A SUGGESTED PLAN FOR THE MANUFACTURE OF PLYWOOD IN PERU

by

JORGE RAHME SUCCAR

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APPROVED:

Redacted for privacy

Professor of Wood Products

In Charge of Major

Redacted for privacy

Head of Department of Wood Products

Redacted for privacy

Chairman of School Graduate Committee

Redacted for privacy

Chairman of College Graduate Council

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PREFACE

Peru possesses a great potential timber resource in its Amazon Valley, a valley covering more than half of the country, and supporting an abundant growth of valuable woods. Notwithstanding the increasing importance, throughout the world, of innumerable plywood products for use on the land, on the sea, and in the air, Peru has not yet begun the manufacture of plywood.

This thesis, which is intended to be a partial basis for the future development of a plywood industry in Peru, is not an economic treatise, but a review of American Plywood Manufacturing Methods, to determine those that might be applicable to the production of plywood in Peru.

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INTRODUCTION

Wood, a product of nature, is a non-homogeneous material. Its strength parallel to the direction of the grain may be 10 to 20 times greater than its strength across the grain. Wood is also a hygroscopic material which changes dimensions with a gain or loss of moisture. However, the dimension parallel to the grain is affected very little by changes in moisture content.

These facts suggested the possibility of modifying the strength properties of wood and of reducing its dimensional changes by alternating the direction of grain in a laminated construction, which is technically known as plywood.

Plywood is the product resulting from three or more layers of veneer* joined with glue and usually laid with the grain of adjoining plies at right angles. Almost always an odd number of plies are used to secure balanced construction. The outside plies are called faces, or face and back. The center ply is called the core, and intervening plies, laid at right angles to the others, are called crossbands. A technical distinction is usually made between plywood, as such, and laminated wood. The term laminated wood is most frequently applied when the

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*Veneer. Thin layer of wood (usually less than 1/6" in thickness).

plies are too thick to be classified as veneer and the grain of all plies is parallel.

Plywood possesses four main advantages over natural wood. First, plywood that is properly designed and manufactured has very slight tendency to expand or contrast and thus satisfactorily retains its dimensions. Second, as a result of the approximate equalization of strength properties along the length and width of the panel, plywood might be described as being equally strong in all directions. Third, it has great resistance to splitting by nails, screws, or other types of fastenings. Fastenings may be made very close to the edges without damage. Fourth, it is available in almost unlimited sizes.

The story of veneer begins in the sculptures of Thebes, dated as early as the time of Thothmes III (c. 1500 B. C.). Down through the centuries, Babylonia and Assyria continued to advance the art of veneering. Influenced by the Egyptians, they too enriched plain, sturdy furniture with thin sheets of rare woods, precious metals, and jewels. History records that veneer was first used by the early Romans on an extensive scale for door frames and panels. It was the Romans who antedated the usage of plywood panelling as seen today in homes, shops, and office buildings. Yet it has taken modern ingenuity plus engineering and technical skill to develop a product capable of meeting the large scale but exacting requirements of today.

In developing the plywood industry of Peru, it is intended to utilize native species. A few of the many species most suitable for veneer are listed below.

The woods suitable for face veneer are Swietenia Macrophylla King (Caoba-Mahogany), Cedrela Odorata L. (Cedro Colorado), and Juglans Neotropica Diels (Nogal-Peruvian Walnut).[20].

Swietenia Macrophylla King is the most common of the species available for face veneer and for this reason it will be given major consideration in this study.

The light species suitable for core stock are Ochroma Boliviana Rowlee (Palo de Balsa), Bombax Munguba Mart. (Huina-Caspi), and Guazuma Crinita Mart. (Bolaina).[20]

A moderately heavy wood suitable for core stock is Ajouea Jelskii Mez. (Moena del Agua). [20]

Due to the lack of available data on physical properties of most of the woods mentioned, specific data are not complete and further study of the native woods will be required.

The available markets for the finished article include ornamentation, furniture and cabinet manufacture, store and office fixtures, packaging, and possibly at a future date in such specialized fields as airplane, automotive, and marine construction.

THE MANUFACTURING PROCESS

VENEER PRODUCTION

The following description of the production of veneer is based on a one-lathe plywood factory with a veneer slicing unit (See Appendix). For purposes of convenience, the description is divided on the basis of the product produced rather than on the basis of the natural flow of the process.

Plain veneer for backs and cores.

In the proposed plant the plain veneer for backs and cores will be rotary cut. Rotary veneer is used principally for non-decorative purposes and for back and core stock.

Preparation of logs for cutting.

The first step in the veneer making process is to bring the wood fiber into the best condition for clean, smooth cutting. This is accomplished by soaking the logs in hot water. Steaming, which is used for species that do not rupture easily under sudden increases in temperature, will probably not be desirable for the species under consideration, although further study may indicate the need for steaming of certain species.

The soaking is performed in vats of concrete covered with loose cover-boards. The size of the vats for the proposed plant (See Appendix) will be approximately 18 feet wide, 36 feet long, and 5 feet deep. Live steam will be discharged at several points below the water level under thermostatic control.

The logs will be placed in the vats when the water is no more than moderately warm. The temperature will be raised gradually to the maximum, which will vary with the size, species of log, and the character of the veneer to be cut. Accurate control is necessary: if the logs are not heated through they will cut "rough"; if soaked too long the logs will shred in cutting. The thicker the veneer to be cut, the higher the temperature required to reduce the hazard of fracturing.[(10)(15)] The exact temperatures required for the Peruvian species to be cut will be determined experimentally.

On leaving the soaking vats the logs will be cut into lengths by a log band cut-off saw, and the bark removed while hot. The logs will be barked manually in this plant with axes and spuds, and the more apparent defects cut out. Then the logs will be brought to the rotary lathe by means of an electric hoist. The elapsed time from the vat to the lathe should be as short as possible.

Rotary cutting.

Plain or rotary cut veneer is produced in massive lathes (See Fig. III),(10) consisting primarily of a rigid frame with sturdy fixed housings at either end. The housings are equipped with bearings for the main spindles. The log, fastened between the dogging and tail spindles of the machine, revolves on the spindles toward a knife running the whole length of the log. The knife, together with a pressure bar, is mounted on a movable assembly. This mechanism is shown in Fig. IIIA, where A is the knife bed casting; B, the pressure bar bed casting; C, the knife; D, the pressure bar; E, the spurs for trimming the edges of veneers as cut; and F, the log. The log revolves against the knife and the pressure bar holds the wood firmly at the instant of cutting. The knife carriage is moved into the log by automatic feed screws revolving at a speed that controls the thickness of the veneer. A gearbox feed mechanism controls the movement of the assembly carrying the knife and pressure bar.(15)

The pitch of the knife, as determined by the angle which the bevel of the knife makes with a perpendicular line through its cutting edge, should be varied for logs of different diameters. It follows that the pitch of the knife should be adjusted as the diameter of the log decreases.

As the veneer comes from the lathe it will be wound on to a reel and taken to the clipper.

Clipping.

The rotary cut veneer will be trimmed into dimensions to suit the desired panel size and defects in the veneer will be cut out. In cutting out defects, it is essential that the cut be made as close to the defect as practicable so that the amount of veneer discarded is kept at a minimum.

Motor actuated veneer clippers will be used in the proposed plant (See Appendix). Each will consist of four essential parts: 1. An iron frame with vertical knives; 2. A shear plate; 3. A cutting table; 4. A heavy movable knife. To make a cut the operator depresses a floor switch. This starts a back-geared motor which transmits its power through large eccentrics to both ends of the knife bar. After each stroke a cam-type limit switch stops the motor, and a spring loaded brake holds the knife at the top position.

From the loaded reel the veneer is propelled through the clipper at any desired speed, the operator carefully watching the veneer as it passes before him. As the sheets of veneer come from the clipper they fall on a belt conveyor table. This table should be long enough to permit accurate sorting.

Sorting.

At this point the sap* and heart# veneer will be separated, with each class being sorted by sizes. Each pile will be stacked on a truck and conveyed to the dryer.

Drying.

The moisture content of the veneer should be reduced to about 5% as soon as possible since there is a strong tendency for mold and fungus growth to develop on wet veneer.

The dryer specified (See Appendix) will be used for plain as well as for face veneer. It is an automatic roller type dryer in which the veneer is slightly pressed between the rollers by the weight of the upper roll. The dryer is 8 sections long and 3 lines high. (Fig. IV shows a similar automatic roller type dryer 10 sections long and 4 lines high.) Each of the bottom rollers is driven by a chain and sprocket, and above each lies an idler roller. Laid across the dryer at regular intervals is the steam piping. Between the pipes and the rollers lie a series of air nozzles which diffuse the air under the veneer as it

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*Sapwood: the outer (younger) portion of a woody stem (or a log), usually distinguishable from the core (Heartwood) by its lighter color.

#Heartwood: the dead inner core of a woody stem (or a log), generally distinguishable from the outer portion (sapwood) by its darker color.

passes. The veneer moves in one direction. Conditions within the dryer range from a low temperature and a high humidity at the feed end to a high temperature and low humidity at the discharge end. The temperature used is above the atmospheric boiling point so that as water is evaporated from the veneer, it is converted into superheated steam which, mixed with air, makes an excellent drying medium. This is kept in constant circulation by the fans, and the veneer is subjected to additional heat from the coils and the rolls. The temperature is controlled at both ends by an air-operated thermostat and diaphragm motor valve. The speed of the dryer is regulated through a variable speed transmission and is varied to adjust for the thickness of the veneer, kind (sap or heart), and the desired ultimate moisture content.

As the veneer leaves the dryer, off-bearers select it according to size, grade and thickness.

Face veneer.

Face veneers are those which form the outer surfaces of plywood. The beauty of face veneer depends very largely on the revelation of the figure in wood. Obtaining the best figure from a log will demand workmen who can visualize in advance a beautiful and artistic veneer face while looking at a flitch* in its original irregular shape.

Figure in wood. (See Fig. I)

Figure in wood is the pattern produced by the (1) annual growth rings, (2) wood rays, (3) pigment figure (irregular infiltrations of coloring matter), (4) irregularities of growth, and (5) the method of cutting. In many instances figure may result from a combination of two or more of these basic factors.

Annual growth rings. Growth occurs in what is known as the cambium, which is a thin layer of growth tissue between the bark and the wood. Each year, by growth in the cambium, a tree adds a layer of wood on the outside of that previously formed, increasing the diameter of the trunk. If growth is interrupted each year, by cold weather or dry seasons, the character of the cells at the end of each year's growth and the beginning of the next differs sufficiently to define sharply the annual layers or growth rings. Thus, the various species of trees produce a wide variety of cell structure, size and arrangement in each annual growth ring which, in turn, produces variable figures or patterns when cut into veneer.

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*A flitch is a portion of a log sawed on two or more sides and intended for sliced or sawed veneer. The term is also applied to the resulting sheets of veneer laid together in the sequence of cutting.

In parts of the tropics, where tree growth is continuous throughout the year, no well-defined annual growth layers are formed.

Wood rays. Rays are rows of cells extending radially within a tree. When rays are composed of very large cells, or are many cells wide, the produce what is called a flake figure.

Pigment figure. Uneven distribution of color or pigment is the principal cause of figure in some woods, and also frequently accentuates the figure resulting from other causes.

Irregularities of growth. Any distortion of the normal course of the fiber growth will produce figure of peculiar shapes. Irregular grain is a factor of outstanding importance in the production of figure in wood. Some of the most important of these irregularities are considered below.

Stump (or butt). At the base of some trees of certain species, the wood becomes distorted from lack of growing space and, perhaps, from the swaying of the tree. (See Fig. I).

Burls. These are huge tumors or warts that may appear anywhere on a tree as a result of some pathological or mechanical disturbance of the growth area. (See Fig. I).

Crotch. A crotch is a section of a tree just below the point where it forks. The twisting of the fibers between the two limbs as they increase in girth makes one of the most striking figures to be found in wood. (See Fig. I).

Interlocked grain. Interlocked grain is produced when the direction of fiber alignment alternates at intervals, resulting in what is known as ribbon or stripe figure when quarter cut.

Method of cutting. The proper method of cutting is essential in order to make the most of the natural figure in wood. Three methods are used: (1) Slicing, (2) Sawing, (3) Rotary cutting.

Slicing. Sliced veneers may be either flat cut or quarter cut. Flat cut veneers are produced by cutting tangent to the rings or at right angle to the rays. (See Fig. IIA). Quarter cut veneers are obtained by cutting a flitch at right angles to the annual rings or parallel to the rays. (See Fig. IIB).

Sawing. Sawn veneers are produced by cutting flitches or logs with a band or circular segment saw. Sawing is usually restricted to woods that cannot be sliced or rotary cut satisfactorily. Its use is avoided in other species because of the high per cent of waste in the saw kerf.

Rotary cutting. As previously explained, the log is mounted on a lathe and turned against a pressure bar and a knife. (See Fig. IIC). The revelation of unusual grain figures may be obtained by "Half-round" and "Back" cutting, which are variations of rotary cutting. The same lathe is used, except that the log is placed on a device known as a "stay-log". "Half-round" cutting is illustrated in Fig. IID.

Figure in Mahogany. The beauty of Mahogany veneers in both figure and color is of outstanding merit. The characteristic interlocking of the fibers of the wood gives a ribbon or stripe figure to quarter-sliced material. Crotches produce a very attractive figure, the distorted growth yielding unusual effects. Plain cut Mahogany usually has a figure of soft outline and low contrast. The color of the heartwood varies from very pale to a very dark reddish brown, which grows richer and darker with age.

Preparation of logs for cutting.

The beauty of Mahogany may be developed best by slicing. In this method the full length logs are stripped of their bark and opened with a saw to determine the character of the figure. This permits a decision as to whether the most desirable veneer will come from rectangular pieces that will give plain cut veneers or from radial segments of the log. If it is found that plain cut veneers are advisable, the log is sawn to the shape shown in Fig. IIA. If a radial cut is advisable the segments are sawn as shown in Fig. IIB. These segments are called flitches. The flitches are placed in large vats for conditioning. The comments on the preparation of logs for rotary cutting (See page 5) apply equally to slicer flitches. Mahogany cuts best after soaking 14 hours, and sometimes longer, at temperatures from 125 to 175°F.[15] When the flitches are sufficiently soft and pliable, they are ready for the cutting operation.

Slicing.

The operation will be done on a vertical slicer as indicated in the proposed plant layout (See Appendix). A vertical slicer consists of a sturdy bed to which the flitch is fixed by dogs; the knife is carried on a rigid frame. A standard type is shown in cross section in Fig. V.[10] The log bed with the flitch clamped to it, moves up and down on angling slides. The cutting stroke has a vertical motion of about 3 feet and a lateral angling motion of about 1½ feet. The cutting occurs on the down stroke. On the return stroke a cam device rocks the knife back to clear the flitch. At the top of the stroke a ratchet and pawl type feed advances the knife for the next cut.

Each sheet of veneer cut on the slicer is turned over as it is piled so that the last surface cut is always on the top of the pile. In this way the veneer is in perfect sequence, exactly as cut. This sequence will be maintained through all the operations in order to make possible the proper matching of the stock.

Drying.

The drying of face veneer will differ from the drying of core stock only in one respect--the extreme care which is exercised to keep the sheets of veneer in the same order as that in which they came from the slicer.

Dimensioning.

Prior to jointing the sheets of veneer will be cut to length in packages one inch thick, and any sapwood on the edges trimmed. These rough dimensioned face veneers are then ready for jointing and edge gluing. The description of these two operations applies to both plain and face veneer.

Jointing.

When the sheets of veneer are not of sufficient width to make the required panels, the edges are cut straight and true preparatory to edge gluing. This cutting will be done on a veneer jointer of a travelling cutter head type. The veneers are pressed perfectly flat and solid on a stationary steel table by a heavy steel clamp bar and are pushed against calibrated gauge bars which can be adjusted for the desired width of trim. The roughing and finishing cutter heads are mounted on a carriage which moves on rigid steel ways. As the carriage moves past the stationary package of veneer, the first cutter-head makes the roughing out while the finishing cutter-head, revolving in the opposite direction, planes the veneer edges.[12] (See Fig. VI).

Edge gluing.

The glue will be applied to the edges by an automatic glue spreading device, which is mounted on the cutter-head carriage of the jointer, behind the cutter-heads. It will spread the veneer edges with hide glue, leaving them ready for bonding. This bonding operation should be done as soon as possible to obviate the risk of any change in moisture content.

The sheets of veneer are quickly and firmly bonded edge to edge under heat and pressure by a Tapeless Veneer Edge Gluer. (See Fig. VII). The veneer, which has already had glue applied, is carried through the machine by driven rolls and the glue on the edges is moistened automatically with a solution of formaldehyde to shorten the setting time of the glue. As the veneer sheets pass through the machine they are firmly pressed together under controlled electric heat which sets the glue almost instantly.[12] If it is determined that cost factors are satisfactory, synthetic resin glues may be substituted for the hide glue at a later date.

Some of the advantages of a Tapeless Edge Gluing machine are: (1) It eliminates the cost of tape, (2) It eliminates the need for tape removal, (3) Since no sanding is required for tape removal, thinner face veneers can be used without danger of sanding through.

Storage.

Following edge gluing the veneers are placed in the storage room, ready to be assembled into plywood.

The purpose of this storage is twofold: (1) To facilitate plywood assembly by having a reserve of veneer on hand, and (2) To maintain or bring all veneers to the most suitable condition for gluing which, in this case, is about a 5% moisture content. This can be accomplished by keeping the veneers in a storage or conditioning room where a temperature of 70°F. and a relative humidity of 23% are maintained constantly.

GLUING*

The following discussion is confined to the synthetic adhesives used in plywood#, since they are recommended for use in the manufacturing process (See Appendix).

There are many reasons for the use of synthetic adhesives in the manufacture of plywood. Among them, the following can be cited: water resistance, mold resistance, thin spreads, and good strength qualities.

The characteristics of the most common adhesives are shown in Table I.

Four steps could be considered in the process of gluing:

Mixing
Spreading
Assembly
Pressing (Discussed in the chapter which follows)

Mixing.

The purpose of mixing is to put the glue or adhesive into a condition for easy application.

The customary solvent is water, partly because of its low cost, but also because of its special properties and effects on the colloidal materials from which glue is made.

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*A general review of the theory of gluing is included in the Appendix.

#Similar principles could be applied to other adhesives.

The main difficulty encountered in mixing is the tendency of glue to foam. Foam is made up of finely divided bubbles of air which become entrapped in the viscous glue liquid. The difficulty of eliminating foam often leads to the necessity of discarding the glue.

The glue mixer chosen for the proposed plant will be provided with double sets of paddles turning in opposite directions. These paddles are equipped with scrapers that closely hug the bottom and sides of the mixer to prevent any accumulation of unmixed material.

After mixing, the glue is transferred to a storage tank. Since the working life of resin adhesives is limited (See Table I), it should be considered as a factor of extreme importance in the storage of the mixed glue. In all cases the glue should be mixed and used in accordance with the instructions furnished by the glue manufacturer.

Spreading.

In three-ply construction, the glue is applied to both sides of the core but not to the face or back. In the proposed plant layout (See Appendix), glue will be applied to the core by passing the core through two glue carrying rolls, each roll being provided with a doctor roll to regulate the amount of glue applied. These doctor rolls are of metal and chromium plate. The glue rolls are covered with corrugated rubber to permit very thin spreads. The lower tank of the spreader is used as a reservoir for a rotary pump, which will supply resin to the rolls.

The amount of glue spread should be from 30 to 40 pounds of liquid mixture per 1000 square feet of glue line. Since both sides of the core stock are coated, the total amount of glue spread will be from 60 to 80 pounds of liquid mixture per 1000 square feet of three-ply plywood.

Test for amount of glue spread. The following method will be used to determine the amount of glue spread: one square foot of core stock will be weighed, run through the spreader for an application of adhesive (both sides), and reweighed. Then the following formula will be applied:

$$S = \frac{(W-W')1000}{453.6}$$

Where:

S - Spread in pounds of liquid mixture per 1000 square feet.

W - Weight of sample in grams before spreading.

W'- Weight of sample in grams after spreading.

Assembly.

The time which elapses between the spreading of the glue and the application of full pressure is called the "assembly time".

During this stage very important changes take place in the glue. Perhaps the chief change is a loss of water from the glue film to the wood, which raises the viscosity of the glue. This change in viscosity is very important from the standpoint of the final quality of the glue joint, since the making of a strong glue joint depends primarily upon having the proper correlation of gluing pressure and glue consistency at the moment the pressure is applied. Two types of weak joints may be produced as a result of not having a proper combination of glue consistency and pressure.

1. The starved joint, which is due to insufficient spread, the application of too much pressure in dense woods, or rapid absorption of glue into the cell cavities of less dense woods.

2. The dried joint, which may occur with any glue that has lost so much water that it will not adhere to wood, even under a very heavy pressure.

Panel assembly. For three-ply plywood the veneer used for face and back are conveyed from the storage room to the glue spreader and placed on the discharge side of the machine. A load of core stock is brought from the same storage room and placed at the loading side of the spreader. A load of sixteen-gauge zinc cauls are placed near the discharge side of the machine. An empty platform truck is positioned at the discharge side of the spreader.

Two panels will be laid up between each caul. The assembly for three-ply plywood is: caul, face veneer, glue-coated core, face veneer; face veneer, glue-coated core, face veneer, caul. This process is repeated until as many assemblies have been made as will fill the openings of the press. As soon as one batch is ready, it is trucked to the press.

PRESSING

The principal variables of this process, depending on the material to be bonded and the type of adhesive used, are the moisture content of the veneers, the pressure, and the temperature-time relationship.

Moisture content of veneer.

Moisture in the veneer retards the penetration of heat into veneer assemblies. Higher moisture contents require longer bonding cycles and tend to set up internal stresses that might cause warping and twisting in the final plywood panel. Wet spots may also cause blistering. Fig. X is a chart which shows the effect of differences in moisture content of veneers on pressing time and temperatures where the penetration depth is 3/8 of an inch. Similar curves can be prepared for any depth of penetration.

Pressure.

The purpose of pressure is to create close contact between the plies and to effect the proper degree of penetration of the glue. Good adhesion occurs only if the wood surfaces are brought into close contact. If pieces of veneer are absolutely uniform in thickness and if the press platens are perfectly flat, very little pressure is necessary to obtain a good joint. However, variations in thickness and imperfections in press manufacture are unavoidable. For these reasons, substantial pressures are necessary to obtain the desired results. The allowable deviations in thickness are much larger than might be expected since the wood becomes somewhat plastic when it is heated. Pressures varying from 100 to 175 psi. are considered satisfactory for the species to be used in the proposed plant.

Temperature and time relationships.

The synthetic resin glues gain strength by a set which is the result of a polymerization or condensation reaction. This set or polymerization is accelerated by heat and heated press plates are required to set the glue in a reasonable length of time. Heat is essential to evaporate the water of condensation resulting from polymerization of the resin glue, as well as the water with which the glue was mixed. An additional advantage of hot pressing is that pressure is applied for a relatively brief time, (normally 5 to 30 minutes as compared with 4 to 6 hours in cold pressing), and this permits the use of higher pressures. If long continued these high pressures would result in excessive flattening of the wood cells and a consequent densification of the material.

Most of the resin glues used require a relatively high temperature to set and should be held at that temperature for a definite period of time to complete the curing of the glue. In the manufacture of plywood the problem is that of determining how long a panel must be left in the press in order that the glue line farthest from the press plates will be heated to the proper temperature. The problem was solved by Fourier with his basic equation.[8] Gurney and Lurie showed that it is possible to construct a chart which covers the general case.[4] The Gurney and Lurie chart is discussed in detail in the Appendix.

Type of press.

The press for the proposed plant (See Appendix) will consist of 12 daylights*, requiring 13 steam heated platens, thus producing 24 panels to each charge#. It will be equipped with indicating gauges showing hydraulic pressure in the pistons. The pressure is produced by two pumps: a low pressure pump for closing the press quickly, and an intensifier for building up the high pressure required after the press closes. The pump pressure is

*Daylight is the vertical, clear opening between each pair of platens.
#Two panels per opening.

determined by the formula:[10]

$$\text{Gauge Pressure (lbs/sq. in.)} = \frac{\text{Plywood Area (sq. in.)} \times \text{Specific Pressure (lbs/sq. in.)}}{\text{Aggregate Area of Pistons (sq.in.)}}$$

The proper maximum time allowance in closing the press is one minute. If this interval is appreciably longer, there is danger of precuring the glue before the pressure becomes effective.

The steam main serving the press will be properly drained of condensate just ahead (boiler side) of the pressure-reducing valve by a thermostatic air trap.[5] The pressure-reducing valve on the boiler side of the press is used to regulate the steam pressure entering the press platens and thus control the platen temperature. The proper regulation of steam circulation through the platens is one of the most important elements in hot press operation since any water standing in the platens tends to make cool spots and may result in irregular bonding. The trap beyond the press, to remove the condensate, will be of the Bucket Steam Trap type,[5] and should be properly by-passed so that the press can be heated rapidly every morning.

Reconditioning after pressing.

The plywood panel dries very little while in the hot press, but gives off its moisture chiefly during its initial cooling, immediately after removal from the hot press. Hence, there is a tendency for the hot-pressed panel to be unusually dry, a condition that makes the wood brash and brittle and encourages warping.(10)

In order to restore the normal moisture content of the panels and to hold them flat during this reconditioning process, they are customarily piled, immediately after removal from the hot press, on a solid base, with all edges in vertical alignment. They are then weighted down with head blocks and short "I" beams. The panels should be allowed to remain piled until they have reached room temperature and the desired moisture content. Although it is fairly common practice to spray or dip the panels in water as they are removed from the press in order to restore the moisture content of the panels, these methods are more expensive and will not be used in the proposed plant.

FINAL STEPS IN MANUFACTURE

Dimensioning.

When the plywood has been properly reconditioned, it will be trimmed to the required size and squared up on double cut-off saws.

Any sawing in plywood is partly crosscutting and partly ripping, due to the alternating directions of grain. This requires a combination circular saw blade, with groupings of fine teeth for the cutting across the grain, and larger teeth and deeper throats for the cutting parallel to the direction of the grain.[10]

The plywood dimension saws will be arranged in tandem (See Appendix). The panels (two at a time), will be cut to length, while being held flat by rollers, on one set of parallel saws and to width on a second set. Then the panel will be ready for sanding.

Sanding.

From the dimensioning saws the panels will pass through a triple drum sander for a smooth even finish.

The sander drums are positioned above the table, and are given a lateral and reciprocating movement in addition to the rotary action. The first drum carries the roughest paper; the second, a finer one; and the last, a finishing grade. Each drum is covered with felt which acts as a cushion between the roller and abrasive paper. The thickness of the panel is controlled with great accuracy by careful adjustment of the sanding drums.[21]

The panels will be fed squarely to the drums, one panel following the other as closely as possible to reduce the risk of rounding the leading edge. The back side of the panel is sanded first in order to give a better foundation for the accurate sanding of the face.

Belt sander.

A belt sander may be added to the equipment at a later date, to be used for touching up low spots which have escaped the triple drum sander.

A belt sander consists of a belt of abrasive paper, an oscillating table, and a manually operated pad with which the belt of abrasive paper is pressed against the plywood panel. The pad is kept moving to and fro on the running belt at the same time that the panel is moved forward and backward by the movement of the table.[21]

Storage.

The finished plywood panels will be stored under conditions that will maintain the desired moisture content. They will be stacked in solid piles, the panels in perfect alignment, with a solid cover over the top of each pile to protect the panels against rapid changes in moisture content, warping, dust accumulation, and discoloration due to light.

SOME PROBLEMS ENCOUNTERED IN THE MANUFACTURE OF PLYWOOD

The warping of plywood.

Although dimensional stability is one of the advantages plywood possesses in comparison with plain lumber, stability of plywood in use is not attained unless the principles of balanced construction are rigidly followed. Balanced construction is obtained in the following manner: (1) By using an odd number of plies, (2) By assuring that the grain direction of complimentary plies (on opposite sides of the core) is parallel, (3) That complimentary plies are of the same species and thickness, or, if of different species, that the woods used have similar mechanical and physical properties*, (4) That complimentary plies are the same distance from the core, and (5) That all plies be at approximately the same moisture content at the time of gluing.

Violation of the above principles usually results in warping. Warping can be classified as either cupping or twisting. Cupping may be defined as that type of warping in which the four corners of the panel can be made to rest on a flat surface but the center portion is raised from the flat surface.[1] A panel is twisted, if, when laid on

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*It is possible to use species of different densities providing the thickness is adjusted to conform with density.[1]

a flat surface, one corner is out of the plane of the other three. These two types of warping in plywood result from somewhat different causes although both may occur together. As a general rule, twisting is a matter of grain direction. Tests have shown that with thin panels, deviations as small as 5 degrees between the grain of any two corresponding plies may introduce considerable twisting.(3) On the other hand, cupping can be considered as resulting when the forces that restrain the core are of unequal magnitude on the two sides.(1)

The following outline summarizes the different factors that may contribute to warping:(1)

Twisting:

1. Grain direction.
2. End drying.
3. Method of fastening*.

Cupping:

A. Defects in construction:

1. Thicker crossbands on one side than on the other.
2. Cross-grained# crossbands on one side and straight grained on the other.
3. Doty crossband on one side and sound on the other.

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*Twisting has been observed when plywood panels were fastened rigidly to supporting members whose shrinkage characteristics differed from those of the plywood panel.

#The term cross-grain has been used with two different meanings. In this sentence the term implies that the grain dips abruptly through the sheet of veneer from one surface to the other while in outlining the causes of twisting the term implies that the grain was parallel to the surface of the sheet, but not parallel to the edges.

4. Compression wood in one crossband and normal wood in the other.
5. Species of widely different shrinkage characteristics.
6. Widely varying moisture content at the time of gluing.

B. Improper handling:

1. Drying more rapidly from one side than the other.
2. Highly resistant finish on one side with a finish of lower resistance on the other.
3. Method of fastening*.

General:

1. Moisture content at the time of gluing.
2. Density of species.
3. Ratio of core thickness to total panel thickness.

Of the general causes of warping, changes in moisture content are the most important. A change in the moisture content of plywood will introduce or relieve internal stresses. The magnitude of the stresses will depend on whether or not the construction of the panel is balanced and on the difference between the moisture content at that particular time and at the time the glue was set. The greater the moisture changes, the greater will be the stresses developed, and the greater will be the tendency to warp. Therefore, it is important that the moisture content of the veneer at the time of gluing be as nearly

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*Twisting has been observed when plywood panels were fastened rigidly to supporting members whose shrinkage characteristics differed from those of the plywood panel.

as possible equal to the average moisture content the stock is expected to reach in service.

Tests carried out by the Forest Products Laboratory, Madison, Wisconsin, have shown that the warping of plywood panels, when subjected to varying moisture conditions, is least for panels made of low density species, and generally increases with increasing density of the species used. A high percentage of core to total plywood thickness helps to maintain a flat, unwarped surface. The core should comprise 1/2 to 7/10 of the total thickness of the panel.

Plywood and veneer waste.

The waste in the manufacture of veneer and plywood exceeds, sometimes, that of the lumber mill. From tests conducted on Yellow Birch, the waste from converting the log into veneer amounted to 54.2%, exclusive of bark. Plywood manufacturers report a waste of about 50% in converting hardwood veneers to plywood.

The seriousness of waste is clearly manifested, and economical operation requires careful consideration of this factor.

The general points to consider in a study of veneer and plywood waste are indicated below:(2)

1. Waste in veneer manufacture:

Removal of defects. Losses from defects cannot be completely eliminated but they can be materially reduced by instructing workmen in the importance of avoiding unnecessary waste.

Excess length in veneer bolts. Veneer bolts are always cut longer than the required veneer sheet. This leaves a small allowance to take care of stain, end checks, and lack of squareness at the ends of the bolts. Care should be exercised in the woods to reduce losses from this cause.

Rounding waste. This is the waste produced by the preliminary cuts of the lathe in "rounding up" the log. It is not until the log is symmetrical that veneer is produced in a continuous sheet, free from voids. Careful chucking of the log in the lathe will reduce these losses.

Clipping waste. In addition to normal clipping losses incurred in trimming to size and removing defects, there are irregular pieces produced during the rounding operation which can be salvaged by proper clipping.

Core. The average rotary lathe leaves a core 8" in diameter. By comparison, the slicing process leaves only a 1" board on the machine. However, the slicing process results in a significant loss at the cut up mill in the form of sawdust, slabs, etc.

Miscellaneous. Losses from damage during handling and drying. Extreme care is required to avoid severe losses in the handling of dry face veneers.

2. Waste in plywood manufacture. The losses that should be considered are due to:

Breakage of dry veneers
Jointing
Trimming
Sanding, and
Rough handling

The utilization of waste.

Waste is inevitable in a veneer plant. The customary use of this waste is for fuel, and if no less expensive fuel is available, this is an economical practice. Where inexpensive fuel is available, there are several possibilities for the utilization of veneer waste. The following is a suggested method which would not only make economical use of the waste material but which would also increase the value of the primary product of the plant.

The steps in this process are:

1. The production of wood fiber.
2. The refining of the resulting fiber.
3. Forming the fibers into preforms.
4. Molding the preformed fiber under heat and pressure (Hardboard).
5. Impregnation of the hardboard with resin of low molecular weight.
6. Set of the resin under heat and pressure.

It is logical to assume that the bulk of this fiber could be used at the proposed plant to expand the diversity of plywood products by manufacturing fiber-faced panels using low quality rotary-cut veneer for core stock.

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APPENDIX

Theory of gluing.

It is generally conceded that both mechanical adhesion and specific adhesion play a part in the bonding of wood, although there is a lack of agreement as to the relative importance of each.

Mechanical adhesion. When two wood surfaces are brought together under pressure, with a film of wet glue between them, the glue will flow into the minute openings in the two surfaces. The bond which is obtained is attributed to the interlocking of the glue and wood, which results from the solidification of the numerous projections of glue within the openings of the wood.

Specific adhesion. Smooth materials, i.e., glass, sheet of plastics or polished metals can be made to adhere with certain types of glues. It is conceivable that the surface of a piece of dense hardwood can be made approximately as smooth as glass with a minimum of cavities for the accommodations of the prongs of the adhesive. It is a well known fact that such smooth surfaces can be satisfactorily glued together. This indicates that there is another form of adhesion which is termed specific adhesion.

Two closely related factors play a part in specific adhesion. 1. The polarity of the wood and the glue.
2. The hydrogen-bonding ability between the resins and the

cellulose or the adsorbed layer of water molecules already present on the cellulose.[19]

Polarity. Polar molecules contain powerful fields of force and, therefore, tend to orient themselves in an electric field.[6] In some highly polar compounds there are permanently localized electric fields at different points upon the surface. Thus, the molecule acts as a charged body having a positive charge at one point and a negative at another, opposite in sign but equal in charge.[6] The molecule is electrically similar to a short bar magnet and is called a dipole. Like a magnet, it will develop a moment, which can be measured by the molecule's tendency to turn in an electric field. A polar molecule, then, is one that has a permanent dipole moment.[6] Liquids and solids are grouped into polar and non-polar categories. Strong joints cannot be made with polar adherents to non-polar adhesives nor with non-polar adherents to polar adhesives.[10]

Hydrogen-bonding ability. The concept of hydrogen bond formation, in the simplest terms, is that hydrogen can act as a link between two strongly electronegative atoms, such as O and N. Generally strong hydrogen bonds are O-HO, N-HO, O-HN.[19]. Most of the synthetic resins glues used, and the proteins and starch glues as well, are amply supplied with groups which can form hydrogen bonds to cellulose or water.

Colloidal properties of glues. It is impossible to discuss the theory of gluing without mentioning the colloids, since glues are typical colloids, and exhibit colloidal reactions at each stage of their use. The word colloid, as used by the chemist, denotes a state of matter which is distinguished chiefly by the size of the ultimate particle of the dispersed material.

One of the properties which is peculiar to the colloidal state is its propensity to change in viscosity. Colloidal liquids may change in both ways, that is, a thick liquid may get thinner or a thin liquid may get thicker until it reaches a solid state (gel). The point to be noted in colloidal liquids is that they may change when there is no easily observed reason for their change. It is found experimentally that, as particle size decreases, the stability of the system tends to increase very greatly.(6)

Both, the sol and gel states are requisites of a glue. Colloidal liquids are capable of high viscosities, and have the proper consistency to be spread by mechanical means. They also remain in the position spread, do not dry up too quickly and readily pass over to the gel state. The gel state of a colloid may be very high in liquid and yet have very considerable strength. It is such properties as these which enable a glue gel to have considerable strength long before it has changed into a dry solid.

As stated by Charles B. Norris in his book, "Technique of Plywood,"[9] "wood itself is a colloid, both the cellulose and the lignin as well as possible other components of the wood are colloids. Particularly when the wood is wet by the glue does it begin to exhibit its colloidal properties." Since wood is colloidal in nature, it has the property of permitting the passage of certain substances and of preventing the passage of others. This is determined by the size of the molecules. Colloidal particles are in general of such a size that they will not pass through the cell walls of wood. On the other hand, small molecules such as those of water, caustic soda, chemical salts and the like, are small enough to pass through the colloidal film of the cell walls of wood. If it were not for the fact that glue contains a large amount of colloids, there would be nothing left to form the glue joint, since any substances of lower molecular size than colloids would almost completely migrate into the wood.[9]

Gurney and Lurie chart. (See Fig. IX)[4]

As previously described, an important problem in the manufacture of plywood by the hot press method is that of determining how long a panel must remain in the press in order that the glue line furthest from the press plates will be heated to the proper temperature and held there for the required time. The problem may be solved by the use of the Gurney and Lurie chart.

The curve was obtained by converting some of the more common formulas for heat transmission into expressions containing pure ratios or non-dimensional variables only, thereby enormously reducing the necessary basic calculations.

The abscissas 0 to 3 are in units obtained by multiplying time, Θ, by thermal diffusivity*, h^2, of the material, and then dividing this product by the square of one half the thickness of the panel, R^2. The expression generally employed in denoting this relation is: $\tau = \Theta h^2/R^2$.

The ordinates 1 to 0.002 refer to the ratios of unaccomplished temperature change to the total, limiting, or maximum possible temperature change that the thermal environment can impress upon any part of the body; i.e. the temperature-difference ratio at the start is conceived to be unity and to approach or eventually become zero. At any time, Θ, in question, the temperature is conceived to differ from the final temperature by a temperature ratio, Δ, which

*Diffusivity is a measure of the change in temperature that would be produced in a unit volume of the substance by the amount of heat that flows in unit time through unit area of a layer of unit thickness and having unit difference of temperature between faces.

approaches zero as a limit. The expression employed in denoting this temperature-difference ratio is: $Y = \frac{T-t}{T-t_1}$, where, t_1, is the temperature of the panel before pressing, t, is the temperature within the panel at distance, r, from the center and at a time Θ, after the panel is inserted in the press, and, T, is the temperature of the press.

The ordinates are functions of two variables other than time. The first of these, p, is the ratio of the distance from the center to the point in question, r, to the distance from the surface to the center. This ratio, p, is, therefore, zero at the center and unity at the surface, with intermediate values. The expression of this position ratio is: $p = r/R$.

The other function, m, is the ratio of the thermal conductivity, k, of the material to the product of the thermal surface conductivity, E, and the semi-thickness, R, of the panel. This is expressed symbolically by: $m = K/ER$. In the case of plywood panels where the surface of the wood is immediately raised to the temperature of the plates, the thermal surface conductivity could be considered infinite, then $m = 0$. If the surface is perfectly insulated ($E = 0$), then $m = \infty$ [4]

The chart is expressed in Arithlog ordinates, that is, the abscissas progress according to equal arithmetic increments, while the ordinates progress in a logarithmic order.

Use of the chart. As mentioned before, two panels per opening of the press will be used in the proposed plant. For the purpose of illustration, a 3/8" panel is used, thus having a total thickness per opening of two times 3/8", which is equal to 3/4". The core of each panel will be considered as 1/4" thick and both mahogany faces as 1/16" thick.

This is a case where the panels contain two species of wood. The calculations would become too complicated if an attempt were made to take into account differences in diffusivity of the different species. Sufficiently close results can be obtained by using the diffusivity of the wood comprising the greater portion of the panel, or, the wood of higher density which heats more slowly. (The diffusivity decreases as the specific gravity increases.) Due to the lack of data for the wood comprising the greater portion of the panel, the calculations will be made by using the data available for mahogany.

The data available for mahogany are:

Thermal conductivity (K) = 0.09 BTU/(hr)(sq.ft)(^{o}F per ft)

Density (D) = 34 lbs. per cu.ft. (at 60^{o}F)

Specific heat (Sp) = 0.50 BTU/(lb)(^{o}F)

Thermal diffusivity (h) =

$\sqrt{k/DSp}$ ---h^2 = 0.0053 sq.ft./hr.

Assuming a temperature of 80°F. for the veneers before they are placed in the press, a press plate temperature of 300°F., and a phenol formaldehyde resin which sets in 3 minutes at 290°F.;[14] the problem consists of determining the time the panel should be left in the press in order that the innermost glue line (5/16" from the surface) may reach the proper temperature.

The temperature-difference ratio will be:

$$Y = \frac{300-290}{300-80} = 0.045$$

The position-ratio: $p = r/R = 1/16 \; 3/8 = 0.167$

The thermal-resistance ratio: $m = 0$

With this data, starting at the upper left hand margin of the chart at a temperature difference ratio of 0.045 and moving horizontally to the right to the curve representing the position ratio of 0.167, and then downward where it is found that the value of dimensionless time expression is around 1.37. Then:

$$\mathcal{T} = \frac{h^2(\text{sq.ft./hr})\theta}{R^2} \quad \text{or} \quad 1.37 = \theta \times 0.09$$

$$\theta = 15.2 \text{ minutes}$$

If the glue requires 3 minutes to set at this temperature, the panel should be left in the press about 18 minutes.

Results obtained by this chart agree very closely with values obtained by the use of MacLean[7] curves.

Testing for Adhesive Strength, Moisture Content, and Moisture Absorption.

Testing for adhesive strength.

Plywood shear test. This test is made on dry plywood, and on plywood soaked in water at room temperature for various intervals of time.

The test pieces, 3¼" long by 1" wide by 3/16" thick, (selected to give a representative sample), are cross slotted, leaving a center section, to resist the pull of the testing machine. (See Fig. VIII). The ends of the specimen are gripped in jaws of the type shown in Fig. VIIIA, and given a shear test in any standard machine having a rate of load application of 600 to 1000 pounds per minute. The samples are tested until separation occurs, and the maximum load is recorded. The dry test is usually conducted with the plywood samples at a moisture content of between 8-12%.

Plywood consisting of more than three plies should be stripped of all except any three selected plies, and then prepared as shown in Fig. VIII. In plywood with face plies thicker than 0.047 inches, the shear area should be one square inch, as shown in Fig. VIII, specimen A. Specimens of plywood with face plies 0.047 inches or less in thickness should be of the form shown in Fig. VIII, specimen B, in which the shear area should be reduced without changing the width of the specimen to 1/2 inch.[16]

The wet test for aircraft plywood requires complete immersion of the sample in boiling water for 3 hours. They should then be removed from the boiling water, placed in cold water, until at approximately room temperature and, while still water soaked, tested to failure by the method above mentioned.

Moisture content test.

Proper moisture content is an important consideration in all plywood operations, so that the plywood panel will remain flat when it is in equilibrium with the atmospheric conditions encountered in use.

To determine the moisture content, small samples are cut from different points in order to be truly representative. The samples should be free of slivers or loose particles that might drop off in handling. Each sample should be weighed in its original condition, then placed in the oven until a minimum weight is reached, which is, for practical purposes, bone dry; the sample is weighed again promptly on removal from the oven and the new weight is recorded as the Bone-Dry weight. The percentage of moisture content will then be given by the following formula:[10]

Per cent moisture content =

$$\frac{\text{Original weight} - \text{Bone Dry weight}}{\text{Bone Dry weight}}$$

Moisture absorption.

Moisture absorption capacity is an important factor in plywood used in boats or in evaluating high density plywood for such uses as airplane propellers, where slight increases in weight might destroy a carefully established balance.[10] This test is the reverse of the above, and is usually computed on the original weight, as the Bone Dry weight is often difficult to determine. The formula then becomes:[10]

Per cent of moisture absorption =

$$\frac{\text{Weight after soaking - original weight}}{\text{Original weight}}$$

Estimation of the Specific Gravity of Plywood.

This is a very important factor in plywood used in boats and airplane construction.

In order to produce a plywood of a given specific gravity, certain factors must be considered. They are: pressing conditions, number of plies in a given thickness of plywood, the weight of the bonding medium applied per unit area, etc. These factors result in the final product having a greater specific gravity than the veneer used. Therefore, two steps are required to obtain the specific gravity of a plywood panel.

1. To obtain the average specific gravity of the veneer plies weighted according to thickness. This is done by multiplying the thickness by the specific gravity for

each veneer, and dividing the sum of the products by the sum of the thicknesses.

A method for determining the specific gravity of veneers has been developed by the Forest Products Laboratory, Madison, Wisconsin. A sample of veneer is cut with an ordinary paper trimmer to 100 square centimeters (10 by 10 centimeters) or 50 square centimeters (7.07 by 7.07 centimeters) depending upon its thickness. The thickness of the veneer is measured by a micrometer to 0.001 of an inch. The veneer is then attached to a sensitive spring of the type used in a Jolly balance and a chart is read directly in specific gravity for the given thickness of veneer employed. (See Fig. XI).[11]

2. To obtain the increase in specific gravity. It may be computed from the following formula developed by the Forest Products Laboratory, Madison, Wisconsin:

$$Gi = \frac{Gav. \, (Tv-Tp) + 0.002 \, (N-1)}{Tp} - 0.01$$

Where:

Gav. - Average specific gravity of plies weighted as to thickness (from step 1).
Tv - Sum of thicknesses of oven dry veneer plies.
Tp - Thickness of oven dry plywood.
N - Number of plies.
0.002- Constant for phenolic resin glue (0.035 grams per sq. in.).
0.01 - Constant to correct for difference in shrinkage of plywood and veneer.

The value obtained from the formula is added to the value obtained from step 1, to give the specific gravity of the plywood.

A simpler method, which eliminates most of the mathematical calculations, has also been developed by the Forest Products Laboratory, Madison, Wisconsin.[13] It consists of a chart to determine the specific gravity of large sized thin panels, particularly when panels of uniform surface area are involved. (See Fig. XII).

The data necessary for the chart are the weight of the plywood panel in pounds and ounces, its average thickness in inches to the thousandth of an inch, and the surface area in square inches. With these data, the chart is used as follows:

1. On the vertical scale to the left of the chart, locate the line representing the weight and follow it horizontally to its intersection with a vertical line representing the thickness.

2. Follow this position along the oblique lines to its intersection with the vertical line representing the area of the plywood.

3. From this point follow horizontally to the right hand margin and read the specific gravity.

There are two specific gravity scales. The first scale is to be used when the plywood has been weighed and measured in the oven dry conditions. It has been found that panels that have been pressed in a hot press at approximately 300°F. are practically oven dry about 30 seconds after removal from the press if a normal pressing schedule has been used and if the plywood is 0.200 inch in thickness or less.[13] The second scale is to be used when the plywood has been weighed and measured at 10% moisture content.

A PROPOSED PLANT FOR PERU

Plant equipment.

The proposed plant for Peru is designed to produce 1,000 cubic feet of finished plywood panels per day, which would be equivalent to 32,000 surface square feet of three-ply panels, 3/8" thick. This is based on the veneer dryer operating 24 hours a day, and the remainder of the machinery operating 8 hours a day.

The equipment will be suitable for handling logs having an average diameter of 30 inches; a maximum diameter of 48 inches for rotary cutting; a maximum length of 102 inches for rotary cutting; and a maximum length of 12 feet for slicing.

The cost of this equipment packed for export, f.o.b. factory with freight allowed to New York, is $135,750.00. This estimate, made by the United States Machinery Co., Inc., 90 Broad Street, New York, is based upon a one-lathe plywood factory with a veneer slicing unit, including the electric motors for equipping the factory. It is understood that electric power will be delivered to the factory and that its characteristics will be 220 volts, 60 cycle, 3 phase current. A boiler of sufficient size to furnish steam for the roller veneer dryer and the press is included.

To this estimate should be added the cost of soaking vats, log yard equipment and conveyors for transporting the waste. A rough estimate suggested by the United States Machinery Co., Inc., is $6,000 for the soaking vats and log yard equipment, and $2,500 for the conveyors taking the waste from the lathe to the hog, and from the hog to the boiler house.

These estimates do not include: (1) The mill for cutting the log into flitches for the slicer since this will be conducted as a separate operation; (2) The blower system for the elimination of sawdust from the machines.

Machinery.

One Log Band Cut-off Saw, complete with drive motor for cutting logs to proper lengths for the lathe and slicer.

A complete set of fittings for a 4-ton capacity stiff legged derrick.

One 3-ton capacity Electric Hoist, complete with electric trolley and monorail.

One Motorized Lathe for rotary cutting. Machine to be furnished complete with four-speed 50 h.p. main drive motor, V-belt drive, and also necessary controls.

Three Motor Actuated Veneer Clippers having a knife length of 100". These clippers will be used for clipping the rotary cut veneer coming from the lathe.

One Automatic Roller Veneer Dryer. Machine to be 8 sections long, 3 lines high, and equipped with 14'6" rolls spaced on $5\frac{1}{4}$" centers. When supplied with steam at a pressure of 175 lbs. per square inch, this machine will dry 64,000 square feet of 1/8" thick rotary cut veneer, plus 32,000 square feet of 1/16" Mahogany down to 5% moisture content every 24 hours.

One Travelling Head Veneer Jointer with automatic glue spreading attachment.

One Motorized Tapeless Veneer Splicing Machine.

One 12' Veneer Slicing Machine. The machine is suitable for handling flitches up to 12'6" long by 28" square. Machine to be furnished complete with main drive motor, knife carriage motor together with necessary drives and controls.

One Motorized Veneer Clipper having a knife length of 165". This machine will be used for dimensioning face veneer prior to jointing.

One Motorized Veneer Knife Grinder. Machine to be suitable for handling knives as used with the machines listed above.

Two Motorized Cold Glue Mixers. Machine to be suitable for preparing all types of synthetic resin glues, casein and similar adhesives which do not require the use of heat during their preparation.

One Resilient Roll Glue Spreader. A motorized machine complete with variable speed drive and a circulating pump system complete with pump, relief valve, bypass distributing pipes and separate motor and switch for the same.

One Steel Frame Plywood Press. Machine to be equipped with platens measuring 100" long by 50" wide and having 12 openings. Equipment to be furnished with press includes two pump, two motor hydraulic pumping system, and all necessary temperature and pressure indicating instruments.

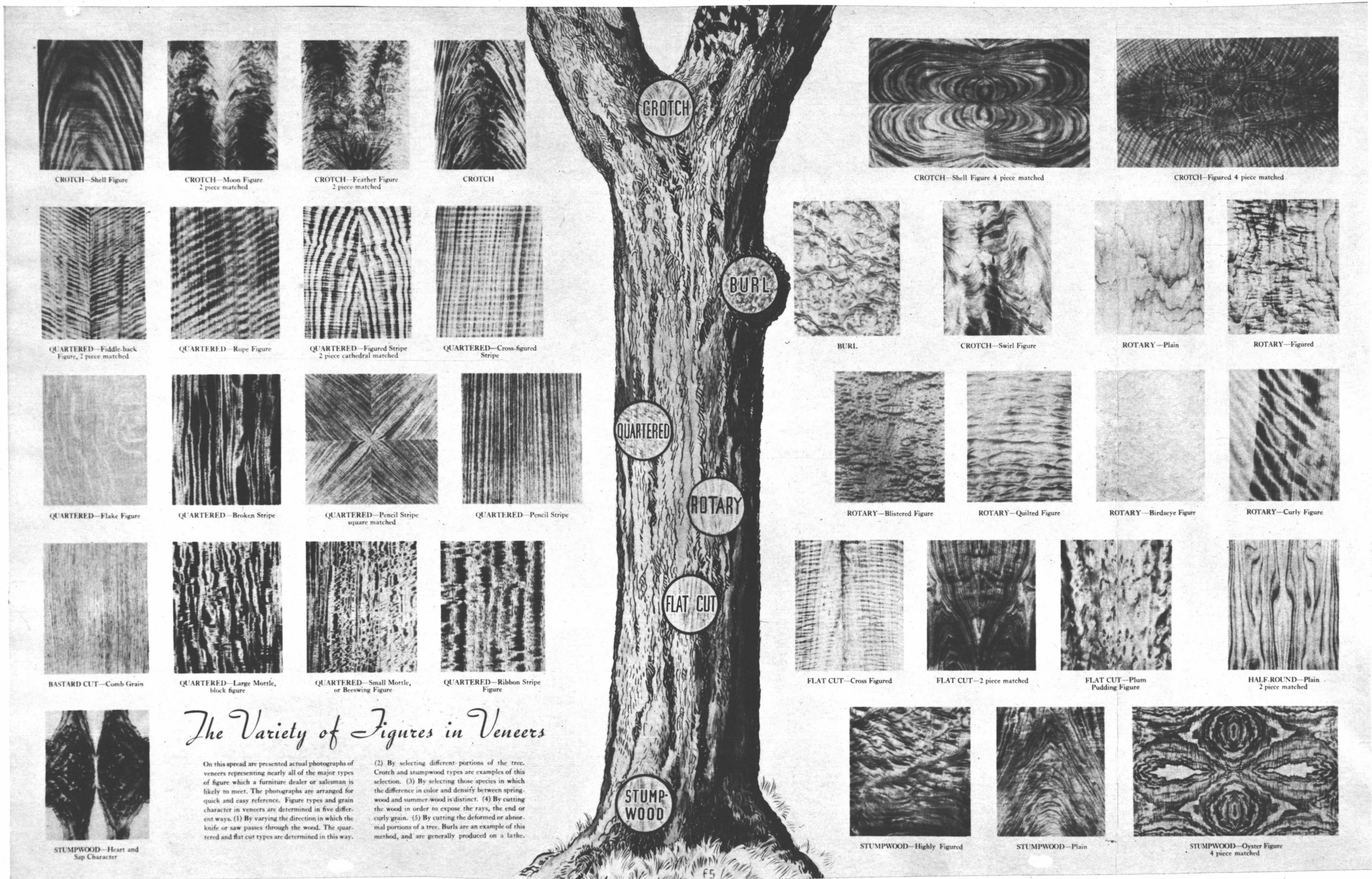
One Panel Sizing Unit. A unit to consist of two machines having the same general specifications except that the first machine will be used to size panels to any width up to 48", and the second one for sizing the panels to any length up to 96".

One Three Drum Sander having a bed width of 55". Each sanding drum is driven by a separate built-in motor, and the feed bed is also driven by a separate motor through a variable speed control.

One Veneer Waste Hog, complete with main motor direct connected by a flexible coupling. This hog is suitable for grinding veneer waste and small cores into chips of suitable size for use as boiler fuel.

One HRT (Horizontal Return Tubular) boiler built for an operating pressure of 200 lbs. per sq. in. and capable of producing approximately 5,000 lbs. of steam per hour.

Machine layout. (See Fig. XIII).



CROTCH—Shell Figure

CROTCH—Moon Figure 2 piece matched

CROTCH—Feather Figure 2 piece matched

CROTCH

QUARTERED—Fiddle-back Figure, 2 piece matched

QUARTERED—Rope Figure

QUARTERED—Figured Stripe 2 piece cathedral matched

QUARTERED—Cross-figured Stripe

QUARTERED—Flake Figure

QUARTERED—Broken Stripe

QUARTERED—Pencil Stripe square matched

QUARTERED—Pencil Stripe

BASTARD CUT—Comb Grain

QUARTERED—Large Mottle, block figure

QUARTERED—Small Mottle, or Beeswing Figure

QUARTERED—Ribbon Stripe Figure

STUMPWOOD—Heart and Sap Character

The Variety of Figures in Veneers

On this spread are presented actual photographs of veneers representing nearly all of the major types of figure which a furniture dealer or salesman is likely to meet. The photographs are arranged for quick and easy reference. Figure types and grain character in veneers are determined in five different ways. (1) By varying the direction in which the knife or saw passes through the wood. The quartered and flat cut types are determined in this way. (2) By selecting different portions of the tree. Crotch and stumpwood types are examples of this selection. (3) By selecting those species in which the difference in color and density between spring-wood and summer-wood is distinct. (4) By cutting the wood in order to expose the rays, the end or curly grain. (5) By cutting the deformed or abnormal portions of a tree. Burls are an example of this method, and are generally produced on a lathe.

CROTCH

BURL

QUARTERED

ROTARY

FLAT CUT

STUMP-WOOD

CROTCH—Shell Figure 4 piece matched

CROTCH—Figured 4 piece matched

BURL

CROTCH—Swirl Figure

ROTARY—Plain

ROTARY—Figured

ROTARY—Blistered Figure

ROTARY—Quilted Figure

ROTARY—Birdseye Figure

ROTARY—Curly Figure

FLAT CUT—Cross Figured

FLAT CUT—2 piece matched

FLAT CUT—Plum Pudding Figure

HALF-ROUND—Plain 2 piece matched

STUMPWOOD—Highly Figured

STUMPWOOD—Plain

STUMPWOOD—Oyster Figure 4 piece matched

Fig. I

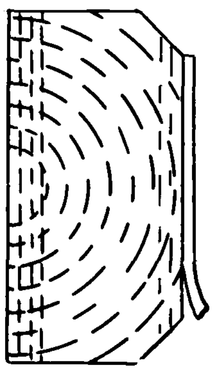


FIG II A, FLAT CUT

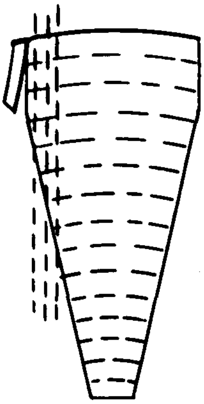


FIG II B, QUARTER CUT

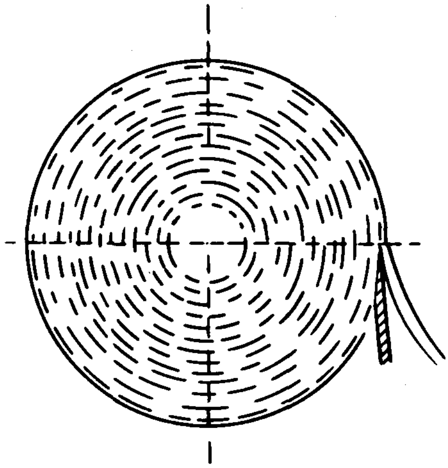


FIG II C, ROTARY CUT

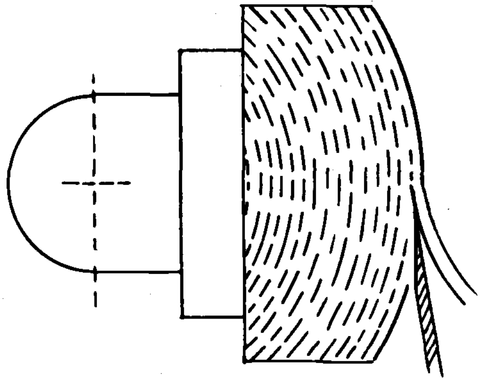
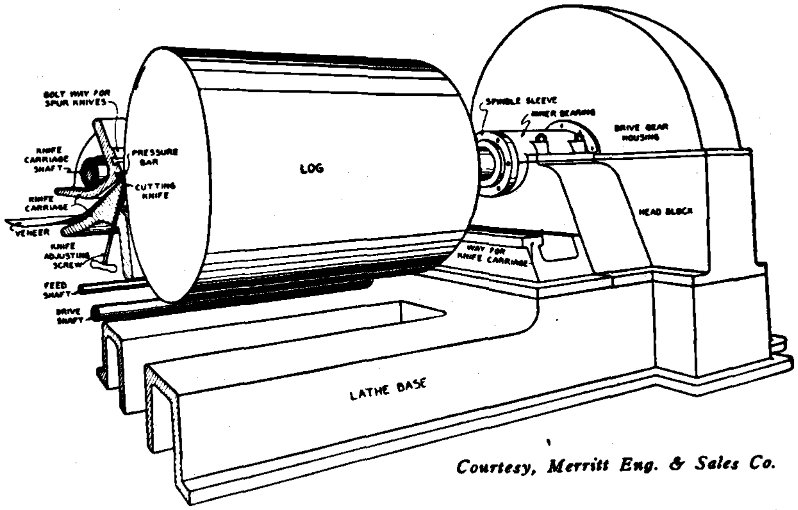


FIG II D, HALF ROUND CUT



Courtesy, Merritt Eng. & Sales Co.

Fig. III- Perspective view of standard lathe, with left end removed to show cutting mechanism.

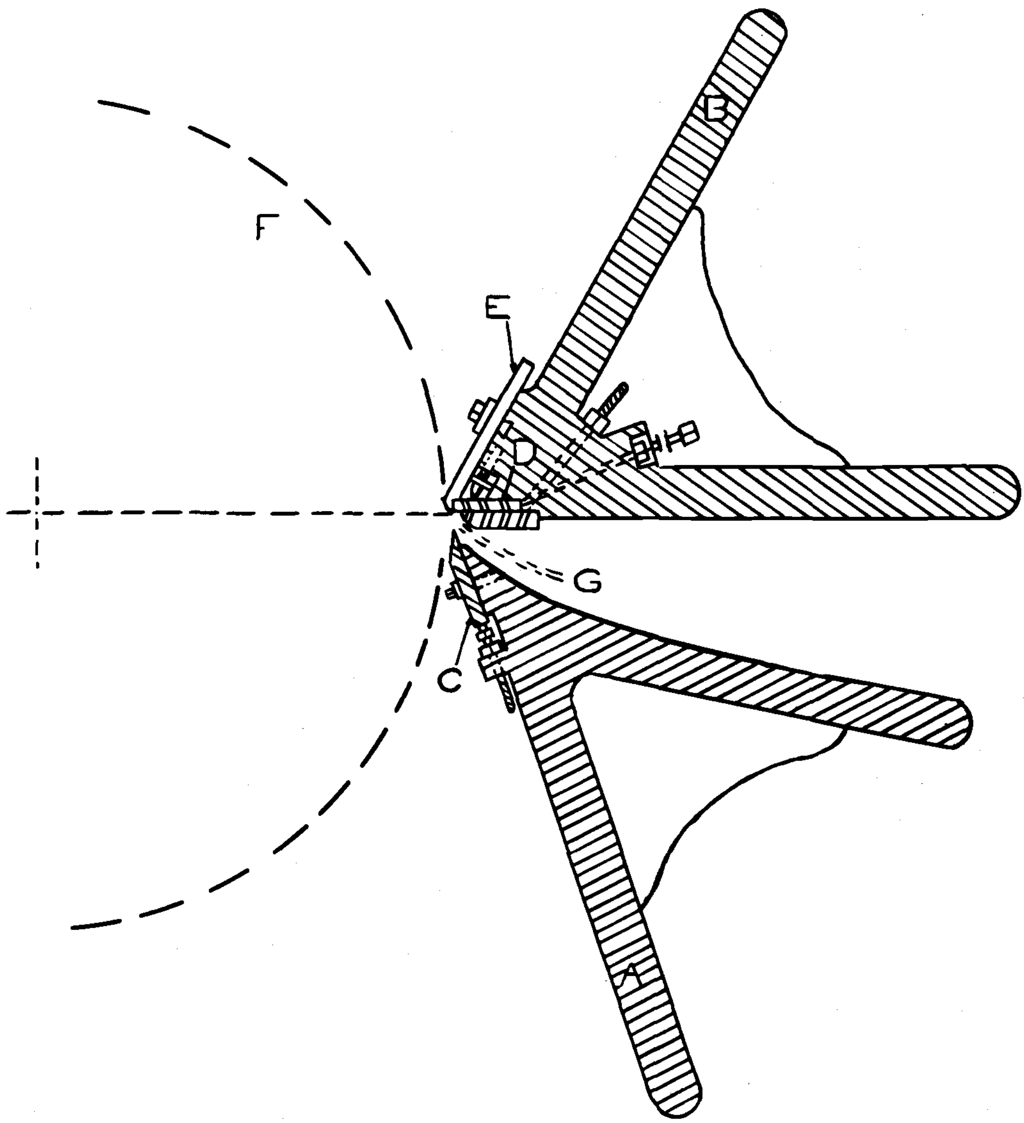


FIG III A, PRESSURE BAR AND KNIFE

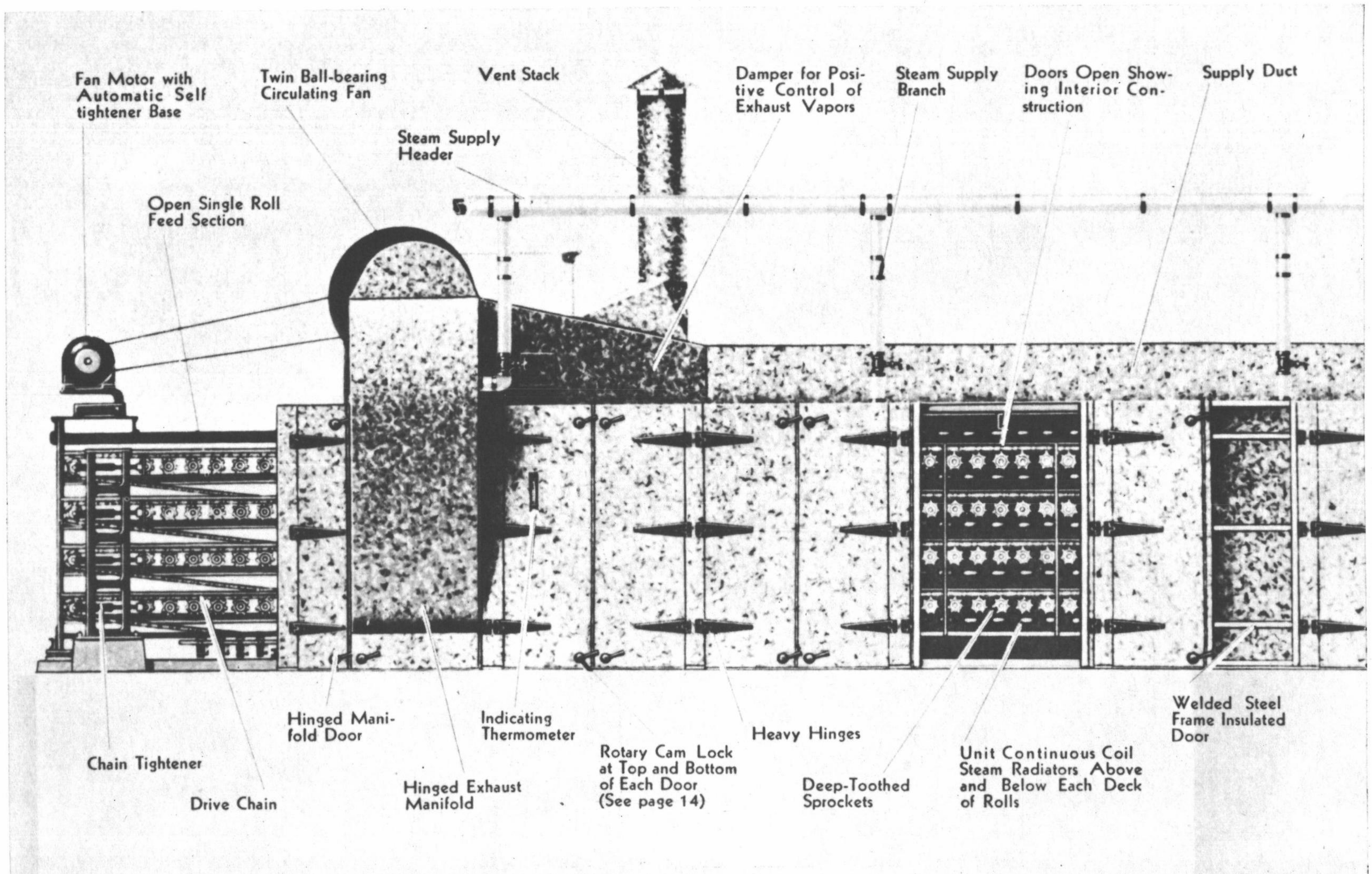
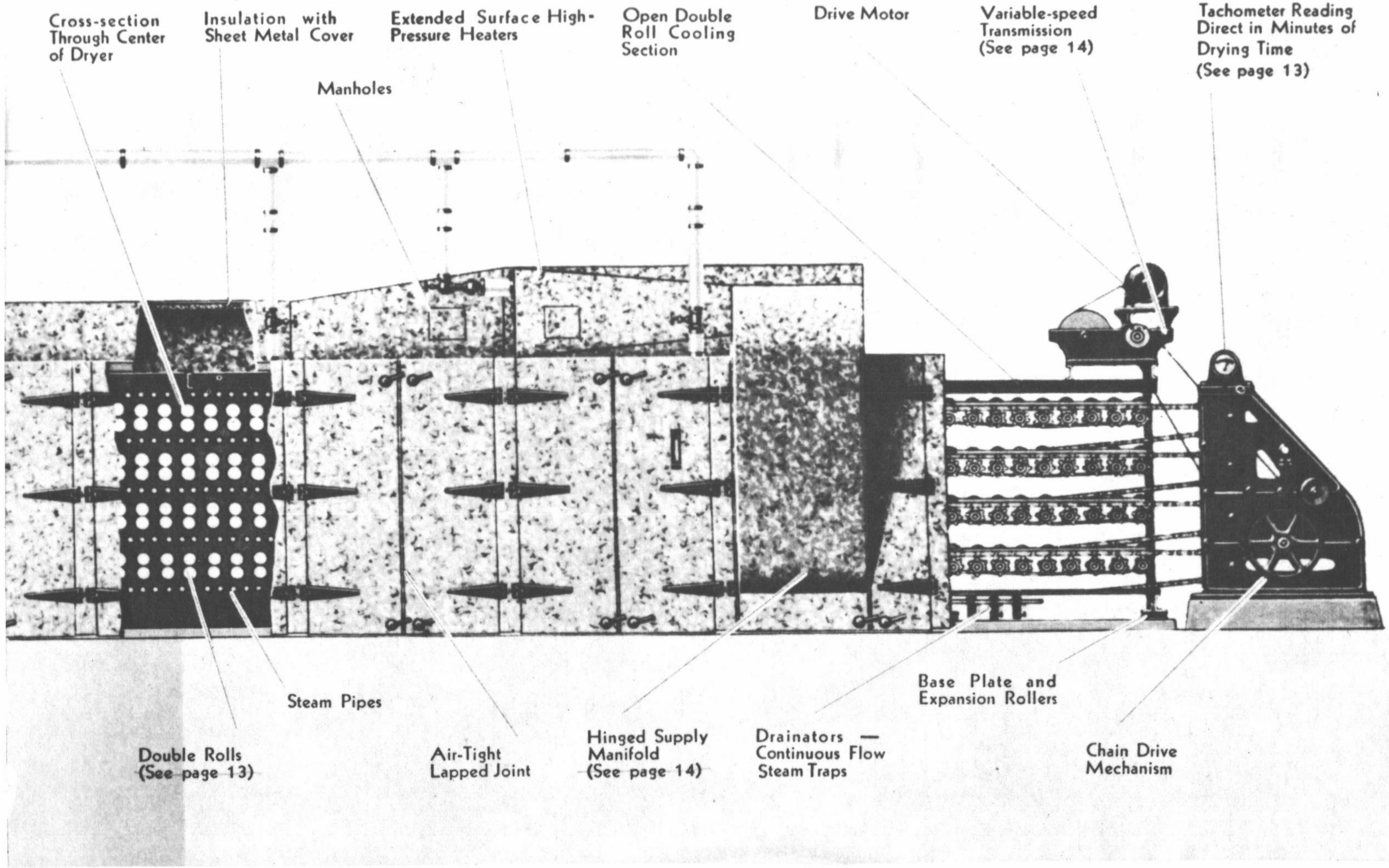
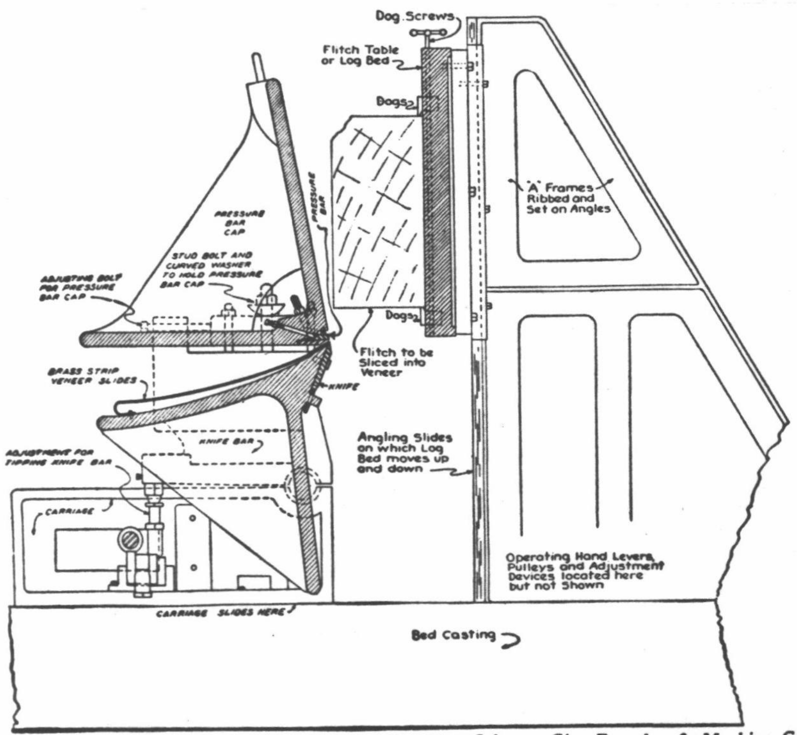


Fig. IV-Roller Veneer Dryer


Cross-section Through Center of Dryer
Insulation with Sheet Metal Cover
Extended Surface High-Pressure Heaters
Open Double Roll Cooling Section
Drive Motor
Variable-speed Transmission (See page 14)
Tachometer Reading Direct in Minutes of Drying Time (See page 13)
Manholes
Steam Pipes
Base Plate and Expansion Rollers
Double Rolls (See page 13)
Air-Tight Lapped Joint
Hinged Supply Manifold (See page 14)
Drainators — Continuous Flow Steam Traps
Chain Drive Mechanism



Courtesy, Johnson City Foundry & Machine Co.

Fig. V—Cross-section diagram of a standard veneer slicer.

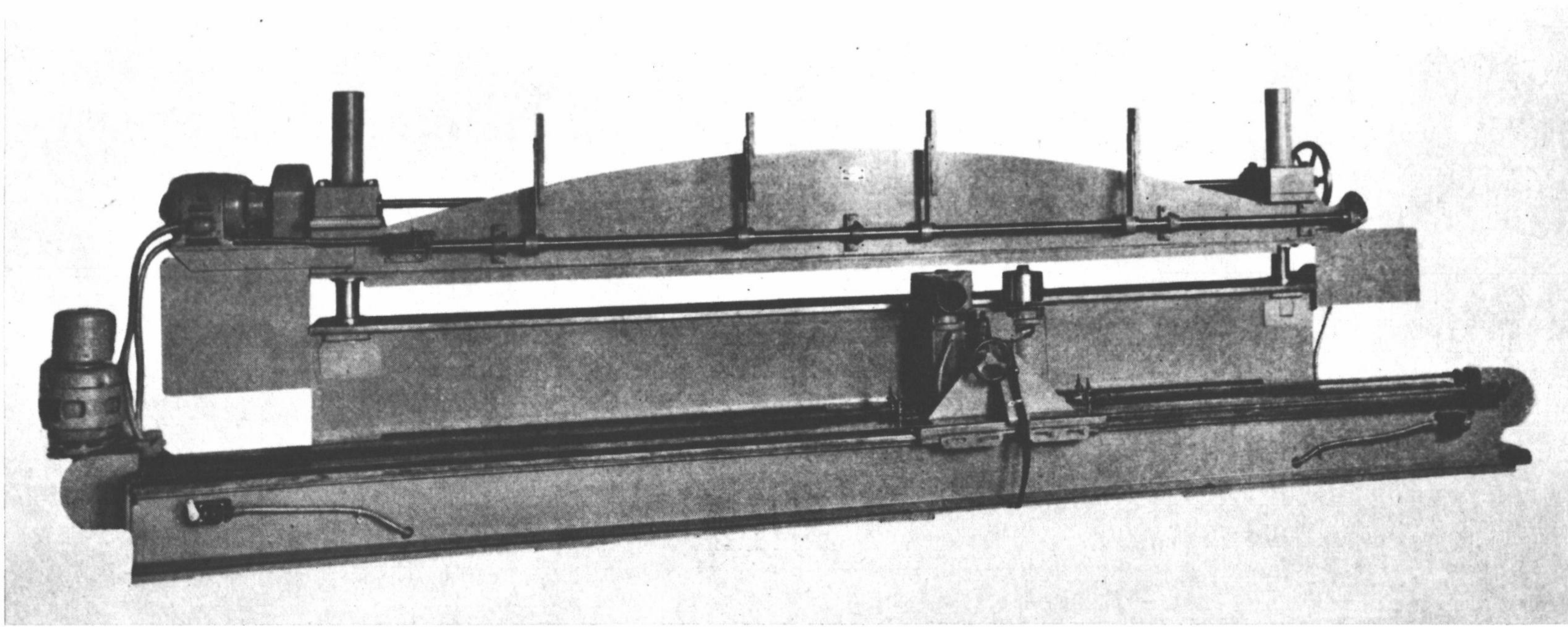


Fig. VI-Traveling Head Veneer Jointer, Cutter Head Side

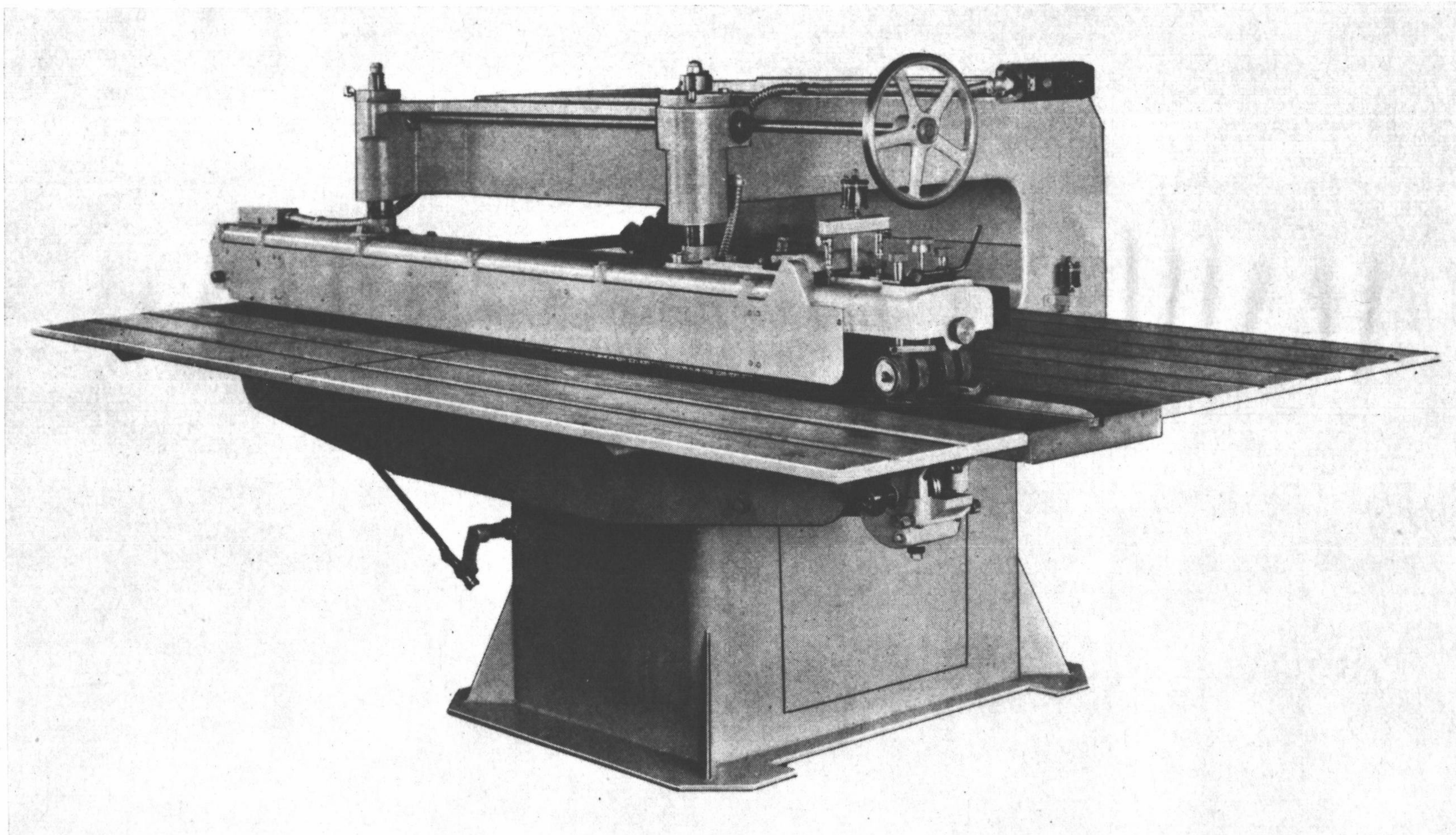


Fig. VII-Tapeless Veneer Splicer

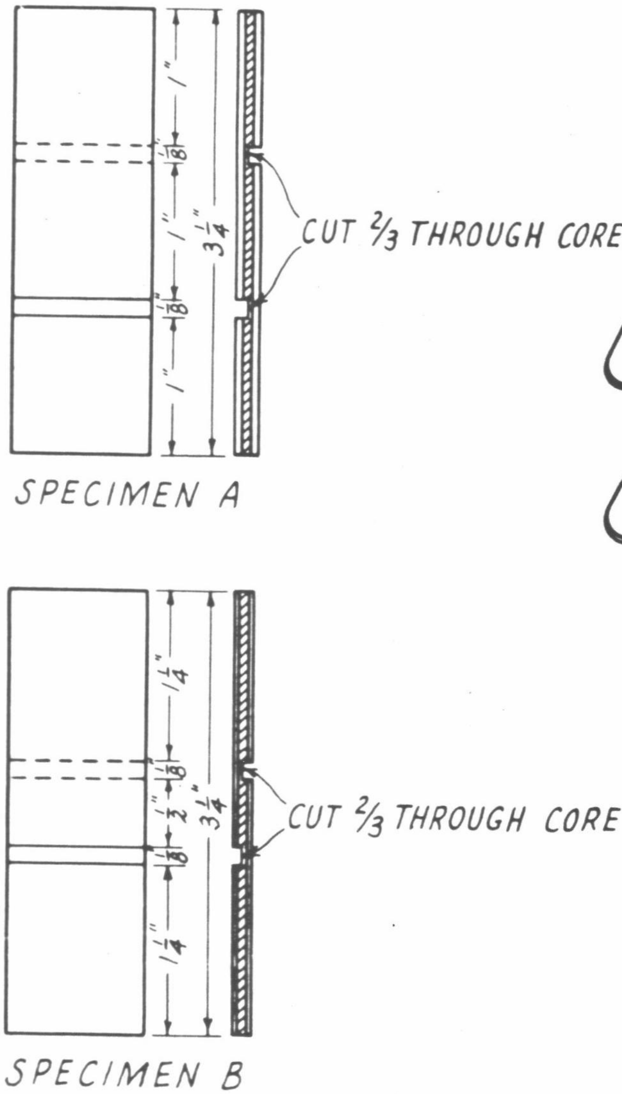


FIG. VIII - PLYWOOD GLUE SHEAR-TEST SPECIMENS

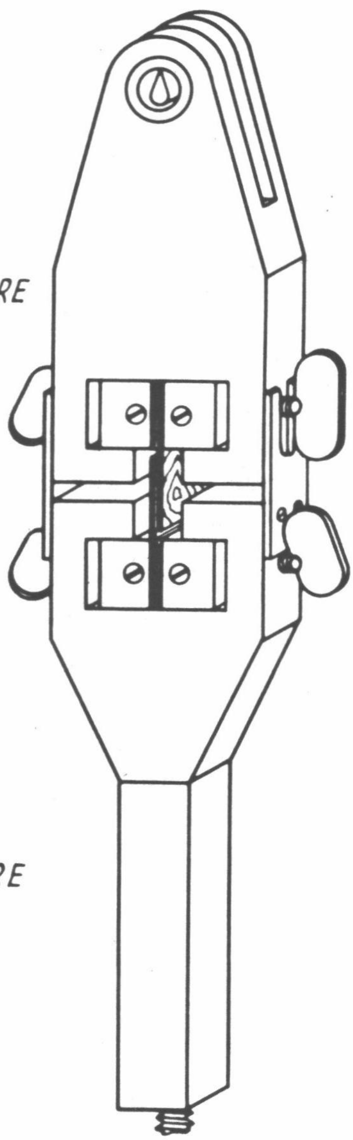


FIG. VIIIA - TESTING GRIPS

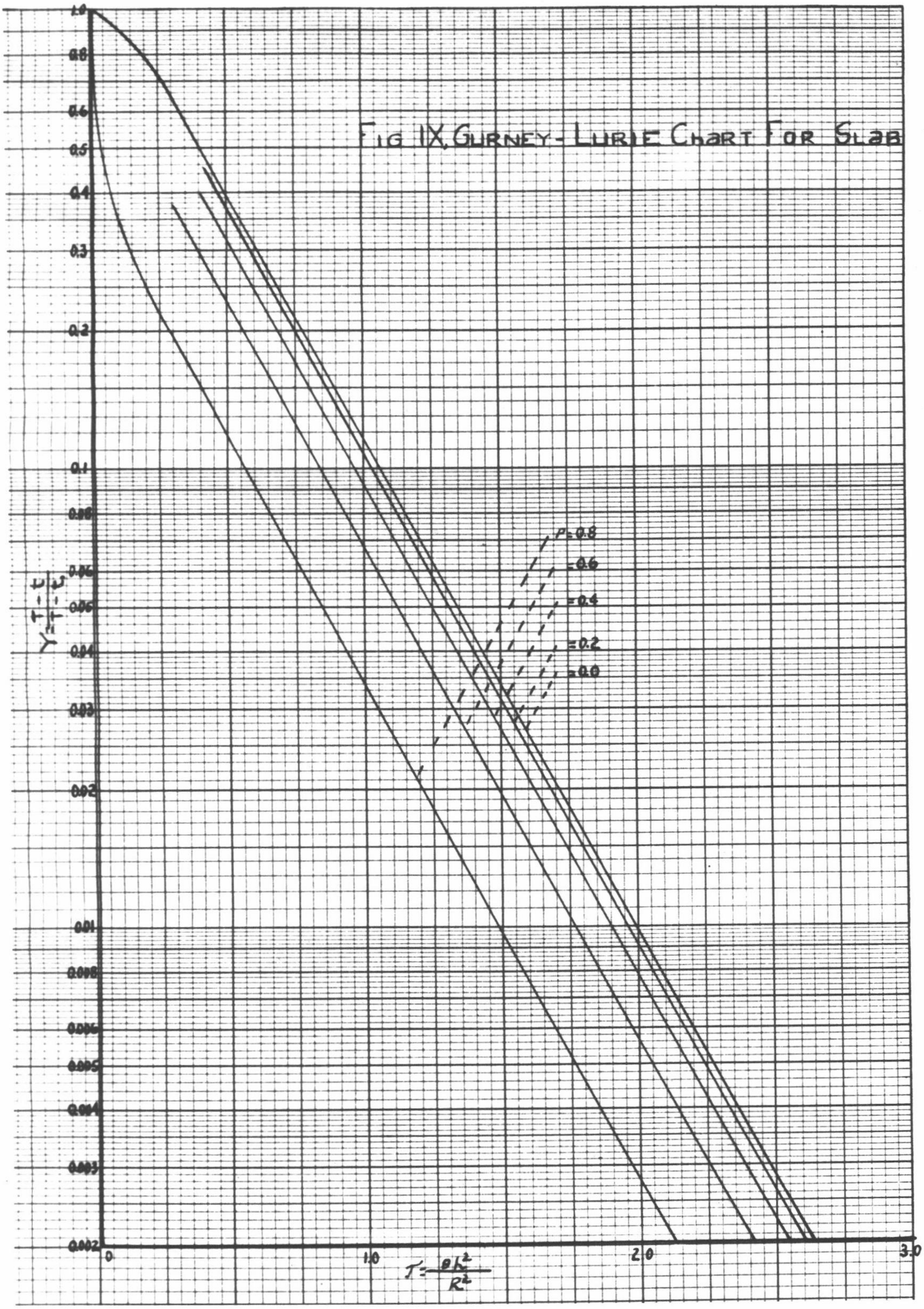


FIG IX. GURNEY-LURIE CHART FOR SLAB

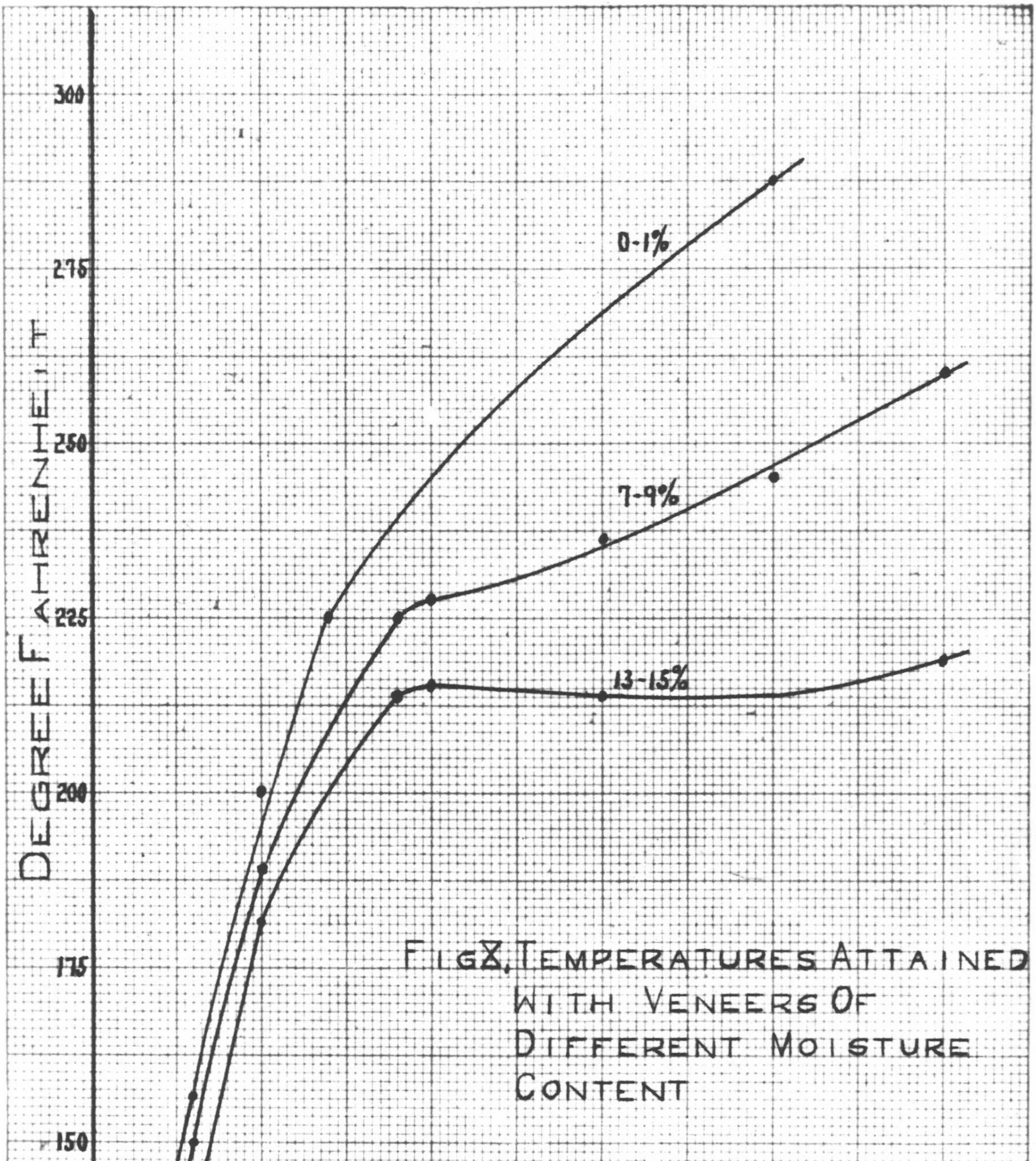


FIG X, TEMPERATURES ATTAINED WITH VENEERS OF DIFFERENT MOISTURE CONTENT

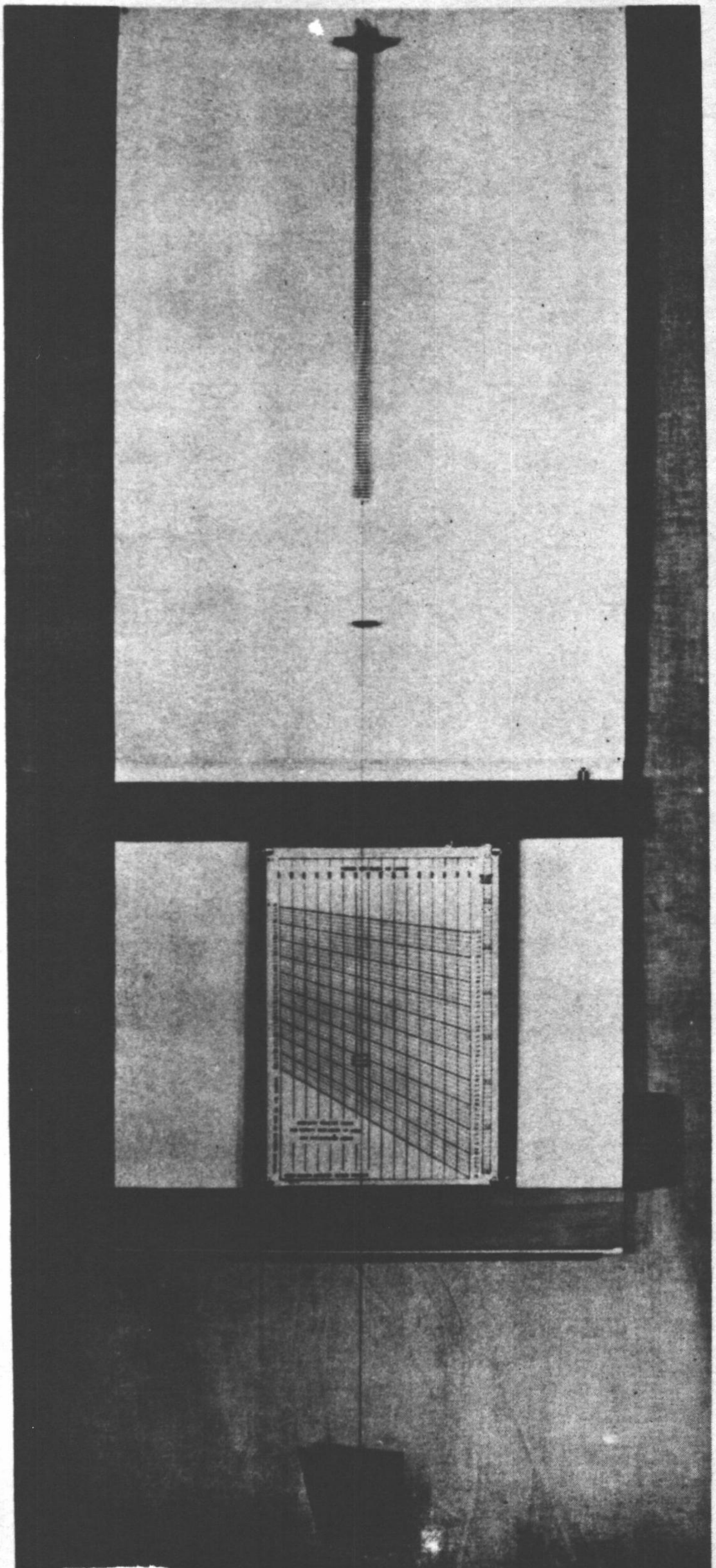


Fig. XI- **Determining specific gravity of veneer.**

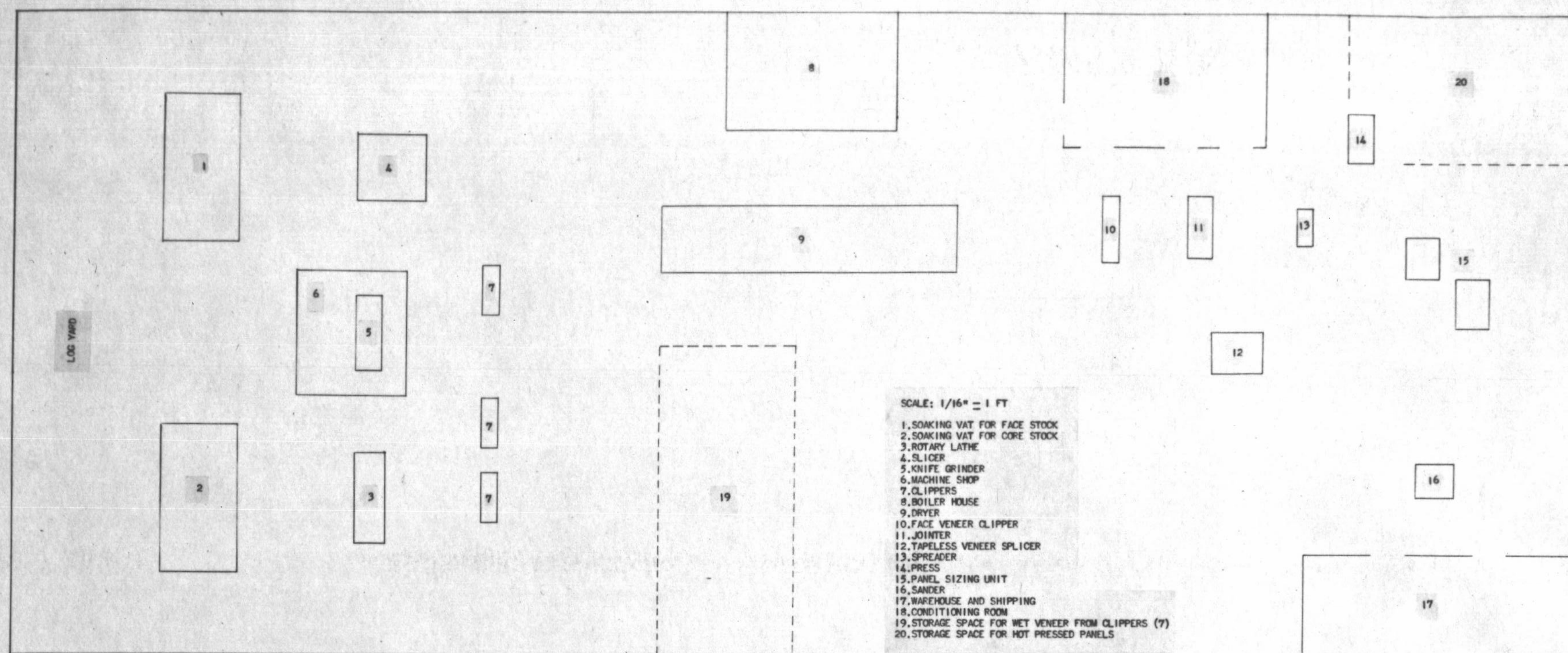


FIG. XIII- MACHINE LAYOUT

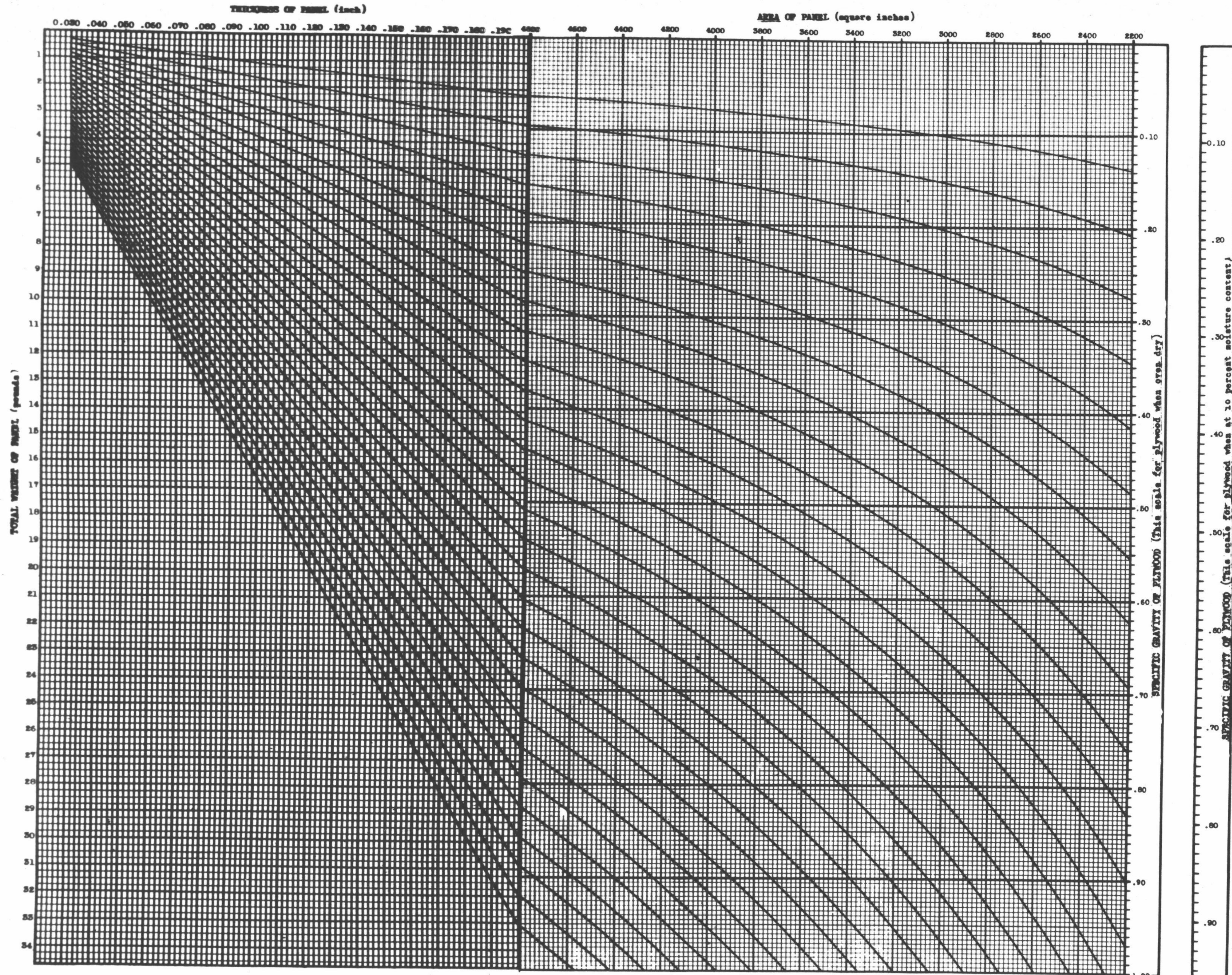


Fig. XII- Specific gravity chart for plywood (based on weight and volume when oven dry)

TABLE I -- CHARACTERISTICS OF SOME PLYWOOD ADHESIVES.

ADHESIVES	SOURCE	FORM SUPPLIED	PRESSING	ADDED INGREDIENTS	LIFE of MIXTURE (1)	SPREAD- lbs/1000 sq.ft. SINGLE GLUE LINE DRY BASIS(1)	ASSEMBLY TIME CLOSED (1)	CURING TEMPERATURE (1)	PRESSING TIME (1) (2)
BLOOD ALBUMEN	Dried Beef Blood.	Powder, Flake	Hot and Cold	Water, Alkalis, Paraformaldehyde, Hydrated Lime, etc.	2 Hours to Several Days	30 to 80	10 to 40 Minutes	Hot Press:180-250°F. Cold Press:Room Temp.	Hot Press: 3 to 6 Min. Cold Press: Overnight.
CASEIN	Precipitated from Milk.	Powder	Mainly Cold	Water, Alkalis, Formaldehyde, Preservatives.	Up to 24 Hours.(Preferably Short)	30 to 60	1 to 20 Minutes	Hot Press: 180-250°F. Cold Press:Room Temp.	Hot Press: 3 to 8 Min. Cold Press: 4 to 6 Hours.
ANIMAL	Hides and Bones of Animals	Powder, Pearl Flake, Shreds	Cold and Cold with Warm Cauls	Water, Some Preservatives	Up to 24 Hours.	30 to 50	1 to 15 Minutes	Room Temperature and Warm Cauls.	2 to 18 Hours
VEGETABLE STARCH	Vegetable Carbohydrates, Base: Mainly Cassava (Tapioca)	Flour	Cold	Water and Alkalis (NaOH)	Many days.	30 to 50	1 to 40 Minutes	Room Temperature	4 to 18 Hours
SOYA BEAN and VEGETABLE PROTEIN	Mainly: Soya Bean; also Peanut and Cotton Seed	Flour	Cold or Hot	Water, Lime, Silicate of Soda, Carbon Bisulphite.	Several Hours for Cold Press.	25 to 40	1 to 20 Minutes	Hot Press: 180-250°F. Cold Press:Room Temp.	Hot Press: 2 to 6 Min. Cold Press: 2 to 5 Hours.
UREA	Urea-formaldehyde, (Condensation Reaction)	Water Suspension (60-70% Solids),Powder	Mainly Hot	Water, Wheat, Rye or Walnut Shell Flour, Accelerators	Several Hours to One Day	15 to 30	Up to 24 Hours. No Critical.	230 - 260°F.	Hot Press: 3 to 15 Min. Cold Press: 8 Hours.
PHENOL	Phenol-formaldehyde,(Condensation Reaction)	Film, Dry Powder, Alcohol or Water Solution.	Mainly Hot	Alcohol, Water and Extenders.	Several Hours for Liquid.	Film: 1 or 2 Sheets (12.5 lbs/1000 sq. ft. of Sheet) Liquid: 10 to 20 lbs.	Hot Press. Liquid Resin 10 Min. to Several Weeks. Film: Several Months.	280 - 340°F.	2 to 8 Min.
RESORCINOL	Resorcinol-Formaldehyde, (Condensation Reaction)	Partially Polymerized Resin in Alcohol or Water.	Low Temperature	Hardener,(Formaldehyde), Filler, (Walnut Shell Flour).	2 to 5 Hours at 75°F.	15 to 30	1 to 2 Hours	75 - 200°F.	5 to 8 Hours at 75°F.
MELAMINE	Melamine-formaldehyde, (Condensation Reaction)	Powder	Hot	Water, Hardener and Filler	2 to 36 Hours at 75°F.	15 to 30	Up to Several Months. (No Critical).	190 - 300°F.	Several Minutes

(1) The most suitable conditions for individual glues has been established by the Manufacturers.

(2) The time under pressure with all hot pressing glues is dependent on such factors as distance to the glue line farthest from the platen, M.C. of veneer, species, thickness, and number of glue lines.

(3) Ratio of wet shear strength to dry shear strength.

(4) Despite this immunity, they do not afford protection to the adjacent wood, and for this reason, plywood should be considered no more decay resistant nor water resistant than solid wood of the same species.

TABLE I. (CONT.)--CHARACTERISTICS OF SOME PLYWOOD ADHESIVES

FAVORABLE M.C. OF VENEERS	DRY BOND STRENGTH	WET BOND STRENGTH	WATER RESISTANCE	MOLD RESISTANCE	STAINING POWER CHARACTERISTICS	HEAT and FIRE RESISTANCE	EXTERIOR DURABILITY	RELATIVE COST	PRINCIPAL USES
Faces 2 to 3 % Cores 5% or Less	Medium	Medium	Medium	Poor to Good	Low to High	Poor	Fair to Good	Medium	Refrigerator, Truck and Car Panels.
Item	Medium	Poor to Medium	Low	Generally Poor	Marked	Poor	Poor	Medium	Furniture, Interior Panels.
Item	High	None	Poor	Poor	Not Usual	Poor	None	High	Furniture, Piano Cases.
Item	Medium	None	Poor	Poor	Marked	Poor	None	Low (Cheapest)	Furniture Panels, Games, Packages.
Item	Medium to High	Poor to Medium	Low to Medium	Poor	Marked	Poor	Poor	Low	Building Boards, Concrete Forms.
2 to 14 %	High	Medium to High	High in Cold Water. Poor in Hot Water	Medium. When Highly Extended is Subject to Attack	None	Moderate	Good to Excellent	Resin Alone High With Fillers Low	Concrete Forms, Box Cars, Housing, Radio Cabinets.
Liquid Resin 1 to 5 % Film 8 to 12 %	High	High	High (75 - 100%) (3)	High (4) (Not affected)	Some with Liquids, None With Film	High	Excellent	Medium	Exterior Panels, Molded Panels, Housing.
2 to 16 %	High	High	High (75 - 100%) (3)	High (4) (Not affected)	--	High	Excellent	High	Where Hot Press Cannot Be Used But Where Glue Joints Resistant To Most Deteriorating Agents Are Desired.
6 to 15 %	High	High	High (75 - 100%) (3)	High (4) (Not affected)	None	High	Excellent	High	Well Made Melamine Resin Glue Joints, Resemble Those Made With Phenols.