadruple-rolled.

The following table (Table 1) shows the constituents of UF adhesives and the amounts spread in different countries.

IX LAYING-UP

The lay-up process is the assembling of glue-coated core-veneers and cross-bands with the face and back veneers which are prepared in advance to form packages of three or more layers for pressing into plywood panels.

1) Manual Lay-up

The glue-coated core veneers and crossband absorb considerable amount of water from the adhesives, and are apt to expand during the lay-up process. So adequate allowance has to be made to accomodate veneers of random width. Due to the differences in width of veneer strips, log quality (heartwood or sapwood) and other factors, the extent of expansion can be pre-determined only with great difficulty. Too big or too small an allowance would likely cause an over-lap or a gap. Hence, it is imperative that the working crew involved in the process should be technically skilled.

Table 1 - The constituent of UF adhesives for plywood and the amount of glue spreading

1	2	3	4	5	6	7	8	9
Constituent	Hardwood plywood (USA)	plywood (Mexico)	plywood (Canada)	plywood (Japan)	plywood (South Pacific)	plywood (Australia)	Hardwood plywood (China)	(Shanghai area)
1. Resin	200	100	980	200	40	400	100	100
2. Solid contents (%)	(65)	(65)	(65)	(44)	(65)	(55)	(65)	(49)
3. Extender (Wheat flour)	100	85	60	60	20	220	5	8
4. Filler (Walnut shell powder)	15	15	-	-	10	-	-	-
5. Catalyst NH_4 Cl	16	5	14	1	10	15	1	0.6
6. Water	80	95	550	40	20	140	20	-
7. Others	-	-	7	8	-	50	-	-
8. Total Parts by Weight	411	300	2120	300	100	825	126	108.6
9. Solid content in glue (%)	59.6	55.0	56.5	49.3	56.0	53.3	56	54.3
10. Solid resin (%) of which	31.6	21.6	29.0	29.3	26.0	26.6	52	45.1
11. Extender and filler (%)	28.0	33.3	27.5	20.0	30.0	26.7	4	9.2
12. Water (%)	40.4	45.0	43.5	30.7	44.0	46.7	44	45.7
13. Amount of glue spreading (double line g/m^2)	391	394-464	366	391	391-435	415	350	350
of which: 14. Solid resin (g/m^2)	141	85-100	109-131	115	102-111	110	182	152
15. Extender and filler (g/m^2)	110	130-155	97-116	65	117-132	111	14	32
16. Water (g/m^2)	158	176-209	159-191	198	172-193	194	154	160

In some plywood palnts where manual lay-up is still being practised the glue-coated cores or cross bands are allowed to undergo an assembling time for 15 to 20 minutes before sending into the press.

By the start of the 60's, research into automated lay-up techniques and equipment was undertaken by the plywood industries in various countries. The big handicap to be overcome is the randomness of the widths of veneer strips. The automation of lay-up could only come about with the onset of the spliced core or crossband veneer strips into full-sized veneer sheets.

2) Mechanized Lay-up

The process of mechanized lay-up usually forms a production line with the glue spreader.

Differing in terms of techniques of glue spreading - roll coating which applies the glue on both sides of the veneer, and curtain-coating, spraying or extrusion which applies the glue on only one side - the composition of mechanized lay-up lines falls under two categories:

1. Mechanized lay-up line with a roll-spreader.

This system comprises a pneumatic veneer conveyor, infeed rolls, conveying mechanism for face and back veneers, lay-up lifting table and roll spreader. The cores are fed to the spreader rolls by the concerted actions of the pneumatic conveyor and infeed rolls, which are synchronized with the speed of spreader rolls. The glue-coated veneer cores automatically drop on the back veneer which has already been delivered there. A guard plate keeps the back and core veneers neatly stacked on one end.

The face and back veneers are carried by the pneumatic conveyor and infeed rolls respectively to the upper and lower decks of a conveying mechanism. The back veneer which is on the upper deck drops onto the face veneer which is on the lower deck when the former is released by automatically opening the supporting grate thereof.

The piled up face and back veneers are then conveyed to the assembly table. When the conveying mechanism retracts, the piled up face and back veneers are retained by the guide plate, lying on the glue-coated core or crossband veneers which are already there, thus completing the assembly or lay-up process. All these steps are carried on automatically as programmed.

2. Mechanized lay-up line with a curtain-coater.

Curtain-coating (spray line) is suitable for spreading phenol formaldehyde resin adhesives. It comprises two parts: 1) the curtain-coater which coats the core and back (crossband) veneers on one side, dropping them automatically to be neatly stacked on the lay-up lifting table; and 2) the conveying mechanism for the face veneers which are carried by a pneumatic conveyor onto a supporting frame over the lay-up table. When enough layers of back and core (crossband) veneers as required have been accumulated, the supporting frame releases the face veneers to drop on the packages of core (crossband) and back veneers underneath, and neatly stacks them on one end. And this completes the lay-up process.

The laid-up packages of glue-coated veneers are then sent to pre-pressing or directly to the loader of the hot press.

X. HOT PRESSING

The function of hot pressing is two-fold: 1) to effect a tight contact of the layers under the action of pressure, and 2) to evaporate the solvent contained in the adhesive (chiefly water) and to expedite the curing of the adhesive, bringing the process of adhesion to an end.

1) Pressure

The pressure required for hot pressing varies with the wood species and types of adhesives used. Hardwoods of high density require higher pressure, and vice versa. Adhesives of higher viscosity also require high pressure so as to obtain uniformity in the thickness of glue line.

For ordinary plywood, the ranges of pressure requirements are:

Low density hardwood	10-12 kg/cm^2	(sp. gr. $<$ 0.45)
High density hardwood	12-15 kg/cm^2	(sp. gr. $<$ 0.70)
Extra high density hardwood	15-18 kg/cm^2	(sp. gr. $>$ 0.70)

The plywoods made in China are mainly of high density hardwoods, and the pressure used in hot pressing is inclined toward the higher levels.

Increase in pressure increases the strength and surface hardness of the plywood turned out. For specialty products such as **aircraft** plywood, the pressure used is 20-25 kg/cm^2; for marine plywood, 35-40 kg/cm^2.

With ordinary plywoods with no special requirements with respect to mechanical characteristics, the **reduction of compression** in hot pressing has an important bearing on plywood yield. Any one of the three parameters of temperature, pressure and length of pressing cycle has its influence on compressibility. Research work and mill experience indicate that the two-step process is profitable. In the first step, an initial pressure equal to or slightly higher than as rated is applied for a duration of sustained pressure of about 1-2 minutes, varying with the thickness of laid-up veneer package. This is to expel the air contained in the veneer package and to tighten the contact of the veneer to assure the optimum thickness of glue line. In the second step, pressure is reduced to 2-4 kg/cm^2 in order to cure the glue line under low pressure and to expedite moisture discharge. In this way, the length of high pressure time becomes very short which obviously serves to reduce the compressibility.

2) Temperature

High temperature expedites moisture evaporation and the curing of the glue line. However, with certain wood species of high resin content, the evaporation of moisture is relatively more difficult. In such a case, too high a temperature is not to be recommended.

In multiple layered plywood panels or when an excessive number of packages of assembled veneers is loaded in a daylight, too high a temperature may result in blistering.

What is more important, besides, is that high temperature means high compressibility.

The ranges of temperature listed below are generally accepted as adequate for the respective resin adhesives.

Phenol formaldehyde resin	135 - 145°C
Urea formaldehyde resin	110 - 120°C

3) Length of Pressure Cycle

This is determined by a number of factors: the thickness of laid-up package, the speed of the curing of the adhesives, and the rate of moisture evaporation.

The application of adhesives brings with it considerable amounts of water which elevate the moisture content of core veneer from 8 - 12 per cent to 20 - 25 per cent and hence, lengthens the time required for hot pressing. Protein based glues bring with them still more water.

The empirical rule for calculating the length of pressure cycle in terms of the thickness of laid-up veneer package is: 45 - 50 seconds for each mm of thickness, if urea formaldehyde resin adhesives are used. For phenol formaldehyde resin adhesives some 15 to 20 per cent more time is required. For protein-based glues, still more pressure time is required.

The length of hot-pressing cycle is a key-point in respect of production capacity of a plywood plant, and so plywood manufacturers, as a rule, have done their best to shorten it. Generally, they lay stress on research and application of fast-curing adhesives. However, improvements in glue spreading techniques and equipment with a view to reduce the glue spread to a minimum and to avoid excessive moisture brought into the laid-up veneer package are also being emphasized.

Due to these efforts, the pressing time of 19 mm softwood panels has been shortened from 7 min. to 4 3/4 min. in U.S.A.

Tactically, irrespective of production capacity, the putting of too many packages of laid-up veneer in a daylight is not an advantage. Take, for instance, the pressing of a single package of laid-up veneer with that consisting of four packages for comparison. Though the number of packages contained in a daylight is increased by four-fold, the time required for the heat to reach the core of the thick veneer package far exceeds four times as much. And, moreover, in respect of quality of glue line and thickness variation of finished panel product, the latter case is inferior to the former. Nevertheless, in view of the fact that the time required to load and unload the packages is nearly the same in both cases irrespective of the thickness of the packages, plywood plants would usually put two packages of laid-up veneer in each daylight instead of one.

Two rules of application of heat and pressure during hot pressing process are:

1. Heat applied and time of heating should be kept to a minimum.

2. Never attempt to speed up production by using excessive heat or pressure.

Excessive heat or pressure causes excessive reduction in thickness of panels. The plasticity of wood increases rapidly at temperatures above 100°C.

XI. SANDING AND SURFACE FINISHING

The equipment widely used for surface sanding of plywood panels are drum sanders and wide belt sanders. The drum sander has had also a long history, and because of its relatively low efficiency, is being replaced gradually by wide belt sanders.

1) Drum Sanders

The sander consists of 2 - 4 sanding drums. The first drum covered with rough sand paper is used for rapid wood removal, then follows a finer sand paper and the last a finishing grade. Silicon carbide in grits from 80 to 120 is commonly used for abrasives, but aluminium oxide is said to be the best abrasive for heavy sanding.

During operation, drums are given an axial oscillating motion in addition to rotation.

Amplitude of oscillation	9.5 mm
Frequency of oscillation	20 - 25 cycles/min.

Some technical data of drum sanders are:

Peripheral speed of drum	20-30 m/min.
Feed speed	12-18 m/min (for hardwood)
	24-60 m/min (for softwood)
Depth of sanding	0.15 - 0.70 mm

2) Wide Belt Sanders

The wide belt sarder is often connected with the dimensioning saws, forming an integrated dimensioning-sanding processing line, comprising accessory equipment such as in-feed, out-feed and stacking mechanism. Due to the ever-increasing demand for unsanded panels, however, sanding machines have been installed to function independently.

Wide belt sanders are of: 1) single belt type, suitable for sanding the back side of panels and 2) triple belt type, used for sanding the face side of panels. The maximum in-feed speed is up to 90 m/min, the speed of sanding belt is up to 1550 m/min.

Much like drum-sanding, the wide belt sander, during its operation, oscillates along the axis to assure the desired sanding quality.

Defects often happening in the process of sanding and their rectification are:

1. Sand-through. Lower the pressing shoe, and slightly raise the pressure rolls.

2. Waviness in Finishing. Clean the belt to remove the built-up materials (sander dust, resin, etc.) on the surface of sanding belt or change for a new belt, adjust the tension of infeed conveyor belt, check up and adjust the level of the respective pairs of pressure rolls.

3. Taper on one end of panel. Adjust the levelness of the surface of the table, tighten locking device and remove the build-up of materials on the surface of pressure rolls.

4. Damage on leading end of panel. Lower infeed pressing shoe. In sanding short panels, overlap the ends of successive panels in infeeding.

5. Damage on trailing end of panel. Lower outfeel pressing shoe. Slightly elevate infeed pressing shoe.

6. Sander Machine vibrating. Adjust the equilibrium of contact rolls, replace bearings of contact rolls. Replace driving belt of electric motor, or sanding belt, if necessary. Adjust other driving mechanisms, if loosened.

XII. POLLUTION CONTROL

The main sources of pollution
of cooking vats, veneer dryer emissions and waste water from glueroom. The extent of pollution of the plywood industry is not a prodigious one at least quantitatively, however, it has a certain degree of perniciousness.

1) Effluent from Cooking Vat

The cooking vat uses ample water which darkens with the accumulation of wood solvents such as resin, sugars and a number of suspensions of fibers and bark shreds, which elevates the BOD and COD to 1,200 and 6000 mg/l upwards respectively , and results in water pollution, if it is not properly treated.

A plywood plant of 20,000 m^3/yr capacity has a sludge discharge of about twenty liters/hour (solid content fifty per cent), comprising 3 - 4 per cent of the total weight of waste water.

If space is available, re-cycled waste water treated by vacuum separator may be used to advantage.

Waste water from steaming or cooking vat is transferred to lagoons wherein it is automatically treated by separation equipment, and thence transferred to a mechanically aerating pond for five days treatment to reduce the BOD and COD by 85 - 90 per cent. This is then followed by treating in a 2-step natural aerating pond to achieve zero discharge of the waste water. The sludge separated out is transferred by a sludge pump or conveyor for incineration in a boiler furnace.

Evaporation may be resorted to in plants lacking space. In this device, the waste water is entirely retraced to the vat. A certain amount of waste water is evaporated through an evaporator with sludgy residue having a solid content of fifty per cent, equivalent to that from vacuum separation. A large part of the water is recycled and reused.

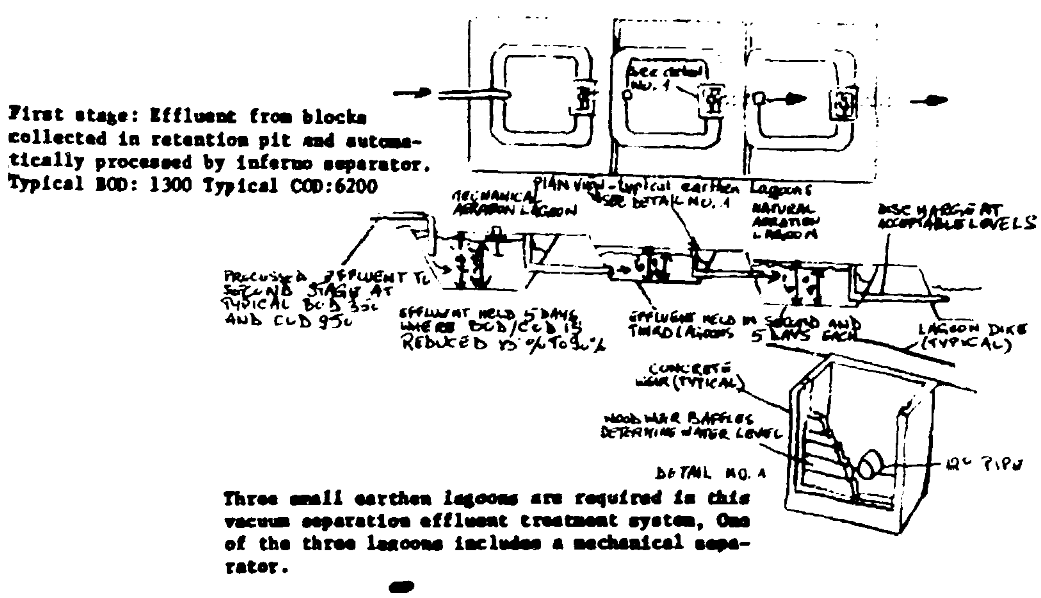


Fig. 11 : **Vacuum separation effluent treatment method.**

2) Emissions from Veneer Dryer

The air emissions from the veneer dryer contain active hydro-carbons which were not looked on as injurious previously. However, they are now calling for rigid control due to the ever-increasing emphasis on preventive measures for air-pollution

The emission from drying 1 m^3 of veneer contains 0.0046 g. of solid particulate and 250 g hydro-carbons. The latter, containing terpene and hemi-terpene constituents mix with water vapor to form the blue fumes.

The consistency of emission is expressed by opacity and the Ringlemann scale is generally followed. In the USA, the standard for allowable emission from veneer dryers is stipulated as Ringlemann Class I, opacity 20 per cent (the highest rate at Ringlemann scale is no. 5, opacity 100 per cent). The requirement for air pollution control is stipulated as ten per cent opacity at the emission outlet and 0 percent at a distance of 16 metres from the outlet.

There are three methods for emission control: filtration, incineration and scrubbing. Besides, static sedimentation is also a recommendable device for veneer dryer emission control.

1. Filtration. The emission is passed through a fiber glass filter at a flow speed above 180 meters/min, thence through a smoke separator, and then exhausted into the ambient atmosphere. This method has good effect, but it is costly.

2. Incineration. This is perhaps the most economical method. The emission is conducted to the boiler furnace by a pipe.

3. Scrubbing. This is most widely used. The emission from the veneer dryer is passed through a scrubber. By contacting the misted aqueous film, the pernicious constituents are caught by the film, thus reducing the opacity from 40 per cent to below ten per cent.

The extent of emission from a veneer dryer is closely related to the technology of drying. When temperature in the dryer exceeds 200°C, big amounts of volatile matter contained in the wood escape from fully opened ventilating dampers. Then the extent of emission would be at its maximum. If the veneers are dried for too long a time, and the ultimate moisture content becomes too low, the emission will darken in blueness. Therefore, by adequately adjusting the technological parameters, higher efficiency in plywood production and lower magnitude of emission could be achieved, thereby reducing the cost of emission control.

3) Waste Water from Glue Room

The waste water from glue spreader contains a high concentration of pollutants which are both pernicious and irritating. Formerly, it was discharged into the drains, log pond and other channels.

The glues/adhesives used in plywood plants are mainly of three types: 1) Protein-based glues, 2) phenol formaldehyde resin adhesives and 3) Urea formaldehyde resin adhesives. The sources of waste water coming from the glue mixing process are: 1) the leakage from glue tank, 2) the waste water discharged in vacuum pumping and cleansing the reactor. The waste water from the glue spreader comprises: 1) the waste water from the cleaning of the glue spreader and 2) over-flowing or leakage from the glue tank.

The amount of waste water for cleansing the glue spreader after producing 1 m^3 of plywood is about 32 liters of which the solid content of glue is two per cent, the rest is saw dust, splinters and suspended matters. Preventative measures such as good maintenance to avoid leakage, proper management to prevent over-flowing are of primary importance, followed by an effective closed system to recycle and re-use the waste water.

Items for checking up the waste water containing phenolics are: pH values, content of dissolved oxygen, opacity, odour, pernicious matter and others.

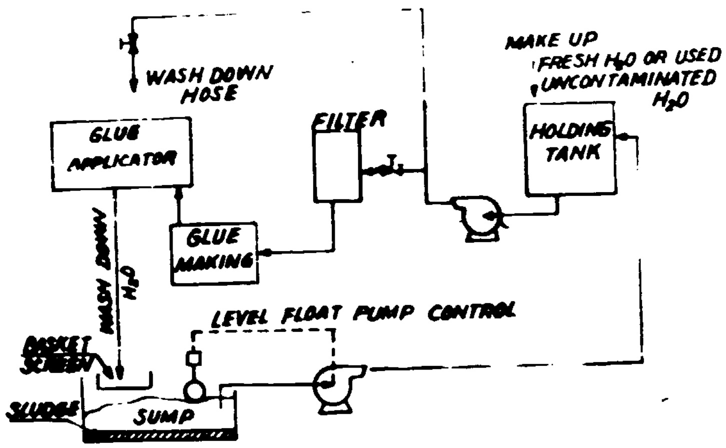


Fig. 12 - Flow diagram of recirculation of plywood glue waste water.

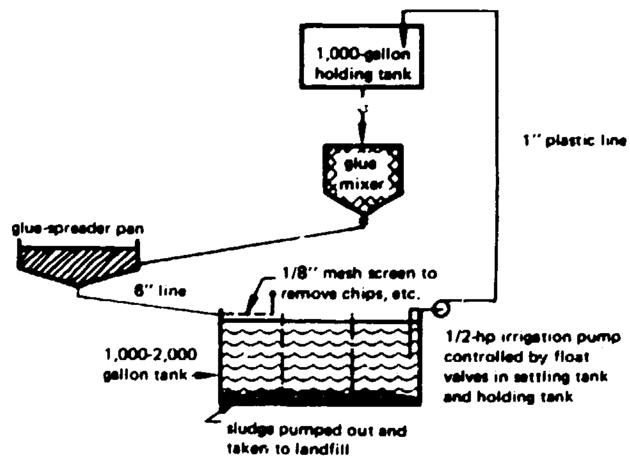


Fig. 13 - Closed glue waste water reuse system

APPENDIX

The foregoing is a brief account of the processes of the technology of plywood manufacture. Such a technology, like that of any other industry, could be nothing but the application of certain basic principles of science. Thus, the manufacture of plywood is more or less related with those branches of science such as mechanics, thermo-physics, fluid-dynamics, electronics etc. **To touch on these subjects, even superficially,** would not be within the reach of a manuscript like this, however, in order that 'know-how' of the industry might be better explained, some digressions to the following topics might not be out of place here by way of appendices.

I. FUNDAMENTAL CONCEPTS IN ROTARY CUTTING

Rotary cutting is the basis for the plywood industry. About 95 per cent or more of veneer is produced by this method.

In rotary cutting, the knife is set with its cutting edge horizontally in line with the centers of spindles. Its bevel face (ground face) is set approximately in vertical position, and tangentially to the cutting point on the bolt.

During cutting, the bolt rotates in a uniform circular motion, while the knife is in a uniform rectilinear motion. The knife moves ahead uniformly with a definite distance equal to the thickness of veneer being cut per revolution of bolt, and peels veneer off from the bolt.

1. Kinematics of rottary cutting

Locus traced out by the knife tip during cutting.

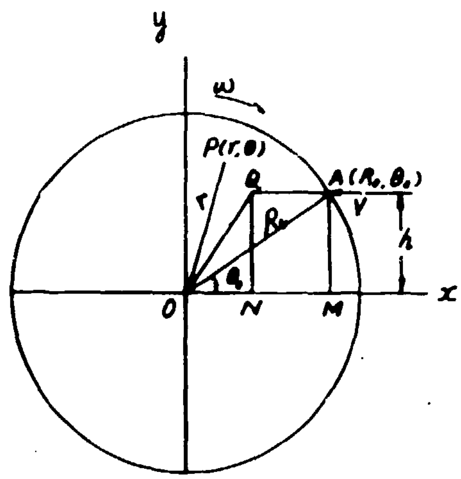


Fig. 14 - Veneer peeling diagram

From Fig. 14, A is an initial cutting point on bolt, R_o is maximum radius of bolt. h is knife setting height above the center line of spindles. When the knife edge moves from A to Q_1, point P moves simultaneously to point Q and the line OP coincides with line OQ.

$OQ = r$

$QA = OM - ON = R_o \cos \theta_o - \sqrt{r^2 - R_o^2 \sin^2 \theta_o}$

The time required for point P to move to point Q

$t = QA/v$ where v = feeding speed of knife

$$= \frac{R_o \cos \theta_o - \sqrt{r^2 - R^2 \sin^2 \theta}}{v}$$

$$\angle QOP = wt = w \frac{R_o \cos \theta_o - \sqrt{r^2 - h^2}}{v} \qquad (h = R \sin \theta)$$

where w = angular velocity of rotating bolt.

$$\angle QON = tg^{-1} \frac{r}{\sqrt{r^2 - h^2}}$$

$$\theta = \angle QOP + \angle QON = \frac{w}{v} (R_o \cos \theta_o - \sqrt{r^2 - h^2}) + tg \frac{h}{\sqrt{r^2 - h^2}}$$

$v/w = a$

$$\theta = \frac{R_o \cos \theta_o - \sqrt{r^2 - h^2}}{a} + tg^{-1} \frac{h}{\sqrt{r^2 - h^2}}$$

a) When $h = 0$

$$\theta = \frac{R_o \cos \theta_o - r}{a} = \frac{R_o - r}{a} \qquad (h = o,\ \theta = o)$$

$\therefore r = R_o - \theta a$

The cutting locus is an Archimedes spiral curve.

b) When $h = -a$ $(a = t/2\pi)$

$$\theta = \frac{R_o \cos \theta_o - \sqrt{r^2 - a^2}}{a} - tg^{-1} \frac{a}{\sqrt{r^2 - a^2}}$$

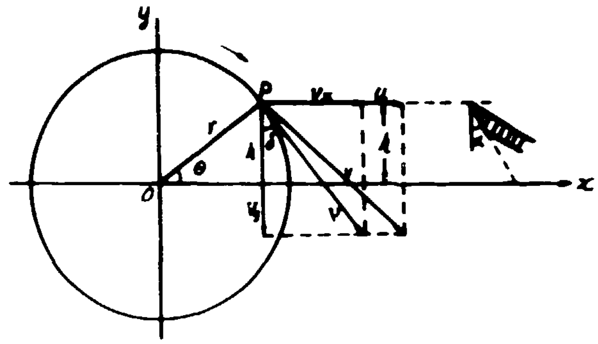
$$\theta = \frac{R_o \cos \theta_o - \sqrt{r^2 - a^2}}{a} + tg^{-1} \frac{a}{\sqrt{r^2 - a^2}} - \frac{\pi}{2}$$

(h = -a, the cutting point is below the x-axis)

The cutting locus is an involute.

2. The amount of change of angle δ

Angle δ is defined as the angle between the vertical line and tangent line of the cutting point.



v = cutting velocity
α = apparent clearance angle
$\alpha - \delta$ = effective clearance angle

Fig. 15: change of angle (δ)

when v = cutting speed — h = setting height of knife

r = radius of bolt — t = thickness of veneer

α = clearance angle ($\alpha = K - 90^{0}$) — n = rpm of bolt during cutting

$$V = 2\pi rn \qquad \sin\theta = \frac{h}{r} \qquad \cos\theta = \frac{\sqrt{r^2 - h^2}}{r}$$

$$V_x = V\sin\theta = 2\pi rn \cdot \frac{h}{r} = 2\pi hn$$

$$V_y = V\cos\theta = 2\pi rn \cdot \frac{\sqrt{r^2 - h^2}}{r} = 2\pi n\sqrt{r^2 - h^2}$$

From Fig. 15

$$\mathrm{tg}\,\delta = \frac{V_x + u}{V_y}$$

$$= \frac{2\pi hn + nt}{2\pi n\sqrt{r^2 - h^2}}$$

$$= \frac{h + \frac{t}{2\pi}}{\sqrt{r^2 - h^2}}$$

u = the linear velocity of knife tip related to the velocity of moving point P.

u = nt (mm/min)

Case I. when h = 0

$$tg\ \delta = \frac{t}{2\pi r}$$

$$\therefore \delta = tg^{-1}\ \frac{t}{2\pi r}$$

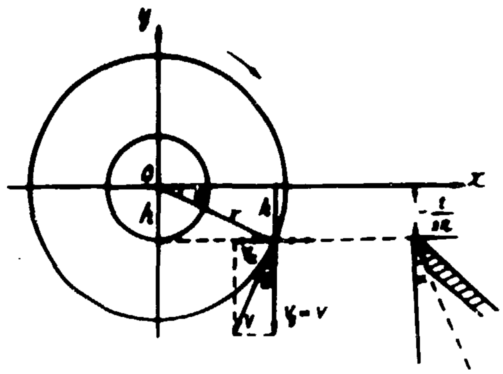
The angle δ increases as the bolt diameter decreases.

Case II. when h = -a $a = t/2\pi$

$$tg\ \delta = 0$$

$$\therefore \delta = 0$$

The angle δ remains unchanged, thereby the vertical line drawn from cutting point coincides with the tangent line of the same point.



V= cutting velocity
α= clearance angle

Fig. 16: Optimum position of knife tip.

Case III when h $>$ 0

$$\delta = tg^{-1}\ \frac{h + \frac{t}{2\pi}}{\sqrt{r^2 - h^2}}$$

The angle δ increases as the bolt diameter decreases.

During the cutting process, the knife moves ahead with the knife setting height remaining unchanged, the tangent line of cutting point moves gradually to the knife side.

Obviously, the clearance angle α decreases with the increase of angle δ.

In conclusions:

$h > 0$ Angle δ increases and angle α decreases as the bolt diameter becomes smaller.

$h = 0$ Angle δ increases and angle α decreases as the bolt diameter becomes smaller. Rate of change of angle with respect to bolt diameter ($d\alpha/dr$) is less than that in the case of $h > 0$.

$h < 0$ Angle δ increases and angle α increases as the bolt diameter decreases.

$h = -t/2\pi$ $\delta = 0$, α remains unchanged.

The terminology of angles involved in veneer cutting has not yet been standardized internationally. For comparison, the different nomenclatures generally used are given below:

Terminology of angles in lathe setting

Symbols	U.S.A.	Britain	Germany
α	Clearance angle	Clearance angle	Freiwinkel
β	Bevel angle	Grinding (sharpness) angle	Keilwinkel
γ	Rake angle	Cutting angle	Span Winkel
$k = 90 \pm \alpha^{o}$	Knife setting angle (knife angle)	-------------	-----------

II. THERMOPHYSICS OF VENEER DRYING

1. Drying Resistance

$$\frac{1}{\sqrt{C}} = \text{Rid} + \text{Red}$$

Where $\frac{1}{\sqrt{C}}$ = drying resistance (obtained by experiment)

Rid = internal diffusion resistance of wood

Red = external diffusion resistance in the boundary layer between drying medium and wood

Recent investigations indicate that the internal diffusion resistance of veneer does not influence the drying rate.

Investigations also show that a consistent drying rate actually never appears during drying process. The rate of veneer drying decreases immediately when the heating period is ended.

In drying resistance, only the portion of external resistance influences the drying rate, therefore, the drying resistance does not vary in proportion to the veneer thickness. The relationship between the different veneer thickness and the drying rate is as follows:

$$\frac{dw_1}{dt} : \frac{dw_2}{dt} : \frac{dw_3}{dt} = (t_1 + \text{Red}) : (t_2 + \text{Red}) : (t_3 + \text{Red})$$

where t_1, t_2, t_3 are different thicknesses of veneer, and

$\frac{dw_1}{dt}$, $\frac{dw_2}{dt}$, $\frac{dw_3}{dt}$ are drying rates of different veneer thickness respectively.

Evidently, the drying rates are independent of internal diffusion resistance. It is also obvious that the drying time does not increase in proportion to the thickness of veneer.

The boundary layer appearing on the veneer surface resists both heat transmission and water evaporation.

This layer can be broken by circulating air with higher velocity, especially a turbulent air stream.

The higher the air velocity, the better the heat transmission. The relationship between the air velocity and heat transmission, as demonstrated by experiments is as follows:

$$\frac{dQ}{dt} \propto v^{0.8}$$

where v = the velocity of circulating air.

$\frac{dQ}{dt}$ = the rate of heat transmission.

2. Drying Rate

$$\frac{dw}{dt} = -Cw^{n}$$

where $\frac{dw}{dt}$ = drying rate ($\frac{g}{g.min}$) w = moisture content

c = coefficient of drying rate

Experimental data show that the foregoing formula holds true for veneer drying.

3. Humidity of circulating air

The relative humidity of circulating air may be expressed as the difference of readings of dry bulb (t_d) and wet bulb (t_w) of thermometers.

Too low R. H. means that the difference of the readings is too great. In such a case, although the drying resistance decreases and rate of drying increases, the drying quality of veneer decreases. Too rapid drying causes severely wrinkled veneer ends and the dried veneer becomes brittle.

4. Evaporating rate

$$\frac{du}{dt} = -k\ (t_d - t_w)$$

$\frac{du}{dt}$ = evaporating rate

t_d = dry bulb temperature

t_w = wet bulb temperature

k = coefficient of evaporation

Veneer drying during first phase (heating up period),

$\frac{du}{dt}$ = cons.=2.61 x 10^{-3} g/cm^2 . hr.°C. The rate of evaporation bears no relation to the density of wood during heating up period, but the density of wood has great influence upon the rate of evaporation in the second and third periods.

III. QUALITY CONTROL OF (ROTARY) VENEER PRODUCTION

Like any other product, the quality control of veneer production involves a number of factors. Here, only two of the most important aspects are discussed. They are:

(1) the method for the assessment of veneer quality and
(2) the techniques of veneer quality control.

Method for the Assessment of Veneer Quality

By "quality of veneer" discussed here is meant the quality of veneer processing, not involving the natural defects of veneer. The main items are:

(1) thickness uniformity.
(2) surface roughness, and
(3) depth of lathe checks.

1) Thickness uniformity

Variations in veneer thickness are due to one of the following reasons:

a) Inappropriate veneer block quality and poor control of their heat treatment.
b) Faults in the precision or performance of rotary lathe, such as worn out or loosened feed screw, pitch rail, chuck spindle and the like;
c) Faults in setting or adjusting the cutting knife or nosebar.

The knife setting angle, degree of compression, the slope of the pitch rail may be not adequately set up.

Evidence of thickness variations may be observed from the following phenomena.

a) Veneers peeled from the outer layers of veneer block are thick, thining as they approach the core.

b) The veneer ribbon is thicker in the middle than at both ends.

Assessment should be made by sampling full-sized veneer sheets respectively from the outer layer of the blocks and near the core, and also by measuring at the middle and at both ends of the veneer with a precision up to 0.01 mm. Note down the measurements. Samplings to be made 2 - 3 times in a shift.

2) Surface Roughness

Surface roughness is due to:

a) Inadequate temperature and time duration of heat treatment, and or

b) Faults in the height of knife tip, compression and other technological parameters, mismatching and sharpness of cutting knife.

Evidences of surface roughness are:

a) Surface torn grain or localized collapse;

b) Washboarding with 2 - 4 mm in pitch distance, or waviness with a large pitch appearing periodically.

Currently, the following different methods are used to assess surface roughness.

(a) Contact Needle Method

A test specimen of 20 cm in width is cut from each of the sample veneer sheets used in thickness measurement. Surface roughness is measured by means of a profile-meter, with the contact needle moving cross wise on the veneer surface. The recording component of the profilemeter would depict an enlargement of the wave peaks. A mid-line is drawn and measurement taken of the distance from the mid-line to the peak and the valley respectively. Take the average of the values thus measured on each test specimen.

The radius of the tip of contact needle and the magnitude of pressure applied on the veneer surface vary with different wood species. This is a rather simple method and lacks precision.

(b) Light Section Method

In this method, measurement is made by means of a binocular microscope. Three 10 X 10 cm test specimens are cut from areas on the test specimens where the measurements of thickness are to be made. Select several small squares (usually 3 - 5) on the specimen for testing and on each test square find out the lowest valley, and the maximum peak. The measurement of the difference denotes the height of surface roughness. Successive measurements are made on all of the test specimens, thus $h_1, h_2 \ldots h_n$. The mean value or mean square root is taken.

(c) Projection Method

Cut from test specimens cross sections of veneer strips of specified length. Enlarge on a projector two lowest valleys, and measure the distance from this base line to peaks $h_1, h_2 \ldots h_n$. Take the mean or mean square root.

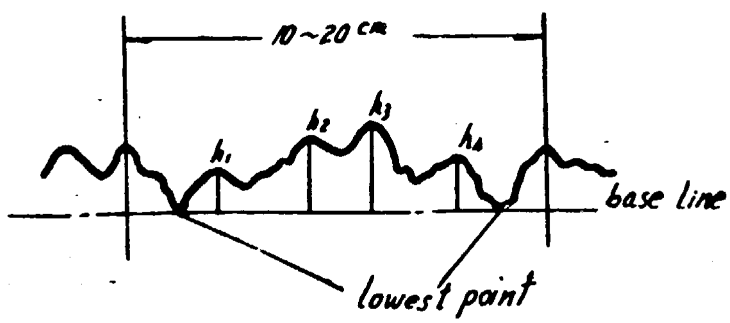


Fig. 17: Method for selecting the base line.

The following are some points relating to surface roughness measurement:

a) μ ($\frac{1}{1000}$ mm) is always taken as the unit for measurement of roughness height h.

b) The calculation of h has not yet been standardized; the following formula are usually used:

Arithmetic mean: $H = \frac{1}{n} (h_1 + h_2 + \ldots\ldots h_n)$

Square root mean: $H = \sqrt{\frac{1}{n} (h_1^2 + h_2^2 + \ldots\ldots n_n^2)}$

Maxima range: $H_1 = h_1 \text{ max.} - h_1 \text{ min}$ (Sample NO.1)

$H_2 = h_2 \text{ max.} - h_2 \text{ min}$ (Sample NO.2)

$H = \frac{1}{n} (H_1 + H_2 + \ldots\ldots H_n)$

c) There is controversy as to whether the roughness is to be measured on the tight side or loose side. In the U.S.A., it is usually made on the tight side, but in Japan, this is done on the loose side.

3) Depth of lathe checks

The deepening of lathe checks is due to an inadequate bevel angle of knife, improper setting of knife and nosebar.

The depth of lathe checks is assessed either by the scarfing test or by the **section test.**

a) Scarfing test: 20 cm x 15 cm test specimens are cut from sample veneer strips dried at 40 - 50°C or airdried to 24 - 30 per cent moisture content with the loose side of veneer coated with black quick ink. Glue up the dried test specimens and cut out an inclined plane on one end. The length and shape of the lathe check will be shown up. Divide the **inclined** plane into equal sections, and measure the longest check in each section.

$$\text{The depth of lathe check} = \frac{\text{length of lathe check L}}{\text{length of veneer inclined plane L.}} \times 100\ \%$$

The arithmetic mean value of depths of lathe checks of every section is taken as the value for test report.

b) Section test: full turns of sample sheets are taken from different portions on the veneer ribbon when being peeled, i.e. the front or outer layers, the inner or the middle and the rear or trailing portions respectively. A test specimen about 6 cm x 10 cm is made from the tangential, radial and between the tangential and radial portions of the sample veneer sheet. Coat both sides with black quick ink. After the drying of the ink, dissect the test specimens at the middle, and plane it to smoothness. Magnify the cross sections 10 - 20 times by a projector, and take down measurements of the depth of lathe checks as the foregoing method.

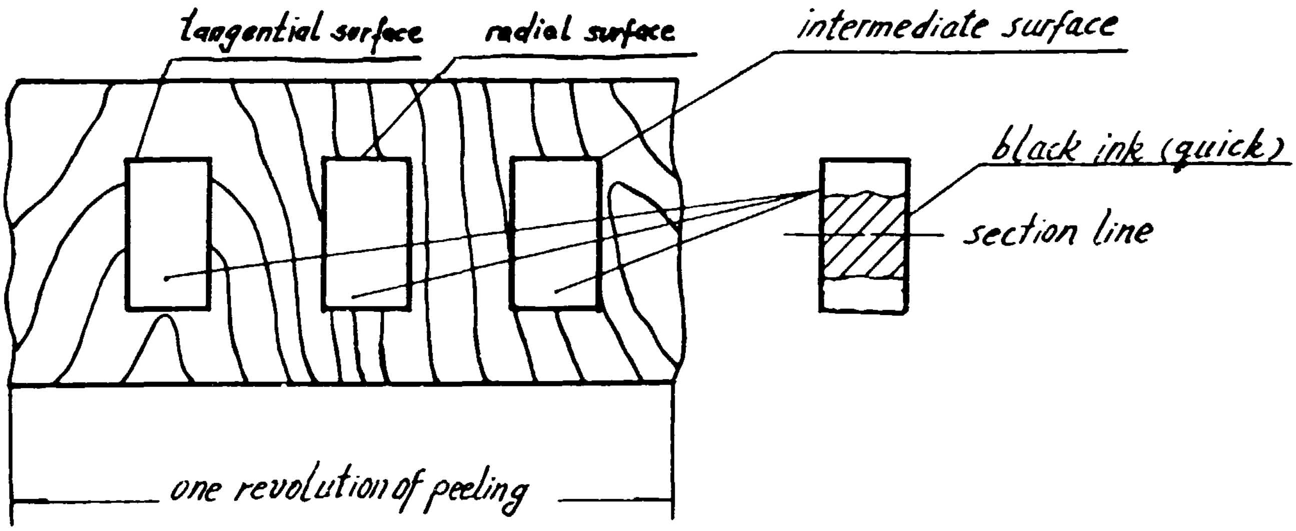


Fig. 18. Method of sampling for section test.

From the pattern appearances of lathe checks, certain irregularities in technological conditions may be discovered.

a) Diagonal pattern. This denotes too large a vertical distance of pressure bar. Compression insufficient.

b) Bent line pattern. Compression is slightly insufficient. The knife setting angle is slightly too large, having a tendency to "cut into" the veneer block.

c) Branched pattern. Knife angle vibrating. Oscillation of the pointer exceeding 0.04 mm may be observed, when the knife edge is tested by a dial gauge. Excessive vibration of knife edge will result in waviness on the surface of veneer due to the serious "cutting into" effect, even though the compression may still be adequate.

The Technique of Veneer Quality Control

The X-R control chart is a typical quality control technique that has been successfully used in the plywood industry, and so it will be dealt with here, in detail. It is a presentation of the level of the quality of the production process as a whole as well as the trend of quality fluctuation through the tabulation of the date of samplings taken on-site. In so doing, the problems arising in the production processes may be analysed with a view to control the quality of the products turned out.

1. Compilation of Data

Samples are taken at random from the various production processes on-site (such as veneer ribbons from the peeling process or veneer sheets and strips from the clipping process) for measuring relevant quality data. The samples taken each time form a subgroup, consecutively numbered, thus:

The data obtained from first group of samples recorded as

$x_{11}, x_{12}, x_{13} \cdots\cdots x_{1n}$

The data obtained from second group of samples recorded as

$x_{21}, x_{22}, x_{23} \cdots\cdots x_{2n}$

The first subscript digit denotes the consecutive order of samplings; the second digit, the order of the sample in each subgroup. The number of samples taken each time should be approximately equal. n = 5 is common practice in mar-- plants.

2. TABULALATION AND CALCULATION

Subgroup No.	Sampling data	Shift	Data Measured 1 2 3 ... n	Items of calculation	
1	9.10	1	X_{11} X_{12} X_{13} ... X_{1n}	$\bar{X}_1 = \frac{\Sigma X_{1i}}{n}$	$R_1 = X_{1max} - X_{1min}$
2	9.10	1	X_{21} X_{22} X_{23} ... X_{2n}	$\bar{X}_2 = \frac{\Sigma X_{2i}}{n}$	$R_2 = X_{2max} - X_{2min}$
3	9.10	3	X_{31} X_{32} X_{33} ... X_{3n}	. . .	. . .
4	9.10	2	X_{41} X_{42} X_{43} ... X_{4n}	. . .	. . .
.	.	.	. . . .	. .	. .
m			X_{m1} X_{m2} X_{m3} ... X_{mn}	$\bar{X}_m = \frac{\Sigma X_{mi}}{n}$	$R_m = X_{mmax} - X_{mmin}$
				$\bar{\bar{X}} = \frac{1}{m}\sum_{i=1}^{m}\bar{X}_i$	$\bar{R} = \frac{1}{m}\sum_{i=1}^{m}R_i$

On the basis of the above data, the position of center line (CL), the upper control limit (UCL) and the lower control limit (LCL) may be determined

In the $\bar{X}$ - Chart

$$CL = \bar{\bar{X}} = \frac{1}{m}\sum_{i=1}^{m}\bar{X}i$$

$$UCL = \bar{\bar{X}} + A\bar{R}$$

$$LCL = \bar{\bar{X}} - A\bar{R}$$

In the R-Chart

$$CL = \bar{R} = \frac{1}{m}\sum_{i=1}^{m}Ri$$

$$UCL = C\bar{R}$$

$$LCL = B\bar{R}$$

A, B, C in above formulas are control limit factors.

3. The Implications of Control Limit Factor

By the principles of mathematical statistics, the standard deviation of a population is σ, the standard error of sample mean $\sigma_{\bar{x}}$, it follows:

$$\sigma_{\bar{x}} = \sqrt{\frac{N-n}{N-1}} \cdot \frac{\sigma}{\sqrt{n}}$$

If the size of population is far greater than the sample size, the factor $\sqrt{\frac{N-n}{N-1}}$ in above formula approaches 1, then the formula becomes $\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$.

In normal distribution, the probability of random error within the range of $\pm 3\sigma$ is 99.7 per cent, and the probability of random errors beyond the said range should be 0.3 per cent. Hence, the UCL and LCL of $\bar{X}$ -R chart can be derived as follows:

1) In the chart for X

$$CL = \bar{\bar{X}} \qquad \sigma_{\bar{x}} = \frac{\sigma}{\sqrt{N}}$$

$$UCL = \bar{\bar{X}} + 3\frac{\sigma}{\sqrt{n}}$$

$$LCL = \bar{\bar{X}} - 3\frac{\sigma}{\sqrt{n}}$$

2) In the chart for R

$$CL = \bar{R}$$

$$UCL = \bar{R} + 3\sigma_R$$

$$LCL = \bar{R} - 3\sigma_R$$

Let $\sigma \approx \hat{\sigma}$, $\hat{\sigma}$ is the inferential value of σ

The relationship between $\hat{\sigma}$ and $\bar{R}$ is $\hat{\sigma} = \frac{\bar{R}}{d_2}$

The relationship between σ_R and σ is $\sigma_R = d_3\sigma$ and $d_3\sigma = d_3\hat{\sigma} = d_3\frac{\bar{R}}{d_2}$

d_2 and d_3 are the inferential coefficient of σ and σ_R respectively.

By substituting,

In $\bar{X}$ Chart:

$$UCL = \bar{\bar{X}} + 3\frac{\sigma}{\sqrt{n}} = \bar{\bar{X}} + 3\frac{\bar{R}}{d_2\sqrt{n}} = \bar{\bar{X}} + A\bar{R} \quad (\text{here } A = \frac{3}{d_2\sqrt{n}})$$

$$LCL = \bar{\bar{X}} - 3\frac{\sigma}{\sqrt{n}} = \bar{\bar{X}} - 3\frac{\bar{R}}{d_2\sqrt{n}} = \bar{\bar{X}} - A\bar{R}$$

In R chart: $UCL = \bar{R} + 3\, d_3 \frac{\bar{R}}{d_2}$

$LCL = \bar{R} - 3\, d_3 \frac{\bar{R}}{d_2}$

$\bar{R} + 3\, d_3 \frac{\bar{R}}{d_2} = \bar{R}\,(1 + 3\, d_3/d_2) = \bar{R}.C$ (here $1 + 3 \frac{d_3}{d_2} = C$)

$\bar{R} - 3\, d_3 \frac{\bar{R}}{d_2} = \bar{R}\,(1-3\, d_3/d_2) = \bar{R}.B$ (here $1 - 3 \frac{d_3}{d_2} = B$)

Thus we get: $UCL = \bar{R}C$

$LCL = \bar{R}B$

In fact, the standard deviation of population is unknown, only its inferential value $\hat{\sigma}$ can be deduced by statistical methods. At the same time, for convenience, the control limit factors (A, B, C) are tabulated for easy reference to simplify calculation.

Table of Control Limit Factors for $\bar{x}$ and R Chart

Number of observations in subgroup			Factor for $\bar{x}$ chart	Factors for R chart	
	d_2	d_3	A	B	C
2	1.128	0.893	1.880	-	3.267
3	1.693	0.888	1.022	-	2.575
4	2.059	0.880	0.729	-	2.828
5	2.326	0.864	0.577	-	2.115
6	2.534	0.848	0.483	-	2.014
7	2.704	0.833	0.419	0.076	1.924
8	2.847	0.820	0.373	0.136	1.864
9	2.970	0.808	0.337	0.184	1.816
10	3.078	0.797	0.308	0.223	1.777

It can be seen from the foregoing table, that the larger the sample size, the narrower the control limits, on the $\bar{X}$ - R Chart, n = 5 is the sub-group size used commonly in plywood plant.

4. $\bar{X}$ - R Control Chart

A $\bar{X}$ - R control chart constructed on the basis of data actually measured and relevant calculation is illustrated by an example of practical application as appended below.

The $\bar{X}$ - R Control chart is a relatively simple quality control technique and a relatively practical one too. It may be applied to the quality control of peeling (roughness, thickness uniformity, depth of lathe checks), bond quality (bond strength), the trimming and sanding quality of plywood panels, etc. By way of illustration, the following is an example of a case of practical application of $\bar{X}$ - R control chart.

Veneer ribbons from the rotary lathe are found to be wedge-shaped in width (wider at one end than the other) after clipping, resulting in insufficient coverage in the lay-up process. If let to pass unnoticed, the finished panel would have to be rejected; otherwise, the face veneer sheet would have to be rejected at the lay-up processes for re-clipping and re-splicing to form a full-sized sheet of face veneer.

For the control of quality of veneer clipping, a $\bar{X}$ - R chart for the range of wedge-shaped clippings is constructed.

1) Sampling, measurement and data recording

Five samples are taken at random from full-sized veneer sheets from the clipper three times per shift. Measure and record the difference between the widths of both ends, and note down also particulars of operating conditions such as the repair or adjustment of equipment, or the change of raw material and so forth.

Original records of $\bar{X}$ - R chart

Machine: Veneer clipper

Area : Veneer processing

Characteristic measurement: Effect of wedge clipping on full sheets. Requirements of recording: By increments of 1/8".

Subgroup No.	Sampling data	shift	data x_1	x_2	x_3	x_4	x_5	Calculations $\bar{x}$	R	Note
1	10.9	1	0.36	0.60	0.50	0.12	0.95	0.45	0.63	
2	10.9	1	0.72	0.84	0.60	0.50	1.63	1.00	1.33	
3	10.12	2	0.05	1.75	0.12	0.25	0.50	0.55	1.63	
.	. .		.	.		.	. .			
24	10.14	2	0.00	0.25	0.12	0.95	0.75	1.05	0.50	
25	10.14	2	1.50	0.25	0.75	3.50	0.25	1.15	3.25	

$\bar{\bar{x}}=1.05$ $\bar{R}=1.75$

Note: The number of observations of each subgroup is 5.

Caclulation of control limits:

$\bar{X}$ control limits

$CL = \bar{\bar{X}} = 1.05 \qquad \bar{R} = 1.75$

$UCL = \bar{\bar{X}} + A\bar{R} = 1.05 + 0.58 \times 1.75 = 2.056$

$LCL = \bar{\bar{X}} - A\bar{R} = 1.05 - 0.58 \times 1.75 = 0.035$

R control limits

$CL = \bar{R} = 1.75$

$UCL = C\bar{R} = 2.11 \times 1.75 = 3.69$

$CLL = B\bar{R} = 0 \times 1.75 = 0$

5. Plotting Chart

The Control Chart

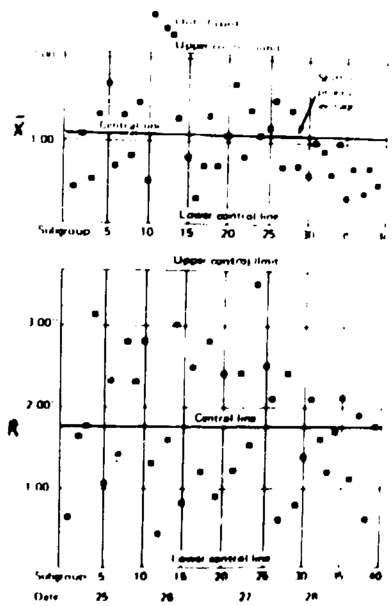


Fig. 19. Control chart for $\bar{X}$ (top)
Control chart for R (bottom)

In $\bar{X}$ chart, the sub-group mean $\bar{X}$ is taken as the ordinate, and the sub-group number as the abscissa.

In R chart, the range of each sub-group is taken as the ordinate, and the sub-group number as the abscissa.

Both UCL and LCL were established after twentyfive sub-groups had been plotted.