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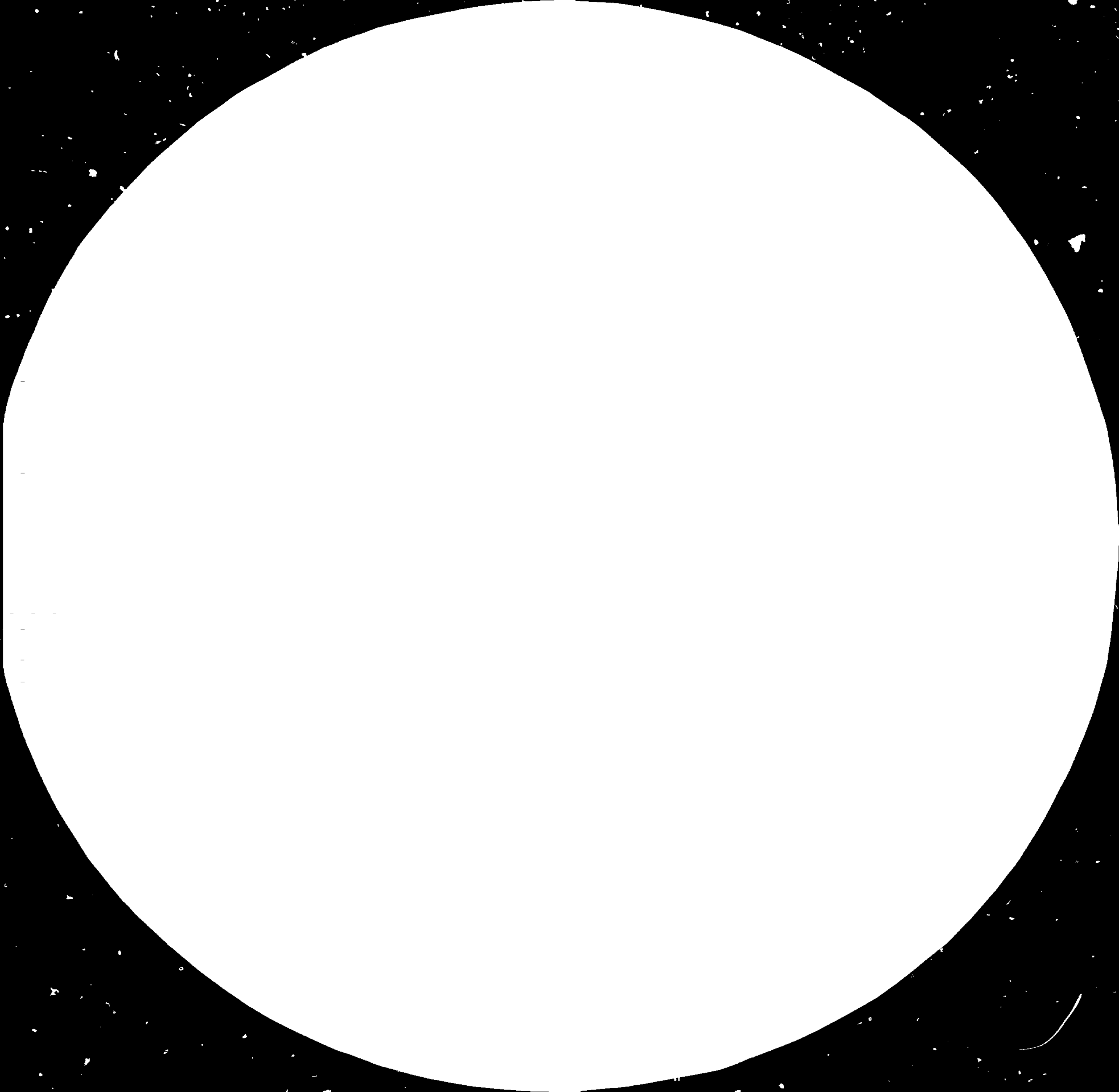

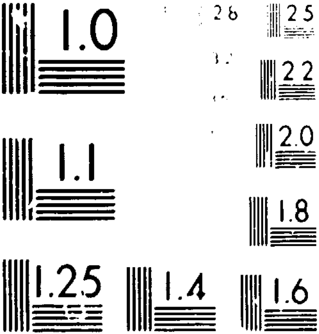
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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

TECHNICAL CRITERIA FOR THE SELECTION OF WOODWORKING MACHINES

UNITED NATIONS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna

TECHNICAL CRITERIA FOR THE SELECTION OF WOODWORKING MACHINES

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EXPLANATORY NOTES

In addition to the common abbreviations, symbols and terms and those accepted by the International System of Units (SI) the following have been used:

Technical symbols and abbreviations

dB	decibel
hp	horsepower (1 hp = 746 W)
kcal	kilocalorie (1 kilocalorie = 4.186 kJ)
kgf/cm^2	kilogram force per square centimetre (1 kgf/cm^2 = 9.807×10^4 Pa)
l.p.	lacquer product
M.P.C.	maximum permissible concentration
PVA	polyvinyl acetate
PVC	polyvinyl chloride
rpm	revolution per minute
v.p.	varnish product

Other abbreviations

DIN	Deutsche Industrie Norm (Federal Republic of Germany)
ECE	United Nations Economic Commission for Europe
EUMABOIS	European Association of Woodworking Machinery Manufacturers
FAO	Food and Agriculture Organization of the United Nations
ICOTERMS	International Rules for the Interpretation of Trade Terms
NEMA	National Electric Manufacturers' Association (United States)

Preface

The United Nations Industrial Development Organization (UNIDO) held a technical meeting on the selection of machinery for woodworking industries in Vienna in 1973. The purpose of the meeting was to assist developing countries in the selection of the right type of machinery and equipment for processing forest resources. This meeting was followed in 1975 by a workshop on wood processing, whose purpose was to explain the various processes which could be used in developing countries to produce specific wood-based products. The reports of these two meetings have been published as ID/133 and ID/180. The papers prepared for the meetings appeared in the series ID/WG.151 and ID/WG.200. Another relevant paper, "Methodology for the purchase of woodworking machines" (ID/WG.256/26), was prepared for a seminar on the furniture and joinery industries held at Lahti, Finland, in 1977.

During the technical meeting in 1973, it was recommended that UNIDO prepare technical manuals and operate training courses for industrialists and officials responsible for the approval of investments in the woodworking industry. In carrying out this recommendation, UNIDO held two technical courses on criteria for the selection of woodworking machinery at the Fifth and Sixth Biennial International Fairs for Woodworking Machinery and Accessories (INTERBIMALL) at Milan, Italy, May 1976 and May 1978. The courses were conducted in collaboration with the Association of Italian Woodworking Machinery Manufacturers (ACIMALL) acting on behalf of the Government of Italy. The courses were attended by 55 representatives from industry and government and by observers from developing countries. The courses were financed from the voluntary contributions of the Government of Italy to UNIDO for those years. In view of the great interest shown in the courses, and the subsequent response from numerous developing countries, UNIDO decided to edit the lectures given at the latter course and publish them in this volume.

One of the papers prepared for the 1973 meeting, "Criteria for the acceptance and ascertainment of the technical standard of machine-tools for woodworking operating by removal of chips and particles" (ID/WG.151/25), and the paper for the furniture seminar meeting, mentioned above, although not discussed during the course, were distributed to the participants. Because of their relevance it was decided to include them in this volume.

CONTENTS

I. Wood characteristics influencing equipment selection and machine operations*

To select any machine tool, it is first necessary to consider the properties of the raw material to be worked. Wood is not a material with homogeneous properties, as there are many growth conditions which modify the hardness, the resistance to tool progress and wear etc. Among the properties to consider, the most important are the density, moisture content, direction in which the log will be cut and the diameter of the log.

In woodworking industries which use timber from countries with temperate climate, the selection of machines may be based on the consideration of well-established working conditions and on many years of experience. Consider, for instance, coniferous logs to be processed for joinery material where the green wood to be machined has a density of 700-900 kg/m^3, a moisture content below 60 per cent and diameters varying between 25 and 50 cm. These characteristics allow for evaluation of the effects of varying conditions of machining on log breakdown at the head saw. It is thus possible to predict the effect of the shape of the teeth, the feed of carriage, the cutting speed and the power supplied etc. However, in tropical countries where growth conditions change frequently and seasonally and vary further due to the wide variety of wood species and large size of the logs, one has to be content with parameters which are a broad average of the variables involved.

Thus persons involved in the selection of woodworking machines for tropical woods must be fully aware of the characteristics of individual species. These characteristics will affect sawing, planing, peeling or slicing operations, the application of glue, lacquer, finishing material and kiln drying operations.

Characteristics of tropical woods

Dimension of trees

There is no secret about the marvel of nature represented by the sequoias and the Douglas firs of North America, or by the eucalyptus of Australia. These trees grow in temperate regions. However, taking into account all the trees grown in specified countries, and not just a few extraordinary examples, we come to the conclusion that the average tree size in tropical regions is indeed larger than the average tree size in temperate regions. As a matter of fact, in the scientifically managed forests of Europe and North America, a tree is considered mature when its diameter is between 40 and 60 cm at breast height, although trees are cut when as small as 12 to 15 cm in diameter. In tropical forests felling selection is biased towards high-quality species. Trees selected for felling are those of high volume, first grade quality and primary species, which bring the maximum return for investment costs of felling, logging, transport, yard handling etc. Trees to be considered in this category are all in the large diameter class, and range from 50 to 60 cm minimum diameter to 1.5 to 2 metres maximum diameter.

While in the past trees were cut into reduced lengths for use as saw logs and peeler logs, the present trend is to bring in the longest possible lengths which can be handled by mobile or stationary cranes, fork lifts, trucks and other powered units.

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* By G. Giordano, Professor of Wood Technology and Forest Utilization, University of Florence, Italy. (This is an edited version of ID/WG.277/1/Rev.1.)

Internal stresses

Few foresters and technicians are aware of the importance of internal stresses. However, they are extremely important because of negative consequences which arise after the felling operation or during log conversion. The phenomena caused by stress forces can be observed more often in tropical wood species than in logs grown in temperate climates (such as beech, oak, eucalyptus and some fast growing poplars). The table shows a list of some of the more common tropical wood species.

TROPICAL WOOD SPECIES

Geographic location	*Common name*	*Scientific name*
African species	Azobé	*Lophira alata*
	Emien	*Alstonia congensis*
	Ilomba	*Pycnanthus kombo*
	Limbali	*Gilbertiodondron dewevrei*
	Makoré	*Mimusops heckelii*
	Sipo	*Entandrophragma utile* etc.
	African mahogany	*Khaya ivorensis*
Asian species	Balau	*Shorea species spp.*
	Bintangor	*Calophyllum spp.*
	Durian	*Neesia spp.*
	Geronggang	*Cratoxylon arborescens*
	Kapong	*Tetrameles nudiflora*
	Kapur	*Dryobalanops spp.*
	Keruing	*Dipterocarpus*
	Lauan	*Parashorea spp.*
	Mengkulang	*Tarrietia spp.*
	Meranti	*Shorea spp.*
	Seraya	*Parashorea stellata*
	Merawan	*Hopea odarata*
	Rosewood	*Dalbergia spp.*
	Sao	*Sapotaceae* etc.

If one considers the cross section of a tree, there is a tensile stress near the periphery and a compression stress near the centre. These forces are in equilibrium in the standing tree. When the tree is felled and cut, all these forces become unbalanced and consequently the periphery tends to contract, the internal part to expand. The final result is cracks in the shape of crow's feet starting from the pith. It often happens that these cracks reach the periphery and really open the log into four or five independent sectors, which cannot be further processed economically. However, even if there are not such large cracks at the sawing time, the boards are under stresses at their ends and can open or undergo strong deformation. The internal stresses are often accompanied, in the tropical species, by the so-called "brittle heart" which is a central area devoid of any fibrousness and with lower mechanical resistance. Throughout the entire brittle heart area, one may find successive cross cracks in the wood on the internal side of the log. It is evident that this wood cannot be used for any building or joinery work.

Soluble components and inclusions

Walls of wood cells are composed of three groups of structural substances, cellulose, hemicellulose and lignin. These are common to all woods, but the percentage composition of each differs from species to species. These structural substances are not the only constituents of the woods. In the ligneous tissues it is possible to find two other types of substances in the cell sap. These include the soluble substances called "extracts" and also the insoluble materials. The extracts vary from one species to another, and determine specific characteristics in the wood.

Several tropical species, especially the dark-coloured ones, contain remarkable extracts. These compounds (tannins) increase resistance to biological deterioration thus protecting the wood. On the other hand inclusions or extractives can damage the tool, damage steel kiln fittings, stain steamed wood, or cause health troubles (eye, skin and lung irritations etc.) to the workers exposed to dust generated during machining and sanding operations.

A rubber resin or sticky substance can be troublesome for sawing and milling operations because of the effect of the resin particles on the tool. Resins are not a common constituent of tropical woods; however, they can be a problem when working with certain wood species. More serious damage is caused by the presence of very hard insoluble mineral substances in the wooden fibre. These substances, usually phosphates, carbonates or silicates can form agglomerates which are like irregular stones, sometimes as large as one's fist, distributed throughout the wood of certain species, such as iroko or some meranti. The substances may be compound materials which are found in internal cracks of a log, as in the Doussie.

These compound materials inevitably cause gullet cracking in the saw blades, or in the cutting edge of the tools. Instead of aggregating to a certain volume, the insoluble substances can sometimes be scattered in crystals or granules of smaller diameter (1/50 to 1/20 of mm) inside the cell cavity; the wooden tissues look perfectly normal, but during sawing increased resistance occurs and causes excessive teeth wear. Even though these crystals are not uniformly composed of silica, the wood species are called "siliceous".

Forest officials and sawyers are concerned because machining of these woods is both difficult and expensive. Tropical wood species known for their troublesome machining characteristics are: akato, makoré, azobé, movingui, mukulungu, aielié, abiurana, some lauan and meranti, the geronggang, kapur, keruing, mengkulang and mersawa. It is necessary to stress that the presence of certain toxic substances in extracts can adversely affect the workers' health. This is so for beté. Admittedly, this has nothing to do with the power or type of machine to select, but it requires a very careful study of the removal systems for sawn off-cuts and sawdust.

Fibre and tissue peculiarities

The tropical woods, more frequently than those of the temperate regions, have the fibre direction which is not oriented parallel to the log axis. The result is a marked counterlip which makes sawing, planing and sanding difficult, but can at the same time, if the fibres are divided into narrow and parallel bands or follow certain arrangements, increase the value of the woods for decoration. This is so in the case of sapelli (*Entandrophragma cylindricum*), sipo (*Entandrophragma utile*), American Mahogany (*Swietenia macrophylla*), afrormosia (*Afrormosia elata*), red lauan (*Parashorea spp.*).

Log and lumber conversion

Log yard operations

Log handling equipment for lifting and transport must be rigid, high-powered, and be capable of several operational uses. If log storage cannot be accomplished in log ponds, it then becomes necessary to create a log concentration yard. This allows for easier handling of the logs and is quite common. The logs, when brought in from the forest, are sorted and stacked in piles which are sprayed by sprinkler systems to protect against end checking, splitting, insect damage etc. The sprinkler system also affords protection against fire in cases of extreme hot and dry weather.

The log yard must be provided with a set of appropriate cross-cut saws. The ones normally used are of the chain-saw type, which can be easily moved either manually or can be mounted on very low carts. It is also necessary to have some metal brushes and monitors to properly clean and inspect the logs before sawing. Additionally, in regions where it is possible that the logs include metal splinters (areas where military fighting or guerilla war has taken place), it is recommended to use metal detectors to locate any hidden metal splinters, or other similar foreign bodies which might be present. Chapters V, VI and IX treat some of these topics in more detail.

Sawing

Before selecting the head rig, it is necessary to prepare the log conversion plan which includes species available and maximum diameter (here the average diameter is of minor importance). It is most important to know whether the logs are all of one species or of more than one species with different characteristics. Finally, it is important to know the specifications of the finished product.

While this chapter is not going to examine the sawing techniques, such as feed speeds, shape of teeth etc. for breakdown of the log, it does wish to dwell somewhat on the problem of internal stresses. In this connection it is worth the effort to examine the most advantageous sawing technique of the following three:

(a) Perform the sawing in parallel boards (through and through sawing) leaving the boards free to crack open in the centre, due to the relief of internal stresses;

(b) Make use of a frame-saw with two blades in order to eliminate four off-cuts (or slabs) passing the log twice through the frame. The waney edged timber will then pass through a gang frame-saw;

(c) Use band head-rigs with two circular sawing units to edge the board simultaneously or for centre rip cuts to eliminate or loosen stresses.

The circular saws are adjusted perpendicular to the sawing plane of the band-saw and can also cut out the brittle heart, when required.

Resinous wood species will be sawn with a spray system which sprays a solvent to the blade, avoiding sticky spots on the tool. Finally, the use of a scraper or a similar device is recommended to remove the caked sawdust from the sawn surface.

Board cross cutting or trimming is done by circular saws with special teeth shapes and suitably set cross cutting operations. The present trend is to use tips made of tungsten carbide, especially when hard and abrasive woods with mineral particles have to be sawn.

In wood industries where wood containing toxic soluble substances has to be machined, and can cause health problems, it is recommended to install a chip and dust exhaust unit. In addition the workers should use protective items such as masks and gloves.

It is also important to study the material flow in the sawmill, to decide on conveying and transport equipment for sawnwood and waste material such as slabs, edgings, trim ends, off-cuts etc. which should be chipped and stored in silos. Chapters V and IX treat these topics in more detail.

Peeling, slicing and production of plywood

The size of the logs is a factor which determines the power needs for the lifting units at the peeling and slicing machines. The kilns, glue spreading machines, presses and sanding machines must accommodate the dimensions of the finished product.

Since there is the possibility of having to face some "brittle hearts", the veneer peelers must be constructed in such a way as to be able to use chucks with different diameters.

Steaming vats have to be adjusted to any quality of wood, both from the point of view of steam temperature and of the length of treatment. It is very difficult to establish a general rule for wood species which have been incompletely studied. In these cases it is necessary to collect data to determine steaming parameters. Chapter XII treats these topics in more detail.

Milling (planing, shaping, turning, boring, recessing)

The extent to which all milling operations are successful is related to wood density, the grain direction of the fibres, the resin content and silicon inclusions. Machine design, however, is not related to these factors, but to design considerations which allow the application of correct tool geometry with the appropriate metallurgical composition of the tool.

In a large plywood factory, the recovery and use of waste in the form of pre-peelers or peeler cores, is an operation of great technical and economical importance which cannot be treated lightly. It is therefore recommended to recognize the various factors affecting these processes right from the start up of the production. Chapters V, XI and XII are among those that treat these topics in greater detail.

Gluing, lacquering and finishing

The equipment required is used for both tropical and non-tropical wood. The only difference is that for oily or greasy woods, such as iroko and teak, it will be necessary to add a preliminary phase to the production line to eliminate substances which cause problems in bonding and coating operations. Finishing is treated in chapter XV.

Kiln drying

As chapter X deals with drying of timber products, no attempt to examine the selection of drying kilns will be made here. However, mention has been made of the fact that under the influence of steam and heat, tropical wood species, very rich in extractives, release some substances which are corrosive for plates, pipes and for the equipment in general. This feature should, therefore, be borne in mind when selecting kilns with hot air systems.

II. Criteria for acceptance of and technical standards for woodworking machines*

Introduction

The quality control of woodworking machines involves a sequence of tests which render it possible to ascertain whether a machine is suitable for its intended use and can be put into service. The development of wood machining and the use of a wide range of more and more complex woodprocessing machines has made it necessary to adopt criteria in the form of performance tests agreed on by the manufacturers and users of machine tools.

These rationally derived standards are designed to group woodworking machines into classes according to the operations they perform. Such standards must be observed in dealings between supplier and purchaser.

The tests specified in acceptance standards are the following:

Testing of the machine at rest, i.e. testing the deviations of the components, their relative position and their movement

Testing the machine while it idles and under full load; including checks of its stability, capacity and output

Testing of the work performed on the machine (from the point of view of machining accuracy and surface quality); this can be done at the same time as full-load testing

Another consideration is that the purchaser should be aware of the current technical standards for each of the woodworking machines. The purchaser can evaluate the technical standard of the machine.

For this purpose it is necessary to know the main characteristics of the machine and the way in which they reflect current technology.

The purpose of this chapter is to present:

(a) Criteria for the acceptance of woodworking machine tools which remove chips or particles. These machines constitute the majority of the machines used in the woodworking industry. These machines are listed in annex I.

(b) Data sheets for representative types of machinery in this same category.

The figures which are presented in this paper, and which generally refer to tolerances, are in line with the norms and standards in force in countries with highly developed wood industries and advanced woodworking machine-tool sectors.

The author has considered it useful to present, in the introductory section of the chapter, a number of basic theoretical concepts with a bearing on working accuracy, possible errors (and their causes) in the machining of wood, and also the indicators of geometrical precision.

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* By V. Radulescu, consultant engineer at the Research and Design Institute for the Industrial Utilization of Wood (ICPIL), Bucharest, Romania. (This is an edited version of ID/WG.151/25, originally issued on 29 October 1973.) The text does not correspond to an internationally accepted standard and represents only the author's view.

General remarks

Basic concepts of precision in the machining of wood

Precision in machining is understood to mean consistency in the dimensions and shapes of parts obtained by machining and the nominal dimensions and shapes specified in the drawings of these same parts, within the specified dimensional tolerances.

The machining process gives rise to deviations from the nominal dimensions. These deviations have many causes.

If the deviation lies outside the permissible limits in a positive direction, assembly is impossible until the part is remanufactured to the required measurement.

If the deviation lies outside the permissible limits in a negative direction, the part must be rejected, as it cannot be corrected by machining.

In modern wood machining, the aim is to obtain interchangeability in mass-produced parts through precision operation.

As used in this context, interchangeability means that, within a set of finished wood products, any one part can be replaced by any other similar part without the need for subsequent machining, provided that the assembly satisfies specified requirements. It clearly follows that, under these conditions, the achievement of interchangeability entails first and foremost a high degree of precision within strict tolerances and established standards.

Deviations in machining wood and their causes

As will be shown below, the causes for such deviations do not lie solely in the machine. These deviations may occur because of the geometrical shape or the dimensions of the part in question. Deviations of shape are of great practical importance in the case of large parts.

Regarding dimensional deviations, it must be noted that each dimension must be measured from a machined surface that represents the reference base.

According to their nature, deviations in machining wood may be divided into two major categories: systematic errors and random deviations.

Systematic deviations originate from the following:

- Faulty adjustment
- Geometrical deviations in the machine
- Geometrical deviations in the attachments
- Elastic deformation of the machine
- Thermal deformation of the machine

Random deviations have the following sources:

- Non-homogeneity in the mechanical properties of the wood
- The wrong choice of the reference base
- Internal stresses in the material
- Inaccuracy of measurement
- Variations in the moisture content of the wood

Deviations of dimensions or geometrical shape may be due to the following:

- The machine (lack of geometrical precision)
- The tooling (lack of geometrical precision, damage, deformation)
- The attachments (deformation, wear etc.)
- The physical and mechanical characteristics of the workpiece
- Operator (faulty adjustments or measurements)

Precision in woodworking machine construction (geometry) and machining

General remarks

The purpose of precision machining is to avoid the need for later touch-up or corrective operations prior to assembly. This can be done only if the machines used are constructed to a high degree of precision so they can produce parts whose dimensional variations remain within the limits permitted by the established system of adjustments and tolerances, thereby ensuring interchangeability.

Verifying the precision of machining involves testing the geometry of the machine and its operating accuracy; such tests must be carried out and certified by the supplier.

Machine tools for woodworking, unlike those for metalworking, have high feed and chip-removal speeds, and have high rotational speeds of the shafts and spindles of the cutting and feed mechanisms.

It follows that special measures must be taken in the construction of woodworking machinery to eliminate vibration and to ensure the necessary rigidity. For example, revolving systems must be dynamically balanced, frames must be of adequate dimensions and specially machined parts stress relieved etc.; all of these factors lead to higher prices and larger production runs.

Geometrical checks of machine tools

Measuring the geometrical precision of a machine tool entails checking its dimensions and the relative movement of its various principal components while the machine is at rest.

To carry out these checks, one must first of all determine the principal conditions to be considered during the tests so as to ensure that the interpretation of the results will provide a clear picture of the quality of the new machine; one must also carefully select the tests and the parameters to be checked.

In addition to being checked for geometrical precision, machines should be subjected to tests during idle running separately from tests under full load, during which their machining precision will be checked.

In order to provide objective test conditions, certain basic requirements must first be met. These are:

(a) Mounting the machine on a suitable foundation so that the levelling accuracy conforms to the applicable standard. In the case of machine tools with a table, the installation is checked by ascertaining that the table is parallel to the horizontal plane in the longitudinal and transverse directions. A spirit level with an accuracy of 0.02 to 0.04 mm per 1,000 mm length is used for this purpose;

(b) The use of measuring instruments for testing purposes whose accuracy (due to design inaccuracies) does not exceed ⅓ of the deviation to be checked.

The accuracy of measuring instruments is usually specified in standards.

Indicators of the geometrical precision of wood-cutting machine tools

The concept of geometrical precision, as applied to machine tools, involves the following properties: straightness, flatness, coaxiality, parallelism, equidistance, coincidence, squareness (perpendicularity), run-out, axial slip and camming.

Straightness may be a geometrical characteristic of a line in two planes, of a mechanism (guideway), or of motion. A line is considered to be straight over a given length if the variation in the distance between points on the line and two perpendicular planes parallel to the general direction of the line does not exceed a given value. Straight-line motion of a component is taken to mean parallelism between the trajectory of a given point on the component and a reference straight line parallel to the general direction of the motion. Checking for straight-line motion amounts to checking parallelism or perpendicularity in the longitudinal motion of an axis on itself or of a plane surface on its own plane etc.

A flat surface is one in which the variation in the distance between points on the surface and a geometrical plane parallel to the general direction of the surface does not exceed a given value. The geometrical reference plane is located outside the surface to be checked and may be represented by a control panel etc. Work tables or mounting surfaces are usually tested for flatness.

The geometrical notion of coaxiality is taken to mean that two or more components, bounded by surfaces of revolution, have a common geometrical axis. In the acceptance testing of a machine tool for coaxiality, two axes are considered to be coaxial if the distance between them, measured at several points, does not exceed a given value. Machine components that are tested for coaxiality are spindles, arbors, sleeves and bearings.

Geometrical checks for parallelism and equidistance relate to the parallelism of lines and planes, and to parallelism and equidistance of motion. A line is considered to be parallel to a plane when the maximum deviation in the distance between various points on the line and the plane over a given length does not exceed a given value. Two lines are parallel if one of them is parallel to a plane in which the other lies. Two planes are parallel if the maximum deviation in the distance between them does not exceed a given value. Parallelism of movement refers to the position in the trajectory of a movable component of a machine with respect to a plane, a straight line or the trajectory of a point on another movable component of the same machine. When checking for parallelism, it is recommended that the measuring instrument be attached to the movable component. The concept of equidistance refers to the distance between certain axes and certain reference planes.

Squareness (perpendicularity) tests cover both the relative position of planes with respect to axis, or of axis with respect to planes, and perpendicularity of motion. In principle, a squareness or perpendicularity check amounts to a check for parallelism, using a precision square to determine deviations from squareness or perpendicularity. Perpendicular motion includes the movement of a component in a specified plane, along an axis, or with reference to the trajectory of another movable component of the machine. When checking the perpendicularity of a trajectory to an axis, the axis is represented by means of a bar, against which a square is placed. The free arm of the square is used to check the movement.

Geometrical checks of rotation include checks on out-of-true running (run-out) and axial slip. In *out-of-true running there is out-of-roundness of a part in a plane perpendicular to its axis* For a shaft, the value of the out-of-round is given by the difference between the diameter of the circumscribed circle and the smallest measurable diameter of the shaft in a given plane. For a hole, it is given by the difference between the diameter of the inscribed circle and the largest measurable diameter of the hole, in a given plane. The eccentricity of axis, at a point on that axis, is the distance between the projections of the geometrical axis and the axis of rotation of the part in a plane perpendicular to the axis of rotation. Axial slip is a periodic reciprocal movement of a rotating part in an axial direction, resulting from a fault in the construction of that part. Axial slip should not be confused with axial play. For the correct measurement of axial slip, suitable axial pressure should be applied to the shaft to be checked, so as to take up any axial play.

General standards of geometrical accuracy for machines and accuracy classes

Precision classes in the machining of wood, referring to operations at a single setting of the machine, correspond to fundamental operating characteristics of various machines and serve as a basis for the determination of precision classes in the system of tolerances and adjustments. There is a reciprocal relationship between the precision classes adopted under the system of tolerances and adjustments in the machining of wood and the characteristics of machines.

Geometrical errors in a machine may be errors in any of its components, errors in the relative position of machine components or errors of movement.

The rigidity of the machine and play in its shafts and moving parts critically affect its performance and give rise to machining errors proportional to the amount of play.

The degree of geometrical precision of wood-cutting machine tools depends on the degree of precision built into the metal-cutting machine tools used in their production.

The tolerance limits which must not be exceeded in the various operations involved in producing joints and ensuring the interchangeability of parts serve as the basis for the establishment of general standards of geometrical accuracy. Similarly, when general standards of geometrical precision are established, consideration will be given to the technological and operating conditions that follow from the use envisaged, and also to the cost and complexity of the machines in the light of the class of precision required.

In the light of these factors, woodworking machines operating by chip and particle removal may be grouped into three precision classes, namely:

(a) Machines of precision class 1, which are used in particular for finishing operations, such as copying machines, sanding machines (drum sanders, wide belt sanders, contact sanders) etc.;

(b) Machines of precision class 2, this being the basic class including most woodworking machines, such as planing machines, moulding machines, spindle moulding machines etc.;

(c) Machines of precision class 3, which are used for log breakdown, to be followed by other machining processes, including such machines as vertical frame sawing machines, band sawing machines, log band sawing machines, edging circular sawing machines etc.

The general standards governing tolerances (permissible deviations) for the basic testing of woodworking machines are based on this classification; their values are indicated in annex II.

The standards and norms for wood-cutting machine tools that have been devised and introduced in various countries generally follow this scheme.

Procedure for testing machines

General procedure

For the purpose of carrying out tests and checks, machines are mounted on suitable foundations at the manufacturing plant.

Once a machine has been properly mounted, it should be checked for levelness, a machined surface on the machine itself being selected for the purpose as the reference plane. The levelness tolerance is 0.2 mm/1,000 mm. Levelness is achieved by inserting wedges between the base plate of the machine and the foundation or mounting panel. The devices (wedges) used to position the machine horizontally should be inserted only at the points indicated by the manufacturer.

Levelness of the machine

The levelness of the machine is checked at approximately equidistant points (300-400 mm) along the longitudinal and transverse axes by means of a spirit level (see "Geometrical checks of machine tools"). Only devices provided by the supplier should be used to achieve levelness within the limits specified in the standards. Improvised wedges and other devices should not be used.

Rigidity of the machine

The rigidity of the "machine tool and workpiece" system means the relationship between the forces which, when the machine is in operation, act on the guideways and tool-holders in a direction perpendicular to the machined surface. It also refers to the total deformation of these parts as measured in the same direction. Deformations in this system lead to alterations in the machining dimensions and, consequently, to errors. The deforming force is proportional to the cutting force required and inversely proportional to the peripheral velocity. Woodworking machines are tested for rigidity by two methods, the static method and the dynamic method.

The static method consists of applying static loads to the sub-assemblies of the machine.

The dynamic method consists of applying standard cutting-force loads to the sub-assemblies of the machine.

The static rigidity test is carried out by means of a remote-effect dynamometer, the resultant deformations being recorded with the aid of a dial gauge.

The limit load is selected in relation to the maximum normal force which may develop when the machine is operating under the most unfavourable conditions.

Procedure for geometrical checks

The most common methods for checking geometrical and machining accuracy are presented below, with an indication of the devices used in the tests and the tolerances for each type of machine.

The flatness test

The flatness test can be carried out with a straight-edge or with spirit levels.

Testing with a straight-edge[1] (figure 1). Three points A, B and C on the surface to be checked are selected as zero marks. Three gauge blocks of equal thickness are then placed on these three

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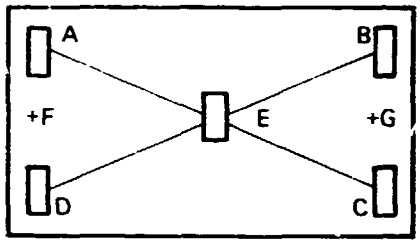
[1] Important only when small components are machined.

points, so that the upper surfaces of the blocks define the reference plane to which the surface is to be compared. A fourth point, D, lying in the reference plane is then selected, after which the procedure is as follows: a straight-edge is placed on A and C and an adjustable block is set at point E on the surface and brought into contact with the lower surface of the straight-edge.

Figure 1. The flatness test done with a straight-edge



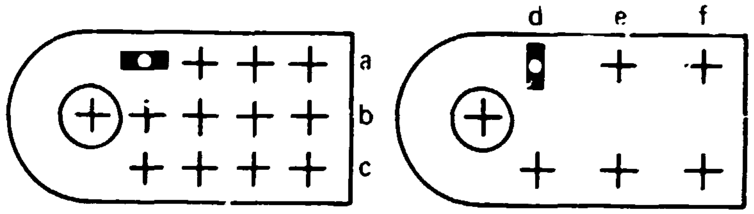
Points A, B, C and E are all in the same plane. The straight-edge is then placed on B and E; an adjustable block is placed at point D and its upper face is brought into the plane defined by the upper surfaces of the blocks already in position. As a result, the upper surfaces of the blocks at points A, B, C, D and E lie in the same plane. By placing the straight-edge on A and D and then on B and C, the locations of all the intermediate points on the surface lying between A and D and between B and C may be found. The locations of the points lying between A and B, C and D, may be found in the same way. Any necessary allowance for sag in the straight-edge should be made.

In this way, the flatness of the surface is checked along the sides of the quadrilateral ABCD.

The measurement is made either by using a dial gauge whose mount rests on the straight-edge placed in the way shown above, or by using parallel flat blocks and a feeler gauge.

Flatness tests using a spirit level (figure 2) are carried out with reference to the horizontal plane. The spirit level is placed in a longitudinal direction at points a, b and c, which are spaced 300-500 mm apart, and then in a transverse direction at points d, e and f, and the readings are taken.

Figure 2. The flatness test done with a spirit level, which is first placed at points a, b and c

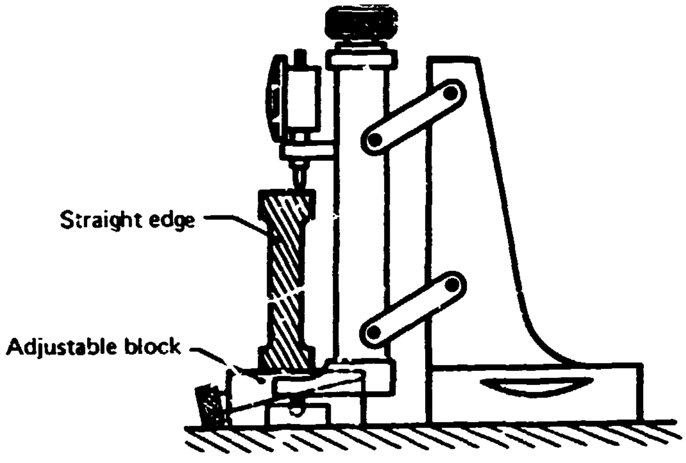


The straightness test

The straightness test checks the straightness of a line in two planes, the straightness of a component, or straight-line motion (see "Indicators of the geometrical precision of wood-cutting machine tools").

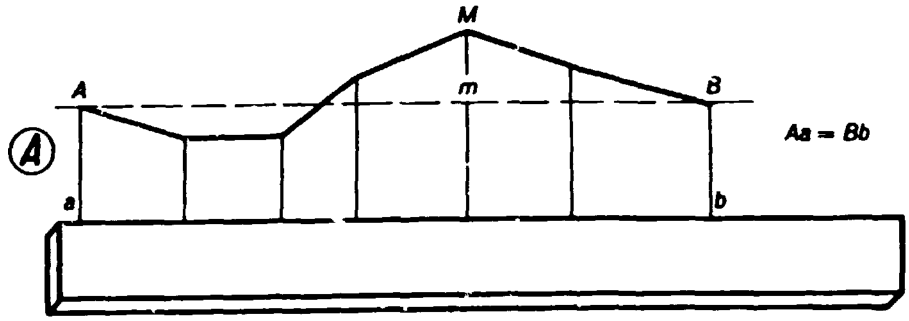
For lengths of less than 1,500-1,600 mm (the usual case), straightness of a line in two planes is checked by means of a straight-edge and a spirit level. Optical instruments are used for greater lengths. In normal situations, when a straight-edge is used, it is laid on two blocks located at points corresponding to the minimum deflection. The measurement is made by moving along the straight-edge a rider of which one point rests on the surface to be measured and the other carries a dial gauge, the plunger of which is in contact with the straight-edge (figure 3). The straight-edge is set by means of adjustable blocks to give identical readings at both ends of the line.

Figure 3. Straightness test of a line in two planes. A straight-edge and a spirit level are used with a rider which has a dial gauge. (Not commonly used for woodworking machines)



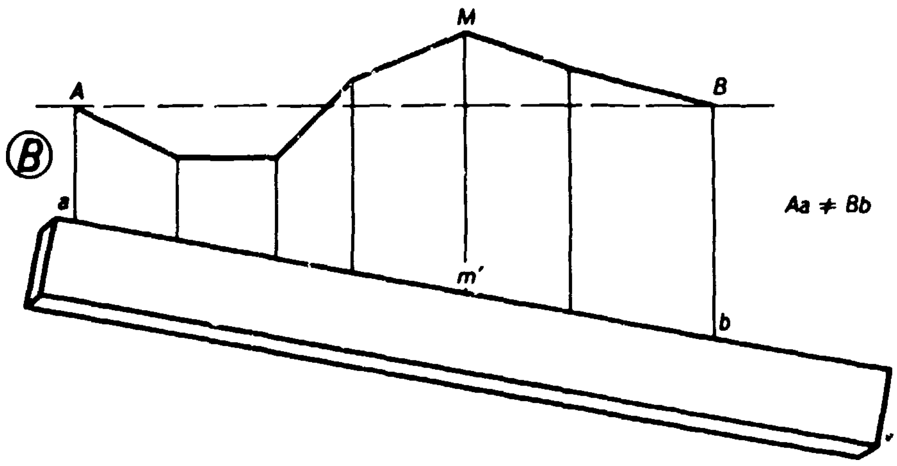
In this way (figure 4), the distances from the different points along the line AMB to the straight line AB can be read directly.

Figure 4. Example of results from a straightness test. In this case identical readings are at each end of the line



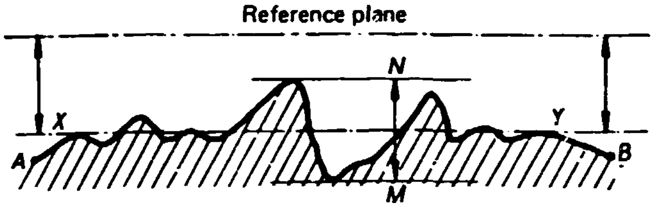
The straight-edge may also be set without aiming at identical readings at both ends of the line; the readings are then plotted graphically and the errors, which must not exceed the specified tolerances, checked in relation to the straight line ab (figure 5).

Figure 5. Straightness test results with different readings at ends of the line



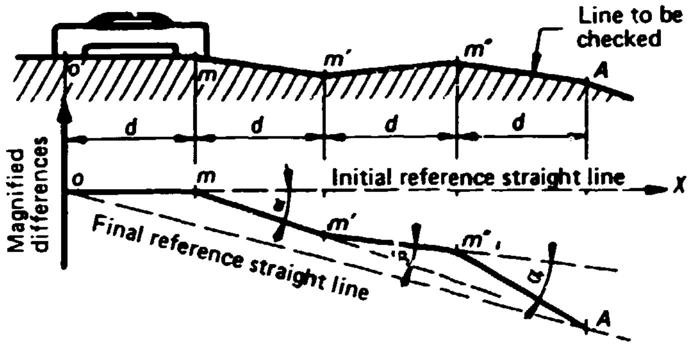
When measuring with a spirit level, the reference plane is the horizontal plane as defined by the level. The measurement is [illegible] sections (figure 6). The general direction of the measured line AB is plotted on the diagram [illegible] measured. The distances MN measured perpendicularly to this direction should not exceed the [illegible]ed tolerances.

Figure 6. When measuring straightness with a spirit level, the reference plane is the horizontal plane. Line xy is a reference line



In the case of a horizontal line (figure 7), the initial reference straight line is the line omx, o and m being two points on the line to be checked.

Figure 7. Measuring the straightness of a horizontal line



The level is placed successively on om, mm', m'm" etc. The distances om, mm' etc. are equal to a value "d", related to the total length oA, which is to be checked (usually, d is between 100 and 500 mm).

The readings of the level on mm', m'm" etc. are compared with the reading at the initial position om.

If an adjustable level is used, the bubble should be brought to zero in the original position, so as to obtain in the operations which follow a direct reading of the position of the lines mm', m'm" etc. in relation to omx. The measurements are then repeated in the opposite direction Ao, using the same points, and the average of the results obtained is calculated.

The profile of the line omm'm"A can then be traced.

The tolerance with regard to the straightness of a line is the maximum permissible deviation between points on the line and a reference straight line joining the ends of the line (line xy in figure 6).

Checks for straightness of a component relate mainly to slideways of machine tools. Flat slideways are checked with a straight-edge, as in the case of lines, while V-slideways are checked with a level laid on a cylinder or some intermediate part made to the shape of the slideway (figure 8).

Straight-line motion relates to the travel of a component in the longitudinal direction. Tests for straight-line motion are in effect tests for parallelism or perpendicularity and can be performed with a dial gauge and a straight-edge (figure 9).

The gauge is mounted on the moving component so that the plunger slides along a straight-edge representing the reference line.

The tolerance for accurate straight-line motion is the maximum permissible deviation, in relation to a straight line, of the trajectory of a point on the moving component. It is necessary to specify the plane in which the check is performed and the position of the field of tolerance with respect to the reference line, e.g., "trajectory concave only, in the vertical plane".

Figure 8. Checks for straightness of a V-slideway

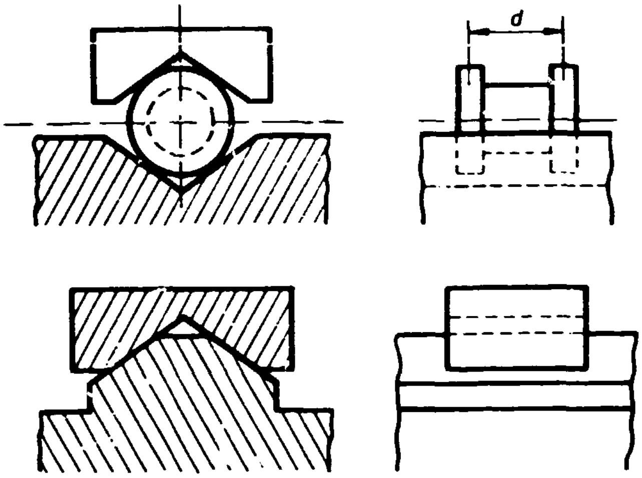
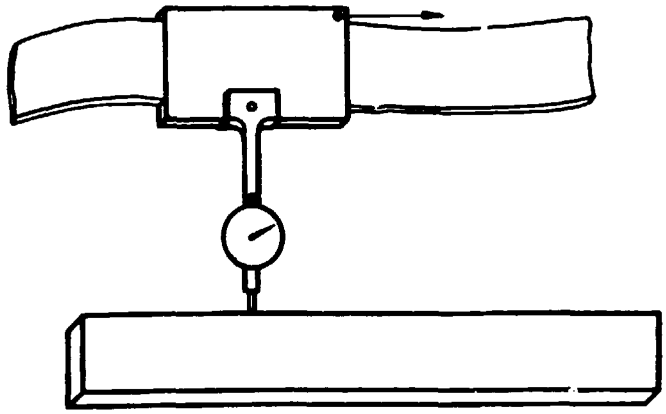


Figure 9. Checks for straight-line motion



Checking for coaxiality

Coaxiality is checked by the following methods:

(a) The opposite-points method;
(b) The two-mandrel method.

The opposite-points measurement method is shown in figure 10. The dial gauge is mounted on rotating shaft A. Shaft B is the elongation of shaft A. It is assumed that the geometrical axis of shaft B is out of alignment, with respect to the geometrical axis of shaft A, by the amount δ in the vertical plane and by the amount ε in the horizontal plane.

When the plunger of the gauge reaches the upper generatrix of shaft B, the displacement of the shaft will be δ; when it reaches the lower generatrix, the deviation will also be δ, but in the opposite direction. If the indicator pointer is set at zero when the plunger reaches either the upper or lower generatrix, then, after rotating through 180° the deviation will be 2δ, representing the maximum value of the discrepancy.

However, in this method, there is one inherent source of error which must be considered in relation to the degree of accuracy required of the machine tool undergoing acceptance testing.

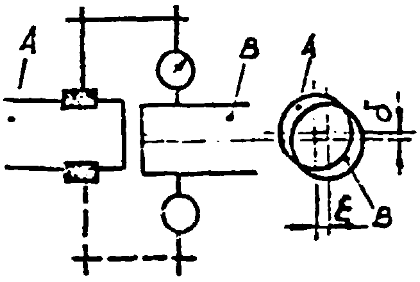
These errors are the following:

(a) The error due to the weight of the plunger, which in the upper position increases the pressure exercised, and in the lower position decreases it;

(b) The error due to the use of an intermediate mandrel. There may be a sag in this mandrel, due both to its own weight and that of the dial gauge, thereby increasing the coaxiality error;

(c) The error due to lack of rigidity in the mounting arm of the dial gauge.

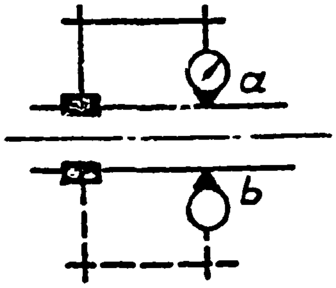
Figure 10. The opposite-points measurement method



It is possible to calculate the sum of the errors caused by the curvature of the arm and the pressure due to the weight of the plunger.

For this purpose, the gauge should be mounted on the same spindle against which its plunger rests as in figure 11.

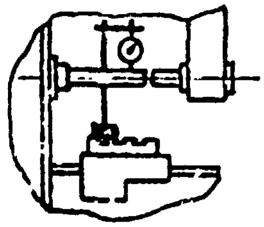
Figure 11. Measurement of inherent deformation for errors in the opposite-points measurement method



The difference in the readings obtained at positions "a" and "b" represents the sum of the errors caused by the deformation of the arm and the weight of the plunger.

The two-mandrel method is used to check the alignment of the axis of two bores (figure 12). In this method, a test mandrel is inserted into one of the bores, while an auxiliary mandrel, whose diameter is exactly identical to that of the test mandrel, is inserted into the other.

Figure 12. The two-mandrel method to check bore alignment



In order to determine the vertical error, the plunger of the dial gauge is traversed along the upper generatrix of the two mandrels, sliding along the surface of the machine table or a straight-edge laid horizontal with the aid of a level.

The operation is then repeated along the lower generatrix and the sides.

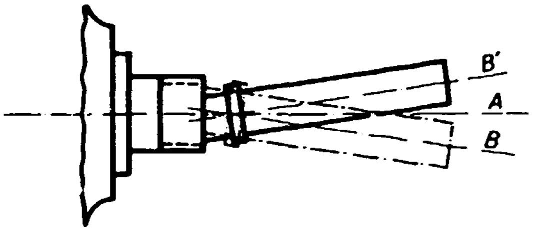
Testing for parallelism and equidistance

Parallelism

Parallelism is checked in definite planes, e.g., the horizontal or vertical planes or in a plane perpendicular to the surface to be tested, over given lengths.

When checking of parallelism involves two spindle axes, test mandrels are used, which are fixed and centred on the end of the shaft or in the bore. When using test mandrels, it is important to remember that it is impossible to centre them exactly on the axis of rotation. When the spindle is rotating, the mandrel axis will occupy two extreme positions B and B' lying in the test plane as shown in figure 13.

Figure 13. Extreme positions of the mandrel axes B and B' during testing for parallelism



Therefore, when checking for parallelism a measurement is first made with the mandrel at any position, and is then repeated after rotating the spindle through 180°. The arithmetic mean of the two results represents the error with respect to parallelism in the given plane.

To check the parallelism of two planes, the measuring instrument, mounted on a support with a flat base, is moved in one of the planes, while its plunger slides along the second plane (figure 14).

The parallelism of two axes is checked in two planes. For the first check, a dial gauge is mounted on a base of suitable shape (figure 15). It slides along a cylinder representing one of the axes, while its plunger slides along the cylinder representing the other axis. The gauge is traversed over a given length. In order to determine the smallest distance between the two axes at any point, the gauge is slightly rocked in a direction perpendicular to the axes.

Figure 14. Checking parallel levels (planes)

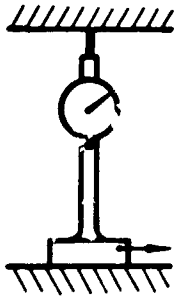
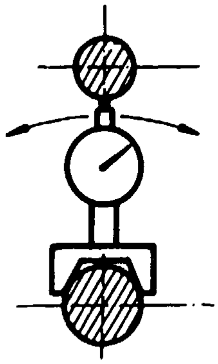


Figure 15. Dial gauge for checking parallelism of aligned spindles

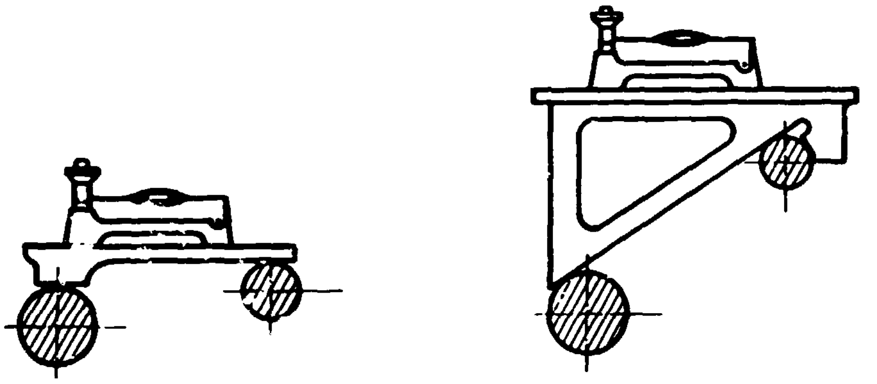


For the check in the second plane, an additional plane is needed, perpendicular to the plane that passes through the two axes.

If this additional plane exists by virtue of the fact that the two axes are parallel to a surface of the machine, the parallelism of each axis, considered separately, should be determined in relation to this surface. If not, the test should be made with reference to a theoretical plane by means of a level with an adjustable glass tube. The level should be placed on the two cylinders representing the axes, and the air-bubble set to zero.

Depending on the vertical distance between the two axes, either an auxiliary block (figure 16A) or a square (figure 16B) may be used.

Figure 16. Testing for parallelism



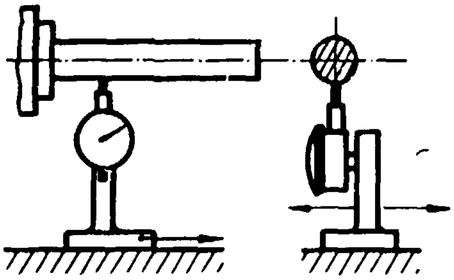
A. Auxiliary block for testing parallelism.

B. Square for testing parallelism

The level is moved along the axes by the amount specified, and the readings are taken. The measurement is expressed in terms of the distance between the axes (e.g., 0.05 mm/200 mm).

Parallelism of an axis to a plane is checked by means of a dial gauge whose support is moved along the plane by the specified amount. The plunger will slide along the cylinder representing the axis (figure 17).

Figure 17. Testing parallelism of an axis to a plane



At each point, the shortest distance (the distance as read) is found by slightly moving the gauge in a direction perpendicular to the axis.

Parallelism of motion refers to the position of the trajectory of a moving part of the machine in relation to a plane (support or slideway), a straight line (axis etc.) or the trajectory of a point on another moving component of the machine.

In principle, the measuring methods are identical with those used to check the parallelism of lines and planes.

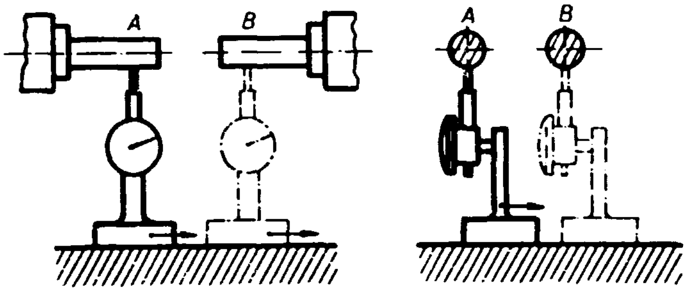
Whenever tests involve movement of the measuring instruments, the instrument should be fixed to the moving component, which takes the place of the supporting base of the dial gauge.

Tolerance on parallelism of movement is the maximum permissible variation in the shortest distance between the trajectory of a given point on the moving part and a plane, straight line or another trajectory within a stated length.

Equidistance

Tests for equidistance are, in effect, checks of parallelism. A test should first be made to check that two axes are parallel to a given plane, then that they are at the same distance from this plane, by using the same dial gauge on the two cylinders representing the axes (figure 18).

Figure 18. Tests for equidistance

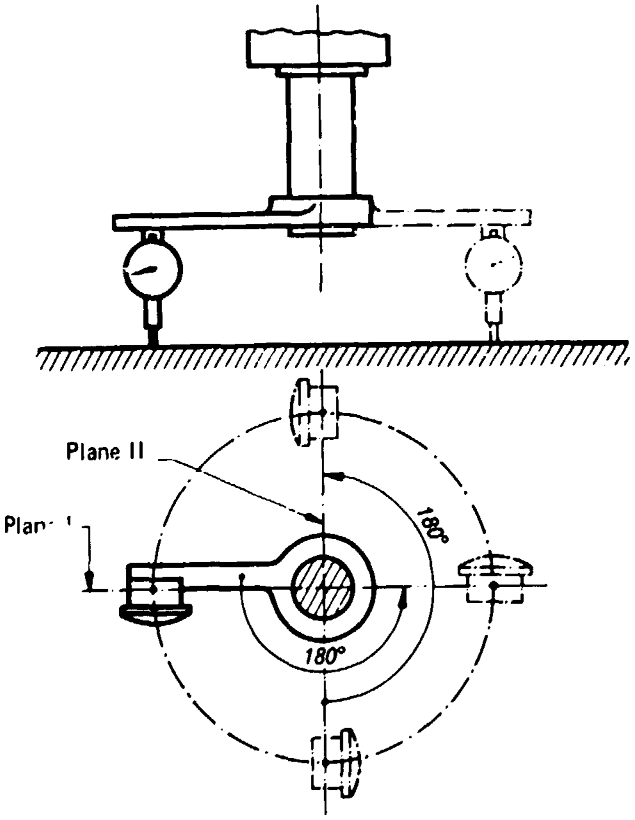


The permitted differences of distance should not be preceded by a sign, and should be generally valid in all directions parallel to the reference plane.

Squareness testing

The checking of squareness is in practice the checking of parallelism. The following general notes apply.

Figure 19. Squareness testing, use of a dial gauge



For an axis of rotation, the square can be replaced by an arm carrying a dial gauge fixed to the rotating component and the plunger of the gauge is adjusted parallel to the axis of rotation. As the component rotates, the plunger describes a circle, the plane of which is perpendicular to the axis of rotation (figure 19).

By measuring the variation in the distance between the plane to be checked and the plane of the circle described by the plunger, the error in parallelism between these two planes can be determined. This error is expressed in relation to the diameter of the circle described.

It is recommended that the squareness of two planes, one to another, be checked by means of a precision square placed on one of the planes to be checked. Using a dial gauge with a flat base placed on the second plane, measurement is made of the parallelism of the free arm of the square and the plane on which the gauge is located (figure 20).

The squareness of two axes one to another can be checked in the same way (figure 21).

Figure 20. Checking the squareness of two planes to one another

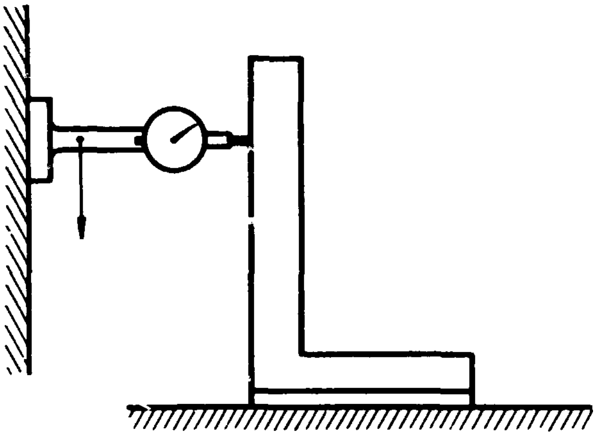
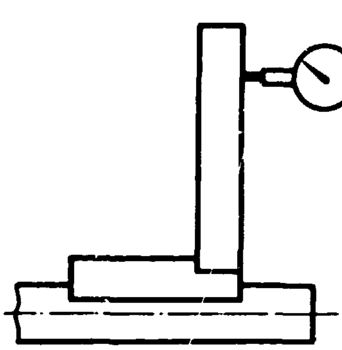
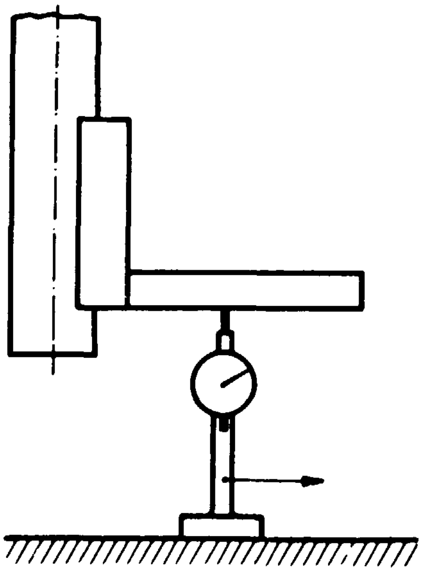


Figure 21. Checking the squareness of two axes to one another



Squareness of an axis to a plane is tested by bringing a square with a suitable base into contact with the cylinder representing the axis (figure 22). Parallelism of the free arm of the square to the plane is checked in the same way as parallelism of two planes.

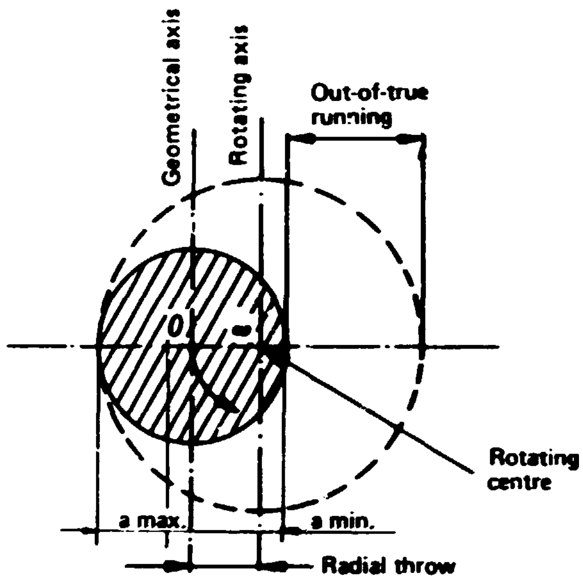
Figure 22. Testing the sqareness of an axis to a plane



Rotation testing

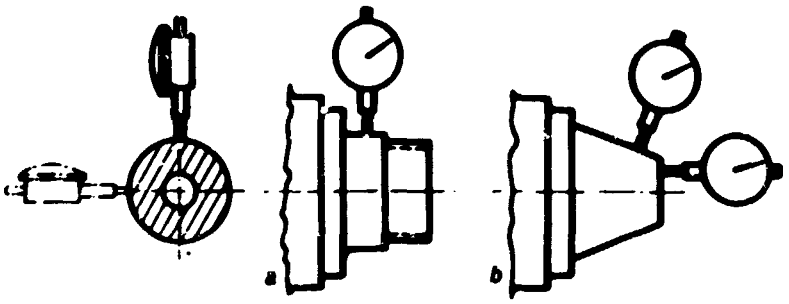
Out-of-true running (run out) of a component at a given section is shown in figure 23. If no account is taken of the out-of-round, the out-of-true running is twice the radial throw of the axis in a given section. Stated otherwise, it is the difference between the maximum and minimum distance between the axes (a_{max} and a_{min}). In general, run out is the resultant of the radial throw of the axis, the out-of-round of the component and the errors of bearings.

Figure 23. Out-of-true running



The measurement procedure in the case of external surfaces is that the dial gauge is placed so that the plunger is in contact with the surface of revolution to be checked, at right angles to the generatrix of the surface. The spindle in question should be slowly rotated (figure 24).

Figure 24. Measurement of out-of-true running for external surfaces

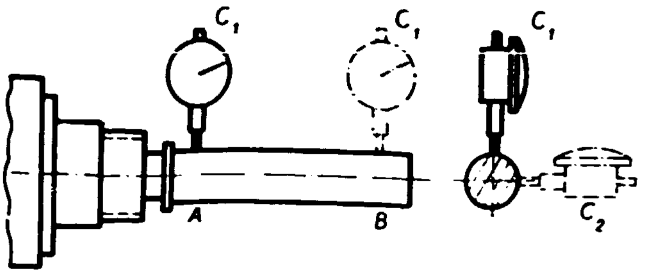


Conical surfaces — especially those with a steep taper — require a preliminary check for axial slip, as this will affect the measurement results in the test for run out.

Where internal surfaces are involved, a test mandrel is mounted in the bore and the check is performed in the same way as for external surfaces, the only difference being that checking is done in two planes, at A and B perpendicular to the axis of the bore (figure 25).

To provide for any lack of accuracy in inserting the mandrel into the bore, these operations should be repeated four times, at 90° intervals with respect to the bore; the average of the readings so obtained is the final result.

Figure 25. Measurement of out-of-true running for internal surfaces



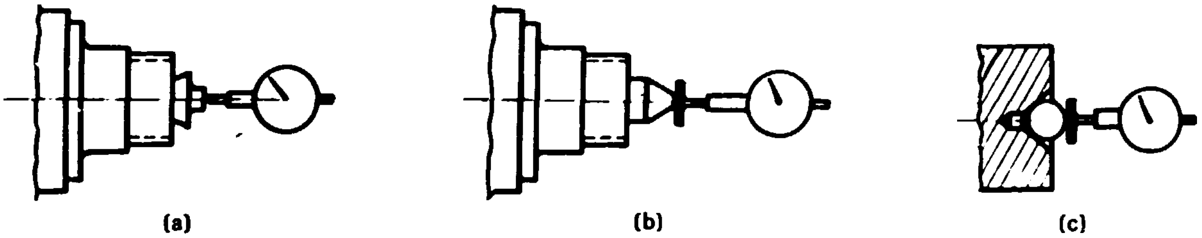
The tolerance on run out is not preceded by a sign. It includes errors in the shape of the revolving surface, the movement, and the lack of parallelism of the axis of this surface in relation to the axis of rotation and the movement of the axis of rotation if bearing or bores are not exactly circular.

To check for axial slip, a dial gauge is used (figure 26A-C) whose plunger touches the centre of the front face of the component to be checked, and is aligned along the axis of rotation.

The component being tested is slowly rotated, while axial force is applied in order to eliminate any play.

In the case of a rotating hollow component (spindle), a short mandrel is inserted into the spindle; this mandrel should have a plane face perpendicular to the axis against which a plunger with a round point may bear (figure 26A). Alternatively, a mandrel with a rounded face may be used with a plunger having a flat contact point (figure 26B). If the rotating component (spindle) has a centre, a steel ball should be inserted for a flat contact point to bear against (figure 26C).

Figure 26. Axial slip testing



A. Axial slip testing with a plane-face mandrel

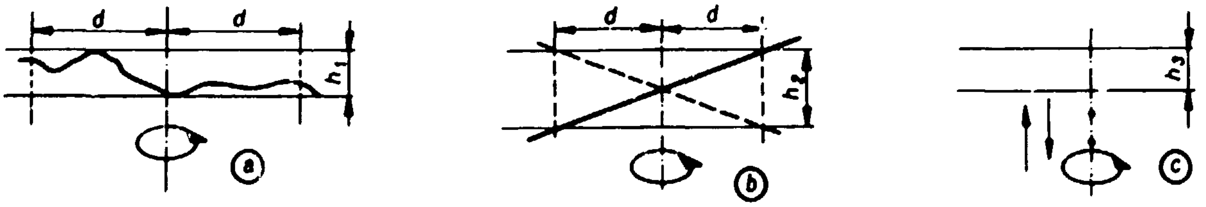
B. Axial slip testing with a rounded-face mandrel

C. Axial slip testing with a steel-ball contact

The tolerance for axial slip is the maximum axial displacement of the rotating element over a complete rotation.

Camming is the defect of a plane surface which, when rotating around an axis, does not remain in a plane perpendicular to this axis. Camming is given by the distance "h" separating the two planes perpendicular to the axis, between which the points of the surface are moving during the rotation (figure 27A-C).

Figure 27. Camming procedure



A. Camming where the surface is not flat

B. Camming where the surface and axis of rotation are not perpendicular

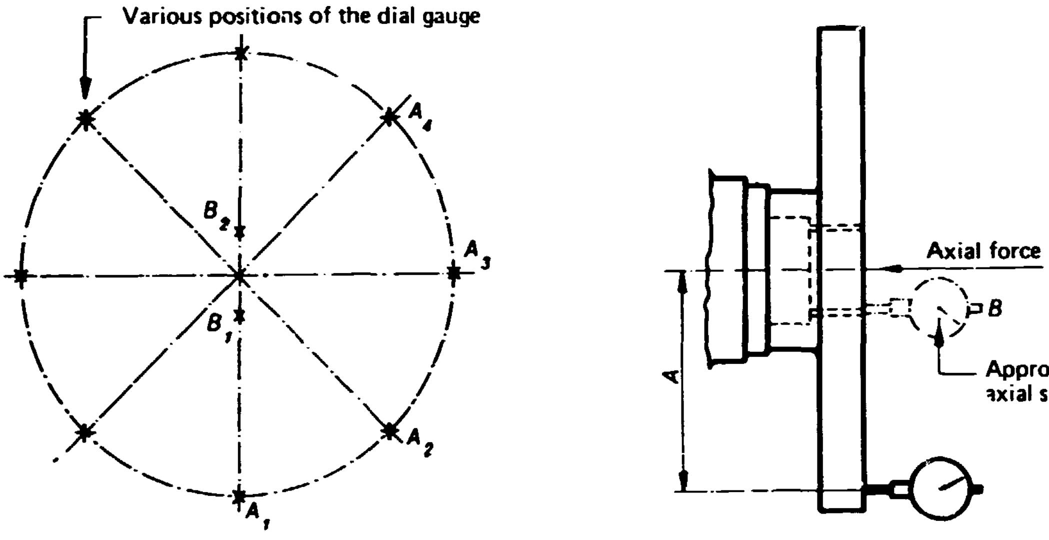
C. Camming due to axial displacement of the axis

Camming may be examined over the entire test surface or only at a distance "d" from the axis.

The reason for the camming of a surface may be that the surface is not flat (figure 27A), that the surface and the axis of rotation are not perpendicular (figure 27B), and that there is axial displacement of the axis (figure 27C).

Camming is measured (figure 28) by applying a dial gauge at right angles to the face.

Figure 28. Measuring camming



A. Positions of dial gauge during camming measurement

B. Measuring axial slip

The component to be tested should be rotated slowly, readings made at several points (A_1, A_2), and the maximum values noted.

Testing of machine tool performance under idle running

The test under idle running consists of starting up the machine and engaging, one after the other (as appropriate), the cutting, feed etc. mechanisms, starting with minimum revolutions and speeds and working up to maximum. At maximum revolutions, the machine should operate continually for at least two hours. During this time, all the auxiliary movements, *e.g.* feed, raising and lowering of the table, should be engaged.

Temperature of bearings

During operation at maximum revolutions (maximum speed), the temperature of the main spindle bearings should be measured every 10 minutes. The temperature should not exceed 60°C for plain bearings and 70°C for roller bearings. The temperature of the shaft bearings of other mechanisms (e.g. speed-reducers, gear boxes etc.) should not exceed 50°C.

Operation of the machine

The following test operations should be carried out during idle running:

(a) Testing the normal operation of clutches and transmissions, correct response to switching and controls, devices to prevent the simultaneous starting of mutually incompatible motions (where appropriate), the reliability of clamping mechanisms and the impossibility of uncontrolled movement and the constancy of the force required for the manual operation of mechanisms throughout their travel;

(b) Testing the operation of automatic devices, limit stops and other mechanisms;

(c) Testing the lubricating system on the basis of the lubricating chart given in the technical documentation for the machine;

(d) Testing the electrical circuits, observing whether starting, stopping, reversing, braking, regulation of rotational speed etc. are carried out on command and whether protective and safety devices operate when they should and without delay;

(e) In the case of an automatic cycle, testing to ascertain whether the devices involved initiate the various phases promptly and without delay.

Testing the speed of the main (cutting) movement

Testing the speed of the main movement takes place after it has been ascertained that the length of the belts and the adjustment of the couplings, bearings etc. are normal. For each value shown in the technical specifications, at least two readings should be taken. The maximum permitted deviation from the technical specifications should not exceed 5 per cent. Rotational speed should be measured with a tachometer. The number of strokes per minute should be determined by counting and timing if it is less than 80. If it is more than 80, the rotational speed of the last rotating component in the main drive chain should be measured and the number of strokes calculated, taking into account the total transmission ratio.

Checking the feed rate

Checking of the feed rate is carried out on the basis of the mode in which feed is expressed.

For feed expressed in millimetres per revolution of the main spindle (mm/rev.), testing takes the form of measuring the longitudinal movement of the component during a given number of revolutions.

Testing the noise level produced (level of acoustic pressure)

The noise level should be tested in accordance with the standards for worker protection enforced in the purchaser's country and on the basis of a preliminary agreement with the producer of the machine concerned.

To give some idea of the limits permitted under standards for worker protection in Romania, we shall quote some of the basic specifications.

The maximum permissible levels for noise produced by wood-cutting machine tools are shown in the table.

RELATIONSHIP OF FREQUENCY TO PERMISSIBLE NOISE[a]

Frequency (Hz)	*Sound intensity (dB)*
31.5	110
63	103
125	96
250	91
500	88
1 000	85
2 000	83
4 000	81
8 000	80
16 000	79
31 500	78

[a] Acceptable at the time the paper was prepared (1972).

The noise produced by the machine is considered to exceed the maximum permitted when the curve of its spectrum (measured by means of a phonometer with a set of filters with a pass band width of one octave) exceeds the permitted values on the noise curve, readings being taken at distances of 1 m and 5 m from the machine.

It is advisable to draw up an agreement under which the supplier of the machine undertakes to indicate the values for overall sound intensity level measured at distances of 1 m and 5 m from the machine under conditions of normal use and operation. The values measured must fall below the values shown on the noise curve permitted by worker protection standards in the purchaser's country.

Testing of machine tool performance under full load

Conditions for full load testing should approximate normal operating conditions for the machine as closely as possible. The test should be carried out when the bearings have reached operating temperature and is intended to confirm the safe and correct operation of the components of the machine and its ability to be operated under load.

The tests should consist of machining samples of wood whose dimensions, species, moisture content and degree of preliminary machining are indicated in the standards for the precision of the machine concerned. The precision of machining must meet the same standards.

The machine is tested by loading it to its normal capacity and operating it under this load for 30 minutes, and under an overload for a short period of time. The amount and duration of the overload should be laid down on a case-by-case basis by agreement between the supplier and the purchaser. The type of testing to which universal machine tools are subjected under full load depends on whether they are intended for roughing or finishing. If the machine is to carry out both types of machining, it should be tested for each operation.

During operation under full load, the temperature of the bearings and correct operation of the components checked under idle running should be checked once more.

During operation under normal load, the speeds of the main and secondary movements (feed, raising of the table etc.) must not diverge by more than 5 per cent from the corresponding speeds measured under idle running conditions.

For measuring the power consumed in the electrical circuit, a wattmeter or an ammeter and a voltmeter should be installed.

In the case of a special agreement between the supplier and the purchaser, capacity tests should also be carried out in accordance with established technical standards.

Testing the geometrical and machining accuracy of representative types of woodworking

For each representative type in the categories of machines for woodworking operating by chip or particle removal, it is necessary to indicate the standard covering specifications for geometrical and machining precision, with a recommendation of testing methods, testing equipment and tolerances, comparable to those provided for in the relevant standards of other countries. These are indicated in annexes IIIa through IIIm. Application of these standards should be based on an agreement between the manufacturer and the purchaser. The testing methods included in the standards set forth should be based on the information given in this chapter. Before carrying out the checking and testing provided for in the standard, the machine should be installed as described in this chapter. The moving parts of the machine should also be put in operating condition. The tests and checks are not listed in order of execution. For operational reasons, this order can be changed.

For combination machines with several tool-holders, the tests indicated for representative types in the attached tables should be adopted as appropriate.

Data sheets for the representative types of machines for woodworking operating by chip or particle removal

The main parameters of the machine and their values in terms of current technology are given in annexes IVa through IVr. These values are indicated in the technical data sheets for each representative type in the categories of woodworking machines operating by chip or particle removal.

Annex I

A LIST OF MACHINE TOOLS FOR WOODWORKING OPERATING BY CHIP OR PARTICLE REMOVAL

a. *Sawing machines with reciprocating tool*
  - Vertical frame sawing machines
  - Horizontal frame sawing machines
  - Log cross-cut sawing machines

b. *Sawing machines with continuous tool*
  - Vertical band sawing machines (for log breakdown, resawing, joinery work)
  - Horizontal band sawing machines
  - Chain sawing machines

c. *Circular sawing machines*
  - Cross-cut circular sawing machines
  - Circular sawing machines, for ripping, with manual feed
  - Circular sawing machines, for ripping, with one or more blades, mechanical feed
  - Multi-blade panel sizing sawing machines
  - Universal circular sawing machines

d. *Planing machines*
  - Surfacing and jointing machines
  - Thicknessing machines
  - Planing machines for two-side dressing
  - Planing and moulding machine, three-side or four-side dressing

e. *Moulding machines*
  - Vertical moulding machines (table moulding machines)
  - Routing machines
  - Chain mortising machines
  - Parquetry matching machines
  - Forming and rounding machines
  - Special moulding machines

f. *Boring machines*
  - Slot mortising machines

g. *Lathes and copying machines*
  - Woodworking lathes
  - Special copying lathes

h. *Sanding machines*
  - Horizontal belt sanding machines
  - Drum sanding machines
  - Wide belt sanding machines, contact

Annex II

DEFINITIONS OF PRECISION CLASSES FOR WOODWORKING MACHINES

Purpose of test	*Permissible tolerances (mm)* *Precision classes*		
	I	*II*	*III*
Flatness of tables, work surfaces and fences in the longitudinal and transverse directions	$\frac{0.15}{1\,000}$	$\frac{0.20}{1\,000}$	$\frac{0.25\text{-}0.50}{1\,000}$
Straight line motion	$\frac{0.15}{1\,000}$	$\frac{0.25}{1\,000}$	$\frac{0.30\text{-}0.50}{1\,000}$
Parallelism between machine components and guides	$\frac{0.15}{1\,000}$	$\frac{0.25}{1\,000}$	$\frac{0.30}{1\,000}$
Squareness	$\frac{0.15}{1\,000}$	$\frac{0.25}{1\,000}$	$\frac{0.30}{1\,000}$
Out-of-true running (run out)	0.02-0.03	0.03-0.05	0.05-0.10
Axial slip	0.02	0.03	0.05
Camming	0.02	0.03	0.05

Annex III

SPECIFICATIONS FOR THE PRECISION OF WOODWORKING MACHINES

IIIa. Specifications for the precision of vertical frame-sawing machines

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
	A. Geometrical checks	
1. Straight-line motion in a vertical plane by the blades mounted in the frame	$\frac{0.2}{1\,000}$	Dial gauge, graduated in units of 0.01 mm, whose base should be placed on a horizontal surface, the horizontality of which is verified by means of a spirit level. The plunger of the gauge should touch the surface of the blade at right angles. The frame should be moved from the top dead centre to bottom dead centre (one stroke) and back. The maximum and minimum readings should be taken with the gauge
2. Parallelism of external surfaces of cross-members (clamping surfaces)	$\frac{0.3}{1\,000}$	Dial gauge with special base, straight-edge and plane-parallel blocks. (Testing should take place before mounting of the frame on the saw)
3. Run out of the pulleys mounted on the main spindle	0.05	Dial gauge graduated in units of 0.002 mm. Complete rotation of the main spindle (360°)
4. Camming of lateral surfaces of pulleys	0.05	Gauge as under (3). The test should be carried out at the level of the machined portion, turning the pulley through 360°
5. Coaxiality of the pulley axles	0.05	Dial gauge graduated in units of 0.01 mm, with special base. The test should be carried out in four positions, i.e. horizontally: left and right; and vertically: top and bottom
6. Parallelism of bottom feed rollers	$\frac{0.5}{1\,000}$	Gauge, as for (5), straight-edge. Measurement over the whole length of the rollers
7. Parallelism of top rollers located in the same horizontal plane	$\frac{0.5}{1\,000}$	Same
8. Parallelism of the top and bottom rollers	$\frac{0.5}{1\,000}$	Same. The top rollers in different vertical positions (measurement required in the lowest and highest positions)

B. Tests for machining precision

Logs from coniferous trees with diameters corresponding to the working width of the saw should be used as samples:

max. $D. = a - 50$ mm, where
max. $D.$ = maximum diameter of the log, in mm
a = working width of the frame, in mm

1. Parallelism of the lateral surfaces of sawn pieces. Boards are sawn to a thickness of 24 mm, and planks to a thickness of 75 mm		Slide callipers
(a) Thicknesses up to 17 mm	*(a)* ± 0.5 mm	
(b) Thicknesses from 18 to 28 mm	*(b)* ± 1 mm	
(c) Thicknesses from 29 to 60 mm	*(c)* ± 1.5 mm	
(d) More than 60 mm	*(d)* ± 2 mm	
2. Roughness of the lateral surfaces of sawn pieces	0.5 mm	

IIIb. Specifications for the precision of band sawing machines for joinery and cabinet making (with pulleys up to 1,000 mm in diameter)

A. Geometrical checks

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
1. Flatness of the working surface of the table in the following directions:		Straight-edge longer than the length or width, respectively, of the table. Feeler gauge, plane-parallel block gauges
(a) Longitudinal *(b)* Transverse	*(a)* and *(b)* $\frac{0.4}{1\,000}$	
(c) Diagonal	*(c)* $\frac{0.5}{1\,000}$	
2. Flatness of the fence	$\frac{0.25}{1\,000}$	Same
3. Squareness of the fence surface to the working surface of the machine table	$\frac{0.2}{100}$	Precision square with a side of at least 100 mm, feeler gauge
4. Testing whether the surfaces of the two pulleys are in the same plane	$\frac{0.4}{1\,000}$	Straight-edge longer than $(D+A)$ where: D = diameter of pulley A = distance between the axes of the pulleys The straight-edge should be placed on the surfaces of the two pulleys, and the gap between the straight-edge and the surface should be measured with a feeler gauge
5. Squareness of the blade to the machine table	$\frac{0.1}{100}$	A straight-edge longer than $(D+A)$ should be placed on the front surface (rim) of both pulleys. The test should be carried out using a precision square with a side 200 mm long placed on the working surface of the table, the vertical arm being in contact with the straight-edge. The gap (the space between the straight-edge and the side of the square) should be measured at the end of the vertical side, using a feeler gauge
6. Run out of pulleys	0.15	Dial gauge graduated in units of 0.01 mm placed on the table of the machine so that the plunger touches the upper and lower rims of the pulley. The pulley should be turned through 360°
7. Camming of pulleys	0.15	Gauge as for (6); the plunger must touch the front face. The pulley should be turned through 360°
8. Testing whether the band remains in the same vertical plane during operation	0.6	Gauge as for (6), placed on the table of the machine behind the band so that the plunger rests on and is perpendicular to the edge of the band. The test should be carried out through at least three full 360° rotations

B. Tests for machining precision

The samples used should be from straight-grain softwood species with a moisture content of 10 per cent, planed to a flat rectangular shape with the dimensions 40 × 150 × 1 000 mm.

1. Parallelism of the sides:		The wood is sawn to a thickness of 30 mm. Testing by means of slide callipers
(a) Longitudinally	*(a)* 0.6	
(b) Transversely	*(b)* 0.4	

IIIc. Specifications for the precision of manual-feed circular sawing machines

A. Geometrical checks

Purpose of the [illegible]	*Permissible tolerances (mm)*	*Remarks and recommendations*
1. Flatness of the work surface of the main table and the adjustable table in the longitudinal and transverse directions	$\frac{0.25}{1\,000}$	Straight-edge greater in length than the table. Plane-parallel block gauges. Feeler gauge
2. Flatness of the working surface of the fence	$\frac{0.2}{1\,000}$	Same
3. Squareness of the fence surface to the work surface of the table	$\frac{0.2}{100}$	Precision square with sides at least 100 mm long; feeler gauge
4. Straight-line motion of the sliding table in the vertical plane	$\frac{0.5}{1\,000}$	Straight-edge greater in length than the moving table, and dial gauge graduated in units of 0.01 mm
5. Run out of the blade shaft	0.05	Dial gauge graduated in units of 0.002 mm
6. Camming of the flange of the blade shaft	0.05	Same
7. Axial slip of the blade shaft	0.05	Same, plunger with flat contact point. A steel ball should be inserted into the spindle centre for the flat contact point to bear against
8. Squareness of the plane of the control disc to the work surface of the machine	$\frac{0.1}{100}$	Precision square with a side more than 100 mm long. Feeler gauge
9. Parallelism of the plane of the control disc to the working surface of the fence	0.1 (for 300 mm diameter blades) 0.15 (for 300-450 mm diameter blades)	Control disc (instead of the circular saw blade). Straight-edge, slide callipers

B. Tests for machining precision

Samples from straight-grain softwood species with a moisture content of 10 per cent, with surfaces and edges planed and parallel, should be used: dimensions: 150 × 30 × 2 000 mm.

1. Parallelism of edges	$\frac{0.5}{1\,000}$	Slide calliper
2. Squareness of the edge to the front face	$\frac{0.5}{100}$	Precision square, feeler gauge
3. Squareness of the sawn edges to the surface on which the sample lies	$\frac{0.1}{30}$	Same

IIId. Specifications for the precision of mechanical-feed circular sawing machines

A. Geometrical checks

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
1. Flatness and alignment of the surfaces of the slats of the feed chain in the longitudinal direction	0.5	Straight-edge greater in length than the table. Plane-parallel block gauges. Feeler gauge
2. Flatness and alignment of the surfaces of the slats of the feed chain in the transverse direction	0.2	Straight-edge whose length is more than twice the width of the band. Plane-parallel block gauges. Feeler gauge
3. Straightness of the work surface of the fence in the longitudinal direction	$\frac{0.2}{1\,000}$ (Concavity only)	Straight-edge greater in length than the fence. Plane-parallel block gauges
4. Run out of the blade shaft	0.03	Dial gauge graduated in units of 0.002 mm
5. Camming of the bearing surface of the blade shaft	0.05	Same
6. Parallelism between the axis of the blade shaft and the working surface of the feed chain	$\frac{0.2}{100}$	Dial gauge graduated in units of 0.01 mm. Straight-edge greater in length than the width of the band
7. Squareness of the fence to the blade shaft	$\frac{0.2}{100}$	Dial gauge graduated in units of 0.01 mm. Special arm to fix the gauge on to the blade shaft. Straight-edge
8. Run out of the pressure rollers	0.2	Dial gauge graduated in units of 0.01 mm
9. Parallelism of the pressure rollers to the working surface of the feed chain	0.2	Same. Straight-edge greater in length than the width of the band

B. Tests for machining precision

Samples from hardwood species, not straight grain, with a moisture content of $\leq$ 10 per cent, surfaces and edges planed and perpendicular, dimensions: 50 mm × 150 mm × 1 000 mm. The samples will be ripsawn.

1. Parallelism of the cut surface to the planed surface	0.4	Slide callipers accurate to 0.05 mm
2. Squareness of the ripsawn edge to the surface on which the sample rests	0.2	Precision square with a side longer than 50 mm. Feeler gauge. Test panel
3. Straightness of ripsawn edges	0.4	Straight-edge with a useful length L = 1 000 mm. Feeler gauge

IIe. *Specifications for the precision of surfacing and jointing machines*

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
A. Geometrical checks		
1. Flatness of the work surface of each table (infeed table and outfeed table) in the following three directions:		Straight-edge longer than the length (or, in the case of (5), the width) of the table. Feeler gauge, plane-parallel block gauges
(a) Longitudinal	*(a)* $\frac{0.2}{1\,000}$	
(b) Transverse	*(b)* $\frac{0.15}{1\,000}$	
(c) Diagonal	*(c)* $\frac{0.2}{1\,000}$	
2. Flatness of the work surface of the two tables, adjusted to the same height, in the longitudinal and diagonal directions	$\frac{0.2}{1\,000}$	Straight-edge longer than the total length of both tables together. Feeler gauge, plane-parallel block gauges
3. Parallelism of the work surface of the infeed table to the surface of the outfeed table at different chip removal depths	0.2	Dial gauge graduated in units of 0.01 mm placed at the edge of the outfeed table in such a way that the plunger touches the work surface of the infeed table. Readings should be taken at different points along the width of the table with the tables adjusted for two chip removal depths between 0 and 5 mm
4. Parallelism of the cutter block to the work surface of the outfeed table	0.1 (for work-piece widths up to 500 mm)	Dial gauge (same) placed at the edge of the outfeed table in such a way that the plunger touches the upper generatrix of the cutter block. The gauge should be moved along the whole width of the table
5. Run out of the cutter block	0.05	Dial gauge graduated in units of 0.002 mm placed as in (4). The shaft should be turned and the maximum and minimum readings taken with the gauge
6. Flatness of the work surface of the fence	$\frac{0.2}{1\,000}$	Straight-edge, plane-parallel block gauges
7. Squareness of the work surface of the fence to the machine table	0.1	Precision square with a side at least 100 mm long, feeler gauge
B. Tests for machining precision		
Samples from straight-grain softwood species with a moisture content of 10 per cent should be used; dimensions: 30 mm × 250 mm × 1 000 mm.		
1. Flatness of the surface of the machined sample	0.2	Straight-edge, feeler gauge
2. Flatness of the edge of the machined sample	0.3	Same
3. Squareness of the machined edge to the machined surface of the sample	$\frac{0.1}{100}$	Precision square, feeler gauge

IIIf. Specifications for the precision of thicknessing machines

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
A. Geometrical checks		
1. Flatness of the work surface of the table in the following three directions:		Straight-edge greater in length than the length (or, in the case of (*b*), the width) of the table. Feeler gauge, plane-parallel block gauges
(*a*) Longitudinal	(*a*) $\frac{0.2}{1\,000}$	
(*b*) Transverse	(*b*) $\frac{0.15}{1\,000}$	
(*c*) Diagonal	(*c*) $\frac{0.2}{1\,000}$	
2. Parallelism of the cutter block to the work surface of the table:		Dial gauge graduated in units of 0.01 mm placed on the edge of the table in such a way that the plunger touches the lower generatrix of the cutter block. The gauge should be moved along the width of the table. The maximum readings should be taken. The test should be carried out first for the highest position of the table and then for the lowest one
(*a*) For work-piece widths up to 400 mm	(*a*) 0.15	
(*b*) Same, more than 400 mm	(*b*) 0.25	
3. Run out of the cutter block	0.05	Dial gauge graduated in units of 0.002 mm placed as in (2). The cutter block should be turned slowly and the maximum and minimum readings on the gauge taken
4. Run out of the feed rollers	0.05	Same (see (3))
5. Parallelism of the feed rollers to the work surface of the table	$\frac{0.25}{1\,000}$	Dial gauge; same (see (2))
B. Tests for machining precision		
Samples from straight-grain softwood species with a moisture content of 10 per cent should be used; dimensions: 30 mm × 150 mm × 1 000 mm.		
1. Parallelism of machined surfaces of samples	$\frac{0.2}{1\,000}$	Slide callipers

IIIg. Specifications for the precision of planing machines for two-side dressing

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
A. Geometrical checks		
1. Flatness of work surfaces of tables	$\frac{0.2}{1\,000}$	See the remarks and recommendations for similar tests for thicknessing machines
2. Parallelism of the work surface of the infeed table and the work surface of the main table	$\frac{0.2}{1\,000}$	
3. Run out of cutter block	0.05	
4. Parallelism of the upper cutter block and the surface of the work table:		
(*a*) For workpiece widths up to 400 mm (*b*) Same, from 400 mm to 800 mm	(*a*) 0.15 (*b*) 0.25	
5. Parallelism of the lower and upper cutter blocks to the work surface of the table. (*a*) and (*b*) as for (4).	(*a*) 0.15 (*b*) 0.25	

Annex IIIg (continued)

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
	A. Geometrical checks (continued)	
6. Run out of feed rollers	0.05	
7. Parallelism of feed rollers to the work surface of the main table. (*a*) and (*b*) as for (4).	(*a*) 0.15 (*b*) 0.25	
	B. Tests for machining precision	
Samples from straight-grain softwood species with a moisture content of 10 per cent should be used; dimensions: 40 mm × 250 mm × 600 mm.		
1. Parallelism of the machined surfaces of the sample in the following directions: (*a*) Longitudinal (*b*) Transverse	(*a*) 0.2 (*b*) 0.1	

IIIh. *Specifications for the precision of planing and moulding machines for three-side or four-side dressing*

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
	A. Geometrical checks	
1. Flatness of work surfaces of tables	$\frac{0.15}{1\,000}$	See the remarks and recommendations concerning similar tests for thicknessing machines
2. Parallelism of the work surface of the sliding tables to the surface of the fixed table	$\frac{0.15}{1\,000}$	
3. Flatness of the work surface of the fence	$\frac{0.15}{1\,000}$	
4. Run out of horizontal spindles	0.03	
5. Parallelism of horizontal spindles to the work surfaces of the table	$\frac{0.15}{1\,000}$	
6. Axial slip of horizontal spindles	0.05	
7. Run out of vertical spindles	0.03	
8. Axial slip of vertical spindles	0.05	
9. Squareness of the axes of rotation of vertical spindles to the work surface	$\frac{0.03}{100}$	
10. Radial slip of feed rollers	0.05	
	B. Tests for machining precision	
1. Flatness of machined surfaces	$\frac{0.2}{1\,000}$	
2. Parallelism of machined surfaces	$\frac{0.3}{1\,000}$	
3. Squareness of the machined edge to the surface on which the piece rests	$\frac{0.2}{1\,000}$	

IIIi. *Specifications for the precision of spindle moulding machines*

A. *Geometrical checks*

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
1. Flatness of the work surface of the machine table in the longitudinal, transverse and diagonal directions	$\frac{0.2}{1\,000}$	Straight-edge greater in length than the table. Feeler gauge, plane-parallel block gauges
2. Flatness of the surfaces of fences	$\frac{0.2}{1\,000}$	Same (see (1))
3. Squareness of the fence surface to the work surface of the table	$\frac{0.1}{100}$	Precision square, feeler gauge
4. Flatness of the work surface of the sliding table	$\frac{0.2}{1\,000}$	Same (see (1))
5. Flatness of the work surfaces of the machine table and the surface of the sliding table adjusted to the same height	$\frac{0.3}{1\,000}$	Same (see (1))
6. Run out of the taper in the spindle	0.04	Use of a taper-shank test mandrel, diameter 30 mm, length 350 mm. Testing with a gauge graduated in units of 0.002 mm
7. Squareness of the tool spindle to the work surface of the table	0.06	Test mandrel and gauge as for (6) arms 200 mm long mounted on the mandrel. Rotation of the arm through 360°. Measurements taken every 90°, the plunger being in contact with the table surface
8. Squareness of vertical movement of the tool spindle to the work surface of the table	0.05	Test mandrel and gauge as for (6) placed on the machine table in such a way that the plunger rests on and is perpendicular to the generatrix of the mandrel in a plane containing its axis. The tool spindle should be moved vertically, making it possible to take readings from the gauge

B. *Tests for machining precision*

The samples of wood used should be from straight-grain softwood species and have a moisture content of 10 per cent. The surface on which they rest should be planed flat and the edges perpendicular to the planed surface. Dimensions of the samples: 55 mm × 55 mm × 500 mm.

1. Straightness of cut surfaces	$\frac{0.2}{1\,000}$	Straight-edge, feeler gauge
2. Squareness of the cut surface to the surface on which the sample rests	$\frac{0.1}{50}$	Precision square, length of side more than 50 mm. Feeler gauge

IIIj. Precision requirements for routing machines

Purpose of the test	Permissible tolerances (mm)	Remarks and recommendations
A. Geometrical checks		
1. Flatness of the work surface of the table in three directions: longitudinal, transverse, diagonal	$\frac{0.2}{1\,000}$	Straight-edge greater in length than the diagonal, width or length of the table. Plane-parallel blocks, feeler gauge
2. Squareness of main spindle in relation to the work surface of the table	$\frac{0.2}{400}$	Dial gauge graduated in units of 0.01 mm. Mandrel with bent arm, length of arm: 200 mm
3. Perpendicularity of the movements of the main spindle in relation to the work surface of the table	$\frac{0.1}{100}$	Gauge as in (2). Test mandrel with taper shank. Square with side longer than the travel of the spindle Test mandrel with taper shank in the bore of the main spindle. The gauge should be fixed to the mandrel in such a way that the plunger is at right angles to the vertical side of the square placed with its base on the work table
4. Run out of the bore of the main spindle	0.04	Dial gauge graduated in units of 0.002 mm placed on the work table. Test mandrel with taper shank placed in the bore of the main spindle, which should be turned through 360°
5. Camming of the surface of the main spindle	0.04	Gauge as in (4), placed on the work table in such a way that the plunger touches the frontal surface of the main spindle, which turns through 360°
6. Coincidence of the axis of the taper bore of the main spindle with the axis of the copying pin	0.04	Gauge as in (4) with special support mounted on the test mandrel in such a way that the plunger is in contact with and at right angles to the generatrix of the copying pin set at its lowest position The spindle should be turned through 360° and the maximum and minimum readings taken. The measuring should be repeated with the pin in the highest position
7. Perpendicularity of the movement of the copying pin to the work surface of the table	$\frac{0.1}{100}$	Dial gauge graduated in units of 0.01 mm with arm support mounted on the pin. Precision square placed on the work table in such a way that the plunger is in contact with and at right angles to the vertical side of the square. The pin should be moved along the entire length and the maximum and minimum readings taken
8. Parallelism between the work surface of the table and its movement in a longitudinal and transverse direction	$\frac{0.1}{300}$	Dial gauge graduated in units of 0.01 mm mounted in such a way that the plunger is in contact with and at right angles to the work surface of the table. The table should be moved along the entire length of travel first in a longitudinal and then in a transverse direction. The maximum and minimum gauge readings should be taken
9. Squareness of the vertical movement of the table to the work surface of the table	$\frac{0.1}{100}$	Gauge and square as in (7). Testing as in (7)
B. Tests for machining precision		
The samples used should be straight-grain softwood species with a humidity content of 10 per cent and planed surfaces and edges. *Size of samples: 50 mm × 200 mm × 400 mm.*		
1. Parallelism of machined edges of the sample	$\frac{0.2}{300}$	Slide callipers accurate to 0.05 mm
2. Squareness of machined edges	$\frac{0.2}{300}$	Precision square with side longer than 300 mm. Feeler gauge
3. Uniformity of thickness of the edges of the machined sample	0.15	Slide callipers, accurate to 0.05 mm

IIIk. *Specifications for the precision of horizontal boring machines*

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
	A. Geometrical checks	
1. Flatness of the work surface of the table in three directions: longitudinal, transverse and diagonal	$\frac{0.3}{1\,000}$	Straight-edge greater in length than the diagonal, width or length of the table. Plane-parallel blocks, feeler gauge
2. Run out of the main spindle bore	0.1	Dial gauge graduated in units of 0.01 mm. Test mandrel with taper shank, 150 mm long and 20 mm in diameter. Shaft rotation 360°; the maximum gauge readings should be taken
3. Parallelism between the axis of the main spindle and the work surface of the table	0.15	Gauge and mandrel as in (2). The plunger should touch the upper generatrix of the mandrel at one of its ends. The gauge should be moved along the mandrel in an axial direction and the maximum reading taken
4. Parallelism between the axis of the main spindle and the downwards (transverse) movement of the table		Gauge and mandrel as in (2). The gauge plunger should touch the mandrel in the vertical and horizontal planes in which the axis of the mandrel lies. Movement of the table towards the mandrel (in a transverse direction); gauge readings should be taken
5. Parallelism of the axis of the main spindle and movement of the tool holder	0.2	Gauge and mandrel as in (2). Testing as in (4). The tool holder should be moved towards the table and the gauge readings taken
6. Parallelism between the work surface of the table and its longitudinal movement	$\frac{0.1}{100}$	Dial gauge graduated in units of 0.01 mm. Straight-edge placed in a longitudinal direction on the table on two plane-parallel blocks of equal height. The gauge should be fixed to the main spindle in such a way that the plunger is in contact with, and at right angles to, the surface of the straight-edge. The table should be moved in a longitudinal direction and the readings taken
	B. Tests for machining precision	
The samples used should be straight-grain softwood species without knots with a humidity content of 10 per cent and planed surfaces and edges which are at right angles to one another. Size of samples: 50 mm × 100 mm × 300 mm.		
1. *(a)* Uniformity of the length of a groove 150 mm in length	$\frac{0.15}{100}$	Slide callipers accurate to 0.05 mm
(b) Parallelism between the lower support surface and the base surface of the sample		
2. Hole boring	+0.13 H 11 according to ISO standard	Hole gauge. Boring bit diameter 20 mm

IIII. *Precision requirements for top drum sanders*

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
	A. Geometrical checks	
1. Flatness and horizontality of the members supporting the rubber pad	$\frac{0.15}{1\,000}$	Straight-edge, plane-parallel blocks feeler gauge and spirit level. Readings should be taken in the middle and at both ends of the members
2. Flatness of the work surface of the rubber belts (work table) *(a)* in the direction of feed *(b)* in a transverse direction	$\frac{0.15}{1\,000}$	Straight-edge, plane-parallel blocks, feeler gauge
3. Parallelism between the surfaces of the members supporting the rubber belt and the surfaces of the cross members *(a)* in the direction of feed *(b)* in a transverse direction	*(a)* $\frac{0.15}{1\,000}$ *(b)* $\frac{0.1}{1\,000}$	Dial gauge graduated in units of 0.01 mm with the plunger placed on the surface of the shoes in such a way that the plunger touches the surface of the upper cross members. Movement over the width of the work surface *(b)* and on each member along the machine *(a)*
4. Parallelism between the sanding drums and the working surface of the belt	$\frac{0.15}{1\,000}$	Gauge as in (3) with the support resting on the work table in such a way that the plunger touches the lower generatrix of the sanding drum. Readings taken along the entire length of the cylinder. (The sanding belt should not be mounted during the measuring)
5. Run out of metal sanding drums	0.04	Dial gauge graduated in units of 0.002 mm with the support resting on the work table set in the lower position. Plunger as in (4). The cylinder should be turned through 360° and the highest and lowest readings taken. Drum as in (4)
6. Straight-line axial motion of the sanding drums	0.05	Gauge as in (5) wth the support resting on the work table set in the lower position, in such a way that the plunger touches the lower generatrix of the drum (without abrasive belt)
	B. Tests for machining precision	
The samples used should be laminated wood 5 mm thick. Size of sample: *b* × 1 500 mm, where *b* = machining width.		
1. Flatness of the sanded workpiece	$\frac{0.1}{1\,000}$	Straight-edge, feeler gauge

IIIm. Requirements for the precision of bottom wide-belt sanding machines

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
A. Geometrical checks		
1. Levelness of the surfaces of the metal edges of the infeed and outfeed tables		Precision level $\left(\frac{0.02}{1\,000}\right)$
(a) In the direction of feed	*(a)* $\frac{0.2}{1\,000}$	
(b) In a transverse direction	*(b)* $\frac{0.15}{1\,000}$	
2. Levelness of the contact drum	$\frac{0.15}{1\,000}$	Level as in (1). Checking of the two extreme positions of the lower and upper drum; measuring of the size of the generatrix by rotating the drum through 90°
3. Run out of the contact drum	0.03	Dial gauge graduated in units of 0.01 mm with support resting on the surface of the line of the infeed and outfeed tables. The plunger should touch the surface of the drum, which should be rotated through 360°
4. Squareness of the guide columns to the surfaces of the fences of the infeed and outfeed tables	$\frac{0.05}{100}$	Square frame level
5. Parallelism of the feed rollers	$\frac{0.15}{1\,000}$	Dial gauge graduated in units of 0.01 mm
B. Tests for machining precision		
The samples used should be of 20 mm thick wood board machined to within ± 0.1 mm. Size of samples: $b \times 1\,500$ mm, where b = machining width.		
1. Flatness of the sanded workpiece	$\frac{0.1}{1\,000}$	Straight-edge, feeler gauge

Annex IV

DATA SHEET FOR SAWING MACHINES

IVa. Data sheet for vertical frame sawing machines

Basic parameter: Inside width of saw blade frame

Note: The most common design is the frame sawing machine with drive and controls below floor-level, with two pulleys and two connecting rods coupled to link pins on the upper cross-member of the saw-blade frame.

Specifications	*Units*	*Current technology* [a]
Inside width of saw-blade frame (standard dimensions)	mm	450-560-710-850-1 000
Length of the travel of the saw-blade frame (H) (standard dimensions)	mm	500 500 600 710 400-600-600-710-850
Maximum number of blades	pieces	16-20
Maximum speed (n) corresponding to the length of the frame travel	rpm	360-360-320-300-250
Feed system		Continuous, controlled by a hydraulic or electric variator from switch desk
Feed rate	m/min	0-10
Average cutting speed (average speed = $H \cdot n/30$)	m/s	5-6.5
Roller rise-and-fall system		Hydraulic action controlled from switch desk
System for adjusting the tension of the blades		Manual, mechanical or hydraulic
Power requirement (corresponding to the frame width)	kW	40-50-(75-110) (75-110) (75-110)

[a] These parameters were valid at the time of the original paper ID/WG.151/25 issued on 29 October 1975. In the intervening years, technological advances have been made.

IVb. Data sheet for log band sawing machines

Basic parameters: Pulley diameter
Feed rate

Specifications	*Units*	*Current technology*
Pulley diameter (D) (standard dimensions)	mm	1 250[a]-1 600[a]-2 000[b]-2 500[b]
Carriage feed rate (continuously variable)	m/min	1-60-90
Return speed (ditto)	m/min	100-120
Cutting speed (cutting speed = $\pi \cdot D \cdot n/60$)	m/s	40-50 (for exotic species provision is made for 2-3 cutting speeds
Power requirement (according to pulley diameter)	kW	60-80-180[b] 100
Thickness setting of the sawn piece		Automatic, either electro-pneumatic or electrical, controlled from switch desk
Actuation of clamps		Pneumatic, hydraulic or mechanical controlled from switch desk
Adjustment of blade tension		Electric, electro-hydraulic
Maximum length of log carriage (correlated with D)	mm	6 000-10 000-14 000-16 000

Note: The ratio between the maximum diameter of the logs (Db) to be sawn and the diameter of the pulleys (D) is the following: $Db = (1.2 \ldots 1.4)\ D$.

[a] For European species.

[b] For exotic species, specially designed band saws.

IVc. *Data sheet for horizontal band sawing machines*

Basic parameters: Pulley diameter
Feed rate

Specifications	*Units*	*Current technology*
Pulley diameter (*D*) (standard dimensions)	mm	1 250-1 400-1 600-1 800-2 000
Maximum diameter of logs to be sawn (depending on *D*)	mm	800-1 000-1 250-1 400-1 600
Maximum length of log carriage (depending on *D*)	mm	6 000-8 000-10 000-12 000-14 000
Cutting speed	m/s	30-40
Carriage feed rate (continuously variable)	m/min	1-40
Return speed	m/min	50
Height adjustment of pulley beam		Electric or hydraulic
Adjusting of blade tension		Electric

IVd. *Data sheet for band resawing machines*

Basic parameters: Pulley diameter
Feed rate

Specifications	*Units*	*Current technology*
Pulley diameter	mm	1 100-1 500
Maximum working width for cutting quartered logs	mm	500-600
Maximum cutting height	mm	600-700
Feed rate (continuously variable)	m/min	1-70
Cutting speed	m/s	30-40
Power requirement (according to pulley diameter)	kW	15-50

IVe. *Data sheet for double edging circular sawing machines, mechanical feed, for resinous wood*

Basic parameter: Maximum edging width

Specifications	*Units*	*Current technology*
Maximum width for double edging	mm	550-630
Maximum working width for single edging	mm	700-800
Maximum cutting height	mm	120-160
Maximum number of blades	pieces	8-10
Maximum diameter of circular blade	mm	400-500
Cutting speed	m/s	60-70
Adjustment of cutting width		Hydraulic system, remote control
Feed rate (continuously variable)	m/min	0-80
Power requirement	kW	20-30

IVf. Data sheet for multiple blade circular sawing machines, for ripping, mechanical feed

Basic parameter: Maximum width of workpiece

Specifications	*Units*	*Current technology*
Maximum width of workpiece	mm	400
Maximum distance between two circular blades	mm	120-320
Maximum cutting height	mm	100-120
Number of circular blades	pieces	6-15
Cutting speed	m/s	60-70
Feed rate (continuously variable)	m/min	15-30
Power requirement	kW	15-30

IVg. Data sheet for surfacing and jointing machines

Basic parameter: Width of cut

Specifications	*Units*	*Current technology*
Working width (normal standard designs)	mm	400-500-630
Total length of tables	mm	2 500
Diameter of cutter block	mm	100-125
Speed of cutter block	rpm	5 000-6 000
Number of knives	pieces	3-4
Power requirement	kW	3-5

IVh. Data sheet for thickness machines

Basic parameter: Working width

Specifications	*Units*	*Current technology*
Working width (normal standard designs)	mm	630-800-1 000
Maximum working thickness	mm	150-200
Feed rate (variable continuously or in steps)	m/min	6-20
Diameter of cutter block	mm	100-125-140
Speed of cutter block	rpm	5 000
Number of knives	pieces	3-4
Power requirement	kW	6-10

IVi. *Data sheet for planing and moulding machines for three- or four-side dressing*

Basic parameter: Machining width

Note: The design which represents current technology has the following features:

Manufacturers have in general adopted the "unit" system with operational blocks for two, three or four operations assembled in an appropriate manner;

The horizontal and vertical cutter heads are interchangeable for machines of the same type, since both cutter blocks and heads are standardized;

High-frequency (100 Hz) electric motors with direct coupling are used to operate the cutter blocks.

Specifications	*Units*	*Current technology*
Working width (standardized)		
Cutter block without counter-bearing	mm	63-80-100-160
Cutter block with counter-bearing	mm	200-250-315
Cutter blocks (standardized)		
Spindle diameter	mm	30-35-40-45
Diameter of cutter block	mm	100-125-140
Speed	rpm	6 000
Number of spindles	pieces	4-5-6
Drive system		100 Hz frequency changer
Continuously variable feed rate	m/min	6-24
Feed system		Pressure roller; chain-feed
Power requirement	kW	20-35

IVj. *Data sheet for spindle moulding machines*

Basic parameters: Maximum thickness of workpiece
Maximum cutter speed

Specifications	*Units*	*Current technology*
Maximum thickness of workpiece (standardized)	mm	80-100-125
Speed of cutter spindle (in steps, driven by pole changeable electric motor)	rpm	3 000 4 500 6 000 9 000
Tiltable spindle	degrees	45
Diameter of taper shank for fixing cutters (standardized)	mm	20-25-30
Power requireme.	kW	3-4.5

IVk. *Data sheet for routing machines*

Basic parameters: Maximum width of grooves and recesses
Maximum speed of tool head
Throat

Specifications	*Units*	*Current technology*
Maximum width of grooves and recesses	mm	20
Cutter spindle speed (activated by frequency changer, $f = 300$ Hz)	rpm	18 000 (usual) 24 000 (maximum)
Travel of cutter spindle	mm	150
Electric motor for driving the spindle	kW	1.0-1.5
Feed system		Pneumatic
Throat	mm	500 630

IVl. *Data sheet for chain mortising machines*

Basic parameters: Maximum width of mortise
Length of mortise
(Travel of carriage)

Specifications	*Units*	*Current technology*
Maximum width of mortise	mm	16-25-40
Travel of carriage	mm	200-250-300
Feed of carriage		Pneumatic or hydropneumatic action
Movements of work table		Longitudinal, transverse, tiltable to 45°
Power requirement	kW	1.5-2.0

IVm. *Data sheet for horizontal slot mortising machines*

Basic parameter: Maximum diameter of cutter bit

Note: There are slot mortising machines with manual control of the longitudinal and transverse movements of the work table and semi-automatic machines with pneumatic, hydraulic or mechanical feed control.

Specifications	*Units*	*Current technology*
Maximum diameter of cutter bit (hole)	mm	20-30
Maximum depth	mm	150-180
Maximum width of slot (elongated hole)	mm	280-300
Frequency of mortising cycles (semi-automatic machines)	Cycles/min	150-180
Speed of bit	rpm	4 500-5 000-7 500
Clamping of the workpiece on to the work table		Pneumatic
Power requirement	kW	1.1-2.2

IVn. *Data sheet for wood turning lathes*

Basic parameters: Maximum swing over gap
Maximum distance between centres

Note: The data contained in this sheet refer to normal lathes and not to special-purpose automatic lathes. Modern wood turning lathes are fitted with a device for continuous variation of the speed of the tool slide.

Specifications	*Units*	*Current technology*
Maximum swing over gap	mm	400-630-1 000
Maximum distance between centres	mm	1 000-1 500-2 000
Maximum swing over bed	mm	350-500
Spindle speed (variable continuously, by variator, or in steps, with gear box)	rpm	300-3 000
Power requirement	kW	1.0-3.0
Tool slide bed		Manual or mechanized and synchronized with cutting speed

IVo. *Data sheet for sanding machines with two and three top drums*

Basic parameters: Width of machining
Maximum feed rate

Note: From the design point of view, there is a distinct difference between two/three-drum sanding machines (fine sanding) and three-drum machines (calibrating sanding machines).

Specifications	*Units*	*Current technology*
Width of machining (standardized)		
With two drums	mm	500-700-900-1 100
With three drums	mm	1 100-1 250-1 800-1 900
Diameter of drums	mm	250-300
Feed rate (continuously variable)	m/min	4-16
Speed of drum (sanding)	m/s	22-26
Power requirement/drum		
Fine sanding	kW	8-10
Calibrating	kW	22-30 (roughing) 10-14 (finishing)
Sanding or calibrating precision (tolerance)	mm	± 0.10

IVp. Data sheet for wide-belt sanders, bottom sanding unit and top sanding units

Basic parameters: Width of machining
Feed rate

Note: The specifications refer to fine-sanding machines.

Specifications	*Units*	*Current technology*
Bottom sanders		
Width of machining	mm	700-1 850
Feed rate (continuously variable)	m/min	4-30
Sanding speed	m/s	22-26
Power requirement for driving the sanding belt	kW	15-22
Belt system		Pneumatically controlled
Top sanders		
Width of machining	mm	700-1 850
Feed rate	m/min	4-30
Sanding speed	m/s	22-26
Power requirement for activation of the sanding belt	kW	9-22

IVq. Data sheet for twin wide-belt sanders with top and bottom sanding units

Basic parameters: Width of machining
Feed rate

Note: The specifications refer to machines for panel calibrating.

Specifications	*Units*	*Current technology*
Width of machining	mm	1 300-2 200-2 600
Feed rate	m/min	0-45
Sanding speed	m/s	22-26
Power requirement for sanding (depending on the width of machining)	kW	2 × (55-100) (roughing) 2 × (30-55) (finishing)
Calibrating precision (tolerance)	mm	± 0.10

IVr. *Data sheet for horizontal stroke sanders with sanding pad or with pressure bar*

Basic parameters: Width of belt
Speed of belt

Specifications	*Units*	*Current technology*
Sanding pad sanders		
Width of belt (standardized)	mm	100-150
Working width	mm	2 200-2 500
Speed of belt	m/s	20-25
Length of belt	mm	7 000
Number of belts	pieces	1 or 2
Electric motors for activation of belt	kW	3-4
Activation of support table		Manual
Pressure bar sanders		
Width of belt	mm	150-200
Speed of belt	m/s	20-25
Number of belts	pieces	1 or 2
Machining length	mm	2 200-2 800
Length of belt	mm	7 000-10 000
Activation of pressure bar		Pneumatic
Movement of workpiece (support table)		Mechanical, with conveyer belts or by pneumatically driven, adjustable stroke system
Electric motor for activation of the belt	kW	4-15

III. General criteria for the selection of machines*

Purchase of woodworking machinery and equipment involves the following considerations:

(*a*) Why should the equipment be purchased?
(*b*) What equipment should be purchased?
(*c*) When should purchases be scheduled?
(*d*) What purchasing arrangements should be made?

Answers to these questions will involve consideration of the technical-productive, economic and commercial implications of the purchase. These considerations must in turn be qualified by two additional considerations. The first is that of machinery as a dynamic productive entity. The second is that of machinery as a static and technical entity. The impact of capital investment costs on sales volume and profit margins is important in all industrial enterprises. Recent introduction of sophisticated industrial woodworking machinery has led to higher investment costs and thus those who purchase woodworking machines and machine systems face a delicate task.

Economic success in the woodworking industry results from the right balance of several production strategies, including high efficiency, quality control, and judicious choice of capital-intensive woodworking machines. This paper will discuss when, why and how to purchase woodworking machines that are used for log processing.

The manufacturing process

The process of considering machinery in its productive context requires examination of a large number of interdependent elements of the productive system (annex I). It should be noted that stages in production of wood products must be understood in terms of the purpose for which the product is intended. Thus plywood may represent a finished product in the wood-sheet industry, whereas it is a "semi-finished" product in the furniture industry.

The product

Consideration of the product requires an understanding of the relationship between industrial design, production facilities and end-user requirements. It is this relationship which will affect:

(*a*) The rate of production;
(*b*) Organization of the production line for final assembly;
(*c*) Supply systems, whether continuous or batch supply systems (work order/stock);
(*d*) Standards of quality required to meet market demands.

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Factory size and location

Size and siting of the factory will depend on:

(a) Economic resources (capital and financing, sales, profit margins, research and development requirements etc.);

(b) Personnel (qualifications, payroll costs, availability etc.);

(c) Geo-economic area (climate, availability of mechanical energy, raw and auxiliary materials, communications and transport, supply logistics etc.);

(d) Organizational structure and its effect on management of resources.

Production planning

Production planning requires the ability to foresee and plan around difficulties. In woodworking production, holdups stem from a wide variety of causes, among them labour unrest, societal problems, technical, logistic and financial problems etc.

There are several planning approaches to help prevent or deal with production problems. Among these techniques is operational research. Another technique is the use of Taylor diagrams for job enrichment and employee motivation. Such approaches may reduce frustration, absenteeism and turnover, and in turn will improve the quality of work and the product.

Specialized management techniques for this purpose include job rotation, job expansion, job enrichment and group work. It is a curious fact that in the artisan type of firm, whose numbers are unfortunately decreasing, these techniques have always been used. At this stage in the development of the subject of management science, these techniques are still experimental and not all students of the subject agree on the potential benefits.

Layout

The design of the production layout involves consideration of a common flow diagram for production (annex II). This flow diagram is obtained from analysis of the production flow patterns of the various parts and subassemblies. The design stage is critical in optimization of production output. The design must take into consideration the rate of production, organization of the production line supply systems, and standards of quality.

These considerations will affect the choice of layout pattern which may be:

(a) Fixed layout; including processing layout (areas with similar machines); product layout (machines arranged sequentially according to the production line); mixed layout (in which the processing and product layouts exist together;

(b) Flexible layout.

It is possible to also have a layout which is obtained by shifting the production equipment from time to time in the configuration most suitable for production flow. In layout design it is important to consider horizontal and vertical handling away from the machine, as well as the direction of flow which should always be positive. In addition to location of machines, layout involves location of the various production departments, stores, buffer stock areas, auxiliary facilities and other related installations. Annex III is a chart analysing the importance of location of various departments.

General machine features

Machines may generally be classified as either single purpose or multi-purpose. The operational modes may be classified as manual, semi-automatic, automatic or numerically controlled.

It is best to try to select a machine which will provide for:

(a) Reduction of direct labour costs;
(b) Reduction of tooling costs;
(c) Increase in production;
(d) Improvement in product quality;
(e) Reduction of rejects;
(f) Predictable production time;
(g) Options of remote or multiple control;
(h) Reduction of floor space required;

It is important to consider the above characteristics with regard to:

(a) Relation of investment cost to productivity;
(b) Possibility of multiple or increased production utilization;
(c) Useful life of the machinery with regard to foreseeable technical advances which may render the machine obsolete;
(d) Ease of service;
(e) Time required to place the machine in service;
(f) Times, costs and practical possibilities for programme preparation for numerically controlled machines;
(g) Ease of obtaining spare parts and special tools.

Technology and productivity

As mentioned earlier, answers to the major questions involved in purchasing machinery involve consideration of the technical-productive, economic and commercial implications of the purchase.

These are, of course, interrelated considerations, but a checklist, which follows, may be of some assistance to decision makers who are contemplating machine purchases.

Hygiene and safety

Accident source statistics indicate that 10 per cent of accidents have technical causes. Woodworking machines are extremely dangerous and must be provided with all possible safety measures. All machine producing countries have strict and precise safety regulations and machines must be sold in conformity with them.

Among the important further environmental considerations are:

(a) Noise (annex IV). Unfortunately nearly all woodworking machines have a high noise level. Noise harms productivity and should be reduced. Noise assumes an important role in factory life due to its social and economic implications. It is a considerable burden and much is done to reduce it at the source (on the machine itself). Further efforts must be made to reduce noise transmission by insulating the machine and the environment with sound deadening material. Protective equipment such as earplugs may be of assistance;

(b) Vibration control. Vibration makes it difficult to work accurately and leads to many errors. Machines must be provided with suitable damping where necessary;

(c) Protection against dust, chips, smoke, vapours and humidity. All machines should be provided with automatic exhaust systems;

(d) Proper illumination of the working zone;

(e) Machine body designed to minimize dangerous projecting parts and sharp edges;

(f) Ergonometrically designed machines and colour coding of operational parts of different types of machinery (controls, electrical and hydraulic equipment, working zone etc.).

Toolings

Tooling considerations include initial cost of special tools and the down time required for tooling.

Maintenance

Maintenance considerations include ease of maintenance, such as access to parts liable to failure, ease of using tools for rapid repairs. Standardization of components and spare parts and their long-term availability is also important. The high cost of machinery does not permit the installation of stand-by machines and therefore the ratio of $\frac{\text{available hours}}{\text{actual hours}}$ must be kept high.

Failures involve repairs or maintenance as well as costs, production losses, re-starting the machine and defective production. If annual maintenance costs exceed 8 per cent of the invested capital, purchase may be unwise.

The lifetime of a machine may be categorized by three periods. The first period is referred to as the "infant mortality" period and is characterized by an initially high breakdown rate (normally manufacturing faults) which soon decreases. The second period is referred to as the "useful life" and is characterized by a constant breakdown rate. Breakdown rate is thus independent of the age of the machine during this period. The third period is usually referred to as the "old age" period and characterized by a breakdown rate which increases with age.

Reliability and efficiency

Breakdowns may result from:

(a) Inherent design (responsibility of the designer);

(b) Manufacture (responsibility of the manufacturer);

(c) Operation (responsibility of the user and influenced by operating conditions and preventive maintenance).

It is necessary to ensure, as far as possible, long-term reliability and efficiency. The reliability of a machine is the probability of it being able to function without breakdown for a certain number of hours under certain pre-established operative conditions.

T is defined as the average time interval between breakdowns and F as the average duration of the breakdown. Efficiency is then represented by: $E\% = \left(\frac{T}{T+F}\right) \times 100$ which is the percentage of time during which the machine should function without breakdowns. Unfortunately these values and technical commercial guarantees, which are very important for the evaluation of costly and complex machines, are still difficult to obtain from manufacturers, as many have only recently begun collecting the necessary statistical data.

Automation

Automation includes the use of reliable automatic devices for loading, clamping; methods for automatic loading and unloading (robot or transfer); and the use of universally adaptable unit heads. As automated equipment is difficult to repair it is often cost effective to purchase stand-by equipment to avoid production holdups during breakdown.

Technological features

Important technological features of machines are:

(a) Overall machine dimensions;

(b) Machine weight (useful for judging stability and fatigue resistance);

(c) Quality of materials used and their metallurgical characteristics;

(d) Characteristics of electric motors as related to power supply and foreseen loads (hermetic sealing, cooling etc.);

(*e*) Dimensions of moving parts or those more subject to stress (shafts, bearings, bushes, gears etc.) and their proper lubrication and cooling;

(*f*) Adequate control instruments for production and ongoing inspection of machine parts;

(*g*) For numerically controlled machines, programmes and their management.

A record of such features is illustrated in annex V

Technological capacity

Technological capacity refers to the operative capability (quantity and quality) of the machine. Among the operations considered are forming (presses), stock removal (sewing machines, planers, etc.), and coating (spreaders, automatic roller painters, sprayers etc.). Operational speed and working tolerances are of importance in considering technological capacity.

Economic component

Investment

Important investment considerations are:

(*a*) Machine purchase price plus charges for transport, customs, insurance etc.;

(*b*) Obsolescence prospects (residual value);

(*c*) Problems concerning machine base, foundations, environmental conditions etc.;

(*d*) Floor space and height;

(*e*) Cost of a numerically controlled unit;

(*f*) Optionals;

(*g*) Cost of connections or alternatives to expansion of infrastructures, such as electric, hydraulic, pneumatic systems etc.;

(*h*) Expenses involved in any modification to existing systems and moving of other machines and equipment;

(*i*) Testing and commissioning costs;

(*j*) Costs for training of personnel;

(*k*) Depreciation indexes (real and fiscal).

Management

Management considerations include:

(*a*) Operational or running costs (direct and indirect labour, breakdown costs etc.);

(*b*) Qualifications of personnel and salaries;

(*c*) Energy consumption by production;

(*d*) Ease of loading and unloading per unit of work;

(*e*) Operational flexibility: maximum and minimum dimensions of workpiece;

(*f*) Rejection rates;

(*g*) Characteristics of waste and losses due to scrap;

(*h*) Cost of floor space occupied.

Commercial component

Elements for commercial negotiations are fully dealt with in "General Conditions for the Supply and Erection of Plant and Machinery for Import and Export" established by the United Nations Economic Commission for Europe (annex VI).

The following, however, may be considered as complementary to these conditions.

Quotation request

It is always advisable to ask for the characteristics of the supply and its price by means of a formal "Quotation request" which, along with the "Quotation", the "Purchase order", the "Order acknowledgement" and the illustrations (leaflets, drawings etc.) constitute technical, economic and legal documentation for the purchase. In periods of price increase, like the present, quotations should include time limits for validity and indicate formulae for possible price escalation.

Customs tariff number

It is advisable to give a precise description (also for customs purposes) of the machine required. In this regard several countries are working on the standardization of the terminology defining all woodworking machines. Standardization work which is already in a fairly advanced state of development is being carried out by European Committee of Woodworking Machinery Manufacturers (EUMOBOIS).

Specifications

The quotation request should include the technical specifications to which the machines intended to be purchased should conform. These specifications should be drawn up by the purchaser or he should refer to well-known specifications.

Documentation

Documentation, to fully describe the purchase, should be in the appropriate language and include:

(a) Installation layouts;
(b) Wiring diagrams;
(c) Operating manuals;
(d) Maintenance manuals;
(e) Programming manuals for numerical control;
(f) Illustrated list of spare parts;
(g) Stock cards.

Delivery scheduling of machinery or equipment

Proper care should be taken to ensure that equipment arrives in proper sequence for installation. If such a programme is not properly adhered to, pieces of equipment or machinery may arrive well in advance of scheduled installation time. These items may be subject to damage due to having to be stored, either crated or uncrated, for a long period of time. In such cases damage could result due to rusting, dust particles, or even pilferage, and the effects of local weather.

General terms of delivery

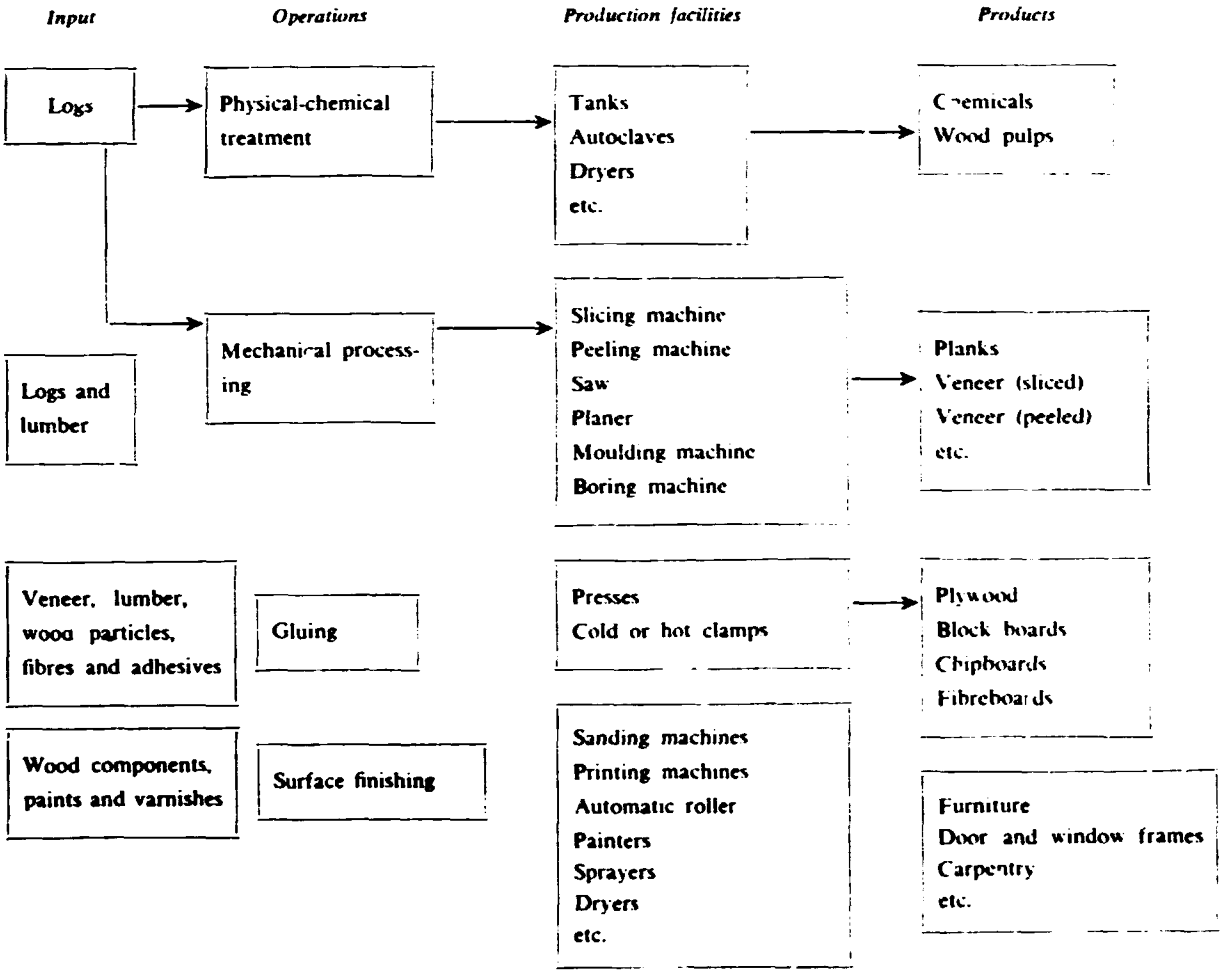
Annex VI includes a supplementary document which refers to "General terms of delivery". This latter document, as indicated therein, has been drafted with reference to Documents Nos. 188A and 730, published and recommended by the United Nations Economic Commission for Europe (ECE). It is a document which has been amended up to 1 January 1977 and is applicable where contracts are involved with the Association of Machinery and Steel Construction Industries throughout Europe.

While including this document it has been necessary to exclude paragraph 1.3 because it concerns special terms for one country only with regard to erection and assembly work. In the case of developing countries it is considered advisable that they pay particular attention to the contents of the supplementary document where they become involved in purchasing of machinery or equipment.

Annex VII is included as a supplementary document which refers to the "General conditions for the supply of plant and machinery for export". This document was prepared under the auspices of the United Nations Economic Commission for Europe.

Annex I

WOOD PROCESSING OPERATIONS



Annex II

PRODUCTION LAYOUT AND PRODUCTION FLOW DIAGRAMS

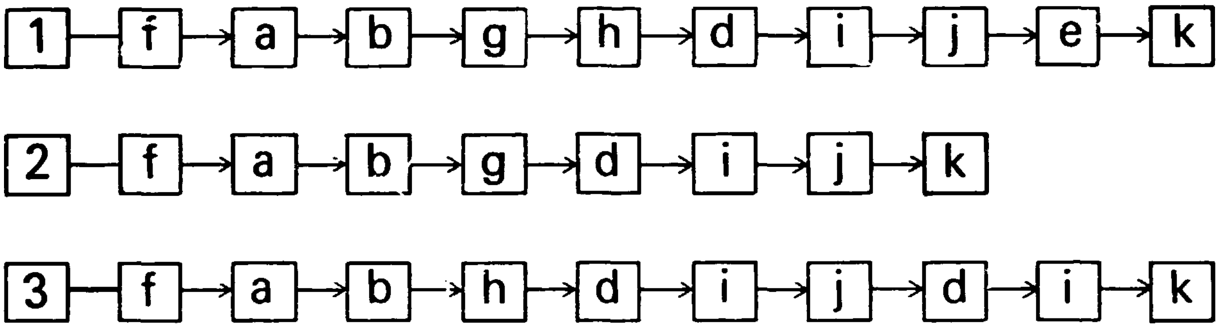
Layout types include:

(a) Fixed point layout. The product is immobile and the materials needed are transported to it. The major manufacturing jobs are done in a fixed position (examples: deforestation, ship building, construction, dams etc.);

(b) Functional or process layout. All the operations of the same type and all the necessary equipment for these operations are in one department. It is useful for small quantities and for products that are not standardized since it permits flexibility in the sequence of the operation;

(c) By-product layout. The product moves in a constant flow. For continuous operations for a large run, the various machines are placed in a functional line corresponding to the successive operations.

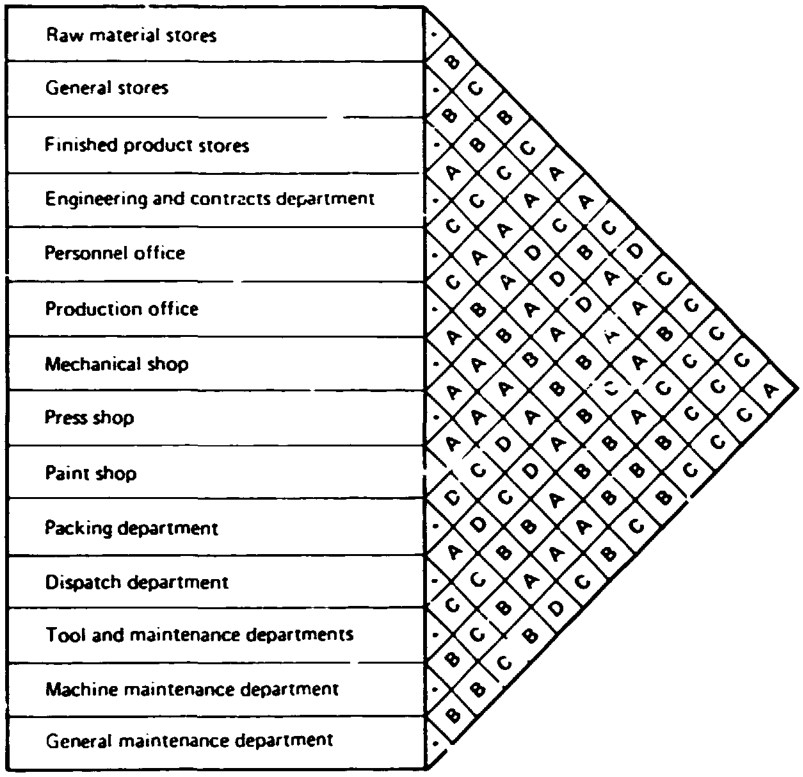
Below is a schematic diagram of the three different layout types.



Key:	a	Press	1	Carcass (exterior frame of panel furniture)
	b	Tennoning	2	Shelving
	d	Sanding	3	Doors
	e	Assembly		
	f	Sawing		
	g	Edge banding		
	h	Boring and milling		
	i	Surface finishing		
	j	Drying		
	k	Finished product		

Annex III

RELATIONSHIP CHART ANALYSING THE IMPORTANCE OF LOCATION OF VARIOUS DEPARTMENTS IN A HYPOTHETICAL MEDIUM SIZE PLANT



Key: A Important for the departments to be located close to each other.
B Preferable (medium importance) for the departments to be located close to each other.
C Unimportant for departments to be close to each other.
D Departments should not be in proximity.

Annex IV

NOISE SOURCES AND THEIR RELATIVE LOUDNESS

Relative loudness (dB)	*Comment*	*Noise source*
130		Jet aircraft at 25 m
120	Deafening	Riveting hammer
110		Moulding machine — planer
	Threshold of pain	
100		Circular saw
90	Risk to hearing	Mechanical workshop
80		Rolling mill
70		Heavy traffic
60	Safe	Normal conversation
50		Quiet conversation
40		Music from radio at low volume
30		Whispering
20		Quiet of the country
10	"Silence"	Rustling of leaves
1	Threshold of hearing	Threshold of hearing

Annex V

RECORDS OF MACHINE CHARACTERISTICS AND POSITION

SCHEDA MACCHINE PER STUDI DI DISPOSIZIONE

(Description)
Descrizione

Macchina **(Machine)**

Marca **(Make)**

Modello **(Model)**

Num. catal. **(Cat. No.)**

Capacità **(Capacity)**

Lista attrezzi **(Tool list)**

N. invent. **(Inventory No.)**

Disegno N. **(Drawing No.)**

Modifiche **(Changes)**

(Cost) ***Costo***	**(Date)** ***Data***	**(Condition)** ***Condizione***

(Length) ***Lunghezza***	**(Width)** ***Larghezza***
(Height) ***Altezza***	**(Weight)** ***Peso***

(Special features)
Dati caratteristici

(Services)
Servizi

(Main motor)
Motore principale

V **(Phase)** *Fase*

Hz **(HP)** *CV*

(RPM) *giri/m*

(Control gear)
Apparecchiatura di comando

V **(AC) (DC)** *CA-CC*

	(Intake) *Aspiraz.*		*Gas*
	(Water) *Acqua*		**(Coolant)** *Refrig.*
	(Outlet) *Scarico*		
	(Steam) *Vapore*		

(Foundation) *Fondazione* **(Yes)** ☐ *Si* **(No)** ☐ *No*

(Drawing No.)
Disegno N.

☐ **(Grouting)** *Cementata*

☐ **(Anchor bolts)** *Bulloni d'ancoraggio*

☐ **(Dampers)** *Antivibranti*

☐

(Location)
Dislocazione

(Factory) *Fabbrica* **(Floor)** *Piano* **(Bay)** *Campata*

(Notes)
Note

(Date) *Data*

Annex VI

GENERAL CONDITIONS FOR THE SUPPLY AND ERECTION OF PLANT AND MACHINERY FOR IMPORT AND EXPORT *

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

Geneva, March 1957

1. Preamble

1.1. These general conditions shall apply, save as varied by express agreement accepted in writing by both parties.

2. Formation of Contract

2.1. The Contract shall be deemed to have been entered into when, upon receipt of an order, the Contractor has sent an acceptance in writing within the time-limit (if any) fixed by the Purchaser.

2.2. If the Contractor, in drawing up his tender, has fixed a time-limit for acceptance, the Contract shall be deemed to have been entered into when the Purchaser has sent an acceptance in writing before the expiration of such time-limit, provided that there shall be no binding Contract unless the acceptance reaches the Contractor not later than one week after the expiration of such time-limit.

3. Drawings and descriptive documents

3.1. The weights, dimensions, capacities, prices, performance ratings and other data included in catalogues, prospectuses, circulars, advertisements, illustrated matter and price lists constitute an approximate guide. These data shall not be binding save to the extent that they are by reference expressly included in the Contract.

3.2. Any drawings or technical documents intended for use in the construction or erection of the Works[1] or of part thereof and submitted to the Purchaser prior or subsequent to the formation of the Contract remain the exclusive property of the Contractor. They may not, without the Contractor's consent, be utilized by the Purchaser or copied, reproduced, transmitted or communicated to a third party. Provided, however, that the said plans and documents shall be the property of the Purchaser:

(a) If it is expressly so agreed, or

(b) If they are referable to a separate preliminary development contract on which no actual construction was to be performed and in which the property of the Contractor in the said plans and documents was not reserved.

3.3. Any drawings or technical documents intended for use in the construction or erection of the Works or of part thereof and submitted to the Contractor by the Purchaser prior or subsequent to the formation of the Contract remain the exclusive property of the Purchaser. They may not, without his consent, be utilized by the Contractor or copied, reproduced, transmitted or communicated to a third party.

3.4. The Contractor shall, if required by the Purchaser, furnish free of charge to the Purchaser at the commencement of the Guarantee Period, as defined in Clause 23, information and drawings other than manufacturing drawings of the Works in sufficient detail to enable the Purchaser to carry out the operation and maintenance (including running repairs) of all parts of the Works and (except where under the Contract the Contractor is responsible for commissioning the Works) the commissioning thereof. Such information and drawings shall be the property of the Purchaser and the restrictions on their use set out in paragraph 2 hereof shall not apply thereto. Provided that if the Contractor so stipulates, they shall remain confidential.

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* These Conditions may be used, at the option of the parties, as an alternative to the General Conditions *for the Supply and Erection* of Plant and Machinery for Import and Export prepared at Geneva, in March 1957 (No. 57 + A).

The English, French and Russian texts are equally authentic.

The observations of the experts who drew up these General Conditions, together with a description of the procedure followed, are embodied in the "Commentary on the general conditions for the supply of plant and machinery for export No. 188" (Document E/ECE/169), published by the Economic Commission for Europe. It can be obtained direct from the Sales Section of the European Office of the United Nations, Geneva, Switzerland, or *through United Nations Sales Agents.*

[1] In these General Conditions "Plant" means all machinery, apparatus, materials and articles to be supplied by the Contractor under the Contract and "the Works" means all Plant to be supplied and work to be done by the Contractor under the Contract.

4. Packing

4.1. Unless otherwise specified:

(a) Prices shown in price lists and catalogues shall be deemed to apply to unpacked Plant;

(b) Prices quoted in tenders and in the Contract shall include the cost of packing or protection required under normal transport conditions to prevent damage to or deterioration of the Plant before it reaches its destination as stated in the Contract.

5. Local laws and regulations

5.1. The Purchaser shall, at the request of the Contractor and to the best of his ability, assist the Contractor to obtain the necessary information concerning the local laws and regulations applicable to the Works and to taxes and dues connected therewith.

5.2. If, by reason of any change in such laws and regulations occurring after the date of the tender, the cost of erection is increased or reduced, the amount of such increase or reduction shall be added to or deducted from the price, as the case may be.

6. Working conditions

6.1. The price shall be on the understanding that the following conditions are fulfilled, except so far as the Purchaser has informed the Contractor to the contrary:

(a) The Works shall not be carried out in unhealthy or dangerous surroundings;

(b) The Contractor's employees shall be able to obtain suitable and convenient board and lodging in the neighbourhood of the site and shall have access to adequate medical services;

(c) Such equipment, consumable stores, water and power as are specified in the Contract shall be available to the Contractor on the site in good time, and, unless otherwise agreed, free of charge to the Contractor;

(d) The Purchaser shall provide the Contractor (free of charge, unless otherwise agreed) with closed or guarded premises on or near the site as a protection against theft and deterioration of the Plant to be erected, of the tools and equipment required therefor, and of the clothing of the Contractor's employees;

(e) The Contractor shall not be required to undertake any works of construction or demolition or to take any other unusual measures to enable the Plant to be brought from the point where it has been unloaded to the point on the site where it is to be erected, unless the Contractor has agreed to deliver the Plant to the last mentioned point.

Any departure from the conditions mentioned in this paragraph shall attract an extra charge.

6.2. If the circumstances resulting from such departure are such that it would be unreasonable to require the Contractor to proceed with the Works, the Contractor may, without prejudice to his rights under the Contract, refuse to do so.

7. Erection on a time basis and lump sum erection

7.1 When erection is carried out on a time basis the following items shall be separately charged:

(a) All travelling expenses incurred by the Contractor in respect of his employees and the transport of their equipment and personal effects (within reasonable limits) in accordance with the specified method and class of travel where these are specified in the Contract;

(b) The living expenses, including any appropriate allowances, of the Contractor's employees for each day's absence from their homes, including non-working days and holidays;

(c) The time worked, which shall be calculated by reference to the number of hours certified as worked in the time-sheets signed by the Purchaser. Overtime and work on Sundays, holidays and at night will be charged at the special rates mentioned in the Contract. Save as otherwise provided, the hourly rates cover the wear and tear and depreciation of the Contractor's tools and light equipment;

(d) Time necessarily spent on:

- (i) Preparation and formalities incidental to the outward and homeward journeys;
- (ii) The outward and homeward journeys;
- (iii) Daily travel morning and evening between lodgings and the site if it exceeds half an hour and there are no suitable lodgings closer to the site;
- (iv) Waiting when work is prevented by circumstances for which the Contractor is not responsible under the Contract;

(e) Any expenses incurred by the Contractor in accordance with the Contract, in connexion with the provision of equipment by him, including where appropriate a charge for the use of the Contractor's own heavy equipment;

(f) Any taxes or dues levied on the invoice and paid by the Contractor in the country where erection takes place.

7.2. When erection is carried out for a lump sum, the quoted price includes all the items above mentioned. Provided that if the erection is prolonged for any cause for which the Purchaser or any of his contractors other than the Contractor is responsible and if as a result the work of the Contractor's employees is suspended or added to, a charge will be made for any idle time, any extra work, any extra living expenses of the Contractor's employees and the cost of any extra journey.

8. Inspection and tests of the Plant

Inspection

8.1. If expressly agreed in the Contract, the Purchaser shall be entitled to have the quality of the materials used and the parts of the Plant, both during manufacture and when completed, inspected and checked by his authorized representatives. Such inspection and checking shall be carried out at the place of manufacture during normal working hours after agreement with the Contractor as to date and time.

8.2. If as a result of such inspection and checking the Purchaser shall be of the opinion that any materials or parts are defective or not in accordance with the Contract, he shall state in writing his objections and the reason therefor.

Tests

8.3. Tests provided for in the Contract other than taking over tests will be carried out, unless otherwise agreed, at the Contractor's works and during normal working hours. If the technical requirements of the tests are not specified in the Contract, the tests will be carried out in accordance with the general practice obtaining in the appropriate branch of the industry in the country where the Plant is manufactured.

8.4. The Contractor shall give to the Purchaser sufficient notice of the tests to permit the Purchaser's representatives to attend. If the Purchaser is not represented at the tests the test report shall be communicated by the Contractor to the Purchaser and shall be accepted as accurate by the Purchaser.

8.5. If on any test (other than a taking-over test as provided for in Clause 21) the Plant shall be found to be defective or not in accordance with the Contract, the Contractor shall with all speed make good the defect or ensure that the Plant complies with the Contract. Thereafter, if the Purchaser so requires, the test shall be repeated.

8.6. Unless otherwise agreed, the Contractor shall bear all the expenses of tests carried out in his works, except the personal expenses of the Purchaser's representatives.

9. Passing of risk

9.1. Save as provided in paragraph 10.1, the time at which the risk shall pass shall be fixed in accordance with the International Rules for the Interpretation of Trade Terms (Incoterms) of the International Chamber of Commerce in force at the date of the formation of the Contract.

Where no indication is given in the Contract of the form of sale, the Plant shall be deemed to be sold "ex works."

9.2. In the case of a sale "ex works", the Contractor must give notice in writing to the Purchaser of the date on which the Purchaser must take delivery of the Plant. The notice of the Contractor must be given in sufficient time to allow the Purchaser to take such measures as are normally necessary for the purpose of taking delivery.

10. Delayed acceptance of delivery

10.1. If the Purchaser fails to accept delivery of the Plant on due date, he shall nevertheless make any payment conditional on delivery as if the Plant had been delivered. The Contractor shall arrange for the storage of the Plant at the risk and cost of the Purchaser. If required by the Purchaser, the Contractor shall insure the Plant at the cost of the Purchaser. Provided that if the delay in accepting delivery is due to one of the circumstances mentioned in Clause 25 and the Contractor is in a position to store it in his premises without prejudice to his business, the cost of storing the Plant shall not be borne by the Purchaser.

10.2. Unless the failure of the Purchaser is due to any of the circumstances mentioned in Clause 25, the Contractor may require the Purchaser by notice in writing to accept delivery within a reasonable time.

If the Purchaser fails for any reason whatever to do so within such time, the Contractor shall be entitled by notice in writing to the Purchaser, and without requiring the consent of any Court, to terminate the Contract in respect of such portion of the Plant as is by reason of the failure of the Purchaser aforesaid not delivered and thereupon to recover from the purchaser any loss suffered by reason of such failure up to an amount not exceeding the sum named in paragraph A of the Appendix or, if no sum be named, that part of the price payable under the Contract which is properly attributable to such portion of the Plant.

11. Payment

11.1. Payment shall be made in the manner and at the time or times agreed by the parties.

11.2. Any advance payments made by the Purchaser are payments on account and do not constitute a deposit, the abandonment of which would entitle either party to terminate the Contract.

11.3. If delivery has been made before payment of the whole sum payable under Contract, Plant delivered shall, to the extent permitted by the law of the country where the Plant is situated after delivery, remain the property of the Contractor until such payment has been effected. If such law does not permit the Contractor to retain the property in the Plant, the Contractor shall be entitled to the benefit of such other rights in respect thereof as such law permits him to retain. The Purchaser shall give the Contractor every assistance in taking any measures required to protect the Contractor's right of property or such other rights as aforesaid.

11.4. A payment conditional on the fulfilment of an obligation by the Contractor shall not be due until such obligation has been fulfilled, unless the failure of the Contractor is due to an act or omission of the Purchaser.

11.5. If the Purchaser delays in making any payment, the Contractor may postpone the fulfilment of his own obligations until such payment is made, unless the failure of the Purchaser is due to an act or omission of the Contractor.

11.6. If delay by the Purchaser in making any payment is due to one of the circumstances mentioned in Clause 25, the Contractor shall not be entitled to any interest on the sum due.

11.7. Save as aforesaid, if the Purchaser delays in making any payment, the Contractor shall on giving to the Purchaser within a reasonable time notice in writing be entitled to the payment of interest on the sum due at the rate fixed in paragraph B of the Appendix from the date on which such sum became due. If at the end of the period fixed in paragraph C of the Appendix, the Purchaser shall still have failed to pay the sum due, the Contractor shall be entitled by notice in writing to the Purchaser, and without requiring the consent of any Court, to terminate the Contract and thereupon to recover from the Purchaser the amount of his loss up to the sum mentioned in paragraph A of the Appendix.

12. Preparatory work

12.1. The Contractor shall in good time provide drawings showing the manner in which the Plant is to be affixed together with all information relating, unless otherwise agreed, only to the Works, required for preparing suitable foundations, for providing suitable access for the Plant and any necessary equipment to the point on the site where the Plant is to be erected and for making all necessary connexions to the Plant (whether such connexions are to be made by the Contractor under the Contract or not).

12.2. The preparatory work shall be executed by the Purchaser in accordance with the drawings and information provided by the Contractor and mentioned in paragraph 1 hereof. It shall be completed in good time and the foundations shall be capable of taking the Plant at the proper time. Where the Purchaser is responsible for transporting the Plant, it shall be on the site in good time.

12.3. Any expenses resulting from [illegible]ror or omission in the drawings or information mentioned in paragraph 1 hereof which appears before [illegible]ver shall be borne by the Contractor. Any such error or omission which appears after taking over shall be de[illegible] faulty design for purposes of Clause 23.

13. Liaison agents

13.1. The Contractor and Purchaser shall each designate in writing a competent representative to be his channel of communication with the other party on the day-to-day execution of the Works on the site.

13.2. Each such representative shall be present on or near the site during working hours.

14. Additional labour

14.1. If the Contractor so requires in good time the Purchaser shall make available to the Contractor free of charge such skilled and unskilled labour as is provided for in the Contract and such further reasonable amount of unskilled labour as may be found to be necessary even if not provided for in the Contract.

15. Safety regulations

15.1. The Purchaser shall notify the Contractor in full of the safety regulations which the Purchaser imposes on his own employees and the Contractor shall secure the observance by his employees of such safety regulations.

15.2. If breaches of these regulations come to the notice of the Purchaser, he must inform the Contractor in writing forthwith, and may forbid persons guilty of such breaches entry to the site.

15.3. The Contractor shall inform the Purchaser in full of any special dangers which the execution of the Works may entail.

16. Overtime

16.1. Any overtime and the conditions thereof shall, within the limits of the laws and regulations of the Contractor's country and of the country where erection is carried out, be as agreed between the parties.

17. Work outside the Contract

17.1. The Purchaser shall not be entitled to use the Contractor's employees on any work unconnected with the subject-matter of the Contract without the previous consent of the Contractor. Where the Contractor so consents, he shall not be under any liability in respect of such work, and the Purchaser shall be responsible for the safety of the Contractor's employees while employed on such work.

18. Contractor's right of inspection

18.1. Until the Works are taken over and during any work resulting from the operation of the guarantee the Contractor shall have the right at any time during the hours of work on the site to inspect the Works at his own expense. In proceeding to the site, the inspectors shall observe the regulations as to movement in force at the Purchaser's premises.

19. Instruction of the Purchaser's employees

19.1. In appropriate cases the Contract may provide on the terms and conditions therein set out for instruction to be given by the Contractor to the Purchaser's employees who will run the Plant.

20. Time for completion

20.1. Unless otherwise agreed the completion period shall run from the latest of the following dates:

(a) The date of the formation of the Contract as defined in Clause 2;

(b) The date on which the Contractor receives notice of the issue of a valid import licence where such is necessary for the execution of the Contract;

(c) The date of the receipt by the Contractor of such payment in advance of manufacture as is stipulated in the Contract.

20.2. Should delay in completion be caused by any of the circumstances mentioned in Clause 25 or by an act or omission of the Purchaser and whether such cause occur before or after the time or extended time completion, there shall be granted subject to the provisions of paragraph 5 hereof such extension of the completion period as is reasonable having regard to all the circumstances of the case.

20.3. If a fixed time for completion is provided for in the Contract, and the Contractor fails to complete the Works within such time or any extension thereof granted under paragraph 2 hereof, the Purchaser shall be entitled, on giving to the Contractor within a reasonable time notice in writing, to claim a reduction of the price payable under the Contract, unless it can be reasonably concluded from the circumstances of the particular case that the Purchaser has suffered no loss. Such reduction shall equal the percentage named in paragraph D of the Appendix of that part of the price payable under the Contract which is properly attributable to such portion of the Works as cannot in consequence of the said failure be put to the use intended for each complete week of delay commencing on the due date of completion but shall not exceed the maximum percentage named in paragraph E of the Appendix. Such reduction shall be allowed when a payment becomes due on or after completion. Save as provided in paragraph 5 hereof, such reduction of price shall be to the exclusion of any other remedy of the Purchaser in respect of the Contractor's failure to complete as aforesaid.

20.4. If the time for completion mentioned in the Contract is an estimate only, either party may after the expiration of two thirds of such estimated time require the other party in writing to agree a fixed time.

Where no time for completion is mentioned in the Contract, this course shall be open to either party after the expiration of nine months from the formation of the Contract.

If in either case the parties fail to agree, either party may have recourse to arbitration, in accordance with the provisions of Clause 28, to determine a reasonable time for completion and the time so determined shall be deemed to be the fixed time for completion provided for in the Contract and paragraph 3 hereof shall apply accordingly.

20.5. If any portion of the Works in respect of which the Purchaser has become entitled to the maximum reduction provided for by paragraph 3 hereof, or in respect of which he would have been so entitled had he given the notice referred to therein, remains uncompleted, the Purchaser may by notice in writing to the Contractor require him to complete and by such last mentioned notice fix a final time for completion which shall be reasonable taking into account such delay as has already occurred. If for any cause other than one for which the Purchaser or some other Contractor employed by him is responsible, the Contractor fails to complete within such time, the Purchaser shall be entitled by notice in writing to the Contractor, and without requiring the consent of any Court, to terminate the Contract in respect of such portion of the Works and thereupon to recover from the Contractor any loss suffered by the Purchaser by reason of the failure of the Contractor as aforesaid up to an amount not exceeding the sum named in paragraph F of the Appendix, or, if no sum be named, that part of the price payable under the Contract which is properly attributable to such portion of the Works as could not in consequence of the Contractor's failure be put to the use intended.

21. Taking-over tests

21.1. Unless otherwise agreed, taking-over tests shall be carried out. If such tests are to be carried out, the Contractor shall notify the Purchaser in writing when the Works will be ready, and such notification shall be in sufficient time to enable the Purchaser to make any necessary arrangements. The tests shall take place in the presence of both parties. The technical requirements shall be as specified in the Contract or, if not so specified, in accordance with the general practice existing in the appropriate branch of the industry in the country where the Plant is manufactured.

21.2. If as a result of such tests the Works are found to be defective or not in accordance with the Contract, the Contractor shall with all speed and at his own expense make good the defect or ensure that the Works comply with the contract, and thereafter, if the Purchaser so requires, the test shall be repeated at the expense of the Contractor.

21.3. Subject to the provisions of paragraph 2 hereof the Purchaser shall free of charge provide any power, lubricants, water, fuel and materials of all kinds reasonably required for final adjustments and for taking-over tests. He shall also install free of charge any apparatus necessary for the above mentioned operations.

22. Taking over

22.1. As soon as the Works have been completed in accordance with the Contract and have passed all the taking-over tests to be made on completion of erection, the Purchaser shall be deemed to have taken over the Works and the Guarantee Period shall start to run. The Purchaser shall thereupon issue to the Contractor a certificate, called a "Taking-over Certificate", in which he shall certify the date on which the Works have been completed and have passed the tests.

22.2. If the Purchaser is unwilling to have the taking-over tests carried out, the Works shall be deemed to have been taken over and the Guarantee Period shall start to run on a written notice to that effect being given by the Contractor.

22.3. If by reason of difficulties encountered by the Purchaser (whether or not covered by Clause 25) it becomes impossible to proceed to the taking-over tests, these shall be postponed for a period not exceeding six months, or such other period as the parties agree, and the following provisions shall apply:

(a) The Purchaser shall make payments as if the taking over had taken place, provided that, in the case of a difficulty due to any of the circumstances falling within paragraph 25.1, the Purchaser shall not unless otherwise agreed, be required to pay at the due time of taking over the cost of uncompleted work or, before the expiration of the Guarantee Period fixed in accordance with sub-paragraph *(d)* hereof, any sum retained by way of guarantee.

(b) At the appropriate time, the Purchaser shall give notice in writing to the Contractor stating the earliest date on which the tests can be carried out and requesting him to fix a new date for the tests. Such new date shall be within the period stated in paragraph G of the Appendix after the date mentioned in such notice.

(c) The Contractor may, at the cost of the Purchaser, examine the Works before making the tests and make good any defect or deterioration therein that may have developed, or loss thereof that may have occurred, after the date when the Works were first ready for testing in accordance with the Contract.

(d) The Guarantee Period shall run from the date when the postponed tests have been successfully carried out.

(e) If the Purchaser so requires, the Contractor shall, subject to the provisions of the Contract in respect of the passing of risk, protect and preserve the Works until the tests are carried out or for one month from the time when the Works were first ready for testing in accordance with the Contract, whichever is the shorter period. The Contractor shall be entitled to recover from the Purchaser the costs of any measures actually taken by the Contractor to protect and preserve the Works. Unless otherwise agreed, the liability of the Contractor for protecting and preserving the Works shall cease on the expiry of such month. If by reason of other commitments the Contractor is unable to leave his employees on the site, he shall give the Purchaser any directions required to enable the Purchaser to make satisfactory arrangements for protecting and preserving the Works.

(f) If at the end of six months or such other period as the parties may have agreed the tests have not taken place the provisions of paragraph 22.2 shall apply unless the provisions of Clause 25 are applicable.

23. Guarantee

23.1. Subject as herein after set out, the Contractor undertakes to remedy any defect resulting from faulty design, materials or workmanship.

23.2. This liability is limited to defects which appear during the period (called "the Guarantee Period") specified in paragraph H of the Appendix and commencing on taking over.

23.3. In respect of such parts (whether of the Contractor's own manufacture or not) of the Works as are expressly mentioned in the Contract, the Guarantee Period shall be such other period (if any) as is specified in respect of each of such parts.

23.4. The daily use of the works and the amount by which the Guarantee Period shall be reduced if the Works are used more intensively are stated in paragraph J of the Appendix.

23.5. A fresh Guarantee Period equal to that stated in paragraph H of the Appendix shall apply, under the same terms and conditions as those applicable to the original Works, to parts supplied in replacement of the defective parts or to parts renewed in pursuance of this Clause. This provision shall not apply to the remaining parts of the Works, the Guarantee Period of which shall be extended only by a period equal to the period during which the Works are out of action as a result of a defect covered by this Clause.

23.6. In order to be able to avail himself of his rights under this Clause the Purchaser shall notify the Contractor in writing, without delay, of any defects that have appeared and shall give him every opportunity of inspecting and remedying them.

23.7. On receipt of such notification the Contractor shall remedy the defect forthwith and, save as mentioned in paragraph 8 hereof, at his own expense. Save where the nature of the defect is such that it is appropriate to effect repairs on site, the Purchaser shall return to the Contractor any part in which a defect covered by this clause has appeared, for repair or replacement by the Contractor, and in such case the delivery to the Purchaser of such part properly repaired or a part in replacement thereof shall be deemed to be a fulfilment by the Contractor of his obligations under this paragraph in respect of such defective part.

23.8. Unless otherwise agreed, the Purchaser shall bear the cost and risk of transport of defective parts and of repaired parts or parts supplied in replacement of such defective parts between the place where the Works are situated and one of the following points:

(i) The Contractor's works if the Contract is "ex works" or F.O.R.;
(ii) The port from which the Contractor dispatched the Plant if the Contract is F.O.B., F.A.S., C.I.F., or C. & F.;
(iii) In all other cases the frontier of the country from which the Contractor dispatched the Plant.

23.9. Where, in pursuance of paragraph 7 hereof, repairs are required to be effected on site, the incidence of any travelling or living expenses of the Contractor's employees and the costs and risks of transporting any necessary material or equipment shall be settled, in default of agreement between the parties, in such manner as the arbitrator shall determine to be fair and reasonable.

23.10. Defective parts replaced in accordance with this Clause shall be placed at the disposal of the Contractor.

23.11. If the Contractor refuses to fulfil his obligations under this Clause or fails to proceed with due diligence after being required so to do, the Purchaser may proceed to do the necessary work at the Contractor's risk and expense, provided that he does so in a reasonable manner.

23.12. The Contractor's liability does not apply to defects arising out of materials provided, or out of a design stipulated, by the Purchaser.

23.13. The Contractor's liability shall apply only to defects that appear under the conditions of operation provided for by the Contract and under proper use. It does not cover defects due to causes arising after taking over. In particular it does not cover defects arising from the Purchaser's faulty maintenance or from alterations carried out without the Contractor's consent in writing, or from repairs carried out improperly by the Purchaser, nor does it cover normal deterioration.

23.14. After taking over and save as in this Clause expressed, the Contractor shall be under no liability even in respect of defects due to causes existing before taking over. It is expressly agreed that the Purchaser shall have no claim in respect of personal injury or of damage to property not the subject matter of the Contract arising after taking over nor for loss of profit unless it is shown from the circumstances of the case that the Contractor has been guilty of gross misconduct.

23.15. "Gross misconduct" does not comprise any and every lack of proper care or skill, but means an act or omission on the part of the Contractor implying either a failure to pay due regard to serious consequences which a conscientious Contractor would normally foresee as likely to ensue, or a deliberate disregard of any consequences of such act or omission.

24. Liability for personal injury and damage to property

24.1. In the event of personal injury or damage to property occurring before all the Works have been taken over, the liabilities shall be apportioned as follows:

(a) (i) The Contractor shall at his own expense make good any loss or damage to the Plant or Works occurring before the risk therein has passed and arising from any cause whatsoever other than an act or omission of the Purchaser;

(ii) The Contractor shall at his own expense make good any loss or damage to the Plant or Works occurring after the risk therein has passed, if such loss or damage is caused by an act or omission of the Contractor;

(iii) If any portion of the Plant or Works is lost or damaged from a cause for which the Contractor is not responsible by virtue of sub-paragraphs *(a)* (i) or *(a)* (ii) hereof, the loss or damage shall, if required by the Purchaser, be made good by the Contractor at the expense of the Purchaser.

(b) In respect of damage to the Purchaser's property other than the Works, the Contractor shall indemnify the Purchaser to the extent that such damage was caused by the Contractor, or by the failure of equipment or tools provided by the Contractor for the purpose of the erection, if the circumstances show that the Contractor failed to use proper skill and care.

(c) (i) In respect of personal injury, the respective liabilities of the Purchaser and of the Contractor towards the injured person shall be governed by the law of the country where the injury occurred;

(ii) If the injured person brings a claim against the Purchaser, the Contractor shall indemnify the Purchaser against such claim to the extent that the injury was due to any of the causes mentioned in sub-paragraph *(b)* hereof;

(iii) If the injured person brings a claim against the Contractor, the Purchaser shall, to the extent permitted by the law of the country where the injury occurred, indemnify the Contractor against such claim save to the extent that, by the operation of sub-paragraph *(c)* (ii) hereof, the Contractor would have been liable to indemnify the Purchaser had the claim been brought against the Purchaser.

(d) In respect of damage to property of third parties, the provisions of sub-paragraph *(c)* hereof shall apply mutatis mutandis.

(e) The provisions of this paragraph shall apply to the acts or omissions of the respective servants of the parties as they apply to the acts or omissions of the parties themselves. Provided always that as respects acts or omissions of the additional labour provided by the Purchaser in accordance with paragraph 14.1, the Contractor shall be liable for the consequences of such orders and instructions as have been incorrectly given, inadequately expressed or given to a person not purporting to possess the necessary qualifications.

24.2. In order to avail himself of his rights under sub-paragraphs *(c)* and *(d)* of paragraph 24.1 the party against whom a claim is made must notify the other of such claim and must permit the other, if the other so wishes, to conduct all negotiations for the settlement of such claim and to act in his stead or, to the extent permitted by the law of the country where the action is brought, to join in such litigation.

24.3. Any limitation of the indemnities payable by either party by virtue of this clause shall be as stated in paragraph I of the Appendix.

24.4. The provisions of this Clause shall apply equally while the Contractor is on the site in fulfilment of an obligation under Clause 23.

25. Reliefs

25.1. The following shall be considered as cases of relief if they intervene after the formation of the Contract and impede its performance: industrial disputes and any other circumstances (e.g. fire, mobilization, requisition, embargo, currency restrictions, insurrection, shortage of transport, general shortage of materials and restrictions in the use of power) when such other circumstances are beyond the control of the parties.

25.2. The party wishing to claim relief by reason of any of the said circumstances shall notify the other party in writing without delay on the intervention and on the cessation thereof.

25.3. The effects of the said circumstances, so far as they affect the timely performance of their obligations by the parties, are defined in Clauses 10, 11, 20 and 22. Save as provided in paragraphs 10.2, 11.7 and 20.5, if, by reason of any of the said circumstances, the performance of the Contract within a reasonable time becomes impossible, either party shall be entitled to terminate the Contract by notice in writing to the other party without requiring the consent of any Court.

25.4. If the Contract is terminated in accordance with paragraph 3 hereof, the division of the expenses incurred in respect of the Contract shall be determined by agreement between the parties.

25.5. In default of agreement it shall be determined by the arbitrator which party has been prevented from performing his obligations and that party shall refund to the other the amount of the said expenses incurred by the other less any amount to be credited in accordance with paragraph 7 hereof, or, where the amount to be so credited exceeds the amount of such expenses, shall be entitled to recover the excess.

If the arbitrator determines that both parties have been prevented from performing their obligations, he shall apportion the said expenses between the parties in such manner as to him seems fair and reasonable, having regard to all the circumstances of the case.

25.6. For the purposes of this Clause "expenses" means actual out-of-pocket expenses reasonably incurred after both parties shall have mitigated their losses as far as possible. Provided that as respects Plant delivered to the Purchaser the Contractor's expenses shall be deemed to be that part of the price payable under the Contract which is properly attributable thereto, due account being taken of any work done in the erection of such Plant.

25.7. There shall be credited to the Purchaser against the Contractor's expenses all sums paid or payable under the Contract by the Purchaser to the Contractor.

There shall be credited to the Contractor against the Purchaser's expenses that part of the price payable under the Contract which is properly attributable to Plant delivered to the Purchaser or, in the case of an incomplete unit, the value of such Plant having regard to its incomplete state. In either case due account shall be taken of any work done in the erection of such Plant.

26. Limitation of damages

26.1. Where either party is liable in damages to the other, these shall not exceed the damage which the party in default could reasonably have foreseen at the time of the formation of the Contract.

26.2. The party who sets up a breach of Contract shall be under a duty to take all necessary measures to mitigate the loss which has occurred provided that he can do so without unreasonable inconvenience or cost. Should he fail to do so, the party guilty of the breach may claim a reduction in the damages.

27. Rights at termination

27.1. Termination of the Contract, from whatever cause arising, shall be without prejudice to the rights of the parties accrued under the Contract up to the time of termination.

28. Arbitration and law applicable

28.1. Any dispute arising out of the Contract shall be finally settled, in accordance with the Rules of Conciliation and Arbitration of the International Chamber of Commerce, by one or more arbitrators designated in conformity with those Rules.

28.2. Unless otherwise agreed, the Contract shall, so far as is permissible under the law of the country where the Works are carried out, be governed by the law of the Contractor's country.

28.3. If the parties expressly so agree, but not otherwise, the arbitrators shall, in giving their ruling, act as *amiables compositeurs.*

Appendix

(To be completed by parties to the Contract)

		Clause		
A.	Maximum amount recoverable on termination by Contractor for failure to take delivery or make payment	10.2. & 11.7.	———	(in the agreed currency)
B.	Rate of interest on overdue payments	11.7.	———	per cent per annum
C.	Period of delay in payment authorizing termination by Contractor	11.7.	———	months
D.	Percentage to be deducted for each week's delay	20.3.	———	%
E.	Maximum percentage which the deductions above may not exceed	20.3.	———	%
F.	Maximum amount recoverable for non-completion	20.5.	———	(in the agreed currency)
G.	Maximum postponement of taking-over tests by Contractor	22.3.	———	weeks
H.	Guarantee Period for original Works and parts replaced or renewed	23.2. & 23.5.	———	months
I.	Maximum indemnities for personal injury or damage	24.3.	———	(in the agreed currency)
J.	(1) Daily use of Plant	23.4.	———	hours/day
	(2) Reduction of Guarantee Period for more intensive use	23.4.	———	

Supplementary clause

PRICE REVISION

Should any change occur in the cost of the relevant materials and/or wages during the period of execution of the contract, the agreed prices shall be subject to revision on the basis of the following formula:

$$P_1 = \frac{P_0}{100}\left(a + b\frac{M_1}{M_0} + c\frac{S_1}{S_0}\right)$$

where:

P_1 = final price for invoicing

P_0 = initial price of goods, as stipulated in the contract and as prevailing at the date of [a]

M_1 = mean[b] of the prices (or price indices) for (type of materials concerned) ___ ___

over the period ___ [c]

M_0 = prices (or price indices) for the same materials at the date stipulated above for P_0.

S_1 = mean[b] of the wages (including social charges) or relevant indices[d] in respect of ___

(specify categories of labour and social charges) over the period [c]

S_0 = wages (including social charges) or relevant indices[d] in respect of the same categories at the date stipulated above for P_0.

a, b, c, represent contractually agreed percentage of the individual elements of the initial price, which add up to 100.

$$(a + b + c = 100)$$

a = fixed proportion =

b = percentage proportion of materials =

c = percentage proportion of wages (including social charges) =

Where necessary, b (and if need be, c) can be broken down into as many partial percentages (b_1, b_2, b_3 . . . . . .) as there are variables taken into account ($b_1 + b_2 . . . . . . + b_n = b$).

Documentation. For the purpose of determining the values of materials and wages, the parties agree to use the following documents as sources of reference:

1. Materials: prices (or price indices) ___ (type of materials)

   published by under the headings

2. Wages: wages (including related social charges) (or relevant indices)

   published by under the headings [e]

Rules for applying the Clause. In the case of partial deliveries which are invoiced separately, the final price shall be calculated separately for each such delivery.

Period of application of the Clause. The revision clause shall cover the delivery period fixed in the contract, together with any extension thereof granted under Clause 20.2, but shall in no case apply after the date on which the work is completed.

Tolerances. Prices shall not be revised unless the application of the formula produces a plus or minus variation of ___ [f]

Saving Clause. If the parties wish the revision formula to be adjusted or replaced by a more accurate method of calculation when the plus or minus variation exceeds a certain percentage, they shall expressly so agree.

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[a] It is recommended that the parties should, as far as possible, adopt as the initial price the price prevailing at the date of the contract and not at an earlier date. This is normally the contract price less cost of packing, transport and insurance.

[b] Arithmetical or weighted.

[c] Specify the datum period, which may be defined as part or the whole of the delivery period.

[d] If legal social charges are covered by the index, they need not be taken into account again.

[e] Indices relating specifically to the engineering and electrical industries should be used as far as possible.

[f] State the percentage plus or minus variation which must be exceeded before the formula is applied.

General Terms of Delivery

(Drafted with reference to the General Conditions of Contract, Documents Nos. 188 A and 730, published and recommended by the United Nations Economic Commission for Europe)

of 1st March, 1963, as amended up to 1st January, 1977

1. Preamble

1.1. These general terms shall apply, save as varied by express agreement accepted in writing by both parties.

1.2. The following provisions concerning the delivery of goods shall also apply correspondingly to the performance of services.

2. Conclusion of contract

2.1. The contract shall be deemed to have been entered into when, upon receipt of the order, the vendor has mailed his acknowledgment of such order.

2.2. To be valid any changes in the contract and supplements thereto require the acknowledgment of the vendor in writing. Any purchasing conditions stipulated by the purchaser shall only be binding on the vendor if they have been specifically acknowledged by the latter.

2.3. Offers made by the vendor are subject to confirmation. The offers are made subject to prior sale.

2.4. In the event of import licences, export licences, foreign exchange authorizations or the like being required for the implementation of the contract, the party responsible for the procurement of the supplies shall undertake all reasonable steps in order to obtain the requisite licences and authorizations in due time.

3. Drawing and descriptive literature

3.1. Data concerning weights, measures, capacities, prices, performance ratings and the like found in catalogues, leaflets, circulars, advertisements, illustrated pamphlets, price lists etc. shall be binding only when they are expressly referred to in the acknowledgment of the order.

3.2. Drawings, sketches and other technical documents, as well as samples, catalogues, leaflets, illustrations and the like always remain the original property of the vendor, i.e. they must not be reproduced, distributed, published or used for the purpose of demonstrations without the express consent of their owner.

4. Packing

4.1. Unless otherwise specified

(a) Prices quoted shall be deemed to apply to unpacked goods;

(b) Goods will be packed in the customary manner in such a way as to prevent their being damaged under normal transport conditions until they reach the destination stated in the contract, such packing to be charged to the purchaser, with packing materials taken back only by prior mutual agreement.

5. Passing of risk

5.1. In the cases listed below, the moment at which the risk passes shall be determined as follows:

(a) On a sale "ex works" the risk shall pass from the vendor to the purchaser when the goods have been placed at the disposal of the latter. The vendor shall advise the purchaser of the date from which the goods will be at the latter's disposal. Notice to this effect must be given in due time so as to enable the purchaser to take the necessary steps customarily required for the purpose of taking delivery.

(b) On a sale "ex wagon, lorry, barge" (agreed point of departure), "frontier" or "place of destination", or on a sale "carriage paid up to..." ("free..."), the risk shall pass from the vendor to the purchaser at the moment at which the means of transport loaded with the goods in question is taken over by the first carrier.

(c) On a sale "F.O.B." or "C.I.F." or "C. & F.", the risk shall pass from the vendor to the purchaser when the goods have effectively passed the ship's rail at the agreed port of shipment.

5.2. Unless otherwise stipulated, the goods shall be considered as sold "ex works".

5.3. The vendor shall be obligated to arrange for insurance coverage of the goods only if and in so far as this has been agreed upon in writing.

5.4. As for the rest, the INCOTERMS 1953 as amended up to the day of the conclusion of the contract shall apply.

6. Delivery

6.1. Unless otherwise agreed, the delivery period shall run from the latest of the following dates:

(a) Date of the acknowledgment of the order;

(b) Date on which all technical, commercial and financial obligations incumbent on the purchaser have been met;

(c) Date of receipt by the vendor of such payment in advance of delivery as is stipulated in the contract and/or at which a stipulated letter of credit is opened.

6.2. The vendor is entitled to make partial- and advance deliveries.

6.3. Should a delay in delivery be caused by the vendor as a result of any of the circumstances mentioned in Clause 10 as constituting a ground for relief, a reasonable extension of the delivery period shall be granted.

6.4. Should the vendor be responsible for any delay in delivery, the purchaser shall be entitled to demand either specific performance or, after having granted the vendor a reasonable period of time to meet his obligations, to withdraw from the contract. In fixing a period of grace allowance has to be made for the fact that in the case of special fabrications the vendor may not be able to find any alternative use for components which have already been partly completed.

6.5. Should the vendor culpably fail to deliver the goods within the period of grace provided for in Clause 6.4, the purchaser shall be entitled to terminate the contract by the simple act of sending a written notice to that effect to the vendor, both in respect of all goods undelivered and in respect of goods which, though delivered, cannot be properly used without the undelivered goods. In such cases the purchaser is entitled to recovery of any payments he has made both in respect of all goods undelivered and in respect of goods which by themselves cannot be used appropriately and, in so far as the delay in delivering the goods may be due to the gross negligence of the vendor, to the recovery of the expenses incurred by him up to the termination of the contract and in the performance of the latter inasmuch as there is no further use for them. Goods already delivered and goods that cannot be used must be returned by the purchaser to the vendor.

6.6. Any claims of the purchaser against the vendor with respect to the latter's default, other than those mentioned in Clause 6, are precluded.

6.7. Where the purchaser does not take delivery of the goods at the place and time provided for by the contract for any reason other than an act of commission or omission of the vendor, the latter shall be entitled to either claim specific performance or, after granting a reasonable period of time for taking delivery, to withdraw from the contract.

On appropriation of the goods to the contract, the vendor shall arrange for their storage at the risk and cost of the purchaser. The vendor is entitled furthermore — to the exclusion of any other claims against the purchaser for the latter's failure to take delivery of the goods — to recover any expenses properly incurred in the performance of the contract and which are not covered by payment received.

7. Prices

7.1. Unless otherwise agreed upon, prices are to be understood as "ex works" of the vendor, not including packing and loading charges. If delivery to the consignee has been agreed upon, the prices shall not include unloading and handling charges.

7.2. Prices are based on the costs at the time the quotation is made. Should there be any changes as regards costs prior to the time of delivery, the differences are to be charged to the debit or credit of the purchaser, as the case may be.

7.3. Where the prices are not fixed in the contract, current selling prices as prevailing on the day of delivery shall be charged.

8. Payment

8.1. Payment shall be made in the manner and at the time or times agreed by the parties. Unless different times of payment have been expressly agreed upon by the written acknowledgment of the vendor in his acceptance of the order, one half of the purchase price shall be payable on receipt of the acknowledgment of the order, with the balance due on receiving notice that the goods are ready for shipment.

8.2. The purchaser is not entitled to withhold payment because of claims of warranty or other counter-claims not recognized by the vendor as valid.

8.3. If the purchaser falls in arrears in making the agreed payments or delays in meeting any other contractual obligation, the vendor may either insist on compliance with the terms of the contract and

(a) Postpone meeting his own obligations until such payment is made and other commitments fulfilled,

(b) Demand a reasonable extension of the delivery period.

(c) Fix a due date for payment of the entire balance of the selling price still outstanding.

(d) In so far as the purchaser is not able to claim any grounds of release as provided for in Clause 10, recover interest on arrears at the rate of 4% over and above the bank rate charged at that time by the vendor's Bank, such interest to be charged from the time fixed for payment,

or, after granting a reasonable period of grace, terminate the contract.

8.4. Should the purchaser — after the period of grace specified in Clause 8.3 — fail to make payment or to meet any other obligation, the vendor shall be entitled to terminate the contract by giving notice in writing. On being asked to do so by the vendor, the purchaser must return to the vendor any goods that have already been delivered and reimburse the latter for the depreciation of the goods in addition to defraying all expenses properly incurred by the vendor in the performance of the contract. As regards goods which have not yet been delivered, the vendor shall be entitled to place the finished or unfinished parts, as the case may be, at the disposal of the purchaser and debit the purchaser's account with the corresponding share of the selling price.

8.5. The vendor retains legal title to the goods until such time as the purchaser shall have completely discharged all his financial obligations. The purchaser is obligated to comply with all required formalities conducive to ensuring the retention of legal title by the vendor. In case of attachment, seizure or other distraint, the purchaser is under obligation to file the vendor's retention of title to ownership of the goods and to notify him of same without delay.

8.6. Claims of the vendor against the purchaser, other than those mentioned in Clause 8, arising from the latter's default are not admissible.

9. Guarantee and liability

9.1. Subject as hereinafter set out, the vendor undertakes to remedy any defect resulting from faulty design, materials or workmanship.

9.2. This liability is limited to defects which appear during a period of six months in single-shift operation of three months in multiple-shift operation ("Guarantee Period"), commencing from the passing of risk or, in the case of delivery that includes installation, from the time of completion of erection and assembly work.

9.3. The purchaser can only avail himself of his rights under this Clause if he notifies the vendor in writing and without delay of any defects that have become apparent. On receipt of such notification, the vendor — if the defect is one which, under the provisions of this Clause, is to be remedied by him — shall at his own option:

(a) Repair the defective goods in situ or

(b) Have the defective goods or parts returned to him for repair; or

(c) Replace the defective goods; or

(d) Replace the defective parts.

The repair of any defects does not result in an extension of the guarantee period.

9.4. Where the vendor has defective goods or parts returned to him for replacement or repair, the purchaser shall, unless otherwise agreed, bear the cost and risk of carriage. Unless otherwise agreed, the return to the purchaser of goods or parts sent by way of replacement or of repaired goods or parts shall take place at the cost and risk of the vendor.

9.5. Defective goods or parts replaced in accordance with the provisions of this Clause shall be placed at the disposal of the vendor.

9.6. The vendor shall not be under any obligation to defray the cost of repairs carried out by the purchaser himself or undertaken by him unless the vendor has consented to do so in writing.

9.7. The liability of the vendor shall apply only to defects that become manifest under operating conditions as stipulated in the contract and in the course of normal use. In particular his liability does not extend to defects arising from faulty installation carried out by the purchaser or the latter's agent, poor maintenance, faulty repairs or alterations, or those made without the written consent of the vendor by persons other than the vendor or his agent, nor is he liable for normal deterioration.

9.8. For those parts of the goods which he himself has obtained from sub-suppliers, the vendor shall only be liable to the extent of the guarantees granted him by the sub-suppliers. Where goods are made to order by the vendor in accordance with design- and construction specifications, drawings or models supplied by the purchaser, the liability of the vendor does not extend to the correctness of the design but to its execution in accordance with the instructions of the purchaser. In such cases the purchaser is fully responsible to the vendor for all damages or claims that may result from any infringement of patent rights. The vendor assumes no warranty liability in accepting repair orders or orders for alterations and modifications of goods that are not new or have not been manufactured by the vendor.

9.9. From the commencement of the guarantee period the vendor assumes no further liability, save as provided for in this Clause, nor shall he be liable even in respect of defects due to causes existing prior to the passing of the risk.

9.10. It is expressly agreed that the purchaser shall have no claims on the vendor in respect of personal injury or of damage to goods that are not subject of the contract, for any other damage and for loss of profit, unless it is evident from the circumstances of the case that the vendor has been guilty of gross misconduct.

10. Reliefs

10.1. The following shall be deemed grounds of relief if they intervene after the formation of the contract and impede its performance:

industrial disputes and all other circumstances that are beyond the control of the parties, e.g. fire, mobilization, requisition, embargo, currency restrictions, insurrection, general shortage of materials and restrictions in the use of power.

10.2. The effects of the said circumstances with respect to the obligations of the contracting parties are defined in Clauses 6 and 8.

11. Jurisdiction, law applicable, place of performance

11.1. Disputes arising out of or in connection with the contract shall be under the jurisdiction of the national court of law having original jurisdiction over the headquarters of the vendor.

The vendor may also appeal, however, to another court of law having jurisdiction over the purchaser.

11.2. The parties can also agree as to the competency of a court of arbitration.

11.3. The contract shall be governed by the law of the vendor's country.

11.4. The place of the vendor's headquarters shall be deemed to be the place of performance for purposes of delivery and payment even when delivery is — by mutual agreement — made at some other place.

Annex VII

GENERAL CONDITIONS FOR THE SUPPLY OF PLANT AND MACHINERY FOR EXPORT *

Prepared under the auspices of the

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

Geneva, March 1953

1. Preamble

1.1. These General Conditions shall apply, save as varied by express agreement accepted in writing by both parties.

2. Formation of Contract

2.1. The Contract shall be deemed to have been entered into when, upon receipt of an order, the Vendor has sent an acceptance in writing within the time-limit (if any) fixed by the Purchaser.

2.2. If the Vendor, in drawing up his tender, has fixed a time-limit for acceptance, the Contract shall be deemed to have been entered into when the Purchaser has sent an acceptance in writing before the expiration of such time-limit, provided that there shall be no binding Contract unless the acceptance reaches the Vendor not later than one week after the expiration of such time-limit.

3. Drawings and descriptive documents

3.1. The weights, dimensions, capacities, prices, performance ratings and other data included in catalogues, prospectuses, circulars, advertisements, illustrated matter and price lists constitute an approximate guide. These data shall not be binding save to the extent that they are by reference expressly included in the Contract.

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* The English and French texts are equally authentic. The observations of the experts who drew up these General Conditions, together with a description of the procedure followed, are embodied in the "Commentary on the general conditions for the supply of plant and machinery for export", published by the Economic Commission for Europe. It can be obtained direct from the Sales Section of the European Office of the United Nations, Geneva, Switzerland, or through United Nations Sales Agents.

3.2. Any drawings or technical documents intended for use in the construction of the Plant or of part thereof and submitted to the Purchaser prior or subsequent to the formation of the Contract remain the exclusive property of the Vendor. They may not, without the Vendor's consent, be utilised by the Purchaser or copied, reproduced, transmitted or communicated to a third party. Provided, however, that the said plans and documents shall be the property of the Purchaser:

(a) If it is expressly so agreed, or

(b) If they are referable to a separate preliminary Development Contract on which no actual construction was to be performed and in which the property of the Vendor in the said plans and documents was not reserved.

3.3. Any drawings or technical documents intended for use in the construction of the Plant or of part thereof and submitted to the Vendor by the Purchaser prior or subsequent to the formation of the Contract remain the exclusive property of the Purchaser. They may not, without his consent, be utilised by the Vendor or copied, reproduced, transmitted or communicated to a third party.

3.4. The Vendor shall, if required by the Purchaser, furnish free of charge to the Purchaser at the commencement of the Guarantee Period, as defined in Clause 9, information and drawings other than manufacturing drawings of the Plant in sufficient detail to enable the Purchaser to carry out the erection, commissioning, operation and maintenance (including running repairs) of all parts of the Plant. Such information and drawings shall be the property of the Purchaser and the restrictions on their use set out in paragraph 2 hereof shall not apply thereto. Provided that if the Vendor so stipulates, they shall remain confidential.

4. Packing

4.1. Unless otherwise specified:

(a) Prices shown in price-lists and catalogues shall be deemed to apply to unpacked Plant;

(b) Prices quoted in tenders and in the contract shall include the cost of packing or protection required under normal transport conditions to prevent damage to or deterioration of the Plant before it reaches its destination as stated in the Contract.

5. Inspection and tests

Inspection

5.1. If expressly agreed in the Contract, the Purchaser shall be entitled to have the quality of the materials used and the parts of the Plant, both during manufacture and when completed, inspected and checked by his authorised representatives. Such inspection and checking shall be carried out at the place of manufacture during normal working hours after agreement with the Vendor as to date and time.

5.2. If as a result of such inspection and checking the Purchaser shall be of the opinion that any materials or parts are defective or not in accordance with the Contract, he shall state in writing his objections and the reasons therefor.

Tests

5.3. Acceptance tests will be carried out and, unless otherwise agreed, will be made at the Vendor's works and during normal working hours. If the technical requirements of the tests are not specified in the Contract, the tests will be carried out in accordance with the general practice obtaining in the appropriate branch of the industry in the country where the Plant is manufactured.

5.4. The Vendor shall give to the Purchaser sufficient notice of the tests to permit the Purchaser's representatives to attend. If the Purchaser is not represented at the tests, the test report shall be communicated by the Vendor to the Purchaser and shall be accepted as accurate by the Purchaser.

5.5. If on any test (other than a test on site, where tests on site are provided for in the Contract) the Plant shall be found to be defective or not in accordance with the Contract, the Vendor shall with all speed make good the defect or ensure that the Plant complies with the Contract. Thereafter, if the Purchaser so requires, the test shall be repeated.

5.6. Unless otherwise agreed, the Vendor shall bear all the expenses of tests carried out in his works, except the personal expenses of the Purchaser's representatives.

5.7. If the Contract provides for tests on site, the terms and conditions governing such tests shall be such as may be specially agreed between the parties.

6. Passing of risk

6.1. Save as provided in paragraph 7.6, the time at which the risk shall pass shall be fixed in accordance with the International Rules for the Interpretation of Trade Terms (Incoterms) of the International Chamber of Commerce in force at the date of the formation of the Contract.

Where no indication is given in the Contract of the form of sale, the Plant shall be deemed to be sold "ex works".

6.2. In the case of a sale "ex works", the Vendor must give notice in writing to the Purchaser of the date on which the Purchaser must take delivery of the **Plant**. The notice of the Vendor must be given in sufficient time to allow the Purchaser to take such measures as are normally necessary for the purpose of taking delivery.

7. Delivery

7.1. Unless otherwise agreed, the delivery period shall run from the latest of the following dates:

(a) The date of the formation of the Contract as defined in Clause 2;

(b) The date on which the Vendor receives notice of the issue of a valid import licence where such is necessary for the execution of the Contract;

(c) The date of the receipt by the Vendor of such payment in advance of manufacture as is stipulated in the Contract.

7.2. Should delay in delivery be caused by any of the circumstances mentioned in Clause 10 or by an act or omission of the Purchaser and whether such cause occur before or after the time or extended time for delivery, there shall be granted subject to the provisions of paragraph 5 hereof such extension of the delivery period as is reasonable having regard to all the circumstances of the case.

7.3. If a fixed time for delivery is provided for in the Contract and the Vendor fails to deliver within such time or any extension thereof granted under paragraph 2 hereof, the Purchaser shall be entitled, on giving to the Vendor within a reasonable time notice in writing, to claim a reduction of the price payable under the Contract, unless it can be reasonably concluded from the circumstances of the particular case that the Purchaser has suffered no loss. Such reduction shall equal the percentage named in paragraph A of the Appendix of that part of the price payable under the Contract which is properly attributable to such portion of the Plant as cannot in consequence of the said failure be put to the use intended for each complete week of delay commencing on the due date of delivery, but shall not exceed the maximum percentage named in paragraph B of the Appendix. Such reduction shall be allowed when a payment becomes due on or after delivery. Save as provided in paragraph 5 hereof, such reduction of price shall be to the exclusion of any other remedy of the Purchaser in respect of the Vendor's failure to deliver as aforesaid.

7.4. If the time for delivery mentioned in the Contract is an estimate only, either party may after the expiration of two thirds of such estimated time require the other party in writing to agree a fixed time.

Where no time for delivery is mentioned in the Contract, this course shall be open to either party after the expiration of six months from the formation of the Contract.

If in either case the parties fail to agree, either party may have recourse to arbitration, in accordance with the provisions of Clause 3, to determine a reasonable time for delivery and the time so determined shall be deemed to be the fixed time for delivery provided for in the Contract and paragraph 3 hereof shall apply accordingly.

7.5. If any portion of the Plant in respect of which the Purchaser has become entitled to the maximum reduction provided for by paragraph 3 hereof, or in respect of which he would have been so entitled had he given the notice referred to therein, remains undelivered, the Purchaser may by notice in writing to the Vender require him to deliver and by such last mentioned notice fix a final time for delivery which shall be reasonable taking into account such delay as has already occurred. If for any reason whatever the Vendor fails within such time to do everything that he must do to effect delivery, the Purchaser shall be entitled by notice in writing to the Vendor, and without requiring the consent of any Court, to terminate the Contract in respect of such portion of the Plant and thereupon to recover from the Vendor any loss suffered by the Purchaser by reason of the failure of the Vendor as aforesaid up to an amount not exceeding the sum named in paragraph C of the Appendix or, if no sum be named, that part of the price payable under the Contract which is properly attributable to such portion of the Plant as could not in consequence of the Vendor's failure be put to the use intended.

7.6. If the Purchaser fails to accept delivery on due date, he shall nevertheless make any payment conditional on delivery as if the Plant had been delivered. The Vendor shall arrange for the storage of the Plant at the risk and cost of the Purchaser. If required by the Purchaser, the Vendor shall insure the Plant at the cost of the Purchaser. Provided that if the delay in accepting delivery is due to one of the circumstances mentioned in Clause 10 and the Vendor is in a position to store it in his premises without prejudice to his business, the cost of storing the Plant shall not be borne by the Purchaser.

7.7. Unless the failure of the Purchaser is due to any of the circumstances mentioned in Clause 10, the Vendor may require the Purchaser by notice in writing to accept delivery within a reasonable time.

If the Purchaser fails for any reason whatever to do so within such time, the Vendor shall be entitled by notice in writing to the Purchaser, and without requiring the consent of any Court, to terminate the Contract in respect of such portion of the Plant as is by reason of the failure of the Purchaser aforesaid not delivered and thereupon to recover from the Purchaser any loss, suffered by reason of such failure up to an amount not exceeding the sum named in paragraph D of the Appendix or, if no sum be named, that part of the price payable under the Contract which is properly attributable to such portion of the Plant.

8. Payment

8.1. Payment shall be made in the manner and at the time or times agreed by the parties.

8.2. Any advance payments made by the Purchaser are payments on account and do not constitute a deposit, the abandonment of which would entitle either party to terminate the Contract.

8.3. If delivery has been made before payment of the whole sum payable under the Contract, Plant delivered shall to the extent permitted by the law of the country where the Plant is situated after delivery, remain the property of the Vendor until such payment has been effected. If such law does not permit the Vendor to retain the property in the Plant, the Vendor shall be entitled to the benefit of such other rights in respect thereof as such law permits him to retain. The Purchaser shall give the Vendor every assistance in taking any measures required to protect the Vendor's right of property or such other rights as aforesaid.

8.4. A payment conditional on the fulfilment of an obligation by the Vendor shall not be due until such obligation has been fulfilled, unless the failure of the Vendor is due to an act or omission of the Purchaser.

8.5. If the Purchaser delays in making any payment, the Vendor may postpone the fulfilment of his own obligations until such payment is made, unless the failure of the Purchaser is due to an act or omission of the Vendor.

8.6. If delay by the Purchaser in making any payment is due to one of the circumstances mentioned in Clause 10, the Vendor shall not be entitled to any interest on the sum due.

8.7. Save as aforesaid, if the Purchaser delays in making any payment, the Vendor shall on giving to the Purchaser within a reasonable time notice in writing be entitled to the payment of interest on the sum due at the rate fixed in paragraph E of the Appendix from the date on which such sum became due. If at the end of the period fixed in paragraph F of the Appendix, the Purchaser shall still have failed to pay the sum due, the Vendor shall be entitled by notice in writing to the Purchaser, and without requiring the consent of any Court, to terminate the Contract and thereupon to recover from the Purchaser the amount of his loss up to the sum mentioned in paragraph D of the Appendix.

9. Guarantee

9.1. Subject as hereinafter set out, the Vendor undertakes to remedy any defect resulting from faulty design, materials or workmanship.

9.2. This liability is limited to defects which appear during the period (hereinafter called "the Guarantee Period") specified in paragraph G of the Appendix.

9.3. In fixing this period due account has been taken of the time normally required for transport as contemplated in the Contract.

9.4. In respect of such parts (whether of the Vendor's own manufacture or not) of the Plant as are expressly mentioned in the Contract, the Guarantee Period shall be such other period (if any) as is specified in respect of each of such parts.

9.5. The Guarantee Period shall start from the date on which the Purchaser receives notification in writing from the Vendor that the Plant is ready for despatch from the works. If despatch is delayed, the Guarantee Period shall be extended by a period equivalent to the amount of the delay so as to permit the Purchaser the full benefit of the time given for trying out the Plant. Provided however that if such delay is due to a cause beyond the control of the Vendor such extension shall not exceed the number of months stated in paragraph H of the Appendix.

9.6. The daily use of the Plant and the amount by which the Guarantee Period shall be reduced if the Plant is used more intensively are stated in paragraph I of the Appendix.

9.7. A fresh Guarantee Period equal to that stated in paragraph G of the Appendix shall apply, under the same terms and conditions as those applicable to the original Plant, to parts supplied in replacement of defective parts or to parts renewed in pursuance of this Clause. This provision shall not apply to the remaining parts of the Plant, the Guarantee Period of which shall be extended only by a period equal to the period during which the Plant is out of action as a result of a defect covered by this Clause.

9.8. In order to be able to avail himself of his rights under this Clause the Purchaser shall notify the Vendor in writing without delay of any defects that have appeared and shall give him every opportunity of inspecting and remedying them.

9.9. On receipt of such notification the Vendor shall remedy the defect forthwith and, save as mentioned in paragraph 10 hereof, at his own expense. Save where the nature of the defect is such that it is appropriate to effect repairs on site, the Purchaser shall return to the Vendor any part in which a defect covered by this Clause has appeared, for repair or replacement by the Vendor, and in such case the delivery to the Purchaser of such part properly repaired or a part in replacement thereof shall be deemed to be a fulfilment by the Vendor of his obligations under this paragraph in respect of such defective part.

9.10 Unless otherwise agreed, the Purchaser shall bear the cost and risk of transport of defective parts and of repaired parts or parts supplied in replacement of such defective parts between the place where the Plant is situated and one of the following points:

(i) The Vendor's works if the Contract is "ex works" or F.O.R.;
(ii) The port from which the Vendor dispatched the Plant if the Contract is F.O.B., F.A.S., C.I.F. or C. & F.;
(iii) In all other cases the frontier of the country from which the Vendor dispatched the Plant.

9.11. Where, in pursuance of paragraph 9 hereof, repairs are required to be effected on site, the conditions covering the attendance of the Vendor's representatives on site shall be such as may be specially agreed between the parties.

9.12. Defective parts replaced in accordance with this Clause shall be placed at the disposal of the Vendor.

9.13. If the Vendor refuses to fulfil his obligations under this Clause or fails to proceed with due diligence after being required so to do, the Purchaser may proceed to do the necessary work at the Vendor's risk and expense, provided that he does so in a reasonable manner.

9.14. The Vendor's liability does not apply to defects arising out of materials provided, or out of a design stipulated, by the Purchaser.

9.15. The Vendor's liability shall apply only to defects that appear under the conditions of operation provided for by the Contract and under proper use. It does not cover defects due to causes arising after the risk in the Plant has passed in accordance with Clause 6. In particular it does not cover defects arising from the Purchaser's faulty maintenance or erection, or from alterations carried out without the Vendor's consent in writing, or from repairs carried out improperly by the Purchaser, nor does it cover normal deterioration.

9.16. Save as in this Clause expressed, the Vendor shall be under no liability in respect of defects after the risk in the Plant has passed in accordance with Clause 6, even if such defects are due to causes existing before the risk so passed. It is expressly agreed that the Purchaser shall have no claim in respect of personal injury or of damage to property not the subject matter of the Contract or of loss of profit unless it is shown from the circumstances of the case that the Vendor has been guilty of gross misconduct.

9.17. "Gross misconduct" does not comprise any and every lack of proper care or skill, but means an act or omission on the part of the Vendor implying either a failure to pay due regard to serious consequences which a conscientious Contractor would normally foresee as likely to ensue, or a deliberate disregard of any consequences of such act or omission.

10. Reliefs

10.1. The following shall be considered as cases of relief if they intervene after the formation of the Contract and impede its performance: industrial disputes and any other circumstances (e.g. fire, mobilization, requisition, embargo, currency restrictions, insurrection, shortage of transport, general shortage of materials and restrictions in the use of power) when such other circumstances are beyond the control of the parties.

10.2. The party wishing to claim relief by reason of any of the said circumstances shall notify the other party in writing without delay on the intervention and on the cessation thereof.

10.3. The effects of the said circumstances, so far as they affect the timely performance of their obligations by the parties, are defined in Clauses 7 and 8. Save as provided in paragraphs 7.5, 7.7 and 8.7, if, by reason of any of the said circumstances, the performance of the Contract within a reasonable time becomes impossible, either party shall be entitled to terminate the Contract by notice in writing to the other party without requiring the consent of any Court.

10.4. If the Contract is terminated in accordance with paragraph 3 hereof, the division of the expenses incurred in respect of the Contract shall be determined by agreement between the parties.

10.5. In default of agreement it shall be determined by the arbitrator which party has been prevented from performing his obligations and that party shall bear the whole of the said expenses. Where the Purchaser is required to bear the whole of the expenses and has before termination of the Contract paid to the Vendor more than the amount of the Vendor's expenses, the Purchaser shall be en[illegible] recover the excess.

If the arbitrator determines that both parties hav[illegible] from performing their obligations, he shall apportion the said expenses between the parties in s[illegible] seems fair and reasonable, having regard to all the circumstances of the case.

10.6. For the purposes of this Cla[illegible] actual out-of-pocket expenses reasonably incurred, after both parties shall have mitigated th[illegible] possible. Provided that as respects Plant delivered to the Purchaser the Vendor's expenses sha[illegible] part of the price payable under the Contract which is properly attributable thereto.

11. Limitation of damages

11.1. Where either party is liable in damages to the other, these shall not exceed the damage which the party in default could reasonably have foreseen at the time of the formation of the Contract.

11 2. The party who sets up a breach of the Contract shall be under a duty to take all necessary measures to mitigate the loss which has occurred provided that he can do so without unreasonable inconvenience or cost. Should he fail to do so, the party guilty of the breach may claim a reduction in the damages.

12. Rights at termination

12.1. Termination of the Contract, from whatever cause arising, shall be without prejudice to the rights of the parties accrued under the Contract up to the time of termination.

13. Arbitration and law applicable

13.1. Any dispute arising out of the Contract shall be finally settled, in accordance with the Rules of Conciliation and Arbitration of the International Chamber of Commerce, by one or more arbitrators designated in conformity with those Rules.

13.2. Unless otherwise agreed, the Contract shall be governed by the law of the Vendor's country.

13.3. If the parties expressly so agree, but not otherwise, the arbitrators shall, in giving their ruling, act as *amiables compositeurs.*

Appendix

(To be completed by parties to the Contract)

		Clause	
A.	Percentage to be deducted for each week's delay	7.3 ______	per cent
B.	Maximum percentage which the deductions above may not exceed	7.3 ______	per cent
C.	Maximum amount recoverable for non-delivery	7.5 ______	(in the agreed currency)
D.	Maximum amount recoverable on termination by Vendor for failure to take delivery or make payment	7.7 and 8.7 ______	(in the agreed currency)
E.	Rate of interest on overdue payments	8.7 ______	per cent per annum
F.	Period of delay in payment authorizing termination by Vendor	8.7 ______	months
G.	Guarantee Period for original Plant and parts replaced or renewed	9.2 and 9.7 ______	months
H.	Maximum extension of Guarantee Period	9.5 ______	months
I.	(1) Daily use of Plant	9.6 ______	hours/day
	(2) Reduction of Guarantee Period for more intensive use . .	9.6 ______	

Supplementary clause

PRICE REVISION

Should any change occur in the cost of the relevant materials and/or wages during the period of execution of the contract, the agreed prices shall be subject to revision on the basis of the following formula:

$$P_1 = \frac{P_0}{100}\left(a + b\frac{M_1}{M_0} + c\frac{S_1}{S_0}\right)$$

where:

P_1 = final price for invoicing

P_0 = initial price of goods, as stipulated in the contract and as prevailing at the date of ______________ ______________________________[a]

M_1 = mean[b] of the prices (or price indices) for (type of materials concerned) ______________________ ______________________ over the period ______________________________[c]

M_0 = prices (or price indices) for the same materials at the date stipulated above for P_0.

S_1 = mean[b] of the wages (including social charges) or relevant indices[d] in respect of ______________ ______________ (specify categories of labour and social charges) over the period ______________[c]

S_0 = wages (including social charges) or relevant indices[d] in respect of the same categories at the date stipulated above for P_0.

a, *b*, *c*, represent the contractually agreed percentage of the individual elements of the initial price, which add up to 100.

$$(a + b + c = 100)$$

a = fixed proportion = ______________________________

b = percentage proportion of materials = ______________________________

c = percentage proportion of wages (including social charges) = ______________________________

Where necessary, b (and if need be, c) can be broken down into as many partial percentages (b_1, b_2, b_3 . . . . . .) as there are variables taken into account ($b_1 + b_2 . . . . . . + b_n = b$).

Documentation. For the purpose of determining the values of materials and wages, the parties agree to use the following documents as sources of reference:

1. Materials: prices ______________________ (type of materials)
   (or price indices)
   published by ______________________
   under the headings ______________________
2. Wages: wages (including related social charges)
   (or relevant indices)
   published by ______________________
   under the headings ______________________[e]

Rules for applying the Clause. In the case of partial deliveries which are invoiced separately, the final price shall be calculated separately for each such delivery.

Period of application of the Clause. The revision clause shall cover the delivery period fixed in the contract, together with any extension thereof granted under Clause 7.2, but shall in no case apply after the date on which manufacture is completed.

Tolerances. Prices shall not be revised unless the application of the formula produces a plus or minus variation of ______________[f]

Saving Clause. If the parties wish the revision formula to be adjusted or replaced by a more accurate method of calculation when the plus or minus variation exceeds a certain percentage, they shall expressly so agree.

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[a] It is recommended that the parties should, as far as possible, adopt as the initial price the price prevailing at the date of the contract and not at an earlier date. This is normally the contract price less cost of packing, transport and insurance.

[b] Arithmetical or weighted.

[c] Specify the datum period, which may be defined as part or the whole of the delivery period.

[d] If legal social charges are covered by the index, they need not be taken into account again.

[e] Indices relating specifically to the engineering and electrical industries should be used as far as possible.

[f] State the percentage plus or minus variation which must be exceeded before the formula is applied.

IV. Methodology for the purchase of woodworking machines*

The furniture industry of developing countries is often made up of small entrepreneurs who started as craftsmen, made money and expanded their operations by buying machines to increase productivity. Unfortunately in doing so, they still reason as craftsmen and not as industrialists. This is clearly shown in the way in which they make decisions concerning the range of products manufactured, production methods, marketing, costing and last but by no means least, selection of equipment.

This study deals solely with this last topic, which UNIDO considers a field in which the furniture and joinery industry of the developing countries lags a long way behind the developed countries. Unfortunately there are too many cases in the developing countries of instances when the industrialists have purchased the wrong pieces or the wrong assortment of machines. Once this is done, scarce foreign currency — from the point of view of the national economy — has been misspent. In addition, when one looks at the level of profitability of the plant, the investment is unsound because poor use was made of available funds, affecting the plant's overall profitability. In the developing countries capital is the scarcest resource, and misspent capital affects the company's profitability for the entire life expectancy of the machine. Because the industry of these countries is not developed, producers know more about one another than in the larger, more secretive conditions of the developed countries. Consequently, once a wrong decision has been made it is more difficult to get rid of an inappropriate machine in a developing country than in a developed country.

In spite of the lack of capital more mistakes are made in the developing countries because of:

(a) Ignorance about what is needed;
(b) Ignorance about what is available;
(c) Ignorance about the specific requirements of the wood being machined;
(d) Lack of consideration of economics of scale and full utilization of the machine.

These conditions are further compounded by the fact that very often in developing countries personal — human — considerations come into play when selecting a machine. In many instances there are no local firm representatives or, when they do exist, the machine in question only represents a very small part of the firm's turnover and the firm's local staff are not competent to give any technical advice. In the rare instances when technical advice is available, the salesman is far better equipped than the purchaser, since he tends to know what is on the market and what the shortcomings of the product he represents are, when compared to those of his competitors, and he could easily avoid mentioning these points. In this chapter an attempt will be made to give a methodology which could help the smaller industrialists in the developing countries in the selection of woodworking machines most suitable to their needs.

Basically, adequate answers must be found to the following questions:

(a) Why is the machine needed? In fact, is it really needed? This requires the identification of the actual needs for the machine and the listing of its technical specifications;

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* By the secretariat of UNIDO. (This is an edited version of ID/WG.256/26.)

(b) How would the installation of the machine affect the other machines already installed?
(c) How does one purchase a machine?

These topics are discussed below in greater depth.

Identifying the actual needs for the machine

There are many reasons for purchasing a woodworking machine for a furniture or joinery plant in a developing country. The following are some of the most common general reasons:

(a) To mechanize hitherto manual operations thus reducing labour requirements, that is to increase production capacity with the same labour force;

(b) To mechanize manual operations hitherto done by skilled craftsmen, thus reducing the need for scarce or expensive skilled labour;

(c) To lower production costs through mechanization (use of lower cost labour, attainment of higher productivity etc.);

(d) To assure precision during machining which will reduce subsequent assembly costs;

(e) For work safety reasons, to mechanize and automate operations which are dangerous.

In the developed countries there is one further reason which is seldom applicable in developing countries. This reason is to mechanize handling so as to reduce the need for unskilled labour.

The above general considerations apply in the case of the purchase of any machine, but it must be remembered that in purchasing a machine one is in reality always interested in obtaining the performance of a specific operation. It is useful before a decision on purchasing a machine is made to use value analysis for the components to be machined, so as to see whether it is possible to use a simpler — and consequently less expensive — machine. Unfortunately, this can only be done in those factories which specialize in selected ranges of products and manufacture their own line for the market; as opposed to factories — often the case in developing countries — which produce anything provided the price is right. This analysis will determine:

(a) The function of the component — it could well be that it is redundant or could be replaced by a simpler component which would cost less or be purchased as a finished product such as metal corner pieces for chairs;

(b) Alternative materials from which the ccomponent could be manufactured. This might lead to lower material costs, simpler machining and/or less waste. A good example is the use by some Finnish plants of two glued particle board strips instead of sawn-wood to produce the frame for a door panel. This resulted not only in the use of cheaper raw material but also in less waste, with no corresponding increase in machining complexity or machining time;

(c) Product simplification and standardization should be seriously studied as this will affect the choice of machine. Product simplification may allow a simpler and probably cheaper unit to be purchased. Standardization will lead to the possibility of producing in larger series, hence justifying more sophisticated machines which have higher productivity, although they require longer machine set-up times;

(d) The last item in the value analysis of the components relates to determining the machining requirements: type of operations, precision etc. The process presently used should be studied in depth so as to determine whether the machining operation can be carried out on an existing machine which is less fully utilized. For example, it might prove more economic in the immediate future to spray surfaces than to purchase a new curtain coating machine in spite of the former's greater waste of surface coating material. Similarly, a spindle moulder could be used to make tenons etc. It may be that the proposed machine would be too sophisticated or too precise for the product it is to produce. In developing countries this case unfortunately seldom applies as the tendency is to allow poor machining precision which is then hand finished before assembly. This allows for the creation of more jobs. However, it prevents the production of knock down mass produced furniture for export since such furniture would have to be hand fitted at the time of assembly.

It is only when this analysis has been completed that one can determine the type and capacity of the machine one has to purchase. The result might be that through improved efficiency, purchase of components from outside, or re-design of the product there is no need for the machine or that the needed extra capacity is small enough to be satisfied by the use of overtime at peak order periods.

Assessment of existing resources

An individual machine in a factory is part of a whole process or flow line and should never be considered as an individual entity. One of the more common reasons for purchasing a machine is the need for extra processing capacity. It must be remembered that once this machine has been purchased the bottle-neck in the production line has been moved to the next most utilized machine. Doubling the production capacity for the operation in question might result in an increase in overall capacity of the line of only 10 per cent if the next most fully utilized piece of equipment is being used at 90 per cent of its capacity. It is therefore imperative, before deciding on the purchase of any one machine, to study the overall capacity situation in the plant, so as to establish an order of priorities and a long-range plan; and to allocate financial resources according to this plan.

While in no way wishing to minimize the need to introduce changes and modern processing techniques in the developing countries, there is no point in purchasing a machine that is far more advanced technologically and in its operating precision then the rest of the existing plant. The costly new machine will not be used to its full advantage, and its maintenance and adjustment might be too complex for the existing labour force. This will require hiring of either a highly qualified technician, who would not be fully employed, or, worse still, an expatriate. Although consideration has to be given to this point, it should not be an impediment to the introduction of modern woodworking machinery in developing countries. Whenever possible, the plant's technicians and operators should be formally trained in the operation of the new machine, either abroad or locally.

The introduction of a new machine in a plant presupposes the existence of space at the appropriate point in the production line. Consideration should be given to coupling the new machine — if at all possible — to an existing one using conveyors, thus reducing material handling and labour requirements. It is unfortunate that in developing countries very little thought is given to this problem. Management has often not yet realized that no value is added yet unnecessary costs are incurred in moving by hand semi-manufactured components from the ground near one machine and placing them again on the ground near another one further down the line, and repeating this operation throughout the process. Unfortunately, the introduction of a new machine in a process line is too often done at the expense of the area allocated to intermediate storage of components. Whereas the new machine would justify an increase of this area, more often than not, it is the cause for the reduction of this area. Thus, the advantages of the increased capacity are often lost due to physical bottle-necks in material handling. The result is that, whereas in theory the new machine should have smoothed the production flow, in actual fact it creates additional confusion on the shop floor. The higher the capacity of the machine, the larger the need for intermediate storage.

The introduction of a new machine often justifies moving the existing ones; yet this is unfortunately rarely done, despite the fact that woodworking machines are relatively light and seldom need special foundations. It is strongly recommended to use the shut-down time caused by the installation of a new machine to change placement of other machines to minimize the adverse effect on flow caused by the new machine.

In selecting a machine — or types of machines — the plant's "micro-infrastructure" should be taken into account. For example, before a decision to purchase a machine is made, one must consider the availability of electric power sources with respect to available power, voltage and the number of phases. One must also consider availability of sufficient supplies of compressed air, at the required pressure, without starving machines further down the line of compressed air. The availability of enough steam (for kiln and presses) at the required pressure and dust and waste capacity must be determined. The need to install a larger power transformer with a distribution cabin, or a larger boiler or compressor could make the purchase of a new machine of a specific type much more expensive than the price of the machine itself.

By and large physical facilities of woodworking plants need not be greatly modified when introducing new machines. Two exceptions are presses for veneering or laminating which require especially heavy foundations and paint spraying stations which require special ventilation and fire walls to isolate them in a high fire-risk area.

In considering the purchase of a machine, the effects of the introduction of a new machine on the existing tool room facilities should not be overlooked. As far as possible, tools should be standardized. For example, bores of cutter-heads used on spindle moulders should have the same diameter so as to reduce the need for investment in a complete set of tools for each machine. Also, the type of tools used on the proposed machine should be studied carefully to ascertain whether the introduction of new machines in the tool room would be necessary. Carbide tipped tools, for example, need special machines, which are far more precise (and costly) than those used for normal or high speed steel cutters. Even the introduction of the first solid cutter-head or band saw in a plant currently using plane knives and circular saws would mean that modifications to the grinders previously used for maintaining knives and circular saws would have to be made. These could mean considerable additional cost. In all cases, the introduction of new types of tools requires the further training of the saw doctors presently employed or the employment of additional more highly skilled saw doctors and maintenance staff.

Labour and capital considerations

Developing countries have a chronic surplus of labour and shortage of capital whereas the opposite is the case in developed countries. Because of this there is a tendency — and often direct urging from the government — to use (or misuse) labour-intensive methods of production. A common argument in favour of this strategy is that in these countries labour costs are low when compared to developed countries and therefore labour-intensive methods of production should be encouraged. It is often overlooked that in this case productivity is even lower.

While not attempting to play down the role industry could play in the creation of employment, the selection of equipment with an appropriate degree of mechanization should be determined scientifically. One way of industrializing is to minimize investment capital (by using simple equipment, machines, installations and buildings), bearing in mind the low level of education and wages in developing countries.

However, if the industry is to be competitive on world markets, the criteria should not be solely to create employment, but rather to guarantee that the funds invested are used as efficiently as possible to increase the competitiveness and profitability of the company. Fixed investments are larger and the labour cost lower.

The differences between the two investment strategies (capital and labour-intensive alternatives) are compared using an assumed and an amortization rate for equipment. This is not the tax deductible depreciation allowed by law, but a faster rate related not to the life expectancy of machine for tax purposes, but to the duration during which the machine is still considered technologically advanced. (This is related more to the machine's resale value than to its bookkeeping value.) In the case of special machines, purchased to produce a specific product competitively, the expected life of the product, that is the time span during which it will be produced, is used to calculate the amortization rate of the special machines. To this, the yearly interest rate on the extra sum to be amortized in the more expensive alternative is added. These additional annual costs should be less than the costs of additional persons needed in the labour-intensive alternative, for the investment to be justified.

It is recommended that such comparisons be made before deciding on the purchase of major pieces of equipment.

Suitability of second-hand equipment

Industrialists in developing countries are sometimes offered second-hand equipment, and are tempted to purchase it. There is nothing wrong with the concept of second-hand equipment *per se* provided that the following points are borne in mind:

(a) Offers which propose second-hand machinery that has not been re-conditioned to meet precision standards for woodworking machines in the major developed countries, should not be considered.[1] There are, in many developed countries, firms that specialize in the re-conditioning of machines, provided that the re-conditioned machines are still suitable from a productivity point of view and are

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[1] Some of these are given in "Criteria for acceptance of and technical standards for woodworking machines" (chapter II).

guaranteed. When the firm has a good reputation, the concept of buying a re-conditioned second-hand machine should not be rejected;

(*b*) In buying a re-conditioned second-hand machine it must be realized that one is buying obsolescence from a technological point of view;

(*c*) Obtaining spare parts for second-hand machinery tends to be more difficult than for new machines. (This is sometimes not the case for simple, old-fashioned equipment if the spare parts are to be manufactured in the developing country.)

If the above points are taken into account then re-conditioned second-hand equipment can be purchased advantageously for use in furniture and joinery plants in developing countries.

Use of power tools, multi-purpose machines, special purpose machines or complete lines

The type of machine and its degree of sophistication depend on the type of products manufactured, the degree of standardization, size of batches etc. The first stage in mechanization after the use of hand tools is to use power tools. However, even heavy-duty power tools are inadequate for continuous industrial production because of lack of precision and worker fatigue (except for use in assembly operations such as sanding, nailing, spraying and perhaps some boring operations).

Multi-purpose machines are not really suitable for industrial production. This is because the machines have only one or at maximum two motors and thus the machines can only be used to perform one or at maximum two operations at one time. In most developing countries the furniture and joinery industries use individual special purpose machines, since such machines are the most versatile. Complete lines are inappropriate because these countries generally do not have large enough markets to assure such mechanized production. Such lines are also generally too capital intensive and sophisticated for developing countries.

Identification of the actual machine required

Once all the above factors have been analysed, the point when the actual technical specifications of the machine to be purchased can be decided upon has been reached.

An internationally accepted decimal classification of woodworking machines has been adopted by the European Association of Woodworking Machinery Manufacturers (EUMABOIS) in 1965. This original classification, which had been adopted by France and the Federal Republic of Germany as their national standards, has been updated by the technical committee of EUMABOIS and published as a second edition of the classification in 1980. It is given in annex III and it will help the layman to define the machines to be purchased in technical terms. The various specifications of the machine have to be clearly defined: for example in the case of thicknessers and sanders, the maximum width and thickness of the pieces to be machined; in the case of four-side moulders the number of heads, and the maximum and minimum cross-sections etc. Of particular importance to the developing countries is the need to specify the species to be machined, especially if these are to be dense tropical hardwoods, since some machines are sometimes underpowered for such heavy-duty work. Information must also be given on the power available; and it might prove useful to mention the other characteristics which might limit the selection of a given type of machine for example, the non-availability of steam will affect the choice of a small kiln, the lack of compressed air will affect purchases of machines having pneumatic controls. This also applies to limitations in the availability of equipment for the tool room etc.

Methodology for identifying suppliers of equipment

Industrialists in the developing countries are cut off from the main equipment producers in the developed countries. In addition, woodworking and upholstering equipment used in developing countries is relatively simple and is not purchased as complete turnkey plants, or complete lines. The equipment is purchased over the years as the need arises, and industrialists wishing to purchase woodworking and upholstering equipment do so on an *ad hoc* basis. They seldom go to fairs or analyse what is available on the world market before making a decision. Although purchasing on an *ad hoc* basis is inevitable, the purchasing without analysis of what is available can and should be avoided.

The first step is to identify any local suppliers and local sales agents of foreign companies, and determine, based on local knowledge (for example, from local engineers at the local university), whether the local metal working industry could produce any of the ancillary equipment needed. This may include dust extraction systems, conveyers etc. This list of local sources is drawn up, and to it must be added foreign sources. One good source of addresses is the various national associations of woodworking machinery manufacturers of the various developed countries. These exist in the United States of America, Japan and most European countries. In the case of the latter they are grouped under EUMABOIS. Their addresses are given in the *UNIDO Guide to Sources of Information on the Furniture and Joinery Industry*.[2] Other sources are the commercial attachés (or trade representatives) of these various developed countries in the developing country's capital city. They might even have the catalogues of specialized international fairs for woodworking machines. These, if available, are of course the best possible sources. A list of these specialized fairs and their scheduling is given in annex I.

The more advanced developing countries should not be ruled out as potential suppliers of equipment, since some are already producing basic machines of acceptable quality and of the simple yet sturdy designs suited to the conditions in other developing countries. It is important to note that the ideal solution would be to visit one of the specialized fairs.

Methodology for the comparison of the bids received

The comparison of the bids received, in reply to the enquiries placed using the procedure outlined in the preceding section is the final and most complex operation in this sequence. Bearing in mind the actual requirements, as identified in the section "Identification of the actual machine required", the various offers received are analysed and compared in a tabular format. The various specifications and requirements, both technical and economic, are analysed with respect to how well they fulfil each of the requirements.

If a double end tenoner were to be taken as an example, the following are some of the technical parameters which should be compared (these are not listed in order of importance):

(a) The maximum and minimum dimensions of the components that can be machined;
(b) The feed speed and whether or not it is constantly variable;
(c) The rated power of the motors driving machining heads and the feed chain. The suitability of the motors for machining dense tropical hardwoods;
(d) The number of cutter-heads provided and their position;
(e) The possibility of incorporating additional machining heads at a later date;
(f) The rotation speed of the cutter-heads;
(g) The availability of scribing saws;
(h) The possibility of rotating cutter-heads for making mitred joints;
(i) The maximum and minimum size of saws (diameter) and cutter-heads (diameter and height);
(j) The interchangeability of saws and cutter-heads with other tools used in the factory;
(k) The level of precision for various machining operations;
(l) The ease of setting up the machine and ease of changing tools;
(m) The ease of maintenance (e.g. centralized lubrication);
(n) The type of electric controls required,
(o) The safety features of the machine;
(p) The consumption of compressed air (m^3 per minute and pressure required);
(q) The need for special auxiliary equipment in the tool room or maintenance workshop to operate the machine;

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[2] *Information Sources on the Furniture and Joinery Industry*, UNIDO Guides to Information Sources No. 4/Rev.1 (United Nations sales publication) (UNIDO/LIB/SER.D/4/Rev.1, ID/188); *Information Sources on Woodworking Machinery*, UNIDO Guides to Information Sources No. 31 (United Nations sales publication) (UNIDO/LIB/SER.D/31, ID/214).

(r) The net weight of the machine (the heavier the weight, the sturdier the construction and the lower the risk of vibration; heavy machines might require special foundations);

(s) The floor area required.

From the economic point of view the following parameters should be compared (also not listed in order of importance):

(a) The production capacity (pieces of a given size per hour);
(b) The labour requirements; the number and qualifications of staff;
(c) The cost of the basic machine;
(d) The cost of basic spare parts;
(e) The cost of attachments which could be purchased at a later date;
(f) The cost of auxiliary equipment needed in the tool room and equipment for dust extraction;
(g) The cost of tools for the various machining heads;
(h) The cost of installing the machine (including foundations, electric and pneumatic connections, dust extraction connections);
(i) The cost of training the labour to operate the machine.

The following commercial considerations should be taken into account:

(a) The availability of a local agent and services offered by him;
(b) The existence in the plant of machines by the same manufacturer and their proven performance;
(c) The delivery date;
(d) The payment and credit conditions;
(e) The ease of obtaining an import licence for the machine and its tools;
(f) The guarantee with respect to the items covered and its duration;
(g) The availability of instruction manual in a locally understood language for installing and operating the machine;
(h) The currency of payment and currency guarantee clauses;
(i) The *force majeure* clause;
(j) The conditions for price increases at seller's discretion.

Only when all these points have been considered for all the offers received can a final decision be made. Needless to say, simpler, more basic machines, are compared on fewer points.

Points to look out for in comparing offers are the following:

(a) Unrealistic supplier quotes for those items which the purchaser has to provide;
(b) Items which the supplier states should be obtained locally (starters, motors etc.) and which in fact are unavailable on the local market;
(c) Calculation and comparison of different costs of the machine under the different financing arrangements and interest rates proposed by various suppliers.

In comparing complete lines, the basic characteristics of each machine are compared and individual machines are assessed on a point basis. The characteristics of each machine are not compared in as much detail as for individual machines, because the line is purchased as a "package deal". The line is selected on the merits of the whole package and not on the merits of individual machines. This is because individual machines cannot normally be replaced at the discretion of the purchaser. (By analogy, one cannot obtain a car with different electrical equipment or a carburettor than that normally offered by the manufacturer.) Such a point system, as used a few years ago by UNIDO consultants in evaluating bids for a turnkey purchase of a complete particle board line, is given in annex II. It shows the system used. By now some of the considerations listed are obsolete technologically. However, these have to be updated, and a similar list would have to be devised for each and every special processing line.

Conclusions

The above procedure might seem complicated, but it has to be followed if costly mistakes are to be averted. It is often a good investment to seek the advice of specialized, impartial, free-lance woodworking industrial consultants who exist in the developed countries. Some of the developing countries that have large forest resources already have such specialists. In other cases, specialist consultants from the developed countries often operate on a regular basis in some developing countries, and some even have established branch offices The added cost of the consultant is often paid back in a matter of months, since costly mistakes in equipment selection can be avoided.

Annex I

LIST OF SPECIALIZED WOODWORKING MACHINERY FAIRS

City and country	*Name of fair*	*Time held*
Klagenfurt, Austria	Holzmesse	Summer, odd years
Paris, France	Expobois	Spring, even years
Hanover, Federal Republic of Germany	Ligna	Spring, odd years
Milan, Italy	Interbimall	Spring, even years
Nagoya, Japan	Woodworking machinery and equipment fair	Autumn, even years
Rotterdam, Netherlands	Hout	Autumn, odd years
Valencia, Spain	National woodworking machinery exhibition	Autumn, odd years
Basel, Switzerland	Holz	Autumn, odd years
Birmingham, United Kingdom	Iwie	Autumn, odd years
Atlanta, Georgia, United States of America	World woodworking exposition and furniture supply fair	Autumn, odd years

Annex II

CLASSIFICATION SYSTEM

The classification system, devised by Arnost Travik,[a] is a method of evaluation of the desirability of equipment. If four levels are specified (that is 0, 1, 2, 3) level 3 represents the best available technology, level 1 is technology to satisfy the basic requirements and level 2 is intermediate. Level 0 means doing without the machine, and is only specified when the machine is not an absolute requirement. In other cases where the machine is necessary level 0 is omitted. The numbers are not quantitative, they cannot be added to arrive at averages. The prime use of such a system is to quickly compare various mixes of machines in designing a factory. By now some of the considerations listed are technologically obsolete. However, the [illegible] valid. Thus the specific considerations must be updated and a similar list devised for every processing lin[illegible]

	Number of points
New material yard	
Fully mechanized	2
Partially mechanized	1
Not offered	0
Debarking station	
Material losses	
Low-drum debarker	3
Medium-ring debarker	2
High-cutter debarker	1
Debarker not offered	0
Feeding to debarker	
Mechanized, metal detector	2
Mechanized, no metal detector	1
By hand	0

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[a] Originally issued as annex II to a study entitled "General selection guidelines for woodworking machinery" (ID/WG.151/6).

Debarking station (cont.)

	Number of points
Capacity	
1 shift for 3 shift production	3
2 shifts for 3 shift production	2
3 shifts for 3 shift production	1
Not offered	0
Bark removal	
Mechanized including milling of bark	2
Mechanized	1
Not offered	0

Manufacture of particles

System proposed	
Separate manufacturing lines for surface and for core particles and separate storing of sawdust, shavings and particles produced from hogged chips	3
Separate manufacturing lines for surface and for core layer particles but without separate storing of sawdust, shavings and of particles produced from hogged chips	2
One manufacturing line for both surface and core particles without differentiated storing of sawdust, shavings and of particles produced from hogged chips	1
Capacities	
1 shift for 3 shift production of boards	3
2 shifts for 3 shift production of boards	2
3 shifts for 3 shift production of boards	1
Removal of splinters	
Combination of air and mechanical sifting	3
Air sifting	2
Mechanical sifting	1
Not proposed	0
Silo for particles	
Over 100 m³	3
Medium, over 50 m³	2
Small, below 50 m³	1

Drying

Dryer	
Fire protection device with automatic fire extinguishing equipment and automatic control of moisture content of particles	3
The same but with manual control of moisture content	2
Hand operated fire extinguishing device only	0
Possibility of reusing dust from board production	
Combined reuse of dust in the production line as well as by burning in the dryer	2
Burning dust in the dryer or in the boiler	1
No provision made	0
Screening unit behind the dryer	
Combination of air and mechanical sifter	3
Air sifter	2
Mechanical sifter	1
Not proposed	0

Glue blending

Bin for dry particles	
Capacity over 25 m³ with level indicator on several points of the bin	3
Capacity below 25 m³ with indicator for "full" or "empty"	2
Low capacity without level indicator	1
Dosing of particles	
Continuous quantity control	3
Discontinuous quantity control	2
Volume dosing	1

Glue blending (cont.)

	Number of points
Construction of glue blender	
Stainless steel, cooling of drum, no compressed air	3
Steel, cooling of drum, no compressed air	2
Steel, cooling of drum, spraying with compressed air	1
Steel, no drum cooling, spraying of glue with compressed air	0
Dosing of glue and paraffin emulsion	
Interlinked with particle dosing, quantity control	3
Interlinked with particle dosing, no quantity control	2
No interlinking with particle dosing	1

Mat forming station

Type of forming station	
Stationary	2
Moving	1
Type of mat	
Sifting fine particles into outer layers, continuous quantity control	3
Sifting fine particles into outer layer, discontinuous quantity control	2
Sifting fine particles into outer layer, no quantity control	1
Prepressing of mat	
Included	1
Not offered	0
Returning of unduly formed mat	
Included	1
Not offered	0

Pressing

Type of press	
Single opening	3
Multi day-light simultaneous closing	2
Multi day-light without simultaneous closing	1

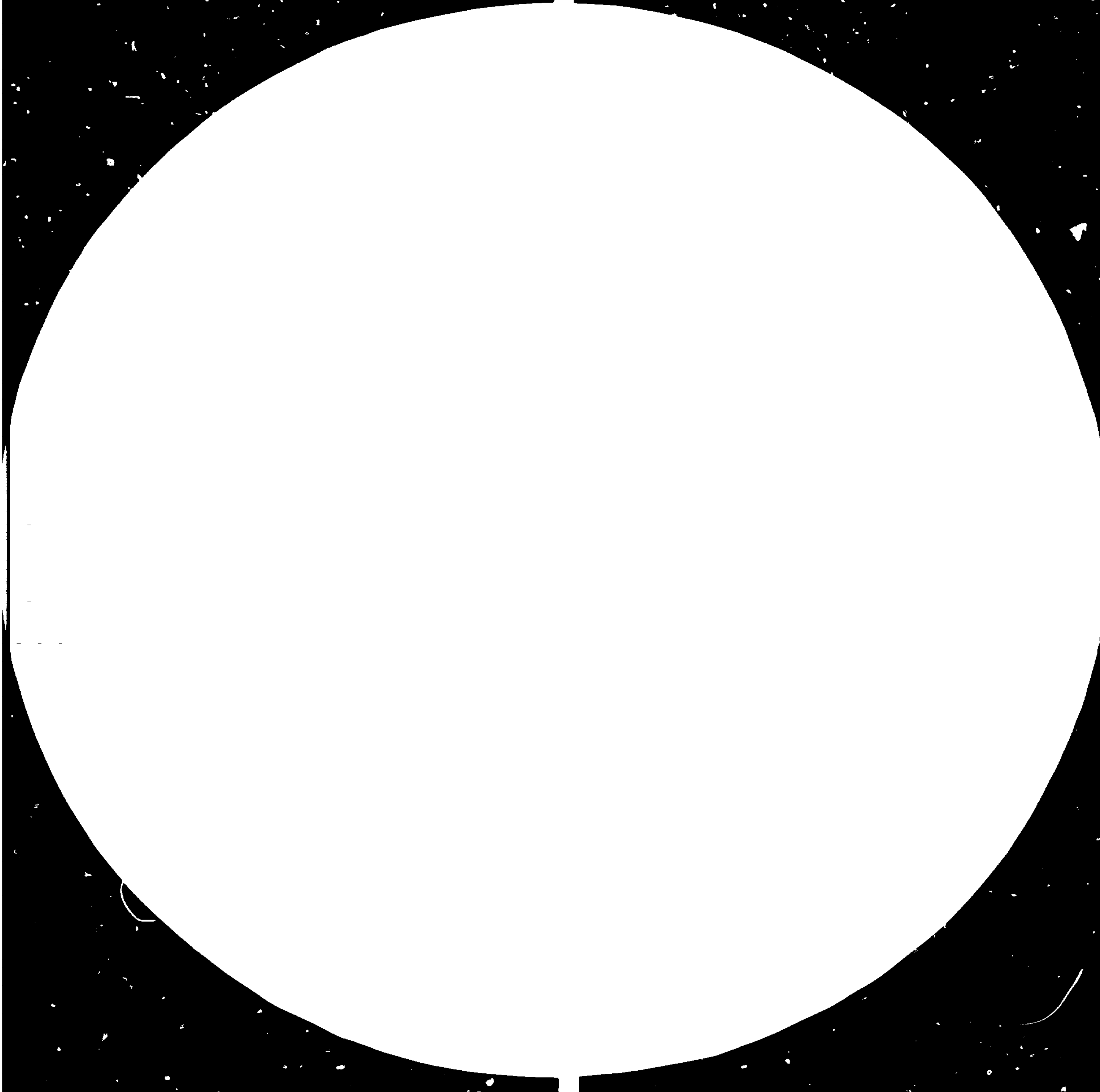
Note: Preference is given to single opening press because of the heavier construction enabling achievement of lower thickness tolerances and equalized properties of the board. It has to be, of course, admitted that multi-opening press has a certain advantage in the potential possibility of increasing the capacity.

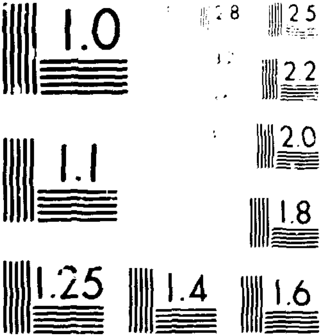
Working pressure	
Min. 35 kgf/cm²	3
Min. 30 kgf/cm²	1
Accumulator station	
Pumps for each piston	3
Accumulator	2
Pumps	1
Feeding system	
Without supporting cauls	3
With transport cauls or divided band	2
Transport band for maintenance and cost reasons	1
Position of press pistons	
Two rows situated above distance bars	2
Two rows closer to the centre line of plates	1
One row in the centre line of press plates	0
Temperature regulation	
Included	1
Not offered	0
Temperature adjustment of pressing table	
Included	2
Not offered	1

Sizing of pressed boards

With tools for simultaneous processing twice two sides	3
With tools processing once two sides	2
With tool processing one side only	1

	Number of points
Cooling of pressed boards	
Forced air stream	2
Natural air stream	1
Not offered	0
Volume/weight control behind the press	
Not necessary due to provisions in other equipment	3
Is necessary, measuring on several points	2
Is necessary, weighting of whole boards	1
Is necessary but not proposed	0
Thickness control of pressed boards	
Measuring the whole width of board	3
Measuring at several points	2
Measuring in one point	1
Not proposed	0
Metal detector	
Before the press	2
Behind the press	1
Not proposed	0
Sanding line	
Processing on both sides with several tools	3
Processing on both sides with one tool	2
Processing on one side	1
Installation of equipment into a line	
With automatic flow	3
With mechanized flow	2
With manual feeding and sorting	1
Sorting of sanded boards	
Into three places	3
Into two places	2
Into one place	1
Storing of ready-made products	
Handling by means of telescopic hoist	2
Handling by means of a lift truck	1
Not proposed	0
Storing and preparation of glue	
Raw material store	
Handling proposed including storing racks	2
Handling proposed without storing racks	1
Not proposed	0
Preparation of glue blend	
Mechanized, allowing for 1 worker to prepare the blend for 3 shifts	3
Not mechanized, 1 worker is provided for each shift	2
Simple, with more than 1 worker for a shift	1
Laboratory	
Offered	1
Not offered	0
Grinding shop	
Complete for grinding of all tools	2
Without the possibility of grinding special tools	1
Not proposed	0

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Annex III

TECHNICAL CLASSIFICATION OF WOODWORKING MACHINES AND AUXILIARY MACHINES FOR WOODWORKING *

Introduction

The European Committee of Woodworking Machinery Manufacturers was founded on January 22nd, 1960.

Its aim is to deal with problems, common to the industry, which daily beset all the manufacturers.

One of the urgent tasks with which it was faced was the classification of woodworking machines so as to enable manufacturers and users to overcome the language difficulty of differing nationalities and to understand each other more readily.

The work of preparing this classification was entrusted to a Working Committee consisting of one technical delegate from each of the member countries of the European Committee, delegates from each National Association and the General Secretariat. The Chairman was the French delegate Mr. Henry Jouhannaud. This second edition of the classification, published in 1980, was prepared by the Technical Committee and takes into account the amendments proposed during the revision completed in 1979. The Chairman was the German delegate Mr. Rolf Schmidt.

Particular attention was given to the wording used in the classification. When there was a risk of confusion the most appropriate expressions were chosen, in each language, in preference to literal translations.

Despite the care which has gone into the production of the classification readers may find that they require additional or more detailed information. This will be gladly supplied in answer to requests addressed to:

Comité européen des Constructeurs de Machines à Bois
150, boulevard Bineau, Neuilly-sur-Seine (France). Phone: 745.43.43

Foreword

(Very important)

This is a technological classification of machines which lists them, so far as possible, according to their method of working. In certain cases when necessary, the end product has been stated.

In the case of a machine built solely for producing a particular end product, the machine has been classified accordingly.

Machines listed in Groups 1 to 6 are machines built exclusively for the purpose described by each heading of their group.

The classification of any machine is not altered by the use of any attachment or tooling.

Group 8 includes all those multi-purpose machines using working methods covered in Groups 1 to 6.

Machines in Group 8 fully process the workpiece, after initial entry, without further manual assistance.

On the contrary the universal woodworking machine has been considered as a single machine combining together types of machines in order to conserve space. It is listed in Group 1 as the workpiece requires manual assistance for each change of operation.

Chapter 91 includes machines or sets of machines solely designed for the purpose of manufacturing a particular end product or products.

Definitions

Woodworking machines, for the purpose of this classification, are stationary or portable machines intended for processing wood, material derived from wood, also cork, bone, ebonite, plastic and other similar materials.

Assembling and coating machines as well as machine tools for cutting and deforming are included in the above definition.

Auxiliary machines, apart from those mentioned above, are understood to be machines specifically used to assist with the working of wood: machines and equipment for wood treatment, mechanical handling devices, grading installations, spreaders, glue room equipment, tool maintenance equipment etc.

1 Cutting machines change the shape or dimension of a workpiece:
  (*a*) Without removal of chips (11);
  (*b*) With removal of chips (12).

11 Chipless machines change the shape or dimension of a workpiece:
  11.1 Cleaving is riving the fibre bond by wedge action.
  11.2 Reducing machines effect the chipless removal of material to produce smaller pieces of a similar predeterminate shape and/or size.

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* Nevilly-sur-Seine, European Committee of Woodworking Machinery Manufacturers, 1980.

11.3 Stamping machines shape by impact cutting.
11.4 Slicing machines are machines for paring by straight cutting edges.
11.5 Veneer shearing machines cut up veneers by straight cutting knives.

12 Cutting machines change the shape or dimension of the workpiece by removal of chips:
12.1 Sawing machines divide by toothed blades or toothed chains.
12.2 Planing machines dress the surface(s) of the workpiece by chip-removing.
Note: The adjustable thicknessing tables of the multi-side planing machines distinguish them from multi-side moulding machines which are sometimes also used for planing.
12.3 Moulding machines shape the profile(s) of the workpiece by removing chips with rotating profiled cutting tools.
12.4 Boring machines cut cylindrical holes by means of rotating tools removing chips and the feed of the tool and/or the workpiece along a common axis.
12.5 Mortising machines cut non-cylindrical holes by means of chisel, mortice chain or routing bit and all feed movements are effected in one plane.
12.6 A lathe shapes a rotating workpiece by tools which can neither rotate nor revolve. Certain machines, carrying a rotating tool, incorrectly called lathes (e.g.: Rounding lathes) do not come under this chapter; see under Chapter 12.3.
12.7 Sanding machines, using abrasives, improve the surfaces and, sometimes, also the dimensional accuracy. Buffing machines impart a lustre on coated surfaces by means of resilient units.
12.8 Universal woodworking machines combine together several types of machines in order to conserve space. The workpiece requires manual assistance for each change of operation.

2 Deforming machines mechanically change the form and/or physical characteristics of the workpiece by action on its structure.

3 Joining machines are for joining two or several pieces.
Coating machines are for joining pieces with coating material (glue, lacquer etc.).

4 Wood conditioning equipment modifies the characteristics of the wood by extraction, impregnation or other processes.

5 Auxiliary machines and equipment are not, properly speaking, woodworking machines but are specifically used by the woodworking industry.

6 Portable machines and machining heads:
61 Portable machines are power-driven machines hand-guided whilst operating.
They include flexible drive and other hand-guided machines e.g. floor sanders, deck planers etc.
62 Machining heads (unit heads) are self-contained production units designed for mounting on and supplementing existing machines, or when mounted on a separate base form an independent machine.

8 Multi-purpose machines using working methods covered by groups 1 to 6: in these machines, the workpiece, after initial entry, is fully processed without further manual assistance.
91 The special machines or sets of special machines are designed for the sole purpose of manufacturing particular end products.

1 CUTTING MACHINES

11 Chipless cutting machines:

11.1 Cleaving machines:
- 11.11 Round wood cleaving machines
- 11.12 Firewood cleaving machines
- 11.13 Root stock cleaving machines
- 11.14 Osier-willow, bamboo and rattan splitting machines
- 11.19 Other cleaving machines

11.2 Reducing machines:
- 11.21 Chopping and chipping machines
- 11.22 Flaking machines
- 11.23 Defibrating machines
- 11.24 Disintegrating machines
- 11.25 Shredding machines for wood wool production
- 11.29 Other reducing machines

11.3 Stamping machines (e.g. Veneer stamping machines)

11.4 Slicing machines:
- 11.41 Slicing machines for board production
  - 11.411 with reciprocating tool
  - 11.412 with rotary disc
  - 11.413 with rocking tool beam
- 11.42 Cutting machines for veneer production:
  - 11.421 Veneer slicing machines
    - 11.421.1 with vertical tool movement
    - 11.421.2 with horizontal tool movement
    - 11.421.3 with inclined tool movement
  - 11.422 Veneer peeling lathes
- 11.49 Other slicing machines

11.5 Veneer shearing machines:
- 11.51 Veneer clippers
- 11.52 Veneer pack edge shears
- 11.53 Veneer contouring machines (nibblers)
- 11.59 Other veneer shearing machines

11.9 Other chipless cutting machines (e.g. hard board circular shears, mitre trimming machines, mullion chopping machines, gas wood chopping machines)

12 Cutting machines (removal of chips or particles):

12.1 Sawing machines:
- 12.11 Sawing machines with reciprocating tool:
  - 12.111 Log crosscut sawing machines:
    - 12.111.1 non-transportable
    - 12.111.2 transportable

12.112 Fret sawing machines
12.113 Horizontal frame sawing machines
12.114 Vertical frame sawing machines:
12.114.1 non-transportable
12.114.2 transportable
12.119 Other sawing machines with reciprocating tool

12.12 Sawing machines with continuous tool:
12.121 Band sawing machines:
12.121.1 Log band sawing machines:
12.121.11 horizontal:
12.121.111 non transportable:
12.121.111.1 stationary machine, mobile carriage
12.121.111.2 stationary log, mobile machine
12.121.112 transportable with mobile log carriage
12.121.12 vertical:
12.121.121 non transportable:
12.121.121.1 hand feed of carriage
12.121.121.2 automatic feed of carriage
12.121.121.21 single-blade
12.121.121.22 multi-blade
12.121.122 transportable:
12.121.122.1 hand feed of carriage
12.121.122.2 automatic feed of carriage
12.121.2 Band sawing machines with carriage but without dogging:
12.121.21 non transportable:
12.121.211 hand feed of carriage (push bench)
12.121.212 automatic feed of carriage (rack bench)
12.121.22 transportable:
12.121.221 hand feed of carriage
12.121.222 automatic feed of carriage
12.121.3 Band sawing machines with rollers or roller table:
12.121.31 non-transportable:
12.121.311 with push table
12.121.312 without push table
12.121.32 transportable:
12.121.321 with push table
12.121.322 without push table
12.121.4 Band resawing machines:
12.121.41 horizontal
12.121.42 vertical:
12.121.421 self-centring and gauge cutting
12.121.421.1 single-blade
12.121.421.2 multi-blade
12.121.429 others (e.g. for mine timber etc.)
12.121.5 Table band sawing machines:
12.121.51 non-transportable
12.121.52 transportable
12.121.9 Other band sawing machines (e.g. multi-blade band sawing machines for parquet strips, pulpwood cross-cutting band sawing machines, three pulley band sawing machines, band rip sawing machines)
12.122 Chain sawing machines:
12.122.1 Cross-cutting chain sawing machines
12.122.2 Chain sawing machines for log breakdown
12.122.9 Other chain sawing machines

12.13 Sawing machines with rotating tool:
12.131 Single blade circular sawing machines:
12.131.1 Single blade stroke circular sawing machines for cross-cutting:
12.131.11 with arcuate tool stroke:
12.131.111 with axis of articulation above workpiece (pendulum)
12.131.112 with axis of articulation below workpiece
12.131.113 with axis of articulation level with workpiece (snipper)
12.131.119 Other with arcuate tool stroke
12.131.12 with straight-line tool stroke:
12.131.121 Parallel link sawing machines
12.131.122 Overhead arm supporting moving saw carriage
12.131.129 Other with straight-line tool stroke
12.131.19 Other single blade circular sawing machines for cross cutting
12.131.2 Single blade stroke circular sawing machines, cutting lengthwise and in various directions:
12.131.21 cutting lengthwise for solid wood and panels
12.131.22 cutting lengthwise for veneer packages
12.131.25 other cutting lengthwise
12.131.26 cutting lengthwise and crosswise:
12.131.261 panel sizing saw machines
12.131.3 Single blade non-stroke circular sawing machines:
12.131.31 Log circular sawing machines with carriage
12.131.32 Log circular sawing machines with roller table
12.131.33 Resawing machines with roller feed
12.131.34 Precision cut circular sawing machines with travelling table for small boards
12.131.35 Single blade edging circular sawing machines:
12.131.351 edging circular sawing machines with roller or chain feed
12.131.352 edging circular sawing machines with moving table
12.131.36 Single blade circular saw benches with tilting and vertical saw adjustment with or without travelling table
12.131.37 Single blade circular sawing machines for special purpose:
12.131.371 sliding table circular sawing machines for cross-cutting
12.131.372 circular sawing machines for firewood table (dimension saw)
12.131.373 circular sawing machines for building sites
12.131.374 circular sawing machines for firewood
12.131.39 Other single blade non-stroke circular sawing machines
12.131.9 Other single blade circular sawing machines
12.132 Double and multi-blade circular sawing machines:
12.132.1 Double and multi-blade stroke circular sawing machines:
12.132.11 Panel sizing machines for parallel cuts
12.132.12 Panel sizing machines for squaring cuts
12.132.13 Panel sizing machines for parallel and squaring cuts
12.132.14 Circular sawing machines for folding
12.132.15 Corner coping saw machines
12.132.2 Double and multi-blade stroke and non-stroke circular sawing machines:
12.132.21 Panel sizing machines for squaring cuts
12.132.22 Panel sizing machines for parallel and squaring cuts
12.132.3 Double and multi-blade non-stroke circular sawing machines:
12.132.31 Double and multiple trim sawing machines

- 12.132.32 Double blade log and timber circular sawing machines:
  - 12.132.321 Saw blades in one plane
  - 12.132.322 Saw blades in parallel planes
- 12.132.33 Double edging circular sawing machines for rough cutting:
  - 12.132.331 with constant distance of saw-blades
  - 12.132.332 with adjustable distance of saw-blades
- 12.132.34 Double edging precision-circular sawing machines
- 12.132.39 Other double and multiblade non-stroke circular sawing machines
- 12.132.9 Other double and multiblade circular sawing machines
- 12.139 Other sawing machines with rotating tool (e.g. concave machines cylindrical saws)

12.2 Planing machines:

- 12.21 Planing machines for one-side dressing:
  - 12.211 Surface planing machines
    - 12.211.1 Surface planing or edge jointing machines with cutterblocks:
      - 12.211.11 hand feed
      - 12.211.12 automatic feed
    - 12.211.2 Surface planing machines with cutter discs
    - 12.211.3 Jointers with travelling heads for veneer packs
  - 12.212 Thickness planing machines with rotary cutterblocks
  - 12.213 Fixed knife planing machines
  - 12.219 Other planing machines for one-side dressing (e.g. one-side balk dressing machines)

- 12.22 Planing machines for two-side dressing:
  - 12.221 Surface planing and edge jointing machines for truing-up and squaring in one operation
  - 12.222 Thickness—jointing machines for thicknessing and edge jointing in one operation
  - 12.223 Machines for planing and thicknessing in one operation
  - 12.229 Other planing machines (e.g. two-side balk dressing machines)

- 12.23 Planing machines for three-side dressing, adjustable table, fixed horizontal cutterblocks

- 12.24 Planing machines for four-side dessing, adjustable table, fixed upper horizontal cutterblocks:
  - 12.241 fixed vertical spindle
  - 12.242 vertical spindle, adjustable in height

- 12.29 Other planing machines

12.3 Moulding (shaping) machines with rotating tool:

- 12.31 One-side moulding machines:
  - 12.311 Single spindle moulding machines and double spindle moulding machines with fixed spindle centres
  - 12.312 Single end tenoning machines with one tool holder, or with detachable circular saw
  - 12.313 Interlocking machines:
    - 12.313.1 Corner locking machines
    - 12.313.2 Dovetailing machines
    - 12.313.9 Other interlocking machines (e.g. finger jointing)
  - 12.314 Pattern milling and recessing machines, routing machines
  - 12.315 Copying machines:
    - 12.315.1 with template control of work-piece:
      - 12.315.11 Spindle shaping machines
      - 12.315.12 Routing machines
      - 12.315.19 Other machines
    - 12.315.2 with template control of tool:
      - 12.315.21 Shaping machines
      - 12.315.22 Routing machines
      - 12.315.29 Other machines
    - 12.315.3 with pattern control of tool:
      - 12.315.31 with automatic rotary movement of work-piece
      - 12.315.39 Other pattern controlled copying machines (e.g. carving machines)
  - 12.316 Single spindle moulding machines with power feed
  - 12.317 Moulding machines for folders
  - 12.319 Other one-side moulding (e.g. grooving machines)

- 12.32 Two-side moulding machines:
  - 12.321 Double end spindle moulding machines (with laterally adjustable spindles)
  - 12.322 Double spindle shaping machines with template control
  - 12.323 Double spindle moulding machines
  - 12.329 Other two-side moulding machines (e.g. tonguing and grooving machines)

- 12.33 Three-side moulding machines, fixed bed, adjustable spindles

- 12.34 Four-side moulding machines, fixed bed, adjustable spindles

- 12.35 Rounding machines

- 12.36 Profile-forming machines with form tools and workpiece rotating

- 12.37 Log milling machines:
  - 12.371 with one cutting tool
  - 12.372 with two cutting tools
  - 12.379 others

- 12.39 Other moulding machines

12.4 Boring machines:

- 12.41 Single spindle boring machines (also with multi-spindle boring heads)

- 12.42 Multi-spindle boring machines:
  - 12.421 with fixed spindle centres
  - 12.422 with adjustable spindle centres

- 12.43 Boring machines for special purposes:
  - 12.431 Knot hole boring machines
  - 12.432 Dowel hole boring machines:
    - 12.432.1 single spindle
    - 12.432.2 multi spindle
  - 12.433 Deep hole boring machines
  - 12.434 Boring machines for acoustic tiles
  - 12.439 Other boring machines for special purposes

- 12.49 Other boring machines

12.5 Mortising machines:

- 12.51 Mortising machines with oscillating tool action:
  - 12.511 Single spindle
  - 12.512 Multi-spindle

- 12.52 Mortising machines with continuous tool:
  - 12.521 Chain mortising machines:
    - 12.521.1 single chain mortising machines
    - 12.521.2 multiple chain mortising machines
  - 12.522 Combined chain and chisel mortising machines
  - 12.529 Other mortising machines with continuous tool

- 12.53 Mortising machines with rotating tool:
  - 12.531 Slot mortising machines:
    - 12.531.1 single tool
    - 12.531.2 multi-tool
    - 12.531.9 special (e.g. for shutters)
  - 12.532 Hollow chisel mortising machines
  - 12.539 Other mortising machines with rotating tool

- 12.59 Other mortising machines

12.6 Turning machines:

- 12.61 Turning lathes
- 12.62 Facing lathes
- 12.63 Lathes with non-rotating profile forming tools
- 12.64 Copying lathes with template control of tool (back-knife lathes)
- 12.69 Other turning machines

12.7 Sanding machines—Buffing machines:

- 12.71 Sanding machines with oscillating action

- 12.72 Belt sanding machines:
  - 12.721 Narrow belt sanding machines:
    - 12.721.1 with fixed table
    - 12.721.2 with sliding table or frame:
    - 12.721.21 non-automatic
    - 12.721.22 semi-automatic
    - 12.721.3 Automatic narrow belt sanding machines:
    - 12.721.31 with one belt
    - 12.721.32 with two or more belts
    - 12.721.4 Special purpose sanding machines:
    - 12.721.41 for edges, rebates and profiled laths
    - 12.721.42 for curves and forms
    - 12.721.43 for round stocks
    - 12.721.44 for swivels
    - 12.721.49 others
    - 12.721.9 Other narrow belt sanding machines
  - 12.722 Wide belt sanding machines:
    - 12.722.1 with one belt
    - 12.722.2 with two or more belts

- 12.73 Disc sanding machines:
  - 12.731 with non-profiled disc
    - 12.731.1 with spindle in fixed position
    - 12.731.2 with movable spindle
    - 12.731.9 others
  - 12.732 with profiled disc
  - 12.739 Other disc sanding machines

- 12.74 Sanding machines with cylindrical tool
  - 12.741 Bobbin sanding machines (extended spindle no cutboard bearing)
    - 12.741.1 hand feed
    - 12.741.2 automatic feed
  - 12.742 Drum sanding machines (drums mounted between bearings):
    - 12.742.1 Single-drum sanding machines:
    - 12.742.11 hand feed
    - 12.742.12 automatic feed
    - 12.742.2 Multi-drum sanding machines (automatic feed)
  - 12.749 Other sanding machines with cylindrical tool

- 12.75 Sanding machines with different tools:
  - 12.751 for a plane surface (e.g. sanding crosswise)
  - 12.752 for several plane surfaces
  - 12.753 for profiled workpieces

- 12.76 Buffing or polishing machines
  - 12.761 Belt buffing or polishing machines:
    - 12.761.1 hand feed
    - 12.761.2 automatic feed
  - 12.762 Bobbin buffing or polishing machines
  - 12.763 Drum polishing machines:
    - 12.763.1 hand feed
    - 12.763.2 automatic feed
  - 12.769 Other buffing or polishing machines

- 12.79 Other sanding machines—buffing machines

12.8 Combined machines (universal woodworkers):

- 12.81 Surface planing and thicknessing machines
- 12.82 Surface planing (without thicknessing) machines with one or several other operations
- 12.83 Surface planing and thicknessing machines with one or several other operations
- 12.84 Circular sawing—moulding—mortising operations
- 12.89 Other combined machines

12.9 Other cutting machines with removal of chips (e.g. for roughing the surface with brushes or sand jet)

2 DEFORMING MACHINES

21 Compressing machines for solid wood:

22 Bending machines

23 Embossing machines

- 23.1 with embossing die
- 23.2 with embossing roll
- 23.9 other

29 Other deforming machines

3 JOINING AND ASSEMBLING MACHINES INCLUDING COATING

31 Joining and assembling machines using building agents (adhesives):

31.1 Edge bonding machines:

- 31.11 Veneer splicing machines:
  - 31.111 Taping type:
    - 31.111.1 Lengthwise
    - 31.111.2 Crosswise
  - 31.119 Other veneer splicing machines:
    - 31.119.1 lengthwise
    - 31.119.2 crosswise

- 31.12 Solid wood gluing machines
  - 31.121 Longitudinal joining:
    - 31.121.1 direct application of the edges
    - 31.121.2 by sliding interlock of the edges
  - 31.122 End joining:
    - 31.122.1 finger joining clamps
    - 31.122.2 scarfing clamps

- 31.13 Panel joining machines

31.2 Squaring up machines:

31.21 Frame clamps

31.22 Carcase clamps

31.29 Other squaring-up machines

31.3 Surface joining machines:

31.31 Plywood presses:
31.311 for flat surfaces
31.312 for formed surfaces

31.32 For laminating wood:
31.321 for flat surfaces
31.322 for formed surfaces

31.33 Veneering presses:
31.331 For flat surfaces:
31.331.1 hand loading
31.331.2 auto loading, alternated
31.331.3 continuous loading and pressure
31.332 For formed surfaces:
31.332.1 with rigid form
31.332.2 with flexible form

31.4 Edge lipping and bonding machines:

31.41 for plane edges

31.42 for profile edges

31.5 Core stock composing and joinery stock offset composing and gluing up machines

31.6 Presses for coated particles:

31.61 Chip and particle board pressing machines:
31.611 for intermittent processing
31.612 for continuously processing
31.612.1 Belt presses
31.612.2 Extrusion presses
31.612.9 Other continuous process presses

31.62 Mould presses

31.69 Other presses for coated particles

31.7 Fibre presses:

31.71 Continuous metal link belt presses

31.72 Platen presses

31.79 Other fibre presses

31.9 Other joining and assembling machines using binding agents (adhesives) (e.g. rotating press with automatic feeding in intervals)

32 Machines for joining by means of fasteners such as nails, staples, wire etc.:

32.1 Machines for driving nails, staples etc.:

32.11 Nailing machines for boxes, for pallets, for cable-drums

32.12 Machines for nailing on strips

32.13 Flat and/or corner staplers

32.14 Stapling and stitching machines for wire-bound boxes

32.15 Machines for inserting screws

32.16 Machines for fitting hardware

32.19 Other driving machines (e.g. corrugated fastener, cramp and dowel pin driving machines, basket stapling machines)

32.2 Machines for assembling by means of wire (e.g.: firewood bundling machines, weaving machines etc.)

32.9 Other machines for joining by means of fasteners such as nails, staples, wire etc.

33 Machines for joining without binding agents and without fasteners:

33.1 Squeeze presses for framework (ladders etc.)

33.2 Baling presses

33.3 Briquetting presses

33.4 Wood wool rope spinning machines

33.5 Interweaving machines

33.9 Others

34 Coating machines (adding coats to wood):

34.1 Glue spreading machines:

34.11 Machines for glue speading on boards and veneers:
34.111 glue spreaders for edges
34.112 glue spreaders for surfaces

34.12 Chip and glue blending machines

34.19 Other glue spreading machines

34.2 Machines for application of lacquer:

34.21 Roller coating

34.22 Curtain coating

34.23 Flow coating

34.24 Spray coating

34.25 Dipping

34.26 Electrostatic coating

34.29 Other machines for application of lacquer

34.3 Machines for printing

34.9 Machines for application of other adhering material (e.g.: synthetical resins)

39 Other joining and asembling machines

4 EQUIPMENT FOR WOOD CONDITIONING (SEASONING, PRESERVING, ETC.)

41 Steaming equipment

42 Dryers:

42.1 Solid wood dryers

42.2 Veneer wood dryers

42.3 Chip dryers
42.4 Lacquer coat dryers
42.9 Other dryers

43 Humidifying equipment

44 Impregnating and preserving equipment

45 Bleaching, staining and smoking equipment

46 Cooling systems

49 Other machines for wood conditioning

5 AUXILIARY MACHINES AND EQUIPMENT FOR THE WOODWORKING INDUSTRY

51 Equipment for moving material:

51.1 Lifting equipment:
51.11 Mobile lifting tables
51.12 Lifting tables and stages
51.13 Tilting hoists
51.19 Other lifting equipment

51.2 Infeed and outfeed devices

51.3 Turning devices

51.4 Feeding devices (especially for feeding workpieces)

51.5 Equipment for transport and storage of chips, strands, waste, particles etc.
51.51 Equipment for transport
51.511 mechanical
51.512 pneumatic
51.52 Equipment for storage (e.g. silos)

51.6 Automatic centring devices

51.9 Other equipment for moving material

52 Installations for grading
52.1 wood
52.2 particles

53 Particle spreaders

54 Glue room equipment

55 Equipment for tool maintenance:

55.1 Equipment for saw blade maintenance:
55.11 Sharpening machines
55.12 Filing machines
55.13 Saw setting, saw swaging and dressing machines and equipment
55.14 Band saw brazers and butt-joint welding machines
55.15 Stretching and rolling machines
55.16 Band saw shearing and lap grinding machines
55.17 Sharpening machines for carbide tipped circular saw blades
55.19 Other equipment for saw blade maintenance
55.22 for shaped edges

55.3 Sharpening machines for moulding cutters and cutter-knives

55.4 Sharpening machines for boring tools and router bits

55.5 Sharpening machines for mortising chisels

55.6 Sharpening machines for chain cutters

55.7 Universal tool and cutter sharpeners

55.9 Other equipment for tool maintenance

56 Equipment for safety and noise reduction:
56.1 Equipment for safety
56.2 Equipment for noise reduction

57 Equipment for assembling, clamping and holding

58 Equipment for measuring, regulating and controlling

59 Other auxiliary machines and equipment (e.g. machines for cleaning surfaces)

6 PORTABLE MACHINES (HAND MACHINES) AND MACHINING HEADS

61 Portable machines (hand machines):

61.1 Portable machines for chipless cutting:
61.11 Portable debarking machines (cleaving action)
61.19 Other portable machines for chipless cutting (e.g. portable shears)

61.2 Portable machines for cutting (removal of chips):
61.21 Portable sawing machines:
61.211 Portable sawing machines with reciprocating tool
61.212 Portable sawing machines with continuous tool:
61.212.1 portable band saws
61.212.2 portable chain saws
61.212.21 portable guide bar chain saws
61.212.22 portable bow chain saws
61.212.29 Other portable chain saws
61.213 Portable sawing machines with rotating tool:
61.213.1 Portable circular sawing machines
61.213.2 Portable ring sawing machines
61.213.9 Other portable sawing machines with rotating tool

61.22 Portable planing machines

61.23 Portable moulding and routing machines:
61.231 for edge routing
61.232 for surface routing
61.239 others

61.24 Portable boring machines

61.25 Portable mortising machines:
61.251 Portable mortising machines with oscillating tool
61.252 Portable mortising machines with continuous tool (chain mortiser)
61.259 Other portable mortising machines

51.26 Portable sanding and buffing machines:
61 261 Portable sanding machines:
61.261.1 with oscillating action
61.261.2 with continuous action (portable belt sanding machines)
61.261.3 with rotating action:
61.261.31 Portable disc sanding machines
61.261.32 Portable drum sanding machines
61.261.9 Other portable sanding machines
61.262 Portable buffing machines

61.3 Portable machines for joining and assembling:

61.31 Portable nailing machines

61.32 Portable stapling machines

61.33 Portable screw drivers

61.39 Other portable machines for joining and assembling

61.4 Portable machines for application of adhering coats:

61.41 Glue guns

61.42 Spray guns

61.49 Other portable machines for application of adhering coats

61.8 Portable machines with flexible driving shaft and other portable machines

62 Machining heads (unit heads):

62.1 Dividing units (chipless cutting)

62.2 Cutting units (removal of chips):

62.21 Sawing units

62.22 Planing units

62.23 Shaping units

62.24 Boring units

62.25 Mortising units

62.26 Sanding and buffing units

62.29 Other machining units

62 3 Joining, assembling and coating units

62.9 Other machining heads

7 FREE

8 MULTI-PURPOSE MACHINES USING DIFFERENT WORKING METHODS COVERED BY GROUPS 1 TO 6

81 Multi-purpose machines for converting logs (e.g. debarking, sawing, hogging)

81.1 Frame converting sawing machines with additional operations

81.2 Band converting sawing machines with additional operations

81.3 Circular converting sawing machines with additional operations

81.4 Profile hogging machines with additional operations

81.9 Others

82 Multi-purpose for secondary tooling operations for solid wood, panels and veneer wood (e.g. sawing, moulding, sanding):

82.1 single-end tenoning machines with several spindles

82.2 double-end tenoning machines

82.3 machines working in feed direction and cross feed direction (e.g. profiling and crosscutting)

82.4 double-end profiling machines with attached units

82.5 planing machines combined with multi-blade sawing machines

82.6 multi-purpose dowel hole boring machines (e.g. sawing, moulding, boring, mortising)

82.7 machines for preparing the position of hardwares (e.g. sawing, moulding, boring, mortising)

82.9 other multi-purpose machines for tooling (e.g. on an indexing table)

83 Multi-purpose for assembling with adhesives and machining:

83.1 For gluing and (additional) machining:

83.11 for production of veneer strip

83.12 for production of core stock from laths

83.13 for production of pieces from chips, particles, fibre etc.

83.14 for production of pieces from laminated material

83.15 Edge bonding machines (e.g. veneer, solid wood, plastic):
83.151 single-end
83.152 double-end

83.16 Wrapping machines

83.17 Postforming machines

83.19 Others

83.2 For machining and gluing with or without additional operations:
  - 83.21 Double-end sizing and edge bonding machines
  - 83.22 Finger jointing machines
  - 83.23 Splicing (scarfing) machines
  - 83.24 Veneer pack edge shears with gluing device
  - 83.25 Automatic knot-plugging, veneer patching machines
  - 83.26 Dowel boring, gluing, driving in machines
  - 83.29 Others

84 Multipurpose machines for cutting and joining by fasteners of metal or plastic:

84.1 machines for preparing the seat of hardwares and/or driving-in

84.2 machines for fitting frames, boxes etc. and joining by fasteners

84.9 Others

89 Other multi-purpose machines

9 OTHER MACHINES

91 Special machines or sets of special machines designed for the sole purpose of manufacturing a particular end product:
Machines and equipment to make:

91.1 Broom and brushes

91.2 Pencils

91.3 Barrels

91.4 Penholders

91.5 Bottle cases

91.6 Fountain and ball point pens

91.7 Gun stocks

91.8 Pit props

91.9 Shoe heels

91.10 Clogs and sandals

91.11 Shoe arches

91.12. Laminated structural timbers

91.13 Combs

91.14 Clothes hangers

91.15 Buttons

91.16 Cork products

91.17 Rulers

91.18 Musical instruments

91.19 Parquetry

91.20 Paving blocks

91.21 Brushes artists, decorators)

91.22 Propeller blades

91.23 Slide rules

91.24 Louvres and shutters

91.25 Parts of coffins

91.26 Shoe lasts and shoe trees

91.27 Railway sleepers (ties)

91.28 Sports equipment (skis, racquets)

91.29 Chopping block (facing)

91.30 Basket work etc.

91.31 Parts of chairs and settees

91.32 Accessories for textile machines (bobbins and shuttles etc.)

91.33 Clothes pegs

91.34 Wheels

91.35 Toothpicks

91.36 Matches

91.37 Dowels

91.38 Fences and posts

92 Various machines:

92.1 Non-portable debarking machines

V. Tools for machining wood*

Sawmilling

Wood saws can be divided into the categories of gang saws (frame saws), band saws, circular saws, and stationary or portable chain saws. Chain saws are used for felling trees, for processing (limbing, bucking) logs and, finally, for some miscellaneous work in the lumber yard. The selection of chain saws will not be discussed here. Gang saws, which were among the first saws to be used to saw logs into boards, beams and other forms of lumber, are used for large quantities of wood which is homogeneous from the viewpoint of species, log size and size of the lumber to be obtained.

Gang saws

The advantages of gang saws are:

(a) Reduction of the time needed to place the log on the carriage. This is because a single pass is sufficient to transform the log into sawn timber, as the saw is usually equipped with several blades which work in unison;
(b) Solid construction of the machine;
(c) Easy inspection and servicing of the blades;
(d) Good quality of the surface obtained;
(e) The relatively low force needed to operate the saw.

On the other hand, the gang saw possesses some disadvantages:

(a) Once started, the position of the log cannot be changed in relation to the position of the blades;
(b) The complexity of the machine's structure and its alternating movement requires a very heavy foundation. Perfect control of the machine requires highly experienced operators.

Gang saws with more than one blade are especially useful in sawing conifers of forests in temperate zones but hand saws are preferable for the processing of trees from tropical forest areas.

Band saws

Band saws have the following advantages:

(a) The position of the log on the carriage or the thickness of the timber may be changed during the course of the work;
(b) The saw is easily controlled, and the blades can be changed quickly;
(c) The filing time is relatively short due to the use of thin blades;
(d) The surfaces obtained are of good quality.

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* By G. Melloni, selector of lumber manufacturing equipment. (This is an edited version of ID/WG 277/17.)

The disadvantages of band saws are:

(a) The time lost in reversing the carriage for further cuts;
(b) The danger of a long unprotected blade;
(c) The danger of injury to those who transport blades to and from the filing room.

On the whole, it may be said that band saws are useful for processing wood such as tropical wood which does not have homogeneous characteristics.

Circular saws

Circular saws normally saw timber with a single blade. However, where large-size logs are involved, two blades are used. The blades are lined up with one over the other. The advantages of using a circular saw are the following:

(a) The position of the log or timber on the carriage may be changed as required by the internal conditions of the wood;
(b) The high work speed;
(c) The ease of operation of the machine and ease of changing of the saw blades.

Disadvantages of a circular saw are:

(a) The time lost in reverse travel time of the carriage;
(b) The hazard to the operators where the saw blade is not guarded;
(c) The excessive loss in sawdust resulting from the extra thickness of the blade and cutting techniques using wide saw teeth.

In summary, it might be said that for the sawing of tropical logs into boards or timber, the band saw machine seems to be the most suitable. For subsequent operations, such as carpentry and joinery work, both the band saw and circular saw have their respective places.

Typical characteristics of a band-saw blade which affect its rigidity are: its dimensions, the assembling stress and the blade tension. The quality of the product produced is based on the physical condition of the saw teeth. This includes their shape, pitch and setting. The dimensions of a typical blade are:

(a) The thickness: between 1/1,000 and 1/1,250 of the flywheel diameter;
(b) The width (initial) is equal to the width of the rims plus the depth of the teeth;
(c) The assembling stress should be approximately 200 N/mm^2 for normal blades and about half of that for very large blades;
(d) The tensioning constraint is difficult to measure; it is in the order of 80 to 100 N/mm^2.

The following terms are used to describe the parts of a saw tooth (figure 1):

Tooth height
Tooth pitch
Tooth gullet
Hook angle
Clearance angle
Sharpness angle

There are very few basic forms of saw teeth. The information provided by the different laboratories is not always based on the same principles. In the case of large tropical logs, the most satisfactory results seem to be those obtained by the "parrot-beak" tooth, the "projected cutting" tooth, or "Belgian" (because of its origin) tooth. Note the outlines in figure 2.

The average pitch values (35-40 mm) are used with relatively small flywheels and difficult to saw timber. Higher pitch values (50-60 mm) are for large diameter flywheels and easy to saw. Swaging and setting are two procedures used to ensure that the saw cuts through the wood more easily. Swaging is a process of widening the tooth near the point. Setting consists of bending alternate teeth in opposite directions. The amount of setting or swaging depends on the thickness of the blade, and the characteristics of the wood. The set is larger for thick blades and for easy to work wood. At present, for large logs from the tropics, the trend is to prefer setting to swaging.

Figure 1. Solid saw-tooth nomenclature

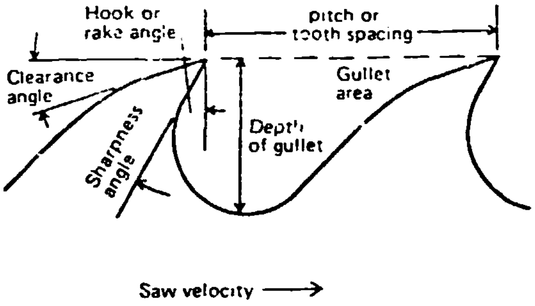
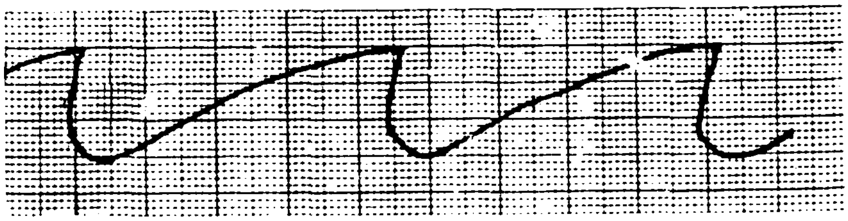
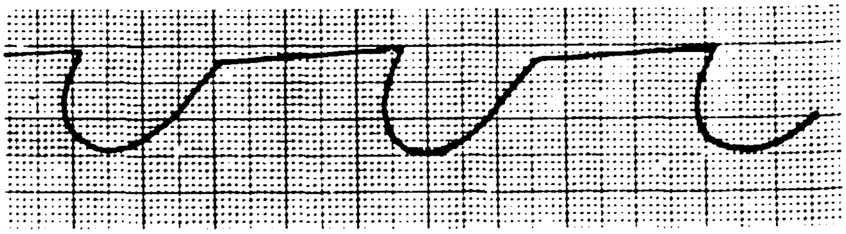


Figure 2. Types of band saw

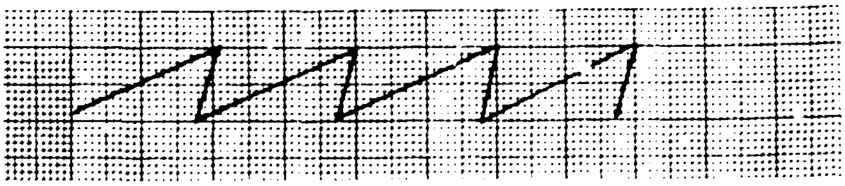


A. Rip-sawing type teeth (Parrot-like)

B. Projected type cutting teeth



C. Belgian type teeth



D. Cross-cutting type teeth

For particularly hard wood or that which contains silicon dioxide, it is best to use tungsten carbide tipped saws or stellite tipped saws. The depth of the gullet is generally 1/10 of the width of the blade if the latter is small and about 1/12-1/13 of the blade if the width exceeds 140 mm. Tensioning, to compensate for unequal expansion during saw manufacture, is extremely important. The blade's tensioning must be checked often and especially each time the saw is ground. For this, satisfactory tools are now available. It must be stressed that good results will be obtained only by proper preparation and servicing of the blades. This can happen only if the operators responsible for these tasks are knowledgeable and experienced in their profession.

Band-saw blades for workshop operations and especially for the finishing of pieces of small sizes are normally between 30 and 60 mm (1.2 and 2.4 in.) in width, with a thickness of 0.5-1.0 mm. The teeth are generally set at a slanting angle, which render servicing easy.

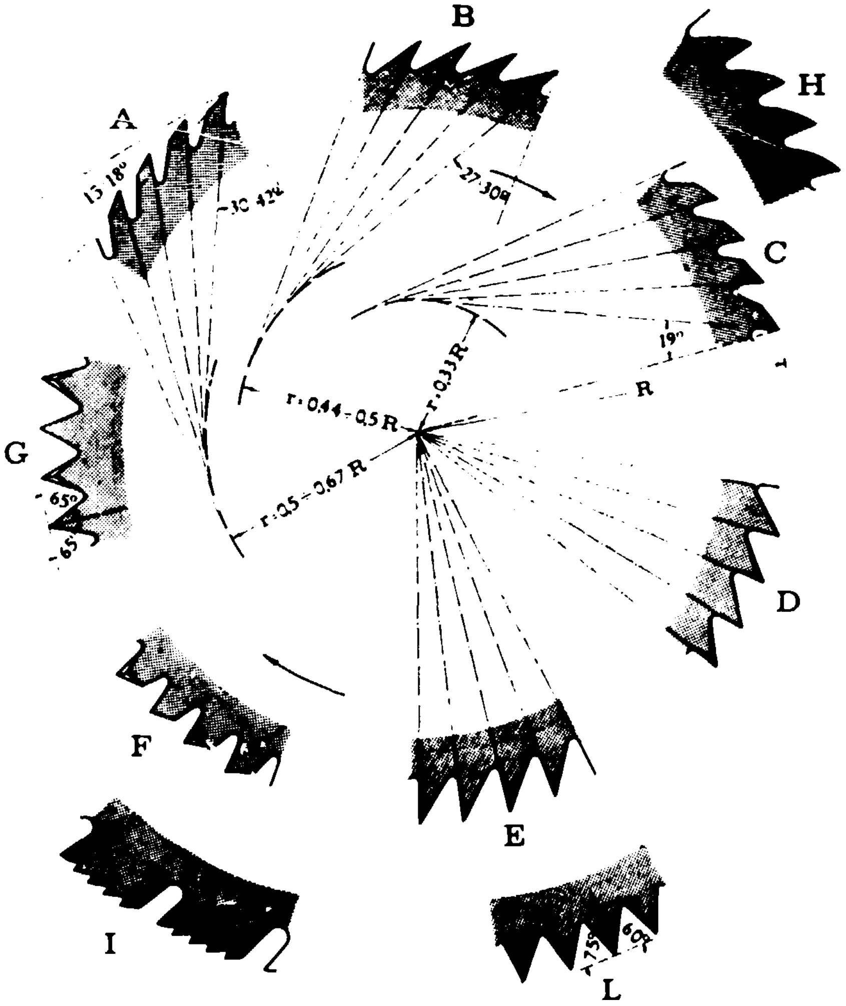
Circular-saw blades for circular-saw benches

Saw-blades with punched teeth are in the form of a steel disc. The rim has teeth. Generally the two faces are parallel but there are certain types with divergent or convergent conical faces. The latter are used especially for the re-sawing of timbers of large thickness.

The diameter for workshop operations must remain under 500 mm. The thickness is determined by either one of the two formulae:

(*a*) Thickness is equal to 0.005 D;
(*b*) Thickness is equal to 0.07 mm + 0.14 $\sqrt{D}$. D is the diameter in mm

Figure 3. Types of circular-saw teeth



For some time engineers have conducted considerable research on the form of saw teeth. In summary, with reference to figure 3, for rip sawing use teeth types A, B or C. Type H may also be used. For cross cutting, use teeth types D, E, F or G. Type L is used in the Union of Soviet Socialist Republics for coniferous woods. Type I tooth (one plain tooth with four alternately swaged cutters) is suitable for all directions of sawing.

Should one choose to saw in the direction of the grain, it is best to use a tooth with a negative cutting angle.

Carbide-tipped tools

Carbide alloys are the most important material for making cutting tools for the removal of chips. They have gradually taken the place of the high speed steel (HSS) tools traditionally used in woodworking. Now tungsten carbide tools are being used more extensively for cutting wood and plastics. These tools last longer than the ones made out of other materials.

In addition to the hardness, and therefore longer operating life between sharpenings, the carbide alloys (tungsten carbide, titanium carbide) are heat resistant. Unlike high speed steel (HSS), the alloys do not require heat treatment for hardening. Many different alloys, some containing cobalt, are used for different cutting purposes.

Standardized toughness of carbide tools

The DIN standard 4990 divides carbide into three main groups: P, M and K. We are interested in group K, which is for chip removal. The cobalt tungsten carbide alloys fall into this group. These carbides are the most suitable alloys for working wood, and material derived from wood and plastics. All these types of carbide tools have a very wear-resistant surface; this resistance decreases with the amount of cobalt in the alloy. As this wear-resistance increases (that is, as the amount of cobalt decreases), the carbide becomes more fragile (see table 1). In general, K40 and K30 carbides give good results for working solid wood. But when there is more friction (cutting wood which is impregnated with synthetic resin, for example), type K20 is better. Type K10 or K05 (which is more wear-resistant) give better results when highly abrasive wood or plastics are worked.

Table 2 shows which carbides should be used on which materials.

TABLE 1. CHARACTERISTICS OF TUNGSTEN CARBIDE ALLOYS IN THE MAIN CHIP REMOVAL GROUP (group K)[a]

Chip removal group	*Specific gravity (g/cm^3)*	*Hardness (Hv30)*	*Cobalt content (%)*
K01	15.0	1 800	4
K05	14.5	1 750	6
K10	14.8	1 650	6
K20	14.8	1 550	6
K30	14.6	1 400	9
K40	14.3	1 300	12

[a] From DIN Standard 4990.

TABLE 2. ALLOYS USED FOR CUTTING VARIOUS MATERIALS

Material to be worked		*Carbide to use*	
Type	*Comments*	*When long life is important*	*When toughness is important*
Solid wood Broadleaf wood Coniferous wood		K30	K40
Densified wood Treated wood Compressed wood Resin impregnated wood		K20	K30
Composite layer wood Plywood Laminated wood Compressed laminated wood		K20	K30
Panels Panels faced with various substances Decorative panels Honeycomb pan	Surface facing or core largely affects longevity of the tool edge	K10	K20
Thermo-setting resins Material for forms	Synthetic resins with organic and inorganic filter material	K05	K20
Thermoplastic resins Material for forms	Low resistance and low heat resistance	K20	K40

Note: The most wear-resistant carbide should always be used with fibre-glass reinforced resins.

Required characteristics of woodworking machines

The main requirements of a machine tool are a wide range of adjustments to provide for optimum operation, vibration resistance and satisfactory controls. The best working speed for carbide tools will be somewhere in the upper half of the 25 m/s to 125 m/s operation range. The best speed depends on the abrasive qualities of the material being cut. Therefore, carbide-tipped tools can be economically used when the spindle speed is high and a relatively wide range of spindle speeds are available. The increase in the initial cost of machine tools due to adding extra devices will pay for itself in a short time due to the increase in output which will develop. Good equipment has important advantages. Among these are that relatively small tools with few edges can be used. High spindle speeds can be used. These tools are long lasting and thus tool costs decrease quite noticeably. The life of a cutting tool largely depends on machine tool vibrations, and vibrations can be reduced or eliminated. Furthermore, efficient machine bearings guarantee silent and continuous power transmission, even when the machine is subject to static and dynamic stress. All rotating parts must be dynamically balanced. These parts and the transmission must be mounted on the frame or in an easily accessible and protected position. Because of competition, companies with large-scale production have had to make even wider use of automation in the production process. The principal companies in the wood and plastics industry feel that this tendency towards full automation is very important and they therefore, plan new investments in plant and machinery. In this connection it would be a good idea to invite experts from the tool manufacturing sector to take part in the preliminary discussions. These experts are able to make practical economic calculations and the anticipated output can be easily measured.

Choosing the correct carbide-tipped circular-saw blades

The different types of circular-saw blades are suitable for many applications The correct choice of the type of tools shown on the following pages increases tool life.

Factors affecting cutting quality

In addition to the above general factors, the geometry of the cut, the number of teeth and the blade mounting and working conditions affect cutting quality of wood and plastic.

According to the Auschuss Wirtschaftliche Fertigung (AWF) there are three categories of cutting quality, as defined in table 3.

TABLE 3. SURFACE QUALITY

(According to AWF; depends on type of sawing)

Category	*Use*	*Characteristics of the cut surface*	*Sawn surface quality*
AWF I	Ready for gluing	Surface which can be veneered	Fine sawn
AWF II	Ready for veneering	Surface which can be planed	Average sawn
AWF III	Ready for construction work	The surface is good enough for building lumber	Rough sawn

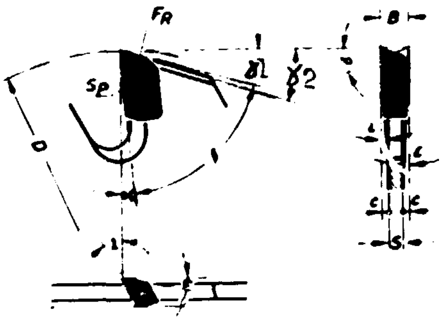
Surface quality with carbide-tipped blades always corresponds to AWF I or AWF II. Carbide tipped circular-saw blades are designed to make a very narrow kerf. Consequently, the usual large diameter blades are rather unstable; but their stability can be increased by "straightening" and "tensioning".

Unlike chrome-vanadium alloy circular-saw blades, carbide tipped blades are not set by blending or by swaging; they are sharpened on the periphery and the sides to the necessary clearance angles. The following angles and dimensions are important for describing carbide tipped blades (figure 4):

γ	clearance angle
β	lip angle
α	radial rake angle
δ	vertex angle
ε	side angle
γ_l	lateral clearance angle
λ	axial angle
S	blade thickness
C	set
B	blade thickness plus set
FR	free surface
SP	lip area

The cutting thickness (*B*) of carbide tipped circular-saw blades varies with blade diameter (*D*).

Figure 4. Carbide-tipped blade geometry



In practice, a set of 0.5 mm has proven to be particularly good for cutting all species of wood: coniferous, broad-leaved, dense, green, dry and all types of synthetic materials.

In some cases, other set values may be used, ranging from 0.25 mm to 0.75 mm.

For good clean cuts, accurate sharpening of the side angle ε is important. This is also true for the vertex angle $\tilde{\varepsilon}$, which varies according to the chip removal characteristics of the material to be sawn.

Angles $\tilde{\varepsilon}$ and λ are partially interdependent. Their ratio influences the lateral stability of the circular-saw blade.

The lateral clearance angle γ_l should be as large as possible. However, the size of this angle is limited by the technical aspects of sharpening. The radial rake angle α does not play an important role in circular sawing.

Cutting edge geometry and the size of the angles on carbide tipped circular-saw blades are generally chosen with regard to the chip removal characteristics of the material to be sawed. The different specific gravity, hardness and moisture content of natural woods, together with the different resistance properties of wood products and plastics make it impossible to use circular-saw blades with the same type of teeth for all these materials.

Therefore, every shape of tooth for carbide tipped circular-saw blades is for a particular application.

Determining the optimum number of teeth

The number (Z) of teeth on the circular-saw blade can play a very important role as far as the quality of the cut is concerned. The number of teeth depends on the desired cutting quality and the conditions under which the sawing is done. For cross-cutting wood, or for cutting faced wood across the grain, a large number of teeth are required. For panels which are faced on both sides with plastic material the maximum number of teeth should be used to prevent splintering.

The pitch t is:

$$t = \frac{\pi D}{Z}, \text{ where the diameter is in millimetres.}$$

For carbide tipped circular-saw blades, the pitch must be at least 12 mm, otherwise they will be very difficult to sharpen. The more teeth there are, the better the tool will behave during sawing. It is best to use blades with a large number of teeth when cutting thin work material. On the other hand, it is preferable to use blades with a small number of teeth when cutting thick work material (especially solid wood when chip discharge is important).

Position of the circular-saw blade

The exact position of the blade must be determined each time by trial and error. If the blade is moved upwards (if the projection increases) the edges of the cut underneath the wood will be less precise, but they will be more precise on the top. Conversely when the projection is decreased, the edges of the cut underneath the wood will be more precise.

Approximate rotational speed

The blade diameter is chosen with regard to the depth of the cut a and the available spindle speed n. It is better from the economic point of view to have more than one cutting speed. As speed increases, the circular-saw blade becomes more stable and cutting quality improves.

The following formula may be used to calculate rpm:

$$\text{rpm } (n) \ \frac{v \times 60}{D \times 3.14}$$

where the cutting speed v is in m/s and the diameter is in metres.

A low cutting speed should be used for tool-wearing wood-products and heat-sensitive thermoplastic materials. But for soft wood and plastics with good chip removal characteristics medium and high cutting speeds should be used.

For manual feed sawing the feed speed u is 6 m/min. High rpm should be used because less feeding force is required.

Table 4 shows some approximate cutting speed values

TABLE 4. APPROXIMATE CUTTING SPEED VALUES (v) FOR CIRCULAR-SAWING MACHINES

Material to be sawn	*Properties*	*Approximate cutting speed (v in m/s)*
Solid wood		70-100
Laminated wood	With or without low specific gravity wood	60-90
Densified wood	High specific gravity and impregnated wood (for example, compressed laminated wood and plywood etc.)	35-70
Solid densified wood		35-70
Thermosettings	Laminated panels with organic or inorganic cores	35-70
Thermoplastics	Low strength, heat sensitive material	25-50

The following formula can be used to calculate cutting speed:

$$\text{Cutting speed} = \frac{D \times 3.14 \times n}{60}$$

where the diameter (D) is in metres and (n) is the number of rpm.

Blade diameter can be calculated as follows:

$$D = \frac{60v}{3.14n} \qquad 20\frac{v}{n}$$

Tangential velocity of the saw tooth for various materials is shown in table 5. The average theoretical chip thickness (hm) depends on the depth of cut (a) and the material to be sawn.

The average chip thickness should not be less than 0.02 mm. Thinner chips shorten tool life appreciably. Relatively thin chips are caused by unstable blades.

TABLE 5. TANGENTIAL VELOCITY OF THE SAW TOOTH FOR VARIOUS MATERIALS

Material	*Cutting speed m/s*
Coniferous wood	70-100
Broad-leaved wood	50-80
Very hard tropical wood	30-60
Particle board and plywood panels	40-70
Dense particle board panels (more than 720 kg/m^3)	35-50
Compressed wood treated with synthetic resins (900-1 400 kg/m^3)	30-60
Plastic laminates	30-60

There are several interrelated variables which must be considered in cutting speed calculations:

S = feed speed (m/min)
Z = number of teeth
A = Bite per tooth (mm/tooth)
n = rpm

The relationship is $Z = \dfrac{S}{nA}$

Table 6 gives the bite per tooth (A) for various materials.

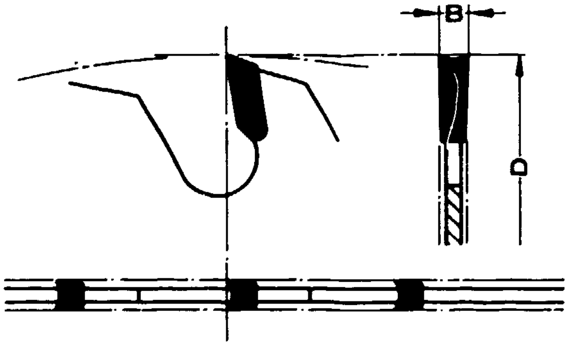
TABLE 6. BITE PER TOOTH (A)

Material	*Bite/tooth (mm)*
Plastic laminates	0.03-0.05
Thin or coniferous wood panels—sliced wood 0.6 mm thick bonded on panels or veneered. Low or medium density particle board (with low screw holding force). Extruded or continuous pressed (with tube holes) particle board. Thermoplastic panels (PVC etc.)	0.05-0.08
Particle board, plywood, fibreboard, veneered panels	0.07-0.10
Cross-cutting solid wood	0.09-0.12
Rip sawing hardwood	0.12-0.15
Plain particle board	0.09-0.12
Rip sawing coniferous wood	0.15-0.20

Note: When down-milling: use lower speed. When up-milling: use a higher speed. These are approximate values for thicknesses up to 40 mm.

The following figures (5 through 8) are of different carbide tipped blades. The applications and advantages of each are described.

Figure 5. Straight teeth



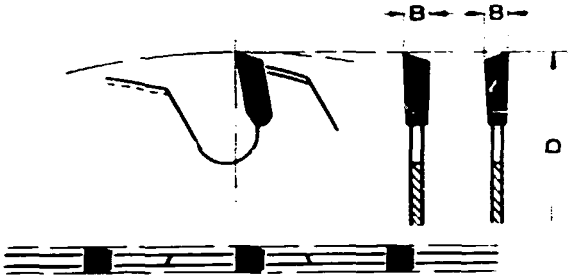
Applications:

- Cutting all materials in direction of feed
- Rip sawing solid wood (either broad leaved or coniferous) down-milling

Advantages:

Greater longevity
Easy maintenance
Can be used on wood which does not splinter easily

Figure 6. Alternating bevel teeth



Applications:

Down-milling with universal blade for sizing and squaring

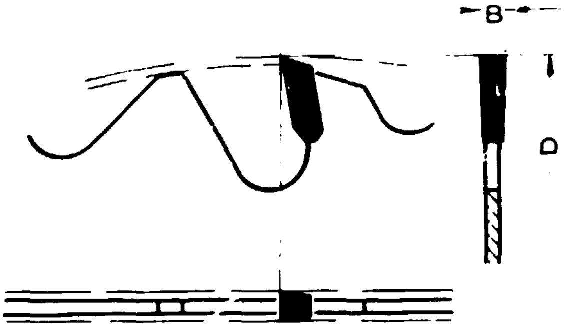
Advantages:

Cuts gradually from the point to the base of the tooth
Cutting width is only half: less splintering

Disadvantages:

Only every other tooth on each side is actually cutting

Figure 7. Straight teeth with chip thickness limitation butts



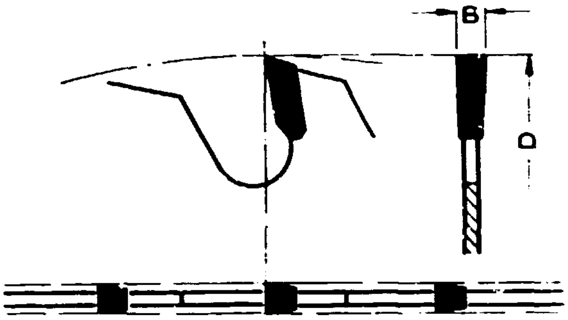
Applications:

For single blade manually fed sawing machines: down-milling suitable for ripping coniferous wood
Also used on multiblade sawing machines

Advantages:

The chip thickness limitation butt also pushes the wood away so feed is silent and uniform, and the teeth are not broken by knots or splinters

Figure 8. Concave face teeth



Applications:

For cutting down-milling

Advantages:

The two points lead to the centre of the tooth
The cut is always gradual, but not as gradual as with alternating teeth
The symmetrical curvature of the teeth makes for easier edge penetration

Disadvantages:

The cut is not subdivided
The number of teeth for a given diameter blade is limited because enough space must be left for sharpening
Increased maintenance cost
Cutting quality is immediately affected if feed is not perfectly horizontal
The teeth are smaller than usual because the grinding wheel has to discharge while it is making the gullet.

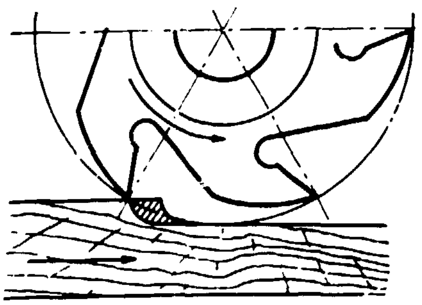
Milling cutters (moulding, shaping)

It is important to choose the right material for cutters and to select the right feed rate and cutting speed. If these operations are done correctly, chip thickness will be good and output will increase. Only high quality materials — such as high speed steel and carbide alloys — can be used for these tasks. Avoid using the cutter to remove very thin chips because this is closer to friction cutting than chip removal and the tools will not last very long. On the other hand, there will be more splintering with thicker chips.

Direction of rotation

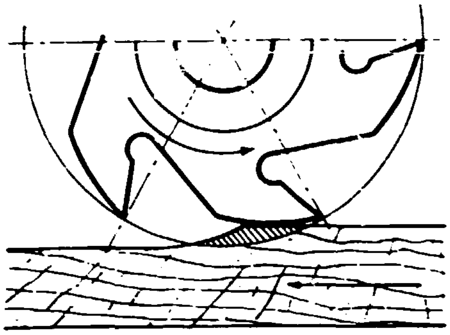
Cutters can either rotate in the same direction as workpiece travel (figure 9) or in the opposite direction (figure 10).

Figure 9. Cutter travelling in same direction as workpiece



Down milling

Figure 10. Cutter travelling in opposite direction of workpiece



Up milling

When they rotate in the same direction as workpiece travel the wood will have a better finish, because the cutter starts removing the thickest part of the chip first. Thus the chip is gradually separated from the workpiece without splitting or splintering. Furthermore, higher feed rates can be used. This technique cannot be used with manual-feed machines (because the cutter pulls the workpiece); it calls for larger clearance angles and this shortens the life of the tool. When the cutter rotates against the direction of workpiece travel, it start removing the thinnest part of the chip first and the cutting edge cannot get a good bite. First the edge compresses the wood, then it begins to penetrate. Chip thickness increases rapidly and chips are violently removed from the workpiece.

Cutter characteristics

Woodworking cutters may be made out of:

(a) High speed steel Cr-W-Mo-V alloy known commercially as HSS (high speed steel) especially suitable for normal cutting speeds. They have reasonable tool life. They are recommended for all types of natural wood; these cutters are not widely used today;

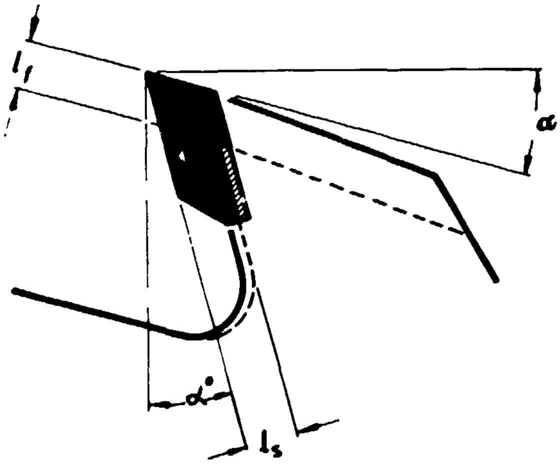
(b) High speed Cr-W-Mo-V-Co alloy steel. Such tools are suitable for high cutting speeds. They give longer tool edge life. This type of tool has almost completely replaced the HSS type. It is recommended for all types of solid wood and large-scale production;

(c) Carbide tipped tools with very high abrasive resistance. These tools are commercially known as HM (Hartmetall). They are recommended for working very hard wood and plastics.

Figures 11, 12, and 13 show tip positions for carbide tipped blades.

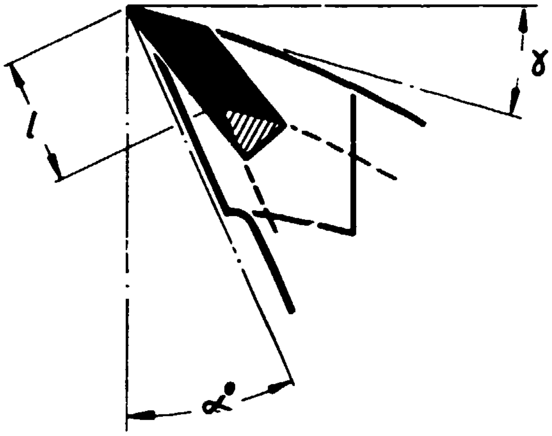
The rectangular system is normally used because both manufacture and maintenance are easy. This tip can easily be replaced (figure 11).

Figure 11. Rectangular tip shape (swage tooth)



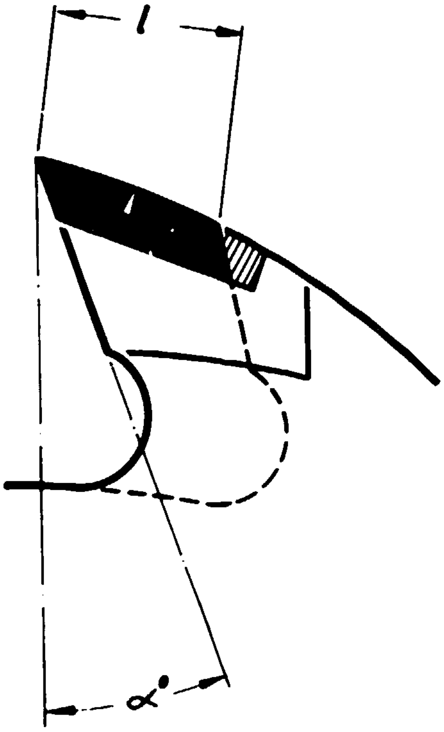
The top bevel tip allows constant and proportional edge wear during sharpening. It is not widely used because of high production costs. The tip cannot be replaced (figure 12).

Figure 12. Top bevel tip shape



The front bevel tip shape is normally used on constant profile cutters and on cutters which must maintain their maximum diameter (their maximum diameter must decrease as little as possible during sharpening) (figure 13).

Figure 13. Front bevel tip shape

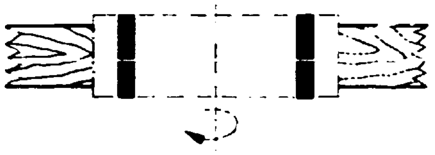


Edge arrangement

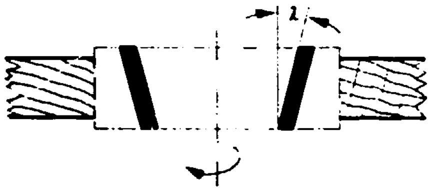
Edge arrangements (figure 14) include:

(a) Edges parallel to the axis, for working wood and plastics in general. This is sometimes used on shaping tools and is frequently used on cutter-blocks and cutter-heads;

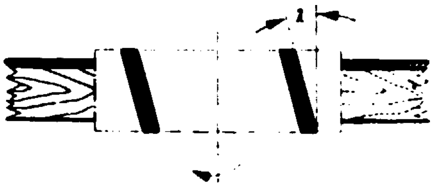
Figure 14. Cutting edge arrangements



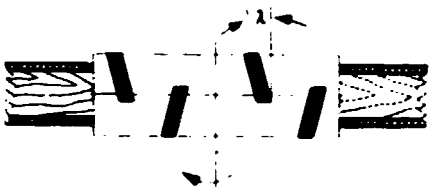
A. Cutting edges parallel to axis



B. Cutting edges inclined in alternate directions



C. Cutting edges inclined in the same direction



D. Pairs of alternating edges

(b) Edges inclined in different directions, for working solid wood and plastics without splintering the edges of the cut;

(c) Edges inclined in the same direction, for working wood with a plastic or wood veneer on one side;

(d) Edges inclined in the same direction towards the centre, for working wood with plastic, linoleum and other facing, on both sides. This arrangement is always advisable when very clean cuts are required. The angle ranges from 5° to 15°, depending on the thickness of the edge. Carbide edges have the configurations which vary according to the type of work.

Cutters for machining glue joints, rebates and tenons

Cutters may be:

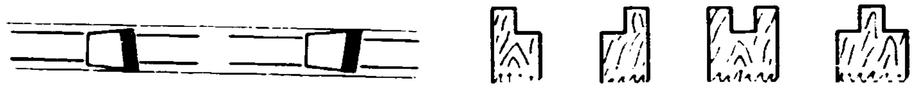
(a) Without spurs. The edges are inclined in different directions. The cutter cuts on both sides (figure 15A). (For glue joints, rebates and tenons in solid wood and particle board);

(b) With spurs on both sides. The edges are inclined in different directions; the cutter cuts on both sides (figure 15B);

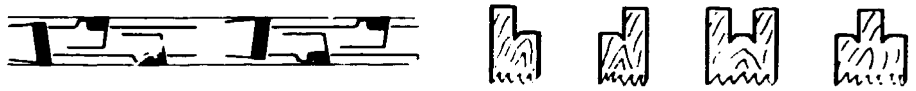
(c) With alternate spurs. The edges are inclined in different directions; the cutter cuts on both sides (figure 15C). (For glue joints, rebates and tenons in solid wood, laminated wood board and particle board);

(d) With spurs on one side (either right or left). The edges are inclined in the same direction (figure 15D). (For machining rebates and tenons in veneered or plastic-faced panels when perfect cuts are necessary.)

Figure 15. Cutting discs with and without spurs, showing cuts produced



A. Without spurs



B. With spurs on both sides

C. With alternate spurs

D. With spurs on one side

The spurs are always necessary in woodworking when the tool cuts against the grain or when veneered or plastic-faced panels are being cut. Furthermore, the number of spurs on each side of the cutter depends on the desired edge finish and the feed rate (figure 16).

Figure 16. A spur

ü = Spur depth

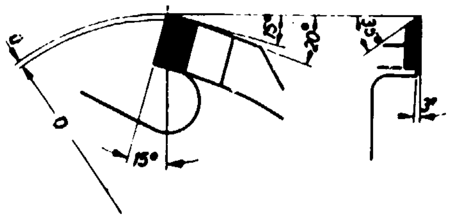


Table 7 shows the working angles for various materials.
Table 8 shows approximate cutting speeds for various materials.

TABLE 7. WORKING ANGLES FOR VARIOUS MATERIALS

(Degrees)

Material to be machined	*Working angle for*								
	HSS cutters			*Carbide cutters*			*Solid cutter heads*		
	γ	β	α	γ	β	α	γ	β	α
Softwoods	15	45	30	15	50	25	15	55	20
Hardwoods	15	50	25	15	55	20	15	55	20
Laminated wood board, plywood (not compressed)				15	60	15	15	55	20
Compressed and glued laminated wood board				15	63	12	15	63	12[a]
Thermoplastics				15	63	12	15	63	12[a]
Thermosettings				15	55	20	15	55	20

[a] Carbide tipped knives must be sharpened to 0.3 mm edge thickness to reinforce the cutting edge.

TABLE 8. APPROXIMATE CUTTING SPEEDS FOR VARIOUS MATERIALS

Material	*Cutting speed for straight edges (m/s)*	*Cutting speed for profiled edges (m/s)*	*Observations*
Natural wood	30-70	30-65	
Laminated wood	30-60	25-50	Low specific gravity (plywood etc.)
Laminated wood	25-50	20-45	High specific gravity and impregnated wood (compressed wood, laminated wood, compressed plywood etc.)
Solid compressed wood	25-50	20-45	
Hard plastic materials	30-60	25-50	Laminated panels with organic or inorganic cores
Thermoplastics	25-50	20-45	Low strength, heat sensitive material

Cutter heads

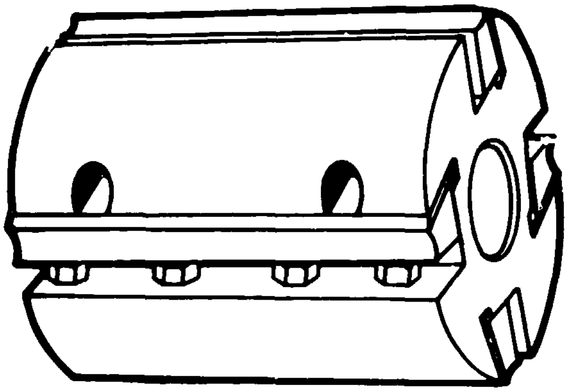
Cutter heads are widely used for planing with the grain. These tools are basically the same for all types of machines, planing machines, moulding machines etc. They are made out of high strength alloy steel; usually they are fitted with four knives which are held in place by wedges and a series of screws (figure 17). The wedges are the same length as the knives and they are hardened and shaped so that the knives will be firmly held in place during working. The knives can be quickly changed. Calipers or templates are used to align the knives. A spring built into the cutter head presses against the back of the knives.

Special, very high strength light alloy cutter heads are presently used on moulding machines.

Routing bits

For greater stability, most small cutters are made for Morse taper chucking. The shank mounted tools have a relatively small cutting diameter, so when they are used on normal moulding machines they often work below their optimum cutting speed. Therefore, it is best to use these tools on machines with high spindle speeds such as routing machines with 12,000 rpm or even more.

Figure 17. A cutter head



Routing machines are used for template-controlled shaping. Single-fluted cutters are usually used. These are chucked eccentrically so the edge can cut the base of the hole without exerting pressure on the outside of the cutter. Therefore, the radial rake angle can only vary within a certain range. When $\gamma_l = 30^\circ$, the radial rake angle γ_f reaches the optimum value. This is especially true for chip removal with softwoods.

For larger angles — $\gamma_l \approx 50^\circ$ — the radial rake angle γ_f and the cutter diameter D are decreased. This adjustment is always recommended for working laminated boards, plastics and light metal alloys. The amount of eccentricity is equal to the average distance between the secondary edge and the cutter axis. These cutters usually work against the feed direction of the workpiece, thus preventing the surface edge from splitting. A template below the workpiece is guided and makes internal and external cuts. A limit stop in the corners is sufficient for cutting simple shapes which are parallel to the outside edges of the workpiece. Templates are required for more complicated cutting tasks. If there is a lot of play in the shaped panel, the cutter should rotate against the direction of workpiece travel. Furthermore, both arms should be used to shift the template table; the operator should never lean against it because incorrect feed increases the risk of breaking the tool.

Flute router bits

Because of their shape, single flute router bits (figure 18) are unstable.

This situation is particularly evident when deep cuts are being made and the tool is subject to high or intermittent pressure. In these cases, the double flute router bits (figure 19) are more suitable because they have a more stable shape.

These tools are mounted concentrically on the spindle; they have either a straight shaft or a Morse taper DIN 228.

Maintenance

A cutter with inserted carbide knives or a circular-saw blade with inserted carbide teeth is a valuable tool and it deserves the best treatment. These tools are not particularly delicate, but they must be kept in good condition. The carbide tips must be protected from blows. Never lay them on hard surface. Always put the tools in their case when not in use. The cutter cups, spacers and locking flanges must always be kept perfectly clean. The knives must also be kept clean because resin deposits or other material can cause overheating during cutting (when this happens, the tools take on a bluish colour). This overheating shortens tool life and destroys tensioning. This normally puts

Figure 18. Single flute router bits

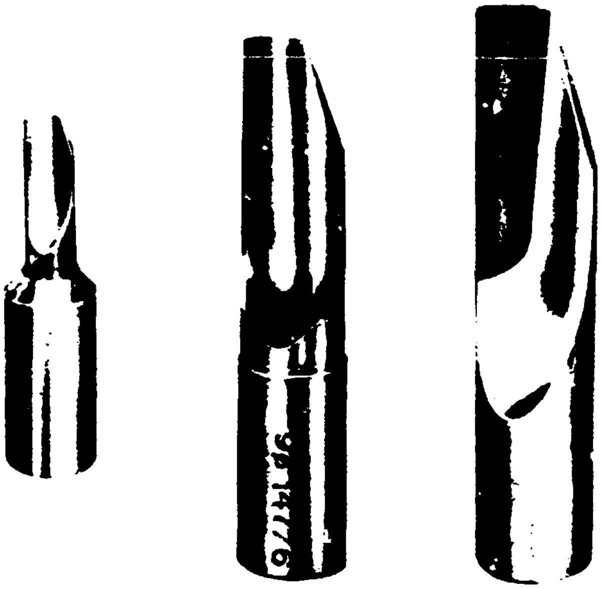
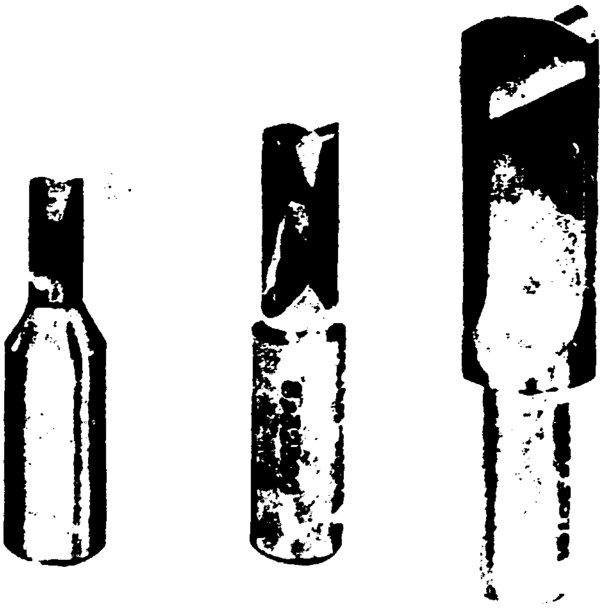


Figure 19. Double flute router bits



the tool out of balance and it no longer rotates concentrically. Special solvents for removing these deposits are available (but if it is impossible to find them, the tools can be immersed for a short time in a water and caustic soda solution). Carbide-tipped and high-speed-steel tools must be sharpened before it is too late. Using tools which have lost a great deal of their cutting power is not economical. Sharpening badly worn cutting edges is more expensive and badly worn circular-saw blades and cutters which are sharpened will not last as long (more time is required for sharpening and more abrasive grinding wheel and tool tip material is consumed). Therefore, periodic inspection of edges is advisable. The cutting edge must never be more than 0.2 mm thick because dull edges increase cutting pressure.

Tool maintenance equipment

Good sharpening is indispensable for keeping tools in good working order. The original working angles must be maintained. Therefore the sharpening department must be equipped with the following:

(a) A universal tool sharpening machine. It must be solidly built, vibration free and the grinding wheel spindle must be mounted on a bearing which allows it to rotate around each of two axes. The spindle must have at least two speeds — 2,800 and 5,500 rpm — so the correct speed can be used with different diameter wheels. It should have a movable slide mounted on guides and provided with devices for micrometric positioning, and a tool holder which can be turned and inclined along each of two axes. It must be provided with a standard disc with 24 divisions and a micro-metric screw so the angles can be set correctly. Cutter spindles which can be mounted on the tool head should fit with the required tolerance. There should be flat parallel spacers and a device for concentric adjustment;

(b) Automatic sharpening machine for carbide-tipped circular-saw blades; this machine is able to sharpen any shape tooth with absolute precision;

(c) An automatic sharpening machine for making carbide-tipped circular-saw blades perfectly circular. This operation used to be done (and sometimes it still is) by hand. It took a long time and it was not very precise. The diamond grinding wheel only removes metal from the carbide tip. It does not remove the steel from the body of the blade (this would greatly decrease the life of the grinding wheel);

(d) An automatic sharpening machine for chrome-vanadium circular-saw blades. This is normally also used for sharpening band-saw blades;

(e) Saw setting equipment for band-saw and chrome-vanadium saw blades;

(f) An automatic sharpening machine for planing machine cutters;

(g) An automatic sharpening machine for band-sawing machine blades;

(h) A bench-mounted grinding wheel for normal roughing.

General rules for sharpening

Remove the same amount of material from all the edges: this will keep the tools balanced and avoid eccentricity.

For integral HSS tools, grinding wheels having the same radius as the saw must be used to work the base of the edges; avoid local overheating. Grinding wheels with sharp edges and overheating cause initial breakdown in tool steel and make tools dangerous. Always use cooling fluid during sharpening. Sharpening can be divided into three steps: roughing, finishing and lapping. The last operation is often thought to be superfluous, but it is a good way of increasing edge life.

Specific sharpening rules

Routing bits are sharpened as shown in figures 20-23.

The profiling cutters are always sharpened on the face, without changing the original working angles so that the profile will always be the same (figure 24).

Since the cutters for jointing usually have a constant profile, only the backs of the edges are sharpened so the size of the joint will always be the same (figure 25).

The spurs on rebating and jointing cutters are only sharpened on the back; they must project 0.3-0.6 mm (figures 26, 27).

The chip limitation butt is lowered by circular grinding, so that it is 0.6-0.8 mm lower than the edges (figure 28).

When sharpening the circular cutter units for double end tenoning machines, unscrew the circular edging saw blade; the sector teeth are not removed for sharpening. If the sector teeth are in the "step cut" position, they should be set in the circular position before sharpening.

Carbide-tipped circular-saw blades must be sharpened both front and back. Never sharpen the sides.

Chrome-vanadium circular-saw blades and band-saw blades are normally sharpened by automatic sharpening machines which restore the original profile. Wide and narrow band-saw blades are also set while they are being sharpened.

Figure 20. Sharpening a double « v » flute routing bit by back grinding

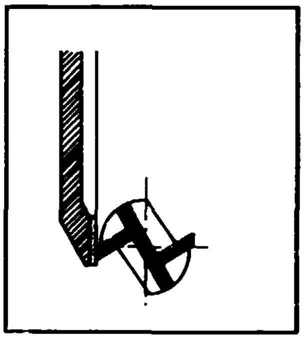


Figure 21. Sharpening a double « v » flute routing bit by face grinding

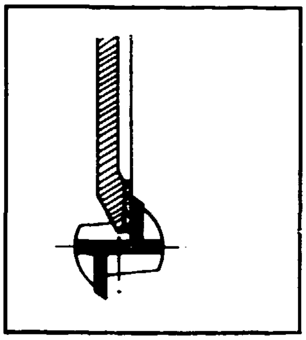


Figure 22. Sharpening a routing bit with a single edge « o » flute

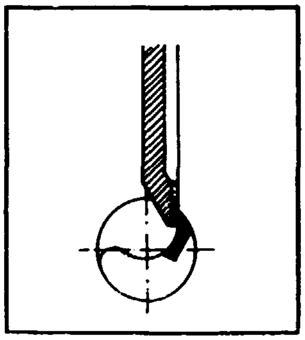


Figure 23. Sharpening a routing bit with a formed grinding disc

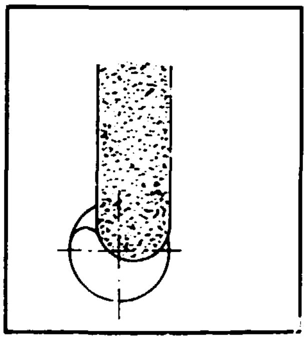
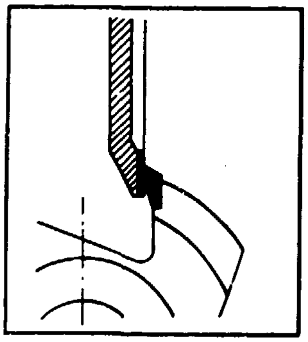


Figure 24. Sharpening a profile cutter by face grinding



Thin grinding wheels should be used for sharpening HSS bits so both the cutting edge and the spur will be sharpened at the same time.

Figure 25. Sharpening the back of a cutting edge

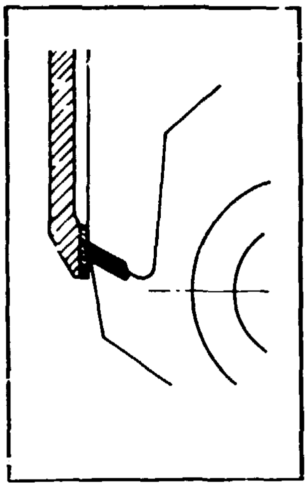


Figure 26. Sharpening the back of a spur

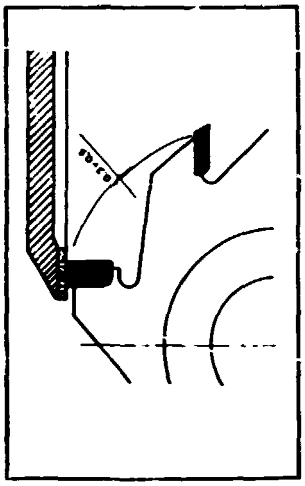


Figure 27. Sharpening a planer knife

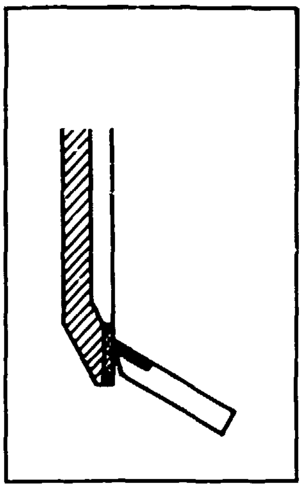
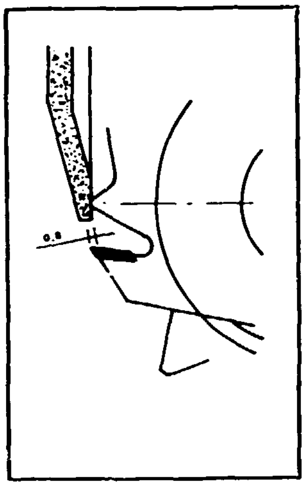


Figure 28. Regrinding chip limitation butt



Safety rules

Never use a tool with too big a hole without using the right reducing bush with calibrated tolerance.

Never angle the tool (in relation to the direction of workpiece travel) in order to obtain a wider cut.

Do not weld broken or seriously damaged tools.

Avoid unbalanced tools. These are usually caused by improper sharpening. Make sure that the tool is concentric with the shaft; if it is more than 0.01-0.02 mm off centre this defect must be corrected.

Never exceed the maximum rotation speed marked on the tool or shown in the catalogue. Always use the ideal cutting speeds indicated for the various materials.

Always mount all necessary guards before using the tools.

VI. Power-supply and auxiliary systems in wood processing industries*

The continual evolution of machinery and production system, the growing need for safety, the need for improved working conditions, and the need for adherence to environmental requirements, has required improved design and construction approaches to the furnishing of power supply facilities, especially those in the field of wood processing. Therefore, the design of power supply facilities must proceed hand in hand with the design of manufacturing units. Thus when equipment is selected it will be compatibie with the entire manufacturing system.

As power unit systems are essentially service installations they must be chosen to ensure plant efficiency. They must also be designed to allow for future expansion. The purpose of this chapter, therefore, is to suggest a guideline for general design of these installations, without claiming to exhaustively cover this complex topic, which is always subject to continual improvements and innovations. The sections which follow will deal with:

Electricity supply and distribution system
Chip and dust conveying systems
Compressed air stations
Heat generation and distribution
Water supply and distribution

Electricity supply and distribution system

Electric systems consist of:

Transformer station
Distribution to machinery
Lighting
Earthing and lightning rods
Auxiliary facilities

Transformer station

Since factories are often located far from power stations and since power demand is ever increasing, transmission at intermediate voltages is becoming more common. The designer must make provision for an "intake transformer house" at the factory where current is received and stepped-down to the desired voltage. In medium to small factories the two facilities, intake and transforming, are usually adjacent. These facilities are separate in larger factories, where the transformer house is equidistant from the intake and the equipment. Transformer houses contain the transformers together with their switchgear, fuse-boxes and main board. This board contains all control switches and feeder connections to the mounted panels for various departments. A section of the board contains the phase advancers.

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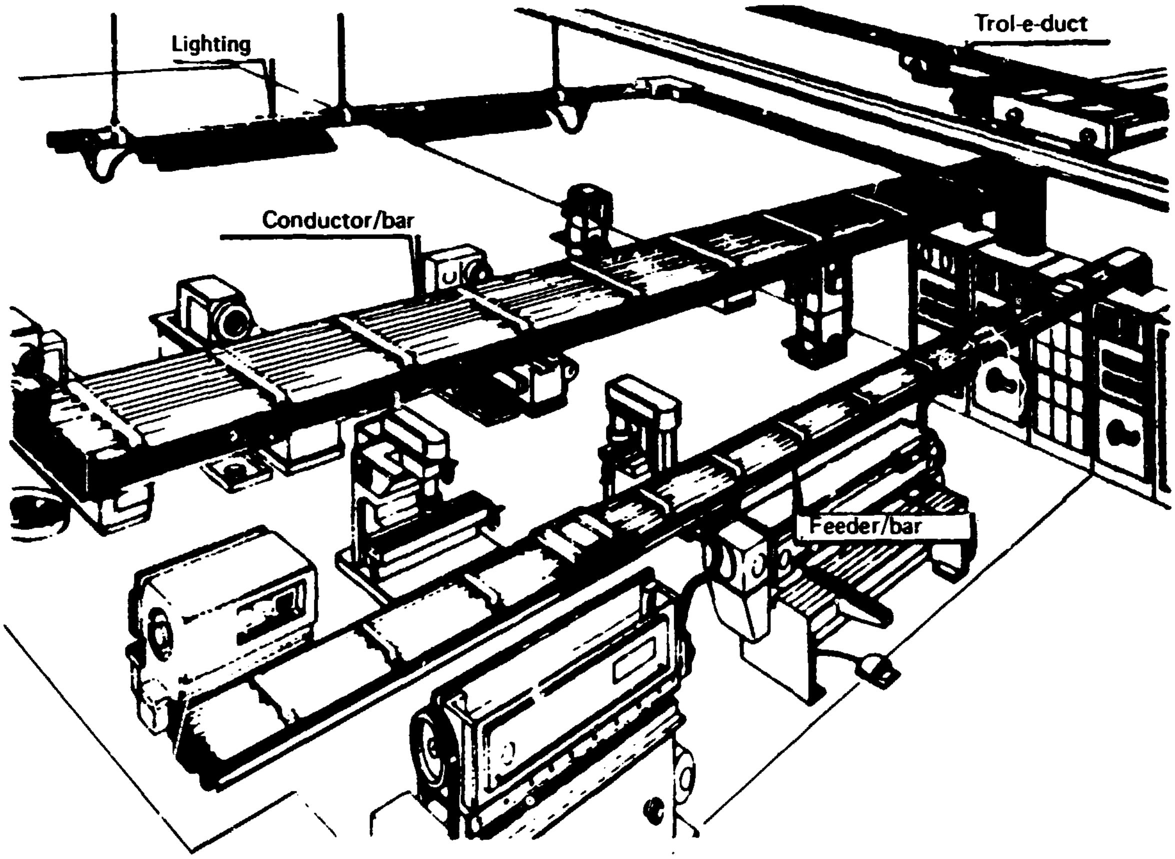
* By A. Mottadelli, freelance professional consulting engineer. (This is an edited version of ID/WG.277/13.)

The most frequently used system of distribution is the radial type. Feeder lines branch out from low voltage busbars, which are protected by a circuit breaker in the transformer house. Quantity and location of local panels depend essentially upon the layout and arrangement of the machinery. Normally each bay or service facility should have its panel, located near the bay so as to guarantee easy access. Primary cables, from transformer house to local panels, are usually laid in underground PVC tubing, with frequent inspection wells. Secondary distribution is achieved usually by means of prefabricated systems.

The busbar system (figure 1) consists of rectangular cross-section copper or aluminium bars complete with a wide range of accessories designed to allow quick connection of shunts and protections.

Figure 1. The busbar system



The advantages are:

(*a*) Independence from restrictions imposed by building structures and location of users;

(*b*) It is possible to dismantle and adjust the system to new demands;

(*c*) It is possible to dismantle and re-use the installation in case of changed utilization of the area serviced;

(*d*) Rapid installation and dismantling.

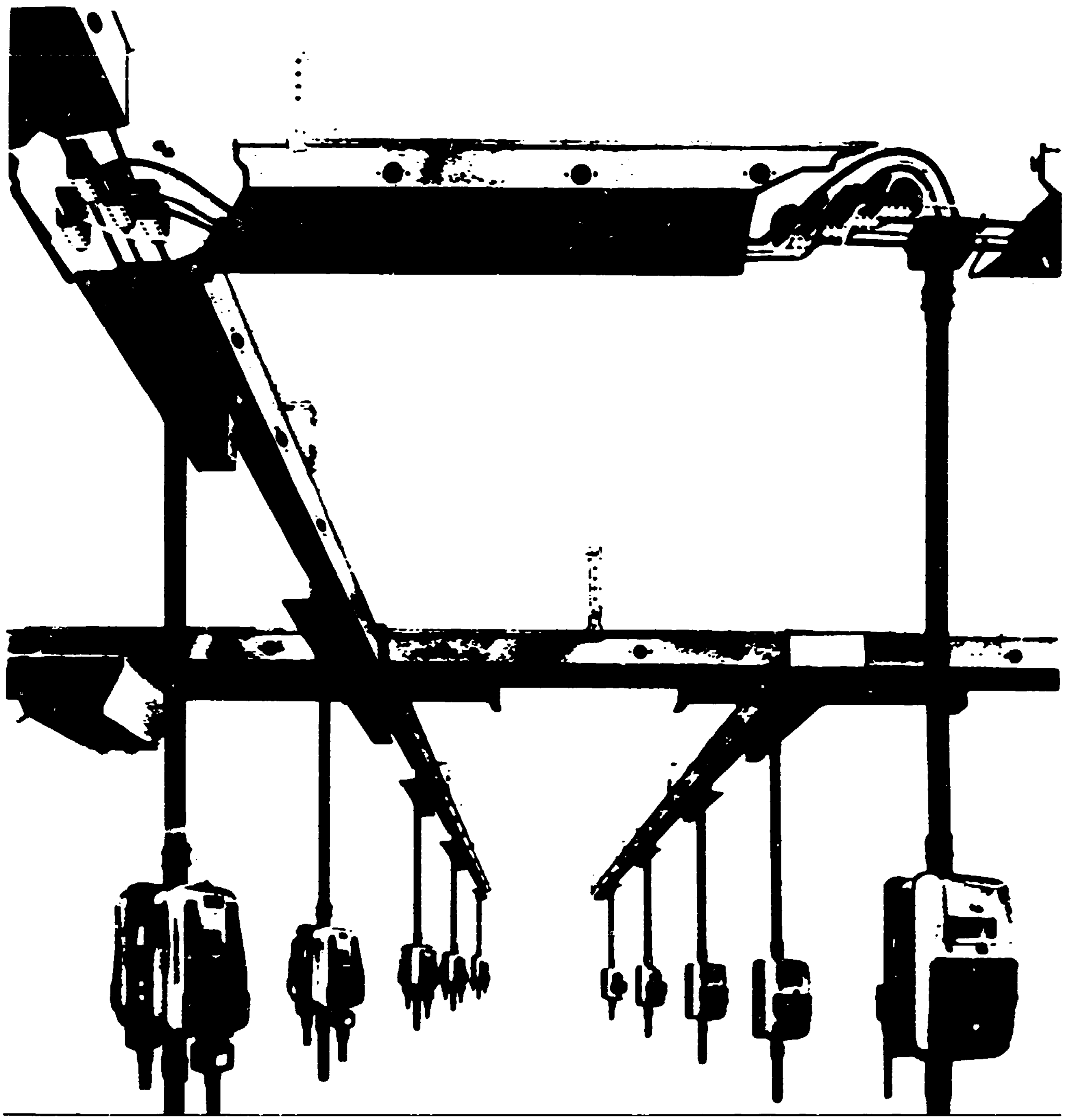
The disadvantages are:

(*a*) It is more expensive than the cable system;

(*b*) A separate system must be provided to supply lighting fixtures;

(*c*) Line insulation is more difficult with busbar systems than with cable systems.

Figure 2. The box system



The cable-tray or box system consists of metal channels or trays supported by the building structures within which copper conductors are laid (figure 2). This type of installation is usually preferred in the woodworking industry. In addition to possessing most of the advantages of the metal enclosed conductor system, it has also the following advantages:

(a) Lighting fixtures for normal, night and emergency use can be attached under the trays with the corresponding cables inside the channels;

(b) Cables feeding signal, personnel call, sound systems etc. can be put in the channels;

(c) It is possible to supply various groups of machinery from the local panel. For example,

all the machinery making up a sizing-edging line, using a feeder separate from that bringing power to the pressing machines;

(d) It is always possible to give more power to a line by adding a new cable in parallel with the existing one.

In some cases both systems, busbar and cable-tray, complement each other. There may be a main system of the cable-tray type and some secondary branches of the metal enclosed busbar type. For example, bridge cranes are fed by a cable-tray system and the assembly lines, which are subject to rapid fluctuations in load, use sections of metal enclosed busbars. Cable-tray systems are installed above cloth and leather cutting benches, while small busbars are used for sewing machines.

Connections to machinery are made by PVC or steel-tubes containing the feeder and earthing cables. Protection is ensured by a fuse switch.

Lighting

The installation includes:

Normal lighting

Distribution of normal lighting should be as uniform as possible, without shadows or reflections. Lighting fixtures with 65 W fluorescent bulbs which provide the maximum amount of light per unit cost, the cheapest at equal lux, are usually preferred for average height buildings (5.5 m). Lighting values adopted for workrooms are 200-250 lux and 80-100 lux for warehouses.

Night and external lighting

A separate circuit feeds a series of lamps (normally 20 W fluorescent lights) which supply lighting at night. A second circuit feeds lamps outside buildings. Both circuits can be turned on or off at twilight by an automatic relay.

Earthing and lightning rods

All electrical equipment and metal masses must be earthed. This is accomplished by laying the proper line in a closed circuit inside the factory, and earthing it underground through dispersion wells. It is also recommended to have a lightning rod capable of covering the entire factory.

Auxiliary facilities

These include all those facilities which, although not essential, satisfy widespread demands. They are:

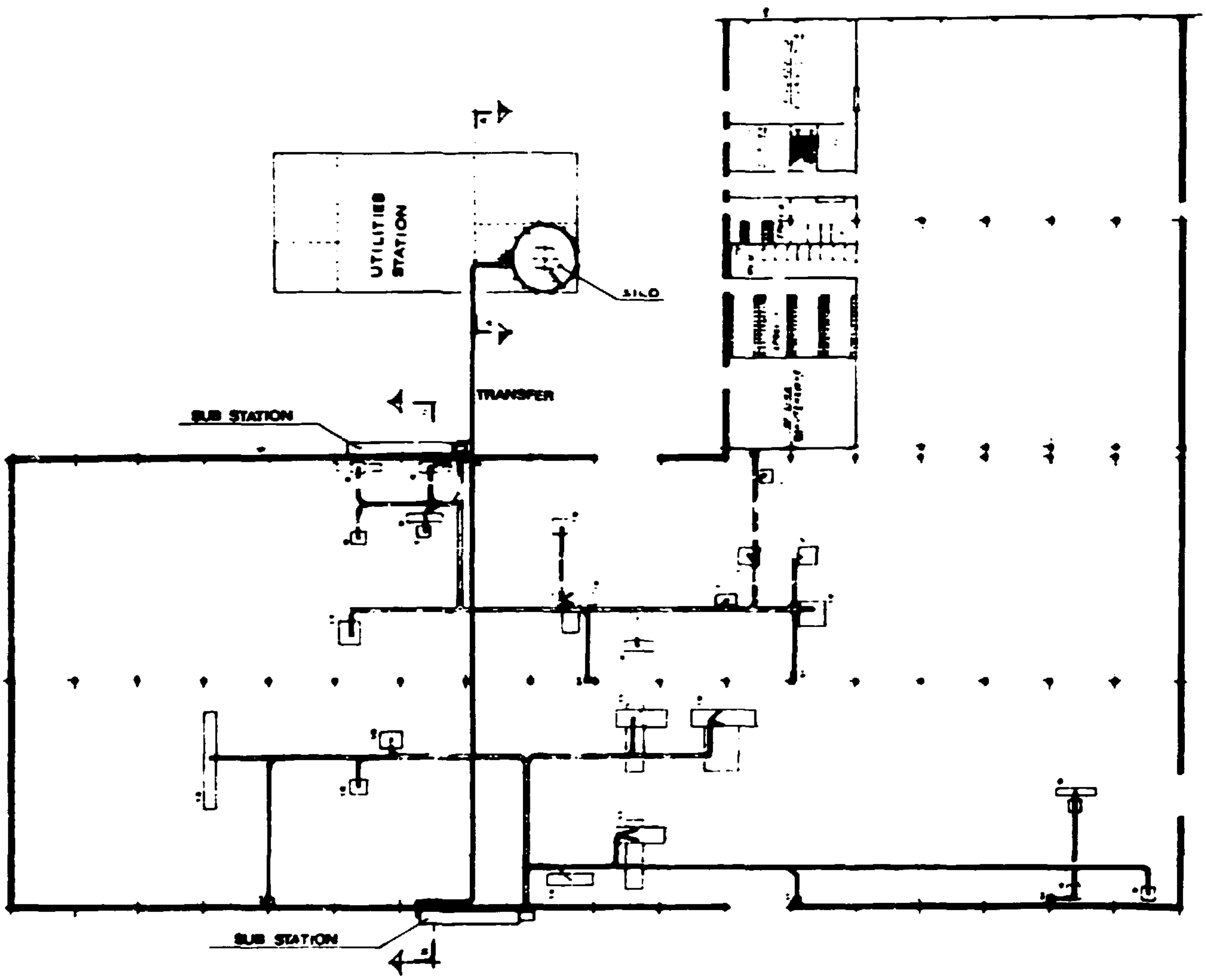
Personnel call systems, which can be radio, sound or light devices
Internal telephone system
Loudspeaker system
Emergency lighting, supplied from storage batteries
Emergency power, supplied by current generators, in case of failure of the main supply

Chip and dust conveying systems

Chip and dust conveying systems have two functions. The first is to collect chips, sawdust and sanding dust generated in wood processing. The second is to convey these waste materials from one area of the plant to another.

Plants working on wood and manufacturing wood panels will mainly use the collection function and hence importance must be given to chip and dust collection despite the high amounts of energy used. Plants where wood chips and dust are the raw material to be processed, such as those manufacturing particle board, need to convey the waste. In these cases a comparison should be made of pneumatic versus mechanical conveyance systems.

Figure 3. Layout of a pneumatic system



GROUND FLOOR PLAN

A pneumatic system shown as a layout plan in figure 3 has these advantages:

(*a*) It uses simple machinery;

(*b*) The system uses a minimum amount of duct lines;

(*c*) The conveyor can pass above buildings, roads etc. or underground and generally can be routed through areas where access for maintenance would be difficult;

(*d*) It is easy to modify after installation.

The disadvantages are:

(*a*) High power consumption (five times as much approximately, as that required by mechanical conveyors);

(*b*) Limits on size of material to be handled;

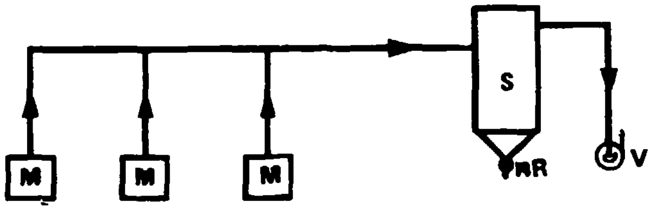
(*c*) Difficulties arising in separating the air from the dust at the outlet. This requires the use of costly and cumbersome filtering units.

Suction technique

A suction technique is diagrammed in figure 4. Its advantages are:

(*a*) Simple construction;
(*b*) It can be connected to machinery or stockpiles;
(*c*) The material does not pass through the fan.

Figure 4. Pneumatic exhaust system, suction technique



Key: M Machine
S Silo or substation
V Fan
R Rotary valve

The disadvantages are:

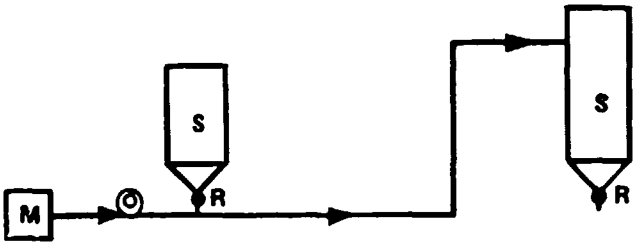
(*a*) A limited capacity, as it is difficult to obtain pressures below 0.4 atm. using fans or below 0.9 atm. using pumps;
(*b*) At lower pressures air does not carry material satisfactorily.

Pressure technique

The advantages of a pressure technique (figure 5) are:

(*a*) It is possible to increase pressure at will;
(*b*) Higher air density hence better carrying capacity.

Figure 5. Pneumatic exhaust system, pressure technique



Key: M Machine
S Silo or substation
V Fan
R Rotary valve

The disadvantages are:

(*a*) It cannot be used to collect chips and dust from the machine;
(*b*) There are greater difficulties encountered bringing material into the system.

Combined suction-pressure technique

The two techniques may be combined to give the advantages of each, and hopefully to minimize the disadvantages.

Selection of suitable network

Networks may be classified as centralized systems or substation systems.

A centralized system

When processing machines are grouped in a narrow area located near the utilities plant, it becomes more convenient to adopt the centralized system (figure 6A) with its network of vacuum piping connected directly to a central storage facility.

A substation system

In larger factories where groups of machinery are located at various distances apart, a substation system (figure 6B and 6C) is usually preferred. In this system every group of machines is joined to its own exhaust filter (substation) equipped with an adequately sized storage hopper. Chips and dust are picked up from this hopper, either continuously or at scheduled intervals and sent by way of a secondary piping system to the central storage bin or silo. Although at times more expensive than other types, this system is preferable, particularly for large factories, because of its advantages:

(a) Less power is required for suction since substations are located near the machinery. Also, conveyance of chips from the substation to the central silo requires less power and small diameter piping as it is possible to have a relatively high shavings weight to air volume ratio;

(b) For the same reason it is possible to obtain more uniform exhaust from the machines;

(c) There are fewer risks of breakdown. Failure of one substation does not stop the operation of machinery served by the other substations. Furthermore, if exhaust filtering units are equipped with an adequate storage hopper, exhaust will be sustained during temporary stoppage of the central storage station;

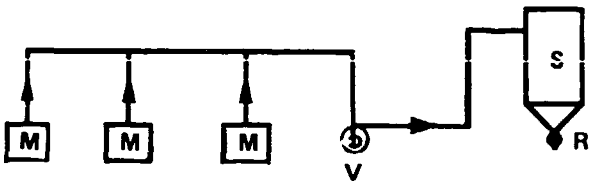
(d) The factory can expand, adding new substations, without any modifications to the existing substations or to the central storage station. It is also easier to make modifications to the existing substation systems;

(e) Any fire, an ever-present risk on this kind of plant, can be limited to the substations and rarely does it reach the storage station. This is particularly true in the case of substations with hoppers periodically emptied by an operator, who will then be able to notice the presence of smoke. It is a good rule, furthermore, even when not required by safety regulations, to locate substations outside the factory, placing fire baffles on exhaust piping.

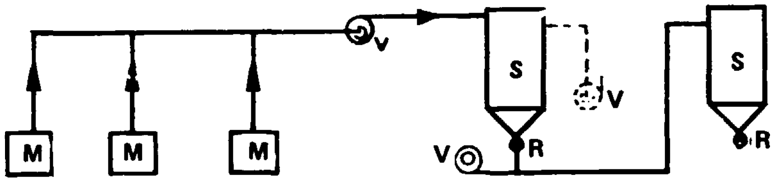
A combined system

A combined system has advantages for furniture manufacturing plants. In some factories sometimes there is a large group of machinery concentrated in one area and another group at a peripheral area away from the silo. In this case the large group of machines can be served by a centralized exhaust system and for the peripheral ones a substation will be provided. This is shown schematically in figure 6D. The combined system is generally used by furniture manufacturing plants. The substation serves the non-grouped machines. A combined system, moreover, is usually the best method of expanding an existing "centralized" system.

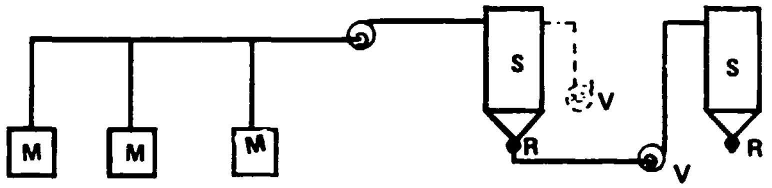
Figure 6. Various collection systems



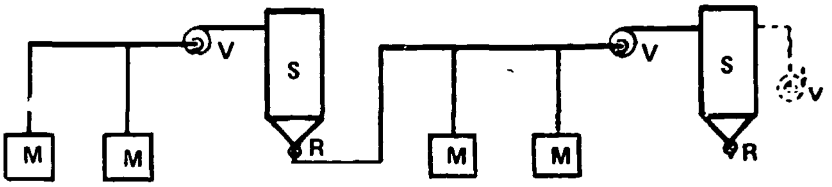
A. A centralized system



B. A substation system



C. A substation system with fan behind rotary valve



D. A combined system

Key:	
M	Machine
S	Silo or substation
V	Fan
R	Rotary valve

Components of an exhaust plant

The exhaust plant consists of a piping network, fans, substations and silos.

Exhaust hoods

Usually machines are sold complete with exhaust hoods. Unfortunately they are not always well designed and at times fail to satisfy particular manufacturing conditions and must therefore be modified or adapted. A check vane should be installed between the hood and the exhaust. The hood can be connected to the piping system by means of fixed pipes in case of stationary equipment and flexible piping for mobile equipment. The flexible piping wears quickly, especially at bends. Bending sections should be avoided or else curved sections should be constructed of metal sheet.

Pipes

The piping should be steel for medium and high pressure installations and sheet metal for low pressure. In this case wall thickness should be:

$$T = 0.5 + \frac{\text{diameter}}{1{,}000} \text{ mm}$$

Pipe sizes should be larger than needed, to allow for future addition of machines and to limit air velocity and thus limit the waste of electric energy. It is advisable to maintain air velocity above 25 m sec in order to avoid chip pile-up inside the piping, causing clogging.

Fans

Centrifugal fans are used on low pressure systems (those with 0.6 atm. maximum). These fans are used in cases where rotary blowers may be obstructed. The systems have relatively low cost, quite good efficiency and are unaffected by the material. Medium to high pressure conveying systems require rotary blowers with a pressure capacity of 4 atmospheres.

Fans must be heavy-duty types and if the design is such that material must pass through the blades, should be designed so the material will pass through easily. Fan to motor coupling is usually carried out by belt and pulley so as to ensure, in addition to a smoother start-up, that capacity and pressure can be varied by varying the number of revolutions of the fan.

It is advisable to install fans of low rpm (1,300-1,400 rpm) so that it will be possible to increase performance if it should become necessary as a result of plant expansion or modifications.

Air separators

At the point of arrival of the transfer line it will be necessary to install units to separate chips and dust from air. The most widely used are cyclones and filters.

Cyclones

Cyclones consist of a conical or cylindrical-conical shell into which the flow enters tangentially. The solid matter slows down and falls to the bottom while the air flows out through the top. The smaller the diameter, the greater the efficiency of these cyclones. The centrifugal force is inversely proportional to the radius of the cyclone.

$$F_c = \frac{Gv^2}{gr}$$

where

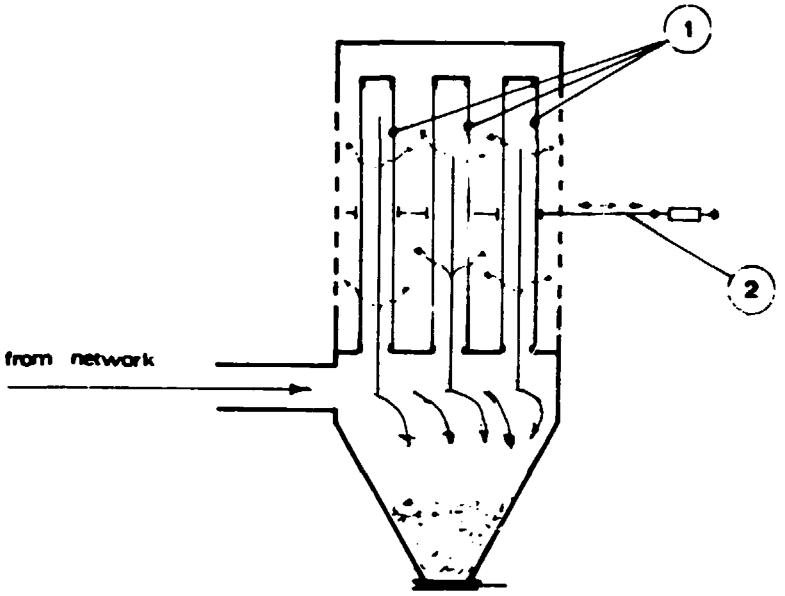
F_c = centrifugal force
v = velocity
r = radius of cyclone
g = acceleration of gravity
G = weight of particles

If a higher rate of separation is desired it will be necessary to install several cyclones in parallel or multi-cyclones.

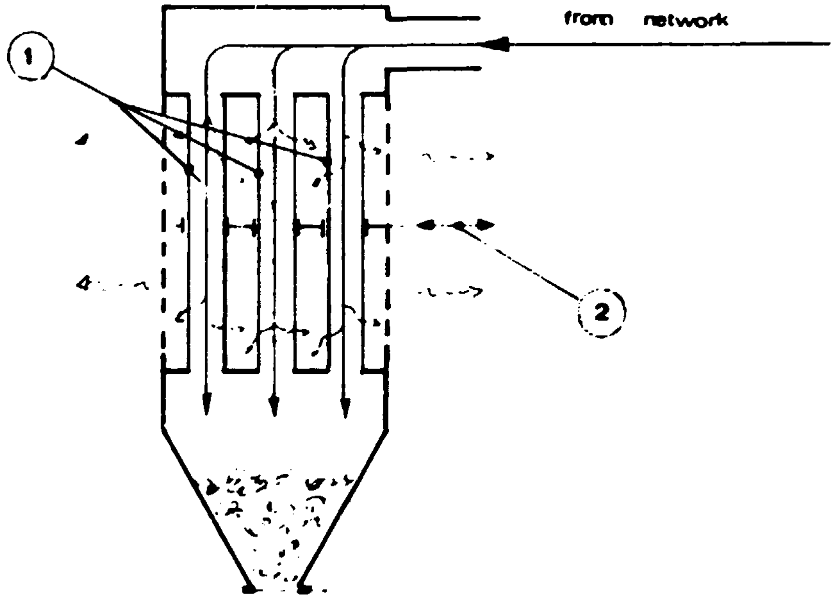
Filters

Better separation can be achieved if the flow passes through a filter which also collects dust. Such a filter is usually composed of a series of cloth tubes (cotton nylon etc.) inside a box. The flow enters the box, goes through the tubes, deposits the dust and leaves. The cloth tubes are cleaned periodically by shaking off the dust to fall to the bottom of the box (figures 7A, 7B). Figures 8A and 8B illustrate more efficient methods of cleaning the textile tubes. The first one possesses a number of jets that release compressed air inside the tubes thus dislodging the dust attached to the external surface. In the second one automatically controlled dampers reverse the flow of air through the tubes. These devices contribute to maintaining a virtually constant efficiency of the filters.

Figure 7. Filtering systems with vibratory frames



A. Bottom inlet filter system



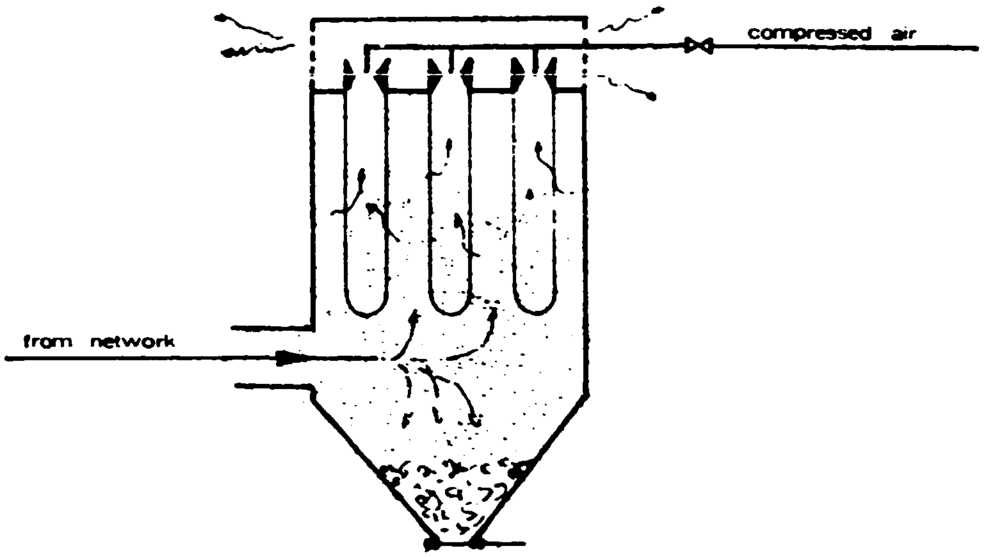
B. Top inlet filter system

Key: 1 Filtering hoses
2 Vibratory frame

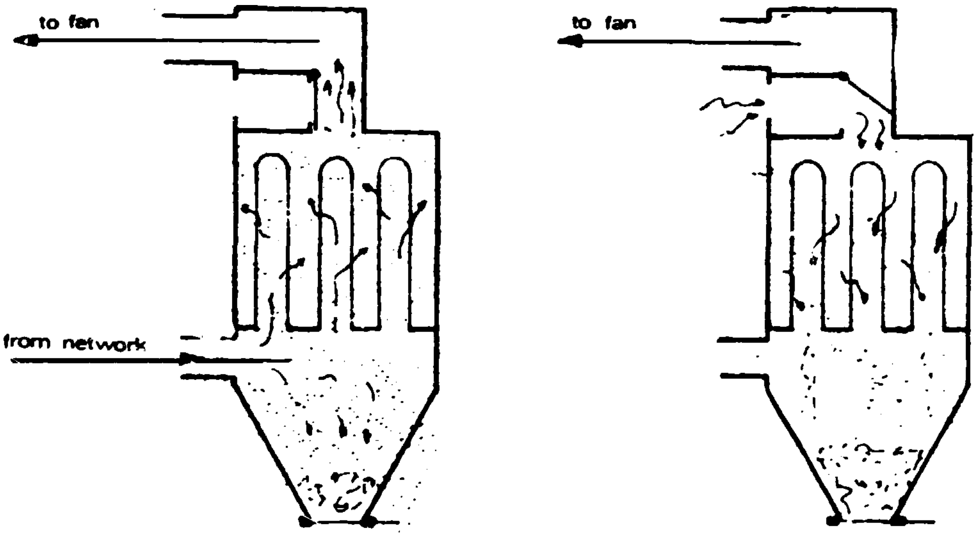
Substations

Substations consist of a metal structure housing a certain number of tube filters. Underneath they have a storage hopper equipped with an extraction mechanism. Filters must be equipped with a

Figure 8. Filtering systems with compressors



A. Compressed air wash filter



B. Backwash filter

vibratory device (ideally pneumatically operated) for periodical cleaning. Chips can be removed from the hopper by means of screw conveyors or raker conveyors. Downstream of the extractor it is necessary to install a rotary valve to apportion the discharge and separate pneumatic transfer system from the system local to the filters.

Silos

The silo can be in masonry, reinforced concrete construction or even metal construction. The reinforced concrete silo is cheapest and therefore often chosen. The cross section of the silo may be square. circular or polygonal. Nowadays metal silos are constructed with a polygonal base (8, 12, 16 sides) which make it possible to use flat sheets which are easily prefabricated and may be easily adjusted to fit various diameters. A square cross section is not recommended as the chips-extractor cannot remove shavings from the corners. The upper part of the silo houses the tube filters and their cleaning devices. The centre part is used for dust and chip storage. Silo height should not be more than approximately twice the silo's diameter because otherwise the material will tend to "bridge". At the bottom of the silo there is an extractor for removing chips. At present there are in operation various types of extractors that give a good performance. Some of these are shown in figure 9. They are all widely proven and dependable. It is, however, essential that any mechanical part buried in the shavings be heavy-duty. This is because in case of extractor failure, shavings must be removed by hand which, especially for large silos, is never an easy operation. This problem is less frequent with the conical scraper extractor as its mechanical parts are outside the chip area. Various accessories complement the silo, including:

- A ladder leading to the filter chamber
- Doors for inspection of the shavings level
- Gates for manual discharge at the bottom
- Quick-opening explosion-proof doors
- A sprinkler system

A sprinkler system can be actuated by a fire detector located inside the silo. In this case the lower part of the silo must have doors which open automatically to get rid of the water, otherwise the water pressure would become too great.

Compressed air stations

Compressed air has boosted productivity in many woodworking plants. It is therefore necessary to examine, from the standpoint of performance and cost, choices of compressors and choices of sizes for the pneumatic piping system.

Compressor types

Air compressors belong essentially to two categories: positive displacement blowers and dynamic compressors. Positive displacement blowers take in air and force it into a chamber thus compressing it. In dynamic compressors air is sucked in by the action of a rotor and acquires high velocity. The kinetic energy developed by the air is then transformed into energy used to raise the air pressure in a device called a diffuser.

Positive displacement blowers are generally preferred to dynamic compressors. There are the reciprocating, screw and blade types of compressors. Reciprocating compressors compress by means of one or more cylinders, inside which pistons compress the air. As these machines are particularly strong and easy to maintain, they are used for continuous heavy-duty operations.

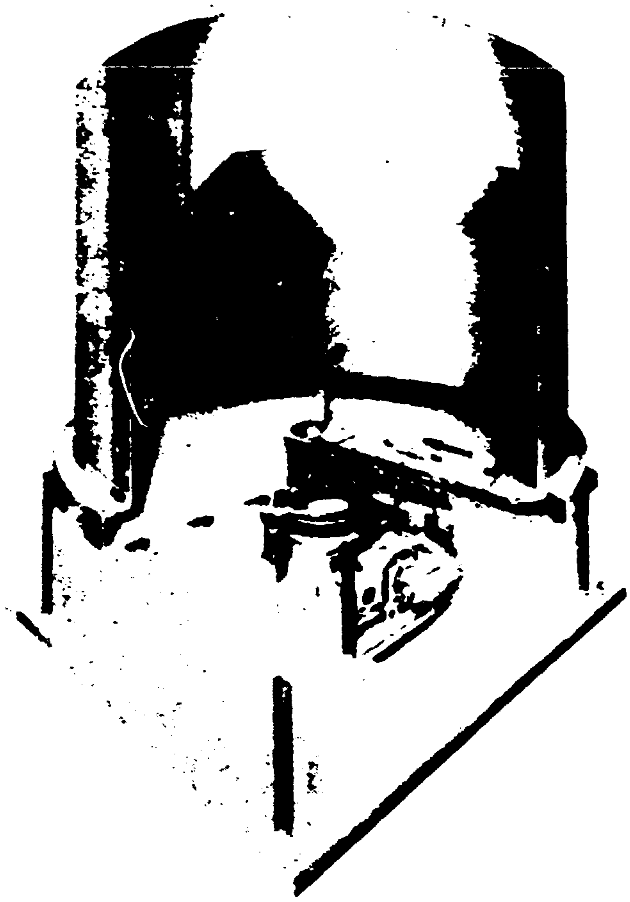
Screw compressors have a rotor chamber within which two rotors rotate in opposite directions. Air enters through the suction inlet, is compressed between the rotors and leaves the chamber through the discharge outlet. As no contact exists between the rotors and between these and the chamber walls, there is no need for lubrication. Hence these machines are especially suitable where there is a requirement for totally oil-free air.

Blade compressors have a cylindrical casing inside which another cylinder with radial blades rotates eccentrically. The volume of air between the blades diminishes progressively from inlet to outlet, thus compressing the air. These compressors are virtually vibration free and therefore do not need a supporting pad. They respond quickly to demand fluctuations. However, they have a high oil consumption and need careful and regular maintenance.

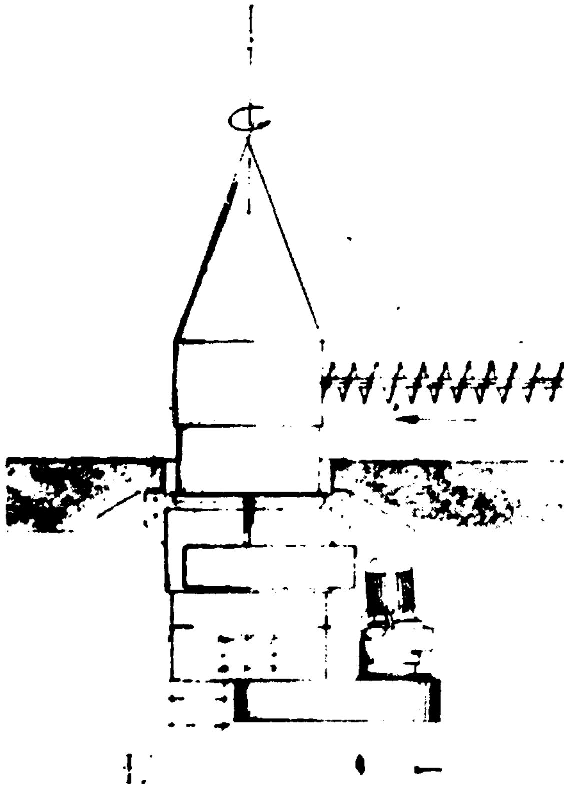
All the machines described above can be air or water cooled. The availability of water and the ability to add facilities for its recovery and recycling will affect the choice of the type of cooling. In addition to design and mechanical considerations, power consumption, which ideally should be minimized, should be borne in mind when selecting one type or another.

Compressors should be grouped together in a single unit which supplies the whole factory. This arrangement has the following advantages:

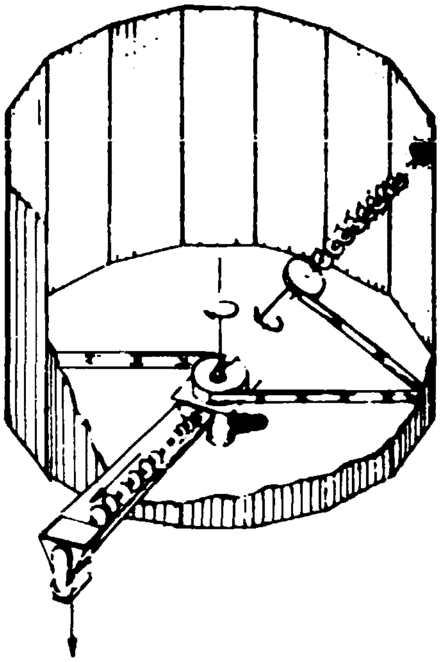
Figure 9. Chain and rotary screw extractors



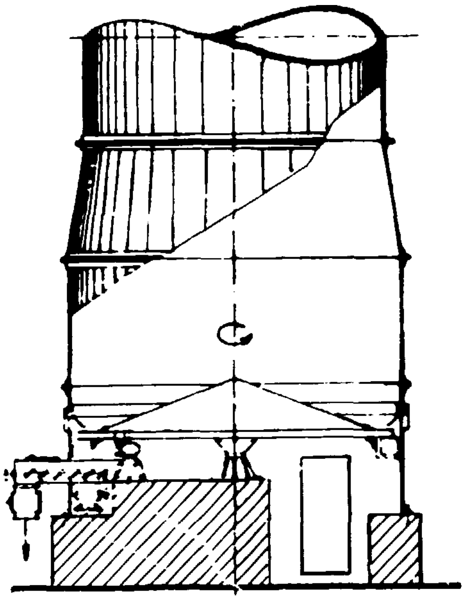
A. A scraping chain extractor



B. A rotary screw extractor



C. A leaf spring extractor



D. A scraping cone extractor

- *(a)* Greater efficiency as more powerful equipment can be installed;
- *(b)* Fewer spare parts are required;
- *(c)* Easier supervision and maintenance;
- *(d)* The unit can be placed at the best location.

The compressor unit should be located so as to minimize expenditure for power lines, for cooling water and for drainage provisions. Usually such a location is at or nearby the other services (boilers, transformer room, extraction plant etc.). Thus the supervision and maintenance service is simplified. Particular care should be given to air filtration and noise and vibration abatement. Aftercoolers and air storage tanks are essential accessories. A supercooler is becoming quite common. Forced cooling causes vapour condensation. The supercooler prevents condensate formation inside the piping.

Compressed air system requirements

In order to ensure maximum efficiency, safety and reduced operating costs, the compressed air system must meet the following requirements:

- *(a)* A small pressure drop between generating and operating units;
- *(b)* A reliable condensate elimination;
- *(c)* Provision made for future expansion.

The pressure drop should be kept within acceptable limits (usually 0.3 kgf/cm^2) provided piping is correctly dimensioned. Design of the system should take future air requirements into account.

It is furthermore advisable to loop-connect the piping in order to ensure better air distribution. Condensate, whenever it is not completely eliminated at the compressed air plant, must be drained from the piping. Branch-offs to users must be connected to the upper part of the main pipes and be equipped with a condensate tank and drainage. To ensure maximum system flexibility and to facilitate checking air leaks, the piping run should be visible in the factory. Another good practice includes installation of valves to section lines and the use of threaded connections and fittings between the main line and branches to users.

Heat generation and distribution

Boiler stations

Heat production has recently undergone important developments. These developments provide greater comfort on the work site and also provide higher temperatures to speed up processing. It is necessary to choose heat generators after a careful study of all heat requirements and the types of fuel available has been made. There is a wide range of choice of boilers. For small to medium plants a single boiler can meet both heating and process requirements. The boiler can operate at partial load in the warm seasons and at near peak load during the cold seasons.

For larger plants, two or more units are usually needed, especially to maintain reserve capacity. Boiler selection must consider the following:

- *(a)* Construction material, whether of cast iron or steel;
- *(b)* Fuel, whether liquid, gas, solid or mixed;
- *(c)* Firing, whether reduced pressure or pressurized;
- *(d)* Fluid, water or diathermic oils;
- *(e)* Operating temperature, whether below 100°C or above 100°C;
- *(f)* Principle of construction, whether gas piping or water piping.

In the woodworking industry in particular the principles for selection are that steel is generally chosen as the material of construction, and that it is advisable to install boilers suitable for burning either oil, gas or wood, be it wood dust or chips. The wood material can be fed to the boilers either manually (for coarse material and waste offcuts); or mechanically, by means of screw or belt conveyor; or pneumatically for dust and chips, by a fan and pipe duct running from the extractor of the silo to the boiler. Wood waste can be fed directly into the boiler or into a hogging system in front of the boiler. The hogging system feed costs more and requires more maintenance. However, it is recommended because it has the advantage of combustion, even if the material is wet, and it permits manual feeding of wood pieces and other waste to be incinerated.

Boilers fired exclusively on wood or mixed fuels are low pressure operated and generally have a forced draught. The combustion chamber and the secondary smoke runs are kept at a pressure lower than the atmospheric pressure and a fan installed between boiler and chimney forces the smoke out. Oil or gas boilers, often installed in parallel with mixed fuel boilers when wood waste fuel is not sufficient, can be either vacuum or pressure operated. In the pressure method, combustion gases are kept at a pressure slightly higher than the atmospheric pressure. This kind of boiler offers a greater efficiency and is also more compact owing to the higher calorie yield per equal exchange surface area.

The temperatures at which steam or superheated water (figure 10) may be used are restricted to a lower range of temperatures due to the high pressures involved (at 200°C we have a pressure of 20 kgf/cm^2). Diathermic oils can be used at high temperatures with atmospheric or low pressures. For this reason heat generators employing diathermic oils are becoming widespread in the woodworking industry, where high temperatures are necessary in many processes (for instance drying of veneer sheets). In those industries where heat is needed only at low temperatures (for instance for heating and/or lacquer coat drying) and when the distance between point of generation to points of use is limited, hot water boilers (figure 11) below 100°C are advisable in view of reduced installation and operating costs as well as simplicity of installation. In large plants and other industries requiring higher temperatures for process reasons (for instance presses for wood based panels and veneers) steam and superheated water are used. Superheated water is preferred because of its advantages:

(a) It does not need accessories like steam traps, filters, condensate drums, which are costly and liable to break down;

(b) It causes less corrosion inside piping;

(c) There is no loss of water. A certain amount of steam is always lost to the atmosphere in the condensate drum;

(d) It requires a simpler and smaller feed water purifier;

(e) It allows for better heat conservation due to greater quantity of heat accumulated in piping.

Smoke-tube boilers are designed to allow flow of flue gases through tubes surrounded by water that fills the boiler shell. By virtue of the large volume of water, these boilers can quickly adapt to load variations. Their operating pressure is below 15 kgf/cm^2. In water-tube boilers the water flows inside the tubes whilst flue gases circulate around them. These boilers have a greater efficiency, can operate at higher pressures and damaged tubes can be replaced easily. The design of water-tube boilers can be used with an efficiently designed forehearth. The water-tube boiler is therefore preferred when there is a large supply of wood waste and a need for high temperatures as, for instance, in the case of factories producing veneer sheets.

Distribution and use of heat

Piping serving work-area heating outlets should be kept separate, if possible, from piping serving process outlets because of the difference in temperature requirements and the different load variations. Heat for work-area heating is delivered in a variety of ways:

(a) By radiators and convectors. These are more suitable for offices and service rooms;
(b) By radiating panels. These are useful to heat only parts of work area;
(c) By unit heaters. These are the most versatile and cheapest equipment;
(d) By fan convectors and airfin units. These are used for air-conditioning.

There are many uses of heat for processing. Controlled temperatures are often required. It is therefore impossible, within the limits of this chapter, to discuss process heating. However, it is important to have maximum flexibility in the fluid distribution system. All the pipes must be easily accessible for maintenance, additions or modifications to the system. They should therefore run, as much as possible, in full view on suitable supporting structures, both inside and outside the factory. Trench ducts, whenever they cannot be avoided, must be easily inspected.

Smoke purification

Often required by the authorities — but in any case always recommendable — smoke purification, designed to trap soot and unburnt suspension, is usually carried out by means of:

(a) Dry purifiers;
(b) Water injection purifiers.

Figure 10. Boiler for steam or superheated water

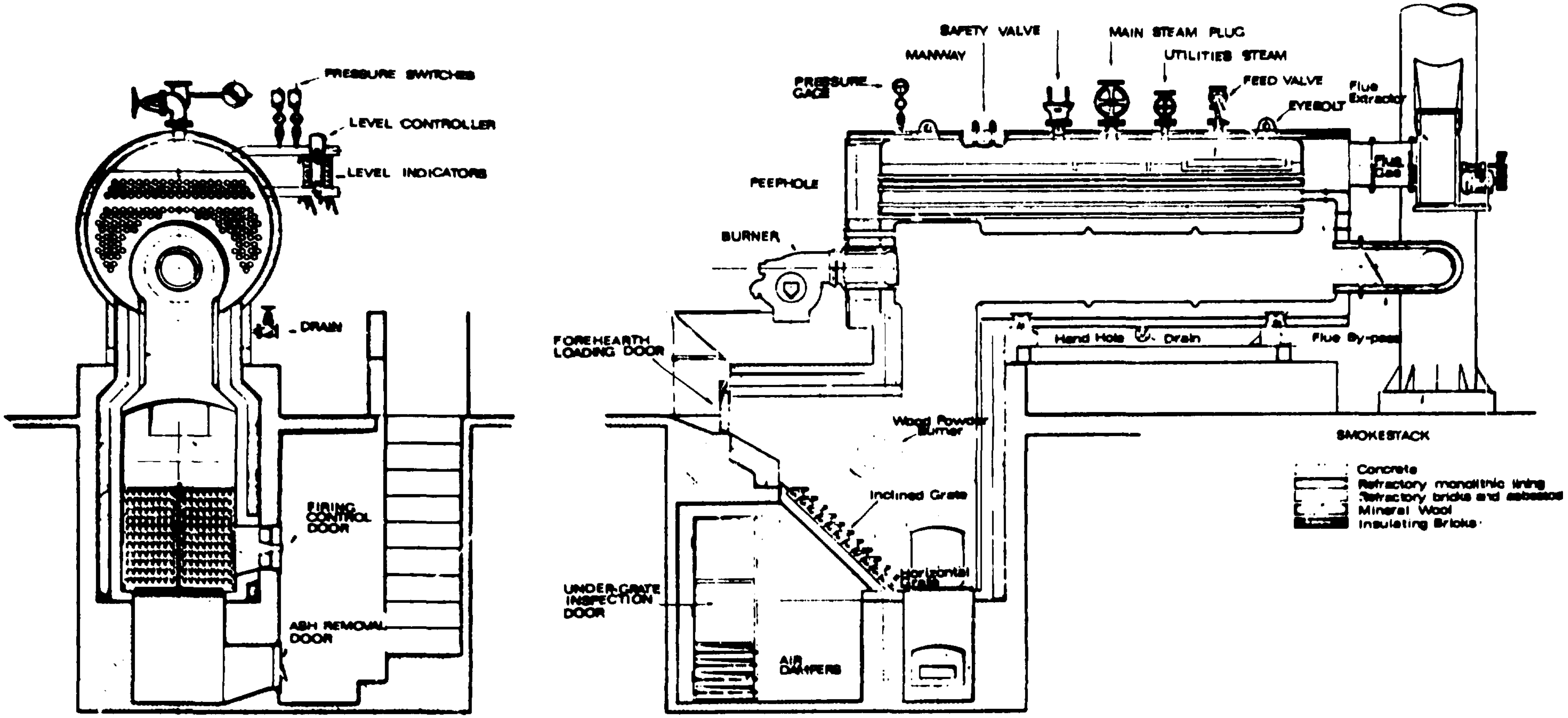
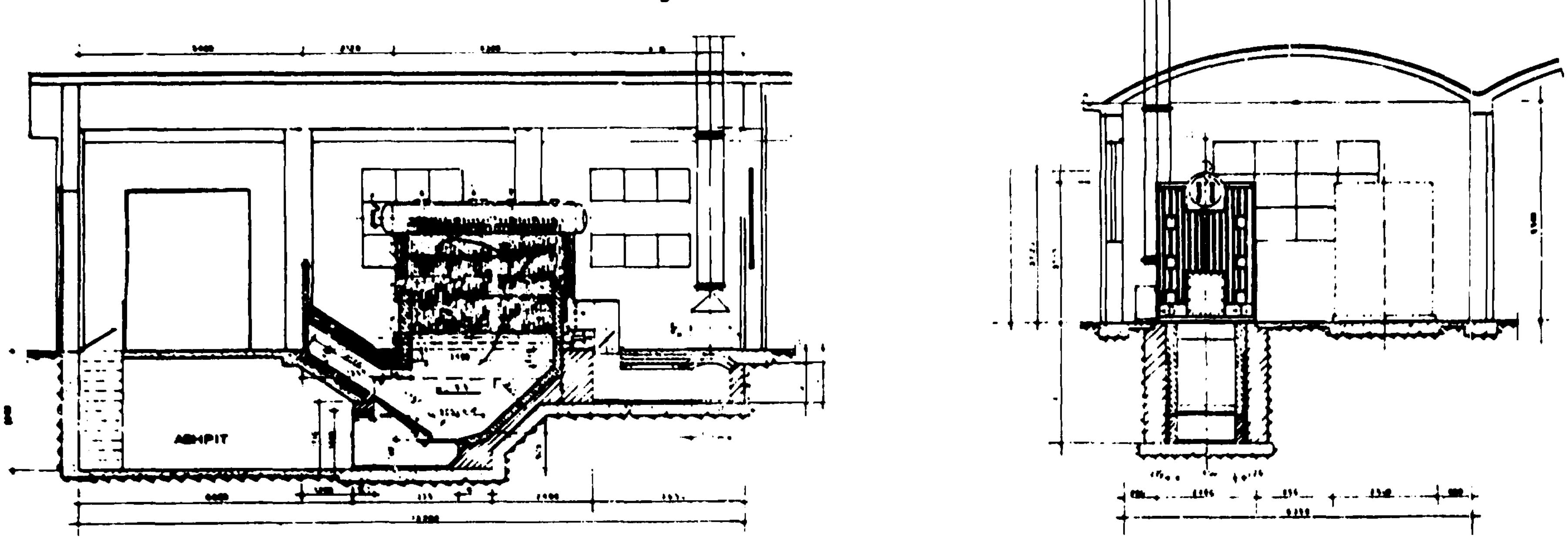
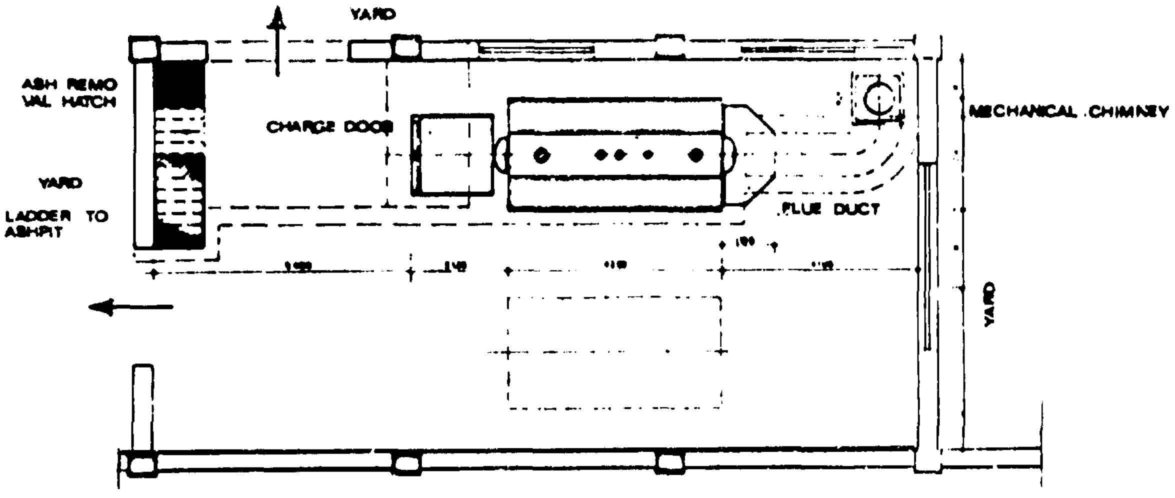


Figure 11. Water-tube boiler



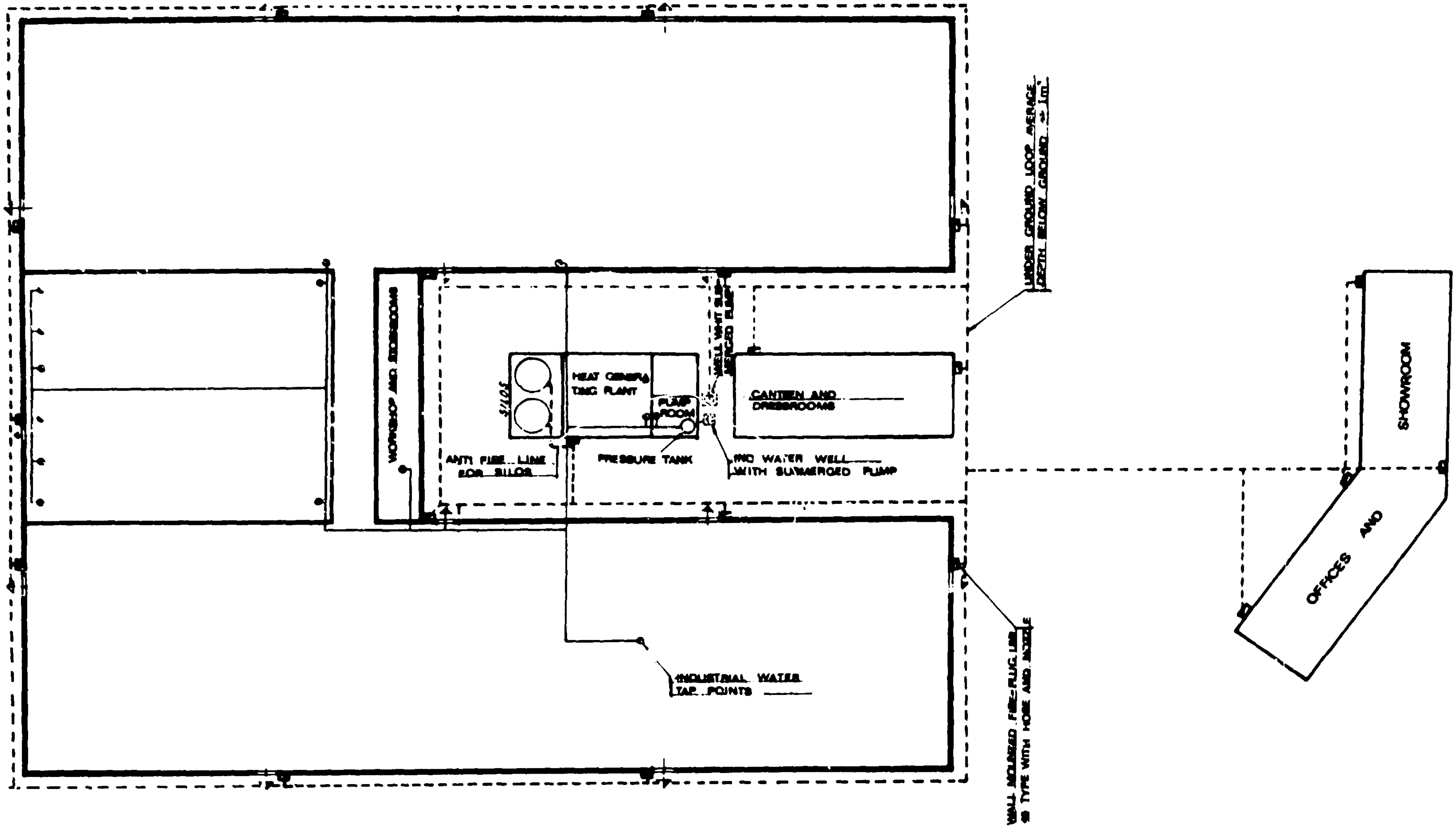
A. Cross section

B. Front view



C. Plan view

Figure 12. Water supply and distribution plant



The most widely used "dry" purifiers are the cyclone types, often used in banks (multicyclones), which guarantee good efficiency with little trouble. Water injection purifiers consist of a chamber through which flue gasses pass, with spray nozzles which atomize the water, which washes the gases. The sludge is collected on the bottom of the chamber. Such equipment, although more efficient than the dry type, has a few drawbacks. It must be constructed with corrosion resistant material, it has a cooling effect on flue gases and it converts soot into sludge, which is quite troublesome to handle.

Water supply and distribution

Water availability is one of the factors to be borne in mind when choosing a site for a plant. Water can be supplied externally, or it can be taken directly from a surface stream or pumped up from the water table. Wherever a continuous supply is not guaranteed, such as in large factories, storage tanks connected to an autoclave system should be installed.

Water use may be for utility-sanitary use, process use, or fire-fighting use.

While utility-sanitary and process uses can be united (when the water is already potable), water for fire-fighting must be carried by a separate system directly from the point of supply. This system must always be operable and it is therefore buried and laid in a loop (figure 12) around the buildings. This loop supplies hydrants and the sprinkler system protecting areas like silos, storehouses housing flammable materials etc.

Often underground tanks beneath the factory collect rain-water to be used as emergency water for fire-fighting. This water is pumped to the system by electrically driven pumps operated by a generator unit or by diesel pumps.

The amount of water required for utility and sanitary uses depends on the number of people working at the factory and the type of woodworking activity carried out. The amount of water required for processing depends on the type of activity and the water consumption of the other general facilities such as compressors and boilers.

Due to ever-growing water supply difficulties, there is a need for recycling industrial water. When the water is heated only during the industrial process, as is the case in most furniture factories, then it is easy to recover it by means of cooling towers. When it collects polluting substances through the process, it must be adequately purified before discharging it. The type of purification treatment depends on the quality and quantity of pollutants and often requires a sizeable investment of money, even for relatively small quantities of water to be purified. In furniture factories there is a need to purify water coming from spray booths. The water is purified in two successive stages. Special injectors cause paint pigments and solid particles to thicken and precipitate into a tub. Afterwards solvent residues are absorbed by activated carbon.

VII. Selection of forestry equipment*

Logging includes forest operations beginning with the selection of trees in the forest, and extending to the felling, limbing, bucking, skidding, decking and then loading of them in log lengths on to trucks or railroad cars for transport to a market or processing area.[1] In other words it represents the extraction of a raw product from the forest. In this operation there are a number of successive functions all of which require the need for a rather tough or rustic type of worker who can live under rough conditions and who invariably is found somewhere in far-flung areas of the forest wilderness. Nevertheless, logging is becoming more and more a sophisticated occupation due to continued pressure from government bodies to make the forests throughout the world better controlled and managed. For instance, industry is now required to lay out and construct their logging roads so that, eventually, these roadways will either tie in with or form part of the national road system of a country.

Whereas only a few years ago, the job of a lumberjack was considered a difficult, dangerous and low paying one, for some time now a steady move towards the complete mechanization of forestry operations has been made so that there is now a trend towards the utilization of more and more specialized manpower and consequently towards a more and more elevated standard of living of the lumberjack. This situation can be considered as a step forward in a business that was once considered by many as being unthinkable to work in. Logging operations and the job of the logger have become more and more attractive to the younger generation and society in general.

Logging operations

Different phases of logging

A phase is defined as any operation which consists of executing a job without the need for changing tools. For example, the felling of a tree encompasses the first phase. The actual job of felling is done by using a power saw (figure I). Once the tree is felled, the operation of limbing, requiring the use of a manual tool or lighter power saw, is a second phase. Bunching the timber is the third phase and skidding is the fourth. Stacking the logs and bunching the timber in order to execute this operation is an auxiliary phase. After the skidding, the logs are stacked along the roadside. This is the stopping point for forest operations. The loading of the logs onto the trucks is considered a phase and the hauling of the logs afterwards another phase. The unloading at the arrival point is normally the final phase unless the material is to be subject to further transport by other means such as railway or barge.

Operation analysis of time use

The different phases, as they have just been described above, were the object of systematic studies by many specialized institutions. Without going into detail on these studies, we may assume that the

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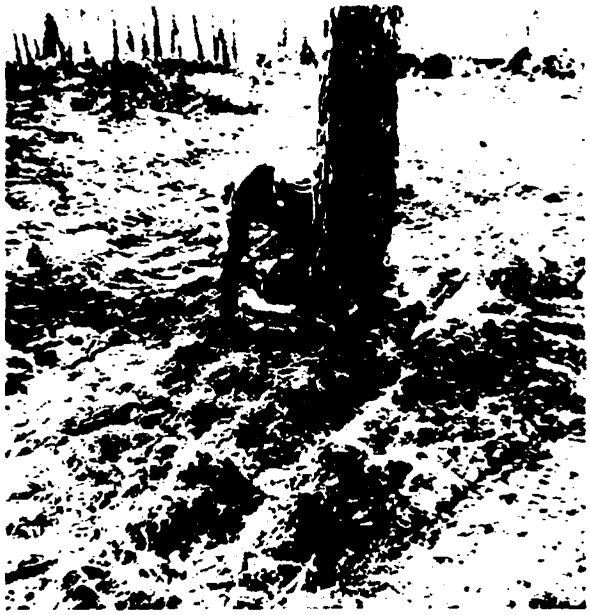
* By X. De Megille, expert in forestry equipment. (This is an edited version of ID/WG.277/6/Rev.1.)

[1] For additional sources of logging information see chapter VIII.

felling operation represents only a small percentage of total logging time, whereas the burning of small limbs and branches may represent up to 15 per cent of the total time. A cost coefficient is used in this analysis. The coefficient depends on the material used during each given phase. For example, the felling operation with a power saw costs the salary of the worker who executes the job plus the reasonable amortization of the machine and its hourly utilization cost; that is, the hourly cost of the consumption of fuel oil and the cost of required maintenance per hour of operation.

Figure 1. Felling a tree with a power saw



For the skidding operation, the cost per work hour is much higher, because, in addition to the salary of the operator and possibly an assistant, the amortization of the skidder plus its operating cost must be taken into account. These costs can be up to ten or twenty times the cost of the operator's salary.

In examining each phase, by multiplying the time spent for a given operation by the hourly cost of each technical process used, we can determine the total cost of the operation from the forest to the mill. A comparison of the different phases is amenable to analysis by linear programming and solution by computer.

The results of such an analysis permit the planner to determine the best method to employ in order to exploit a given forest area. But in addition to these theoretical calculations, it is necessary to take into account the inherent technological limitations of the logging process.

Technological and physical limitations

There are three types of technological limitations. These are the physical, silvicultural and economic limitations. In addition, there is the psychological aspect of work, which must also be considered.

Physical geography

In mountainous regions, the slope of the terrain is the determining factor in the choice of equipment to be used. For slopes steeper than 20-25 per cent, it is not feasible to utilize self-propelled vehicles over the ground. However, a crawler tractor can work on 30 and even 35 per cent as they may be unstable at steeper slopes. In the case where work must be done on steeper slopes, cable systems which may be assisted by balloons or helicopters are used. If self-propelled vehicles are used the choice of the vehicle is determined by its stability on the given slope. In addition to this, the power required to make the vehicle climb a slope is often a determining criterion in the choice of an engine. It is essential on rough terrain that the tractor be able to climb the slopes without cargo at an appropriate speed with good handling capabilities. One naturally tries to use gravity for skidding loads and as often as possible tries to plan the work in such a fashion that the machines move down the slope rather than up it. However, it is interesting to observe that in the case of cable systems, or in particular cable-cranes (figure 2), it is easier to work by lifting the loads rather than trying to lower them. This is because in the case of lifting the logs towards the top of the slope, the logs are pulled upwards from the soil. If they are dragged downwards, they may slip and risk floundering in the soil. It is also advisable to think about the altitude as combustion engines have lower efficiency at higher altitudes because of the rarefication of oxygen with increasing altitude. The loss of power at 800 to 1,500 metres is 10 to 15 per cent of the power at mean sea level. This loss reaches 30 per cent when the engines are at an altitude of 3,000 metres above sea level.

Figure 2. A cable crane

On relatively flat terrain, where the problems of slope are no longer important, the state of the soil becomes the determining element in the choice of transport vehicles. On dry terrain problems of slippage are of minor importance. For marshy terrain, with very wet conditions for most of the year, slippage problems are so important that in certain cases, technicians prefer to use traction cables at ground level in preference to using amphibious vehicles. By the same token, in regions such as in the Southern United States, or in tropical regions, the railway was for a long time the best way to penetrate the forest. It costs less to use than the established routes and had characteristics that were most appropriate for early exploitation of the forests.

Finally, it is advisable to note that for man-made forests special solutions may be required.

Climate

Climate is an important physical condition. The first consideration is the variation in temperature. It is necessary to remember, as is true for the changes in altitude, that the efficiency of a combustion engine varies greatly with ambient temperature. Although this fact is often overlooked, climate has great influence on the state of the soil, which changes with changing climatic conditions. In cold regions such as Siberia, the Scandinavian countries or Northern Canada, snow becomes an aid in logging timber because it allows roads to be made over compressed snow or ice. The loads may be hauled over the snow with or without a sled. Actually, considerable quantities of timber can be moved, because of the low coefficient of friction under these conditions. In temperate climates this approach does not work as work slows up during the rainy period. The rain transforms the soil, which usually has sufficient holding ability, into ground particularly unsuitable for vehicles. Thus, the period of time when wood skidding is profitable is reduced. A similar observation can be made for the countries with a tropical climate. In these regions the rainy season generally prevents penetration of the forest by mechanical means for long periods of time. This requires full use of transports during the dry season when the holding ability of the soil allows the passage of heavy equipment. Finally, the wind factor is also important. Wind can be a predominant cause of stoppage or slow-down of logging in rough terrain or by the sea. Therefore, the forest operations planner should, in all instances, take into account the effect of the wind when scheduling cuttings, in particular clear cuttings. Such planning will also avoid large losses from trees being blown over.

The soil

Forest soil is generally formed from the decomposition of leaves and of needles. This decomposed matter forms a more or less thick humus layer that lies directly on the mother rock, whereas in agricultural soils the surface contains a layer of cultivated plant roots which form an excellent support to prevent slippage of the transport machines. If the operator does not have knowledge of and experience with driving on this type of soil, difficulties will arise. The different types of forest soil according to their mother rock may be defined as:

(a) Clay soil, which is a particularly resistant soil when it is dry. It has very high holding ability. On the other hand, it becomes very slippery when wet and its holding power often diminishes quite suddenly with increasing water content. It is, therefore, necessary with such soil to plan the logging during the dry season although emergencies will arise, requiring work during the rainy season. In this case, it is necessary to anticipate the need for equipment which will permit the vehicles to pass over the slippery places. The most useful tool for this is the self-hauling winch which is attached to the front of the vehicle, as shown in figure 3;

(b) Humus soil is most typically forest trail which is covered with more or less decomposed humus. The humus is often mixed with a bed of leaves. Humus soil is similar to the type of soil which one finds in marshy ground. In order to pass over this type of terrain, it is necessary to use very large crawler tractors which have a soil pressure of less than 100 g/cm^2;

(c) It often happens that there are large plantings of trees in sandy soil areas. This type of ground quite often has good holding power but insufficient cohesion and when a vehicle starts in motion it suddenly becomes bogged down in the soil. Consequently, it is necessary to use large tyres with very low pressure. It is also not recommended to use a crawler tractor in sandy soil because the sand is a strong abrasive which will quickly damage the steel parts of the equipment;

(d) Rocky soil is that in which the superficial humus has disappeared either by erosion or by repetitive wear from travel. It, therefore, lacks elasticity. To move over this type of terrain, relatively low pressurized tyres are used. In all cases it is recommended that the machines which move on this soil be equipped with a scraping blade to allow for the smoothing of the ground surface which becomes irregular.

In order to define the technical characteristics of the diverse soils, it is necessary to take into account the following:

(a) The holding-power of the soil. This is measured with the help of a penetrometer. This measures the pressure required to deform the soil under defined conditions. In general, soils have a holding-power which varies from some hundred grams to 10 kilograms per centimetre;

(b) The resistance to movement is the force in kilograms parallel to the surface of soil necessary to move a given vehicle. It is expressed by this formula: $R = K \times W$. R is the resistance to movement expressed in kilograms per ton; and W is the weight of the vehicle in tons. K is a coefficient which varies according to the type of soil and the wheel system used. K will be different for iron wheels, for wheels equipped with high or low pressurized tyres, or crawlers;

Figure 3. A tractor with a winch

(c) Resistance to sliding is the horizontal force necessary to move a body resting directly on the soil. There is a coefficient of resistance to movement which relates force to the weight (in tons) of the load to be moved. The resistance varies with the type of soil and the shape of the object to be moved. The diameter of the logs plays an important role and the way the logs are dragged (on the ground or partially raised) has an effect on the coefficient of resistance to sliding. The resistance varies from 450 to 700-800 kg per ton to 560 kg per ton for crawler tractors on dry black humus;

(d) The adherence coefficient is generally expressed by the formula $A = \frac{F}{W}$. A is the adherence coefficient per ton. F is the force exerted by the hook of the tractor in kg. W is the weight of the motor elements of the tractor expressed in tons. The magnitude of this coefficient indicates the efficiency of the tractor. This depends on the condition of soil, and especially on soil moisture content. The adherence coefficient for tractors equipped with pneumatic tyres or crawlers varies, for example, from 170 kg per ton to 560 kg per ton for crawler tractors on dry black humus.

The silvicultural conditions

Having examined the physical aspect of the soil, it is now appropriate to consider the forest that grows on this soil.

The diameter and height of the trees is the prime consideration. This gives the volume of the timber which can be obtained.

The mode of forestry operation will vary according to the type of forest being dealt with. It may be a virgin forest, a regularly harvested forest or an underdeveloped forest. It will be necessary to create access roads in order to penetrate the forest. For a regularly harvested forest there are roads, but it may be necessary to log the interior where there may be dense growth. An underdeveloped forest may require both new roads and logging amidst dense growth.

The economic conditions

Economic considerations are important to the study of logging. The price of the finished product will be affected by all the logging costs and will directly depend on the cost of wood. This cost varies with the ownership of the forest. Whether ownership is governmental or private, is important. In some cases a simple royalty is paid which is related to the area of the forest. Such a royalty does not take into consideration the forest productivity, and productivity must be used to calculate the cost of the finished product. It is also necessary to take into account the economic development of the given country. Because, if there is no access road, either into the forest or to a port where the logs can be sent, or if a road or railway is situated at a great distance away, the cost of establishing transport must be included in the calculations of the cost of the raw material. It goes without saying that in the case of very large investments of this type, the community, county, state or country takes charge of all or part of the financing in order to establish these roads.

Management

Besides these economic problems, one of the principal factors of success is the minimization of the cost of human problems. These include personnel, management and social problems. Personnel problems are the most important. It is necessary to determine right from the start what the duration of the operation will be, and if the forest labour will be seasonal or permanent. One must assume that the seasonal manpower will generally be less careful with the equipment, and the equipment will suffer accordingly. Personnel assigned on a permanent basis will be more careful with the operation and maintenance of the equipment. It is always best if at all possible, when organizing the yard, to use personnel of the more permanent type, even if this necessitates making changes in personnel organization, using loggers to make roads or in reforestation during one part of the year and involving them in felling and skidding during other parts of the year. However, in certain countries, the climatic conditions, such as rain in the tropics or snow in Scandinavia, make it impossible to employ workers all year long. It is, therefore, necessary to employ seasonal personnel.

In addition to the important question of whether to use seasonal personnel, it is necessary to determine the type of the available personnel. In over-populated countries, there is an abundant work force, which is often so cheap, that it is sometimes even more economical to use than machines. In other over-populated regions, in spite of the large population, forestry manpower is hard to find because it is a difficult and relatively poorly paid occupation. In this case, mechanization generally raises salaries. It is advisable to base salaries on production. We must not forget that the forestry workers are inclined to be rough with machines and equipment. In developing countries we cannot normally find a trained work-force. Workers who come from the country in which the machine was manufactured may cost three or four times the price that the same labour would cost in the developing country. Local manpower may be used as helpers, and could be trained to accept more responsible positions. Certain manufacturers have done studies on the efficiency loss in yards in terms of work organization. It was found that with a very experienced team which is well paid and properly supervised, the loss per work hour is four minutes. For a new team which is not well co-ordinated, is poorly paid, the time loss is about ten minutes per hour.

We can define a coefficient of personnel efficiency as the ratio of effective minutes per minutes spent at work. The quality of management will affect the number of minutes per hour lost. In a developed country lost minutes per hour may range from three to seven. In a developing country, an efficiency of 0.85 is excellent, 0.60 to 0.75 is acceptable, and 0.50 is unacceptable and unproductive.

It is essential, when one does a study on the overall costs of a logging operation, to take into account national laws, customs and conventions, in particular, the laws which limit or tax the supplementary work hours. The costs of social benefits must be considered as they vary widely from country to country. Accident insurance, for the work-force and for the machinery, varies considerably from country to country. Finally, work habits need to be taken into account. It is often necessary to consider the organization of the work. This is because if a new work system is established and it does not produce the expected results, the workers will very quickly revert to their old habits. These habits will be very difficult to change.

Machines and tools used in the forestry operations[2]

Manual tools

The axe is one of the oldest tools which man has ever used; an excellent striking instrument. The axe handle multiplies the applied force tenfold.

Another striking tool used with the axe is the cutting billhook. The form of the billhook varies according to region. The best are in the form of a nib in a hook form. This enables the billhook to prune, trim and haul timber, and makes handling of the billhook easy.

Another manual tool is the wedge which cleaves the logs and is used during felling operations. Its indispensable companion is the adze. Along with the striking tools we can mention the "debarker", a sort of shovel which is pushed along the tree trunk.

In the second category of manual tools are the scraping instruments. These tools have practically disappeared and have been replaced by power saws. There still exists on the market a small saw for debranching which is mounted at the end of a handle and permits the limbing of trees up to 4, 5 and even 6 metres high.

Grippers and hooks are tools used for the manual handling of wood.

Power chain saws

The technical characteristics of the most common model of power chain saw are a direct drive with the drive pulley directly fixed by a centrifugal clutch to the crankshaft. The motors in these machines revolve at 6,000 to 12,000 rpm. As the diameter of the pulley is 3 to 4 centimetres, the speed of the saw edge is from 10 to 20 metres per second. The power required for a power saw depends on the force required to penetrate the wood. This is generally approximately from 4 to 5 horsepower. This is the power of the majority of machines on the market. During the past few years, numerous accessories have been added to power saws to improve comfort. A Scandinavian manufacturer has developed a method of making the burned gases pass through the handle, so that in winter the logger can warm his fingers while working. A manual switch controlled by the worker which automatically interrupts the power when the worker releases the machine is now mandatory in many countries.

Bunching

The most simple saw used to be the manually operated cross cut saw. This was replaced by the mechanical saw, which was for many years the only regularly used chain type tool especially in sawmills. The power driven chain-saw has recently become very popular for use in cutting logs and timber. Meanwhile, cutting machines were developed for pulpwood. Some were portable and could be used anywhere in the forest. A felling machine is shown in figure 4. These became very popular a few years ago. Now there are vertical units for industrial use which cut wood and stack it. A timber buncher is shown in figure 5. Small cutting units derived from the industrial units have appeared, particularly in planned economy countries and countries with high levels of forestry production, such as the United States. A timber processor is shown in figure 6. Some cutting units are veritable wood conditioning mills. They are inspected by checkers who determine their quality and automatically direct them to the appropriate processing line.

Debarking[3]

The determination of the best place for performing debarking can be done in a mathematical fashion. The cost of debarking in the forest compared to the cost of industrial debarking, and the transportation expenses in moving the timber between the different points for debarking, are used to

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[2] For additional sources of logging information see chapter VIII.

[3] For additional details on log debarking see chapter XII.

determine the optimum site. Studies done on this topic have led to the conclusion that the best site is generally determined by the size of the timber and the technology used.

Friction ebarking involves the simplest machines. These were introduced at the early stages of log debarking. They consist of large debarking drums into which the logs destined for the mill are

Figure 4. A felling machine

Figure 5. A timber buncher

fed. The logs fall over each other during rotations of the drums. The number of rotations required is related to the size of the log. This technique has been abandoned in favour of the more efficient scrapers.

Figure 6. A timber processor

Scrape debarking involves machines which operate around the tree, and debark along the axis of the tree. These machines have been highly developed. They are certainly, on the world market, the machines which give the best results for the lowest cost. They allow preselection in sorting centres, they can be adapted to various sizes of timber, and they operate with high efficiency. A debarking machine is shown in figure 7.

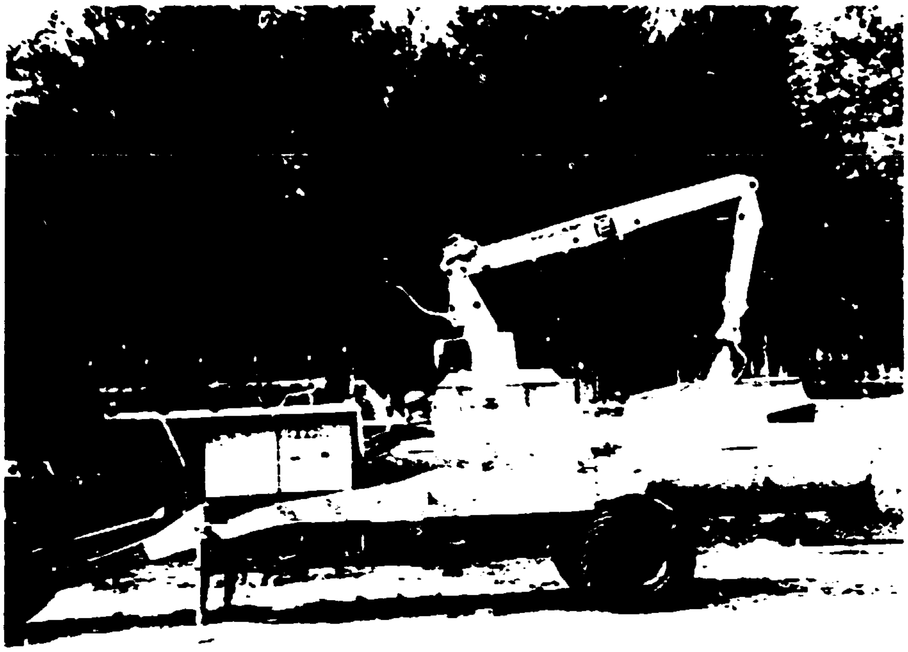
Other models include a friction machine known as the friction head. The logs are subject to a spiral movement under the heads. Unfortunately, most of these machines have been discontinued and replaced by blade heads which perform a very high quality debarking job. However, the blade heads have the disadvantage, in comparison to the friction head, of consuming up to 5 per cent of the wood.

Combined machines

The comparative study of the different phases of logging indicates that some phases can be best done by hand. Others which need mechanizztion have been relatively difficult to mechanize. If we examine all of the phases concerned with the harvesting of timber, we note that limbing, for example, is an operation which requires up to 30 per cent of the total harvesting time and has been very difficult to mechanize. It is equally well-known that debarking, if necessary, is a time consuming and burdensome operation. This is because the efficiency of the worker with the debarker is low, and attempts at mechanization in the forest have been unsuccessful. Research efforts were made to mechanize debarking. The first successful combination machine was the limber-buncher. The two operations of limbing and bunching represent up to 60 per cent of the timber work-up time. By comparison, felling never represents more than 5 per cent of this time; the rest of the time is devoted to handling, regrouping, transporting etc.

The most important harvesting phase is the limbing. Manufacturers and research institutes tried to mechanize this operation, which for conifers was rather easy to do. There are machines which take the trees that have been manually felled, pass them through a metal belt where cutting tools limb them by a hydraulic jack system, which forces the trees through the machine.

Figure 7. A deberking machine



The next development phase was to try and mechanize the felling and to attach to the felling machine a limber similar to the ones developed on previous machines. The first feller-limber was the "Beloit-harvester" developed 15 years ago in Canada and the United States. But this machine was huge and very costly. Other manufacturers put out other machines in the years following, such as the "Beloit", which had a hydraulic pruner in front and a limber similar to the above machines. That is to say, they had simple blades which surrounded the tree while it was lifted by a hydraulic jack system. These various manufacturers preferred to use a crane with a hydraulic pruner and a head that did the limbing by means of studded wheels. The tree passed horizontally into the head and the branches were removed, even though this machine was not actually a debarker.

We can compare these modern techniques to the experiments that were recently conducted in Finland. In the experiments, up to a 10 to 15 per cent improvement in the linear production of logs could be achieved with a stumper feller which cut below the surface of the ground. At the same time, the soil was left in better condition for reforestation.

The forestry tractor

Tractors include:

(a) The four-wheel-drive tractor which was used in the forest for many years is a tractor with four equal diameter driving wheels. These wheels are often driven by equal gear ratios. The tractor can easily get out of ruts due to the combined action of the front and back wheels;

(b) The articulated steering tractor (figure 8) had the advantage of permitting a relatively long engine to have a very short braking range. If the tractor falls into a pot-hole, it can easily get its two front wheels out of the hole and secure sufficient adherence to permit the vehicle to get out of the bad situation by a forward and backward movement called a "duckwalk". The articulated steering tractors were developed only a short time ago for public works and were used for agricultural purposes shortly thereafter. An articulated tractor with a fork-lift is shown in figure 9. They conquered the entire forestry market and took the place of four-wheel-drive tractors, and many of the crawler tractors. The articulated steering tractors are equipped with a rear winch and a forward levelling blade. The vehicle can be loaded by a hydraulic crane called a forwarder. The forwarder (figure 10) is commonly used for loading cut wood and even small logs. In the Scandinavian and North American forests, this machine has taken the place of all other types of forestry transport equipment;

(c) The rigid crawler tractor was used for many years in tropical or virgin forests where it was

necessary to develop roadways in order to remove the timber. These machines were equipped with a powerful rear winch and many forward accessories such as a bulldozer blade;

Figure 8. An articulated-steering tractor

Figure 9. An articulated-steering tractor with a fork-lift

(d) The flexible crawler tractor has advantages over the rigid crawler tractor. The drawback of the rigid crawler is that when it moves through the forest the tractor is not flexible enough to by-pass the obstacles. Thus, some manufacturers produced flexible type crawlers. These roll on oscillating tracks which permit the machine to go over obstacles. These tractors were developed in Canada and the Union of Soviet Socialist Republics;

(e) The articulated steering crawler has appeared in the past few years. These machines have the advantages of both the articulated steering tractor and the crawler, and are used for oil rig operations in Northern Canada. These tractors are useful over forest soils, such as marshy zones, or those which are flooded a great portion of the year.

Accessories used with forest tractors include:

(a) Logging pans; which were quite commonly used long ago in mountainous regions. They have unfortunately become less common recently;

(b) Logging arches; which have two wheels and a sort of crane arm mounted on the wheels. The crane arm is usually hooked on to the rear of a crawler tractor. This accessory was used for many years to lift the end of the logs while moving them. This avoided dragging the logs on the ground and damaging them. The effort of the ' actor to drag the logs over the ground was reduced by 30 to 40 per cent;

Figure 10. A forwarder

(c) The two-wheeled loading device; which is another wheeled accessory used behind relatively light tractors in order to transport heavy logs. The log is lifted off the ground and rolled, thus reducing the effort required to move it;

(d) The trailer with power drive, used to transport cut up timber. Farm trailers were used for many years and it is only in the past few years that power drive trailers have been introduced. They are equipped with a crane, usually hydraulic, which loads the trailer. Generally, the wheels of the trailer are power driven to allow movement in particularly difficult areas. These trailers, equipped with cranes and power drive, were the original "forwarders". The original forwarder was essentially a farm tractor connected to a trailer by an articulated link;

(e) Forestation accessories may also be used. The use of a farm tractor in the forest is not simply limited to harvesting. It can also serve to prepare the soil before afforestation or to maintain newly planted areas;

(f) Ground breaking and levelling devices used in the forest on the crawler machines can also be used in making and maintaining roadways. These operations are necessary in harvesting virgin or unpenetrated forests.

The winch

Winches are used in the forest principally on the rear of loading tractors. Winches are sometimes used at the front for emergency repairs. A self-hauling winch on the front of a tractor would permit it, if it were bogged down in the forest, to be able to extract itself under most circumstances. Besides their use on tractors, winches also serve with cableways of either one or two cylinders. This equipment can move materials over considerable distances.

Small timber handling machines

Techniques for the handling of small timber in the forest have progressed considerably during the past ten years. As a result of this, manual loading has been replaced by machines such as cranes, especially hydraulic cranes mounted directly on the loading machine. These machines have been described in this chapter with tractors and trailers.

Forwarders were previously referred to when discussing articulated and farm trailers. The device called the forwarder is self-propelled and carries a crane which permits loading and unloading. Crane unloading is often used because it permits the preselection of timber.

Conveyer belts, which are directly mounted on trailers, permit workers to handle timber of small size, such as material for making charcoal or for the paper or board industry. The timber is gathered at ground level, piled and thrown directly on the conveyer belts.

Hydraulic lifter and winch devices: for many years, the most common device for loading trucks was the cable lifter.

Transport trucks

We distinguish among the different types of trucks by their number of wheels or number of axles. More supporting axles reduce the pressure on the ground and consequently increase the load which may be transported.

The truck with a logging trailer (figure 11) can operate behind the route trailer to transport the logs, particularly full length logs. This equipment which has one or two axles can be carried empty on the truck itself (figure 12).

It is most essential that the braking system on wood transport vehicles be very strong, because when a loaded vehicle must descend long slopes, normal brakes overheat, and lose their braking power. It is, therefore, necessary at all times that the vehicle be equipped with an emergency brake near the gearbox.

Cable techniques

There are a number of cable systems, each with advantages and disadvantages. These systems should be studied carefully when making a decision as to which to use. Among these systems are the lost log cable, continuous cables, go and back cables, tree cables, Wyssen cables and Bloding cables.

Of special interest are cables which use balloons. In rough terrain regions which have a convex profile, such as old mountains (Black Forest, Vosages etc.) the use of cable-cars is difficult because of the concave catenary shape of the supporting line. Researchers have tried to use the balloons to handle the load and transport the load over long distances. These materials were developed in the United States, with some in the USSR, but do not seem to have passed the experimental stage.

Helicopters are also of interest. Experiments were done quite a few years ago with helicopters having high lifting power. Certain military machines can carry loads of up to 40 tons, and can lift the largest trees in the forest.

Other methods for transporting timber

Floating

Floating wood is a technique which is still used in the Northern Hemisphere. In fact, in plains regions the transport of wood by floating is one of the oldest methods. In Norway, there is an association for floating whose beginnings date back to the 12th century. The traditional method is the lost log method. During the winter the timber is placed on the ice of the lake. When the ice breaks up in spring, the logs travel down the river and are collected at the mouth of the river, where the processing industry is usually situated. In Canada and also quite often in the Scandinavian countries, the forestry franchises are for logging within a river basin. The timber of the basin can be floated to the paper mill or sawmill in the valley below. When there are many important rivers which flow into the same basin, which is frequently the case in Scandinavia, a small metallic plaque or insignia permits wood sorters to identify the timber for a mill. This operation is now simplified by sorting centres, some of which in the USSR are electronic and semi-automatic and permit the classification of timber not only by origin but also by quality and destination.

Figure 11. A truck with two trailers

Figure 12. Truck carrying its own trailer

Water transport

Water transport must not be confused with floating. Water transport is transporting timber on light barges on canals which are made for the transport of industrial materials. There is a system in Canada, and no doubt other countries, in which steel barges are used to transport timber products. Self-unloading barges are used for logs.

Railway

Privately owned tracks for the transport of timber were very popular in the 19th century and at the beginning of the 20th century, especially in developing countries where a railway could be constructed much more cheaply than a road. The railway allowed transport of large tonnages of wood where suitable terrain conditions existed.

Costs

Calculating the cost of work material

In all cost price calculations, we must consider three types of costs. These are fixed costs, proportional costs and functional costs.

Fixed costs

Depreciation or amortization of material is a fixed cost. Year after year a machine will lose its value. It is, therefore, necessary that the owner have the capital required to replace unusable equipment. It is thus important to estimate the life of the machine. This estimate is very necessary because the hourly cost price of the machine is highly dependent on the number of hours used per year. The number of hours during which the machine is used is related to its productivity and its condition. Usually, time for replacement occurs when repair costs become greater than the return costs. The simplest method of amortization is to consider the amortization rate directly proportional to time. This is known as straight life. Another more realistic method consists of using the actual market value. When value is plotted versus time the result is a hyperbolic curve. In the calculation of costs, it is preferable to use the hour as the unit of time. Depreciation may be calculated by subtracting the actual value from the purchase price, and dividing the result by the total number of hours over which the machine is amortized.

It is fitting to remember that for certain machines, such as crawler tractors in particular, it is important for a rigorous analysis to separately amortize the crawler tracks and the tractor itself. The tracks are used up more quickly than the tractor. The same goes for large size tyres used on public-works machines. In amortizing machines it is always necessary to take into account the age of the machine. Even if it has been used very little and still may have a number of usable hours, it is necessary to realize that, after a given period of time, the machine may have lost all of its intrinsic value, despite the limited amount of work it has done.

The interest charges on capital invested in machinery are another item which should be incorporated into fixed costs. This cost should normally be subtracted from the residual capital value in progressive steps in accordance with the amortization of the machine. Insurance, taxes etc. must be incorporated in fixed costs.

Proportional costs

Proportional costs consist of maintenance and functional costs. When we refer to vehicles, the maintenance cost of the rolling tracks can be taken separately from that of the vehicle. The maintenance costs of the vehicle itself are those that we are quite familiar with in the operation of an automobile, such as repair of mechanical parts, brakes, clutch etc. These repair costs are important as well for the other machines, such as the loading machines.

Other maintenance costs are those of accessories. If on one hand we must proportionally amortize the functioning of the tractor itself, we must also amortize all the accessories of the tractor.

Functional costs

The energy used by a machine during its operation can either be in the form of chemical energy stored in motor fuel or electrical energy in the case of machines driven by electric motors. In order to calculate the consumption of motor fuel of a tractor we can use a theoretic fuel consumption curve, and correct the resulting approximation for the actual efficiency of the motor. In calculating costs of accessories for fuelled motors, we must not overlook the lubricants, grease and all other supplies.

These are often costs which are proportional to those of the cost of the motor. The accessory costs are about 20 per cent of the functional costs of some motors and may be 4 to 5 per cent of the functional costs of tool machines.

The salaries and cost of fringe benefits of people who operate the machines as well as those of auxiliary services, such as the maintenance service, must be taken into account.

Use of cost prices

A theoretical determination of the optimum work strategy may be made. If cost prices may be expressed in equation form, it is then possible to compare cost prices by a graphic or algebraic method. The majority of the cost prices can be expressed in a first degree equation. It is thus possible to see the relative contribution of both the fixed costs and the proportional costs to the total and to see how these vary with levels of production. In general, we express the cost as so much per unit of production. The cost involved may, for example, be a function of the loading distance, the diameter of the logs etc. The costs are presented in such form that we can graph them. In comparing a certain number of work methods for a given logging operation, we discover that one method is best from a certain point of view, while another method becomes more economical from another point of view. Consequently, we will find a number of cost constraints which will define the optimum cost conditions. Such a study can be done on computers which have been programmed with the linear coefficients of each cost component. In this fashion, we can determine the theoretical optimum work organization to minimize costs.

This analysis can determine the organization of a network of roads or a cable-car system in a forest and can determine in advance the advantages or disadvantages of the different systems with respect to productivity. It is necessary to always keep in mind the social problems that can result from the use of mechanical operations.

Conclusions

The choice of material, equipment and harvesting methods to be used for logging operations can be determined by calculations performed with the help of computers. This advanced selection method should be prepared and analysed by qualified technicians and engineers who possess the knowledge necessary to recommend the best methods and machines, as well as the capacity to analyse the social and psychological results of the planned project.

In effect, the human element, while not considered in the calculations, will contribute to the success or failure of a project. Thus, it is most necessary that common sense and good judgement prevail, especially in the area of management-employee relations.

VIII. Mechanization of forest operations*

Logging operations begin with the selection of standing forest. The trees are felled, bucked and delivered to manufacturing plants.[1] The plants process the raw material into a variety of products, such as sawn timber, fibreboard, pulp and plywood. These products are sold on domestic and export markets and in many instances represent a major source of revenue, particularly for those countries which happen to be blessed with large forested areas.

In planning logging operations it is most important to adhere to both national and local government regulations. Over recent years these have been upgraded considerably for the purpose of conserving forests, as well as for the purpose of fulfilling environmental requirements. Governmental forestry departments, and other organizations which are involved in expanding and upgrading agricultural lands, co-operate and jointly regulate land usage; be it for growing trees, agricultural crops, or for grazing.

Thus it is no longer possible to exploit forested land at will. Instead it is necessary to first learn the requirements and laws as they pertain to soil erosion, road layout, fire protection and logging practices. Having become acquainted with the thinking and planning of the various governmental organizations it is then possible to proceed in a businesslike manner with logging operations by selecting the type of equipment best suited for [illegible]ork. Over the past 50 years machinery and equipment for logging, land development and road building etc., has continuously been improved, and has become more productive. At the same time safety features for the protection of the operator have been developed.

One type of machine which has become popular is the track-type tractor. This machine has attachments and is considered to be the basic machine for use in most forest-site work, development of agricultural lands and heavy-duty construction. Its advantages are thrusting power, grappling power, stability, especially where sloping terrain is involved, manœuvrability in restricted areas and floatability on yielding ground.

Land clearing

Land clearing provides materials for the wood industry, prepares land for reforestation programmes or crop production, and opens areas for settlement. To clear the land, the angle-dozer is used to fell trees, remove stumps, uproot bushes and undergrowth, pile up debris and to skid the felled trees to a collection area. The angle-dozer also prepares the land for further use. The angle-dozer is chosen for land clearing because of the attachments which may be fitted to it in either an upright or angular position as needed. The thrust C-frame, because of its structure, provides for a large number of attachments. This is not so for the bulldozer which has its thrust-arms hinged to the blade. In this case, adding attachments is more difficult, more expensive and more cumbersome. Further, the blade cannot be set at an angle. Thus the angle-dozer is best capable of opening new transport roads and skidding tree trunks.

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* By M. Caselli, expert in forestry equipment. (This is an edited version of ID/WG.277/5/Rev.1.)

[1] For additional details on logging see chapter VII.

Rigging the angle-dozer

Power shift transmission

The quickly reversible gear provides safety in cases of danger (trees falling, ditches hidden by vegetation, thick roots remaining after logging). The pedal control allows for close work. Another advantage is that the clutch may be linked to the power shift gear. This facilitates the use of the machine's total thrust power and sensitizes the operator. On the other hand, rigid friction gearing immediately gives the operator the sensation of feeling of the variations of resistance to the dozer's advancement.

Protection

The bulldozer must be protected for operator safety and to avoid damage to the machine. The causes of damage are protruding rocks, roots, branches and bushes, and falling trees. A heavy duty frame, connected by two arms to the radiator shield, protects the operator, the engine and the exhaust pipe. The arms must be shaped to allow for movement in the forest. A heavy-duty cab guard and rear and lateral grill guards prevent branches or foliage from entering the cab. The roll-over-protective-structure must be strong enough to support the tractor if it rolls over. Various other devices are used to protect delicate mechanical parts.

Winch

A heavy-duty towing winch, at the rear of the machine and at a convenient height, is used to skid both very large diameter felled trees and also bunches of smaller trunks. The winch keeps the trunk ends off the ground avoiding obstacles. A raised fairlead (figure 1) is often used as an accessory to the winch. The fairlead lifts the cable's pulling line. Generally, the winch has a tow hook for use when towing sleds, rolling choppers and other implements used for ground preparation.

Figure 1. Raised fairlead used as an accessory to the winch

The dozer with a winch is suitable for towing operations on difficult, steep, muddy ground with jutting rocks or sharp wooden spikes where special wheeled machines for skidding would not be effective or would have excessive tyre damage and wear.

Clearing vegetation

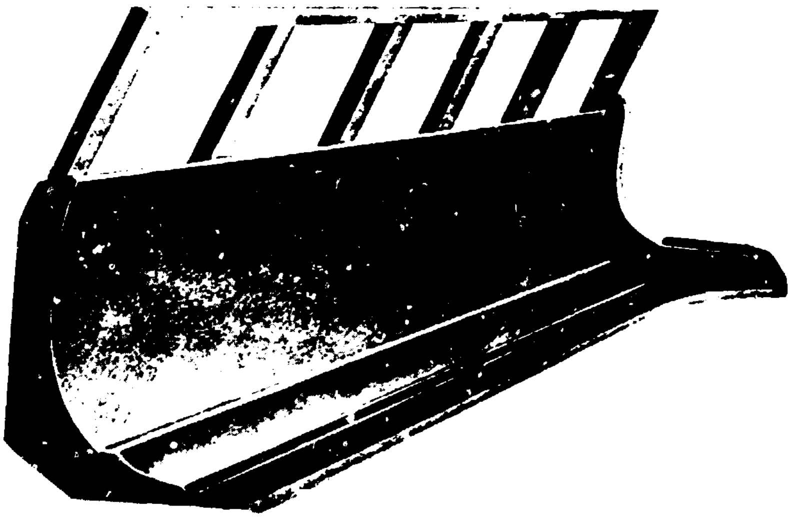
A track-type tractor is often used to fell trees, by shearing them at ground level. By shearing at ground level there is no wastage. The tree shearer is mounted in front of the tractor, and can shear trees whose diameter is under 60 cm (23.5 in.). The common mechanical saw is also still widely used to fell trees. For less efficient, general logging, an angle-dozer is used. The angle-dozer is used for tree felling, land clearing with chains, stump digging, uprooting and removing undergrowth and debris, and dragging the felled tree trunks.

Tree felling

The following special attachments are used:

(a) Angle shear blade for tree felling (figure 2). This is a fixed position blade, set at an angle of 30°. It has a curved mouldboard, a thick cutting edge and a stinger device at the end. The edge can be resharpened and replaced, and there are structural elements welded to the frame. The stinger cuts into the trunk and splits it as a result of the off-centred thrust of the dozer. The blade completes the felling operation. On the upper part of the blade, a guide bar, which is strengthened by many connecting elements and inclined in a forward position, may be welded as a protective device against falling trees. This guide bar is also used to hold back low-lying uprooted vegetative growth. The inclined position of the blade causes the felled trees to always fall on the same side of the tractor for easy collection. The angle shear blade is also suitable for excavation and ground levelling work, for drain-ditch digging (in a "tilt" position), and to collect and pile up the surplus material. Using several passes, it can uproot the embedded material. It is fixed to the C-frame of the angle-dozer.

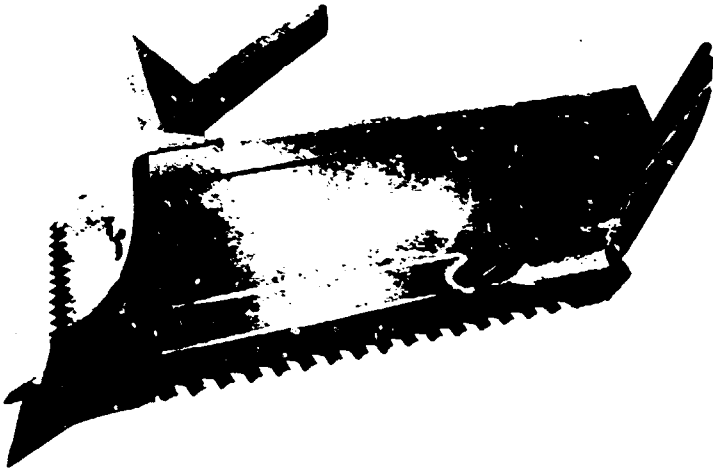
Figure 2. Angle shear blade used for tree felling. The trees are pushed to one side



(b) The "V" blade for felling trees (figure 3) is made of two curved blades, converging in a V. At the vertex is a heavy-duty "splitter" or "stinger". The cutting parts are two angled serrated blades with sharpened sawteeth. Converging protective brush racks are welded to the upper extremity of the blade to cast the vegetation on both sides of the tractor. It has trunions hinged to the vehicle and these are used instead of the C-frame to support the "V" blade. This blade is very efficient and

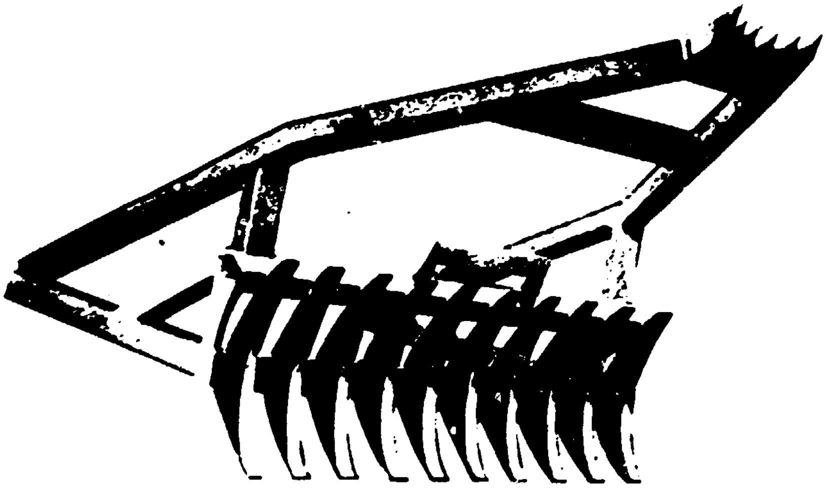
productive in felling trees, in stump digging and in undergrowth removal. However, its work is rough and disorderly which makes subsequent gathering and land clearing more difficult. Because of its destructive action, the "V" blade is used when high yields are not important, and when the work must be completed rapidly. Rubble piling or excavating can be done with this blade.

Figure 3. Felling "V" blade for rough tree felling



(c) The tree-pusher. The tree-pusher has a rigid frame, made up of two converging brackets, hinged to the top of the C-frame of the dozer and fixed by means of forks and pins to the blade. At the vertex of the two arms is a tooth or a spur with well sharpened multiple teeth. The attachment is placed on the blade in a straight position with its end pointing upward. It fells by uprooting as it exerts a much greater force on the tree trunk than on the ground (figure 4). Therefore, stump digging is eliminated. Since the tree-felling process is very crude and the trunk and roots are ripped out together, many deep holes are formed in the ground and these will eventually have to be filled up again (figure 5). There are also derivatives of the tree-pusher which use an angle-dozer attachment, with the hinges and hydraulic jacks control.

Figure 4. The tree pusher fells by uprooting



(d) A tree boom (figure 6). The tree boom is a frame with a square rack, for both angle and straight dozers and can be either detachable or welded on. The transverse bar of the frame, supported by angular cross members, provides thrust and because of its size can be used on more than one trunk at a time. The tree boom is used to remove medium stock brushwood and can be added on to either the angle blade or the brush-removing blade.

Figure 5. Tree pusher. With the tree pusher no stumps are left, but many deep holes are formed

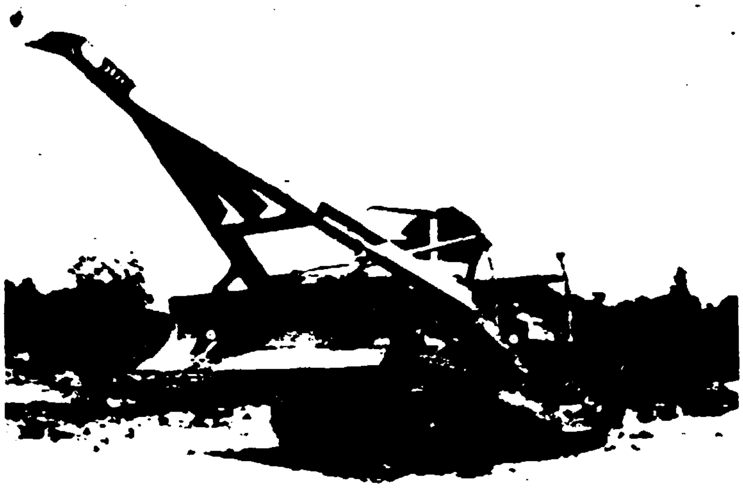
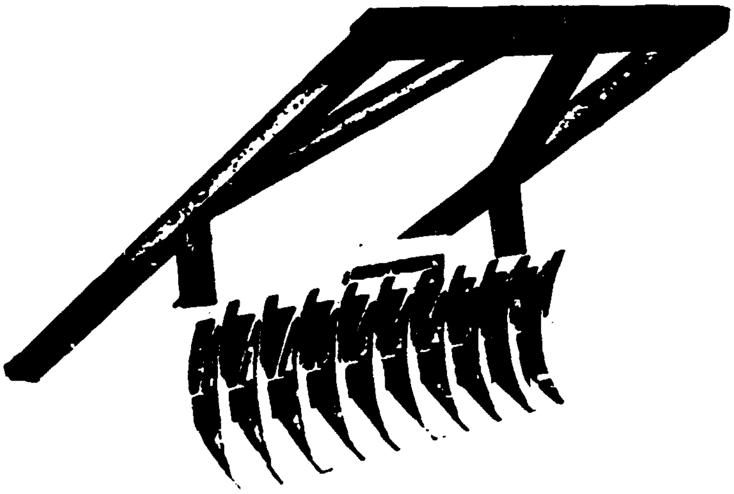


Figure 6. A tree boom is used to remove brushwood



Land clearing with chains

Chains give good results for the uprooting of arid or semi-arid type brushwood. A common naval anchor chain is used. Its ends are attached to the tow bar of two angle-dozers, which are rigged for forest work. Moving in a parallel line at a fixed distance from one another, the angle-dozers drag the chain. The chain forms a curved line and, by scraping the ground, rips up the vegetation. The distance between dozers is equal to ⅓ of the chain's length. The chain is divided into segments to help overcome resistance, and each segment is linked to the other by joints. The diameter of the chain's rings is 50 to 80 mm (1.9 to 3 in.), depending on the type of vegetative growth and the towing machines. Often, a third angle-dozer is used as an auxiliary and is equipped with a plate or tree-pusher.

The third angle-dozer follows the chain and works to loosen stubborn objects, making the operation more regular and continuous. The auxiliary dozer will also fell larger-sized trees which cannot be uprooted by the chain. At times the chain is weighted with one or more cement-filled spheres, which have a set distance between them. These spheres prevent the chain from riding high on the vegetation instead of staying at ground level. This system cannot be used if the terrain is wet, muddy or very irregular. The dragged spheres or balls have a diameter of 1.20 to 1.80 m and a weight of 2 to 6 tons. In chain clearing, it is preferable to pass twice over the same area in perpendicular directions.

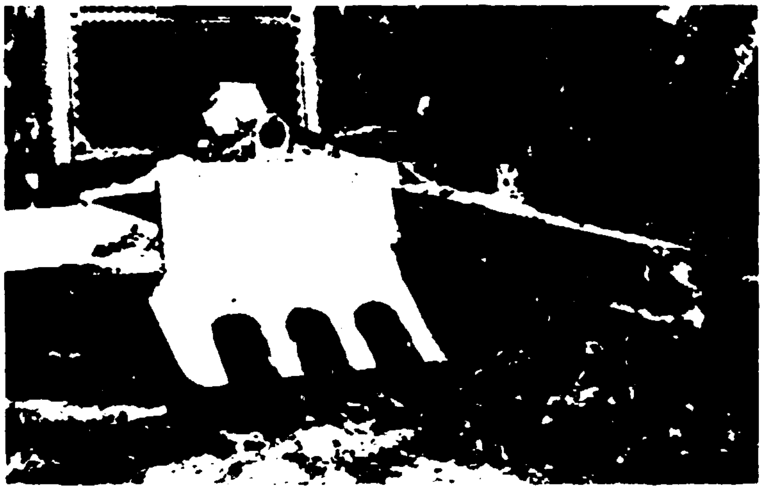
Stump digging

The stumps which remain buried, after the trunks have been sawn or sheared by means of tree-shears or split at the foot of the tree, are removed by means of suitable attachments.

Stumper for stump-digging

Different versions of stumpers are available. Essentially, the attachment consists of a very thick and compact steel plate fitted with teeth underneath. The plate is placed at the centre of the angle-dozer's C-frame in place of a blade. The high force per small unit area and the penetration of the teeth allow the stumper to wedge itself under the tree stump and dislodge it (figure 7). The teeth are welded perpendicularly to the plate, in order to allow the tool to work at various angles.

Figure 7. The stump digging stumper wedges under the tree and dislodges it



In order to root out the stumps of large trees which are sawn off at the base of the trunk, it is necessary to cut off the roots and split up the trunk into many parts which are then removed separately. For this purpose, a long sharp raking-shore, designed to penetrate and split the stump (figure 8), is welded on at the side of the stumper, perpendicular to the plate.

Traction stumper

The traction stumper (figure 9) is similar to a single-toothed ripper and is both long and quite strong. It may be hydraulically controlled or controlled by a winch. The tooth is curved and sharp. It sinks into the ground, roots up the stumps and rocks, and rips and cuts off the roots.

Uprooting and removing of undergrowth and debris

The most common land clearing operation is uprooting and removal. The attachments used have a similar basic structure but differ considerably in detail, depending on use. Multi-application equipment is generally light-duty and specialized equipment is generally heavy-duty. The equipment is used to fell trees of small diameter, remove stumps or rock and stone, clear the ground of low vegetation and push and pile the residual debris.

Figure 8. Stump digging stumper, showing the raking-shore for stump removal

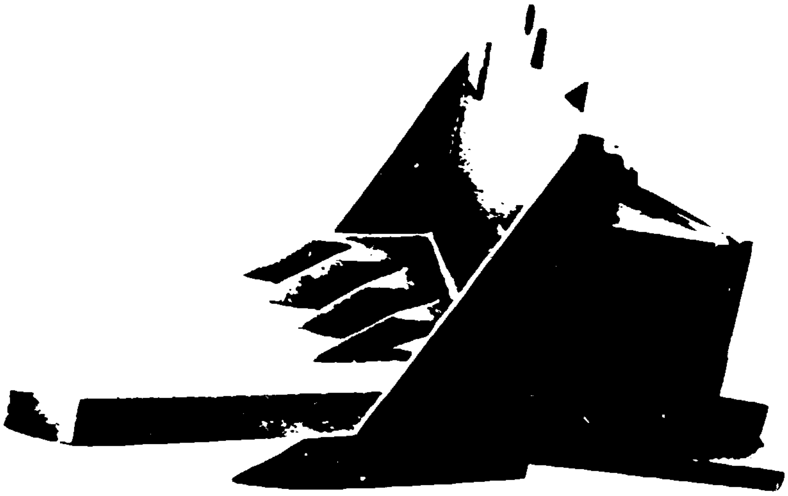


Figure 9. Traction stumper

Blade rake

The blade rake attachment (figures 10 and 11) is available in a wide variety of types. It consists of a strong frame, which is shaped like an angle-dozer. Curved teeth are fixed to the front. The teeth jut outwards and may be fixed or removable. They may have two edges and thus be reversible. The points may be interchangeable and vary in length. The blade rakes are somewhat like multi-toothed pitchforks designed to overcome particularly difficult areas encountered in the land clearing operation.

The tooth-bearing frame extends upwards and gives good protection. The frame is slanted forwards and supported by many beams to act as a thrust cross member in felling trees and to stack and pile vegetation. The blade rake can be used in place of the angle-blade. Its raked angle is best suited for piling debris into piles. The piles are then removed by loaders or burned on the spot. Blade rakes are also available for more specialized and heavier tasks (such as the removal of boulders or stumps); or for more general and lighter tasks (such as the removal and uprooting of bushes, and land clearing).

Figure 10. Blade rake. The raking blade is used to clear particularly difficult areas

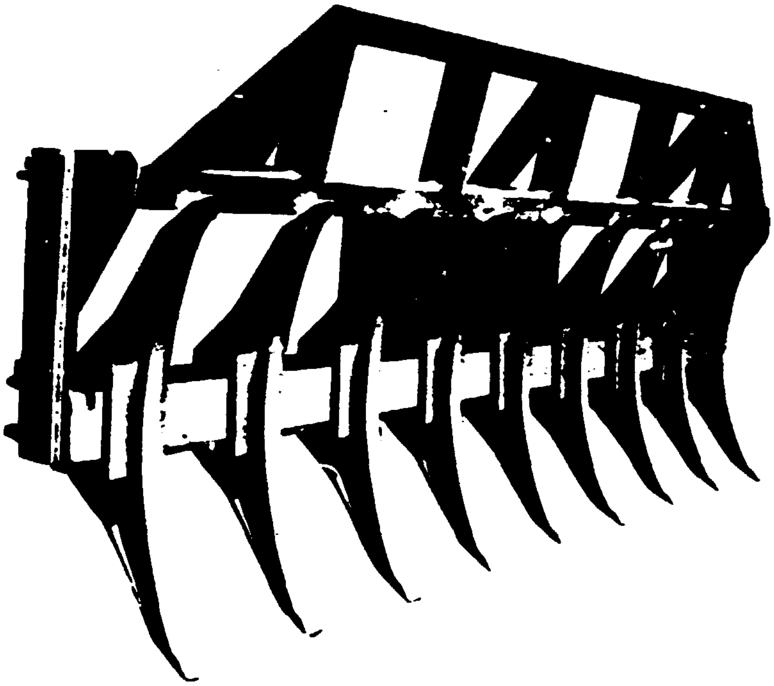


Figure 11. Blade rake for angle dozer. The blade rake is available in a wide variety of types. This is for lighter operations

The blade rake attachment is easily dismantled and makes the angle-dozer suitable for lighter operations such as the removal of light vegetation or the transportation and collection of debris.

Dragging felled trunks

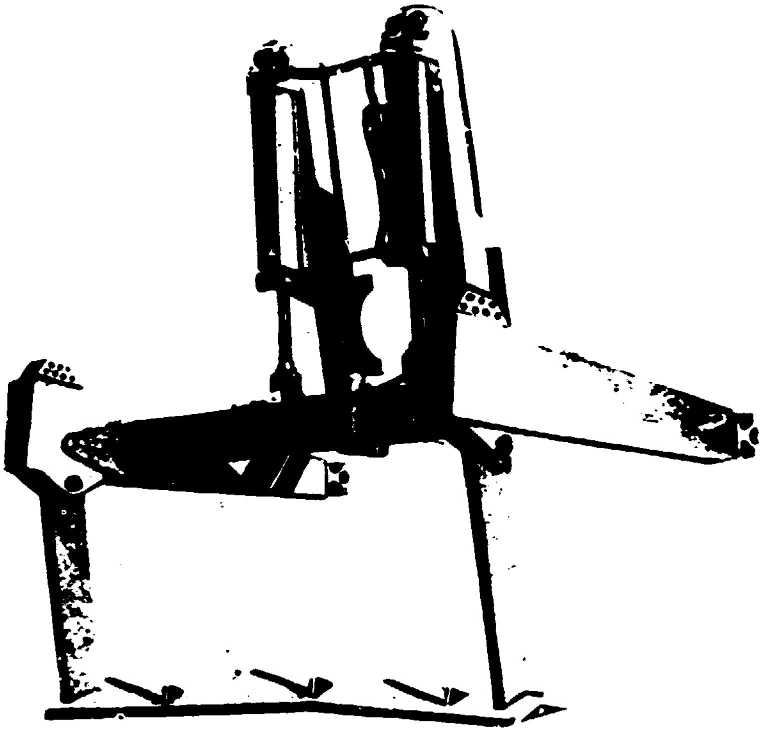
Dragging felled trunks can be done by a winch attached to the dozer. The dozer can drag or skid trunks on any terrain. However, the skidder as a wheeled machine is limited by the consistency of the terrain and the vulnerability of the tyres to puncture by rocks or wood. The winch is an essential piece of equipment for the use with the dozer in land clearing operations.

If agricultural growth or replanting is planned for the cleared land, it is necessary to destroy the buried roots, to smooth the surface, and to chop up the debris. In this operation, the dozer is used to tow various pieces of equipment.

The equipment for surface clearing and smoothing includes:

(a) A root-shearing blade (figure 12). The root-shearing blade is attached to the angle-dozer. It is mounted at the rear and is attached by means of push arms to the hinged parts of the angle-dozer's C-frame. The blade is horizontal and is sunk into the ground by hydraulic jacks. It is then towed so as to tear up the buried roots.

Figure 12. Root shearing blade. The blade is sunk into the ground by hydraulic jacks



(b) Rolling choppers (figure 13). These are hollow cylinders which are filled with water to weigh them down to the ground. The drum of the chopper has cutting blades welded on. The drum is

Figure 13. Rolling chopper. The chopper is filled with water to weigh it down

towed by the dozer and clears the surface as the result of its weight and the knife-action, which chops up the remaining vegetation and crumbles the crust of the soil, without causing any damage in depth. The crushing drum is used alone or in groups of two or three.

(c) Disc harrows for land clearing (figure 14). These are attachments which are towed to prepare the soil before cultivation. The harrow has a heavy supporting frame for the discs and their radial cutting sections. The harrows can be placed either perpendicular to or at an angle to the direction of the dozer's motion. If the frame is a V-shape the harrow gives a double action to the soil surface. The frame of the V-shaped harrow may be rigid or flexible and, in this case, its setting may be manual, cable or hydraulic.

Figure 14. Disc harrow for land clearing. The frame is V-shaped, resulting in a double harrowing action at the surface

Path opening

Clearing land for development is done to open paths for access by machines and labourers. Clearing requires dragging felled trunks from the shearing site so they may be piled and hauled away. Path opening can be rudimental if the paths are for temporary use (e.g., for some months), especially if the path is only needed until the land clearing of an area is completed. If the paths are to be used later for other purposes, they may be repaired or reopened even after long periods of inactivity. Temporary paths are justifiable from an economic viewpoint as these paths do not require maintenance. If the paths are later transformed into access roads to hydroelectric stations, mines, grazing grounds or places of tourist interest, the initial undertaking should be planned to provide for later usage. In either case, the machine for path opening is the track-type tractor with a semi-U blade having a hydraulic "tilt".

The selection of the tractor to be used depends on the type of ground (sandy, clayish, mixed with rock or really rocky) and the trees to be felled. In multi-application operations, the dozer has the advantage of having a hydraulic tilt available. For more strenuous tree-felling work, machines and equipment indicated in the chapt · on land clearing are used. If the undertaking is particularly simple, even the land clearing angle-dozer may be used.

Attachments for clearing machines

Blade with semi-U profile

Compared to the straight blade, the semi-U blade develops a more effective cutting action at its ends. The ends of the semi-U blade are slanted forward and offer a brush rack with larger load carrying capacity.

Hydraulic tilt

When set in the "tilt" position, the "bull" blade is inclined so that one of its ends points to the ground. Hydraulic control of the tilt permits the blade to be moved by the operator. In a tilt position the blade is particularly effective in removing slabs of rock or logs from the ground. It is also effective in piling debris as its angle can be continuously changed to adapt to the irregularity of the terrain during the tractor's forward motion. The tilt position of the blade is also used to crumble the soil surface in a manner similar to ripping before the digging process or similar to a manœuvre used by the tractor to maintain direction if it swerves as a result of obstruction or an unbalanced load.

Power shift transmission

Power shift transmission is safer and allows for closer work than the friction transmission. There is a great advantage in the combination of an oil-bath clutch transmission with the power shift transmission.

Winch

The winch used on the bulldozer is one of the multi-application attachments used in logging road construction. It is used to rescue its own vehicle or other vehicles when they are in difficulty or swamped down in muddy ground. The winch pulls out stumps, breaks up rocks and skids trunks out of the way. A raised fairlead winch is recommended as auxiliary equipment to improve the manœuvrability of the load-skidding tractor.

Ripper

This ripper is an alternative auxiliary tool for the bulldozer and is useful for path-clearing operations. The ripper is useful on clay loam soil or rocky ground when it is necessary to rip vegetation from the soil in preparation for excavation work. The choice of the type of ripper (multi- or single-toothed) largely depends on the terrain. As far as possible and if the vegetation does not offer excessive resistance, the multi-toothed ripper is used for the sake of economy. The single-toothed ripper is needed when large-sized blocks or slabs are to be ripped. The operation consists of edging forward at minimum speed and maximum possible depth, rather than at a high speed and lesser depth. At low speeds, wear and tear of the dozer's mechanical parts is reduced.

Ripping operations may call for the use of a bulldozer to provide power and weight to boost the traction power and increase the penetration of the teeth into the ground.

Rolling choppers

Rolling choppers are pulled by track-type tractors and may be either simple choppers or vibrating ones which furrow the soil crust to an even depth. The chopping evens the soil surface and tamps it to prevent water seepage and extend path life. Heavily ballasted rollers are used in soil tillage when it is necessary to break up rocks, and to make the surface hard and smooth, and to lessen excessive wear to the tyres of load vehicles.

Conclusions

The specially equipped track-type dozer is universally adaptable for work in the forests of the world.

In land clearing operations, the track-type angle-dozer is the most versatile machine, especially because of the following characteristics:

(a) The option of power shift transmission, preferably with a clutch (in place of a converter), and with protective guards for both the operator and machine;

(b) The option of interchangeable special equipment with angle blades or other devices to fell trees, remove stumps, uproot vegetative growth and dispose of litter accumulated from the cleared land;

(c) The option of equipment to rip out the embedded roots, to till the soil to prepare it for agricultural use;

(d) The option of the winch for the skidding of tree trunks.

In path-opening, the machine most suited for the basic land clearing operation is the track-type bulldozer having a semi-U blade with hydraulic tilt; and having a winch or ripper for emergency situations.

IX. Selection of sawmilling equipment*

This chapter presents a case study of the selection of band saws commonly used for tropical hardwoods.

Breakdown capacity

The yield of converted sawn lumber for a given volume (in cubic metres) of logs depends on the quality of the logs and the required grade of sawn lumber. Therefore, basic data have to be obtained to obtain a realistic estimate of the sawmill capacity. If all the other conditions remain constant, the log feed rate depends on blade quality and maintenance.

When converting medium-hard logs, 4 m long and 1.5 m in diameter (about 7 m^3 for each log), on the headrig, the slab cut and three to five other cuts for thin boards will be made before cutting 50 mm thick planks. All the logs more than 1 m in diameter will be centre cut to prevent splitting of full size heart boards.

Hourly log breakdown capacity is calculated to be 14 m^3/h. This figure is rather optimistic because work is usually slowed down for various reasons and practical production time will not exceed 80 per cent of the total available time. It is well to remember when a plant is highly mechanized and the various phases of the production cycle are closely interrelated, that a small problem which causes downtime in a part of the plant will decrease the output of the overall system. It may be assumed, however, that a plant with just one log band saw can convert 70-80 m^3 of logs in an eight-hour shift.

Increased output calls for a plant with two headrigs: these band saws should be the same size so that band saw blades can be interchangeable on both headrigs.

If a log to be sawn is less than 1.5 m diameter, a small and a large carriage should be used. The smaller logs travel on the small carriage which normally operates at a higher feed speed.

The log breakdown time for different sawmilling operations in calculated in tables 1 and 2.

Production steps used to calculate log breakdown time (table 2)

The calculations are for a double headrig sawmill with band resawing machine. The operation time is for breakdown of a log 4 m long and 1.5 m in diameter. The steps are:

(a) Loading the log on the carriage, rotating and centring;

(b) Selecting the position and cutting the slab,

(c) Sawing two side boards;

(d) Three carriage return strokes;

(e) Releasing the dogs, lifting and rotating the log, setting the sawn surface to the knees; setting the dogs and readjusting the knees;

(f) Positioning and sawing the opposite slab;

(g) Sawing two side boards;

(h) Three carriage return strokes;

(i) Moving the knees towards the blade so that the centre of the log is lined up and cutting the log through the centre;

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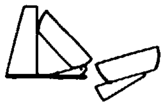
* By G. Dalla Valle, consultant in sawmilling. (This is an edited version of ID/WG.277/11.)

TABLE 1. SINGLE HEADRIG SAWMILL. HEADRIG OPERATION TIME FOR LOG BREAKDOWN

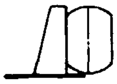
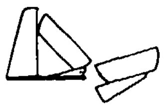
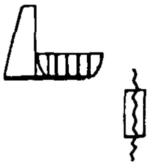
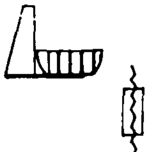
Log: 4 m long, 1.5 m diameter

Log position	*Operation*	*Depth of cut (m)*	*Feed speed (m/min)*	*Cycle time (s)*	*Total time (s)*
	Log loading on to the carriage, log rotating and centring			30	30
	Selecting the position and slab sawing	0.4	30	20	20
	Sawing 4 boards	0.7	15	18	72
	Carriage return 5 times		67	4	20
	Dog release for resetting the log, log lifting and rotating to the sawn surface on to the knees; log dogging and resetting the knees moving the clamps forwards			60	60
	Selecting the position and sawing the opposite slab	0.4	30	20	20
	Sawing 4 boards	0.7	15	18	72
	Carriage return 5 times		67	4	20
	Moving the knees towards the blade for centre sawing	1.5	12	40	40
	Unloading the flitch on to the log deck, release the dogs, turning, positioning and dogging the flitch, carriage return, align the flitch and saw edged boards	0.25	35	95	95
	Sawing 4 boards	0.35	30	9	45
	Carriage return 5 times		67	4	20
	Sawing 24 boards	0.6	18	15	360
	Carriage return 24 times		67	4	96
	Dog release, reposition and turn the remaining flitch, dog it and align the flitch	0.25	35	20	20
	Sawing 4 boards from the remaining flitch	0.35	30	9	36
	Carriage return 4 times		67	4	16
	Dog release, loading the second flitch on to the carriage, align and dog it, carriage return and sawing the waney slab	0.25	35	70	70
	Sawing 4 boards	0.35	30	9	36
	Carriage return 5 times		67	4	20
	Sawing 24 boards	0.6	18	15	360
	Carriage return 24 times		67	4	96
	Dog release, rotating the remaining flitch positioning against the knees dog it and align it	0.25	35	20	20
	Sawing four waney edged boards	0.35	30	9	36
	Carriage return 5 times		67	4	20
			Grand total time(s)		1 700
			(Approximately 30 minutes)		

Note: Log breakdown capacity per hour: 14 m^3. Sawing and carriage time return calculated for a 4.5 m carriage length.

TABLE 2. SAWMILL WITH TWO HEADRIGS AND A RESAW. LOG BREAKDOWN TIME

Log: 4 m long, 1.5 m diameter

Log position	*Operation*	*Depth of cut (m)*	*Feed speed (m min)*	*Cycle time (s)*	*Total time (s)*	*Number of boards for resawing*
	Log loading on to the carriage, rotating and centring			30	30	
	Selecting the position and slab cutting	0.4	30	20	20	
	Sawing 2 boards	0.7	15	18	36	2
	Carriage return 3 times		67	4	12	
	Dog release for resetting the log, lifting and rotating the sawn surface on to the knees, log dogging and resetting the knees			60	60	
	Selecting, positioning and sawing the opposite slab	0.4	30	20	20	
	Sawing 2 boards	0.7	15	18	36	2
	Carriage return 3 times		67	4	12	
	Moving the knees towards the blade for centre sawing, aligning and sawing	1.5	12	40	40	
	Unloading the outer flitch to the log deck, releasing the dogs, turning, positioning, dogging the flitch, carriage return, aligning the flitch and sawing the waney edge	0.25	35	95	95	
	Sawing 2 boards	0.35	30	9	18	2
	Carriage return 3 times		67	4	12	
	Sawing 12 boards (which will be resawn by the band resaw)	0.6	18	15	180	12
	Carriage return 12 times		67	4	48	
	Dog release for resetting, turn the remaining flitch, reposition and dog it, align it and saw the waney boards	0.25	35	20	20	
	Sawing 2 boards out of the remaining part	0.35	30	9	18	2
	Carriage return 2 times		67	4	8	
	Dog release for resetting the flitch, loading, aligning, dogging and carriage return, sawing the fifth boards	0.25	35	70	70	
	Sawing 2 boards	0.35	30	9	18	2
	Carriage return 3 times		67	4	12	
	Sawing 12 boards to be resawn	0.6	18	15	180	12
	Carriage return 12 times		67	4	48	
	Dog release for resetting the remaining flitch part, positioning and dogging against the knees, aligning the flitch and sawing the sixth waney edged boards	0.25	35	20	20	
	Sawing 2 boards	0.35	30	9	18	2
	Carriage return 2 times		67	4	12	
					1 043	36

Note: $\frac{1\,043}{60}$ = 17.38 min ⟶ 18 min to break down log (actual time). Log breakdown capacity per hour: 23 m^3 for each headrig.

(j) Unloading the flitch on to the waiting area, releasing the dogs, positioning the remaining flitch, dogging it, carriage return stroke, aligning the flitch and sawing the waney edge;

(k) Sawing two boards from the outside portion;

(l) Three carriage return strokes;

(m) Sawing twelve boards to be resawn;

(n) Twelve carriage return strokes;

(o) Release the dogs, positioning at the sawn surface resting against the knees, dogging, aligning the lumber and sawing the waney boards;

(p) Sawing two side boards;

(q) Two carriage return strokes;

(r) Releasing the dogs, loading the other half of the log on to the carriage, aligning and dogging it, carriage return stroke, and sawing the fifth outside slab;

(s) Sawing two side boards;

(t) Three carriage return strokes;

(u) Sawing twelve boards (which will be resawn by the resawing machine);

(v) Twelve carriage return strokes;

(w) Releasing the dogs, rotating the flitch, positioning it so that the surface rests against the knees, dogging it, aligning the lumber and sawing the sixth outside slab;

(x) Sawing two boards from the outside section;

(y) Two carriage return strokes.

A second headrig will certainly not double the hourly output (which is calculated for a sawmill with two headrigs in table 2); even though the idle time for loading, unloading and turning will be the same, it will be the log sawing operation gaining less volume. On an average, the headrig capacity is about 55-65 m^3 in an eight-hour shift.

A plant equipped with two headrigs each with a pulley diameter of 1.6 m and automatic carriage drive can cut 125-145 m^3 of logs in an eight-hour shift providing that other conditions described above are met.

For a plant to saw the same species with a capacity of more than 120 m^3 in an eight-hour shift, two headrigs and one self-centring band resawing machine are recommended. Instead of a carriage travelling to and fro, this machine has endless feed mechanism for the boards. Theoretically, this system should decrease the time lost in carriage return. The frame on the band resawing machine is equipped with a tensioning device for the blades and a remote control for rise and fall of the blade-guide. The feed mechanism can be fences on opposite sides of the table with motor driven feed rollers, chains or belts.

These two fences are interconnected mechanically and electrically so as to move symmetrically in relation to the blade. These fences guide the boards so they travel straight and parallel to the saw blade. The feed rollers on the fences turn at the same speed. The best device is remote controlled with infinitely adjustable speed so that the operator can adjust the feed rate according to the wood species. The roller pressure is also adjustable. Where the thickness of the boards varies, a servo-control which automatically readjusts the fences is useful. When breaking down the same log dimensions as before (1.5 m in diameter and 4 m long) and applying the same sawing technology with the exception that the boards sawn on the two headrigs will be twice as thick and centre sawn at the band resawing machine, the calculation will follow the sample in table 2.

Each of the two headrigs supplies the resawing machine with 36 boards 4 m long every 18 minutes. Therefore the resawing machine will have to work at the following (theoretical) average rate:

$$\frac{36 \times 2 \times 4}{18} = 16 \text{ m/min}$$

However, in practice the resawing feed is not constant. Therefore, the actual feed rate of at least 20 m/min will produce 288 m of boards every 18 minutes.

In the above calculation the pulley diameter must be 1.6 m. The theoretical capacity of the sawmill –equipped with two headrigs with pulley diameter of 1.6 m and a self-centring resawing machine also with pulley diameter of 1.6 m– is 14 m^3 every 18 minutes which is about 46 m^3/h. In practice, as the operation is not continuous, this sawmill would have a capacity of breaking down about 230-250 m^3 of logs in one eight-hour shift.

To summarize, three output levels have to be considered:

(a) A sawmill with one headrig. The log breakdown is 70-80 m³ per shift. This equals 10-11 logs of 1.5 m in diameter and 4 m long;

(b) A sawmill with two headrigs. The log breakdown is 125-145 [illegible] per shift. This equals 10-11 logs of 1.5 m in diameter and 4 m long and 12-14 logs 1.2 m in diameter and 4 m long;

(c) A sawmill with two headrigs and a self-centring resawing machine. The log breakdown is 230-260 m³ per shift. This equals 33-37 logs 1.5 m in diameter and 4 m long.

Headrig and carriage

The headrig is composed of a vertical band saw with 1.6 m pulley driven by a 110 kW motor. A geared electric motor mounted on the column is used to tension the blades. The adjustment of both the saw blade and the upper blade guide is remotely controlled.

The carriage is equipped with dogs for clamping the log on to the head blocks. The distance between the saw blade and the knees is 1,600 mm, large enough to hold logs up to 2 m in diameter. Most dogs are adjustable. Fixed-hook dogs are mounted to the head blocks to hold the logs parallel to the direction in which the carriage is travelling. The log turning device can either be mounted on the carriage or the log deck. It is used to align and position the log. It is also used for turning the log after slabbing. The setworks are electrically or hydraulically controlled. The carriage is offset by about 10 mm during the return stroke. This prevents splintering or scratching the sawn surface or striking the back of the blade which could cause it to run off the pulley. Before the feed stroke the log is automatically reset. Carriage feed speed is controlled by electric or hydraulic drive or hydraulic transmission; feed rate is infinitely variable and the rapid return stroke decreases idle time. The push-button control panel for the headrig, carriage, conveyers and the setworks is controlled by the head sawyer. The setworks are infinitely adjustable. When the operator presses the button, the dogs clamp the log and the knees push the log close to the saw blade before the board gauge is selected.

Selecting the standard type of a sawmill

Analysis has indicated that the headrig with pulleys of 1.6 m in diameter is the most suitable machine for sawing large logs of tropical species.

The following are possible layouts. The numbers refer to items in the figure. The partial layout includes log deck cross conveyers (items 11 and 12); headrig and carriage (C); a conveying system for sawn lumber, waste and the boards from the log (items 14, 34 and 35). Waney boards will pass the double-edging circular saw for edging (F) to the cut-off saw (L) (items 15 and 39-42). Some boards have to pass the single blade edging circular saw (H) (items 16, 49 and 50). Boards will then pass the sorting line (item 17). The boards which are longer than the standard length (item 18) are unloaded; and a cross conveyer for transporting the finished products (items 54 and 55).

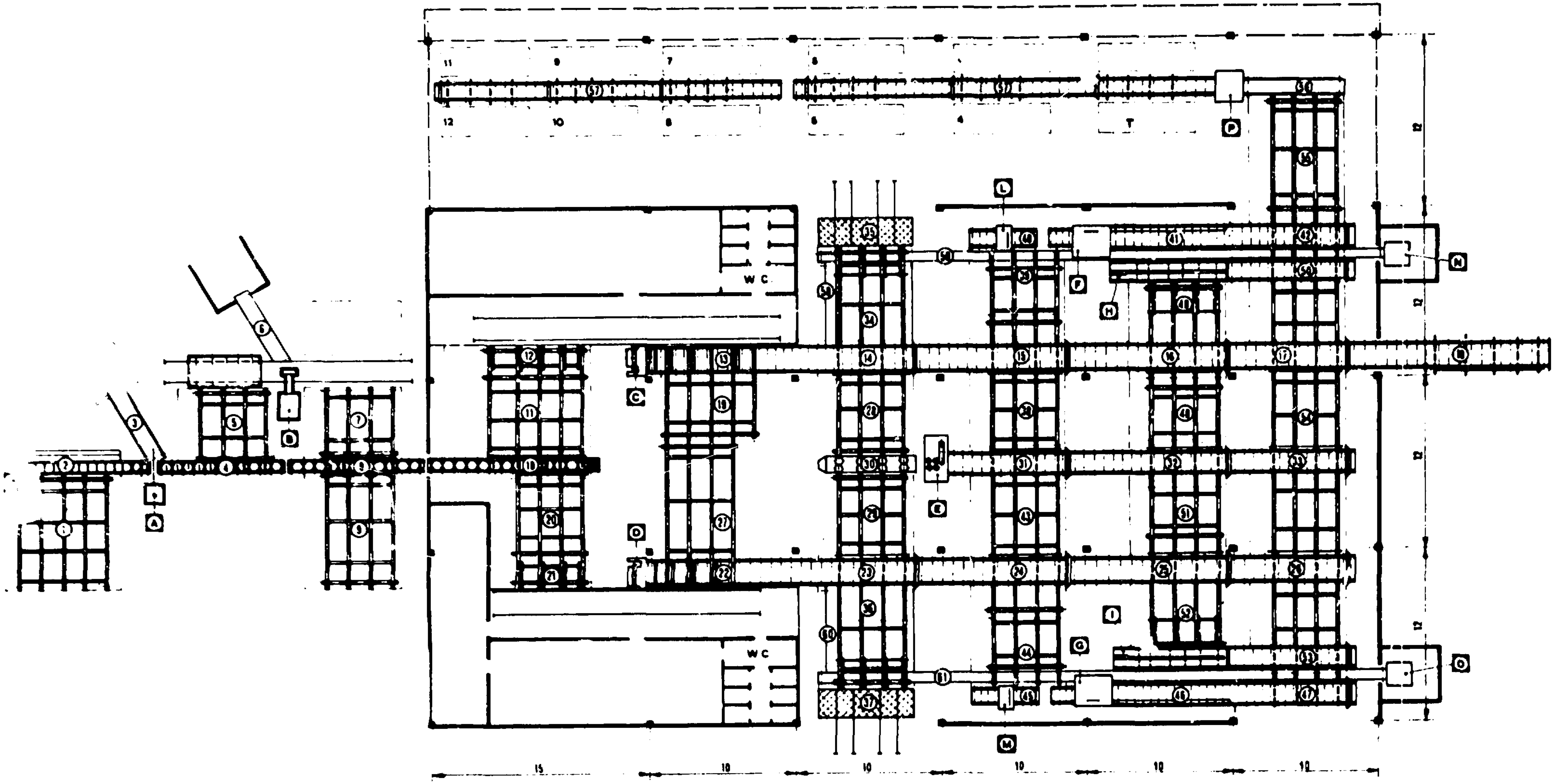
If one vertical log sawing machine has a theoretical output of 70-80 m³ in eight hours (see example above), the output can obviously be increased by increasing the number of sawing machines. A second log sawing machine can either work independently or in connection with the first machine. In the latter case, the material can be turned from one machine to the other by means of items 13, 19, 22 and 27. If the second machine works in conjunction with the first, all the machines and conveyers are used in the first layout outline, plus the:

Feed conveyer (items 20 and 21)
Vertical band sawing machine (D)
Lines for transporting and discharging the lumber that has been sawn (items 22-27, 36, 37, 44-47, 52, 53 and part of 54)
Double edging circular sawing machine (G)
Single blade edging circular sawing machine (I)

These machines operate along the same lines as the ones on the other side of the plant.

There is a third possibility, which uses all the machines and conveyers in the two preceding solutions plus a self-centring resawing machine (E), including the necessary conveyers (items 28-30), the conveyers for transporting the lumber to the two double edging circular sawing machines (items 31, 38 and 43), the

Sawmill machinery layout



Note: The numbered items are conveyers, lifts and feed mechanisms of various types (see text). The lettered items represent various cutting, debarking and hogging machines (see text).

conveyers for transporting the lumber to the two single blade edging circular sawing machines (items 32, 48 and 51) and the conveyer for transporting the finished product to the final chain conveyers (item 33). The layout shows the two headrigs, the self-centring resawing machine and two circular cut-off saws, two double edging circular sawing machines and two single blade edging circular sawing machines. These machines increase the production capacity by assuring full operational time of the log band saws (headrigs).

These solutions have been completed by adding an external log feed line with a station for cutting the logs to length and a debarking line (items 1-9, 10A and 10B). All sawn lumber is transported to a sorting line and the sawdust to a bunker (items 56, 57, P); with all the refuse material being collected in two different sections with hogging stations. The hogged chips are transported to a silo (items 58-61, N and O).

If the refuse material does not need to be hogged, conveyers 59, 61 and the hogging section can be eliminated. Special containers can be placed at the four collection stations to accommodate this material.

It is not intended to present a complete solution to the problem of sawing tropical logs. Different possibilities in log breakdown to meet various cutting requirements have been presented and each company must find the solution best suited to its needs.

The following numbered items refer to the figure and describe the function of the various machines depicted in the layout.

1. Cross conveyer for transporting the logs from the yard to the cut-off station and transfer to the debarking line.
2. Chain conveyer for feeding the logs to the cross-cut chain saw.
3. Belt conveyer for transporting waste from the cross-cut chain saw to the waste container.
4. Trough roller conveyer, complete with mechanical stops for positioning the logs before cutting to length and a device for discharging the logs to one side for debarking.
5. Cross conveyer for log transport to the debarking machine.
6. Belt conveyer for transporting waste from the debarking machine to the waste storage area.
7. Cross conveyer for transporting the logs from the debarking machine to the sawmill log deck.
8. Trough roller conveyer for transporting the logs from the debarking machine and directly from the yard to the sawmill log deck.
9. Cross conveyer for transporting the logs from the yard and the buffer storage area on the debarking machine to the sawmill log haul.
10. Trough roller conveyer where logs up to 6.60 m long are loaded on the right-hand deck and logs up to 10 m long loaded on the left-hand deck.
11. Cross conveyer for transporting the logs to the carriage.
12. Hydraulic log loader in front of the log carriage.
13. Roller conveyer for transporting sawn lumber from the headrig. This conveyer is equipped with a hydraulic return feeder.
14. Roller conveyer. The boards to be resawn are unloaded on the right while slabs, side boards and waste follow to the left.
15. Roller conveyer for transporting sawn lumber from the headrig where the boards to be edged by the double edging circular sawing machine are discharged to one side.
16. Roller conveyer; equipped with unloading unit for boards passing the single blade edging circular sawing machine.
17. Roller conveyer with unloading unit for lumber sawn at the headrig being conveyed to the sorting conveyers.
18. Roller conveyer for sawn lumber passing through the mill, equipped with an unloading device for boards more than 6.60 m long.
19. Cross conveyer; the lumber to be resawn is held here temporarily. The lumber can also be conveyed for reloading on to the log carriage.
20. Cross conveyer for transporting the logs to the carriage feed unit.
21. Hydraulic log loader in front of the log carriage.
22. Roller conveyer for transporting the lumber from the headrig. This conveyer is equipped with a hydraulic loader to handle returned lumber.
23. Roller conveyer. The boards passing the self-centring resawing machine are conveyed to the right; the waste material, rejects and the boards to be resawn are loaded on the left.
24. Roller conveyer for transporting sawn lumber from the headrig while the boards passing the double edging circular sawing machine are loaded to one side.

25. Roller conveyer equipped with an unloading unit for boards passing the single blade edging circular sawing machine.
26. Roller conveyer equipped with unloading unit. Sawn lumber from the headrig will pass on to the sorting conveyers.
27. Cross conveyer: the lumber which returns is temporarily held here. The lumber can also be reloaded on to the log carriage.
28. Cross conveyer for transporting sawn lumber from headrig passing to the self-centring resawing machine.
29. Cross conveyer for transporting sawn lumber from the headrig passing the self-centring resawing machine.
30. Self-centring feed works with grooved in-feed rollers.
31. Roller conveyer, equipped with unloading unit for boards which passed the self-centring resawing machine on to the conveyers on both sides leading to the double edge sawing machines.
32. Roller conveyer, equipped with unloader for boards on to the conveyers on both sides passing the lumber to the single blade edge sawing machines.
33. Roller conveyer, equipped with unloader for edged boards passing the self-centring resawing machine on to the sorting conveyers on both sides.
34. Cross conveyer for transporting the sawn lumber from the headrig for resorting or for other applications. This unit is equipped with a pneumatic system for turning the boards over.
35. Adjustable scissors lift for resorting the flitches or for packaging material which does not have to be sorted. These lifts travel on rails.
36. Cross conveyer for transporting sawn lumber from the headrig. This lumber will be used for other applications which do not require additional sorting. The unit is equipped with a pneumatic system for turning the boards over.
37. Adjustable scissors lift for resorting or for packaging material which requires no sorting. These lifts travel on rails.
38. Cross conveyer for transporting sawn lumber coming from the self-centring resawing machine and the headrig conveyed to the double edge sawing machine.
39. Cross conveyer for transporting lumber to the cut-off line and the double edge sawing machine.
40. Roller conveyer which supports the lumber during the cut-off operation and feeds it into the double edge sawing machine.
41. Roller conveyer located at the rear of the double edging sawing machine. The conveyer is equipped with an automatic device for separating the edgings.
42. Roller conveyer for transporting the boards which have been edged and loading them on to the sorting conveyer.
43. Cross conveyer for transporting the lumber from the self-centring resawing machine and the log sawing machine to the double edging sawing machine conveyer.
44. Cross conveyer for transporting lumber to the cut-off line and the double edging sawing machine.
45. Roller conveyer which supports the lumber during the cut-off operation and feeds it into the double edging sawing machine.
46. Roller conveyer at the rear of the double edging sawing machine: equipped with an automatic device for separating the edgings.
47. Roller conveyer for transporting the edged boards on to the sorting conveyers on the left. The lumber not to be graded (small boards and beams, etc.) is unloaded on the right, outside the sawmill.
48. Cross conveyer for transporting sawn lumber from the self-centring resawing machine and the log sawing machine to the single blade edging sawing machine conveyer.
49. Cross conveyer for feeding the boards to the single blade edging sawing machine. The conveyer is equipped with a pneumatic system for turning the boards over for the operator's inspection.
50. Roller cross conveyer for discharging sawn boards on to the sorting conveyer.
51. Cross conveyer for transporting the lumber from the self-centring resawing machine and the headrig to the single blade edging sawing machine conveyer.
52. Cross conveyer for boards passing the single blade edging sawing machine. It is equipped with a pneumatic system for turning the boards over for the operator's inspection.
53. Roller cross conveyer for unloading sawn lumber on to the sorting conveyer.
54. Cross conveyer for transporting the sawn boards coming from the headrig, double edging sawing machines, single blade edging sawing machines and the self-centring resawing machine to the sorting conveyer.

55. Cross conveyer for transporting sawn boards to the sorting conveyer belt.
56. Conveyer belt for transporting the lumber to the sorting line.
57. Conveyer with six unloading units for sorting boards into the right storage bin on either side. The boards are sorted according to thickness and length.
58. Belt conveyer for transporting rejects and mill refuse from the headrig to one of the two refuse conveyers.
59. One of the two belt conveyers for transporting waste and rejects from the headrig, the cut-off line and the edging sawing machines to one of the hogging machines.
60. Belt conveyer for transporting refuse and rejects from the headrig to one of the two refuse conveyers.
61. One of the two belt conveyers for transporting refuse and rejects from the headrig, the cut-off line and the edging sawing machines to one of the hogging machines.

The letters below refer to machines used in log breakdown and the flow of the breakdown process as shown in the figure.

(A) Chainsaw for cutting logs to length. After cutting to length, the logs are either conveyed directly to the sawmill or to the debarking machine.

(B) Debarking machine with rotating cutter head and rail-mounted carriage. Besides the rotating cutter debarking machines, rotor type debarking machines are widely used. This type of machine is only suitable for relatively small diameter logs and cannot be used to debark tropical logs. The logs are fed to this machine after being cut to length. After the debarking operation they can either be temporarily stored in the yard or conveyed to the sawmill. The logs which are stored in the yard can be sent to the sawmill by means of the independent conveyer (item 9).

(C) Vertical headrig with pulley diameter of 1,600 mm. The logs are loaded on to the carriage after being cut to length, debarking, or directly from the yard. This machine breaks down lumber for the self-centring resawing machine. It produces boards for the single blade edging sawing machine; boards with centre defects, sound boards which pass directly to the sorting line, lumber for resorting, lumber more than 6.60 m long and rejects are conveyed outside the sawmill (item 18). The machine can also break down logs into halves. Flitches and blocks to be returned or transported by conveyers 27 and 19 to the other headrig.

(D) Vertical headrig and carriage with pulley diameter of 1,600 mm. The logs are loaded on to the carriage after being cut to length and debarking, or directly from the yard. The log breakdown includes: slabs, side cuts, boards for resawing, boards for edging, boards with centre defects, sound boards which pass directly to the sorting line, material such as rejects and refuse. This machine can also break down logs into halves. Flitches and blocks to be returned or transported by conveyers 27 and 19 to the other headrig for additional processing.

(E) Self-centring band resawing machine with pulley diameter of 1,600 mm. The lumber sawn by the headrig passes to this machine to be resawn into boards for the two cut-off and edging stations. Boards with centre cracks pass on to the single blade edging sawing machine and sawn lumber is transported to the sorting line.

(F) and (G) Double edging circular sawing machines. Boards from the two headrigs and the self-centring resawing machine pass on to these machines. Edged boards pass on to the sorting line, edgings are unloaded automatically.

(H) and (I) Single blade edging circular sawing machines with chain feed for centring boards. Waste material is discharged to one side and the boards are fed straight out on rollers. The lumber from the two headrigs and the self-centring resawing machine is conveyed to these machines to be edged and passed along to the sorting line.

(L) and (M) Circular cut-off sawing machine. Boards from the headrig and the self-centring resawing machine are conveyed to this machine to be double-edged.

(N) and (O) Hogging machines. The refuse from the headrig, the cut-off sawing machines, the double edging sawing machines and single blade edging sawing machines is conveyed to these machines. The chips are transported to the silos by vacuum conveyer.

(P) Brushing machine for removing sawdust from the edged boards.

X. Kiln drying of sawn lumber*

Reasons for drying wood

It is necessary to dry wood to prevent it from becoming deformed. This is because green wood, after having been sawn into lumber, will dry out by a natural process. During this natural process the wood will shrink differently along different directions causing deformation. In addition, as wood is a heterogeneous and anisotropic material, different parts of the wood will dry and shrink at different rates. This deforms the wood. The process of drying out and consequent deformation will continue over a long period of time. Thus undried wood will continue to lose moisture and to shrink, until the moisture of the wood is in equilibrium with the moisture of the air. This process may take a long time and produce unacceptable warping and shrinking. If wood is dried first, the wood can be brought to a desired moisture content. Its dimensions will change less if the wood is then subjected to changes of environmental humidity. Thus dried wood will shrink less than undried wood. The moisture content of the wood will depend on the relative humidity and the temperature of the surrounding air. Table 1 shows this relationship in a general fashion for many wood species. The moisture content of the wood varies with the humidity, being lower at lower humidities.

However, the processes of drying and regaining moisture are not entirely reversible. At a given atmospheric pressure a lower moisture content is obtained when the wood absorbs water to reach equilibrium with the surrounding air than when the wood dries out to come to equilibrium with the surrounding air. This phenomenon, called hysteresis, results in a difference of moisture content reached by the drying — as opposed to the absorbing — processes of 2-4 per cent. This natural drying tendency is further enhanced by the fact that wood dries more rapidly than it absorbs moisture.

The wood swells when it absorbs moisture and shrinks when it dries. The shrinkage is not uniform in all directions but varies roughly as:

$$a_l : a_r : a_t = 1 : 10 : 20$$

where a_l is longitudinal shrinkage,

a_r is radial shrinkage,

a_t is tangential shrinkage.

Table 1 also shows how shrinkage at given humidity levels varies with direction.

There are new modern wood drying techniques. These techniques have resulted from fresh knowledge of the physical nature of wood and the processes involved in its drying.

The moisture content of wood is expressed in per cent and defined as $\frac{\text{weight of moisture}}{\text{weight of wood}} \times 100.$

Coniferous species in general have a relatively dry heartwood duramen of 31 to 35 per cent moisture content and a sap-wood with high moisture content of 120 to 160 per cent. The strobile pine with heartwood moisture content around 80 per cent and the "wet heartwood" of white spruce with moisture content of up to 220 per cent are exceptions. With broad-leaved species the moisture content differences between sap-wood and heartwood are less marked. In general, moisture content increases towards the top of a tree where sap-wood predominates. Moisture content decreases with age, therefore wood from young forests has more moisture than that from mature ones. In general, average moisture content of trees from uneven-aged forests is higher than that of trees from even-aged forests.

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* By R. Cividini, professor in wood technology. (This is an edited version of ID/WG.277/18.)

TABLE 1. WOOD-AIR HUMIDITY EQUILIBRIUM AND SHRINKAGE AND SWELLING IN THE HUMIDITY RANGE 60-90 PER CENT

Tree	*Equilibrium moisture content at two different relative humidities (%)*		*Shrinkage—swelling (%)*			
			Tangential		*Radial*	
	90% humidity	*60% humidity*	*Between 60% and 90% humidity*	*For each 1% humidity*	*Between 60% and 90% humidity*	*For each 1% humidity*
Obeche (wawa)	19	12	1.25	0.18	0.8	0.12
Afrormosia	15	11	1.3	0.32	0.7	0.17
Maple	23	13.5	2.8	0.29	1.4	0.15
Birch	21.5	12	2.5	0.26	2.2	0.23
Beech	20	12	3.2	0.40	1.7	0.21
Oak (European)	20	12	2.5	0.31	1.5	0.19
Ash	20	12.5	1.8	0.24	1.3	0.17
Iroko	15	11	1.0	0.25	0.5	0.12
Cherry	19	12.5	2.0	0.31	1.2	0.18
Larch (European)	19	13	1.7	0.28	0.8	0.13
Limba	18	12	1.3	0.22	1.0	0.17
Khaya grandif.	23	14	1.9	0.21	1.5	0.17
Khaya ivorensis	20	13.5	1.5	0.23	0.9	0.14
Mahogany (Swietenia)	19	12.5	1.3	0.20	1.0	0.15
Makoré	19	13	1.8	0.30	1.1	0.18
Bété	20	12	2.3	0.29	1.3	0.16
African walnut	18	13	1.3	0.26	0.9	0.18
European walnut	18.5	11.5	2.0	0.29	1.6	0.23
Red oak	18.5	11.5	2.4	0.34	1.3	0.19
Elm	22	13	2.4	0.27	1.5	0.17
Sapele	20.5	13.5	1.8	0.26	1.3	0.19
Teak	15	10	1.3	0.26	0.8	0.16
Wengé	15	11.5	0.9	0.26	0.65	0.19
Abura		11.5		0.20		0.08
Sipo				0.20		0.15
Kossipo		15		0.18		0.13

Some of the moisture in wood is in a free state in the cellular and intercellular cavities (free moisture). The rest is found in the cellular walls (hygroscopic moisture). Hygroscopic moisture represents from 30 to 38 per cent of the weight of the ligneous material. This is percentage of moisture required to saturate the cellular walls.

In an environment where the relative humidity is less than 100 per cent (unsaturated air) the free moisture of the wood evaporates. Wood may be considered as a hygroscopic body which exchanges hygroscopic moisture with the environment (air). Shrinkage of the cellular walls begins at the moisture content below saturation point (below 30-38 per cent).

Shrinkage of timber begins when the wood's average moisture content is in excess of 30 per cent because the external layers begin to lose saturation moisture even though the internal layers are still saturated.

The average moisture at which shrinkage will begin depends in practice on permeability, thickness, initial moisture, intensity of drying and mechanical strength (plasticity, tensile and compression strength).

Shrinkage increases with wood density. The spring wood shrinks less than the summer wood. The heartwood shrinks less than the sap-wood. These shrinkage characteristics due to non-homogeneity of structure together with lack of uniformity in directional shrinkage cause deformation and increased star shake. Finished wood products will tend to adapt to their environment and therefore they must be dried to a moisture level in equilibrium with local climatic conditions. An approximate guide, valid for conditions in Italy, is given as table 2.

TABLE 2. RECOMMENDED FINAL MOISTURE CONTENT OF WOOD FOR VARIOUS PRODUCTS[a]

Product	*Final moisture content* (%)
Commercially sawn timber	16-20
Timber for building purposes	12-18
Timber for sheds	12-15
Panels (plywood, particle board etc.), veneers	6-8
Commercial veneers	12-16
Particle board cores	6-7
Door and window frames (external)	12-15
Door and window frames (internal)	8-10
Internal parquet and matchboarding	6-8
Internal furniture and furnishing in general	6-10
External furniture and implements (garden etc.)	12-16
Coachwork and agricultural machinery	12-18
Coachwork for cars	7-10
Railway coaches (internal)	6-8
Aircraft	6-10
Boats	12-16
Sports goods	8-12
Toys for internal use	6-10
Toys for external use	10-15
Wood moulds	6-9
Rifle butts	7-12
Electrical accessories	5-8
Musical instruments	5-8
Wood dies	6-8
Picture frames	6-10
Casks, packing cases	12-16

[a] Assuming climatic conditions of Italy.

Wood which has been dried will assume an equilibrium moisture content within the limits determined by the hysteresis phenomenon. If the atmospheric humidity varies within the 2-4 per cent hysteresis range, the moisture content of the wood remains constant. Occasional changes of atmospheric humidity outside the limits of the hysteresis moisture range may still not cause the wood to swell or to shrink. The wood absorbs moisture more slowly than it dries. Swelling can also be retarded by paints, varnishes and by other chemicals.

The permeability of wood is the most important factor in the drying process. Permeability in the radial direction is noticeably greater than in the tangential direction which is the reason why laterally sawn boards dry much quicker than radially sawn ones. Permeability in the radial direction increases with the number of annual rings.

The number and frequency of radial lines are unfortunately the cause of lowering the transverse tensile strength of wood which leads to star shakes. Red spruce and all sap-woods may be considered as permeable while white spruce and the heartwoods of other conifers may be considered of medium permeability. Among broad-leaved woods the most permeable are those with many porous openings while tylosed woods are highly impermeable. Light-weight white woods are permeable. Permeability in general is related to density.

There are three phases in wood drying. The first phase is the evaporation of free moisture. Diffusion of water vapour and capillary action cause a moisture gradient with moisture content generally varying as the square of the distance from the surface This phenomenon varies with the permeability of the wood. For impermeable woods and those of medium permeability, vapour diffusion and capillary action are not very important in drying. The diffusion of moisture through cellular walls is more important. In this case the variation of moisture content with depth in the wood shows a steeper curve. The relationship of moisture content varying roughly as the square of the distance from the surface will hold true when the external layers are in equilibrium with the surrounding air. Mechanical strength during this first phase is minimal and high temperatures can cause the wood to deteriorate. When the cellular walls in the external layers have dried to their saturation point, shrinkage and the appearance of tensile stresses begin. This process is more marked in the external layers of medium permeability and impermeable woods. This is called the first critical point and is the end of phase I. The rate of the drying slows and phase II begins. The wood's average moisture content at the first critical point will be around ⅔ of the initial moisture content plus 10 per cent in permeable species and around ⅔ to ¾ of the initial moisture content in species having medium permeability.

When an average moisture content of 21-24 per cent is reached, drying enters into phase III where there is inversion of stresses (centre stress) and external layers are in equilibrium with the surrounding air. Mechanical strength of the wood increases in this phase. Drying slows down because diffusion through the cellular walls is a slow process, and accounts for most of the drying.

Drying is faster when permeability is higher, when density is lower, when temperature is higher, when relative air humidity is lower, when the air circulation is faster. The rate of air circulation is not important during phase III.

Wood drying techniques

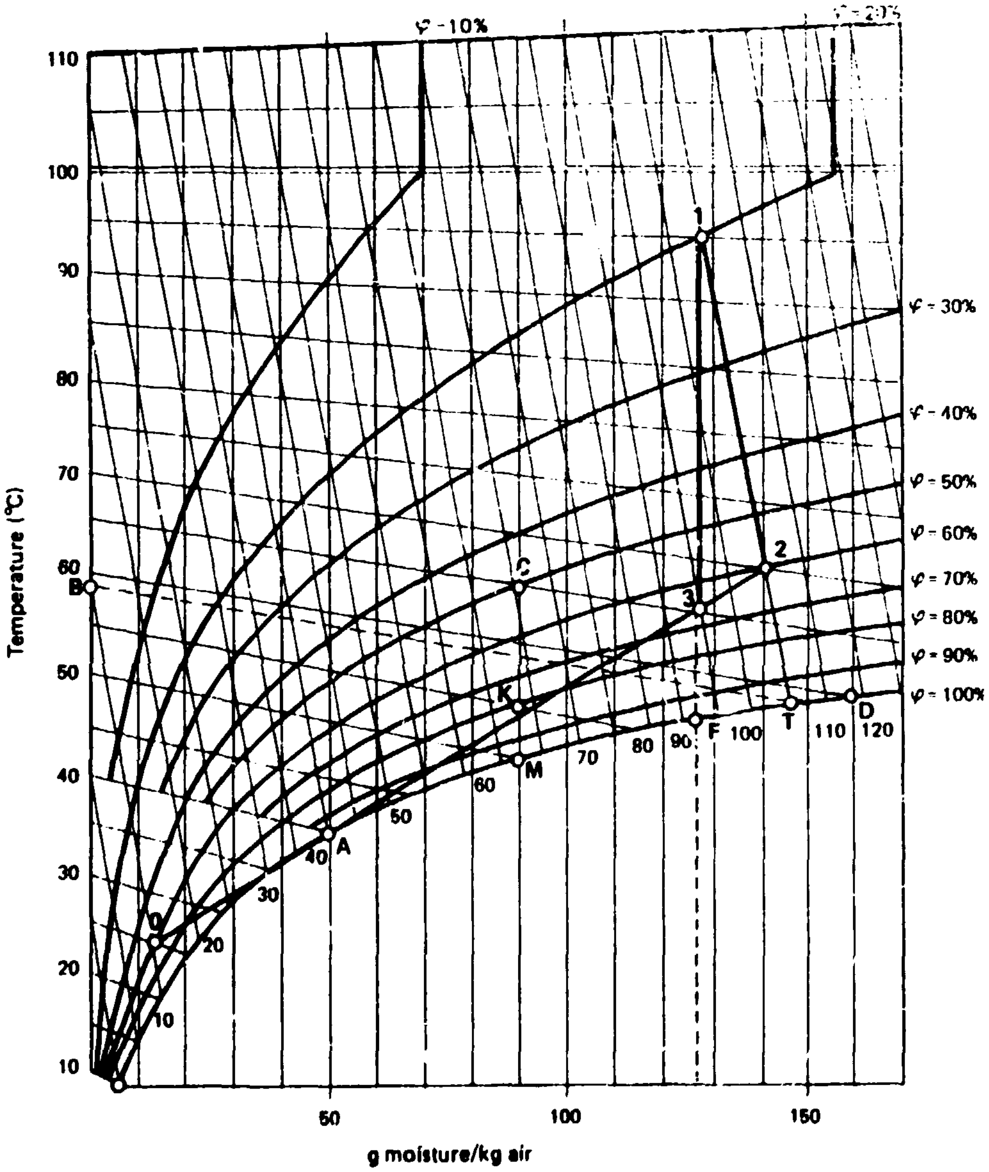
Air

The temperature and the humidity of the air used for drying may be varied to suit the technical demands of the drying process. Figure 1 is a graph showing the relationship between the air temperature and the amount of water absorbed (in g) per kg of air. The figure also shows the thermodynamic cycle of the process of air drying. The drying process may be followed on the graph. Air enters the drying chamber having the characteristics of temperature and moisture content of point 1. The air has a temperature (T) of 95°C and moisture content (x) of 129 g/kg. In the chamber the air is cooled to point 2 ($T = 70°C$) and absorbs 12 g/kg more moisture from the wood to give 141 g/kg moisture. The cool moist air must be dried then heated, so it may be used again. Drying is done by partial exchange with the outside air. Let us assume that the external air has an initial temperature $T_0 = 25°C$ and $\varphi = 60$ per cent represented on the graph by point 0. Sufficient external air is allowed to enter for the mixture to reach the characteristics of point 3 so that the moisture content (x) of the mixture equals that of point 1, i.e. $x_1 = 129$ g/kg.

With this operation the air temperature is further reduced to 66°C (point 3 on the graph). To return to the conditions of point 1 the mixture must be heated. The cycle is represented on the graph by the triangle 1-2-3 which is appropriately called "drying triangle". Another way of reusing the air is by partial condensation of the vapour of the moist air. To do this, the air leaving the pile must be cooled to below its dew-point.

From point 2 the process follows the vertical line $x = 141$ until it reaches the curve $\varphi = 100$ per cent. The cooling process follows the curve $\varphi = 100$ per cent thus decreasing the absolute humidity until $x = 129$ g/kg is reached (point F with a temperature of 57°C). At this point the air is heated to 95°C, and the process may be traced along the ordinate $x = 129$ g/kg (stopping at point 1). The heat required for the recirculated air is 26 cal/kg for the technique of partial vapour condensation. Less heat is required by the "drying triangle" method.

Figure 1. Temperature vs. moisture content of air



Key: φ = relative humidity

Steam

The moisture content of the cell walls of wood at hygroscopic equilibrium in non-saturated steam at atmospheric pressure is below the saturation point of the cell walls. Therefore superheated steam will absorb moisture and dry the wood. The wood is also heated during this process.

Vacuum

Research is being conducted to apply vacuum technology to dry wood. Vacuum techniques may soon be applied to dry woods that are sensitive to high temperatures. Vacuums can be used to evaporate water. In another process, vacuums can be used to cause sublimation of ice from wood whose temperature has been lowered to 30°C. In this process a much higher vacuum (0.2-2.0 mm of mercury) is required.

High frequency electromagnetic radiation

Water may be heated by high frequency electromagnetic radiation. It will thus evaporate from the wood. Frequencies of 2 to 4 MHz are used although experiments have been carried out with frequencies as high as 900 MHz.

Infra-red radiation

Infra-red radiation of 1 to 2 μ wavelength can be used to dry wood. The infra-red technique is quite efficient. However, due to limited penetration of the wood (4 to 5 mm), the method has an effect similar to contact heating or convective air heating.

Liquids

Wood may be dried by immersion in hydrophobic liquids at temperatures above the boiling point of water. Liquids such as paraffin, high viscosity oil and ceresin are used. These substances are usually solid at room temperature, but when heated to about 50°C will liquefy. The boiling points are about 250°C. These materials are non-toxic and have an approximate specific gravity of 0.9.

Another drying technique is to immerse the wood in an azeotropic mixture of water and another substance. The mixture is chosen to have a lower boiling point than that of water. If the water in the mixture is evaporated, it will cause the immersed wood to give up water into the mixture and thus to dry.

A further drying technique involves the use of polar organic solvents such as acetone, alcohols and ethers which are miscible in water. The miscible organic compounds additionally may be used to dissolve and remove wood extracts from the wood as well as to remove the moisture. After extraction the solvents are redistilled.

Volatile organic solvents

Organic solvents with low boiling points, low heats of evaporation, and high conductivity can be used to dry wood. The volatile solvent, when in contact with the cell walls, will cause evaporation of the moisture.

Saline solutions

Saline solutions can be used to dry wood. The osmotic pressure across the cell wall pumps the water faster than the salt can diffuse into the wood. Further salts or hygroscopic compounds such as common salt, urea, molasses or invert sugar, ethylene glycol, are used in solutions of two or even three components for other purposes besides that of drying the wood. They reduce the hygroscopicity of the wood and increase its dimensional stability.

Air seasoning (drying)

The principal aim of seasoning is to lower the moisture content to 18-20 per cent to prevent attack by micro-organisms and insects. The minimum humidity attainable by seasoning depends upon microclimatic and other local conditions. In Italy humidity attainable varies between 8 and 20 per cent, and depends mainly on the season. The humidity of wood, which has been already seasoned and left in the open, varies during the year according to climatic variations. For seasoning, planks are normally stacked or piled on open sites. The sites are fenced in and divided up into lots with space for transport. The ground must be tamped flat, dry and be free of organic material.

The size and number of piles depend on the transport system used and climatic conditions. The more ventilated and drier the site, the wider the piles can be (1.2-4 m). The distance between piles should be 0.75 to 2 m. The positioning of the planks with respect to direction of prevailing winds is studied case by case.

Immediately after being sawn, planks for seasoning must be treated with anti-decay agents, and spaced with laths. Piles must always be covered and, in the case of valuable species, their ends must be protected. Bases for piles consist of concrete pillaring with wooden or reinforced concrete cross pieces so that the bottom planks are at least 30 cm above ground level.

Covering for the piles should be sloped so as not to impede air circulation and also to protect the planks from rain and sun. Piles, too exposed to the sun, should have their ends protected with wood, cane etc. The higher the humidity, the thicker the wooden laths inserted between planks should be (if necessary with a vertical vent in the middle of the pile).

Piles can reach a height of 7 m. Normal heights are 4.5 to 5 m. Each pile must be composed of uniform material as regards species of wood, thickness and initial humidity.

Other grades of wood are piled according to specific needs, such as in crib piles or box piles, up to 7 m long and up to 1.5 m wide. Piling is sometimes on edge to help drying.

Sawn lumber of first grade is air-seasoned in sheds or under fixed roofing, provided with adjustable openings for efficient air circulation.

Methods to facilitate seasoning include boards placed upright (preseasoning of freshly sawn lumber and those susceptible to stain, such as birch, maple, poplar). Rotation of stacks possibly combined with gravitational action, forced air circulation, solar kilns may also be used. Due to their doubtful economic validity these methods are only applied in special cases.

Storage capacity for seasoning varies greatly and depends on many stacking factors. An average figure, for standard piling, is a height of 5 m (0.5 to 1 m^3/m^2 of gross floor area).

Kiln drying

Kiln drying has become vitally important to the timber trade and to allied woodworking industries. Modern technology should be fully applied to shorten drying time and make the entire operation more economical. Technology may be also used to reduce the damage possible to wood by using obsolete methods. Kiln drying differs from air seasoning as controlled conditions can be used to produce a desired moisture content. This chapter deals with drying processes which, at the present time, are most widely used industrially and are also economically justifiable.

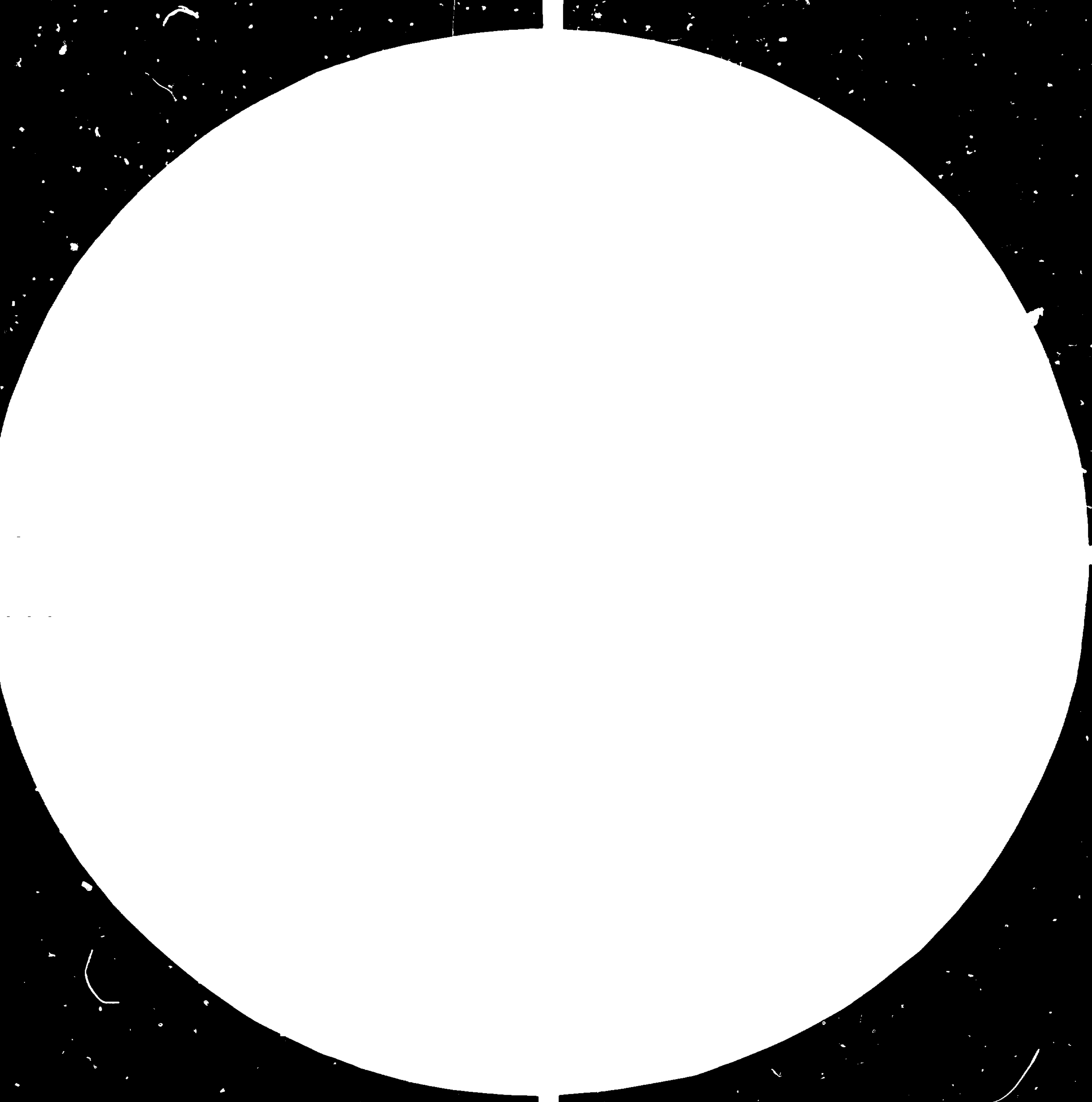
Drying with partial air exchange (conventional drying)

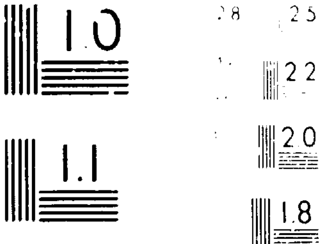
Process

The air circulates between horizontal layers of spaced planks and is re-circulated through the drying chamber by fans. The air drys and heats the wood (convection heating). The air itself absorbs moisture and is cooled. It is necessary to recondition the air by heating it and by partial exchange with external air. The process of kiln drying wood consists of: preliminary treatment (pre-heating), the actual drying and supplementary treatments.

Initial requirements for efficient drying are number of pieces per loading; uniform density; uniform thicknesses; material from the same part of the log; absence of case hardening and internal stresses; and uniform temperature.

Pre-heating is done with air of relative humidity of at least 90 per cent if green wood is involved. For pre-seasoned wood the temperature is increased by 10°-15°C. Heating time in hours equals the

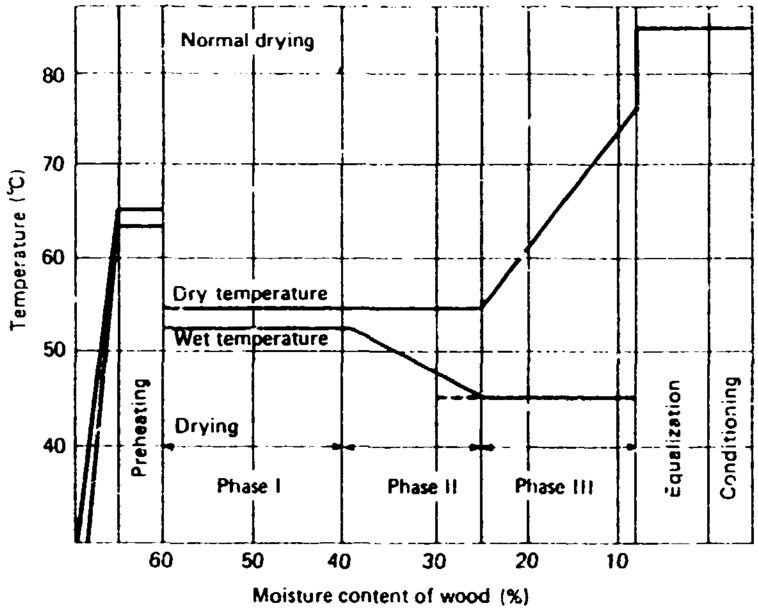



1.0
1.1
2.8
2.5
2.2
2.0
1.8


1.25
1.4
1.6

thickness of the wood to be heated (in cm). Half the time is used for gradual increase in temperature; the other half of the time is used to heat at a constant final temperature (figure 2).

Figure 2. Temperature vs. moisture content for normally dried wood



The choice of drying conditions is influenced by the thickness and density of wood. The presence and content of extractives and various substances (fats, oils) requires that the air have lower temperature and higher relative humidity.

According to modern wood technology, drying should be carried out:

(a) With a constant "degree of drying" at least during the first two phases The "degree of drying" is the ratio of moisture of the outer layers at equilibrium of the wood to the relative humidity of the drying atmosphere;

(b) With a relatively low temperature, which is constant during the first two phases and increases during the third phase;

(c) With the relative humidity of air constant in phase I and diminishing in successive phases.

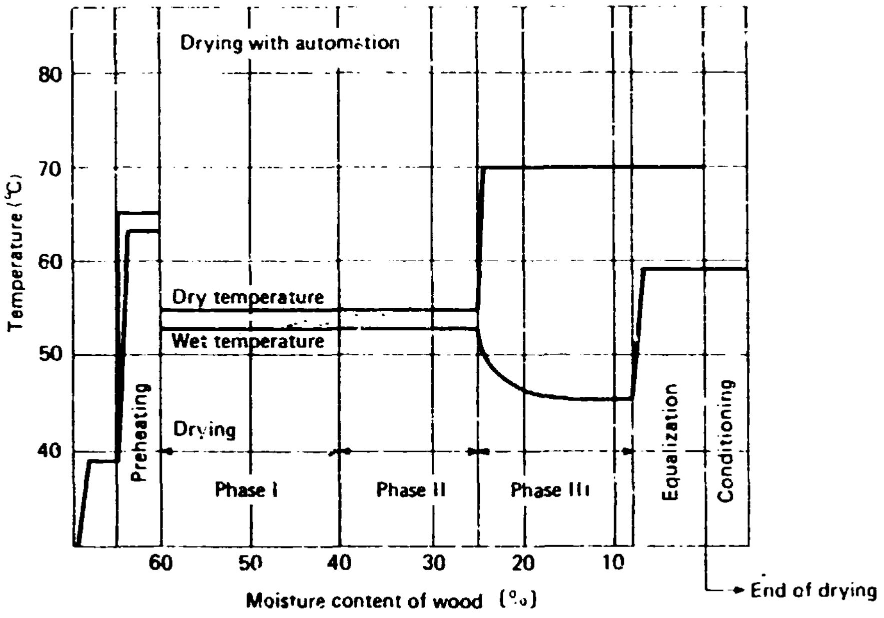
The relative humidity in drying kilns is usually measured with a psychrometer which indicates dry bulb temperature and wet bulb temperature.

Drying is carried out with wet temperature constant in phase I, diminishing in phase II and constant in phase III. The progress of drying must be checked by weighing the test planks, placed in the pile.

For large kilns, automatic control of drying is based on continuous measurement of humidity in test planks by electrical means. Figure 3 shows temperature versus humidity for drying which is controlled electronically with hygrostats. The process has been planned to take place gently. The first change in temperature is at critical point II. This lengthens the drying cycle. Such gentle drying is not necessary for conifers. In the case of spruce, pine and tropical white woods, where high-quality drying is not called for, drying can even be controlled by timers. It is very difficult to theoretically forecast drying duration due to the many factors involved. The assumed times which may be calculated by whatever method, can only be considered as rough estimates. Calculation can serve to roughly determine the times at which the critical points are reached as well as times to bring drying to an end.

The drying time is a non-linear function of the permeability, the wood thickness, the specific gravity and the "degree of drying" of the wood. In addition drying time is also influenced by the width, orientation and length of the planks, the efficiency of drying, and the width of the piles.

Figure 3 Temperature v. moisture content for wood dried with electric control



Supplementary treatment is given to conifer and soft broad-leaved woods only to ensure an even moisture content among different planks. Air is used to modify the wood's average humidity. The temperature is raised at the same time. Hardwoods are given a final "conditioning" treatment consisting of making the internal humidity of the planks uniform by lowering of humidity gradient if there is too steep a humidity gradient inside the planks (case hardening). Conditioning is required in the case of moisture pockets in coniferous woods, such as white spruce and hemlock, when operating with a very humid and warm environment (humidity climate 3-4 per cent above the average of the wood at the beginning of conditioning). The operation is more successful if carried out near the middle of phase III than at the end. The same operation will sterilize the wood and eliminate mildew during drying. It will also "recondition" the collapsed wood.

Artificially dried wood should be stored so that it is protected from seasonal climatic changes. This is advisable even it it is to be used soon after treatment, especially in the case of bulky lots of hardwood which have to undergo further machining. This is because elimination of stresses at the kiln site is difficult and costly. Stresses will be relieved in time. With humidity not too low (12-14 per cent) and the planks piled without spacing laths, storage can be in a closed building having adjustable ventilation. If, however, humidity is low (6-8 per cent) and planks remain spaced with laths as they come from the kiln, the store must be air-conditioned. In the case of piles without spacing laths there will be a better stress relieving effect.

Engineering

Drying kilns are chambers or tunnels made from masonry or sheet metal. They are waterproof, corrosion resistant (vapours and acids) and insulated. Modern kilns have internally mounted equipment for air circulation and conditioning.

Drying of conifer planks is relatively fast, with considerable evaporation per unit of time. This drying calls for much heat and high air circulation rates through the pile (3-5 m/s). In Central Europe, for conifer planks the preference is for chamber type kilns; however, all types of construction are valid providing air circulation is fast and uniform.

When large quantities of wood are handled by fork lift trucks, the most efficient method is to build large chambers for direct loading from trucks, especially when large and dense planks are involved. The capacity of these chambers is as high as 500 m^3.

In modern tunnel type kilns the problem of conveyance, continuous or intermittent for separate piles, is solved by a series of chain driven trucks or by a motor driven roller conveyer.

Stickers should be treated, dried and trimmed and the thickness to width ratio should be at least 1 to 1.5. The thickness of the stickers should normally be ½ or, at the most, ⅔ the thickness of the planks. They should be handled with care and kept under cover.

Fans may be axial or radial. There are many options for fan and baffle placement to assure even distribution of air through the piles. The fans should have high capacities and consume relatively little electric energy. Air heating is generally provided by hot water or steam radiators. Fuel for the boilers is either oil or waste wood. Costs for the various sources of heat must be taken into consideration. Electric energy as a heat source is, for example, very expensive in Italy. In some Scandinavian tunnel kilns the heat from the discharged air is used in a heat exchanger for pre-heating the incoming air.

In the majority of cases, dehydration of the air is carried out by partial exchange of air from the chamber with external air through adjustable air intakes, like a carburettor.

There are also plants which use cold water exchangers to cool and partially condense the water vapour and then heat the air to the drying temperature. The air is humidified by introducing live steam into a kiln.

In addition to the automation of the drying cycle by electrical measurement of wood moisture in the chamber, there are various empirical drying systems based on time and on the relative humidity of the air. These systems, for coniferous and low-density broad-leaved woods, operate reasonably well providing they include an initial and a final checking of the wood's moisture by the weighing method. Of these two checks the final one is the more important to indicate required modifications to the treatment. Such techniques are definitely not recommended for drying broad-leaved hardwoods.

High temperature or steam drying

Where vary rapid rather than quality drying is called for, permeable conifer woods and low density broad-leaved woods can be dried at temperatures above boiling point. Non-saturated steam (superheated) is more suitable than air for this purpose because the drying is milder. The surfaces of the boards darken but they remain white inside. Cracks are prevented because the wood's plasticity is highest at these temperatures. The wood swells more slowly and is therefore more stable. The kilns are made exclusively of metal and tightly sealed because moisture control is very important and the influx of outside air must be avoided. The chambers are relatively small (an average charge is 5 m^3 of wood).

Drying times are from ¼ to ⅓ those for conditioned air. In spite of this advantage the system is not in wide industrial use.

Drying by partial condensation of water vapour (heat pump)

The reduction of the absolute humidity of the air in the drying chamber is done by cooling the air below the dew point, thus condensing out part of the water. The same air always circulates in the chamber without being exchanged with the outside. Although the process is not new it has been widely adopted in industry only recently. An Italian patent has helped pioneer its widespread use.

The technology of this process has been limited until now as electricity has been the only source of energy. Economy has therefore been necessary, especially in Italy where electric energy is costly, so that temperatures and humidities have been kept at fairly low levels. Processing times are thus longer, especially in drying phase III where drying rate is a function of temperature only. To this is added the problem of the large quantities of vapour produced in phase I for drying softwoods. Thus, there are large humidity gradients in the air in the pile. All this has led to overdimensioning the plants.

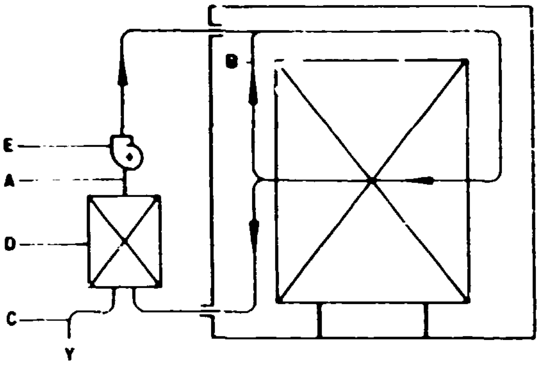
The humidity gradient of the air also determines the humidity gradients inside the wood, especially in these plants having very low air velocities and not provided with air humidifiers.

In order to economize on electric energy and partially regulate the relative humidity of the air according to the requirements of the various species involved, controls provide for regulating the cyclic functions. Temporary stopping of the compressor can alternate condensation phases with non-condensation phases.

A plant for the condensation process consists of a drying chamber having the characteristics already mentioned. Where electric energy is costly the insulation must be carefully considered because drying times are long and thermal losses can be greater than effective energy consumption.

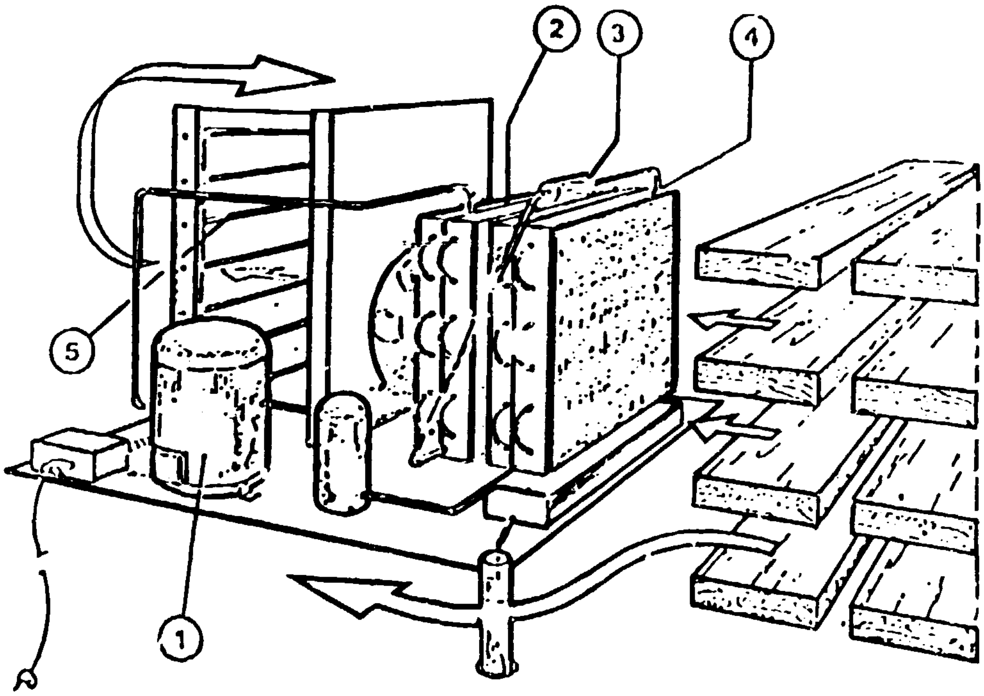
The refrigerator, which may be fitted either inside or outside the chamber, is built as shown in figures 4 and 5. The condenser can be used for the first heating stage (heat pump) of the air after its cooling in the area of the evaporator. Supplementary heat is supplied by an electric radiator.

Figure 4. Air flow through a condensation dryer



Key: A Air recirculating through the conditioner
B Part of the recirculating air inside the chamber
C Outlet of water condensed from the air
D Conditioner
E Fan

Figure 5. A condensation dryer



Key: 1 Compressor
2 Condenser
3 Expansion valve
4 Evaporator
5 Supplementary heater

In those plants where only part of the air passes through the refrigerator, extra recirculator fans are fitted. Part of the air may be recirculated internally under the influence of the air stream entering the chamber at high speed from the refrigerator, through inlets on the ducting. The pre-heating phase uses an electric radiator but steam or hot water can be used to save electric energy.

Other features of condensation drying are: absence of vapours (very important when drying offensive smelling woods in inhabited areas) and the fact that, unlike other dryers, no boilers are needed, and maintenance costs are reduced to a minimum (very important for small industrial and artisan type plants).

Vacuum drying

Lowering the boiling point by decreasing atmospheric pressure gives a noticeable increase in the rate of evaporation at relatively low temperatures. This is very important for drying wood because lower temperatures also decrease the danger of damage, particularly during the first two drying phases. It has furthermore been discovered that with decreasing pressure the permeability of the cellular walls increases rapidly. For these reasons the possibility of applying vacuum technology to wood drying was for a long time under examination. A much wider industrial application of the vacuum for wood drying has recently been introduced in Italy with a "discontinuous vacuum" cyclic process. Attempts to use "continuous vacuum", in spite of qualitative results, have so far not found acceptable economic solutions.

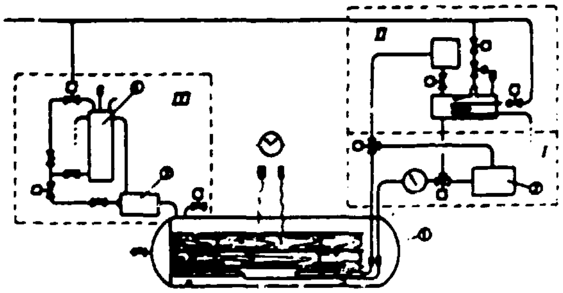
Besides initial pre-heating, the drying process consists of a series of cycles: a heating phase followed by a low pressure phase. The wood is gradually brought up to the required temperature, keeping its internal temperature gradient as low as possible. As a rule the temperature will be somewhat higher than the boiling point corresponding to the vacuum applied. A subsequent decrease in pressure causes immediate evaporation of surface moisture and lowering of the surface temperature to the boiling point and below. The temperature gradient from the centre to external layers decreases and consequently moisture tends to migrate from centre to surface. Heat is transferred from the centre to the surface. This maintains the boiling point temperature, permitting the boiling off of water from the wood's surface. The pressure inside the wood lowers. Boiling follows and there is consequent internal motion of moisture and diffusion of vapour, through the wood's capillarity (providing permeable and non-tylosed wood is involved). The wood cools internally to the dew point. The process is stopped and a new heating phase begins the cycle again. It is presumed that the above phenomena combine to cause continuous moistening of the wood's surface, the result of which is an essential reduction of the humidity gradient inside the wood. In many cases there is an absence of or even a small decreasing gradient towards the centre at the end of the drying cycle.

Pressures used are as low as 25 mm Hg absolute pressure. Temperatures and heating rates roughly follow normal rules. The higher the permeability of the wood and the higher its transverse tensile strength, the higher the temperature can be. During heating phases temperatures can be controlled by inserting tele-thermometers into the wood. Furthermore, as drying progresses, temperatures increase by 20°C or more according to the type of wood involved. Pressure, as a rule, can be varied according to thickness and density of the wood. Drying times are very much shorter than those with conditioned air drying. The higher the permeability the shorter the time which can be as low as $^1/_3$ that for conditioned air drying.

There are two processes in particular which differ from each other in the heating phase. In one case the heating is by means of plates, in the other case by means of conditioned air (in equilibrium with the moisture content of the wood) recirculating between the planks by means of fans.

A heating plate type dryer is shown schematically in figure 6.

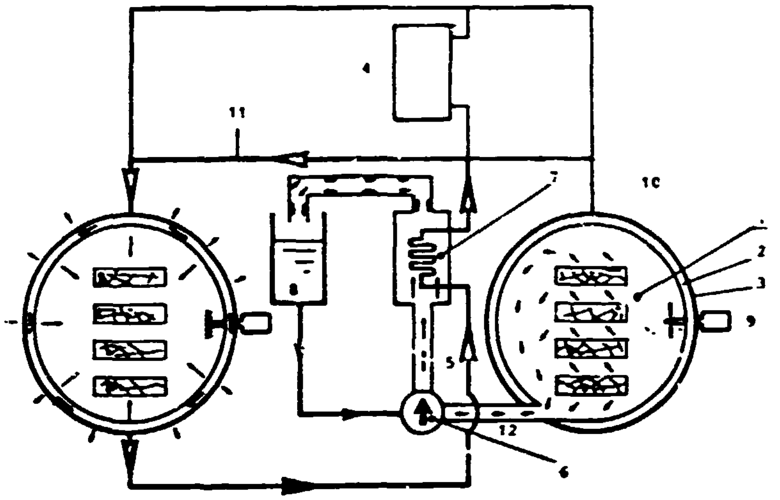
Figure 6. General schematic of a vacuum dryer



Key:	I	Heating system
	II	Cooling system
	III	Vacuum pump unit
	1	Autoclave
	2	Boiler
	3	Vacuum pump
	4	Condenser water feed

A dryer with circulating-air heating, is shown schematically in figure 7. These dryers are built with two autoclaves. The two autoclaves function by alternating the two phases of the cycle.

Figure 7. Schematic vacuum dryer with wood heated by recirculating air



Key: 1 Autoclave
2 Cavity for circulation of hot water and steam
3 External insulating jacket
4 Boiler
5 Pump for hot water circuit
6 Liquid ring vacuum pump
7 Heat exchanger
8 Oil separator
9 Fans
10 Boiler circuit
11 Recovery circuit
12 Ducting for air and steam evaporated from the wood

While one autoclave is in the heating phase the other is in the vacuum phase. When drying begins the heat from the previous heating phase is used to pre-heat the water in the boiler circuit. Later on, the heat recovered from the autoclave and recirculated is sufficient to continue the heating process without heat from the boiler. The hot air from the heated autoclave passes to a heat exchanger and heats the air which has been used in the vacuum phase. Autoclaves are made in diameters from 1.4 to 2 m with useful lengths from 4 to 8 m. Loading capacities are from 2.5 to 8 m³ per autoclave. For producing the vacuum a liquid ring type pump is used while hot water or steam is produced by a boiler.

High frequency electric energy drying (or dielectric heating)

Much faith has been placed in the use of dielectric heating for drying wood because with high frequency the moisture heats up more rapidly than the wood; and because heating is rapid and independent of the thickness of wood (heating rate reaches 20°C/min). The temperature gradient in the transverse section of the wood is the inverse of that with convection heating, that is, it decreases from centre towards surface layers due to surface heat loss caused by evaporation and radiation.

At 100°C, the moisture inside the wood is transformed into steam. The steam pressure increases with temperature and the steam is forced out very rapidly through the capillaries. Some of the steam on the surface of the wood condenses, thus protecting it from excessive drying.

When drying begins, with moisture content above the saturation point of the cellular walls, the moisture gradient in the transverse section is the same as with convection drying. As drying proceeds, the gradient has maximum moisture at the surface and minimum at the centre of the wood.

With dielectric heating four characteristic phases can be noted:

(a) Phase I is pre-heating with maximum energy used and transferred to the lumber. In this phase only the moisture in the wood is heated. The rate of heating is from 4° to 20°C/min and varies with the power of the dielectric oven;

(b) Phase II is the equalization of wood and moisture temperatures which must be achieved before the moisture boils. Heat transfer to wood is minimal;

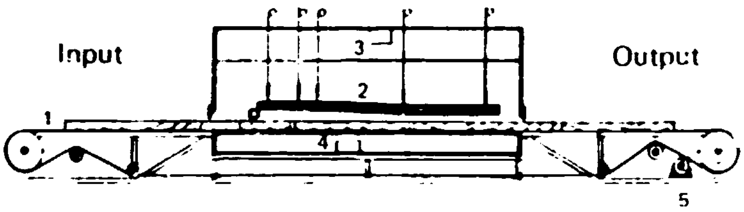
(c) Phase III is the evacuation of steam during which the major part of the thermal energy will be consumed. Rate of evacuation can be very high, if the capillarity of the wood is continuous. This is because steam is formed in the centre of the wood and forces its way out. Therefore the rate will depend on the permeability of the wood;

(d) Phase IV is the equalization of the humidity of the wood to that required and during this phase energy consumption is minimal.

Drying time depends very little on the initial humidity of the wood. It depends very much, however, on the type of wood and the energy available. This is partially due to the fact that the more humid the wood the more permeable it is.

Due to large surges in the consumption of thermal energy from phase to phase, the designing of plants and processes tends to favour the system of continuous feed of wood into the dryer, resulting in greater economy because the generator output remains constant. A system of this type is shown schematically in figure 8.

Figure 8. A radio frequency dryer



Key: 1 Conveyer belt
2 Electrodes
3 } Air ducts
4 }
5 Feed motor

The planks, loaded on a continuous belt, pass through a tunnel between electrodes. The moisture and steam which leave the wood (heated to 100°C) are dispersed in the air which, heated by the high frequency generator tubes, circulates through the tunnel and is finally extracted by a fan.

With this type of plant only permeable woods can be successfully dried: beech (without false heartwood), poplar, limba, abura, agba, lime, spruce, birch, maple etc. Drying times for 50 mm thick planks vary from 2 to 4 hours (beech planks pass from 80-90 per cent humidity to 6-8 per cent final humidity in 3 hours). The drying of tylosed woods and heavy duramen and therefore impermeable woods (oak) is not very successful. With these types the centre of the wood, due to evaporation, dries quickly while the other layers remain moist. In this way the central temperature increases until collapse and carbonization occurs. To prevent this inconvenience, experiments in drying have been carried out in the United Kingdom of Great Britain and Northern Ireland, varying the primary voltage. This method must use contact electrodes.

For other impermeable woods the continuous tunnel process is not applicable.

XI. Wood-based panels: comparison of various types of panels; general considerations and guidelines for selection of machines, equipment and plant*

This chapter considers wood-based panels in general, with emphasis on machines used for their production.

With respect to end use, bonded wood-based panels may be subdivided into two categories. The first category comprises those which are normally used for furniture, furnishing components and doors. The second category comprises those which are used in building construction, including industrially made components and those used in partial prefabrication of various buildings. There are also other uses of wood-based panels, in building supply yards.

Particle boards bonded with synthetic resin

The process of manufacture begins by transforming wood into chips of a given length and thickness. The chips are then mechanically broken into particles of the required size and dried. A fixed amount of synthetic resin binder, and other complementary substances, is then added and mixed so as to be uniformly distributed in the final product. The panels are formed, compacted and bonded in heated presses. The resins generally used to produce this type of panel are urea and formaldehyde based and are thermosetting. The rate of setting is greatly increased by the addition of suitable catalysts.

Besides resin and catalyst, a small quantity of water-repellent material, that is mineral wax in either molten or emulsified form, is generally added to the particles. This provides a limited amount of waterproofing for the panels.

For furniture and other products delivered to countries where wood is subject to biological degradation (particularly by wood-eating insects), the preparation of the particles can be completed by adding a suitable protective chemical agent to the mix. By modern techniques these panels can be made as large as 30-50 m². Panels of any length can be produced by a continuous process. Large panels, and continuously produced panels, simplify any marketing problems. They are simply cut to size as needed.

Thickness can be made to be from 2.5 to 40 mm and thereby satisfy any requirements. Density can vary from 350 kg/m³ to 800 kg/m³ depending on the material used and the production method. The least dense panels are made from wood or other cellulose based materials and are generally thicker than 15 mm. The elastic-mechanical characteristics of these panels are relatively as good as those of better quality plywood and the denser particle boards. The large panel is gaining world-wide acceptance in the manufacture of modern furniture components and panelling, sliding partitions, solid and flush doors etc. Future uses of panels seem almost limitless although panels cannot be used where there is high ambient humidity, contact with water or exposure to severe weather conditions.

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* By M. Bermani, engineer, technician, expert in the production of fibre panels. (This is an edited version of ID/WG.277/4/Rev.1.)

Medium density fibreboards manufactured by a dry process

These panels are an alternative to the resin-bonded boards described above, although they have fewer industrial applications. The manufacturing process is very similar. The main difference is that the wood is initially transformed into fibres, which gives a highly compact and uniform board. This ensures satisfactory workability in all directions.

Thickness ranges from 6 to 30 mm and density ranges from 600 to 700 kg/m^3. These panels can be produced in very large sizes, and are easily cut. So far no continuous production plants have been established. Elastic-mechanical characteristics are similar to those for particle board. Due to the greater amount of energy required to defibre the wood, more raw material is used for a given panel thickness. For this and other reasons, these panels are considerably more expensive than those previously described. They are convenient to use and are the only choice when a panel is needed that has to be carved, countersunk, or accurately shaped etc.

Hard and semi-hard fibreboards

The first step in producing hard and semi-hard fibreboards is to defibre the wood used as raw material. The fibres may then be processed into boards by either a wet or dry process.

In the case of the wet process, lignin already contained in wood acts as a binder. Limited amounts of added synthetic resins act as binders as well. For the dry process, fibres are bonded with synthetic resins similar to those used for particle board.

It is possible to make very large hard and semi-hard boards by the dry process. As far as is known no continuous production plants for these boards have been built. Minimum thickness is usually 2.5 mm and maximum thickness is 7-8 mm. The weight is greater than that of an equally thick normal type particle board. Production facilities are more or less similar to those for the two types of boards previously described. The range of thicknesses is the same for hard and semi-hard boards.

Mineralized wood-wool boards

The ingredients used for bonding are Portland type or magnesium cement and a loose mass of wood wool or shavings. Panels are made with thicknesses from 20 to 100 mm. They are extremely porous and therefore fairly light; the density ranges from 360 to 570 kg/m^3. The main advantages of these panels are good heat and sound insulation. However, the mechanical strength of the panel is low. The "mineralization" of the wood is such that the panels are very permeable to air and resistant to mildew, fungus, bacteria and insects. The panels are also resistant to moisture and fire. They are used in the building industry in temporary buildings, small modest dwellings, rural buildings, as insulation inside masonry walls, and for making false ceilings and lining garrets.

Cement wood-chip boards

Relatively large wood particles are prepared for this product. They are partially dried and after undergoing a "mineralizing" treatment they are mixed with Portland type cement and water.

Panels of small sizes are made with this mixture (usually not much over 1 m^2), the thicknesses are from 20 to 80 mm. To obtain different mechanical characteristics, the density of finished panels brought to a commercial humidity level can be varied from 500 to 700 kg/m^3. The mechanical strength is higher and the field of applications wider than for mineralized wood-wool panels. In particular, surfaces are not porous and while they are not very flat, they lend themselves to plastering. They are easy to work, hold nails reasonably well and may be joined together without difficulty with special, but simple, metal fittings. Heat and sound insulation are excellent and weatherproof and fireproof characteristics are very satisfactory. These properties make the panels highly suitable for "built-in" shuttering (which is installed and left in position for further finishing); for insulation of load-bearing concrete and for reinforced concrete casts. They are also suitable for forming floors, and for that application also serve as false ceilings. They are used for floor foundations, for internal and external facing on perimeter walls, for internal partition walls etc.

Particle boards bonded with synthetic resins having high resistance to humidity and water

The physical structure of particle boards bonded with water-resistant resins is identical to those containing ordinary resins. The facilities for production are also identical. The only difference is in the bonding synthetic resins and additives used to give the panels the required characteristics. The resins used are phenol and formaldehyde based or belong to the melamine group. Thermosetting resins which may be subjected to the action of catalysts are used. Once they have polymerised, they do not react with water. Other synthetic resins have recently been studied, with which panels of the same type can be made, but they are still in an experimental stage and few industrial applications have so far been made. It is not sufficient to merely use a water-resistant resin to make a panel resistant to the severe conditions found in the building industry. It is necessary to limit, as far as possible, swelling of the wood particles, and therefore of the panels, by adding water-repellent substances to the mix and by other special treatments. It is further necessary to prevent biological degradation, particularly by mildew and fungal agents, which can rapidly degrade the material. This is done by adding protective agents. Fireproofing is another necessity for all materials involved in building work. Except for unusual cases, panels intended for use in buildings receive fireproofing treatment during manufacture.

Particle boards bonded with lyes of lignin bisulphite

Production of this type of board is relatively recent. Manufacturing plants can produce these economically if there are pulp or paper mills located close by which are able to supply their by-products (i.e. lignin lyes). These by-products are concentrated into a syrupy substance and used as binders.

Plant and production methods are analogous to those for particle boards bonded with resins. The main difference is at the pressing stage, where the time required is longer than for other types of panel. The longer time can be shortened by adding thermosetting phenolic resins to the lyes, and by heating the panels under pressure with high-frequency electric heating equipment, which shortens the time required to heat the panels. For an equal weight of wood particles, the amount of lignin added is much greater than the amount of synthetic resin used for the other types of particle boards. The total weight of the panel is therefore much higher. This is of no great inconvenience if the panels are in the building industry. Resistance to humidity and water of these lignin bisulphite boards is very high and values for swelling by absorption are extremely low.

High density cement-bonded boards

High density cement-bonded boards have only recently gone into production. They have already met with success and have many applications to modern building techniques. The cost is less than particle-board panels, manufacture is easier and weatherproofing excellent. Durability is more than adequate as the wood particles are also "mineralized" and there are virtually no problems of parasitic attacks or degradation. By closing the pores of the wood so they cannot absorb moisture, there is little dimensional variation due to humidity changes. Fire resistance is good. Production technology is in the process of development. Elastic-mechanical characteristics are now poorer than those boards bonded with synthetic resins and the weight of the board is greater; always over 1,000 kg/m^3.

Sizes are relatively large and usually correspond to modular building elements. Lengths are usually over 3 m, widths vary from 1.25 to 1.83 m while thicknesses are between 7 and 40 mm. At the pressing stage, pressures used are of the same order as those for the production of ordinary particle board. All surface characteristics are good. Surfaces are smooth and uniform and therefore paint, wallpaper and any other type of finish are easily applied.

In spite of a high cement content, operations such as sawing, drilling or countersinking, using suitable tools, are very much the same as for normal particle board. The panels are highly suitable for all kinds of building components, floor foundations, false ceilings, partition and perimeter walls (combined with other materials) etc., due to their excellent resistance to fire, humidity, atmospheric agents, mildew, fungal agents, insects and chemicals. Sound deadening properties are high and, although inferior to those of normal panels, heat insulation is satisfactory. For these reasons, and other features already mentioned, the boards may be used with advantage in situations such as built-in shuttering for normal concrete and reinforced concrete casts which are used as main structural members, slabs and load-bearing walls. High density cement-bonded boards can also be used to make fire barrier doors, industrial and agricultural silos, agricultural buildings etc.

Insulating fibreboards

As in the case of medium density fibreboards and hard and semi-hard fibreboards the wood must be defibred and bonded by wet processes. Generally natural ligneous substances are used as binders. Due to low mechanical strength, large panels cannot be marketed. Generally, thicknesses range from 8 mm to 35 mm. The main advantage of these boards is that of good heat insulation. They are used for all those building applications where rigid insulating and easily erected materials are required.

Fibreboards bonded with mineral substances

The binders used are calcium sulphate or magnesium cement. The panels are mostly insulating types, providing resistance to both heat and sound, especially reflected sound if the surfaces have been suitably prepared with carving, holes, decorative high relief etc. Compared with insulating fibreboard panels they are more durable and have better fire resistance.

Principles and guidelines in the establishment of an industrial programme for the production of wood-based panels

There are two basic considerations:

(a) The primary and other possible applications for the panels. These applications will arise from market demands;

(b) The availability of wood, or other cellulose-based materials such as agricultural by-products, and whether the physical and technological characteristics of the wood are consistent with the processing required to produce a given type of panel. It is also important that a sufficient supply be available at a short distance from the factory so that transportation costs may be minimized.

The first consideration applies mainly to boards to be used in furniture rather than boards used in construction. When end use of the product is known in relation to market needs, flexibility in the manufacture of several types of boards in the same group is possible. For example, wood with a high content of tannin or oily substances is not suitable for synthetic resin-bonded boards. For cement-bonded boards it is not advisable to use wood containing tannins or sugar based substances, and it is possible to produce mineralized wood-wool boards only if wood is available in rounds with diameters not less than 7 or 8 cm. This principle implies that limitations in raw material supplies determine corresponding limitations in the productive capacity of any projected plant.

Among the three types of panel in the group of materials to be mainly used for furniture and furnishing components a distinction can be made between thin panels (between 2.5 and 7 mm) and medium to thick panels. For thin panels, particle boards and hard and semi-hard fibreboards may be considered possible choices of material for furniture manufacture. For thick panels possible choices include medium density fibreboards. The medium density board is cheaper than the semi-hard board, but has more limited workability. The semi-hard boards are absolutely compact and homogeneous, and therefore suitable for any work although their cost is much higher.

Characteristics of the six types of panel which are generally used in building work vary widely. While in principle it is possible to produce every type of bonded board with all the various synthetic resins now available in one well-equipped production facility, it is vital to know the end uses of the material before establishing the plant facilities. This avoids the purchase of machines which are not suitable for the job or do not possess operative adaptability. The choice of facilities depends, as well, on the buildings involved (conventional, partially prefabricated, totally prefabricated), and the specific use to which the panels are to be put (for built-in shuttering, for integrating other materials such as auxiliary elements and as actual building material). For purposes of brevity, among all the possible types of bonded wood panels, only particle boards will be examined in the succeeding paragraphs. Due importance will be given, however, to the differences in technological characteristics of the binders used (various kinds of synthetic resin, lyes of lignin-bisulphite, cement) and specific applications of the bonded boards.

It should also be pointed out that most plants are capable of producing panels of any thickness. If only thin panels are required it is worthwhile considering a much less costly type of plant for this specific purpose.

Principles used to determine the selection of machines and equipment for different sectors of a particle board production plant

Sectors common to all types of plant are:

Raw material storage (wood or other cellulose-based material)
Particle production (mechanical)
Particle drying
Preparation of bonding materials and their mixing with or application to particles
Mat forming and pressing
Panel finishing

Raw material storage

The design of a particle board factory should begin with the allocation of space for raw material and an estimate of the equipment required for unloading, stacking and withdrawal from storage for production

Raw material may be of only one type or may consist of different materials to be used concurrently, in fixed proportions in the initial production step. In the case of sawdust obtained from other operations, storage in silos is feasible. Other raw materials are normally stored in the open.

In addition to space needed for pathways, access, fire prevention etc., the maximum storage area is determined by a consideration of the amount of raw material to be stored, and its rate of turnover. Even in situations where supplies are plentiful, stock should never reach levels lower than those required to cover 40-50 working days. If regular deliveries cannot be made, or if materials are available seasonally, stocks should be kept at a higher level. In calculating area requirements, the dry weight of raw material required for each cubic metre of panels produced should be taken into account, as well as the corresponding apparent volume of the material which will arrive at the factory. It is also important to consider optimum height of storage stacks and whether the wood is evenly sized, or the material is already chipped. In the latter case storage heaps will be smaller than in the former. For the chips and similar material, problems of decay, mildew and fungal growth can arise if storage is long term. This is especially true if climatic conditions are favourable to decay. Special storage arrangements must be made for chips and agricultural by-products.

The only practical method of storing these materials is in the open and they are therefore fully exposed to the elements. Weatherproofing and prevention of decay is done with a ventilation system. This has the advantage of providing some preliminary reduction of humidity. The system blows air through the heaps and maintains a certain air pressure at a level sufficient to prevent the intake of rain water. The system consists of simple galvanized iron or cement ducting with suitable vent holes, which is laid out in parallel configuration through the heaps and connected to a manifold into which a fan blows warm air at low pressure. The air is mixed with smoke and other combustion products to prevent decay inside the heaps.

The ventilation system can be arranged so that it functions automatically when climatic conditions make it necessary. Equipment to store and transport received raw material is shown in figure 1. For raw material in the form of small rounds or branches stacking is normally done by a vehicle with a hydraulic scoop. Manœuvrability is simplified by keeping piles at a maximum height of 4 m, as shown in figure 2. The same facilities serve for faggots and off-cuts in bundles with suitable adaptation of

Figure 1. Equipment for storing and transporting raw material

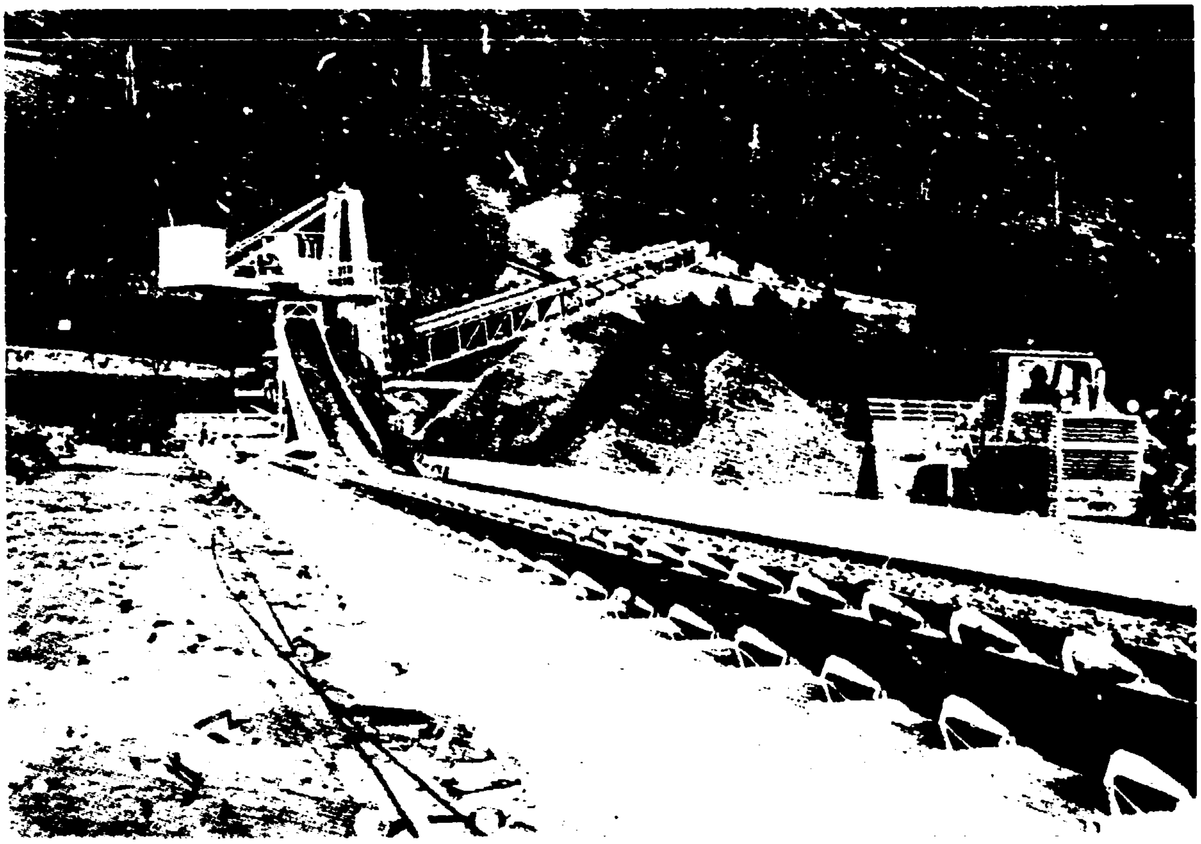
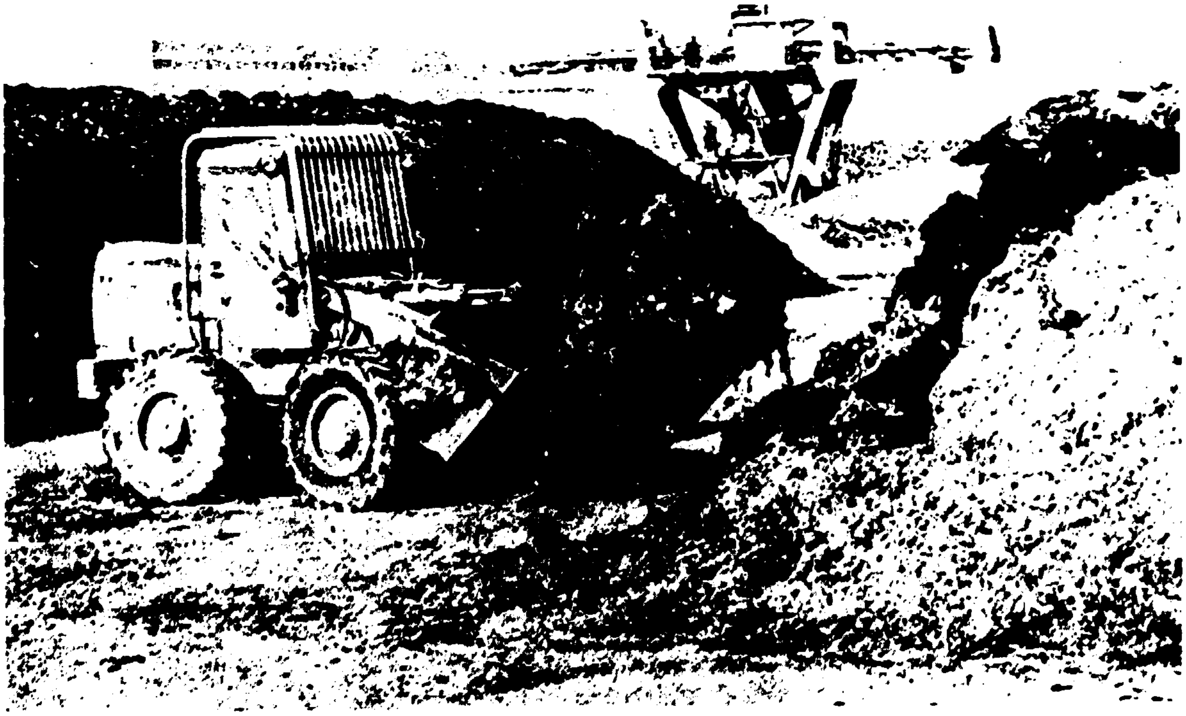


Figure 2. Chip handling equipment



the hydraulic scoop. This lifting equipment is also used for taking material from the piles. Trolleys running on rails or tractor-drawn trailers are used for transport to the factory. A chain conveyer system may be useful for the case of stocks which cover a small area; withdrawals are carried out in a continuous process; and where stocks are situated close to the factory.

Figure 3. Sorting different species for core and face layer chips

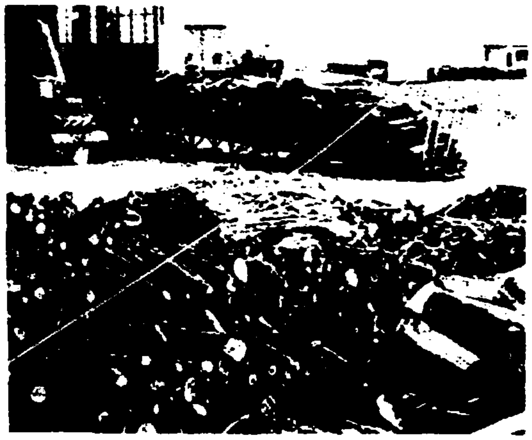


Figure 4. Infeed conveyer for chipper line

For piling small pieces, or bulk materials, mechanical loading shovels may be used. If the material is sufficiently small and uniform, belt conveyers (bucket or hydraulic types) may also be used for transport to the factory. Details are given later on silos containing sawdust and on mechanical withdrawal systems. For reasons of brevity, consideration is not given here to situations where materials contain foreign matter (sand and rubble, nails, wire, iron, splinters etc.) which must be removed to prevent damage to production machinery. Nor are by-products of plants from which textile fibres have already been extracted such as hemp stalks, flax straw, from which all fibrous residuals must be removed mechanically, considered.

For production of panels having three or more clearly differentiated layers, the process begins with different woods. This is done to obtain different particles for the external and internal layers. Such a technique can be used for wood of one species that must be formed into different shapes. In this way, for example, rounds not yet debarked can be used for external layer particles, while lower grade assortments such as branches or faggots are chipped for use as for internal layer particles (figure 3). In these cases each group of materials is stored seprrately with their own handling gear for conveyance to the production line (figure 4).

Mechanical processing of raw materials; breakers, chippers, flakers, and mills

Modern particle boards may have three or more layers, or may be formed so that the particles are distributed with particle size decreasing from centre to surface. In both cases the aim is to obtain panels with external layers made only of fine and uniform particles to give an even and compact surface, thereby making finishing operations easier. Two different machines must therefore be used for the preparation of normal and fine particles. This initial preparation is common to all types of particle board panel production, whatever manner in which the boards are to be bonded. Particles are produced in two or three successive phases. When it is preferable to prepare all the wood from chips because mechanical characteristics make it advisable or because most of it has been purchased in chip form, the wood which arrives at the factory is changed to the desired state to simplify the processing. This production of relatively coarse material is done with knife hogs or knife chippers, as shown in figures 5 and 6. For small logs (rounds) or saw mill by-products (slabs and off-cuts) disc type chippers can be used. The material is conveyed, at a defined angle, to a rotating disc fitted with a series of blades which cut the material into lengths varying from 20 to 40 mm. Disc diameter varies from 1,000 to 2,000 mm and production can exceed 150 m^3/h.

However, a drum type chipper is more advisable, particularly because it can handle a wider variety of different woods. It is also suitable for veneer off-cuts, for small diameter brush wood or other materials which can not be used in disc type chippers. Very strong blades are mounted on the drum and the direction of feed is perpendicular to and above the level of the drum axis. The wood is fed towards the drum by a conveyer belt followed by a set of toothed rollers, the lower ones being fixed and the upper ones oscillating to adapt to the thickness of material involved. Important requirements for chippers are strength and simplicity as well as wear resistance for the parts which receive a large amount of mechanical stress. Careful attention should be paid to the upper oscillating roller system of the feed system which, on more advanced machines, is controlled hydraulically. A safety device stops the feed as soon as the conveyer belt becomes overloaded with wood. If there is any possibility of foreign metal matter in the wood, such as iron wire used to tie up bundles of saw mill by-products, it is advisable to install a metal detector over the conveyer belt, to automatically stop the belt in the presence of even minute metal objects. The length of chips obtainable depends on the rotational speed of the drum, the number of blades on it and the feed rate of the wood. Values are normally arranged to produce chips about 30 mm long. It is useful, however, to have a machine which can easily be adjusted to produce other sizes. To supplement the action of the blades, chippers are fitted with a fixed counter-blade. The most advanced type can be used on each of four edges. This is accomplished by inserts composed of high wear resisting alloy. Thus the position can be changed four times before sharpening becomes necessary.

The arrangement of the counter-blade relative to the characterstics of the drum and its blades is important. Cutting must be done at an angle, which depends on the properties of the wood. The cutting process must ensure minimum energy absorption and best chip quality. It is important to note that the system used to fix the counter-blade may be damaged by frequent and heavy impacts. Under these conditions, repairs may be unreliable and lead to a difficult dismantling procedure. The wedge system is the most advisable one to use.

The drum is made of steel elements welded together and the manufacturers must guarantee that the drum has been stress relieved, otherwise deformation or even breakage might occur. It is important to have accurate dynamic balancing to avoid vibrations which, due to the drum's considerable mass, could shorten the lifetime of the bearings. The chipper drum for the wedge system of chipping is shown in figure 7. The drum is driven by a V belt. The driven pulley, consisting of a flywheel coaxial with the drum, helps to absorb peak loads. The blades are fixed to the drum with bolts and domed lock

Figure 5. Processing of coarse particles with a knife hog

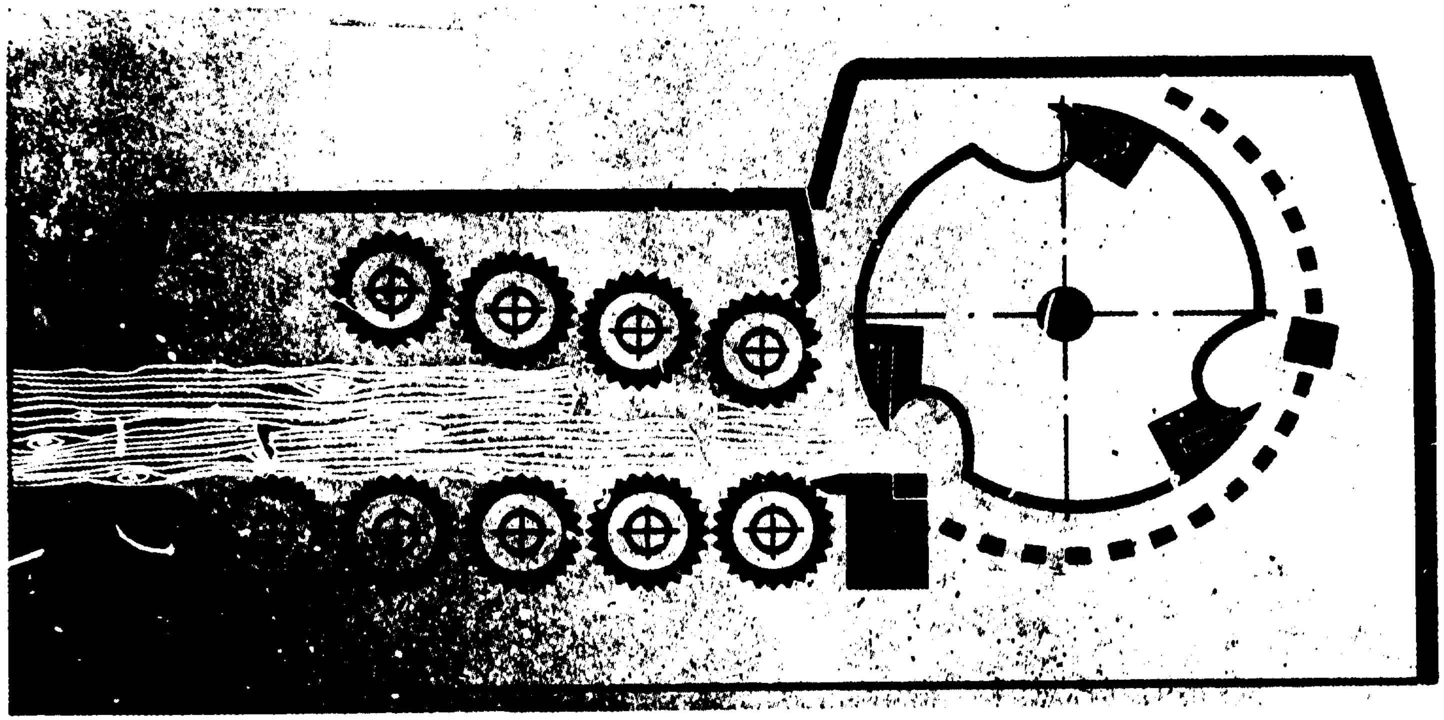
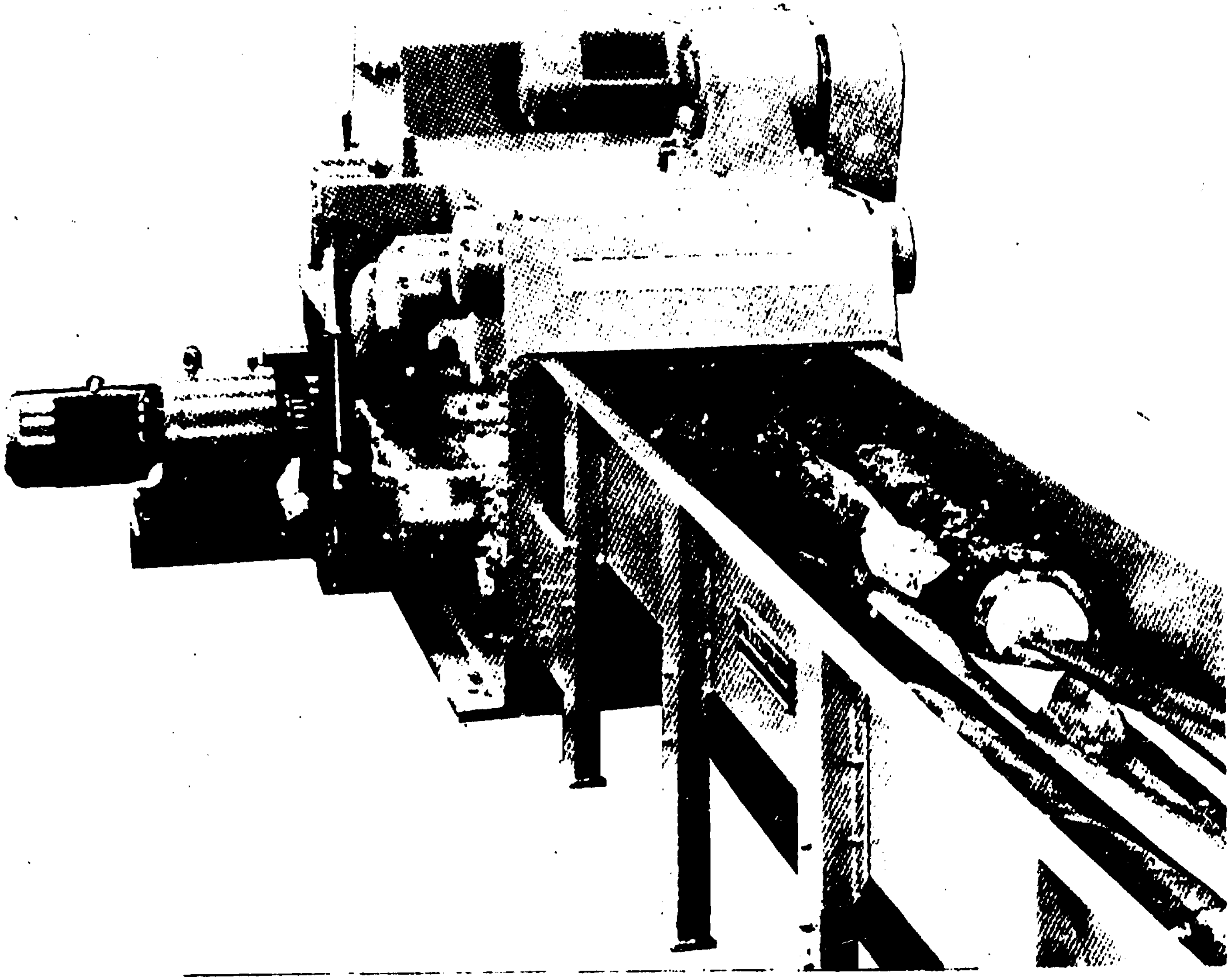


Figure 3. Heavy duty knife chipper with infeed chute



washers. The bolts, which must be locked tightly so as not to loosen while the machine is running, are arranged so that blades may be rapidly substituted. Blade projection must be accurately set. The preferred system is that which allows setting to be done externally by means of adjusting screws. With all types of chipper, including the drum type, it is practically impossible to avoid the presence of a certain percentage of excessively large splinters. The machine must prevent the large splinters from moving forward with the regular sized chips. These are therefore passed through a screen or carder of strong construction. A cross member fixed inside the carder acts as a second counter-blade and the splinters are cut until reduced to regular chip size. Passage of chips through the screen is helped by air suction. The outlet point is connected to ducting which carries the material to a fan and then to a cyclone separator. The inevitable presence of dust on all moving parts, and the impossibility of keeping this kind of machine clean, makes lubrication difficult. For this reason, among all the systems for driving the conveyer belt and the feed rollers, that with a hermetically sealed oil-bath gear box is best. In this case the drive is absolutely smooth and the chips are dimensionally uniform. This is quite different, for example, from chain drive systems where links, which stretch with use, are difficult to keep correctly tensioned.

Figure 7. Chipper drum with wedge system

Ball- and roller-bearing housings must also be fitted with very efficient packing rings to avoid dust infiltration. Principles for the choice of a chipper must therefore be based on its being guaranteed to produce chips of uniform shape and size. It must have wide flexibility to allow for handling many different kinds of wood, it must be solidly built throughout and require minimum maintenance, it must have minimum down-time for blade substitution and, finally, it must have a high hourly output of chips expressed as dry weight or as ratio of output to effective energy used during operation.

Two particular types of chippers are the so called "blade" type and a type for agricultural products. In the blade type the operating element is a drum and the material is fed directly from above. The "blade" type is advisable for processing very short pieces of plank off-cuts or trimming. The second type is used for breaking up material packed in bales, such as agricultural by-products. These are shown in figures 8 and 9. In the latter machine a horizontal feeder pushes the bales against a cutter drum which operates along the entire front area. The diameter of the drum can be from 800 to 1,600 mm according to the size of the bales.

Figure 8. A chipper for short lumber and waste material

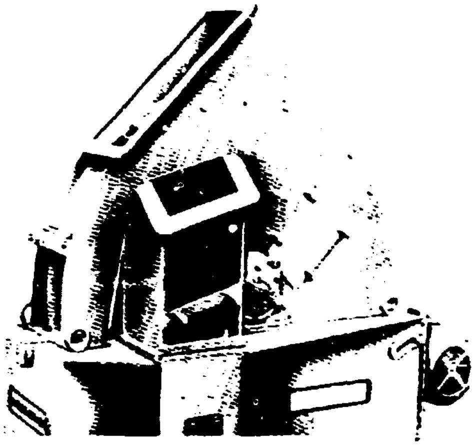
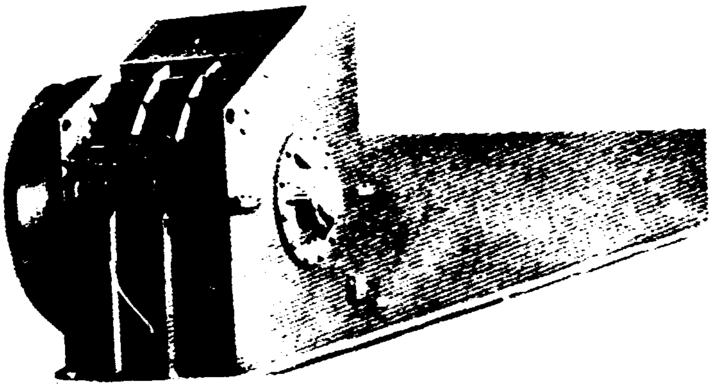


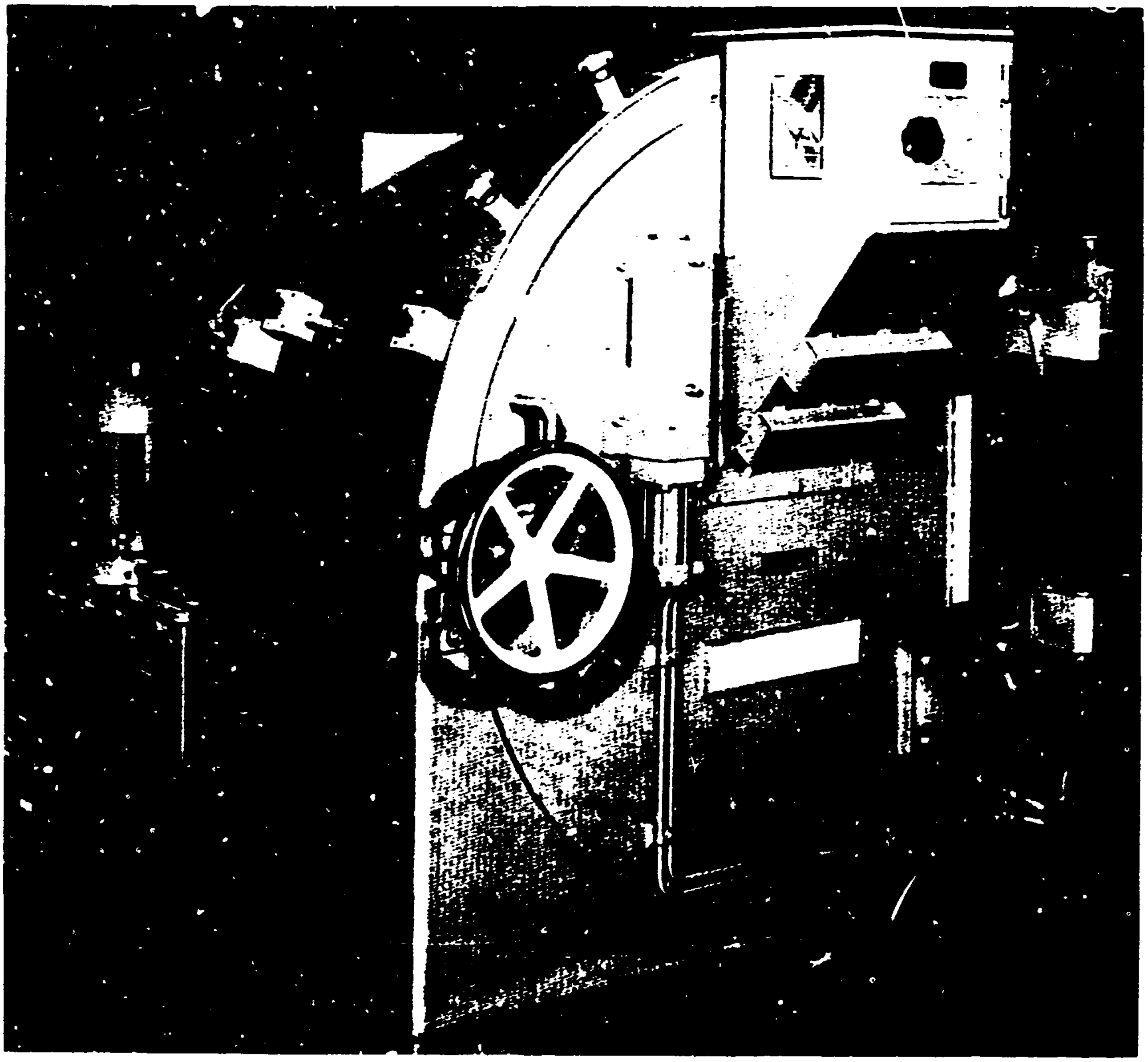
Figure 9. A chipper for processing bales of agricultural by-products



The principal machines for the first process in particle making are flakers. The uniformity of the flakes produced by them largely determines the uniformity of the particles obtained by crushing and, consequently, the uniformity of panels. Flakers may be grouped into two categories: those which operate on chips (either purchased or prepared on machines previously described) or already broken up material; and those which operate only on relatively long pieces albeit pieces of small cross-section. In the first category there are flakers with a rotating knife holder cage (figure 10). The one most recommended is the double flow type (figure 11). This is composed of an internal rotor with vanes and external coaxial cage rotating in opposite directions. Material is fed continuously into the centre of the rotor. The rotor throws the material on to the inside surface of the cage from which the knives project. The flakes produced are sucked through the spaces between the cutting edges and the counter-blades. Knives and counter-knives are mounted and fixed from outside the cage. The thickness of the flakes produced depends on the internal projection of the cutting edges and the distance between the cutting edges and the edges of the counter-knives. Projection and distance must be capable of easy and accurate adjustment. Extremely hard steel wear plates are fixed to the extremities of the internal rotor vanes in such a way as to facilitate their projection adjustment and their removal for sharpening and replacement. These plates must be adjusted so that their edges skim the cutting edges of the knives in the cage so as to ensure that the material is flaked. The cage shaft is tubular and the rotor shaft passes through it. The front part of the machine is therefore free of supports and, as it is mounted on hinges, there is easy access to the interior. The cage is generally chain driven by a motor through a reduction gear.

The rotor is driven by a second motor through a reinforced V belt which provides a certain degree of elasticity.

Figure 10. Flaking machine



The two opposite directions of rotation make it easier for the flakes to be ejected even in the case of very wet material. The base is airtight and is connected by a hopper to ducting which directs the flakes to a fan and a cyclone separator. The need for rugged construction and reliability of bearings and rotating elements must be borne in mind when choosing a cage type flaker. Also of importance is wear resistance of all those parts coming into contact with the material to be flaked. These parts include the rotor vane plates, and the internal surface of the cage and the counter-knives. These must be made of suitable steel to avoid the necessity of replacement or the need for grinding after a relatively short period of use.

One of the most important factors in a flaking machine is the quality of the knives. Even if top grade materials are used, sharpening is frequently necessary if the characteristics of the flakes are to be maintained and energy losses avoided. The ability to rapidly change blades, with consequent short down-times, is an important consideration.

Figure 11. Schematic drawing of the flaking process

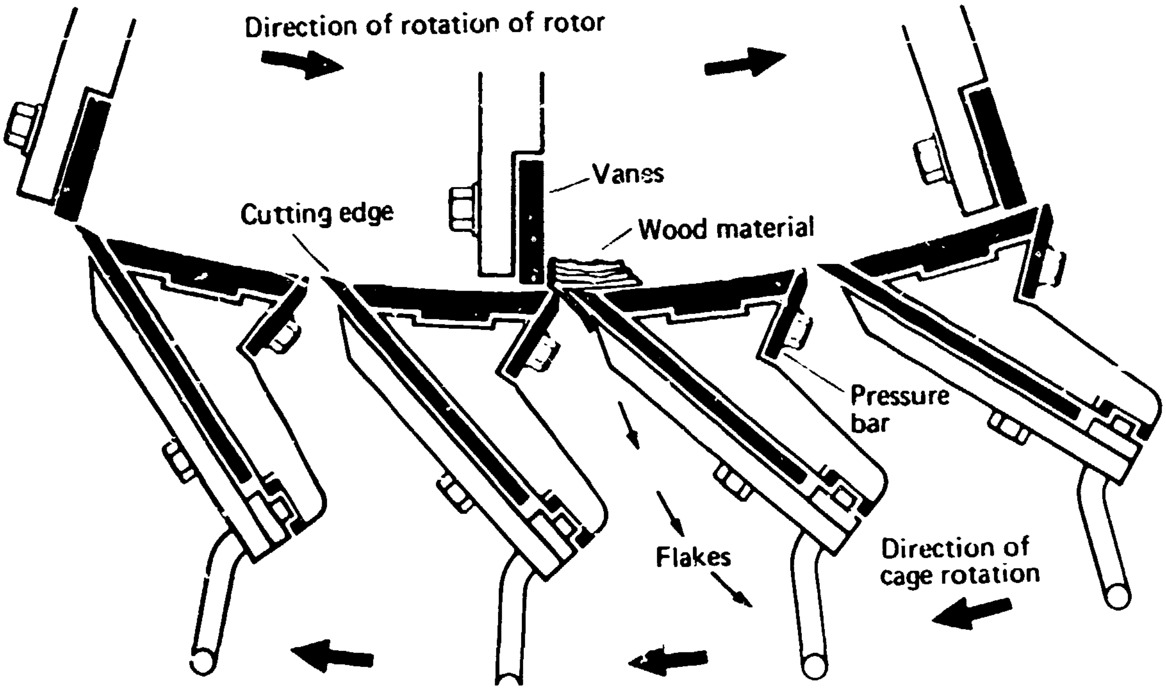


Figure 12. Push-button controlled hydraulic system of the flaker

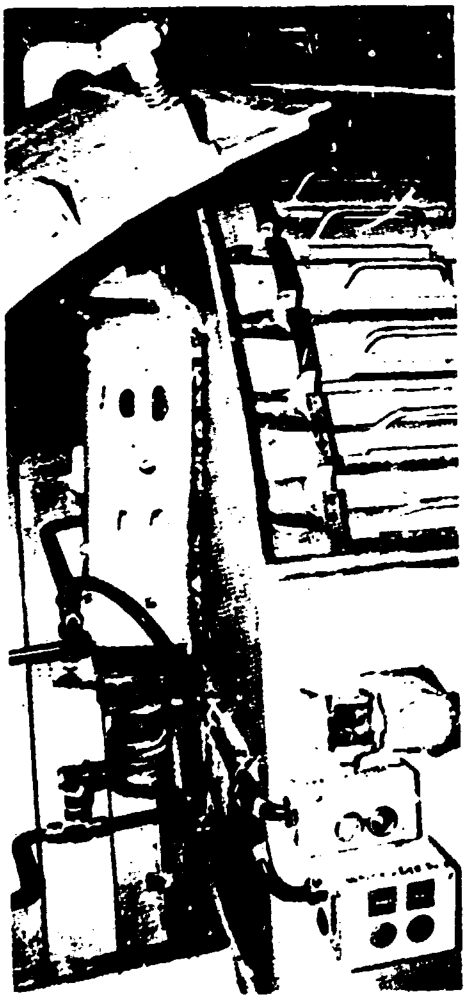


Figure 13. Replacement of the knife units and knife clamps

Flakers on which the entire rotor has to be dismantled to change the knives are not recommended. Those machines on which each knife and counter-knife unit is interchangeable, and can be removed and replaced through an opening in the periphery of the casing, are more practical.

Frequency of sharpening is influenced by the accuracy of inclination of the blades, their cutting angle and the shape of the knife holder. These configurations should allow for the flow and extraction of flakes. Knife wear and replacement have a considerable effect on production costs and therefore knives should be capable of being sharpened many times and be capable of being used even when greatly reduced in width. In a good flaker the knives should still be usable even after having been reduced 65-70 mm by successive sharpenings.

Figure 14. Electromagnetic setting device for accurate adjustment of knife. A power boltdriver is used for tightening of bolts

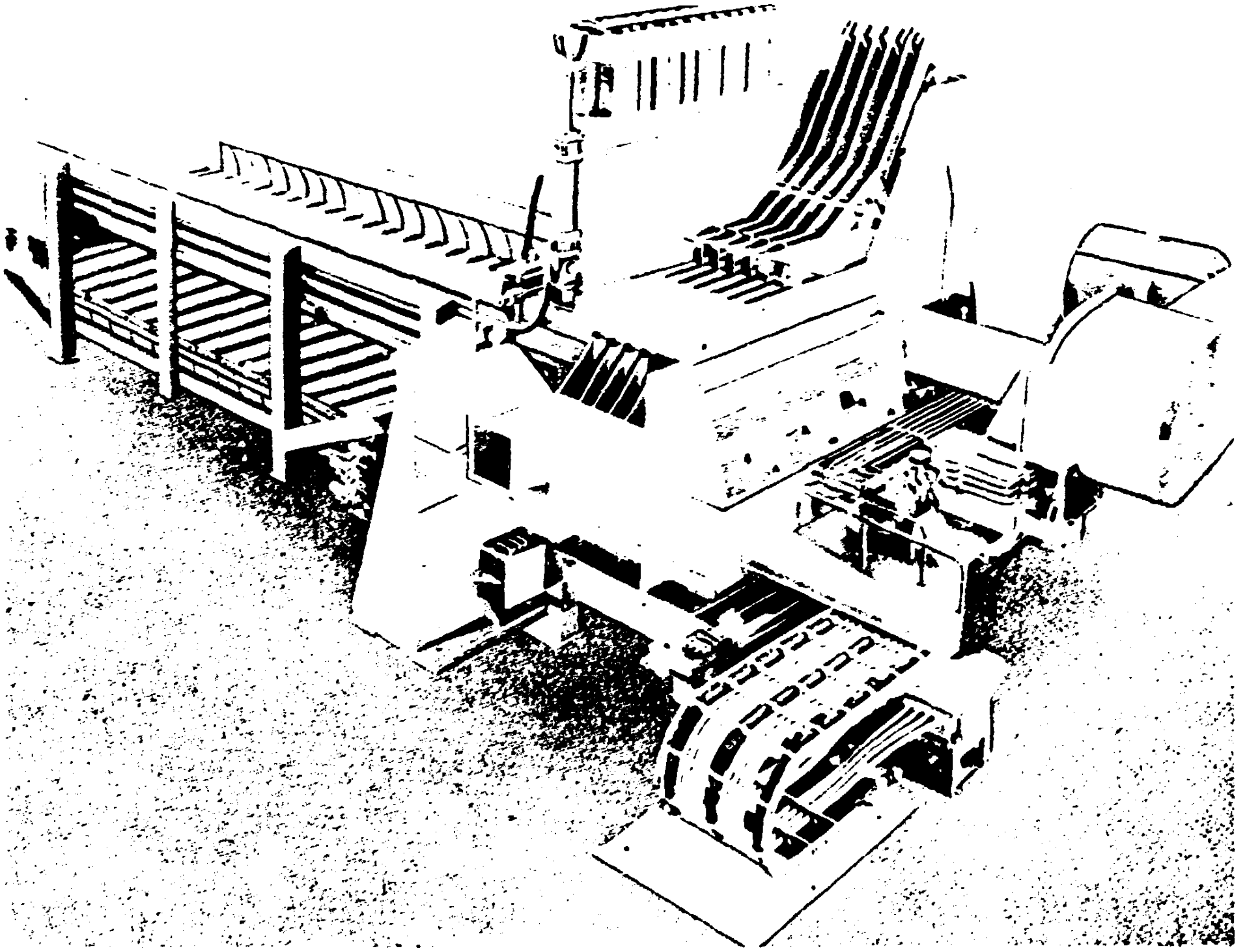
If the arrangement for inserting the knife unit and knife holder in the cage is well designed, replacement is rapid and positional adjustment unnecessary. Push-button controlled hydraulic systems (figure 12) are recommended wherein each depression of the button corresponds to a rotation of the cage equal to the interval between two knife units, and triggers the simultaneous release of the spring which blocks the unit. With this system, loosening screws or bolts is not necessary and replacement takes only 8 to 12 minutes according to the size of the machine and the number of knives on the cage (figure 13).

Flakers which have the internal surface of the cage lined with hard steel wear plates fixed into the side so as to be easily withdrawn for grinding or, if really necessary, for replacement, are highly recommended.

A very useful accessory on cage type flakers is an electromagnetic device to simplify setting and fixing the knives on the interchangeable units. The magnet holds the knife and its fixing plate firmly while an electric boltdriver is used to tighten the fixing bolts (figure 14). A lamp illuminates a reference line which corresponds to the pre-set position for the cutting edge.

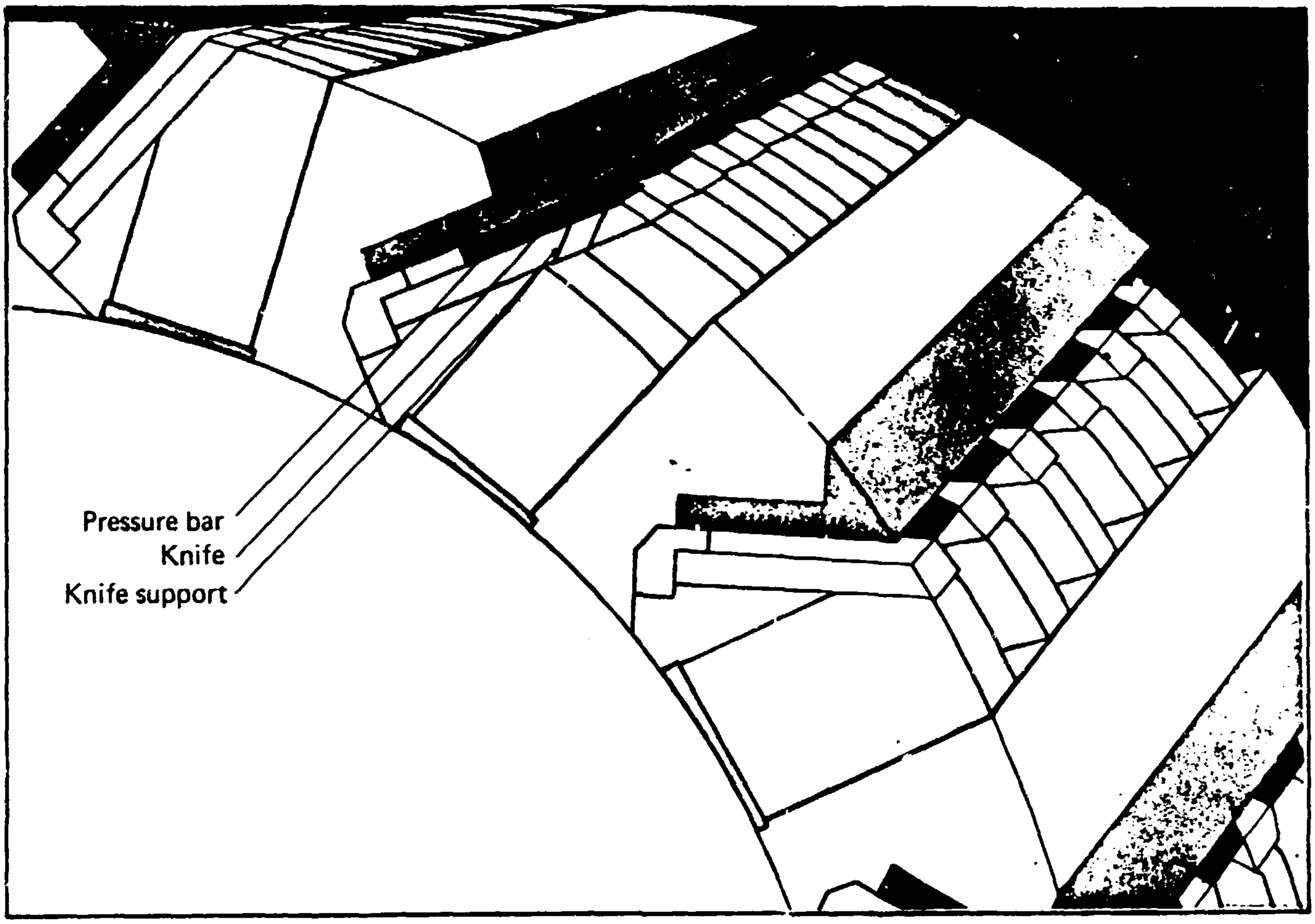
In the second category of flakers (suitable for all kinds of wood in larger sizes) are the vertical or horizontal disc types which, in principle, should be able to produce more uniform flakes as they are machined on the flat. They are only suitable, however, for round wood, which must first be reduced to pieces not longer than 50 cm. The productive capacity of these flakers is relatively low. For this reason their use is decreasing and universal flakers with a cutter head are preferred. These consist of a loading channel with an articulated metal element mat, a hydraulic system for holding the wood during the cutting operation and a slide moving transversely to the axis of the machine, on which the main motor and the cutter head are mounted (figure 15). The characteristics of this head are extremely important.

Figure 15. Universal flaker



On the most advanced types the knives, whose width corresponds to the length of the flakes, are aligned so as to ensure maximum continuity of cutting (figure 16). The knives are screwed to the knife holders which are fixed to the cylinder without screws. The surface of the cylinder is composed of wear plates which can easily and rapidly be replaced. Adjustment of knife projection, according to required flake thickness, is by means of a precision automatic circumferential system. By changing the knives it is possible to vary flake length from 20 to 30 mm. The pressure of the hydraulic pressure device, which holds the wood during cutting, prevents the formation of splinters and vibrations which could lower product quality. These machines are able to process wood of any cross section, and productivity is considerable. Power required varies from 90 to 250 kW and, with the higher power, productive capacity is of the order of 5,000-6,000 kg/l. of flakes 0.4-0.5 mm thick (dry weight).

Figure 16. Alignment of the knives of the universal flaker

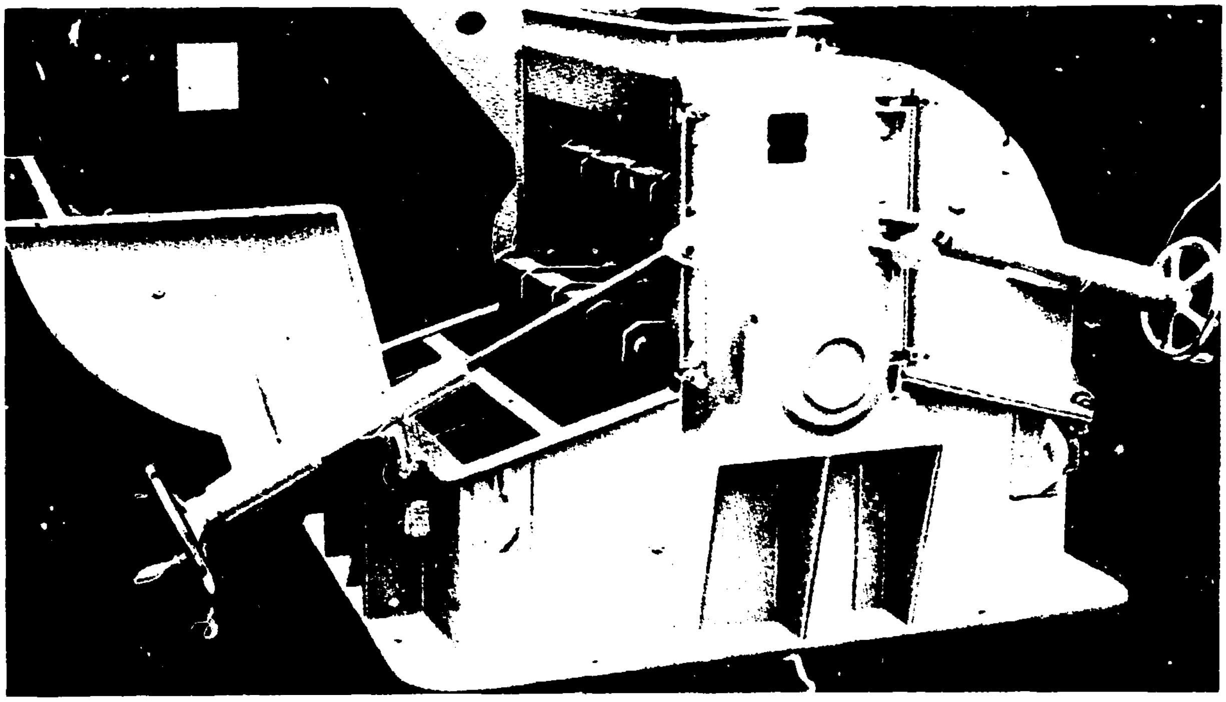


The crushing of flakes to produce particles of sizes according to the layer of the panel they are to occupy is done by mills, the choice of type being determined by the particle size required. For normal particles (middle layers) a hammer mill with wing beaters (figure 17) is recommended. It has articulated rotating plates, which throw the flakes against fixed contrast elements to cause crushing. The hammer profiles can vary according to the nature of the raw material. A screen with holes or slots determines the particle size.

The rotor diameter varies from 400 to 800 mm, depending on machine capacity. The length of the rotor may range from 500 to 1,200 mm. In cases where flakes have medium or low humidity it is possible to use a hammer-cross mill for crushing. A no knife hog with fixed beaters is used to throw the material against a fixed basket type screen on which contrast elements can be fixed to facilitate crushing (figure 18). Particle size is determined by the size and shape of the holes in the screen; the inside diameter of these mills varies from 600 to 1,200 mm and screen width from 200 to 600 mm, depending on machine capacity.

For producing very fine particles (figure 19) or for producing particles in cases where flakes are already dried, it is possible to use a special type of this mill in which the screen, instead of being fixed, rotates in the opposite direction to the rotor (as with a cage type flaker) and which has contrast elements alternating with drilled ones.

Figure 17. A hammer mill with wing beaters



If the flakes have to be defibred which may be the case for boards with extremely compact outer layers, it is necessary to use a refining mill in which the material is made to pass between two profiled segmental discs, one fixed and one rotating. The distance between discs is adjustable for the particle size required. Disc diameter varies from 400 to 1,200 mm. A refining mill is shown in figure 20. Chip paths, grinding profiles and flow direction are shown in figures 21, 22, and 23.

Figure 18. A nc knife hog with fixed beaters

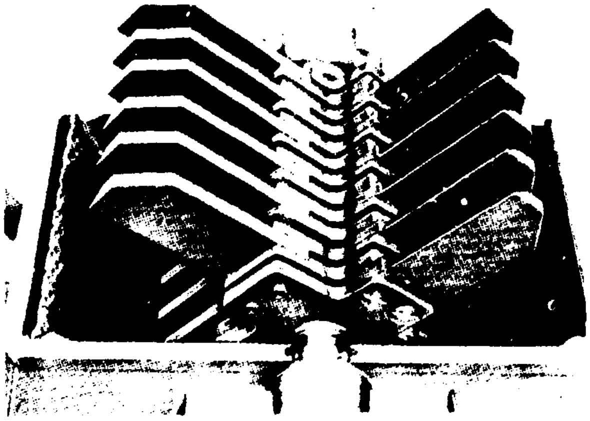
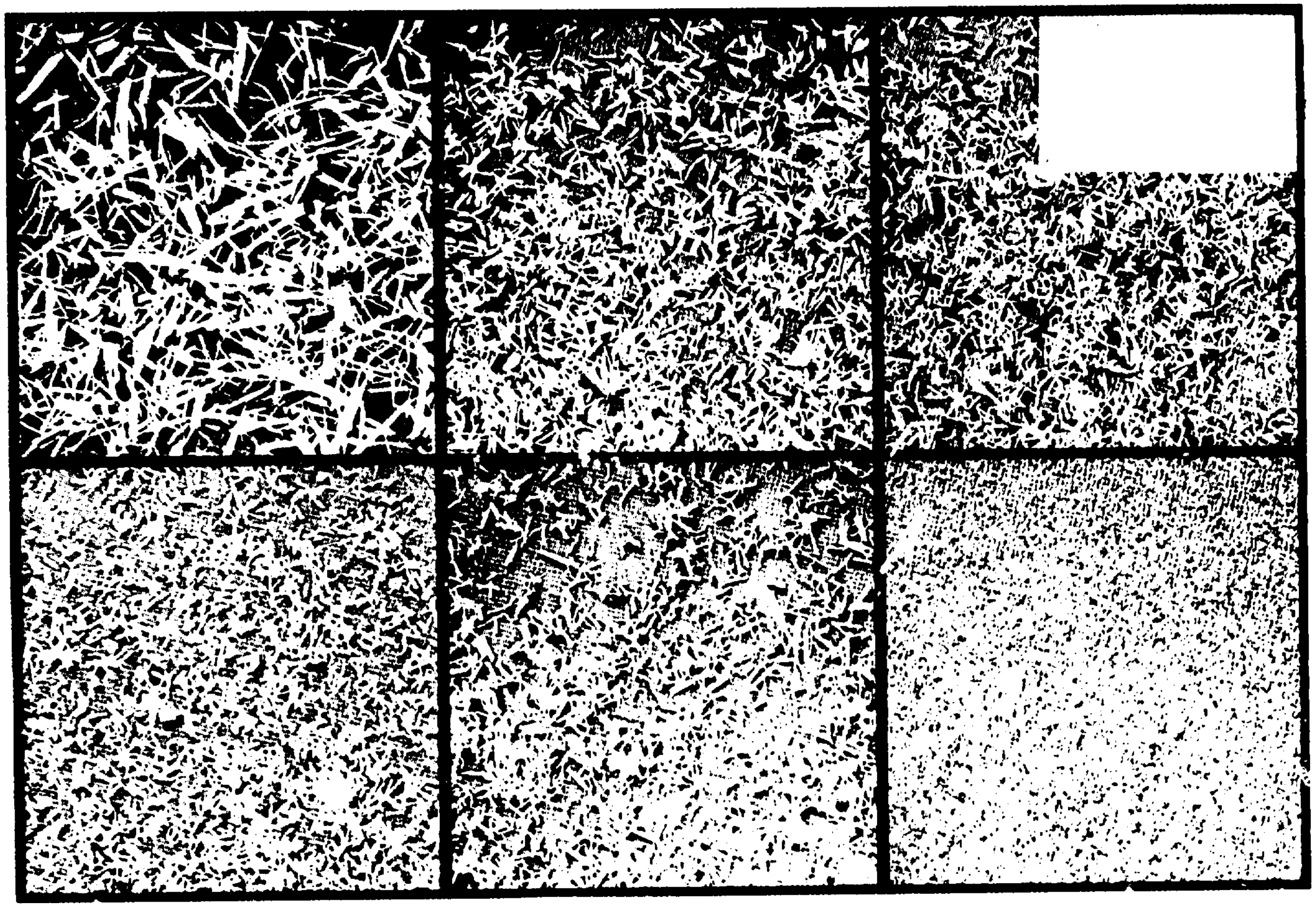


Figure 19. Particle sizes produced in special mill

Final Product



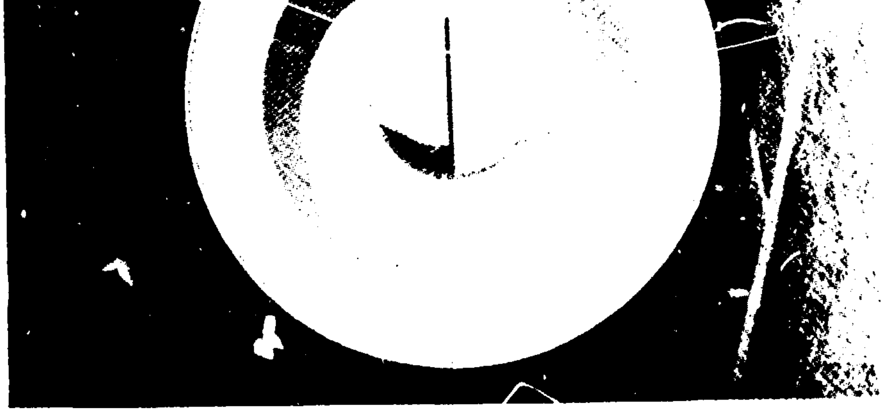


Figure 20. A refining mill

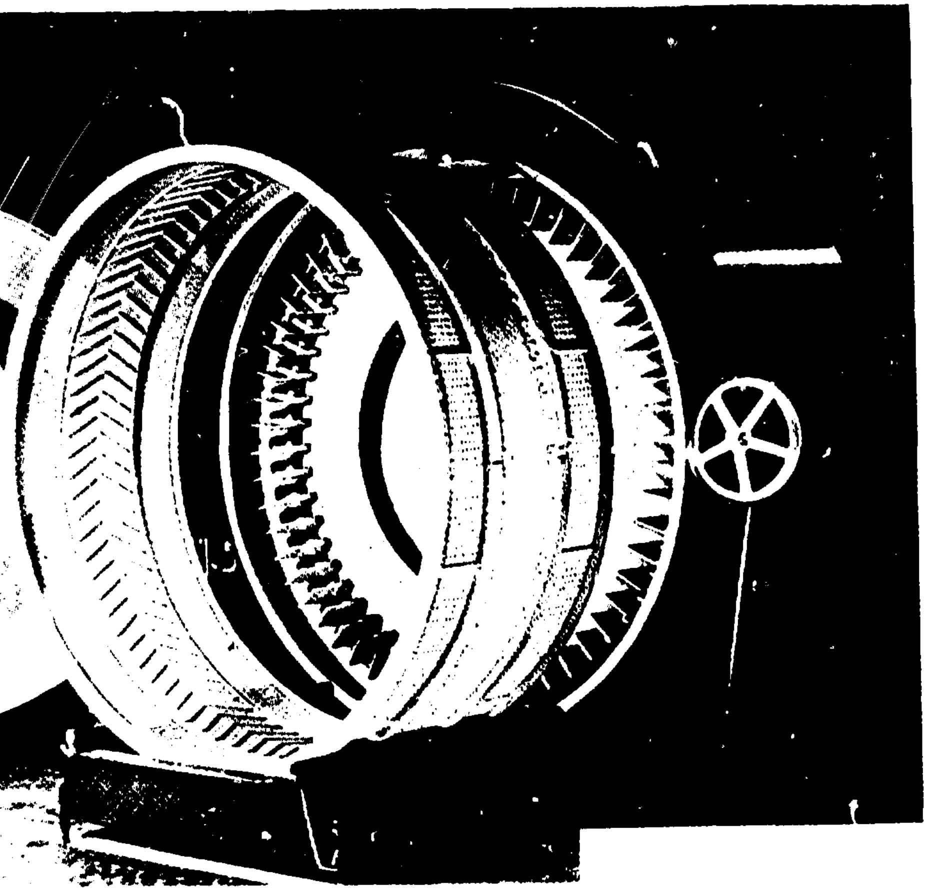
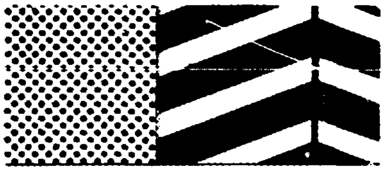
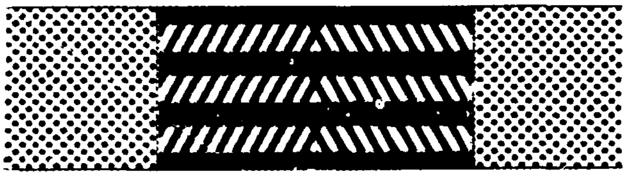


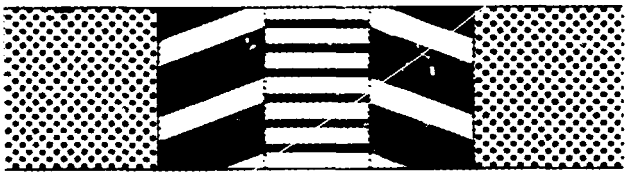
Figure 21. Chip paths during grinding and screening



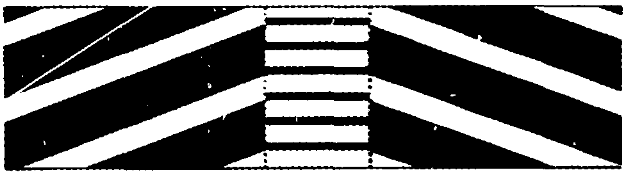
V-ledges with screen



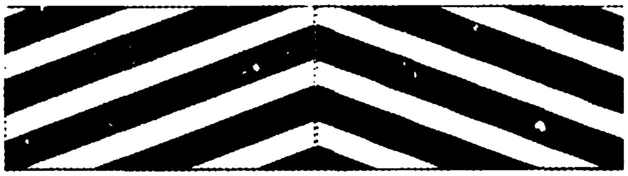
V-grooved ledges with screen



Chip grinding path with screen



Chip grinding path, wide, without screen.



V-ledge grinding path, wide, without screen.

Figure 22. Different grinding-profiles for refining machines

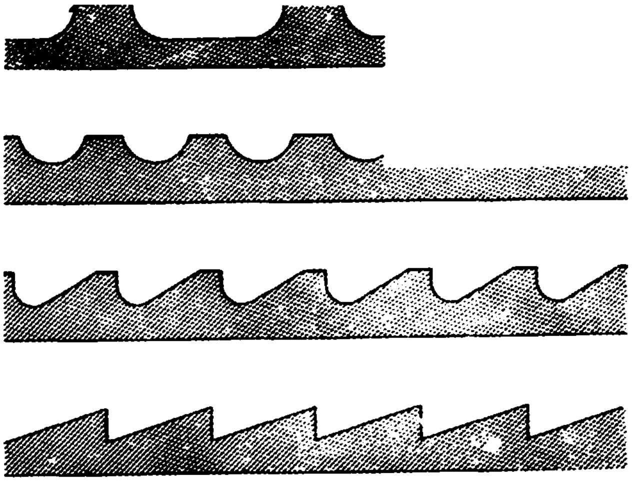
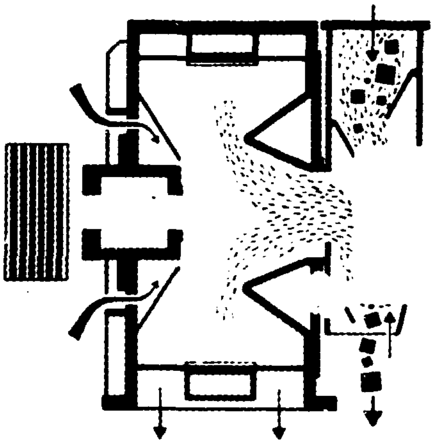


Figure 23. Chip flow direction in refining machine



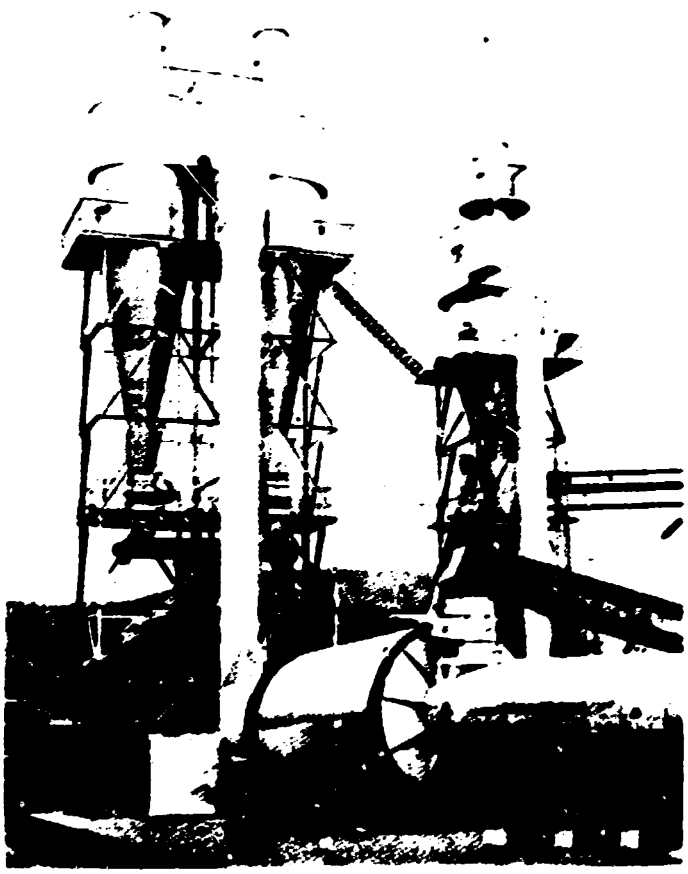
Dryers

Drying is a delicate process. Difficulties may be caused by poorly designed dryers and by fires and explosions which occur when the processing rate is not scrupulously kept within the pre-established limits. On the basis of past experience, from the point of view of wear and maintenance, some dryers, which were widely used in plants up to a few years ago, must now be replaced by dryers of more durable design. When the raw material has a high moisture content there is some difficulty in maintaining constant size during crushing of the flakes. That is to say that for a given type of mill and setting, the particle size varies with flake moisture content. It is thus difficult to ensure correct dryer functioning. It is possible to install a pre-dryer which, independently of the initial humidity content, keeps the flakes at around 50-60 per cent moisture content before they enter the mills and main dryers. In this connection the mills are inserted between the pre-dryer and the main dryers with particle preparation taking place under controlled humidity conditions. This makes the dryer more efficient and assures that the final moisture content will be as desired.

The vertical tube type of pre-dryer is the most common. The working temperature is relatively low and the amount of evaporation is proportional to the length of the tube.

The dryer which has proved to be the most functional and is most widely used is the type with a rotating horizontal cylindrical body consisting of three concentric solidly united cylinders. This gives three passes, in alternating directions, to the particles before they are ejected. The heat is uniformly distributed to the particles. Movement of the particles is determined in part by the mechanical rotating action of the cylindrical body and by the effect of the hot gases passing through it. A pre-dryer is shown in figure 24. A close-up view of kiln drums for chip drying is shown in figure 25. A counter-flow gravity separator is usually placed after the dryer to eliminate any unwanted foreign particles heavier than those of the wood. A high-efficiency fan, made of wear-resisting material, blows the particles in a cyclone pattern. The silos in which the dried particles are stored must be equipped with very sensitive fire prevention devices capable of immediate automatic response when needed. Hot gases for drying are produced by burning liquid fuels (petroleum, naphtha, diesel oil) or gases (propane, butane, natural gas) and also by burning all the wood dust produced during the various processes, such as sanding of the panels, in a separate burner. The liquid fuel furnace is automatically regulated to control the temperature of the gases produced and to control flake moisture. All ducts connected to the dryers are equipped with fire prevention devices and the ratio of carbon dioxide to oxygen is continuously metered, and kept at a safe level, to avoid the risk of fire or explosions.

Figure 24. A pre-dryer



To estimate the production rate of dried particles it is advisable to consider the amount of moisture to be evaporated with respect to the required moisture content. Normal dryers are capable of evaporating moisture at the rate of 2,000 to 10,000 kg/h.

Silos

A certain number of silos must be provided for each production line for the storage of particles which are to be used to form the various layers (in the case of multi-layer boards). Silos must also be provided for a single production line where progressively graded particles are used (a mixture of fine

Figure 25. Close-up view of kiln drums for chip drying

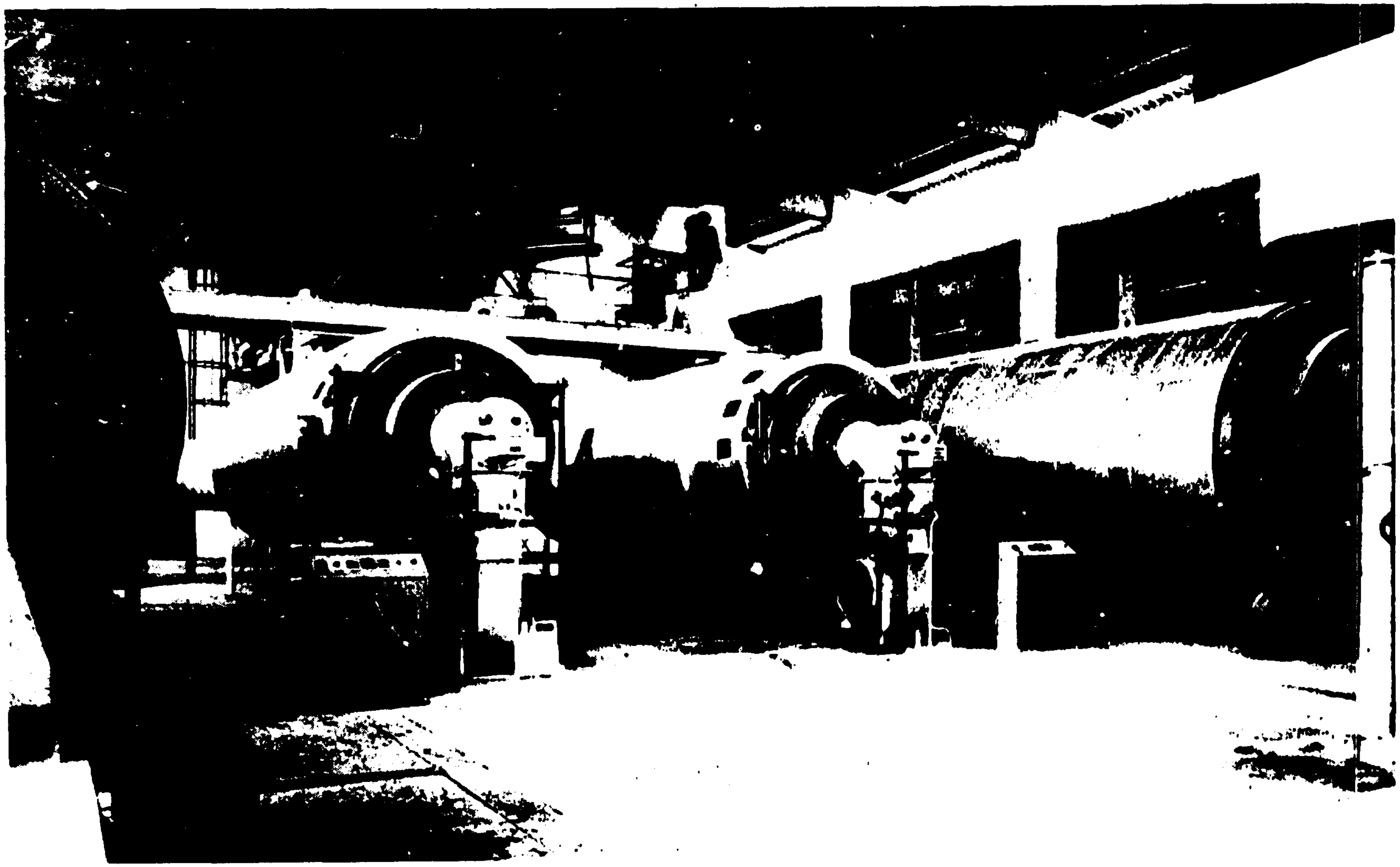
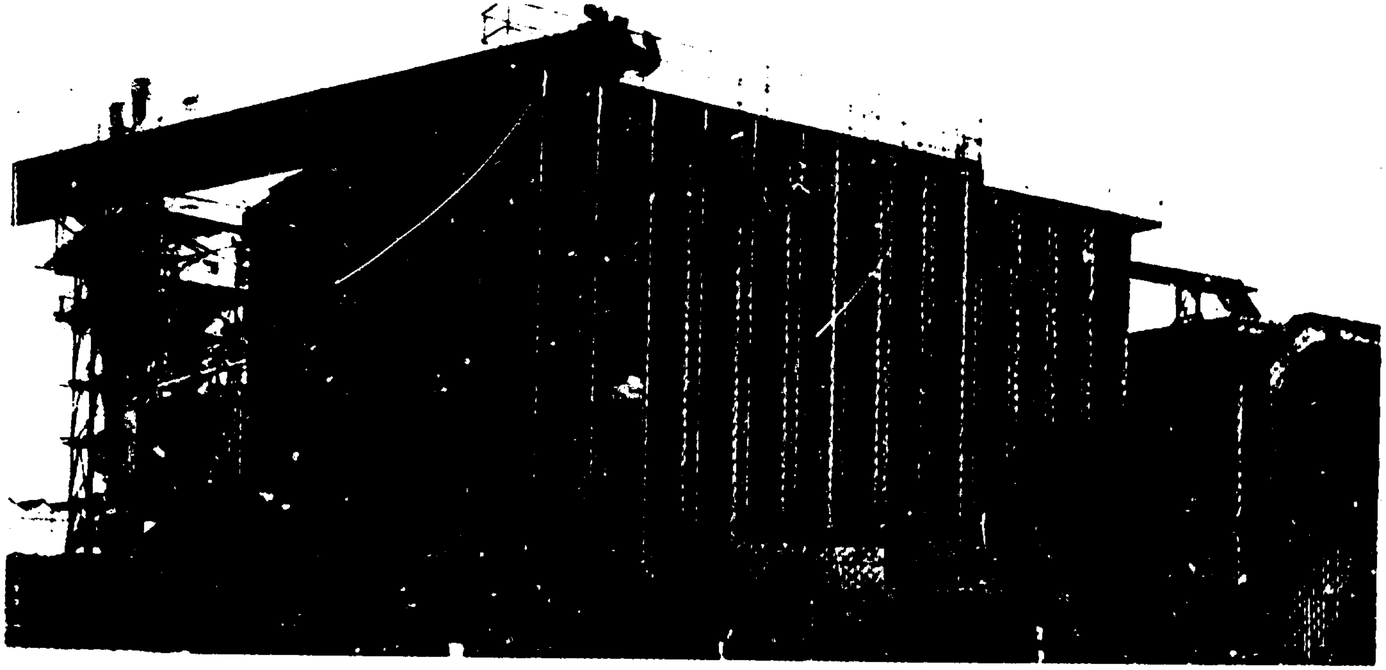


Figure 26. Storage silos for particles



and relatively large particles distributed so that the fine ones will constitute the external layers). These silos ensure a sufficient reserve of material to allow the plant to cover down-times during tool changing, maintenance etc. The shape of the silos (square, rectangular or cylindrical) and, above all, the system for metering the material extracted, depends on the material. Square or rectangular types (figure 26) are preferable for chips and for storing moist materials and those in the early stages of processing. This includes agricultural by-products after the separation of unusable residuals. The most suitable extraction method is to use hydraulic thrusters, arranged in parallel on the bottom of the silos, with transverse screw feeders, as shown in figures 26 and 27. A chip feeding unit is shown in figure 28.

Figure 27. Storage silos with screw feeder

Extraction in cylindrical silos is done by a hydraulic rotor system, on the bottom of the silo, driven by an external motor-reduction gear.

Framework and plating should preferably be of steel (silos can also be in reinforced concrete) which has been galvanized and treated to avoid oxidation and corrosion. This is especially true for silos that have to contain moist material. The inside walls must be perfectly smooth, and free from projections, to avoid the formation of "bridges". If necessary "bridge" formation can also be prevented by extending the rotor spindle upwards and fitting special arms to it. Other essential elements of safe silos include the fire prevention devices already mentioned, rapid opening anti-explosion doors, and ultrasonic level indicators.

Particle grading

After drying, fine particles must be separated from the larger ones which will be used to form the internal layers. The dust, which if left with the particles would cause a lowering of panel quality, is separated. The excessively large particles are separated and sent to a refining mill. As already mentioned, this dust together with that from sanding the panels is used as fuel in the dryers.

Grading can be done both by multi-sieve graders and by air blast separators. Best results are obtained by combining the two systems. Graders can be oscillating, vibrating or orbital (rotating in a plane around an eccentric axis) types. The latter system is preferred for wood particles because it gives them a continuous circular sliding movement on the sieves. The system makes separation easier and prevents elongated particles from entering the mesh endwise.

Graders can be rectangular or circular and the surface area of each sieve is 7-8 m². This gives a total area of 21-24 m² for a three-sieve grader. Orbital graders have a horizontal displacement of 70 mm. The speed of rotation is 200 to 250 rpm. An orbital grader is depicted in figure 29.

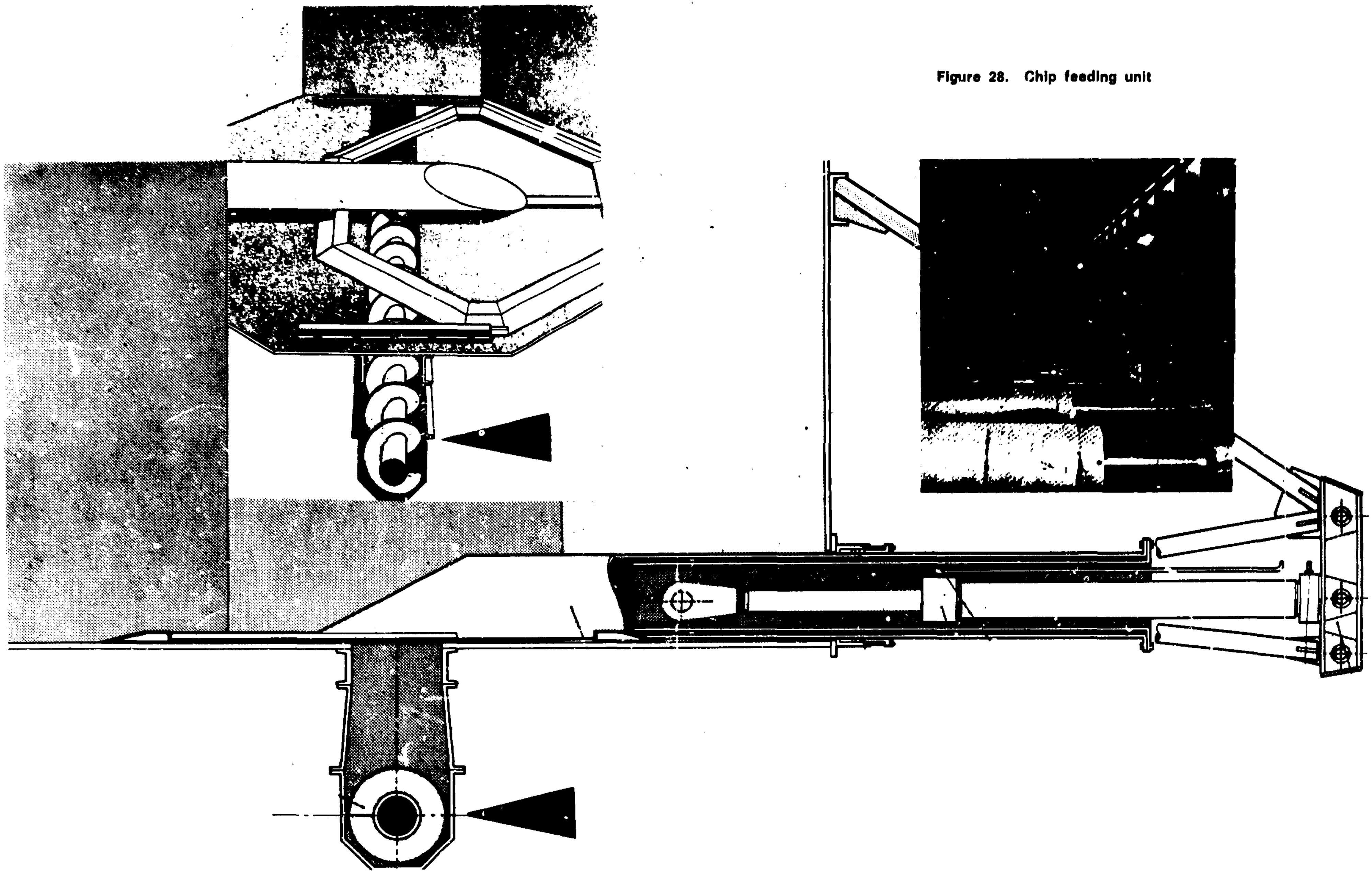
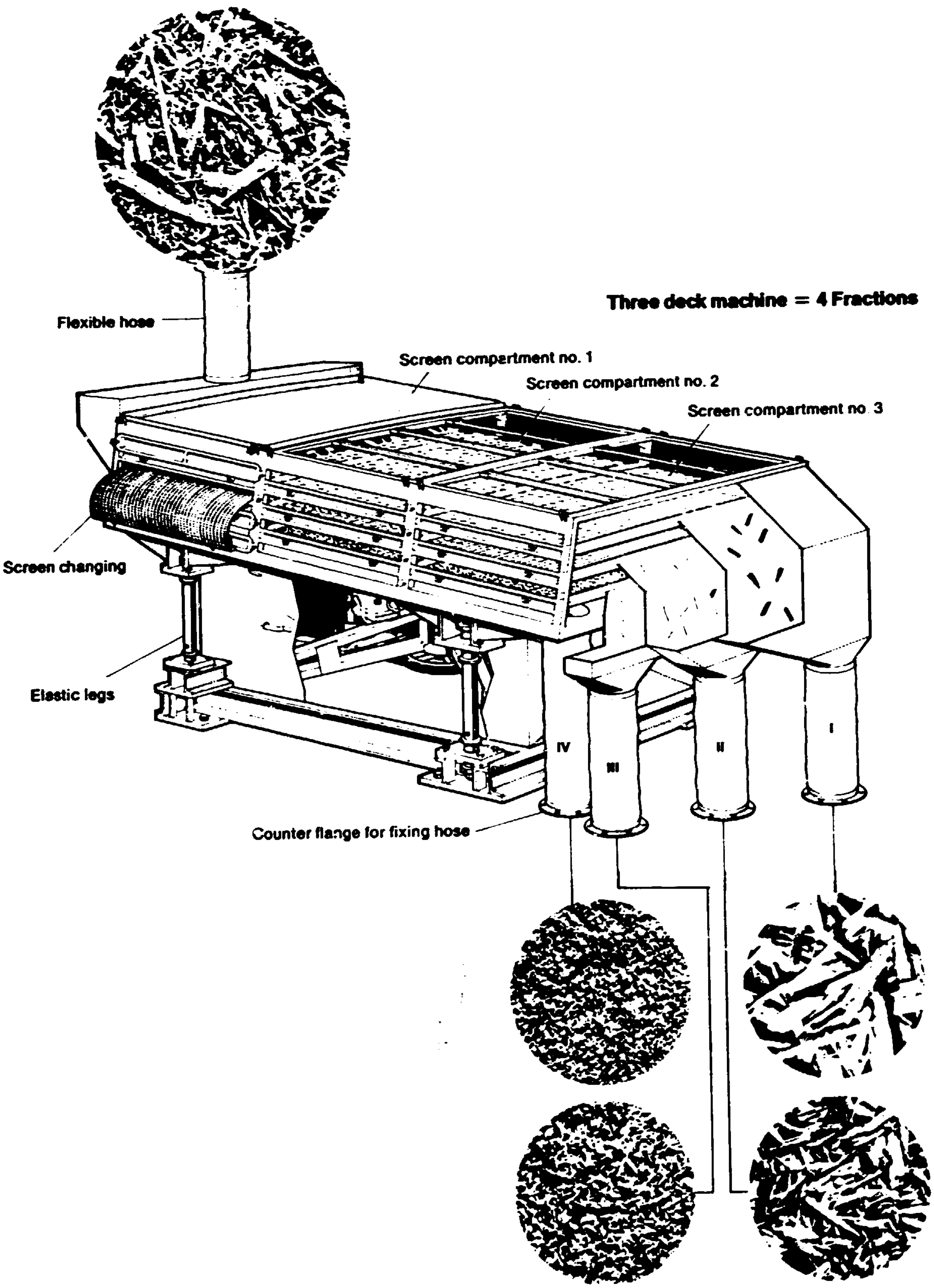


Figure 28. Chip feeding unit

Figure 29. Schematic drawing of the orbital chip grader



For air blast separators the particles are evenly spread out over the whole width of the separator. A horizontal air blast blows the particles a distance which decreases with particle size. Dust is blown farthest. A wind-sifting grader is shown in figure 30.

The main difference between the graders and air blast separators is that the former separates particles according to their surface area, independently of thickness, and the latter separates particles according to particle motion in the air stream.

Figure 30. A wind-sifting grader

Preparation of binding agents and their addition to particles

For the production of synthetic resin bonded boards (urea, phenol or melamine based) it is necessary to carefully prepare measured mixtures of five components. In the simplest type of resin mixture the components include synthetic resin, catalyst or hardener, emulsified mineral wax which gives the board a certain amount of waterproofing, and a complementary chemical which changes the rate of hardening of the resin as a function of the temperature of the board at the pressing stage. The complementary chemical also fixes the formaldehyde which is liberated during the process. The fixing chemical used with urea resins may be an ammonia solution. The fifth additive is water for dilution.

Production plants are automated so as to mix fixed proportions of the five liquid components. Other additives such as anti-parasitic products can be included in the mixture. A good plant has functional simplicity and provision for component metering and mixing. The plant is safe. It has visual and acoustic warning of functional irregularities; provision for automatic stopping if mix proportions are incorrect, and capabilities for effective washing and maintenance. These concepts are illustrated in figures 31, 32 and 33.

A rapid mixer mixes and homogenizes the chemicals. The mixture is then conveyed to a chemically resistant tank of appropriate size. Normal metering and mixing plants are made to supply up to 7,000 kg/h of mixture.

For plants producing cement-bonded boards, dry cement is put into the mixers and the liquid metering process prepares special mineralizing solutions. These solutions must be sprayed onto the particles in the initial stages of mixing. It should be pointed out that, both for synthetic resin bonded boards (multi-layer) and for boards with progressive grading, the outer bonding mixture is different from the mixture used for the interior part of the boards. Two distinct metering and mixing production facilities are therefore required. Particles, and bonding chemicals, must be accurately and continuously measured before being bonded. Liquids and particle bonding mixtures are introduced to the bonding apparatus by variable speed precision rotary measuring pumps. Particulates and solids (cement) are continuously weighed by automatic belt type weighing machines, as shown in figure 34. For these machines to operate properly it is essential that their weighing elements are not contaminated by input materials and that the elements be fully dust proof. The elements must be relatively insensitive to temporary fluctuations in power supply. They must be capable of handling high peak belt loads.

High turbulence continuous gluing machines are widely used. The mixture enters through the hollow shaft, and is thrown by centrifugal force through rotating nozzles on the shaft onto the particles. Besides uniform binder distribution, features of these machines are: high productivity (over 30 t/h of treated particles), small size, high safety and ease of maintenance. The particles enter at one end of the machine through a hopper connected to the belt type measuring weigher. The particles travel axially in the form of an annular layer adhering to the internal cylindrical wall of the machine. The blender consists of a hollow shaft on which three sets of arms are mounted. The first set consists of adjustable elements holding inclined blades which thrust the incoming particles forward by centrifugal force. The second set (where the binder is added) is connected to the inside of the shaft by holes through which the mixture flows to nozzles. The third set (the so called "post-gluing" section) consists of very strong specially shaped arms which spread the particles against the walls to ensure even distribution of the mixture. The length of the arms of the second set is varied to give varying depths of penetration of the mix into the annular layer. As the distance of the particles from the rotational axis depends on particle mass, it is possible to adapt each nozzle so that binder is added in amounts calculated for each particle size. The frictional force generated during operation would, if converted into heat, overheat the machine and harden the mixture. Therefore the cylindrical body is double-walled and cooling water is circulated in the hollow space. Cooling water is also fed into the hollow shaft, at a point opposite to that in which the mixture flows, and made to circulate in the shaft and in the arm cavities in the "post-gluing" section. Maintaining a constant working temperature ensures uniformity of application and distribution conditions for the mixture.

In gluing machines for fine particles both the first and third sets of arms are fitted with pointed elements which, acting as combs, prevent clogging of the material. The cylindrical body is divided into two parts on an axial plane and hinged so that the whole machine can be opened for easy cleaning and maintenance. This is shown in figure 35.

Even though relatively simple in construction, gluing machines need special care in manufacture. They must ensure uniform distribution of the mixture to the particles. They must economize on binder (which depends on suitable nozzles at proper distances from the shaft, and on nozzle efficiency); they must provide for self cleaning of all rotating parts, in order to minimize binder adhesion and ensure a uniform working temperature. Other essential characteristics are perfect dynamic balancing of the shaft; the capability to accurately adjust the distance between the extremity of each set of arms and the internal wall; and the capability to adjust the inclination of the blades of the first set. It is essential that parts subjected to friction be wear resistant and interchangeable, and that bearings be strong and well fitted. A machine of this type is shown in figure 36. Shaft drive, usually by V belts, is from a motor whose power (from 7 to 90 kW) normally varies according to the size of the machine. Gluing machines for the production of high density cement-bonded boards are similar in construction to those for synthetic resin-bonded boards. However, their working principle is different. The cement is fed into the machine in the dry state. The rotating nozzles near the inlet end are used to distribute the mineralizing solution

Figure 31. Automatic adhesive/additives metering station

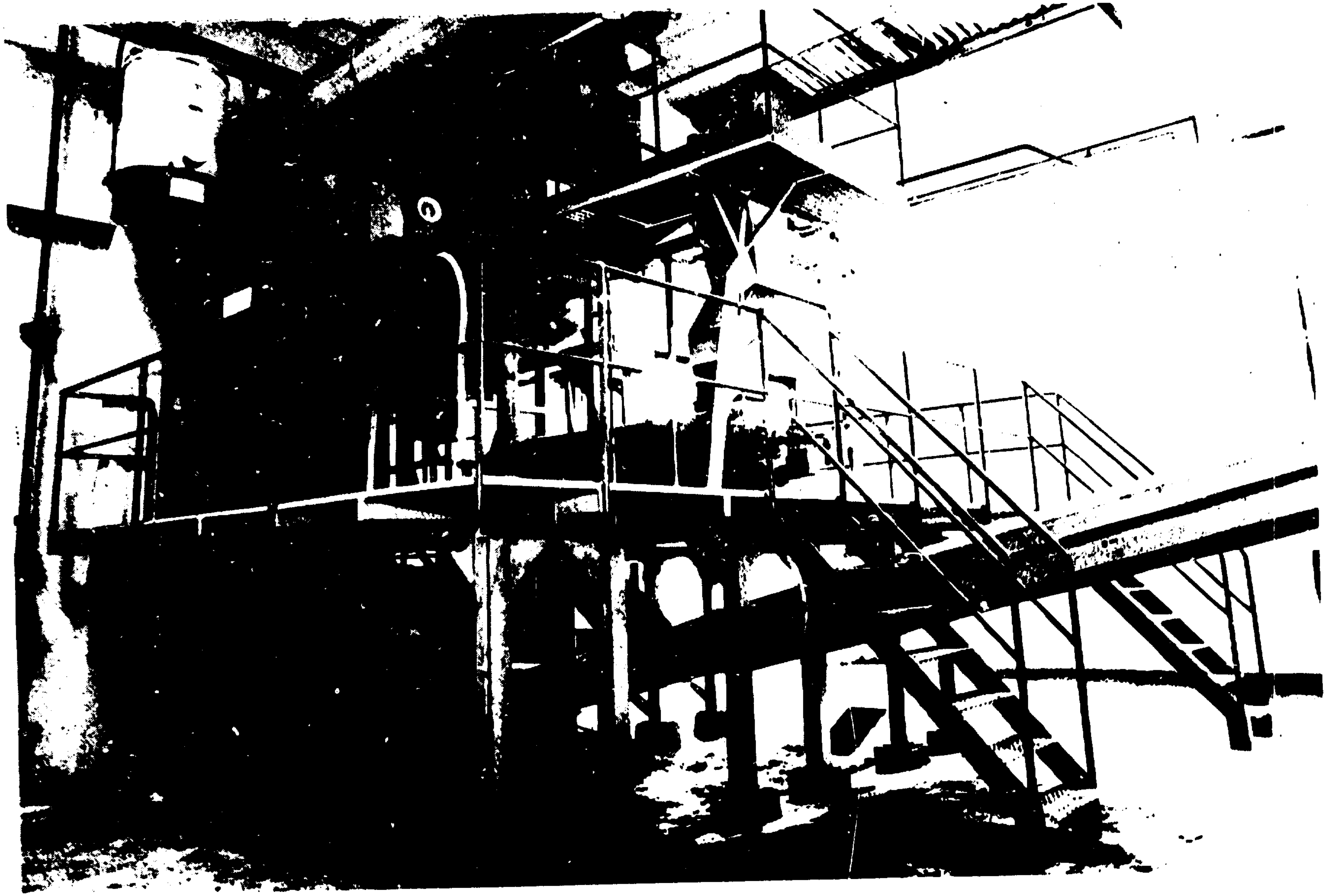


Figure 32. Schematic plan for the automatic metering of binder materials

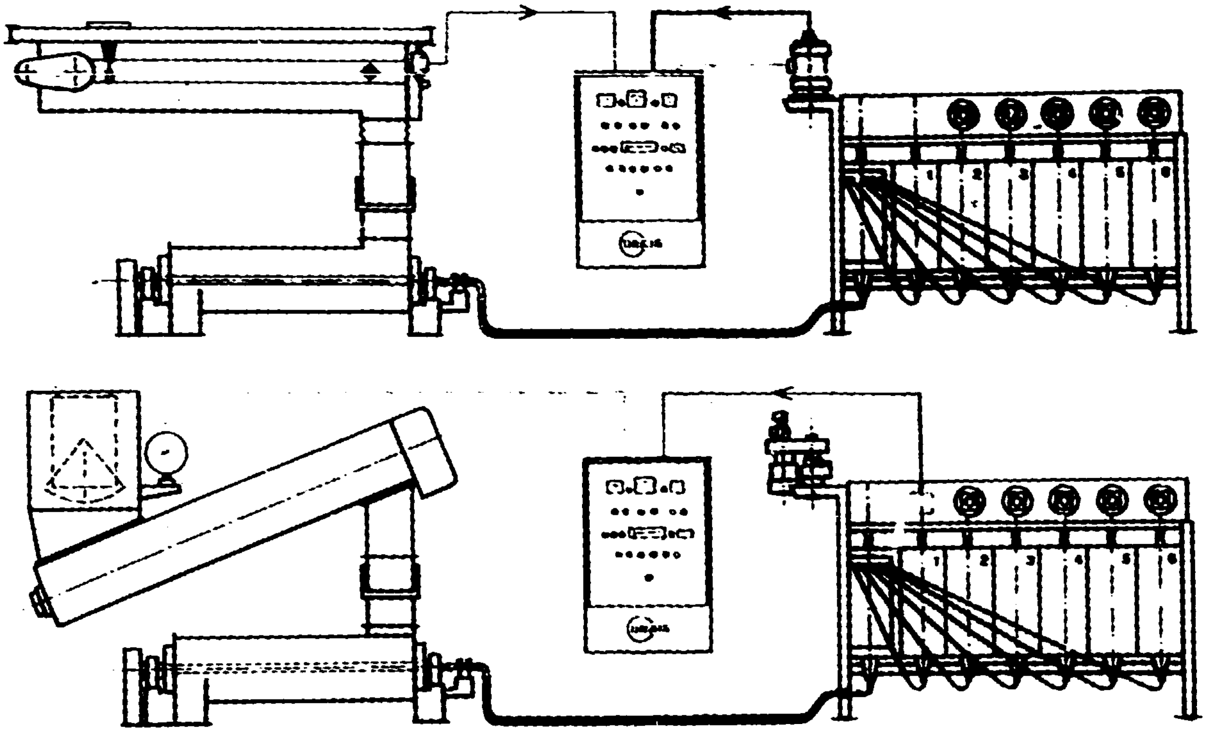


Figure 33. An automatic metering device for binder infeed

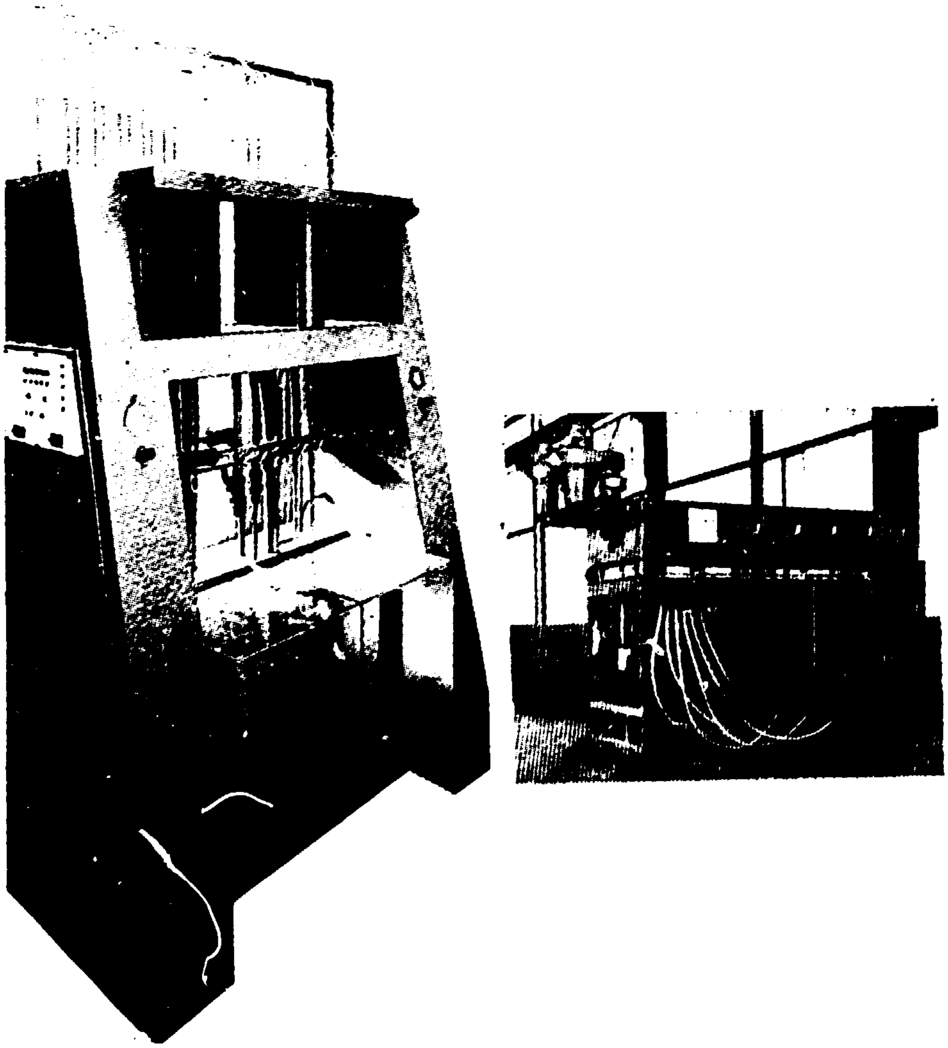


Figure 34. Automatic belt type weighing machine (glue/chip blending)

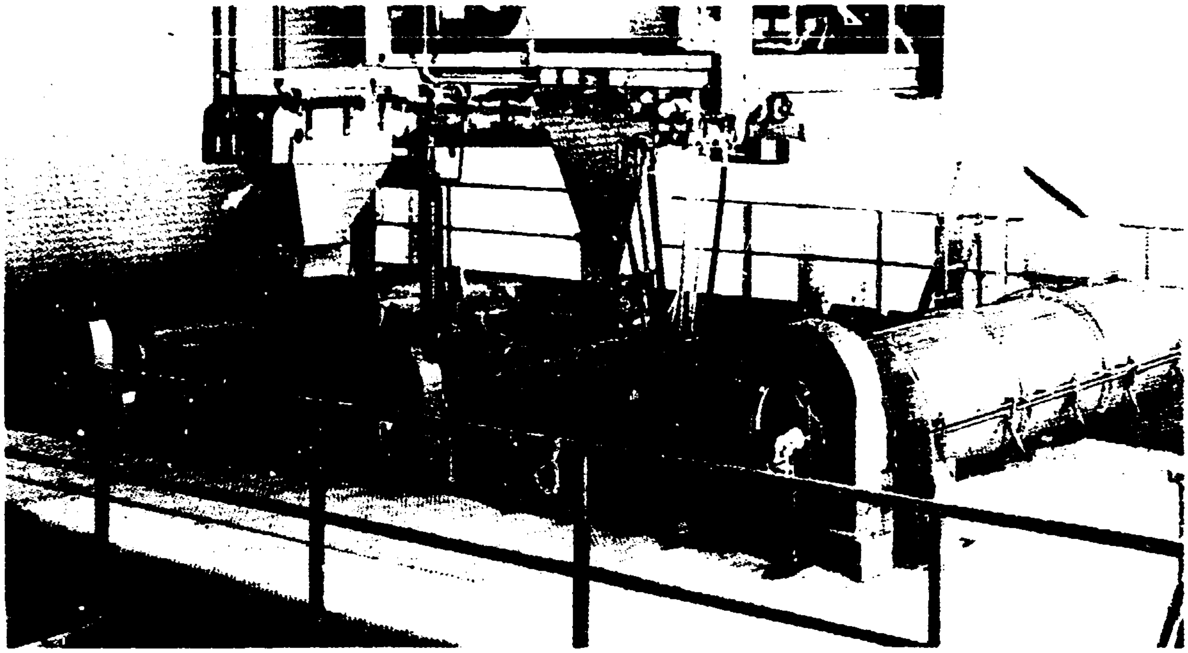
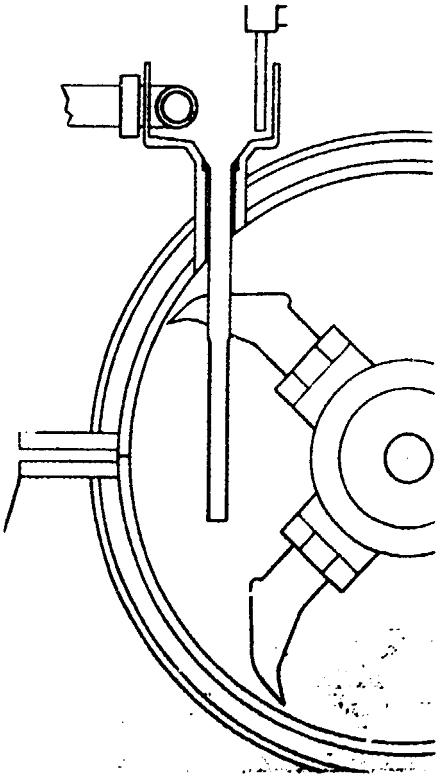


Figure 35. Gluespreading with staggered tines to prevent clogging

Figure 36. Gluespreading machine, showing spraying/mixing arms



which is applied to the particles. The next set of nozzles are used to introduce water to the mix. As there is little friction there is no need for cooling. Due to the abrasive action of cement, it is essential that the extremities of the arms and the internal wall of the cylindrical body be wear resistant.

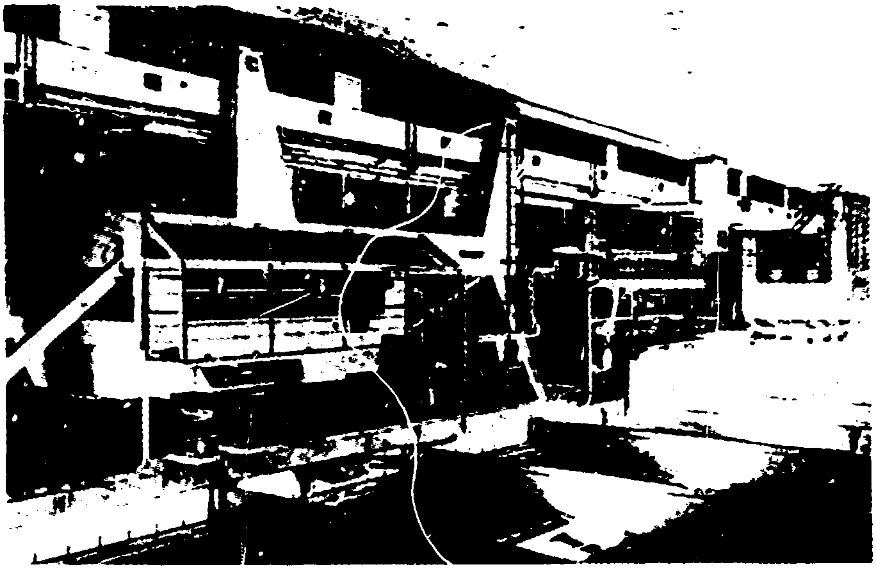
Mat-forming lines

In most plants, boards are formed on a mechanical conveyer belt, whose width corresponds to that of the boards, or which has joined sections corresponding to boards' length. This belt is made of high temperature resisting synthetic fibre fabric, or of steel. The choice depends on the characteristics of the forming and pressing section, and the thickness, structure and binder of the board being produced. Metal belts have the advantage of heat conductivity and longer life The disadvantages are possibility of deformation; some heat retention; impermeability to vapour; and difficulty of repair in the event of fire.

Fabric belts have no thermal expansion and permit faster closing of the heated presses. They have negligible heat absorption and the vapour produced during pressing can be dissipated through the weft. These features can be important for producing thin boards with pressing cycles lasting less than a minute, and where there is little possibility of dissipating vapour through the boards. Although it is easy to substitute for worn or damaged sections, fabric belts have the disadvantage of a much shorter life than metal ones.

Mat-forming machines are used to distribute the particles evenly over the entire surface of the belt (figure 37). It is important to keep wastage to a minimum. It is especially important that the forming machine produce a uniform thickness. This is true whether or not the boards will be sized.

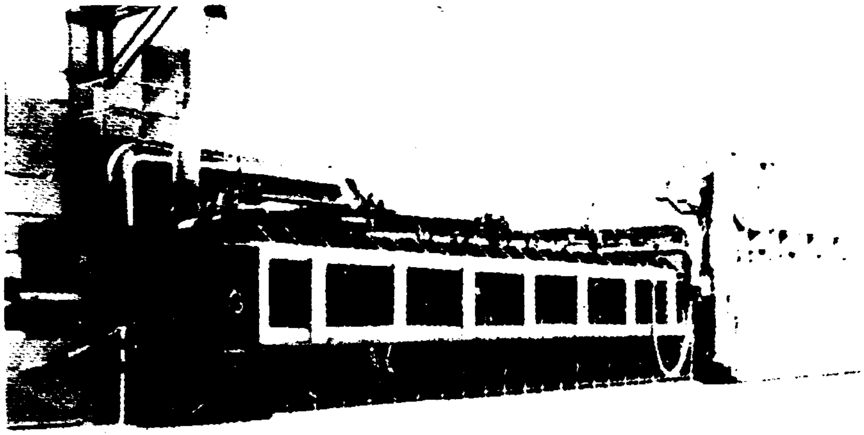
Figure 37. Mat-forming machine for chip spreading



Forming machines either remain stationary as the belt moves underneath them, or they have reciprocating motion and the belt remains still during particle distribution. For graded particle boards one forming machine is sufficient. It is sometimes used in combination with a mechanical or air blast distribution system. The particles are distributed at distances related to their size. This produces a progressive distribution of sizes of particles throughout the board. Multi-layer boards require a distributor for each layer. In some cases a single machine can combine a group of distributors. Control of the density of the particles forming the board, both with respect to absolute value and density distribution, is done by the double process of measuring volume and weight. Another automatic system using gamma rays, from a radioisotope, is used to standardize the forming process.

The installation of a pre-press (figure 38) for densifying particles provides considerable advantages, even if it complicates plant organization and has high initial cost. It is always advisable to install a preliminary press where justified. In addition to compacting the particle mat and preventing crumbling (especially at the edges during the movement towards and introduction into the main press), the preliminary press improves particle location, releases much of the air remaining between particles and reduces the thickness of the mat considerably. This speeds up the closure of the main press. Preliminary presses for synthetic resin-bonded boards were once operated at ambient temperatures. Recently mild temperatures of 60°C for the upper and 70°C for the lower platens have been used. The heating improves pre-bonding of the particles and reduces the final pressing cycle time. The temperature difference between the two platens compensates for the differences in temperatures of the upper and lower surface. This is caused by the heating action of the panel forming and conveyer belt. The asymmetry of the heat distribution especially in small and medium thickness boards causes warping due to stresses brought about by polymerization of the resin.

Figure 38. Pre-pressing unit for pre-pressing the spreaded particle board mass



If the main press is a multi-platen type, the preliminary press must be able to supply a sufficient number of boards in the time corresponding to a main pressing cycle. Recommended specific pressure is approximate [illegible] kgf/cm² even though good results can be obtained with lower pressures.

There a [illegible] calender type preliminary presses (which cannot be heated). The rolls are covered with double s[illegible]h rubberized canvas. While this particular type is more economical and faster than platen presses, the specific pressures that they can exert are relatively low. Thus their use is limited to compacting. The two fundamental categories of preliminary press are the continuous production type, with no board length limitations; and the intermittent type where maximum length of boards corresponds to length of platens. The board forming line is shown in figure 39. There is a specially equipped single chamber press which permits two consecutive operations at the ends of the formed boards and thus produces a board of unlimited length, under conditions where there is a normal succession of opening, closing and pressing phases. Some very special continuous presses have been recently produced. The experience gained so far is not sufficient to establish whether or not they are the best system for pressing bonded wood boards. The particle board process is shown schematically in figure 40.

Continuous particle board presses are the best choice for processing boards for normal use, that is boards bonded with ordinary synthetic resins (with thicknesses between 2.5 and 7 mm). These are shown in figure 41.

With these presses the board is formed on a steel belt and then, without preliminary pressing, wound around an internally heated main drum which is brought to the temperature required for rapid polymerization of the resin. The necessary pressure is applied by rolls which compress the belt and mass of particles against the main drum. The rolls are also heated internally thereby permitting thermal symmetry and adequate heat exchange. These rolls are followed by non-heated calibration rolls which operate on boards that are still in a relatively plastic state, and are able to keep thickness tolerances

Figure 39. Schematic layout of a board forming line

Figure 40. Schematic drawing of the particle board process

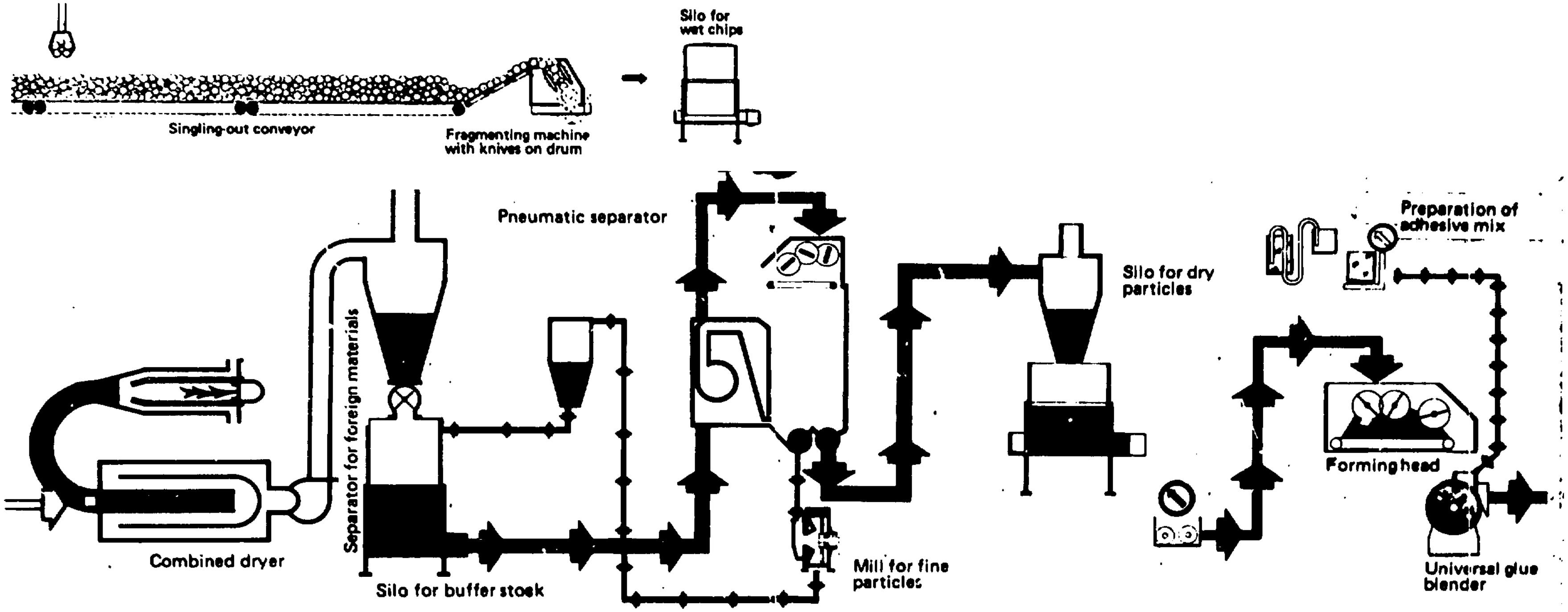
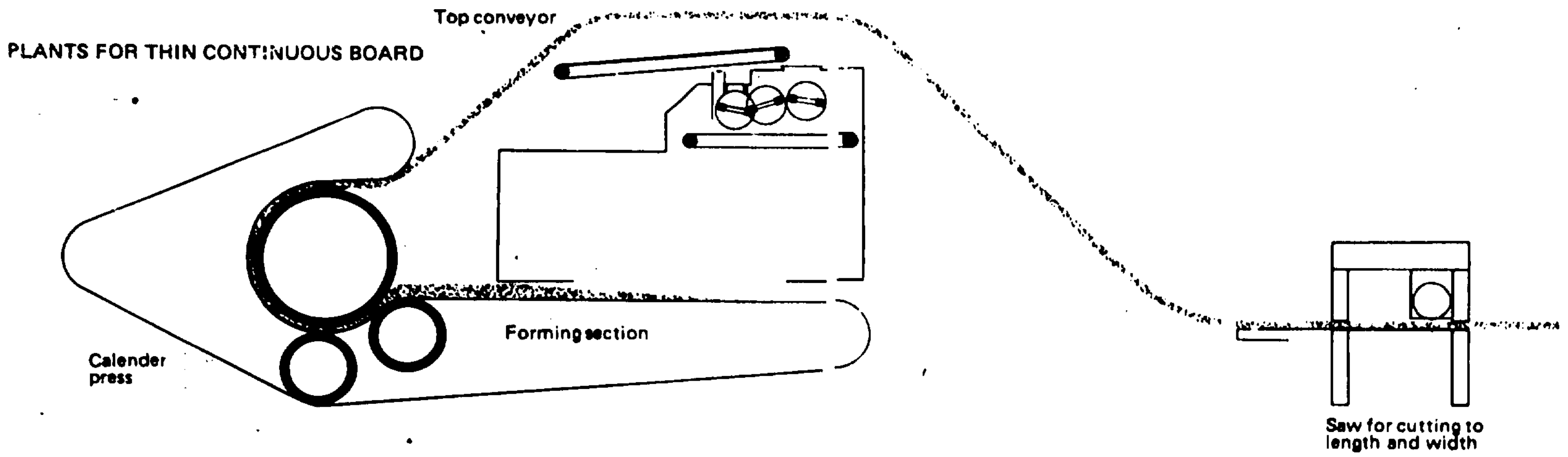


Figure 41. Continuous particle board press



within satisfactory limits (usually of the order of 0.2 mm). The forming belt then separates itself from the boards and passes over guide rollers and stretchers, returning to the forming station while the board is sent by other guide rollers to a track on which it slides forward to the finishing operation. Feed rate is adjustable and varies between 3.5 and 21 m/min, according to board thickness and characteristics of the resin mixture. Drum and pressure roll heating is by circulation of oil brought to the required temperature by a boiler situated near the plant. The temperature in each element is suitably regulated by independent controls. Drum diameter is 3,000 mm and belt width allows production of boards of 2,500 mm and over. Productive capacity of a calender press for maximum width of boards is up to 150 m^3 per day.

Presses with heated platens, for the production of synthetic resin-bonded boards can be single-opening in which case they are very large (30 m long and over 2.65 m wide) and give high production rates even though they press only one panel at a time. These presses may also be multi-opening but must be equipped with automatic board loading and unloading. A sizing saw for the outfeed end is shown in figure 42. Hot platen presses with the control panel in front are shown in figure 43.

While modern technology makes it possible to build large heated platens and still ensure very accurate working, there is a tendency nowadays to prefer plants having single-opening presses. These are undoubtedly simpler and easier to operate. Multi-opening presses, in addition to requiring automatic loading and unloading, require devices for the simultaneous closing of the platens. These presses present difficult problems regarding thickness control and uniform temperature regulation of all the platens. The schematic layout of the entire mdf (medium density fibre-board) process is shown in figure 44. The platen presses are characterized by specific working pressure (which it is convenient to limit to 30 kgf/cm^2); closing speed; accurate distribution of hydraulic pressure; structural ruggedness (whether steel plate or column type); thickness of platens (which is usually not below 80 mm to ensure adequate rigidity and limit fluctuations in temperature; and devices for board thickness control.

Also of prime importance are the machining accuracy of the platen surfaces; the system and precision of holes for circulation of heating fluid (superheated water or, preferably, oil as even a few degrees centigrade difference from one point to another on the platens can cause irregularity of thickness and technological characteristics of boards); heat insulation between platens and the press structure to avoid all heat transmission which would cause expansion and distortion.

All these measures and the high platen temperature (normally over 200°C) reduce pressing time by approximately 10 s per millimetre of board thickness. The techniques restrict over-thicknesses to 0.4 mm or so. Such over-thickness is removed in the final sanding and calibration operation.

In production of cement-bonded boards, the press has the sole function of bringing the board to the required degree of compactness. Setting of the binder is obtained in a later phase in a chamber at a suitable temperature and humidity. Therefore these presses do not have heated platens and feature a very wide opening through which the boards are introduced for pressing in stacks, supported by steel sheets.

Checking and operations immediately following board pressing

In order to control all the preparatory operations in the production of synthetic resin-bonded boards there are thickness gauges and weight checking units immediately after the main press. These instruments are automatic and, besides recording production data, give immediate warning of any irregularities.

In order to avoid boards being stacked when they are still hot, which could cause breakdown and distortion due to internal stresses, the boards must be adequately cooled. The simplest and most successful system is the rotating rack in which boards are arranged radially and cool equally on both faces and during a complete rotation of the unit (figure 45). Prior to being sanded the boards are usually stored in a temporary storage area, as shown in figure 46.

Board finishing

Finishing consists mainly of squaring off (if boards are of normal size when they come off the press) or simultaneous squaring off and sawing (if boards are very large and must be reduced) and then sanding and calibration. Among the most efficient trimming saws are those on which panels move continuously and are sawn simultaneously on all four sides. Circular saw blades with inserted tungsten carbide teeth are used, thereby considerably reducing the frequency of sharpening. Transverse sawing is

Figure 42. Sizing saw for the outfeed end

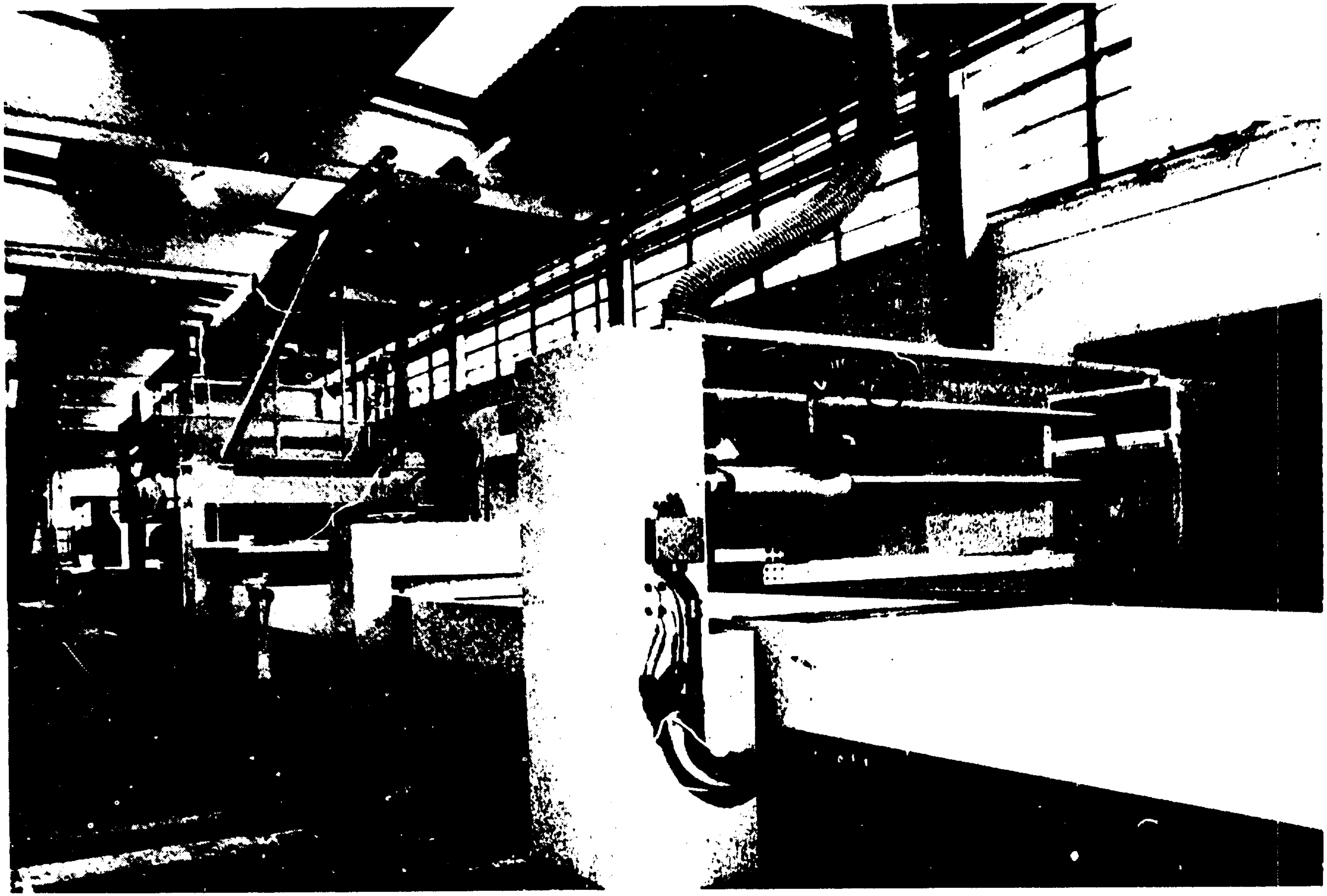
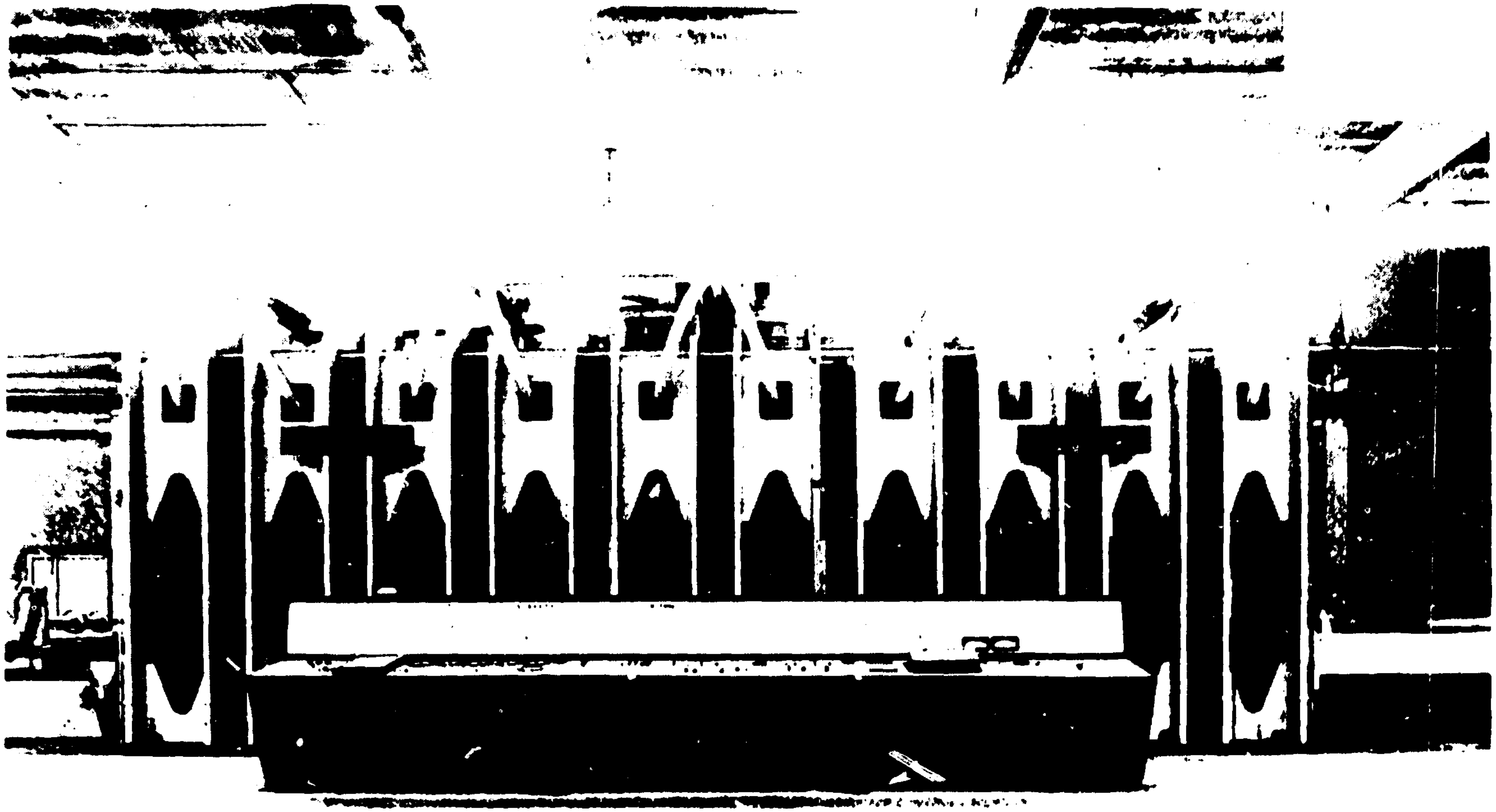


Figure 43. Hot platen presses with control panel in front



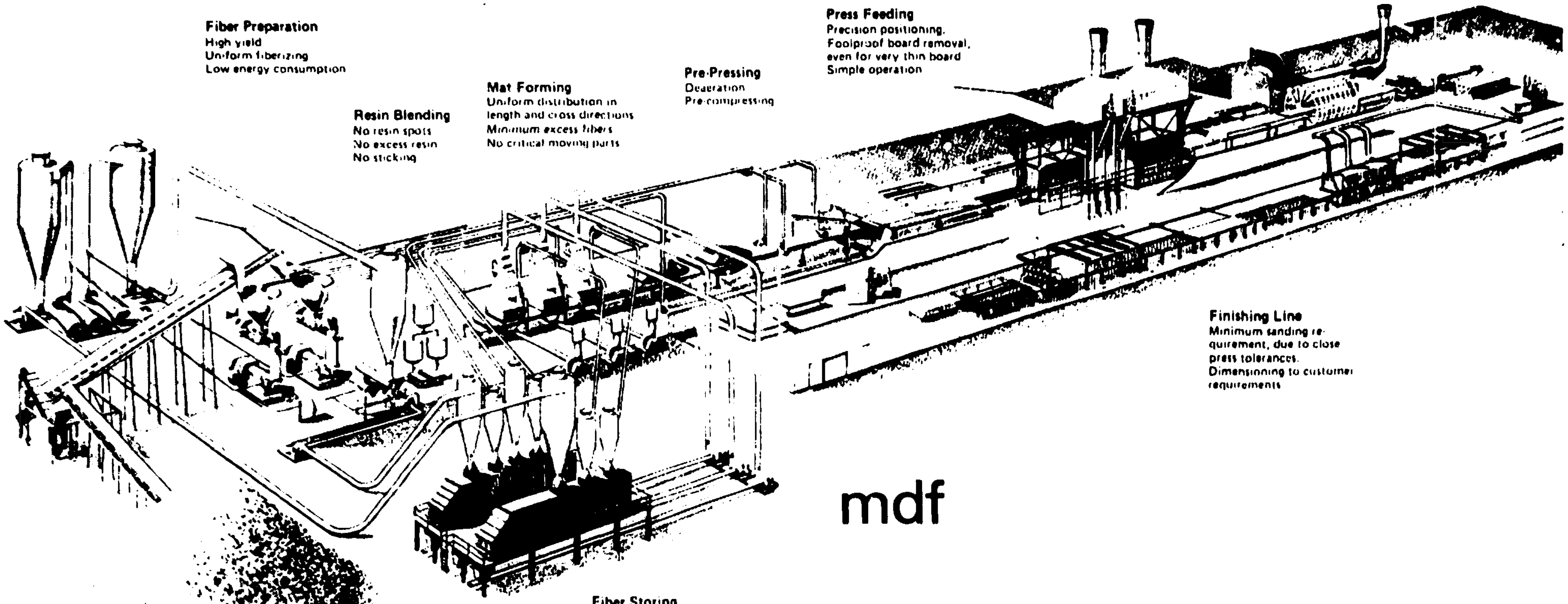


Figure 44. Schematic layout of the entire mdf (medium density fibre-board) process

Fiber Preparation
High yield
Uniform fiberizing
Low energy consumption

Resin Blending
No resin spots
No excess resin
No sticking

Mat Forming
Uniform distribution in length and cross directions
Minimum excess fibers
No critical moving parts

Pre-Pressing
Deaeration
Pre-compressing

Press Feeding
Precision positioning.
Foolproof board removal, even for very thin board
Simple operation

Pressing
Optimum utilization of temperature, press size and feeding system.

Cooling
Precise temperature control for product stability.

Trimming
Accuracy, to very low tolerances.

Finishing Line
Minimum sanding requirement, due to close press tolerances.
Dimensioning to customer requirements

Fiber Storing
Effective buffering for even feeding to the forming station

Chip Storing
Buffer stock of blended raw material chips ensures uninterrupted production

Chip Washing
Prevention of contamination, protection against wear of process equipment
Longer life for tools

Figure 45. Board cooling system with rotating conveyer

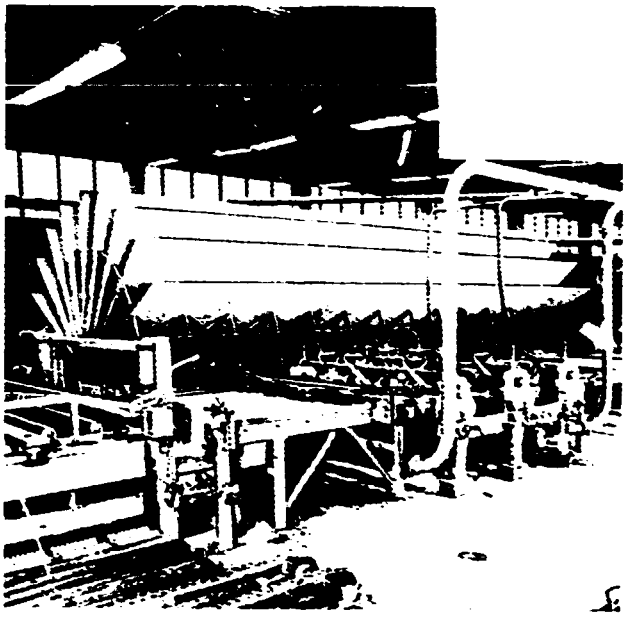
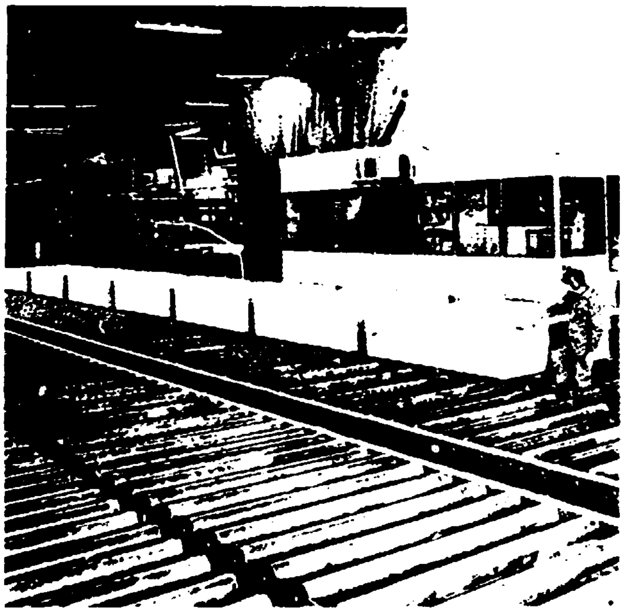


Figure 46. Board storage on roller ways prior to sanding



done by a blade mounted on a slide table which moves at an angle so that the two feeds (panel feed and table cross feed) are square with the longitudinal axis. The same principle is used for the panel saws. In the case of plants with calender presses for producing thin and medium thickness boards, the trimming saw and the transverse saw for cross cutting are located immediately after the press and all the finishing phases are carried out simultaneously. With other plants having platen presses, squaring off and any other work required such as sawing can be carried out with machines which operate, on packs of boards, thereby resulting in high production rate. Sanding is indispensable if surfaces are to undergo further operations and if boards are to have uniform thicknesses within prescribed tolerances.

Sanding machines which are now generally used for particle boards are the so-called wide belt "contact type" that operate at high speed and give excellent results. Other types of machines and, in particular, the bobbin type, are being removed from service. Sanding machines are shown in figures 47 and 48.

Figure 47. Top and bottom wide belt sander

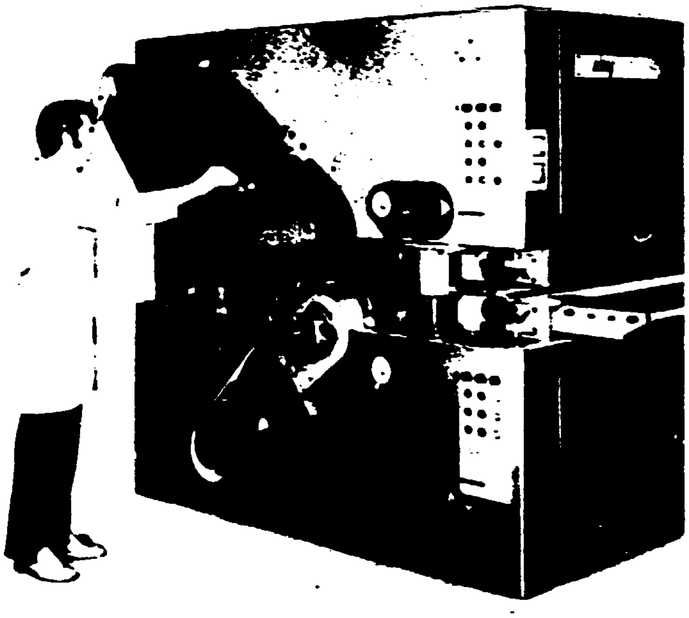
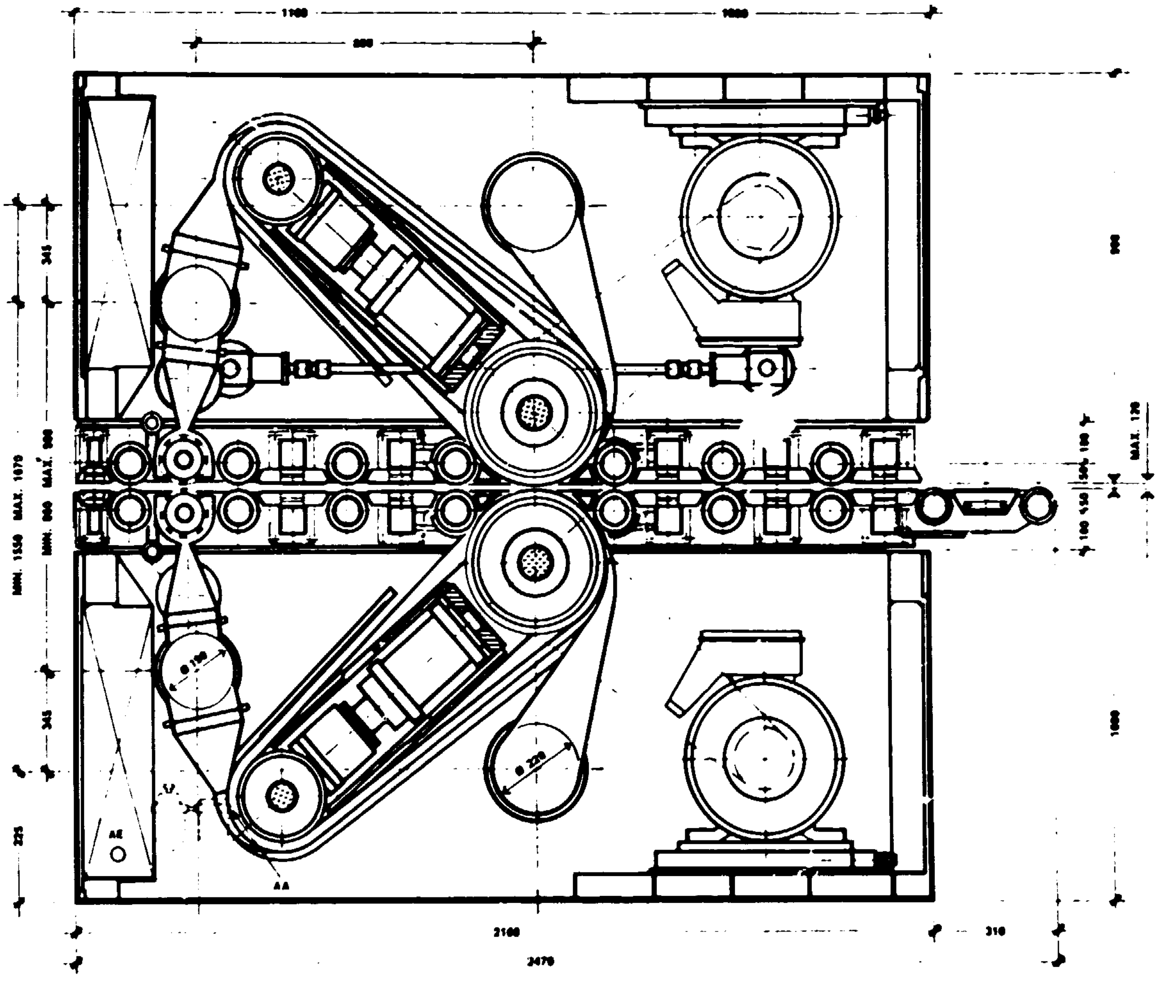


Figure 48. Cross-sectional drawing of a wide belt sander



On the "contact type" machine the flexible abrasive element consists of an endless belt mounted on a pair of cylinders, one of which (motor driven) is in contact with the panel while the other acts as a stretcher. The devices are arranged in opposed pairs so that both faces of a panel can be finished simultaneously and two or three pairs operate in succession. The first pair, having coarse grain abrasive, is used for calibrating while successive pairs have fine grain abrasives for sanding.

As already stated, working speed is high and, with thin panels requiring limited stock removal, it can reach 30 m/min. Each cylinder is driven by a motor of approximately 30 kW power.

Technical data on various plants and special types of particle board: considerations of their characteristics

To complete this chapter an indication is given below of technical data on plants with calender presses for continuous production of particle boards (synthetic resin bonded) as well as on plants for cement-bonded boards.

Plants for continuous production of thin particle boards

Thin boards are those with thicknesses between 2.5 and 7 mm. Normal plants are able to produce boards from 1,300 to 2,500 mm wide. Daily production, all other conditions being equal, is proportional to length, and the output corresponding to the above two thicknesses is respectively 8 m^3 and 150 m^3.

Both energy consumption and labour required per unit produced diminish with increasing plant production capacity:

Electric energy requirements vary from 205 kWh/m^3 in small plants to 150 kWh/m^3 in larger plants;
Heat requirements vary from 600 Mcal/m^3 to 800 Mcal/m^3 (2,510 to 3,350 mJ/m^3);
Labour requirements vary from 2.9 to 1.5 working hours per cubic metre.

The following are independent of plant capacity:

Fuel (heavy oil), around 90 kg/m^3;
Cooling water, 4.5 m^3 per cubic metre;
Compressed air (intake volume), 25-30 m^3 per cubic metre.

To ensure adequate elastic-mechanical characteristics of the boards the synthetic resin binder content must be kept a little higher than that required with conventional plants using platen presses. With urea formaldehyde resins the percentage of the hardener and of the paraffin added to give a certain amount of water repellence is 12 per cent of the dry weight. The following mechanical characteristics are typical:

Panel density is at least 700 kg/m^3 depending on the thickness;
Bending strength varies from 220 to 240 kgf/cm^2 for 2.5 mm thickness up to 280 to 300 kg/cm^2 for 7 mm thickness;
Tensile strength perpendicular to panel faces (transverse) is nearly independent of thickness and is between 6 and 8 kgf/cm^2;
Swelling after soaking in water averages 6 per cent after 2 hours and 15 per cent after 24 hours;
With a plant accurately set up, thickness tolerance from the press can be kept within 0.2 mm.

Major applications for thin boards are for making flush doors, as a base for veneers or plastic coatings; for furniture manufacture, such as back panels and drawer bottoms; for particle board manufacture, as a coating layer instead of ply; and for the packing industry.

Production of thin particle boards is increasing throughout the world at a greater rate than that of thicker types. However, they are not without their disadvantages and those about to build a new plant must concentrate their efforts on limiting these disadvantages. The most common disadvantages are:

(a) A certain tendency to bulge, which depends on the conditions under which they are pressed by the calender system. The effect of bulging may be negligible if the panels are used for small elements but may cause problems with larger sizes;

(b) Fragility due to limited flexibility;

(c) Irregularity of surface absorption when painted, varnished or glued, due to resin distribution not being homogeneous.

There is an increased demand for higher quality boards and these panels are being increasingly used with surface finishes of hard plastic materials or of very thin laminates. It is generally considered that a more careful study of particle size and shape, binders, constructional details of glue spreaders, could lead to considerable improvements.

Plant for the production of high-density cement-bonded boards

High-density cement-bonded board thicknesses are normally from 6 to 40 mm and the most common sizes are 125 × 280 cm, 125 × 320 cm or 183 × 360 cm. These correspond to modules used in building.

On the basis of a 21-hour day of three 7-hour shifts, plant productive capacity is from 50 to 200 m^3/d. Weight is proportional to thickness and density can reach 1,400 kg m^3 for small sizes and drop to 1,100 kg/m^3 for very thick types. Production technology is in the process of development to reduce these values considerably and, at the same time, improve heat insulation. The type of cement commonly used is that defined in German specifications as type PZ450 (Pozzolanic Cement with a crushing strength of 450 kgf/m^2 after 7 days) but it is likely that, in the near future, special cements will be produced having better bonding and more rapid setting properties.

Approximate energy requirements per unit of production are:

Electrical energy, 190-200 kWh/m^3
Heat energy, 380-390 Mcal/m^3 (1,590-1,630 MJ/m^3)

Labour requirements, as is to be expected, decrease with increased productive capacity and may be as low as 4 working hours per m^3 produced.

Raw material requirements are approximately:

Wood, 280 kg/m^3 (dry)
Cement, 770 kg/m^3
Chemical additives (for particle treatment), 50 kg/m^3
Water, 500 l/m^3

Bending strength, depending on thickness and weight, is between 120 and 180 kg/cm^2; compression strength approximately 150 kgf/cm^2 and tensile strength, perpendicular to panel faces, from 6 to 9 kg/cm^2. These values are of the same order as those for synthetic resin-bonded panels. It is interesting that swelling due to soaking in water is very little. Swelling ranges from 0.2 per cent to 0.6 per cent after 2 hours and from 0.6 per cent to 1.2 per cent after 24 hours. Heat conductivity is 0.155 kcal. $\cdot$ m^{-1} $\cdot$ h^{-1} $\cdot$ $°C^{-1}$ (180 mW $\cdot$ m^{-1} $\cdot$ $°C^{-1}$). Nail and screw holding (18 mm penetration) is respectively 50 and 140 kg (nail diameter 2.5 mm, screw diameter 3.5 mm). Weatherproofing is excellent (even for freezing conditions), as is fire resistance. The panels are impervious to biological degradation. These features make the panels particularly suitable for building application. Surfaces are smooth and compact and ideal for all types of finish, whether water based paints, varnish or any other kind of coating material. Due to heterogeneous structure and fairly high weight, sound-deadening properties are satisfactory. Sound absorption, for 12 mm panels, is 32 dB. Permeability to air at a pressure difference of 1.33 mbar is 1.32 ltr $\cdot$ min^{-1} $\cdot$ m^{-2}.

Main applications are for built-in shuttering, false ceilings, all types of floor foundation, cellar doors or wherever panels are exposed to high humidity, rural buildings, roadside billboards etc.

XII. Criteria for the selection of machinery for sliced veneer*

The word "veneer" is used herein to denote thin sheets of high quality woods, having thicknesses varying from a few tenths of to more than one millimetre, which are normally produced by slicing and sometimes by peeling logs. A typical use of veneers is for decorative facing or panelling.

Production methods

Logs used for the production of high quality veneer must be carefully selected because the commercial value of the finished product is dependent on the quality of the wood used. The initial production phases consist of debarking and log conversion into flitches, usually two or four flitches. This phase calls for considerable experience, and is very important because the slicing operation affects the yield. Logs are normally steamed or subjected to hydrothermic treatment. This process is always used for dense or semi-dense veneer logs, which are used for the majority of veneers. Various slicing methods are used. The choice is made according to the species of wood involved or marked requirements. Straight grained or figured veneers can be obtained, depending on how the log is sliced. The sliced sheets are then dried and put into storage after undergoing a few supplementary operations.

Layout considerations

Figure 1 shows a simple and logical layout for a slicing plant. To organize production on an efficient and economic basis it is quite important, among other considerations, to make a correct and careful choice of machines. However, these important considerations may be forgotten if too much attention is paid to the choice of machines. The following must be considered carefully:

(a) Efficient flow of material (from raw material to finished product), ideally represented by a one-way line without bottle-necks. This can be obtained by careful factory layout and co-ordination of the various production phases. This is a relatively simple matter when a new plant is involved. Material flow must be taken into consideration when plants are being re-built and new machines are purchased. This is true even if layout is to some extent determined by existing installations;

(b) Efficient internal and external handling. Care should also be taken in the selection of the correct location of lifting gear. The apparatus should also be adequate with respect to capacity and speeds;

(c) Plant and services should be efficiently designed from the point of view of operational reliability of production machines;

(d) Maintenance, both routine and preventive, to eliminate down time and damage to machines as well as to ensure greater safety for operators, must be properly planned and executed.

While these conditions may seem obvious they are often disregarded, either because their importance is underestimated or because of a false sense of economy.

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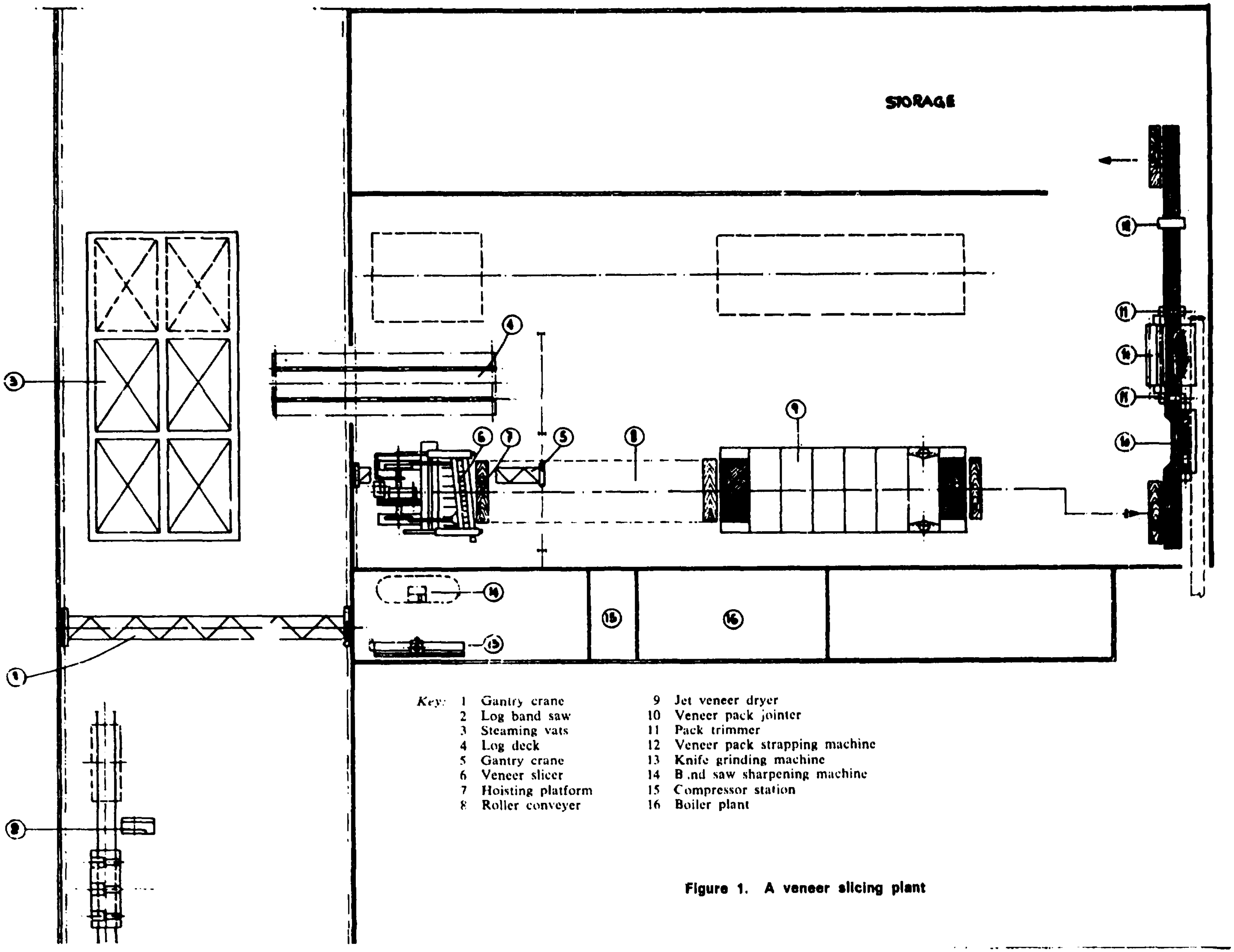
* By A. Colombo, consultant in veneer and plywood production. (This is an edited version of ID/WG.277/12.)



Key:
1 Gantry crane
2 Log band saw
3 Steaming vats
4 Log deck
5 Gantry crane
6 Veneer slicer
7 Hoisting platform
8 Roller conveyer
9 Jet veneer dryer
10 Veneer pack jointer
11 Pack trimmer
12 Veneer pack strapping machine
13 Knife grinding machine
14 Band saw sharpening machine
15 Compressor station
16 Boiler plant

Figure 1. A veneer slicing plant

Operation sequence

Log cutting to length

The first production operation consists of sectioning the logs to the required length. Due to the considerable variation in the dimensions of the logs, a fixed length installation is not easy to use (as it is in plywood factories). The best solution is to use electric portable carriage-mounted chain sawing machines. This simple solution is advisable because of the relatively low frequency of occurrence of this operation with respect to the rest of the production cycle (in plywood factories the frequency of occurrence is higher).

Log debarking[1]

The operation immediately following is debarking. The conventional method of debarking logs is to use portable electric equipment, or semi-fixed installations, but these methods are inefficient. Milling head machines with high speed rotary cutters are much more suitable for debarking operations. There are two versions of this type of debarker. The most common is that in which the log is rotated by a set of discs mounted on parallel shafts. The cutter, under pneumatic pressure, follows the surface of the log and removes the bark. This is shown in figure 2. The most suitable debarker for veneer factories, however, bearing in mind that log conformation is often irregular, is the spindle type. The mill operates in the same manner as described above but the rotation system of the log is different. The log is chucked between two hydraulic spindles, as on a peeling lathe. Chucking of the log is quite safe and no trouble is caused by the irregularities during the debarking. It is therefore evident that any axial or sectional irregularities in the log are of minor importance. This type of debarking machine is shown in figure 3.

Log breakdown

The logs are sectioned into slicing flitches on a log band-saw with a carriage. This is a standard machine, which has to be rigid because of the considerable bulk and weight of the logs. Mechanized loading systems convey the logs to the carriage. These systems reduce down time.

The log band-saw should be equipped with remote controls to facilitate lumber sawing operations. It is sometimes worthwhile to use the machine's idle time to produce boards from low grade logs not suitable for veneer production. Complementary equipment in the log sawing department includes a circular saw for cutting logs into three parts. The log is placed longitudinally on a mobile carriage and can be cut radially at three stages as required thus obtaining flitches with large sections, even from small logs.

Steaming

For easier slicing and to avoid sheets with rough surfaces it is necessary to soften the flitches. This operation is normally done by steaming in proper vats, or boiling in hot water. The vats are made of masonry and are provided with covers to avoid heat loss. The steaming can be direct or indirect. Direct heating is usually done by using saturated steam in the vat where the logs are placed. For indirect heating the vat usually has coils located at its bottom and is heated by means of steam or superheated water. These coils give heat to the water and generate the necessary steam for the treatment of flitches.

Heating done by immersion in boiling water is generally used only when resins or other substances must be eluted.

The temperature of hydrothermic treatment is normally between 80° and 90°C in order not to damage

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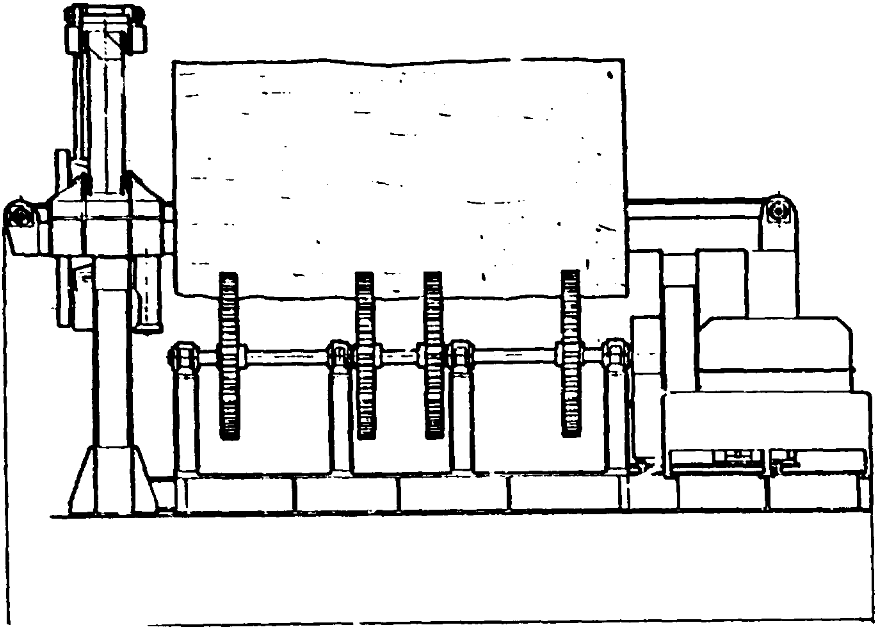
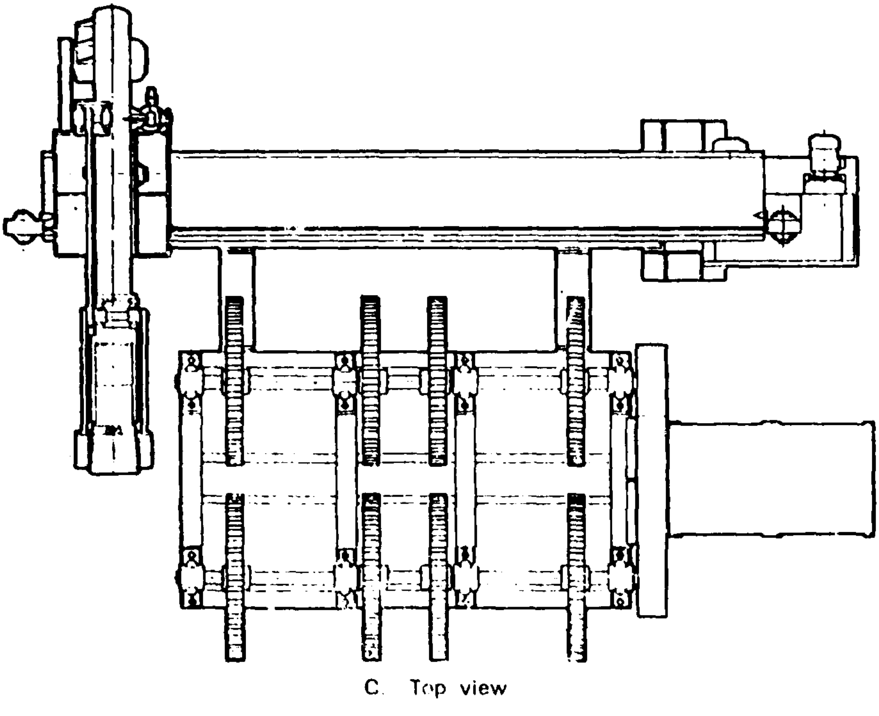
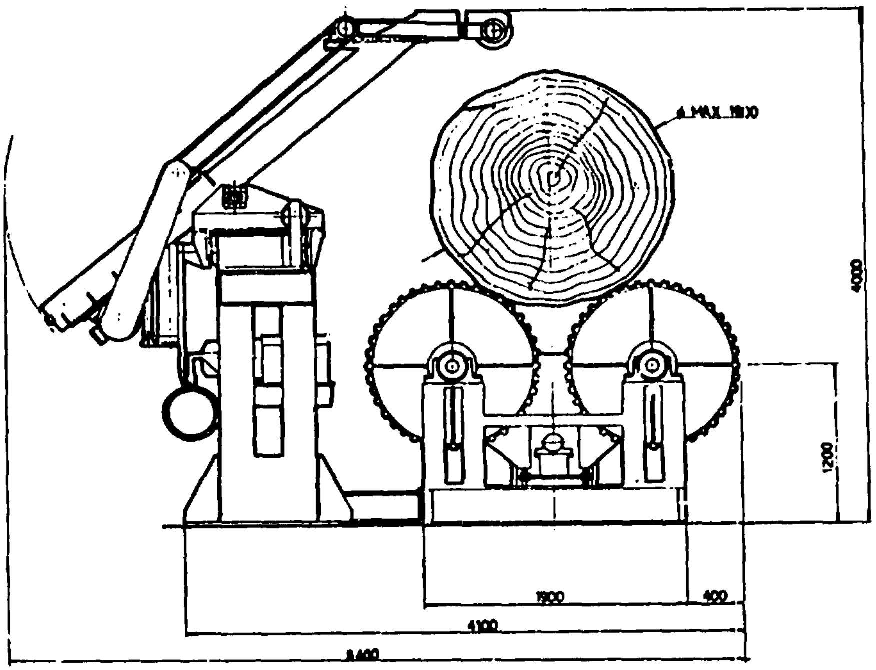
[1] or additional details on log debarking see chapter VII.



A. Front view

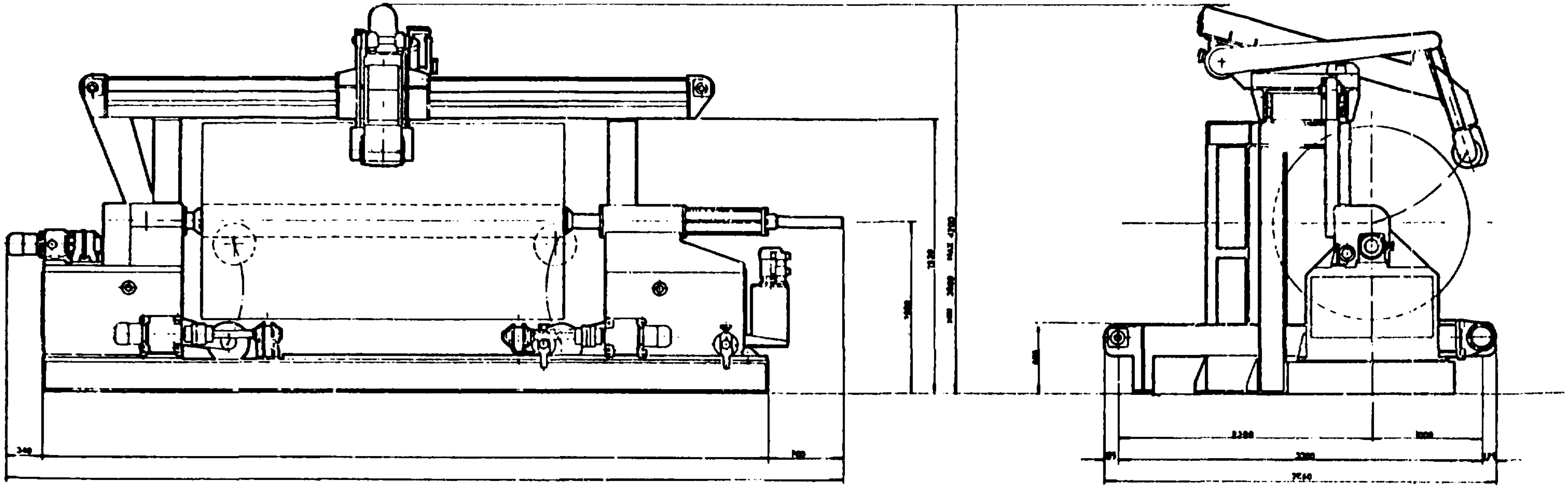


C. Top view



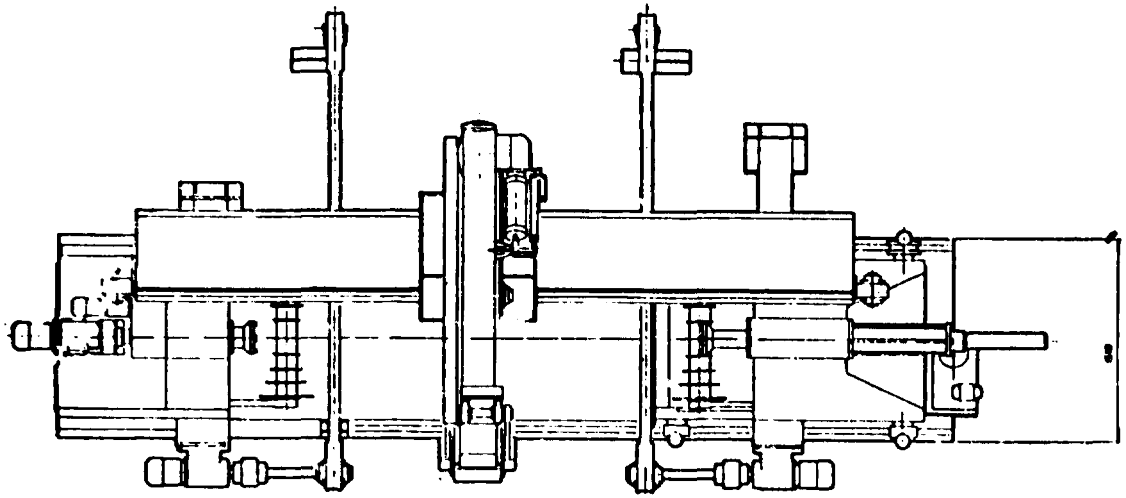
B. Side view

Figure 2. Debarking machine. The log is rotated by a set of discs mounted on parallel shafts



A. Front view

B Side view



C. Top view

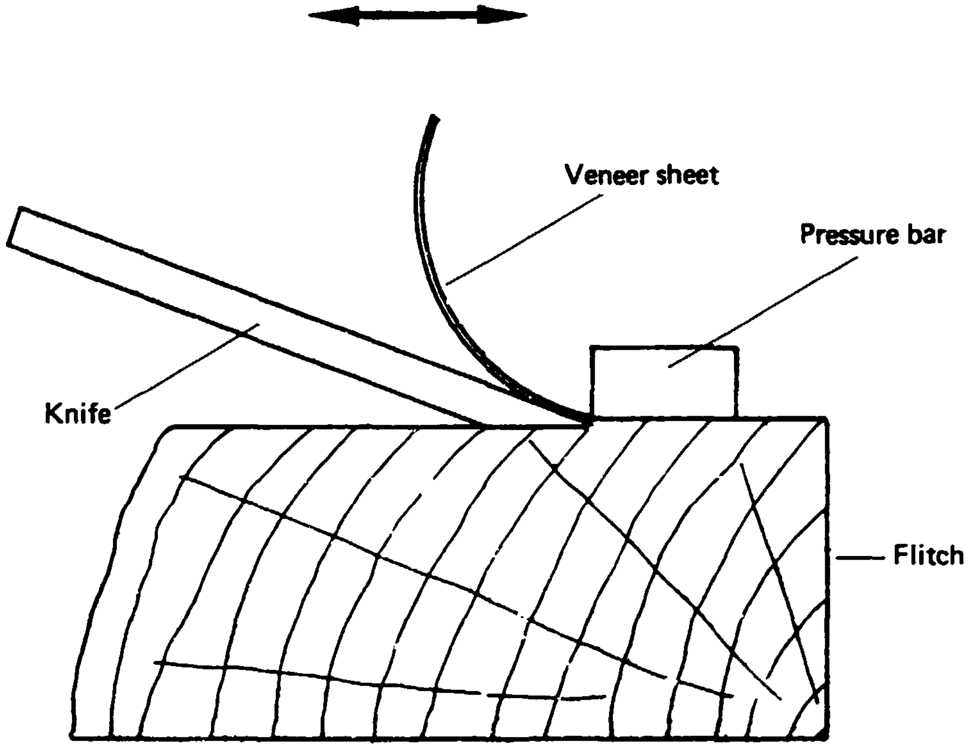
Figure 3. Debarking machine. The log is chucked between two spindles on a peeling lathe

mechanical properties of the wood. The time of this treatment is important and varies depending on species and diameter of the log from 10 to 80 hours. Data and suitable tables are used to choose the exact treatment times. Of equal importance is the efficient design of loading and unloading systems which should incorporate suitable log grips mounted on a gantry crane travelling along the vats.

Slicing[2]

The most important operation of the veneer production is the slicing operation. Conversion of flitches into thin sheets is achieved as shown schematically in figure 4. Specifications for a slicer are shown in figure 5. The slicing unit consists of a well-sharpened knife and a pressure bar. The knife penetrates the wood. Thin sheets are sliced by the action of the slicing unit on the wood. While the function of the blade is obvious, the purpose of the pressure bar is to avoid splitting of the sheets. Splitting would occur if the blade operated without the bar. Many different models of veneer slicers are on the market, but they all operate by having the slicing unit and log move relative to each other with feed equal to slicing thickness at each feed and return stroke.

Figure 4. Horizontal slicing



Various configurations have been developed around this basic slicing principle. These include: log in fixed position and knife moving or vice versa; horizontal or vertical motion; and the knife placed above or below the flitch. The configurations are not dictated by the requirements of slicing, but attempt to solve collateral problems such as loading the flitches and unloading the sheets. Among the configurations tried, two have emerged in practice: horizontal slicing and vertical slicing.

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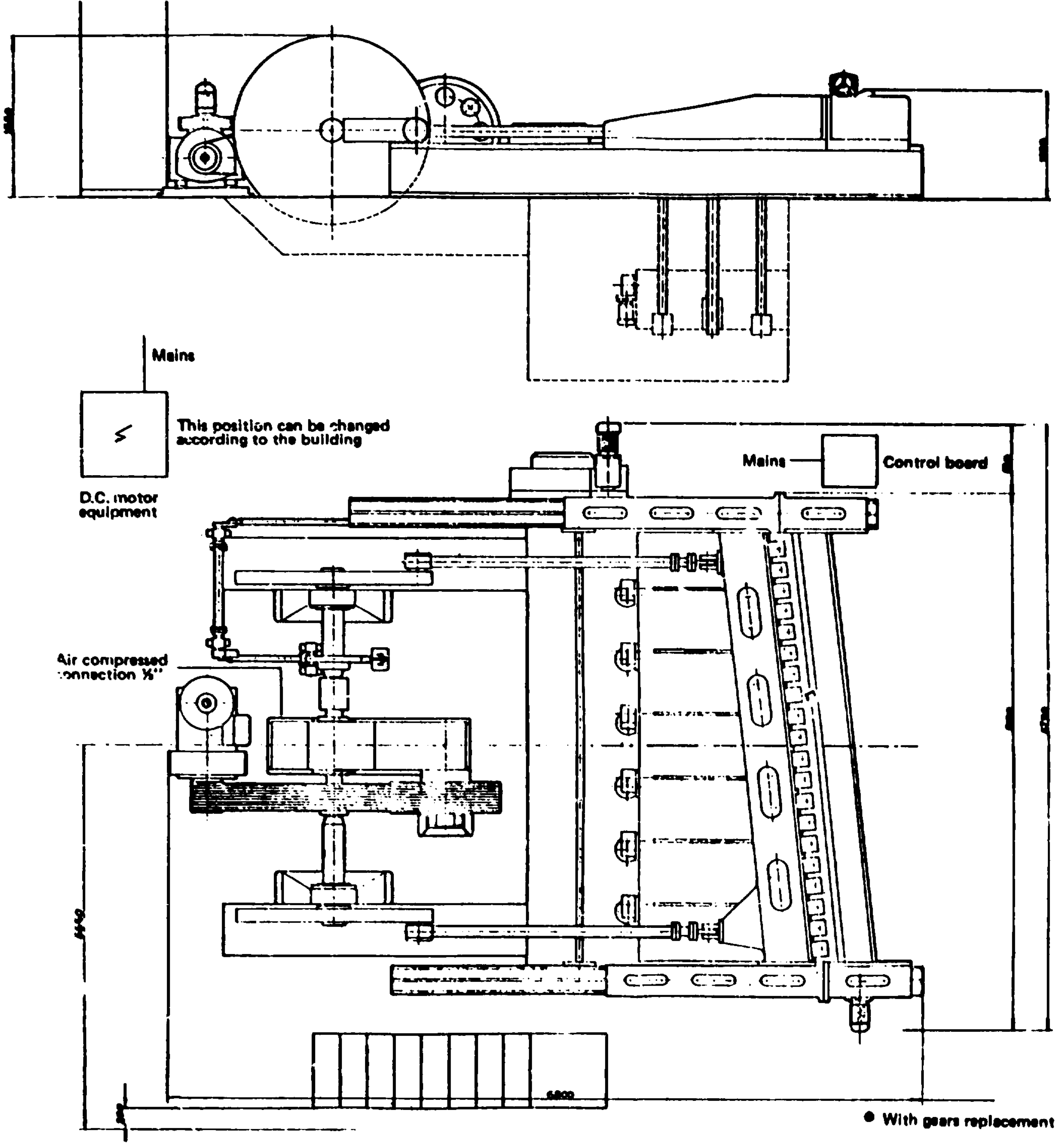
[2] For additional details on veneer slicing equipment see chapter XIII.



Volume	m³	50
Gross weight	kg	35 000
Net weight	kg	31 000
Total power of auxiliary motors	HP	11.5
Power of main motor	HP	80
Maximum height	mm	12.00
Maximum log width	mm	800 (1 100●
Maximum log height	mm	4 000

● With gears replacement

Figure 5. Specifications of a veneer slicer

Horizontal slicing machines

This is the standard machine and is the most widely used and versatile. The flitch is firmly fixed to the bed and rests against the apron of the machine, ensuring safe working and accurate cutting.

Loading the flitches is very simple and inspection of the flitch and cleaning of the machine are easily carried out. The bed is fixed to four threaded spindles for rapid position adjustment. The intermittent motion separates the sheets. The slicing unit (figure 6) moves in the opposite direction. A crank mechanism is one possible mechanism used to actuate horizontal slicers. It is simple and can attain very high working speeds, impossible by other techniques. To simplify the veneer sheet transport, an exit belt conveyer transports the sheet away from the machine. Important factors for smooth and accurate slicing are:

(a) The slicing unit must be at a proper angle with respect to the flitch to ensure smooth cutting without cracking;

(b) The slicing unit must be very rigid. Rigidity is obtained by suitable design of the pressure bar and knife holder carriage. These must be very heavy and the knife must be rigidly fixed.

The rigidity of the blade is very important because a strong carriage is useless unless the blade is also rigidly fixed. Generally, the knife is fixed to its support from above. The knife bar has adjusting screws and knife cap bolts. As the knife is practically free between the two cap bolts, the cutting force causes the knife to flex. The knife support surface is placed on top of the knife, in order to assure a continuous and very rigid support, which is not distorted by reaction forces. Figure 7 shows the assembly of the knife blade.

Automatic bolting and releasing of the knife and nosebar on the pressure bar for assembly and cleaning, substitution of all manual operations by motorized movements, have made horizontal slicers much easier to operate. They are also highly productive, assuming the features of rigidity, versatility and precision are incorporated in the design.

A recent development of horizontal slicers is the mounting of a second set of flitch dogs (front and rear side). Dogging is therefore possible between front and rear dogs, in addition to the standard dogging against the front part of the slicers. This allows choosing of the best inclined position of the flitches which is sometimes necessary for best slicing operations. It is also possible to find the best incident angle between knife and flitch. Any friction between flitch and front of the slicer has to be avoided to ensure the best accuracy of the slicing thickness.

Mechanical guards and photo-electric safety devices, nowadays used for horizontal slicing machines, are a safety feature.

Vertical slicing machines

With these machines the flitch reciprocates vertically and the slicing unit is stationary. An intermittent movement for the division of the sheet is given to the flitch. A vertical machine is shown in figure 8. Compared with the horizontal machine there are a few advantages and disadvantages.

The advantage is in the higher slicing speed. However, this advantage pertains only to flitches which are "easy to work", and not too dense.

The disadvantages are:

(a) The machine is less versatile, only suitable for flitches smaller than those workable on the horizontal slicer;

(b) The flitch fixing system is less rigid and secure;

(c) Flitch loading and veneer unloading is more difficult and more dangerous for the operator;

(d) Flitch cleaning and checking is slower due to the need to withdraw the knife carriage;

(e) Three operators are needed instead of two (one for the machine and two for handling the veneer).

Figure 6. A horizontal slicer

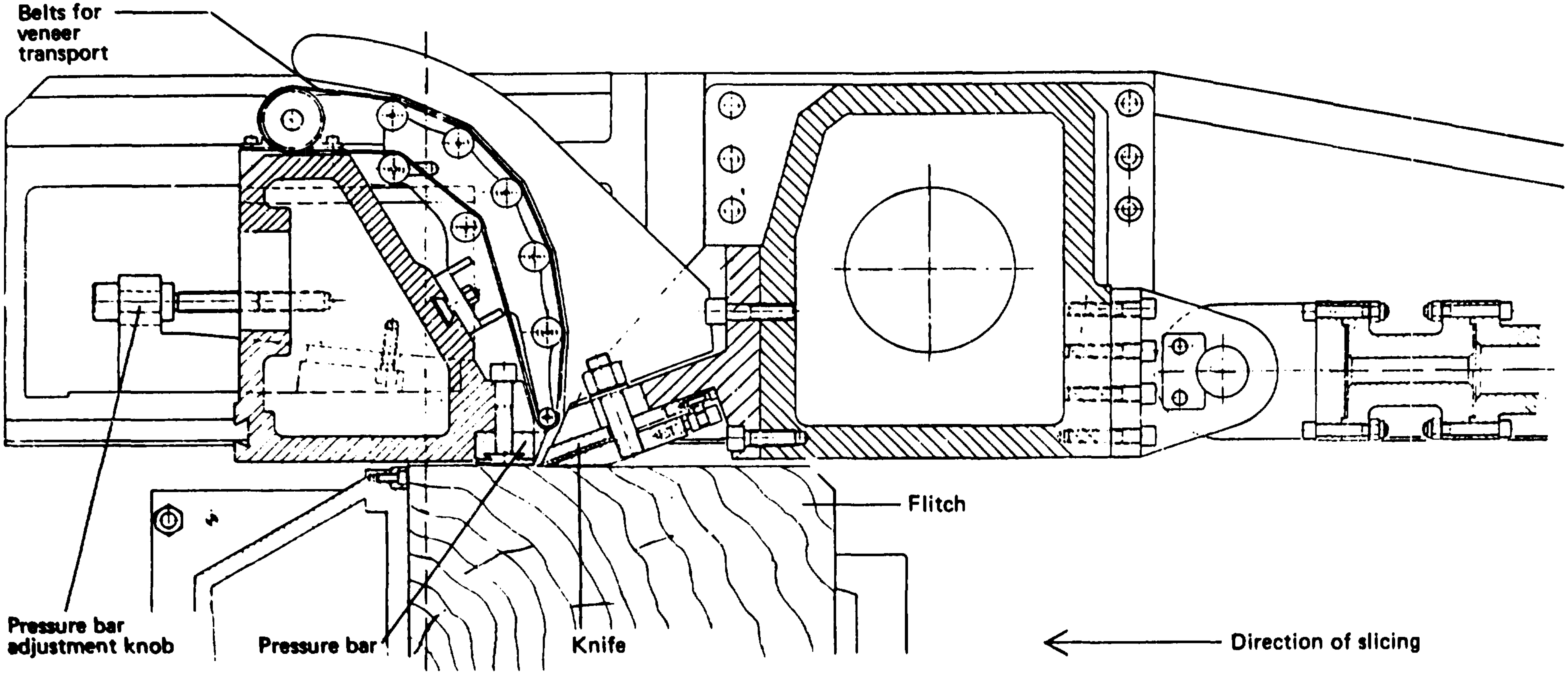
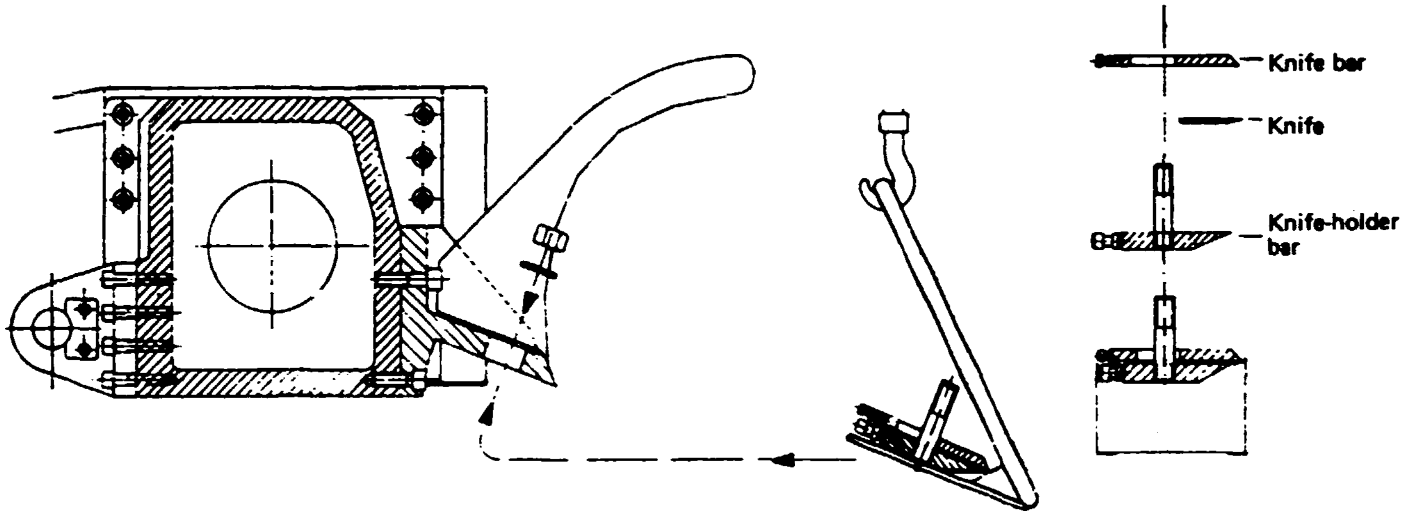
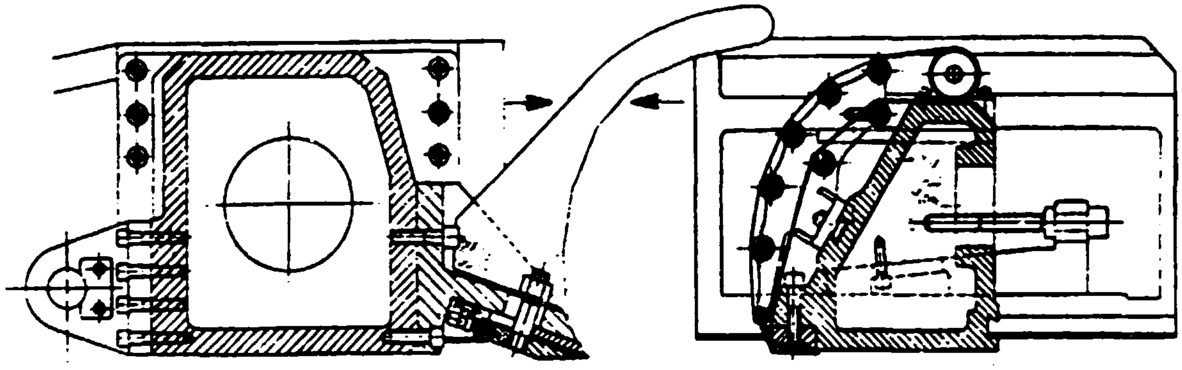


Figure 7. Procedure for knife assembly for a horizontal slicer

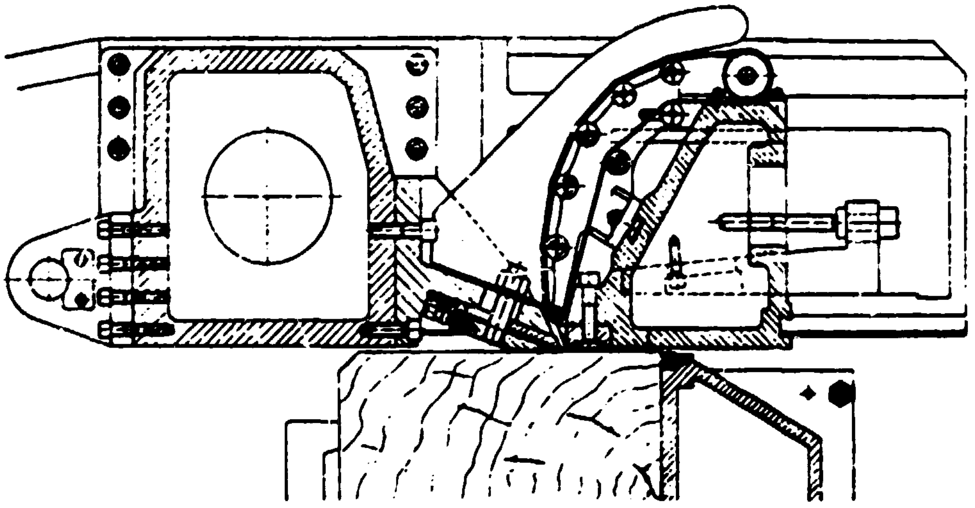


A. Assembling knife bar unit to nosebar

B. Knife bar assembly

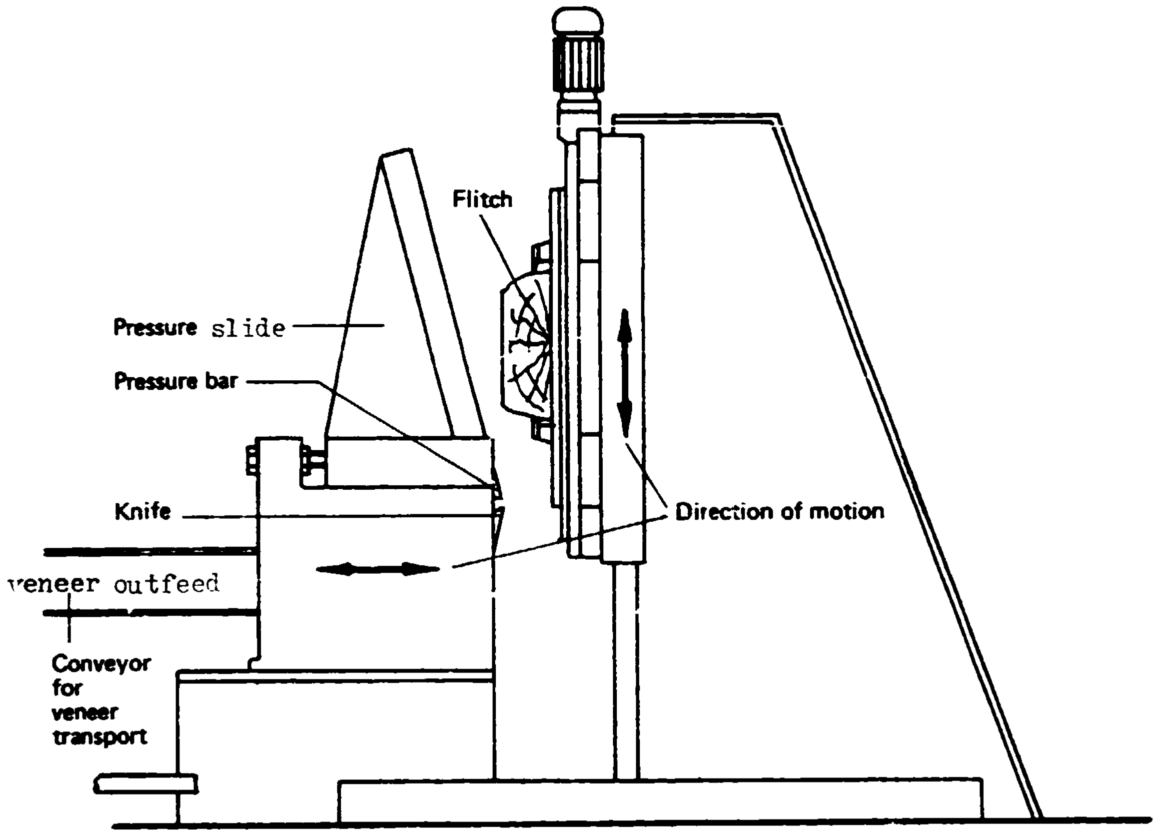


C. Adjustment of knife holder carriage



D. Complete assembly

Figure 8. Vertical slicer



Automatic handling of veneers

Various systems have been developed, to automate handling from the slicer to the veneer dryer, to eliminate labourers.

These interesting links in production lines do, however, have certain limitations in use and must therefore be considered carefully. In fact, satisfactory results are possible only with a few first grade species, those without star shakes and little tendency to curl. Unfortunately these characteristics are rare with veneers. It is usual that different species must be sliced on the same machine. The veneer slicer can sometimes be found limited in its capacity by the limited capacity of the dryer and vice versa the dryer can run idle during loading and unloading of the slicing machine, during cleaning of the flitch or when turning the flitch, or during down times.

Some wood species require intermediate storage in order to bring out the final natural colouring before drying. Automated production lines therefore cannot be recommended in cases involving the slicing of many different wood species having considerable variation in quality or when the problem of reducing labour is not of prime importance. An automated line is therefore advisable only as an auxiliary line to another line on which many standard slicers ensure basic output with any wood species. Preselected and prepared flitches may be sent to the automated line.

Veneer dryers

Sliced veneers have a high moisture content which must be lowered by a drying process. For this the standard operation is to use dryers with wire mesh conveyers to ensure safe, efficient veneer transport, and to ensure good spreading to avoid curling. With regard to the application of hot air, the best system, because of its high efficiency and good circulation, is the jet system. Air heating is usually accomplished by steam or superheated water. A more modern system, which has many advantages, uses oil as a heating fluid. With this system it is possible to reach much higher temperatures, allowing the use of smaller dryers with the concomitant advantages of economy and space. Furthermore, the circuit is not pressurized, is less dangerous and does not require highly trained operators. The dryers have two or three decks but some are equipped with endless "S" shaped conveying systems, resulting in a more compact dryer due to reduction in overall size.

The choice of the dryer must take into account overall dimensions, as well as space for loading and unloading units. Automatic unloading systems are available nowadays and are strongly recommended. They permit automatic stacking with a preselected number of sheets. This is easier and economic when there is only one unloading point. The systems generally consist of vacuum operated sheet pick up and transport systems with mechanical devices for separation and stacking.

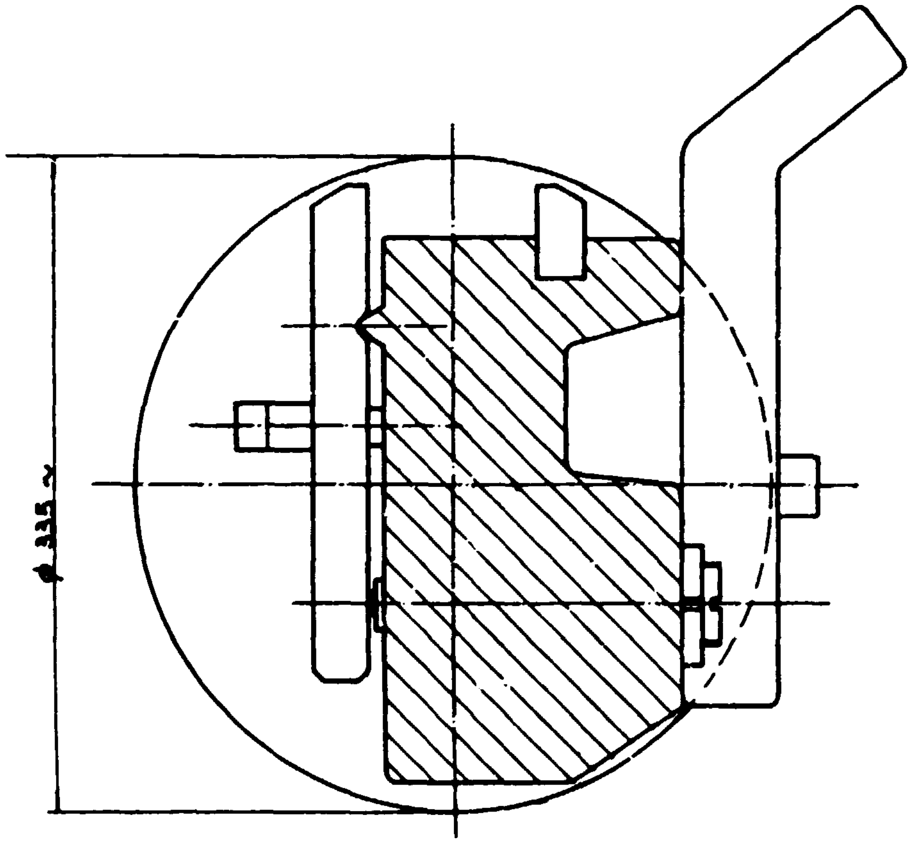
Veneer pack jointing and trimming machines

After drying, the veneer packs are jointed and trimmed. The ideal arrangement of these machines is that of two veneer pack jointers linked with two end trimmers in line. In cases where production rate is not high, the line can be equipped with two jointers and only one trimmer. The line can continue with the binding machine for automatic strapping of the packs. Machines have recently been installed for automatic measurement of the surface of veneers on a continuous basis in order to label, record and supply storage data for each pack. It is even possible to introduce a programmed stores management.

Eccentric peeling

Eccentric peeling is related to slicing. It is done by peeling logs chucked eccentrically between the machine spindles. Of increasing importance is the stay-log attachment shown in figure 9. This is

Figure 9. A peeling lathe for eccentric peeling (end view)



essentially a rod rotating between the spindles and on which the flitch is fixed. The stay-log is equipped with a pneumatic or preferably a hydraulic collet (for greater chucking pressure) which grips a log which has been appropriately cut at both ends. The results of these operations are equivalent to slicing but allow production of larger veneer sheets for the same log size. A number of advantages are connected with this process. It is possible to achieve increased production due to the ease and rapidity of loading, the high working speed, and lower labour requirements. Due to the high stresses involved with eccentric peeling, the machine must be very rigid in design and equipped to take into account the considerable imbalance of the system.

XIII. Production lines for plywood and veneer*

Almost a century has gone by since modern plywood panels were first manufactured in 1884. Industrial production of plywood began around 1910 and it became an important product during the following decades. In the last twenty years world plywood production has almost tripled and in Japan it has increased by 800 per cent.

The forecasting of future developments is of prime interest to managers and business men. FAO experts estimate that in the year 2000 world plywood requirements will be twice that of today's production. Increases in requirements will stimulate progress in woodworking technology. This is a constant process which has accelerated noticeably during the last ten years. For years now scientific laboratories, wood research centres, industrial plant, wood engineers etc. have been conducting research and experiments on the exploitation of forest resources. The building industry has been using more and more plywood in recent years, even though the traditional building industry has been going through a slack period. This is true both in Europe and in the United States of America and everybody knows why: building costs have become "impossible".

This is why prefabricated buildings which use a large quantity of plywood are becoming common in the suburbs of the big cities in the United States. Prefabrication is a good method of building homes which suit people's incomes. In the Union of Soviet Socialist Republics dozens of small towns made from fireproofed wood are being built along the second Transiberian railway.

In central Europe the use of wood in modern buildings is increasing. Today many prefabricated houses are made of plywood. These buildings are very elegant, well designed, comfortable and ecologically sound. This is because today's technology can solve all the problems involved in the use of wood and complementary materials in building.

In the traditional building industry, wood is generally used for making forms for concrete and reinforced concrete. Sawn boards may be reused three or four times at the most whereas the right type of plywood panels may be reused 10 to 15 times. These panels are manufactured in standard or modular dimensions and they make it possible to save much time, material and skilled labour. Their advantages include the adaptability to any type of construction, the stability of the structures, easy transport and assembly as well as a nice and smooth look of the concrete surface obtained by using them.

The use of plywood packaging is growing. There are other reasons besides mechanical resistance for using plywood fc wooden packaging. The large surfaces eliminate cracks, they are lighter, and making plywood packages involves less work than the traditional method of making packages by nailing a number of boards and cross pieces together. In recent years, plywood packaging has also been used as an advertising medium. Designs and lettering in eye-catching colours can be used. In the furniture and interior decorating industry, international exhibitions held in recent years show that plywood panels are increasingly being used in place of plastics or metal. Plywood has become more important for indoor use in the building industry (doors, door frames and wall coverings), in manufacturing technical and sports goods, in boat building and so on.

In the future, traditional products will be replaced by new ones and the plywood sector will be influenced by manufacturing methods with constantly evolving technologies.

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* By E. Mabini, expert in plywood and sliced veneer production. (This is an edited version of ID/WG.277/14.)

Panel classification

Plywood panels may be classified according to use and type of wood as follows.

Classification by composition:

- Three layer plywood from 3 to 8 mm thick
- Plywood with more than three layers, from 8 to 40 mm thick

Classification by use:

- Normal or "interior" plywood is used when moisture resistance is not required
- "Exterior" plywood gives resistance to moisture
- "Marine" plywood resists all atmospheric agents, immersion in cold water (both fresh and sea water), attack by fungal agents and insects

Classification by form:

- Flat panels
- Curved, convex, corrugated or shaped panels

In our study of the criteria for selecting machines for manufacturing plywood, we will only examine the most important sector: flat plywood panels with three or more layers. The appropriate type of wood and glue are used in order to obtain either interior, exterior or marine plywood panels. Some plywood panels are veneered with face quality veneer (about 0.5 mm thick) on one or both sides. These veneers are produced on a slicer.

Preliminary considerations for plant layout

The following factors influence the criteria for selecting the machines in the various sectors of the plywood panel plant:

- Maximum and average sizes of wood species
- Overall dimensions of panels and their physical and qualitative characteristics
- Desired output
- Degree of automation; this depends on output and environmental conditions

In general, this plant can be divided into sectors, according to the step by step transformation of the raw material. Let us suppose that the raw material has already been checked and that the low grade logs are sorted out. The production process includes the following operations:

- Selecting and preparing logs
- Peeling and clipping in standard and substandard sizes
- Drying
- Splicing the smaller pieces
- Preparing the glue
- Panel forming
- Pressing
- Squaring and sanding

Selecting and preparing logs

The problem of storing and selecting logs will only be dealt with briefly because each plant has its own particular problems and it is impossible to find a general solution. The logs used in plywood manufacture must have both suitable physical characteristics and shape for peeling. Logs in bad condition or with obvious physical defects—shakes, cracks etc.—cannot be used because much material and time would be wasted during peeling. The same applies to logs with irregular (non-cylindrical) shapes. The logs which have been selected are piled in the log yard. These logs must be kept in good condition and free from cracks. The size of this log yard depends on plant size and delivery frequency. If space and water are available, the logs can be kept in a pond or vats.

Sometimes it is impossible to make the logs retain the right degree of moisture content for peeling. When log deliveries are several months apart, some of the logs may be too dry for peeling. In this case the logs are steamed or soaked in hot water in special steaming vats. This is absolutely necessary for some hardwood species: it softens the fibre structure for better peeling. The vats are made out of concrete and they are very large. They are usually rectangular, 6 m × 12 m, and more than 4 m deep. A coil which is connected to the heating plant is located at the bottom of the vat and it is covered with water. The logs are placed in these vats which are closed with special covers so the logs are surrounded by the evaporated water.

Today gantry cranes are widely used for handling logs. These cranes are more versatile and they have replaced the overhead and derrick cranes because this hoisting and transporting equipment is more efficient and safer. The logs usually have different sizes and shapes and lengths so that they must undergo some preliminary operations before they can be peeled. The first of these is cross-cutting to the proper length. The length depends on the production cycle. During this operation, the unsuitable portions of the logs are discarded. Chain saws are used for cutting the logs. These saws are usually mounted on a two-wheel carriage. Obviously saw size and blade length are chosen with regard to the maximum log diameter. If output is large, it is advisable to use cross cut stations on log conveying lines. The saw is placed between the infeed and outfeed conveyers and two independent hoists are used to bring the axis of the log horizontal and hold it in place while the saw cuts vertically. By assuming that the cut is perpendicular on the log less material is wasted. The logs which have been cut to size have to be debarked. A plant for cutting logs to size and debarking them is shown in figure 1. The debarking machine has two arms. Each arm has a spindle and the log is held between those two spindles. Different methods are used, depending on log diameter and the type of wood involved.

For logs less than 70 cm in diameter which are green or steamed and have rather thick bark, rotor debarking machines are best. These are automatic machines which consist of a sturdy frame which supports two chain conveyers (one on each side). Each conveyer is equipped with feed rollers or discs. These conveyers feed the log and centre it with respect to the rotor. The rotor is a ring rotating around its centre. Adzing tools are mounted on this ring and a spring pulls the tip of the knife towards the centre of the ring. When passing the log through the ring the tools move in cutting position and springs press them against the circumference of the log. As the ring rotates the knives touch the outside of the bark. Pressure and friction cause debarking. Scoring knives mark the log before it goes through the debarking rotor. They score the bark for easier removal. For logs 70 cm to 2 m in diameter the type of wood and the shape (including the defects) must be carefully studied. Unfortunately, this operation is usually not done very carefully even though it has a noticeable affect on total production costs. In the debarking machine, shown in figure 1, the log turns very slowly and an oscillating cutter at the end moves along the log (the feed speed per revolution is less than the rotation speed). A hydraulic system is used to press the tool against the log. The cutter removes the bark and a small amount of wood, and leaves a screw shaped mark on the log.

The most widely used debarking machines have two oscillating arms each with a cutter. These cutters rotate at high speed removing the bark by combined hammering and cutting action. Large toothed wheels mounted on two parallel shafts and rotating in the same direction are used to turn the log. The log is placed between the wheels. The shafts are driven by a variable speed motor. A hydraulic system presses the cutter arms against the surface of the log and they move lengthwise along the log while it rotates.

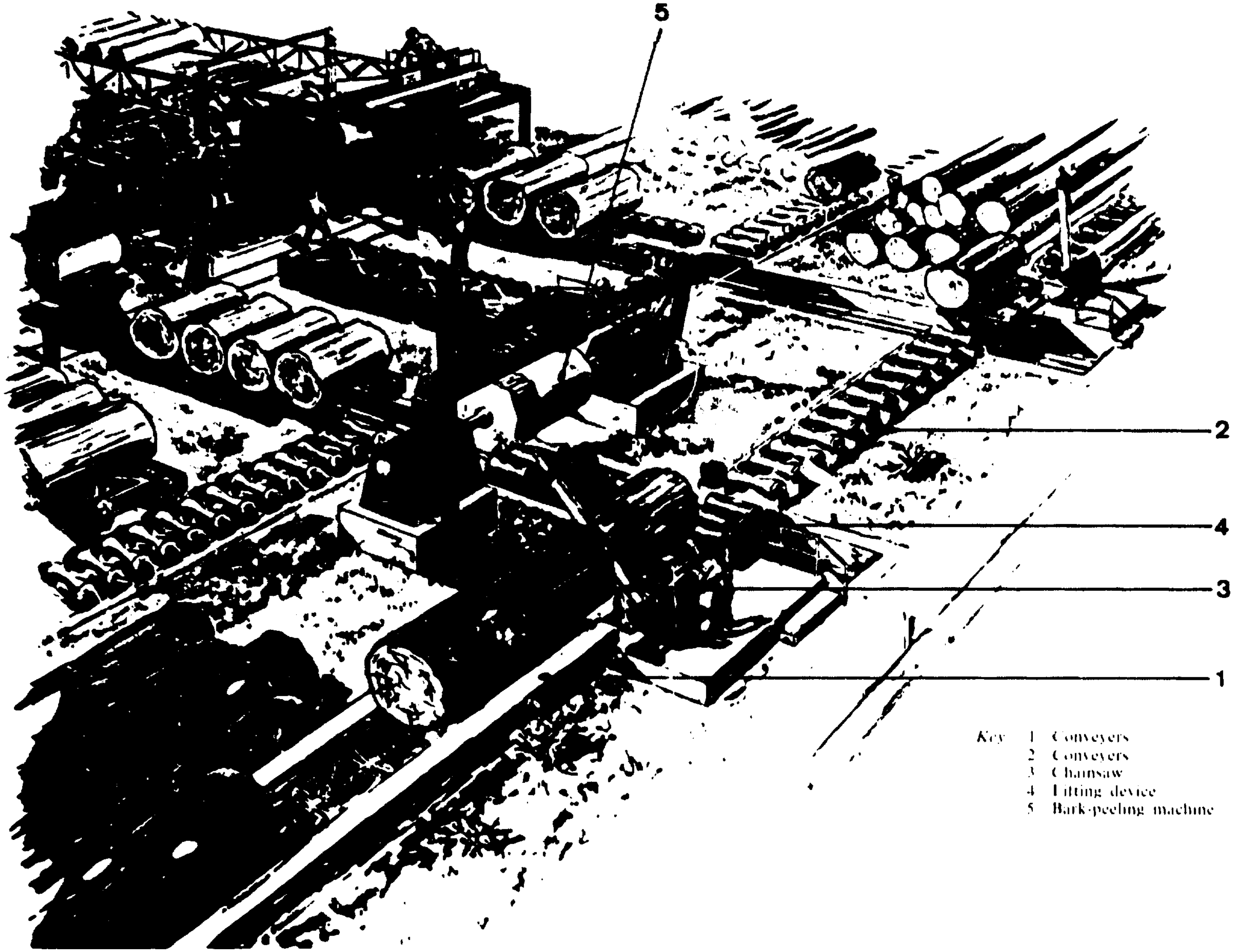
One type of this machine operates by having the log rotate on a feed carriage instead of having the cutter arms move along the log. This type of debarking machine is less rigid but easier to load as the carriage can move the log and position it. The log is unloaded from the other end. Several loading stations can be arranged at different places. These operations can be continued if chain conveyers are installed. Unfortunately when the logs are irregularly shaped, or have holes, the cutter cannot debark the log completely. That has to be done manually.

Debarking cutters may also be used for small and medium diameter logs having thin bark such as beech. Both rotor and cutter debarking machines have a high capacity so that one machine can operate for several production lines, especially when the plant has a good conveyer and bark collection system.

The peeling section

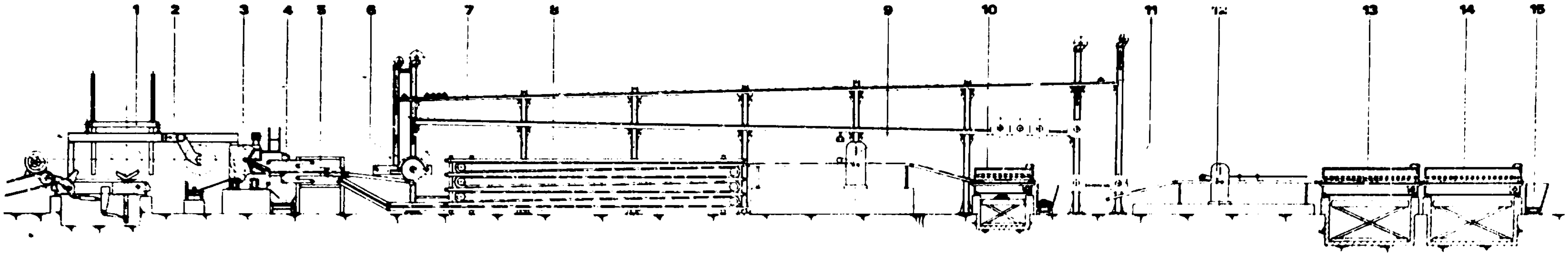
The application of modern technology to plywood production includes the use of automated equipment for continuous manufacturing processes. Figure 2 represents a continuous production line

Figure 1. Plant for cutting logs to size and debarking



Key
1 Conveyers
2 Conveyers
3 Chainsaw
4 Lifting device
5 Bark-peeling machine

Figure 2. A continuous production line to produce wet peeled sheets from logs



Key: 1	Automatic centring and loading device
2	Conveyer for rounds, where cores are unloaded
3	Peeling lathe with double telescopic spindles, and operator controls
4	Conveyer for unutilizable round-ups
5	Conveyer for peeled veneer
6	Automatic reeling device
7	Reel store
8	Multiple conveyer for round-ups
9	Automatic clipper
10	Piling-up device for undersized sheets
11	Automatic unreeling device
12	Automatic clipper
13	Piling-up device for entire sheets
14	Piling-up device for undersized sheets
15	Device for picking up waste

for conversion of logs into green peeled veneer. This plywood production line is suitable for peeling medium sized logs of 0.45 to 1.2 metres in diameter. Floor plans for plywood production to convert large diameter tropical logs and also those for small diameter show that different equipment is required.

Log centring

A log deck unit conveys the logs lengthwise and crosswise to the peeling station. The capacity of the log deck is ten logs. This is necessary to ensure continuous operation. Before peeling, the logs will be centred so that waste material will be kept to a minimum. This operation is quite important from an economic point of view. Centring is done according to the shape and butt end of the log. Out-of-centre heartwood, splits, cup shakes and other defects in the log are features that determine the axis of rotation which is most suitable for a higher yield of the log.

Geometrical centring is done automatically by optical control at four different points. Two different cross sections of the log, about one-third of the way from each end, are measured. Once the log has been centred according to shape, several concentric circles are projected on to both butt ends for the operator's final check. Two mirrors enable the operator to see these projections on both ends and by pressing two push-buttons he can adjust the axis of rotation for maximum utilization of the raw material.

The arms of an overhead crane grip the log at the butt end, and transport it to the veneer peeler. The spindles hold the log on the selected axis of rotation. After chucking the log, the overhead crane is automatically disengaged and travels back to the starting position to pick up the next log which has just been centred. The operation cycle for centring and transporting is about 45 seconds. This means that about 80 logs an hour are fed to the peeling machine. This feed rate is faster than the rate at which the veneer peeling machine can peel the logs. Thus high outputs of technically perfectly peeled wood can be produced efficiently and economically.

Peeling

In modern plants, the controls are located on top of one of the columns of the veneer peeler (figure 2 (3)) so that the operator can control and view the whole peeling operation. This cycle may be divided into the following operations: transport of the log to the centring machine; centring the log and transport to the peeling machine; peeling; sorting out waste and round-ups; transport of the peeled veneer to the automatic reeling system (figure 2 (6)); transport of the reels to the reel rack and placing an empty reel (figure 2 (7)) on the machine; loading the peeler core (figure 2 (2)). In traditional plants, even recent ones, at least four people are required for these operations, and output per person is lower. Naturally we wish to know how it is possible for a single operator to perform all the above operations (figure 3).

Basically, the advantages of a single operator are:

(a) A highly automated plant allows the use of continuous production lines; all the normal operations are programme controlled so the operator only has to intervene occasionally to adjust for different logs;

(b) All plant controls are located in one control desk. They are arranged according to a general scheme which corresponds to the production process;

(c) The operator controls the peeling operation both before and after the peeling machine and intervenes when a defect begins to appear. Normally the operator only has to press one or two push buttons to re-establish optimum working conditions at a given moment.

Under actual working conditions, the operator's experience, together with multi-use equipment, normally allows the operator to intervene even before the log defects can disturb the continuous process. Therefore a modern peeling machine must be equipped with:

(a) Two telescopic spindles. This is because when peeling begins the log is held by large jaws which are automatically withdrawn when the log becomes smaller. The peeling process continues without any interruption until the log has been worked to its minimum diameter (which is equal to the diameter of the internal spindles if the log's characteristics allow it to be peeled to this diameter);

(b) Variable D.C. motor and power supply. A great deal of power is required since the peeling

rate can be as high as 300 m/min. Therefore the motor must develop more than 100 kW output power at one third of maximum rpm.

The speed must be controlled automatically to maintain constant peripheral speed and provision must be made for the operator to perform adjustments as needed. An integrating sensor constantly measures the peripheral speed of the log and converts it into electric signals which are transmitted to the conveyer belts and the reeling equipment so that these three operations all proceed at the same rate. To get a good idea of the concept of automatic reeling, imagine that you have to unreel a roll of paper (which represents the log), transport the strip of paper and reel it on an empty rotating reel six metres away. The paper is unreeled from the first roll and automatically reeled onto the other reel, neatly and without tensioning the paper.

(c) Thickness control. There are at least two different thicknesses plus one large thickness needed during the initial phase when the log is being rounded. It must be possible to change thicknesses during peeling without interrupting the cycle. The distance between the blade and the pressure bar must be automatically changed every time the thickness is changed;

(d) A device for the rapid drawing of the pressure bar from the blade and for readjustment. This device is used when pieces of veneer or bark jam in between the blade and the pressure bar. The device must have rapid action so that the peeled band will not break;

(e) Pressure rollers. These press against the rotating log and prevent it from being forced to bend by the cutting action. This is especially important when the log diameter becomes very small. The peeling machines for medium and small diameter logs must be equipped with devices which press against the whole length of the log. On the larger peeling machines this device is required only for the centre part of the log. These devices are hydraulically operated and pressure can be adjusted in accordance with actual conditions;

(f) Backlash compensation on knife-holder feed screws. During peeling, the sideways motion of the knife-holder must be continuous and uniform so that the thickness of the peeled veneer is accurately controlled. Backlash compensation may be either mechanical, with double lead screws held together by springs, or hydraulic with backlash cylinders;

(g) Operating controls located in the control panel. As with an automobile, where the driver has a good instrument panel, a peeling machine needs instruments which assist the operator. For example, an ammeter connected to the main motor shows how much energy is required for peeling. When this value is above the limit, an experienced operator will know that it is time to change the knife or adjust the knife holder. One or more manometer gauges connected to the spindle cylinders show whether the log is properly fitted or not (if not, the centre of the log is not solid). The tachometer is also very useful because it shows the spindle rpms etc.

The whole peeling machine must be sturdy. Above all it must be rigid because any bending, buckling or twisting under stress would influence the thickness accuracy of the peeled veneer.

Sometimes peeling machines are judged on the basis of their weight. This criterion may be partially valid but it is by no means the only one. The most important characteristic of a peeling machine—rigidity—basically depends on the design which takes all the various loads into account and distributes them over large areas. The larger the areas, the smaller the individual stresses. Using the right materials is also important. A welded steel frame bends twice as much when subject to a force as the same frame made out of cast iron. This is why fewer frames are being made out of structural steel, especially when rigidity is the main objective.

Intermediate storage and clipping

The peeling operation produces three different products: unusable round-ups; usable round-ups; and continuous veneer strips.

The round-ups peeled off the outer portion of the log have an irregular shape and cannot be used in plywood manufacture. The veneer is peeled in thicknesses of about 4 mm to speed up this operation. A belt conveyer transports (figure 2 (4)) this waste material to the knifehogs where it is transformed into chips. These will either be used for fuel or for making particle board. The rest of the veneer which is peeled off before the log is reduced to a cylindrical shape, is used for the inner layers of the plywood panels (core veneer). In three layer panels, the centre layer is twice as thick as the top layer. This peeled veneer is placed on a belt conveyer (figure 2 (5)) and transported to a storage container which is a series of conveyers, one on top of the other (figure 2 (8)). This is called the zig-zag system and it enables a large amount of peeled veneer to be stored in a limited space. The conveyers must have another belt on top of them which keeps the peeled veneers flat so that they can be conveyed easily

The storage container is divided into two or three sections which can receive or send out material. Further, these sections can be activated individually or as a group by either the operator at the peeling machine or the operator at the clipper which is a machine placed after the storage container. This entire process is simple because the peeling machine produces round-ups periodically only whereas the clipper works full time. While the peeling machine sends the peeled veneer to the first section of the storage container which is set at the same speed as the peeling machine, the second section feeds the clipper (figure 2 (9)) at a lower speed.

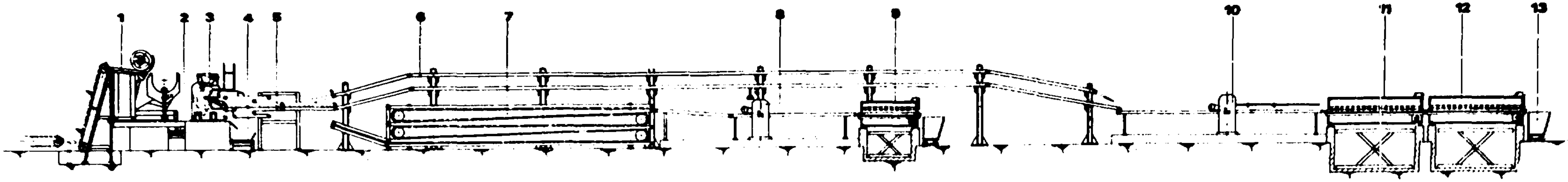
When the log has become cylindrical and the continuous band of peeled veneer is being made, the first section of the storage container is being connected to the second section and is used to feed the clipper. This plant is equipped with an automatic clipper (figure 2 (9)) for clipping irregular pieces of peeled veneer into parallel bands with different widths. The pieces of peeled veneer are fed to the clipper on a variable speed belt; another set of belts acting over the first set is used to keep them flat. Another conveyer at the back of the clipper transports the veneer to the storage. The clipper's knife is operated by compressed air. Plastic hold-down rollers keep the veneer in position while clipping. The cutting cycle lasts only 1/20 of a second and the clipper can be operated on the moving veneer band at up to 80 m/min. An electronic scanning device consisting of a row of photoelectric cells detects any defects in the shape of the pieces of peeled veneer before they are fed to the clipper and decides where the cut should be made, both front and back. This device which is able to separate the usable pieces of veneer from the waste is rightly called an "optimizer". After this operation the bands of peeled veneer are automatically stored in special containers and the waste veneer is conveyed to the chipping machines. The operator on the clipper just has to adjust the conveyer speed according to the amount of waste material. Occasionally, he has to speed up the conveyer belt to the chipper when the pieces of peeled veneer are particularly hard.

The continuous strip of peeled veneer is reeled on metal reels about 80 cm in diameter. When the reels are completely reeled they are lifted away and transported to the storage area. Automatic peripheral reeling has been widely adopted in recent years. Basically, this system consists of a series of drive belts mounted on moveable arms which surround the reel. The belts are pressed against the edge of the reel so it turns and winds up the band of peeled veneer. The speed of these belts and the conveyer which transports the wood from the peeling machine to the reeling station is synchronized with the peripheral speed of the log. Two bands of adhesive paper are automatically applied to the two ends of the full reel to prevent unreeling. At the end of the reel storage area there is an automatic unreeling station (figure 2 (11)) where the continuous strip of peeled veneer is cut into sheets of the desired size for making plywood panels. Two or more stacking machines (figure 2 (13) (14)) stack the veneer sheets.

The best automatic stacking machines operate mechanically. These machines have pairs of rubber rollers which rotate in opposite directions. The rollers are pressed on top of the veneer sheets and fed to the adjusted height of the scissors lift. This system of manufacturing veneer sheets is most suitable for medium sized first grade logs more than 50 cm in diameter because a large number of sheets can be stored in a limited space. Naturally, there are more sophisticated approaches, such as multilevel storage areas used to increase the quantity of peeled veneer or to keep the reels with different thicknesses of peeled veneer separate.

Figure 3 shows a plant suitable for processing logs less than 50 cm in diameter. This is called the "deck system" and it is used when the continuous strip of peeled veneer is not long enough to justify the reeling operation. Furthermore, with small logs the different phases of the peeling operation come in more rapid succession and the deck system ensures that the clipper will have enough veneer to cut even with the limited stock of peeled veneer which is on the deck system belts (figure 3 (6)). The storage system for the veneer peeled during the second phase operates on the principle described above. The only difference is that the deck system has two flaps, one at the beginning and one at the end of the conveyer. As the first flap connects the peeling lathe (figure 3 (3)) with one deck for loading, the other flap connects a different deck to the clipper for unloading. Magnetic clutches which are controlled by flap position are used to adjust belt speed to either peeling rate or the feed rate of the clipper. The clipper is driven by compressed air and the conveyer belt at the back of the clipper has a device for automatically cutting sheets to the proper length. The clipper automatically cuts full, half or quarter

Figure 3. A continuous line for processing logs of less than 50 cm diameter into wet peeled sheets (deck system)



Key: 1 Automatic geometric centring and loading device
2 Round conveyer
3 Peeling lathe with double telescopic spindles
4 Conveyer for peeled veneer
5 Conveyer for peeled veneer
6 Peeled veneer multiple conveyers (deck-system)
7 Multiple conveyer for round-ups
8 Automatic clipper
9 Piling-up device for undersized sheets
10 Automatic clipper
11 Piling-up device for entire sheets
12 Piling-up device for undersized sheets
13 Picking-up device for wastes

size sheets. Naturally, the defective portions are eliminated. The stacking machines at the end of the line automatically separate the sheets according to size. The full size sheets are divided according to quality: first and second grade. Figure 3 identifies the functions under items nos. 1 to 13 inclusive.

Drying

The next operation is drying of the wet peeled veneer. Two different drying methods are used. The difference in the two is the conveying system for the sheets fed through the dryer. Either continuous belt dryers (figure 4) or roller (figure 5) dryers may be used. From the technical point of view in the first case the peeled veneer is fed through the dryer in band form with the grain perpendicular to direction of feed and the veneer is clipped to size after drying (figure 4); whereas in the second case, the peeled veneer is clipped while it is wet (figure 2) and the sheets are fed through the roller dryer with the grain parallel to the feed direction (figure 5).

In recent years, continuous belt dryers are being used more frequently because of their economic advantages. However, production quality may be lower. The plant layout in figure 4 shows a continuous dryer with five different levels. The upper four are used for drying; the lower one is separated from the dryer and is used for cooling the dried veneer so that the remaining moisture is uniformly distributed. Continuous dryers offer several advantages. The most obvious is that if the peeled veneer has already been dried when it is clipped the sheets will be exactly the right size, and no shrinkage will occur. Furthermore, small strips of peeled veneer will have straight parallel edges and will be ready for splicing. This type of dryer also saves labour and it is easy to operate. Continuous operating dryers can be used profitably for drying tropical species. With thin bands of peeled veneer speed can go up to 50 m/min. Unfortunately, when the veneers are much narrower than the dryer, total volume of production will drop. Today's continuous dryers offer many different arrangements and capacities; thus they are able to solve the problems arising from different kinds of wood and different thicknesses. For example, twin level drying lines have been built, with each level moving at a different speed, depending on the type of wood being dried and its thickness. The market offers modern, automatic control equipment for adjusting dryer temperature and the mixture of steam and air used for drying. Thus dryer temperature and humidity can be adjusted according to the characteristics of the peeled veneer.

Roller dryers are normally used for drying difficult woods. Usually these woods contain a large amount of unevenly distributed moisture. When this moisture evaporates, uneven shrinkage occurs and the dried veneer will have ripples in it. When roller dryers are used there is almost no danger of splitting because the sheets are small and free to shrink. The most efficient use of roller dryers is made by first classifying and separating the sheets according to moisture content during the clipping operation. This calls for a certain familiarity with the type of wood; the peeled veneer has different colours, depending on its moisture content, and this aids in classification. Poplar is a typical example: the white areas stand out against the darker zones which contain large amounts of moisture.

Either portable or fixed instruments are used to control the moisture content of the dried sheets. These instruments show the moisture content continuously. This equipment can be used to automatically regulate dryer temperature and feed rate. The sheets which are not sufficiently dry are automatically sprayed with a special coloured liquid so they can easily be identified for recycling. Roller dryers offer another important advantage as far as production quality is concerned. The rollers press the sheets during the whole drying process so the finished sheets have harder and smoother surfaces.

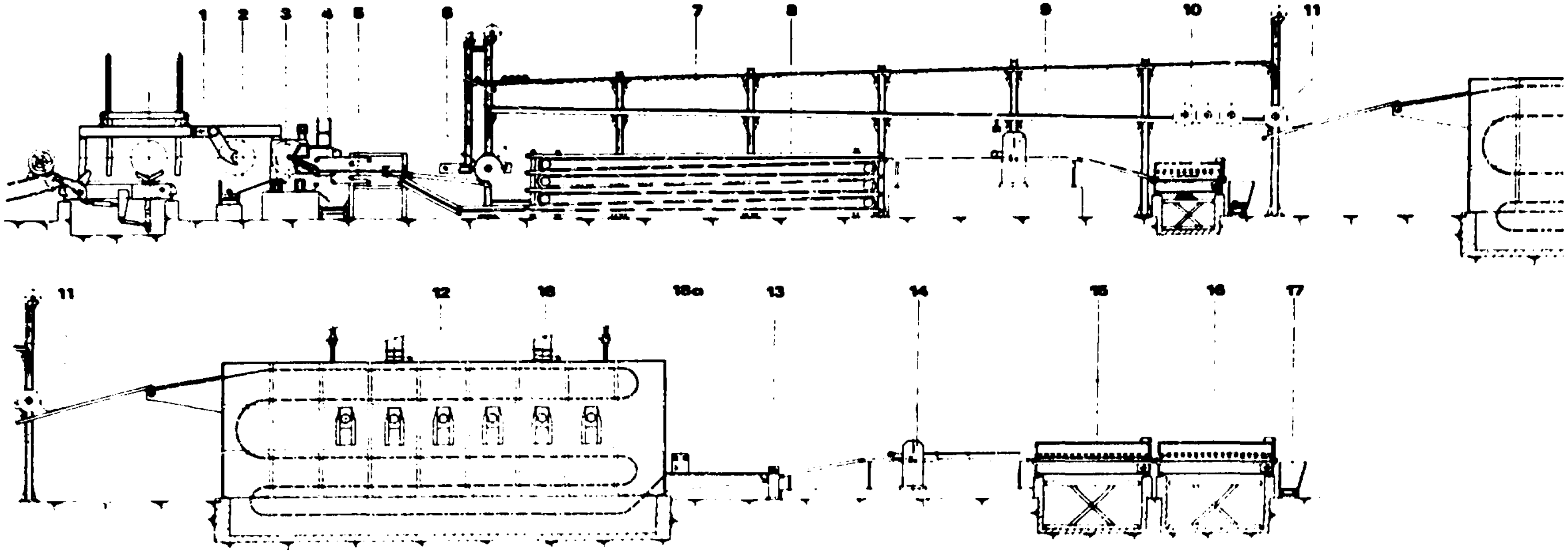
Today the amount of labour required for operating roller dryers has been reduced by using completely automatic feeders and automatic unloading and stacking machines.

The right type of dryer—continuous or roller type—must be selected above all on the basis of the species of wood used and its quality. These two systems rarely compete directly with each other even though the tendency is to use continuous operating dryers in modern production lines. Roller dryers offer more advantages when different types of wood with different characteristics have to be dried and when quality is an important factor in the production of dried sheets.

Jointing of veneers

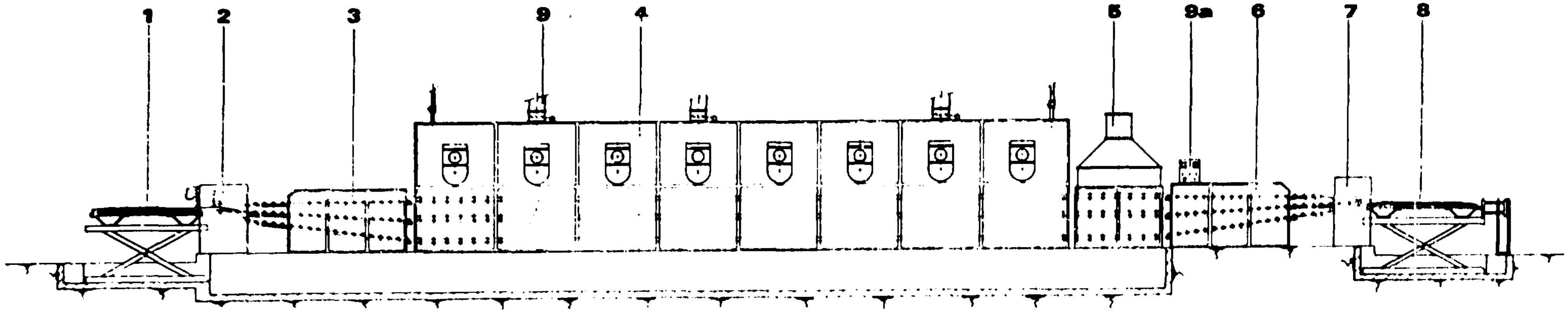
Some secondary operations have to be considered in plywood manufacture because they allow for maximum recovery of the peeled veneer, and require a large amount of labour. It is common knowledge

Figure 4. A continuous line for the transformation of logs into dry peeled sheets showing continuous belt dryer (12)



Key: 1 Automatic centring and loading device
2 Conveyer for rounds, where cores are loaded
3 Peeling lathe with double telescopic spindles, and operation controls
4 Conveyer for unutilizable round-ups
5 Conveyer for peeled veneer
6 Automatic reeling device
7 Reels store
8 Multiple conveyer for round-ups
9 Automatic clipper
10 Piling-up device for undersized sheets
11 Automatic unreeling device
12 Continuous dryer
13 Metering device for residual humidity
14 Automatic clipper
15 Piling-up device for entire sheets
16 Piling-up device for undersized sheets
17 Picking-up device for wastes
18 Chimney with adjustable flow
18a Control of air moisture in the dryer

Figure 5. Roller dryer (4) with automatic loading and unloading of peeled veneer sheets



Key:
1 Elevating platform
2 Automatic taking-in device
3 Conveyer
4 Dryer
5 Cooling chamber
6 Conveyer
7 Automatic ejecting and piling-up device
8 Elevating platform
9 Chimney with adjustable flow
9a Control of air moisture in the dryer

that raw materials account for about half the final cost of plywood. Sheets with knots, worm holes or other small defects are "repaired" by cutting out the defect and patching the sheet by gluing a piece of patch veneer in the patch hole. The bands of peeled veneer with defects can be used to form a new band of peeled veneer The method used in splicing these strips depends on whether they were clipped when they were wet or dry. In the first case, the sheets must be jointed on knife jointers or cutterblock jointers for jointing the packs of veneer. Two splicing methods are known. In the first case a glue string is placed in zig-zag form, across the joint. In the second case thermoplastic glue spots cover the joints. The most modern machines are equipped with a conveyer belt. The bands of peeled veneer are laid side by side on this belt and all the operations—jointing, splicing, gluing and clipping—are done automatically. But it is not always necessary to splice the strips. On medium quality panels, the strips used for making the inner layer may simply be placed side by side when the panels are being made up before pressing.

Preparing the glue

This section of the plant works independently and its operation differs from plant to plant. Wood-based panels are discussed in chapter XI.

Laying of ply sheets

The sheets of peeled veneer are placed one on top of the other in the desired arrangement. The plywood panels are made from these ply layers. In many plants, these layers are made up by hand in the following order: first ply, not glue spreaded, core ply double side glue spread, third ply, no glue spread etc.

Modern plywood plants use vacuum lifting equipment to pick up the ply sheets from piles, transport them and place them on the laying table. The most commonly used glue spreading machines are the roller type double side glue spreaders. Sometimes "curtain" type spreaders—where a thin glue curtain drops through a calibrated slot—are used. The sheet of wood passes underneath this slot and the amount of glue deposited on the surface depends on the feed rate of the sheet.

This type of glue spreader can only spread glue on one side of the veneer, causing internal stresses in the veneer sheets. These panels do not always have a uniform surface after pressing. This problem can be eliminated by pre-pressing the spread ply layers before hot pressing.

Plywood pressing

In modern plants, no matter which gluing system is used, cold pre-pressing offers the following advantages:

(a) The aluminium cauls holding the layers together will be removed when the pre-pressed panel is loaded to the hot press;

(b) The height of the press openings can be decreased from 120-140 mm to 60 mm; this means that the presses are more compact with faster operation;

(c) Automatic loading and unloading equipment can be used. This equipment loads the panels into the press in seconds and unloads the pressed panels at the same time, no matter how many openings the press has;

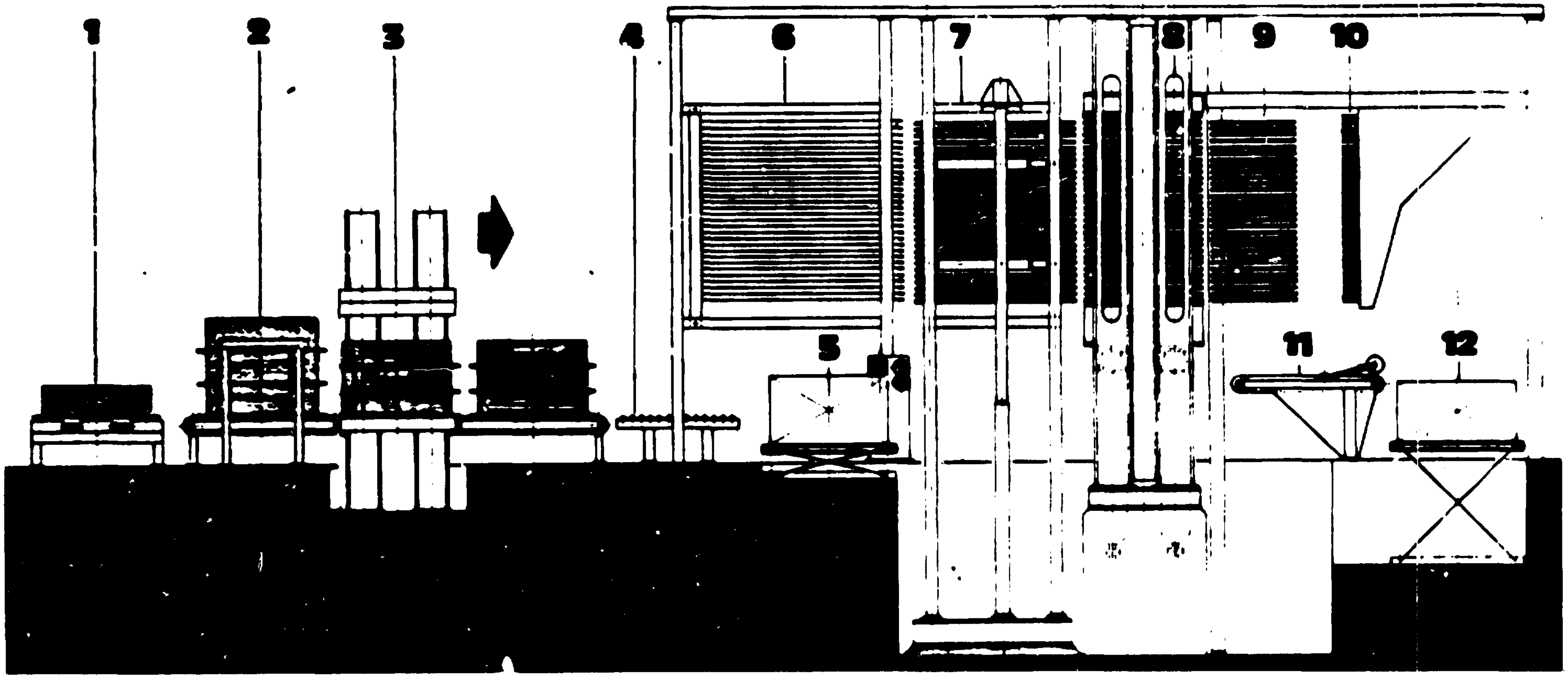
(d) The moisture contained in the glue is more evenly distributed throughout the different layers in the panel;

(e) Defects and rejects caused by sheet slippage during handling and feed are reduced;

(f) Curing time is shorter.

A single opening press is used to pre-press piles of panels about one metre high. Sometimes the press has two openings. Pressure varies between 15 and 20 kgf/cm^2 depending on the type of wood and sheet thickness. An automatic press line is shown in figure 6. Normally, the panels stay in the cold press for a few minutes, depending on the adhesive properties of the glue at room temperature. The glue may be either urea or phenol based. As modern plywood plants have high production rates, the

Figure 6. Automatic pressing lines with pre-press

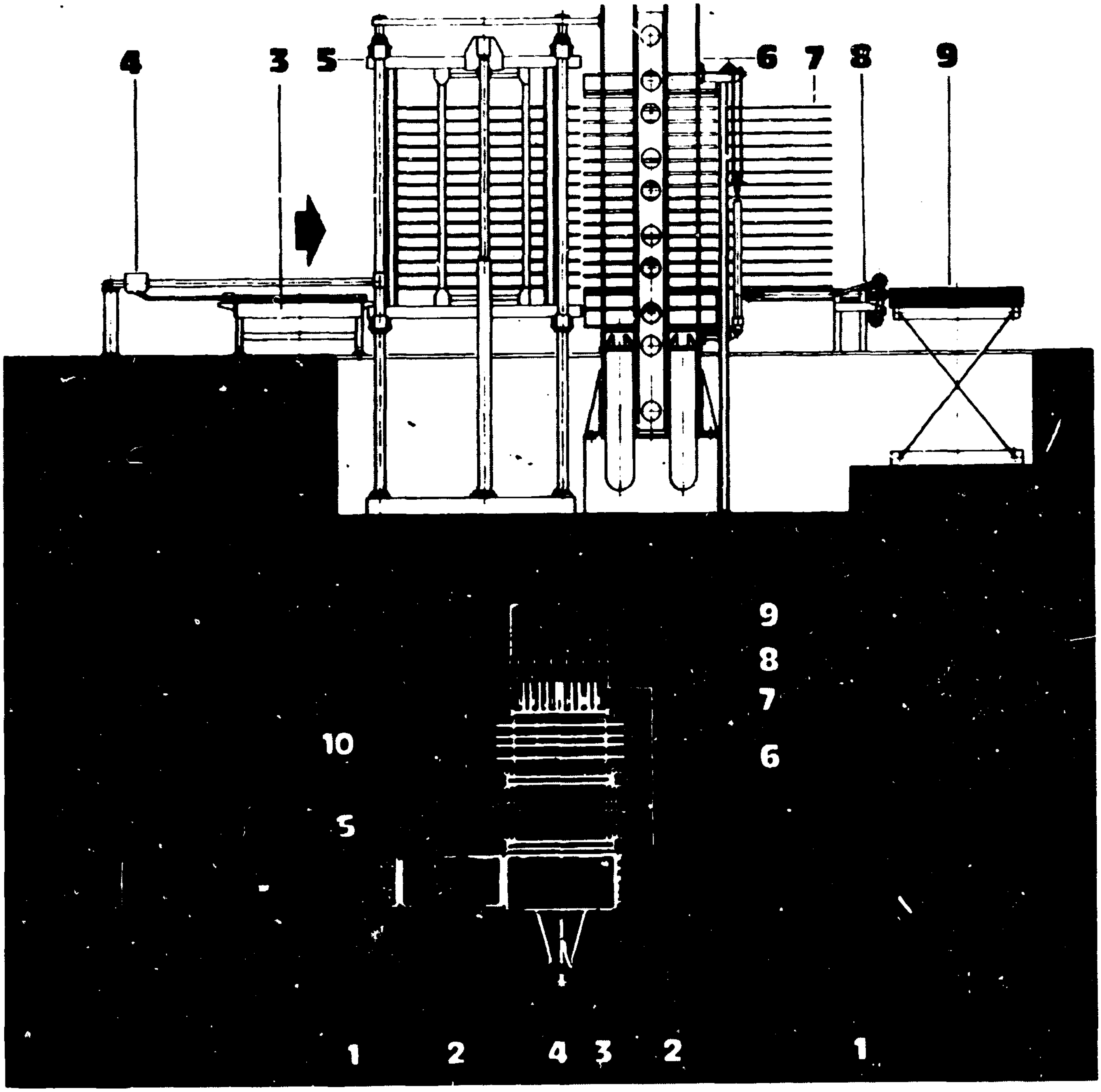


Key

1	Book building conveyer
2	Pre-press conveyer
3	Oil-hydraulic pre-press
4	Intermediate conveyer
5	Board loading device
6	Pushing arm in the press
7	Loading lift
8	Multi-opening hydraulic press
9	Unloading lift
10	Press extracting unit
11	Board ejecting unit
12	Piling platform

hot presses have a minimum of 16 openings and they may have as many as 40. Bonding pressure varies from 10 kgf cm² for softwood plywood to 25 kgf/cm² for hardwood plywood. A multi-opening press is shown in figure 7. The most functional presses are designed so that loading and unloading is done along the long sides of the heated rectangular platens, even though from the mechanical point of view this solution leads to less compact and more costly machinery

Figure 7. Multi-opening press with automatic loading and unloading device



Key
1 Book building bench
2 Intermediate bench
3 Inserting bench
4 Oil-hydraulic pusher
5 Automatic loading lift
6 Press with heating platens
7 Unloading lift
8 Extracting arm
9 Piling platform
10 Control desk

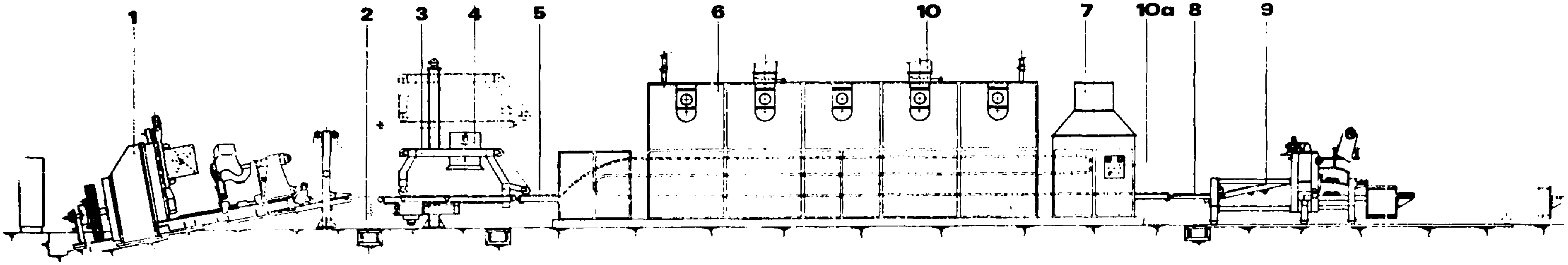
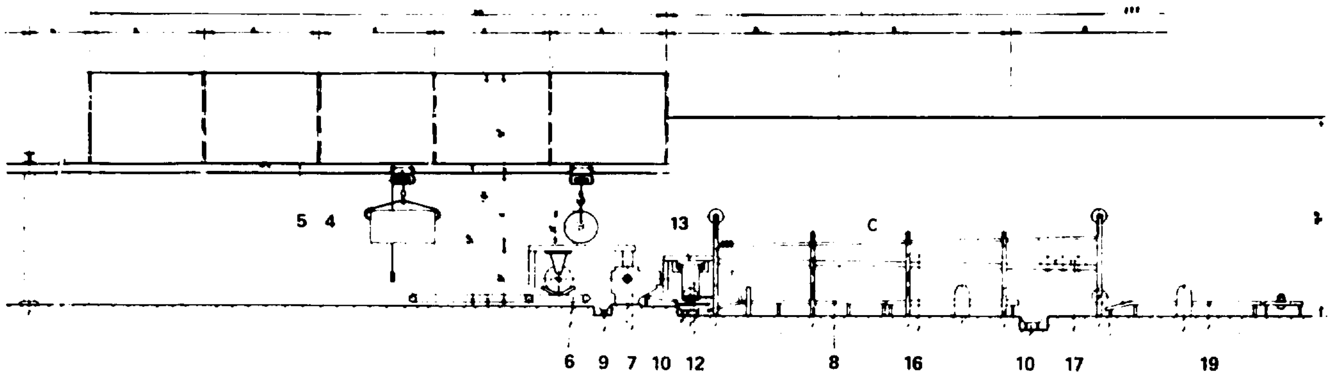


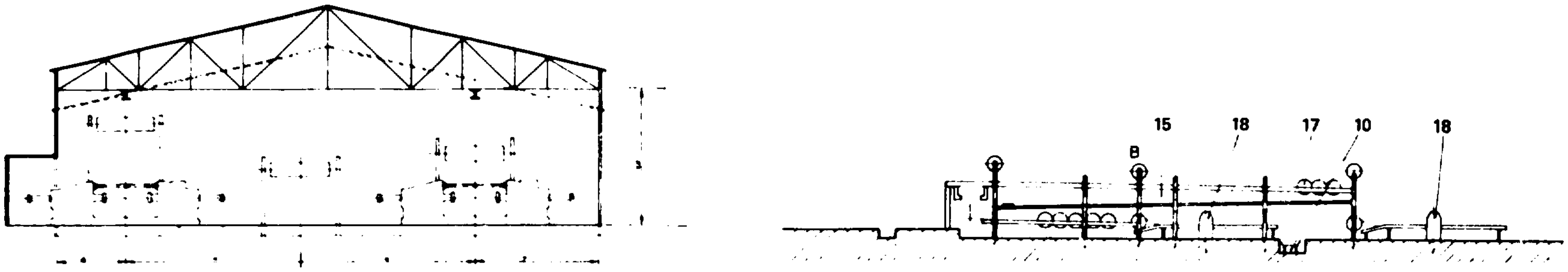
Figure 8. A continuous line for the transformation of logs into dry sliced veneer

Key: 1 Vertical veneer slicer
2 Elevating platform
3 Auxiliary connection conveyer
4 Pre-dryer
5 Lift
6 Band dryer
7 Cooling chamber
8 Lift
9 Piling device for dry sliced veneer
10 Adjustable air exhaust
10a Humidity control for dryer

Figure 9. A plywood plant

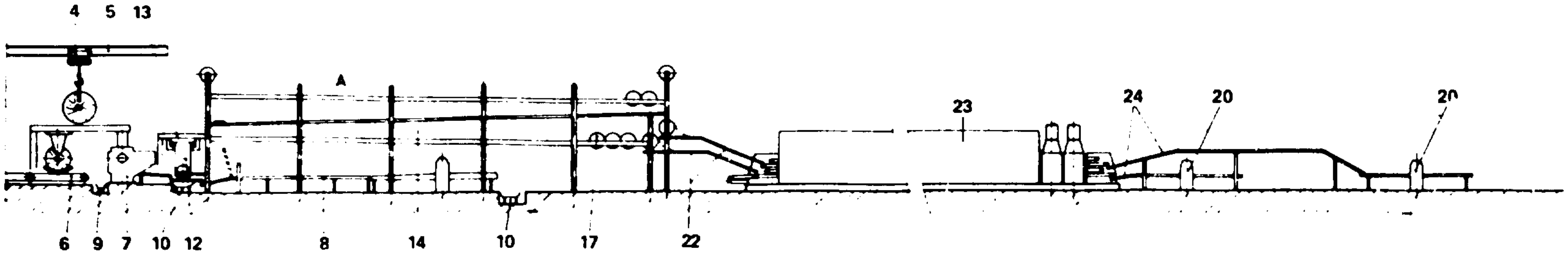


A. Front view showing peeling operation

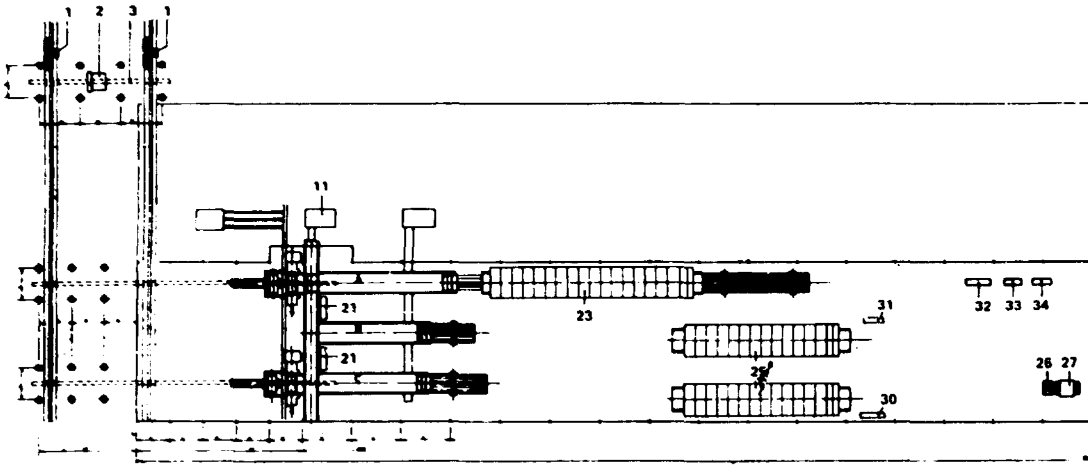


B. Side view

C. Expanded-front view showing reeling equipment



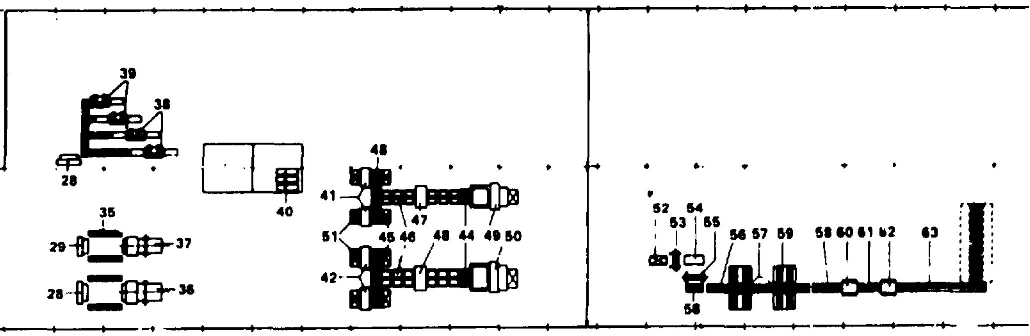
D. Expanded-front view showing feed to dryers



E. Top

Key:

1	2 electric chain-saws
2	1 log debarking machine
3	1 electric hoist
4	3 electric hoists
5	Runways for electric hoists
6	2 optical centring and loading devices for logs
7	2 peeling lathes
8	2 complete lines for waste utilization
9	1 conveyer for rest rolls
10	2 conveyers for peeling wastes
11	1 chip-forming machine for wastes
12	2 hanging trucks for reel transport
13	Supporting framework for reeling truck
14	2-floor reel store
15	2-floor reel store
16	1-floor reel store
17	80 reeling reels
18, 19, 20	5 pneumatically controlled clippers
21	Automatic clippers
22	2 belt conveyers
23	1 continuous dryer with cooling chambers
24	2-floor belt conveyers
25	2 roller dryers with cooling chambers
26	1 electrohydraulic elevator



view

27	Contact sanding machine with upper band
28, 29	3 automatic trimming clipping machines
30, 31, 32	3 automatic clippers for peeled veneers
33, 34	2 clippers with 2 symmetrical sections
35	4 belt conveyers
36, 37	2 transversal jointing machines
38, 39	4 longitudinal splicing machines
40	3 glue mixers
41, 42	4 cylinder gluers
43, 44	6 electrohydraulic elevators with roller table
45	2 roller tables
46	4 double roller tables
47	Hydraulic cold pre-press for panels 2,440 × 1,525 mm
48	Hydraulic pre-press for panels 3,050 × 1,525 mm
49	Hot-plate press for panels with 32 openings
50	Hot-plate press for panels with 32 openings
51, 52	11 electrohydraulic elevators
53, 55	2 double squaring machines
54	1 intermediate device between the squaring machines
56, 57	5 roller and ball tables
58, 59	8 electrohydraulic elevators with roller table
60	1 contact sanding machine with lower band
61, 63	2 motorized roller tables
62	1 contact sanding machine with 3 upper bands

The most modern presses are also equipped with devices which open and close all the platens simultaneously. These are chrome-plated to eliminate corrosion. They improve the appearance of the panel surfaces and facilitate heat transmission. For 4 mm panels, press time is only three minutes.

Today, high-temperature water is used to heat the platens in the presses. This water circulates at a convenient speed and is recycled. Oil can also be used as its temperature can exceed 100°C without boiling. In larger plants where presses have more than 20 openings, there are two lines for preparing the "ply layers".

Single opening presses have been introduced in the last decade. With these presses, the optimization of the technological and production processes is achieved by a very different technique. Instead of having a series of platens stacked one on top of another with one panel in each opening, the single opening processes have only two platens. These are large enough to press several panels side by side at the same time. These presses offer the following advantages:

(a) The whole area of the platen is used even when different sized panels are being pressed;

(b) The time lost in non-productive operations—opening and closing the press, feeding and unloading the panels—is decreased. Loading and unloading is done by a long conveyer belt passing through the press;

(c) The single opening presses are easier to build and operate and they can easily be applied to manufacture of special types of panels.

The platens may be up to 2.80 m wide and up to 12 m long; maximum pressure is 25 kgf/cm^2. Obviously this type of press does not offer a very high production rate and it is often necessary to install several machines in the same plant. Single opening presses are suitable for applying decorative veneered panels.

Trimming and sanding the panels

Squaring consists of trimming all four sides of the panel to remove defects along the edges. Two trimming machines with two blades each are used together with a transfer unit so all four edges of the panel can be machined in one pass. Two circular carbide tipped blades are used to cut the panels

Usually, the circular saw blades are combined with knife hogs for chipping the trimmed edges. This makes it easier to remove waste material from the work area. The panels are sanded so that they will have a smooth surface and a pleasant appearance All modern sanding machines use wide, flexible abrasive belts. Some of these machines are just for finish sanding but some have more than one abrasive belt and can be used for thicknessing and finish sanding of plywood panels. Both sides of the panels can be sanded in just one pass when two sanders are linked in line. One of these machines is a top sander and the other is a bottom sander. The most modern machines have two or more abrasive belts both on top and bottom.

Veneer slicing

Our final topic deals with plywoods which are face veneered. These veneers are about 0.6 mm thick and they are sliced from flitches. They are "decorative veneers".

Since this operation is often included in plywood plants, a plan for a slicing plant is shown in figure 8.

Outline of a plywood plant

An outline for the layout of a plywood plant using tropical logs, operating the peeling lathes and presses on a double shift basis, with the dryers, clippers, veneer splicing machines and finishing line is shown in figure 9.

XIV. Selection of equipment for panel surface improvement *

The direct use of wood-based panels, such as blockboard, fibreboard, plywood and especially particle board, without surface improvement of the appearance and the physical-mechanical characteristics, is gradually disappearing (with the exception of panels used for packing). Surfaces of plywood, fibre and particle board, for use in the building trade, furniture and transport industries, are usually laminated. "Surface improvement" means the process of improving the physical-mechanical characteristics. "Lamination" is a process which, in addition to improving the physical-mechanical properties, also imparts a pleasing appearance. The main surface characteristics obtained by the lamination process are resistance to scratch, abrasion, moisture and heat, and to some household chemicals. Surface improvement depends on substrate material, laminating material (papers and resins) and on the system adopted for lamination.

Lacquering and coating of boards using polyvinyl chloride (PVC) foils is not referred to in this report, as this process is not a true lamination.

Materials for lamination

The substrate materials are:

Plywood
Fibreboard
Particle board (which due to its wide use in the building and furniture industries, will be emphasized in this report)

Laminating materials include:

Decorative laminates
Papers impregnated with melamine
Papers impregnated with melamine modified with urea or acrylic resins

Substrate materials

Plywood (from 3 to 25 mm) bonded with urea resins

The lower grades of plywood are normally used by the packing industry, and the better grades are used in the production of doors and furniture. For the better grades further surface treatment of lacquering or printing and lacquering is done. Today, lamination is done with diallyphtalic, urea, and modified urea impregnated papers. Light papers (about 40 g/m²) may be glued with PVC or polyvinyl acetate (PVA) copolymer based glues, or urea glues. For this process several kinds of papers, which shall be described later on in the section dealing with particle board lamination, are available.

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* By F. T. Slodyk, consultant in wood-based panel industries. (This is an edited version of ID/WG.277/16.)

Plywood board, bonded with phenolic resins (marine use)

Plywood board bonded with phenolic resins may be manufactured, with treated surfaces, following a "one step" or a "two step" process. In the "one step" process the glued veneer, inserted between phenolic resin impregnated papers, is coated with phenolic resin impregnated papers and pressed together with the whole panel sandwich. A high rejection rate occurs in this process, due to faulty veneers.

In the "two step" process, the plywood board is first produced with no coating. It will be then selected and "improved" by pressing in the multi-opening press, if coupled with phenolic resin papers, or by pressing in the single-opening press, if phenolic papers are used. The "two step" process is preferred and in widespread use today. The process requires a pressing time of about 6-10 minutes; pressure, depending on wood type, of about 15-18 kgf/cm²; and a temperature of about 145°C. These products are used in the building industry (moulds), containers, railway wagons etc.

Fibreboard

Fibreboard surfaces are lacquered during production. There are also panels with printed and lacquered surfaces, and "compound" boards (two or more being pressed at the same time). Apart from the processes used for these there are two main lamination processes:

(a) The hot/cold process. This process is done on the multi-opening press, usually with melamine or modified melamine impregnated papers. The pressing cycle is about 10-15 minutes and the working temperature is about 140°-145°C. The pressure used is about 40 kgf/cm²;

(b) The hot/hot process. This process is done on the multi opening press (or rarely in single-opening press) using diallyphtalic papers. The manual or semi-automatic multi-opening press is widely used with this kind of paper. This is because diallyphtalic papers are very flexible and quite sticky, and not particularly suitable for automatic presses, such as the ultra-rapid single-opening ones of the hot/cold type. Fibreboard lamination, by the hot/cold method, using melaminic papers in a single-opening press, has had little success, because of technological difficulties due to the high specific gravity of the panel and the difficulty of exhausting vapours produced during lamination.

Particle board

Since the material is widely used in the laminating process, it is especially necessary to carefully monitor quality. In addition to meeting the various national standards (for example DIN 52360), the panel to be laminated must have the requisite range of properties, so that once processed it may again meet national standards, and be acceptable to the end user. Some of these properties are:

(a) The specific gravity must be constant throughout and never less than 0.65;

(b) The surface structure must be absolutely uniform for the application of light papers (about 40 g/m²). The surface must have light colour or be easy to paint. The panel should be very thin and, if possible, contain only wood of the same species;

(c) The surface must be free of dust, grease, paraffins, glue stains etc. and smooth (grain minimum 120). It must not have the "beating" marks of abrasive paper;

(d) Thickness must be even (tolerance ± 0.1 mm);

(e) The board must have a perfectly balanced structure and the resin content at the surface not less than 12 per cent.

Due to wood shortages particle boards are manufactured with wood waste, including bark, which makes the surface quite uneven, not very pleasant from an aesthetic point of view and of poor physical-mechanical properties. In order to avoid such drawbacks, research is being carried on, in pursuit of economically and technically valid solutions, such as the use of "filling-pores" papers, described later.

Laminating materials

The following papers are used in the laminating process:

(a) Papers impregnated with melamine or modified melamine resins. For the hot/cold and hot/hot processes. The weight of the raw papers is usually 80-120 ;

(b) Papers impregnated with melamine or melamine modified with urea resin. For the hot/hot process. The weight of the raw papers is usually 80-120 g/m²;

(c) "Pore filling" papers (two types) impregnated with urea, which are applied with glue or are self-adhesive. The weight of non-self-adhesive paper is 125-220 g/m². The temperature used is about 120°C, the pressure 18 kgf/cm² and time required about 120 s. The weight of self-adhesive paper is 90-200 g/m². The temperature used is about 160°C; the pressure 12-18 kgf/cm²; and time required about 90 s;

(d) Papers impregnated with melamine or modified melamine resins. They are bonded with urea- or vinyl-based glues. The weight of raw papers is about 120-180 g/m²;

(e) Light papers impregnated with urea or urea modified by acrylic resins, which may or may not be intended to have polyester resins spread on to the surface. These papers will be applied on to the surface to be laminated, and may be (or not) then lacquered. The weight of the paper is about 30-40 g/m²;

(f) Papers impregnated with melamine, urea/acrylic resins, including "hot-melt" spreading, for direct application under the press. Pressing time (provided that spread resins are already bakelized) is about 2 s; the weight of raw papers is 90-150 g/m²; and pressure is about 10 kgf/cm². The temperature depends on "hot-melt" type, but usually it is about 150°C;

(g) Papers impregnated with urea/acrylic resins and micro-pearls of acrylic resins, applied according to a vacuum penetrating system. The weight of raw paper is 90-120 g/m² (it is possible to use lighter papers).

All these papers (except the already bakelized melamine ones) may be pressed with die plates, simulating wood pores. Pores may be embossed, during the impregnating process, on papers impregnated with modified acrylic resins. Pores may be impressed later by means of suitable calenders, or during the laminating process, by either a calender, or in a press using die plates or embossing sheets. Several varieties of each paper exist; their use depends on the board, its end-use, and on specific properties, with due regard to manufacturing cost and final price.

Systems and trends in paper application

There are four different systems for particle board lamination.

System 1

Manufacturing impregnated papers
Manufacturing particle board
Manufacturing decorative laminate
Cold or hot coating with the decorative laminate

System 2

Manufacturing impregnated papers
Manufacturing particle board
Hot/cold or hot/hot laminating

System 3

Manufacturing impregnated papers
Manufacturing and simultaneous lamination of particle board with impregnated papers

System 4

Manufacturing of impregnated or spread papers
Manufacturing particle board
Coating with impregnated or spread papers

Lamination with decorative laminates (system 1) must be done almost without exception on flat surfaces, due to the high operating cost. Simultaneous lamination (system 3) is developing slowly, due to technological difficulties and rejection is common. However, lamination, with impregnated papers and subsequent coating of the boards in press (system 4), has had considerable technological evolution. Among the important technological improvements are those in resins; raw (not impregnated) and impregnated papers; technology in paper setting; and manufacturing plants for this process.

The ever-growing need for laminated products in many fields has required changes in the standards for surface properties. Some of these (DIN 68754) are still not yet observed. The need for definitions of quality and of price and quality expected are strongly debated with regard to end-use. Actually, only the market-place will decide the matter, and technicians will establish new standards, concerning surface characteristics and developments in the industry.

Interest in the lamination process is shown by statistics. Whereas the number of boards veneered with natural wood is decreasing, the number of laminated boards is increasing. Furthermore, about one quarter of all particle board production is laminated. Continuous progress has been made in the development and technology of this process.

Technologies for lamination and new plant development

Lamination with decorative laminates

Lamination with decorative laminates is one of the oldest direct application systems for decorative laminates on to particle board or on to wood-based panel surfaces. Coating is imparted to both sides to avoid bending. One surface is covered with high quality material. The other surface is backed with material which acts as a stress equalizer. Application is very simple (figures 1, 2 and 3).

The sandwich is set up on the brass grating belt. The sandwich consists of a decorative laminate, a glue spread particle board (with urea or PVA and PVC copolymers-based adhesives) and then another laminate. The sandwich is then fed into the press. The press temperature is 100°-140°C; pressure is 5 to 10 kgf/cm^2. The time required for pressing depends on the type of adhesive, the temperature, and the laminate's thickness. The time usually is less than 90 seconds. After the press hot cycle the panel is removed by a hoist or, if the press is the veneering type, by the same loading belt.

This system is used to impart particular surface characteristics, corresponding to standards such as NEMA LD1-1-01, DIN 53799 or similar ones. By using a single opening press, shown in figure 3, it is possible to also do hot/cold lamination, as the press can operate at 25 kgf/cm^2.

Hot/cold laminating system

This process, illustrated in figure 4, is carried out in multi-opening presses. Impregnated papers are applied to both surfaces of the particle board. Two papers are applied to each surface to create better surface uniformity and to cover possible structural faults of the board. Papers in contact with the panel are the sub-layer type, impregnated with phenolic or melamine resins, whereas the surface papers are impregnated with melamine resins. The sandwich (decorative paper, sub-layer, particle board, sub-layer, decorative paper) is placed between stainless steel cauls covered with a "cushion" and then fed into the press by infeed conveyer elements (in some plants the top cushioned stainless steel cauls are fixed in the press).

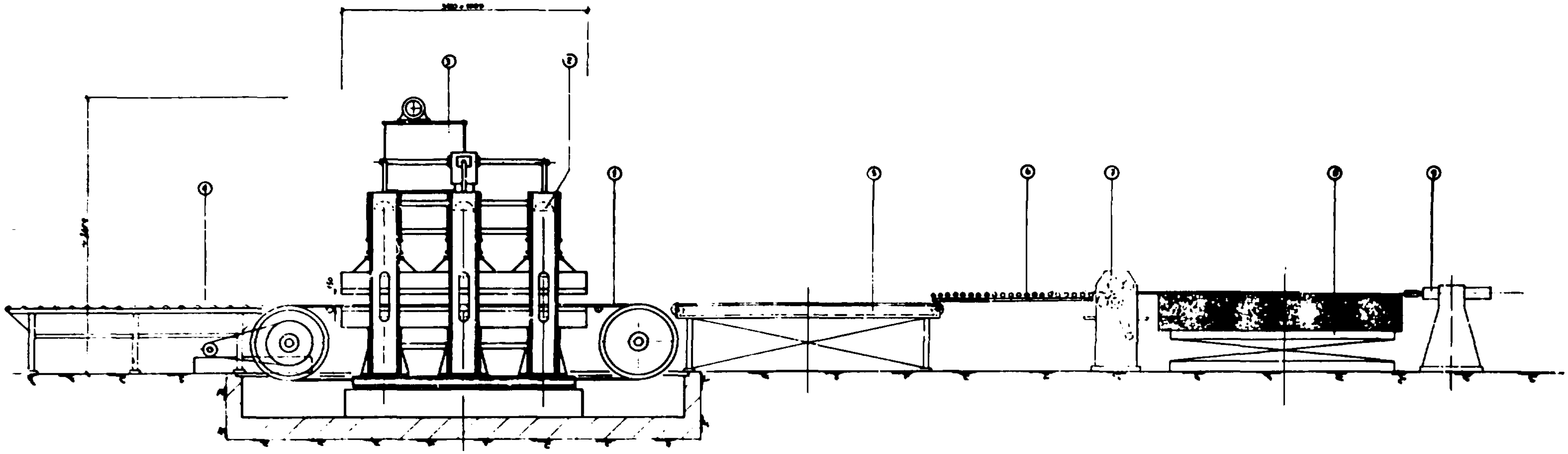
Pressing conditions are: pressure is 18 to 22 kgf/cm^2 and pressing time is dependent on the type of resin. The total cycle usually varies from eight to twenty minutes. Table 1 outlines some basic data with regard to papers.

Resin content of decorative papers, used without overlay, depends on their basic weight. Low weight papers need a higher percentage of resins, to assure a good fluidity on the surfaces subjected to pressure.

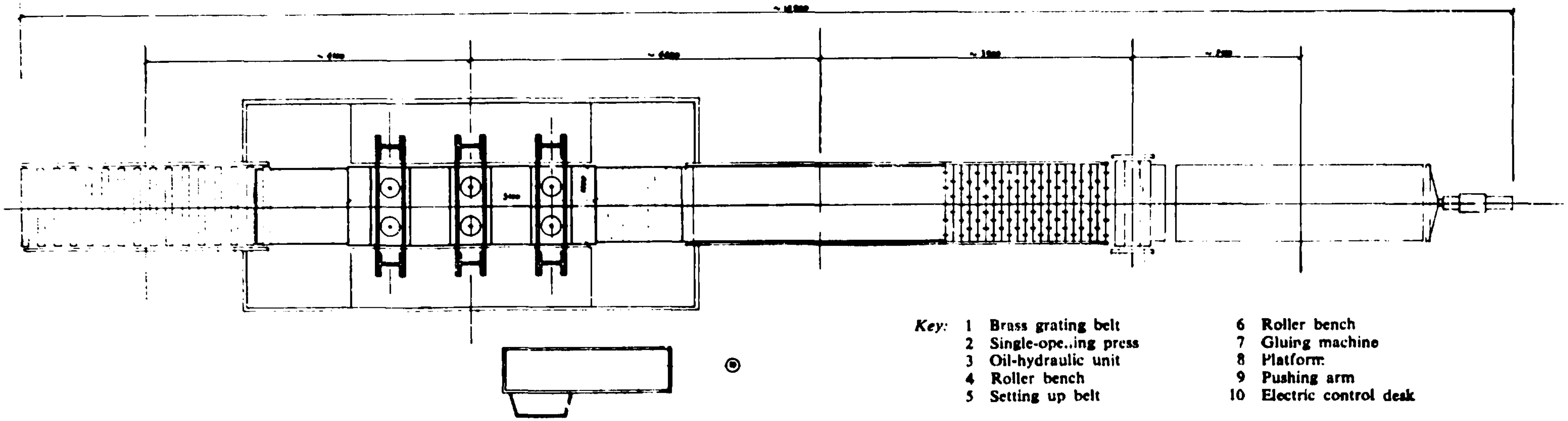
Pressing cycles depend on many considerations such as panel type and thickness, temperature of the laminated surfaces, types of papers and resins, pressure used, manufacturing plant etc. Figures 5 and 6 show temperature versus time relationships for hot/cold cycles.

The hot/cold process may be used with a "tandem" system, consisting of two presses. In the first, heating and curing are done under standard conditions. The second press cools. In this manner it is possible to shorten cycles to approximately 6 minutes, saving about 30 per cent of the total energy.

Figure 1. Pressing line with single-opening hot-press

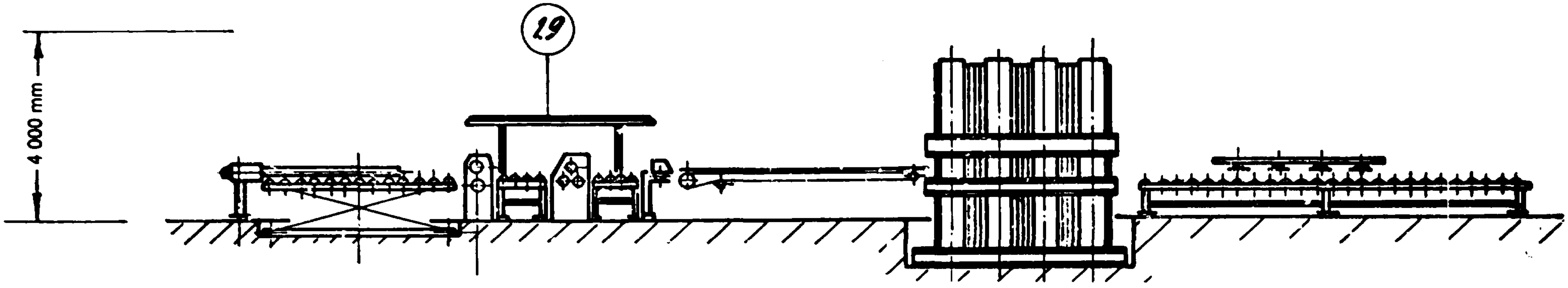


A. Front view

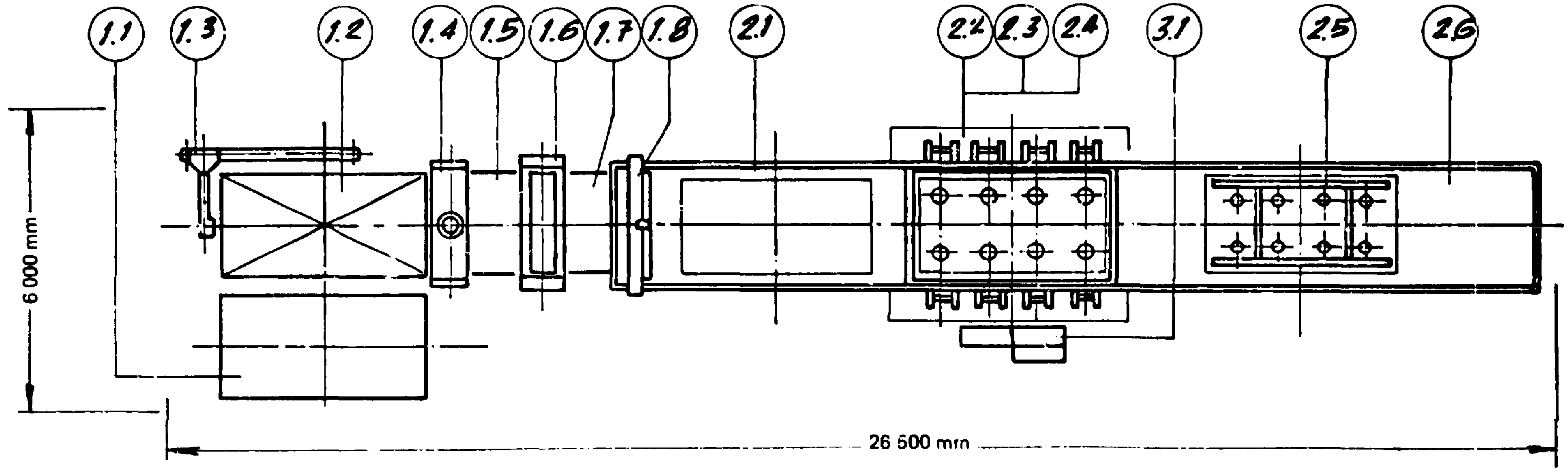


B. Top view

Figure 2. Pressing line with single-opening press



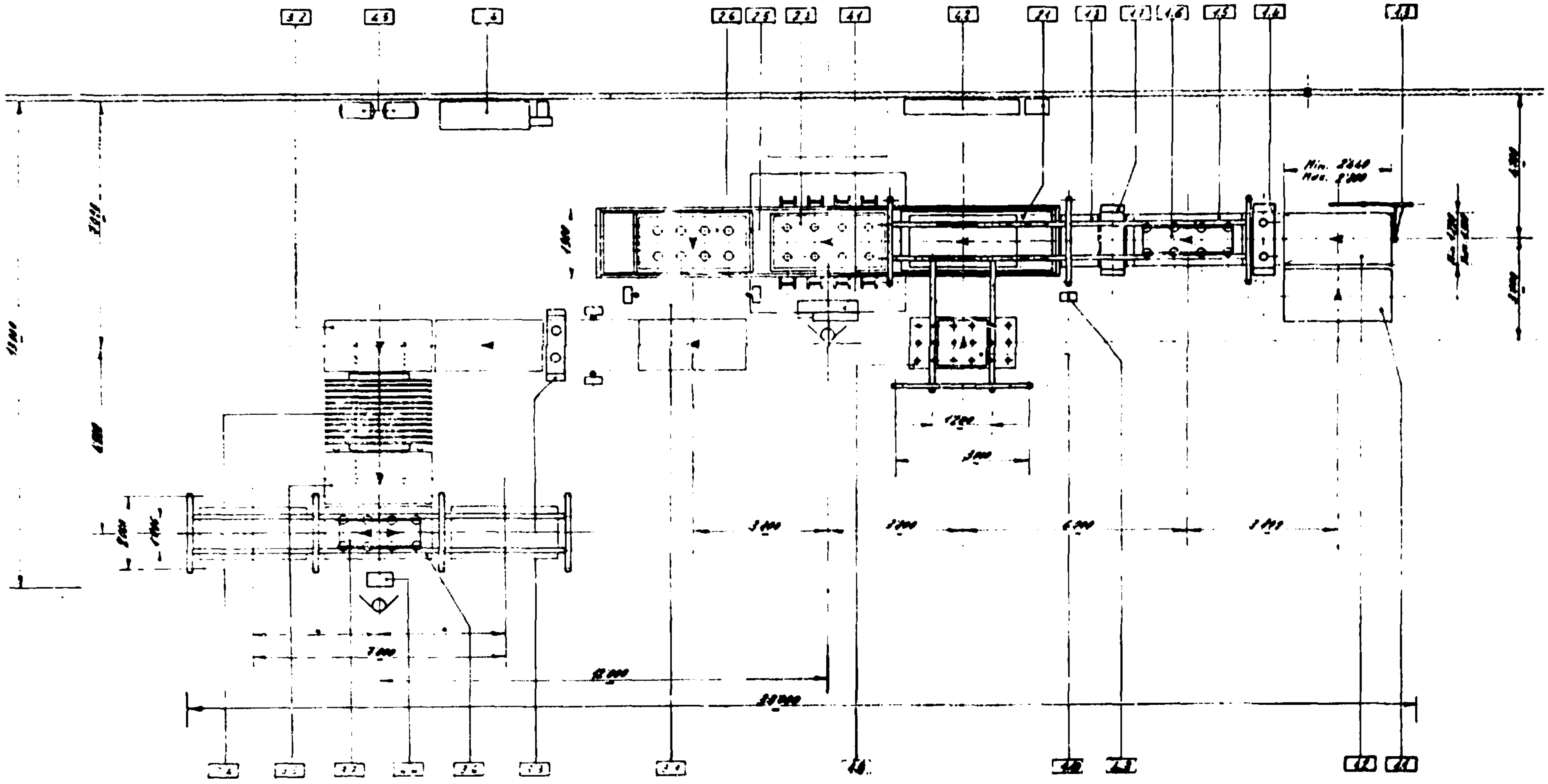
A Front view



B. Top view

Key: 1.1 Bench with motor-driven rollers
1.2 Lifting table with bench with motor-driven rollers
1.3 Pneumatic pushing device
1.4 Brushing machine
1.5 Bench with discs
1.6 Gluing machine
1.7 Bench with discs
1.8 Truck with pliers
1.9 Table for papers
2.1 Inserting truck
2.2 Single opening press
2.3 Hydraulic station
2.4 Sheet stretching devices
2.5 Extracting truck
2.6 Bench with motor-driven rollers
3.1 Control desk

Figure 3. Pressing line with single-opening press for veneering and short-cycle lamination



A. Top view

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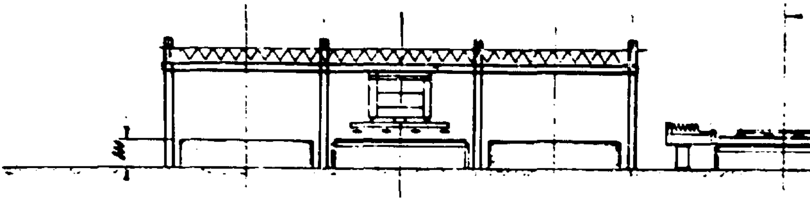
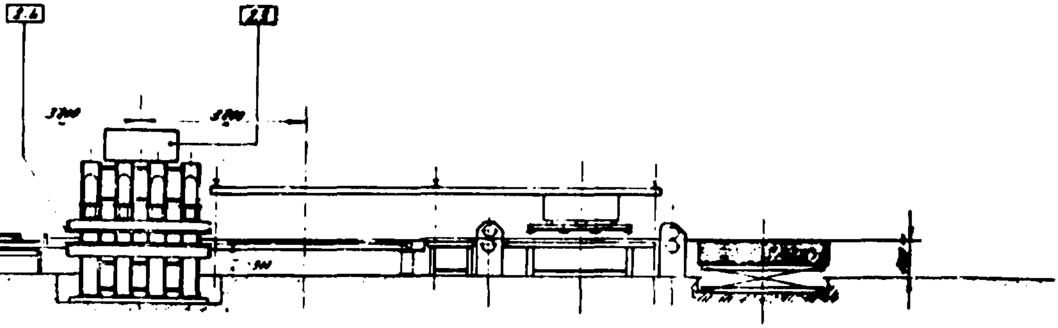


Key: 1.1 Motor-driven roller bench
2 Lifting table with motor-driven rollers
3 Pneumatic pusher
4 Brushing station
5 Bench with motor-driven wheels
6 Vacuum hoists station for board loading
7 Gluing machine
8 Bench with lamellar motor-driven wheels
9 Laying truck for papers and veneers
10 Vacuum hoists for papers and veneer loading
2.1 Feeding truck
2 Single-opening press
3 Oil-hydraulic station
4 Stretching devices for stainless steel sheets
5 Extracting truck with vacuum hoists
6 Pneumatic lifting frame

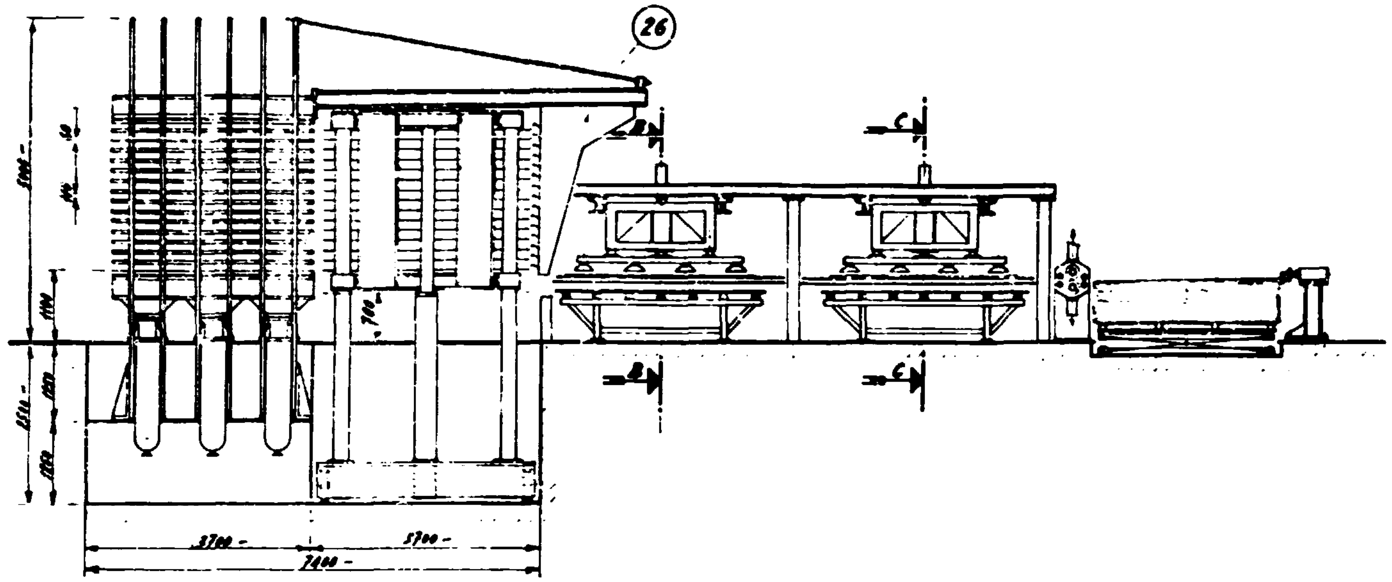
Figure 3 (continued)



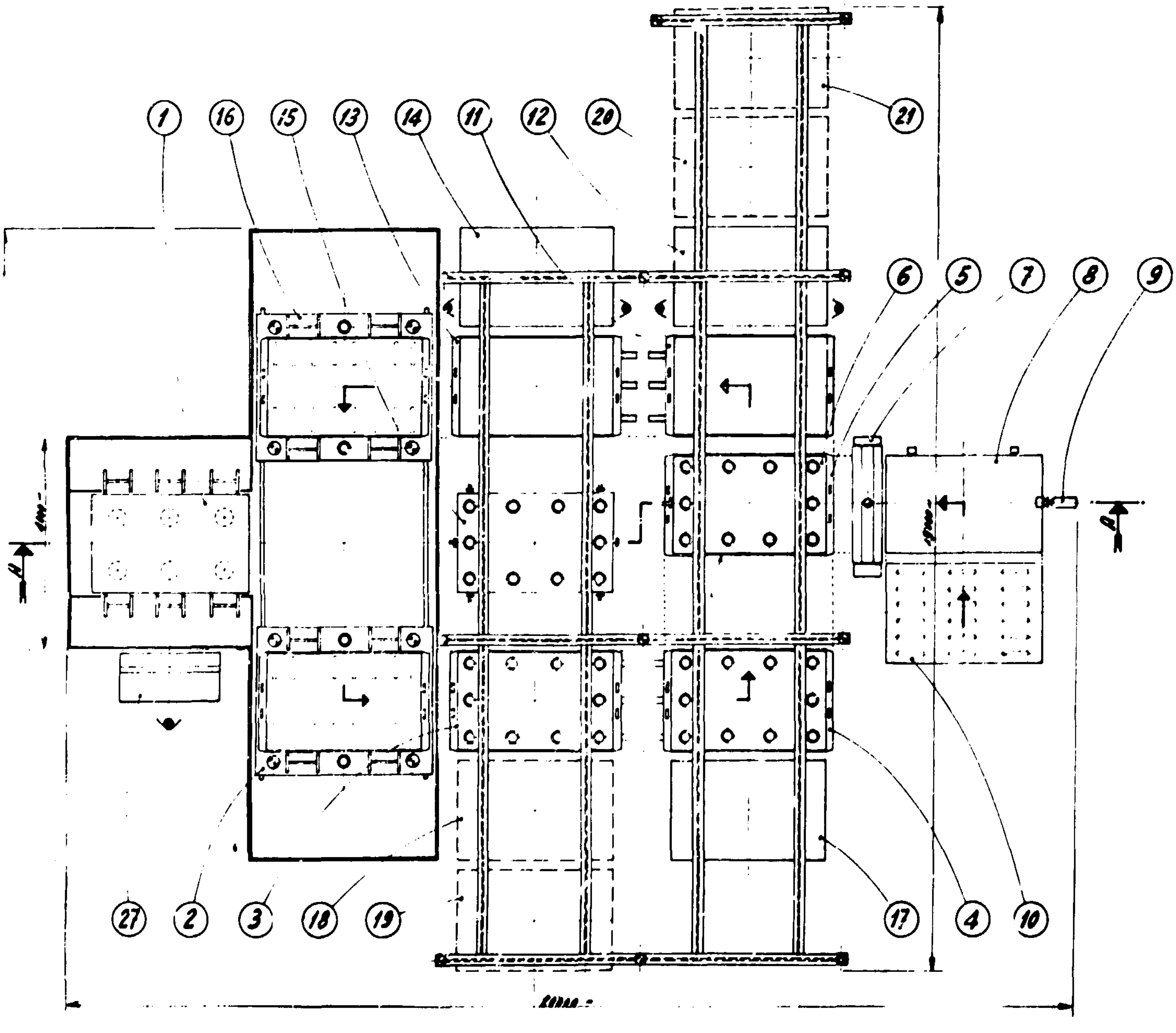
B. Side view

3.1 Motor-driven bench with trimming heads
2 Motor-driven bench with trimming heads
3 Brushing station
4 Boards tipper-cooling device
5 Idle wheels bench with pusher
6 Bench with idle wheels
7 Station of selecting vacuum hoists
4.1 Electric control desk
2 Electric cellular type board
3 Push button box for control of feeding the vacuum hoist
4 Push button box for control of selecting vacuum hoist
5 Vacuum pumps
6 Exhauster filter unit

Figure 4. Layout for a short cycle hot/cold laminating system



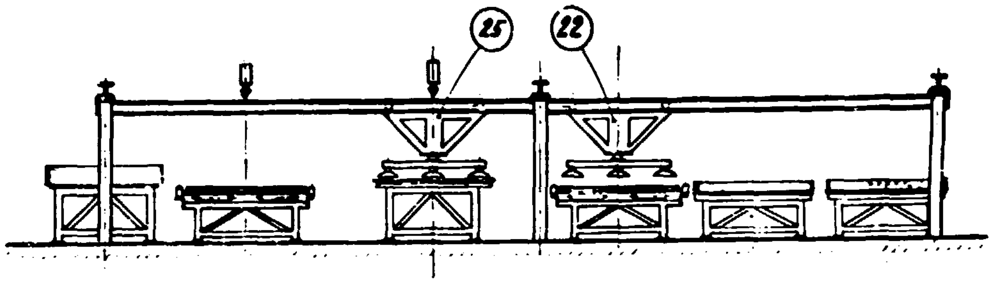
A. Section A-A



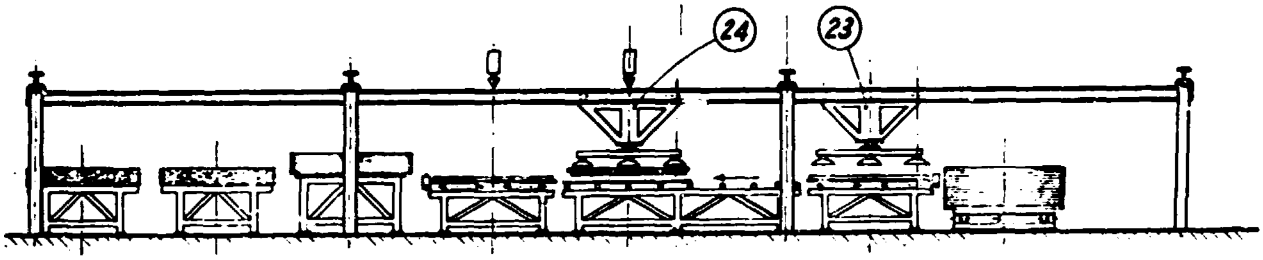
B. Top view

[Continued on next page.

Figure 4 (continued)



C. Section B-B



D. Section C-C

Key:
1 Press 3,150 mm × 1,930 mm
2 Lift—unloading truck
3 Bench for upper stainless steel stripping
4 Bench for stripping finished boards
5 Caul plate waiting station for first setting
6 Fixed frame for centring rough boards
7 Brush for cleaning rough boards
8 Rough board feed
9 Pusher for feeding rough boards
10 Frame with motor-driven rollers
11 Bench for first setting
12 Table for lower papers
13 Bench for second setting
14 Table for upper papers
15 Table for centring upper stainless steel plates
16 Lift—loading truck
17 Finished board stacking table
18 Upper stainless steel plate picking up hoist
19 Upper stainless steel plate stacking table
20 Lower stainless steel plates picking up table
21 Lower stainless steel plates stacking table
22 Vacuum station for stripping upper stainless steel plates
23 Vacuum station for stripping finished boards
24 Vacuum station for setting rough boards
25 Vacuum station for setting upper stainless steel plate
26 Loading and unloading pushing arm
27 Press control desk

TABLE 1. CHARACTERISTICS OF LAMINATING PAPERS

Paper type	*Resin content* (%)	*Volatility* (%)[a]	*Fluidity*[b] (%)	*Resin type*
Overlay, white	66-68	5-6.5	15-20	Melamine
Overlay, colour	72-74	5-6.5	18-25	Melamine
Decorative	54-60	4-5.5	0.8-1.8	Melamine
Barrier	56-59	4-5	2-3	Melamine
Kraft, 150 g/m²	38-40	7-10	7-10	Phenolic
Kraft, 60 g/m²	31-34	5-7	2-2.5	Phenolic 250 g/m²
Overlay	60-62	5-7	10-15	Phenolic
Underlay, white, 100 g/m²	42-44	5-6	6-10	Phenolic 170-180 g/m²

[a] Volatility is defined as $V = \frac{E-A}{E} \times 100$, where E = weight of impregnated and dry papers and A = weight after drying (postdrying 5 min at 160°C).

[b] Fluidity is weight loss during pressing.

Figure 5. Temperature vs. time for classic process hot/cold

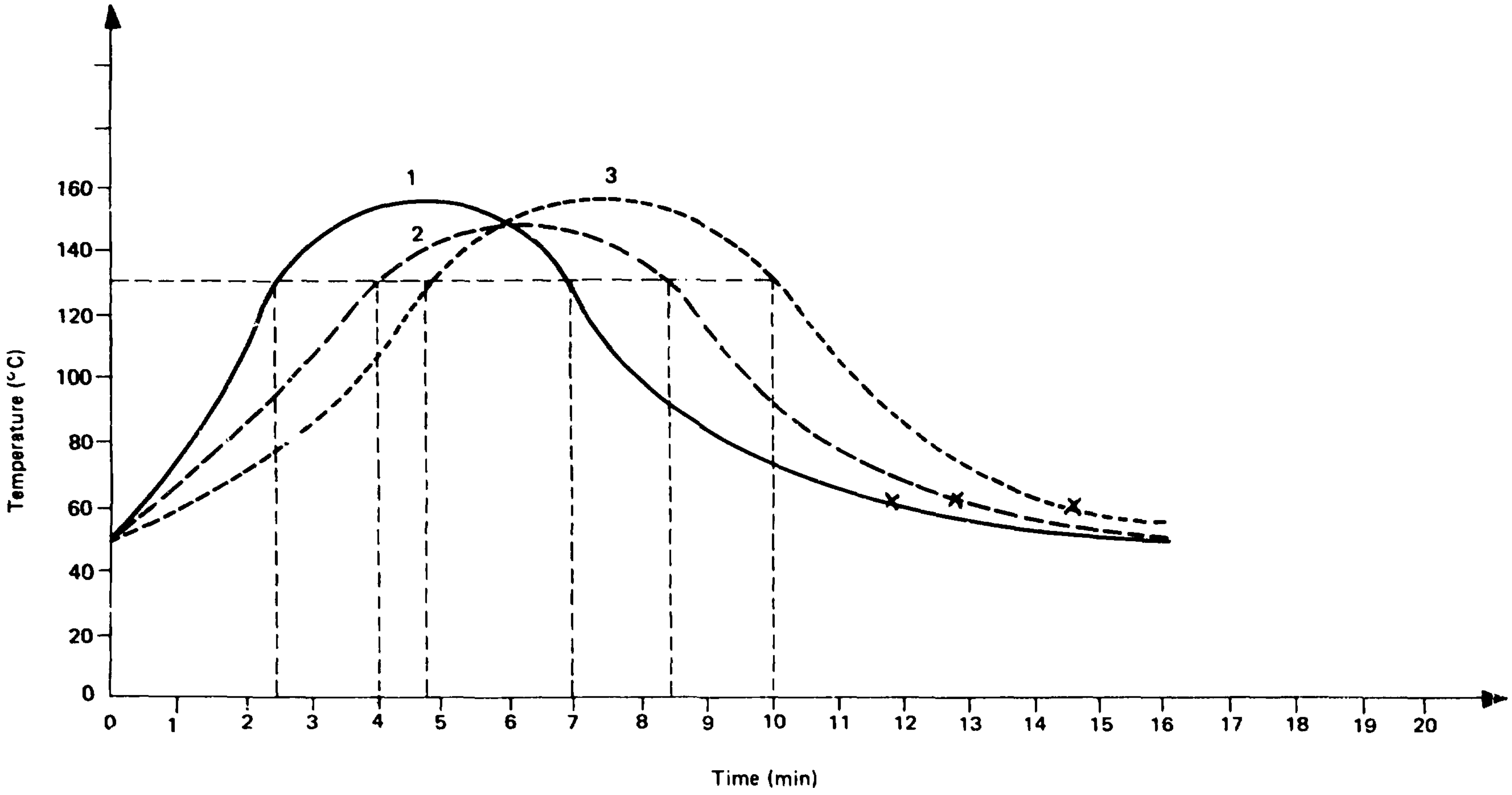
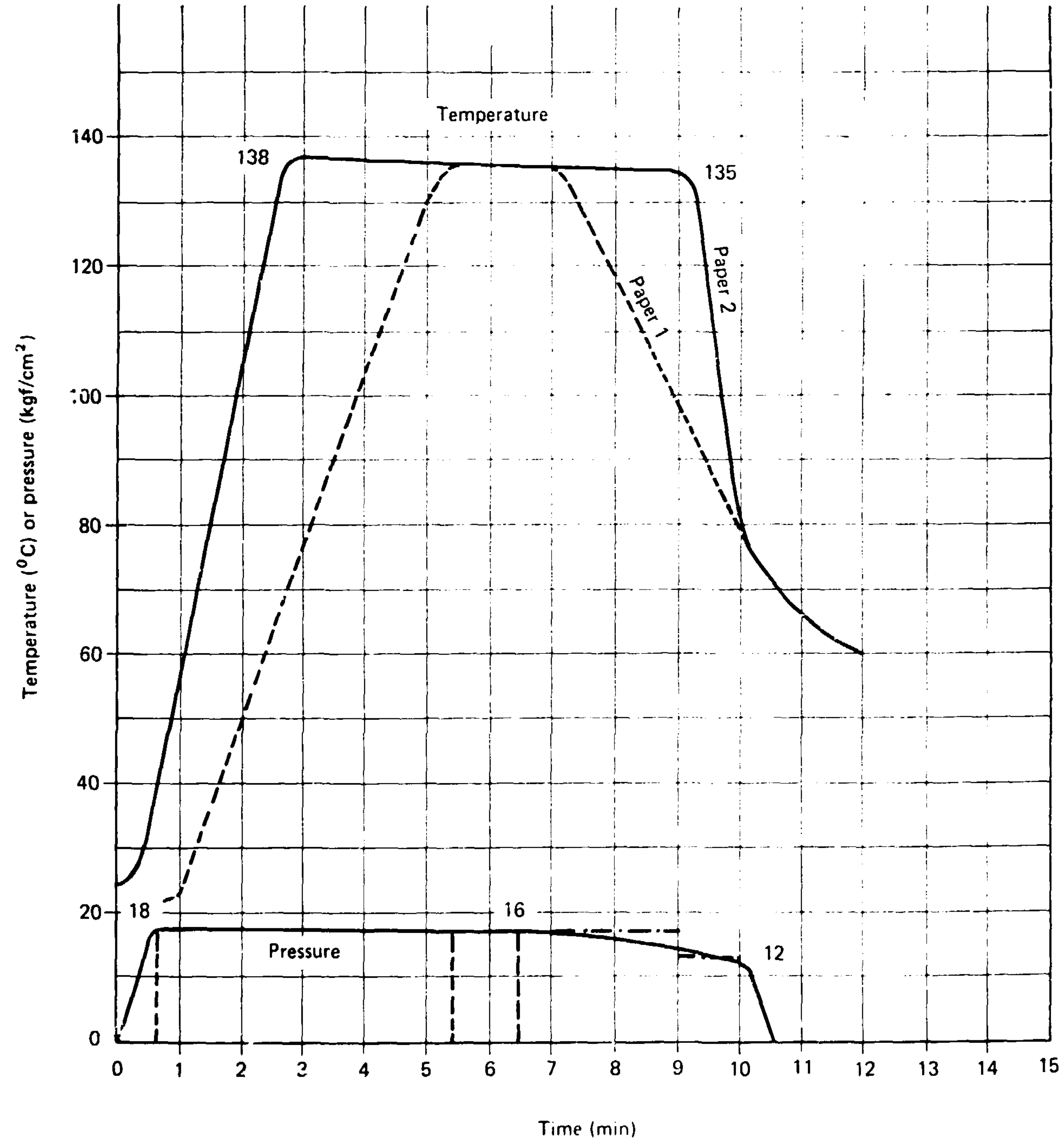


Figure 6. Temperature and pressure vs. time for the hot/cold cycle for two different papers



Laminating processes in single-opening presses (quick hot hot process with conveyer)

The laminating cycle in the single-opening press uses quick setting resins and is very short, about one minute or less. The time depends on the surface temperature, rate of heat transmission (this problem is present in all the plants), resin type, the time the decorative paper remains without pressure in contact with the hot surfaces of sheets, the closing speed of the press, and on the time necessary to reach the maximum pressure. For lamination, impregnated papers are used with melamine resins (modified melamine resins) and diallyphtalic resins which are now very seldom used.

It is possible to laminate particle board with density lower than 0.65, due to the very short time during which it is subjected to the elevated pressures and temperatures. For lamination with melamine

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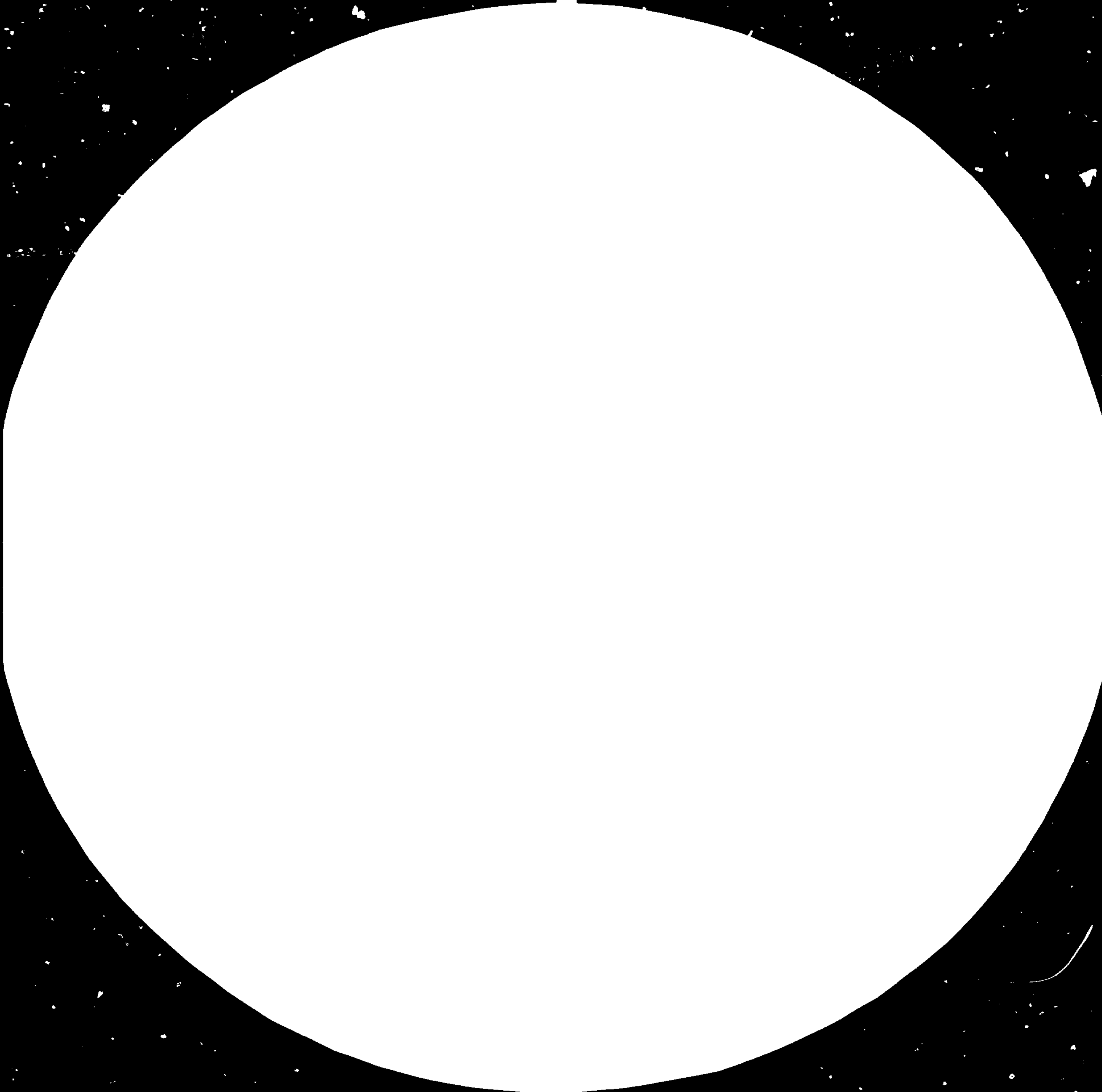
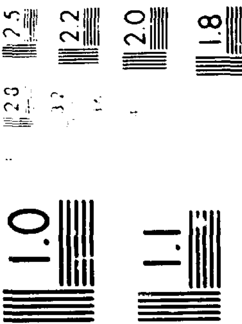



1.0
1.1
1.8
2.0
2.2
2.5


1.25
1.4
1.6

resins, curing times range from 30 s at 180°C to 90 s at 145°C with pressures of 18 to 22 kgf/cm.^{2} (figure 7).

After press loading, it is recommended to r allow the sandwich to contact the hot surface of the platen, if the pressure is applied, for less than 8 s. Otherwise, a premature paper curing will occur. The curing will not be uniform or may be partial, and the surface will have inevitable flaws such as porosity, shadings etc. Some technicians think the time in press, without pressure, should not exceed 20 per cent of the total curing time. This opinion can certainly be challenged, because too high a temperature could generate yellowing and shading in the surface, even if stay time under pressure does not exceed 60 s. After curing and press opening, the board must be unloaded quickly, to avoid overcuring, and then inserted into suitable cooling units, to a temperature less than 60°C. Next a visual control and selection is carried out, for proper storage of the boards.

Figure 3 shows a plant for laminating process with conveyer. The charge is set on a belt, and both are then inserted into the press, where the charge is laid down on the hot surface. When doing this, a difference occurs in touch time with platens' hot surfaces, between one and the other end of the board. This difference amounts to about 4 s, and depends on the board's length.

A variation of this system is shown in figure 8. Here the board, once inserted into the press, is not laid down until the conveyer is drawn back. It remains suspended, on edge, between the two heating platens. At this point, the press closes and the board simultaneously lowers, touching the hot platen, thus avoiding difference in touch time of papers with platens' hot surfaces. This innovation, which appeared recently on the market, increases the productive efficiency by approximately 30-40 per cent and has aroused great interest among laminate producers.

Ultrarapid single-opening press with "drop" loading

In recent years much progress has been made in the development of horizontal presses (as vertical presses have not been developed as quickly as was thought possible). Actually, times of 1.5-2 s to reach half pressure, and dead times of about 16 s, have been obtained. With these times, and using the drop loading system press, it is possible to use papers having bakelizing time of about 18 s and total cycle times held down to 34 s. Currently these presses are capable of producing about 70 boards per hour, depending on the kind of papers and resins which are applied. The resins are modified and accelerated with different hardeners, the action of which is approximately shown in figure 9.

The board is set up and inserted into the press, by a special tray, with arms which release the charge during press closing, thus reducing the contact time of laminating papers to zero (to the platens' hot surface). Complete homogeneity of reaction is therefore obtained in the resins, as the heat effect is simultaneous and even.

Equipment for this system is shown in figures 10 through 14. The types of paper used here differ from those used for the hot/cold system. Their resins content is illustrated in figure 15. Board characteristics should meet the requirements of DIN standard 6875 65.

Hot/hot and hot/cold systems

Positive features of the hot/hot system include:

(*a*) The ability to laminate boards of low specific gravity, without loss of thickness (always for climatized boards);
(*b*) Much lower energy consumption (about 8 times less);
(*c*) Lower initial investment;
(*d*) Easier maintenance;
(*e*) Less labour.

The increase in productivity will depend on the plant.

Negative features in hot/hot system include:

(*a*) The inability to obtain gloss surface (at least with current technology);
(*b*) Stringent processing control required;
(*c*) The need in more sophisticated plants to avoid long touch times;
(*d*) The inferior properties of laminated surface (lower abrasion, staining resistance).

Figure 7. Approximate temperature and pressure vs. time for hot/cold lamination

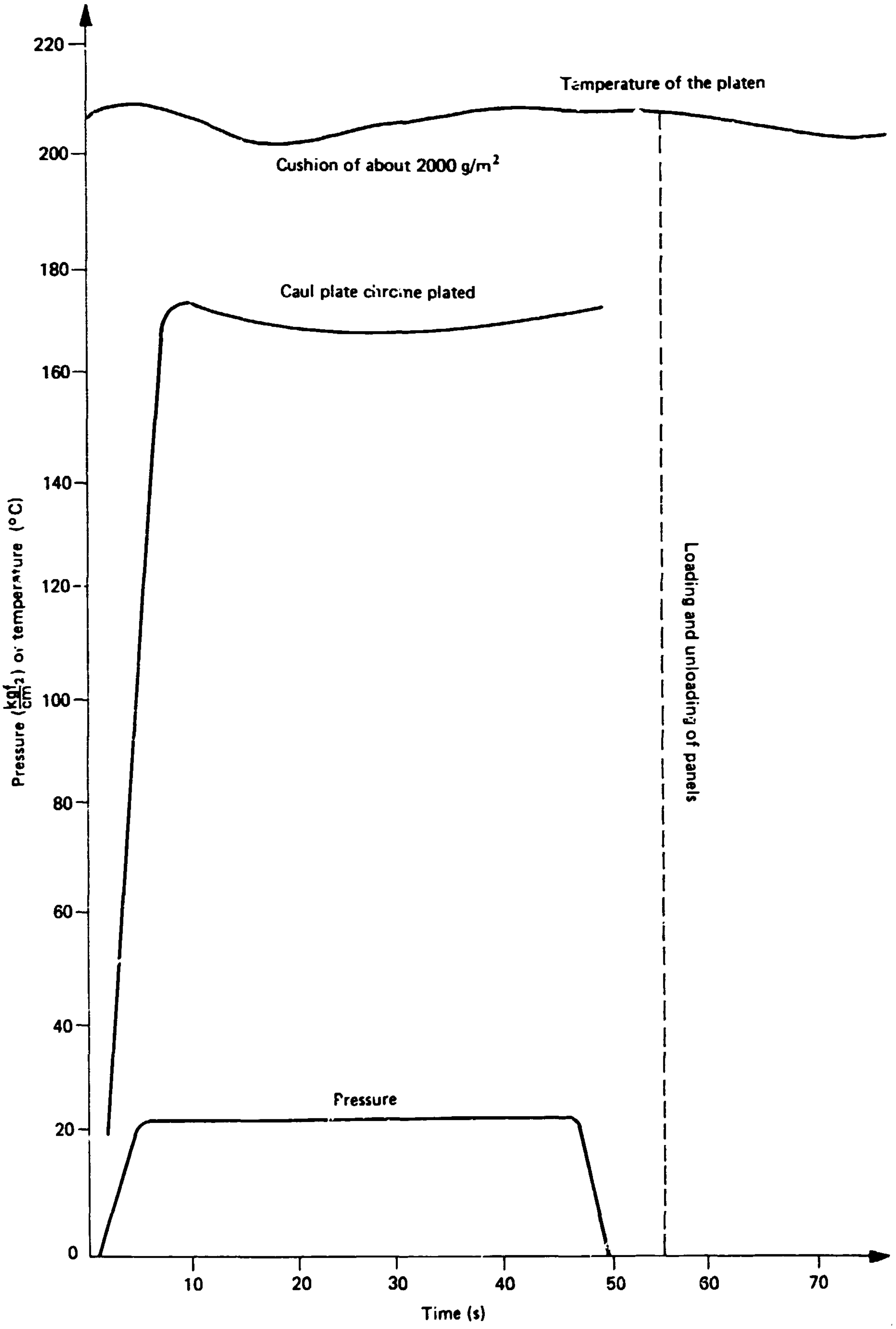
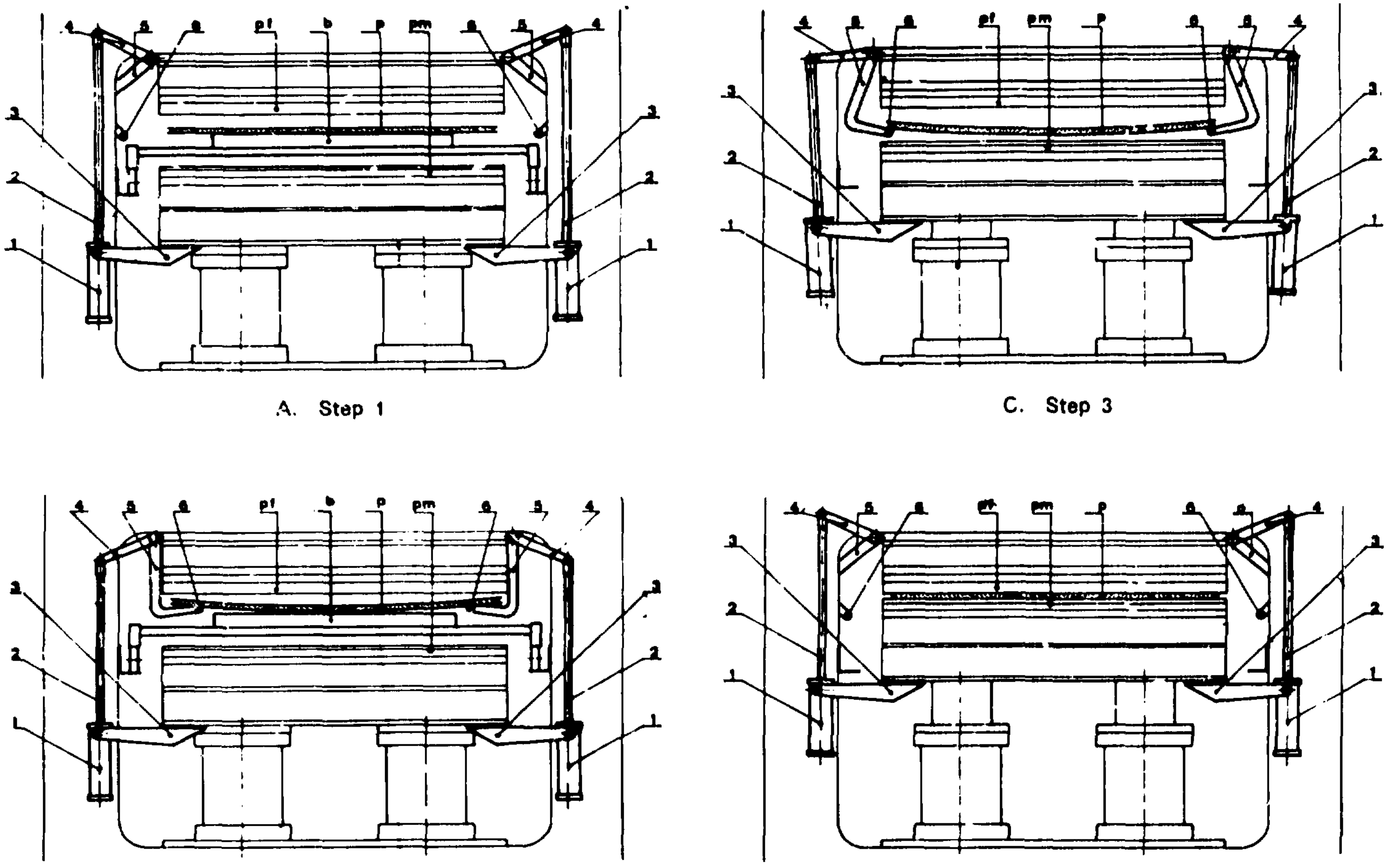


Figure 8. A pressing cycle using a modified belt tray



A. Step 1

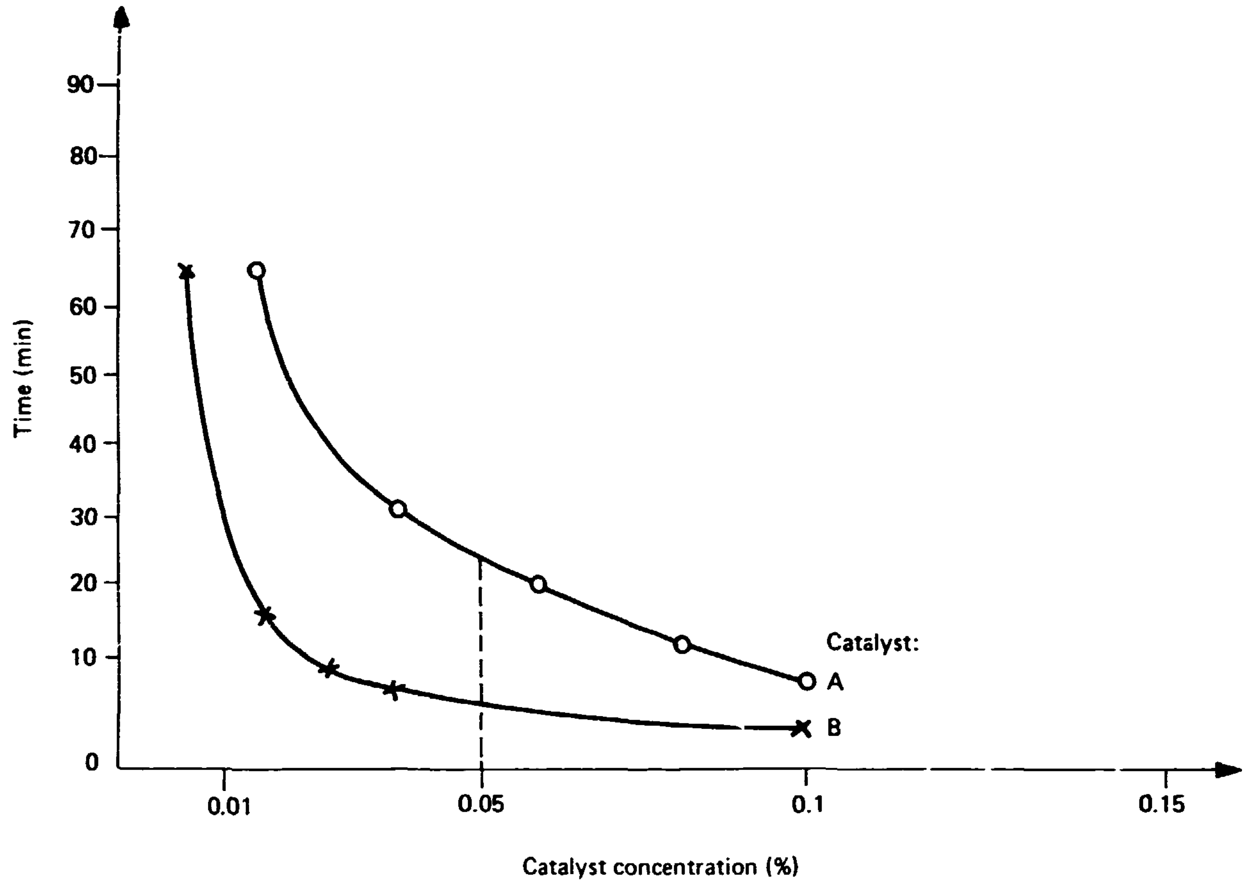
C. Step 3

B. Step 2

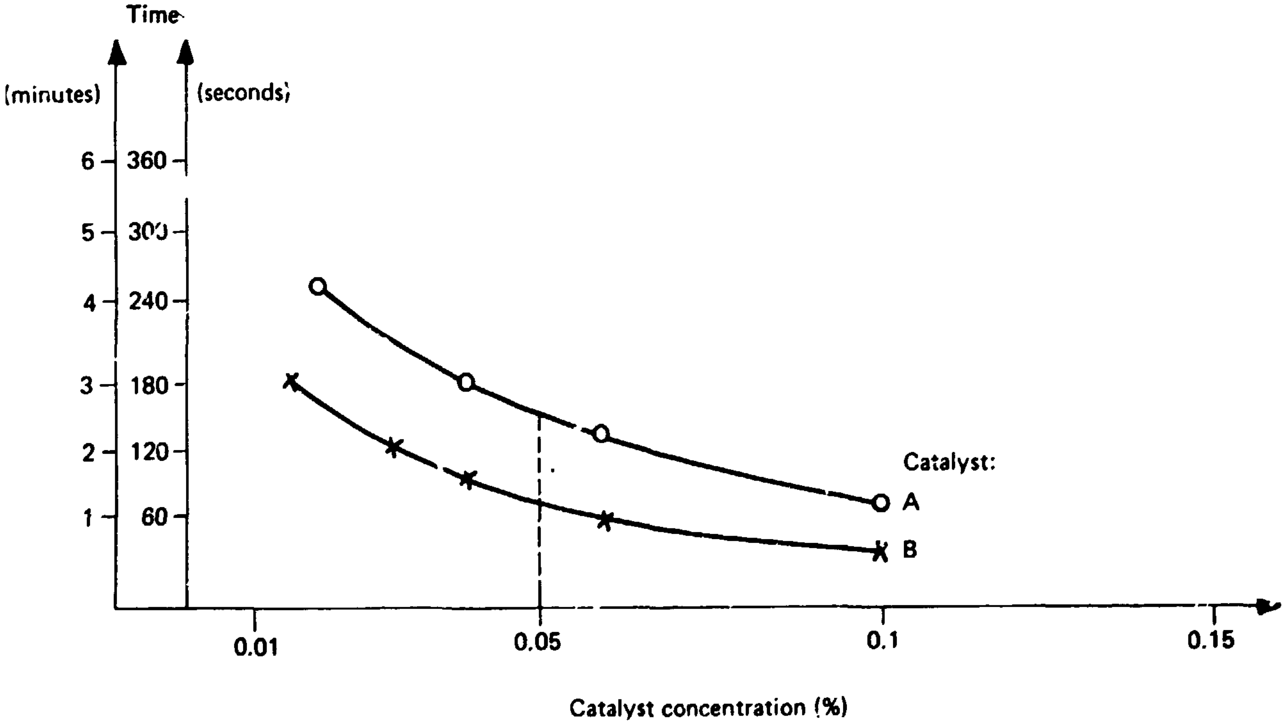
D. Step 4

Key:	1	Pneumatic cylinders	6	Board supporting roller
	2	Cylinder rods	pf	Upper plate
	3	Cylinder support	pm	Lower plate
	4	Upper lever	p	Board
	5	Lower lever	b	Infeed device

Figure 9 Time to reach standard optical turbidity vs. catalyst concentration. Concentration of resin solution 50%

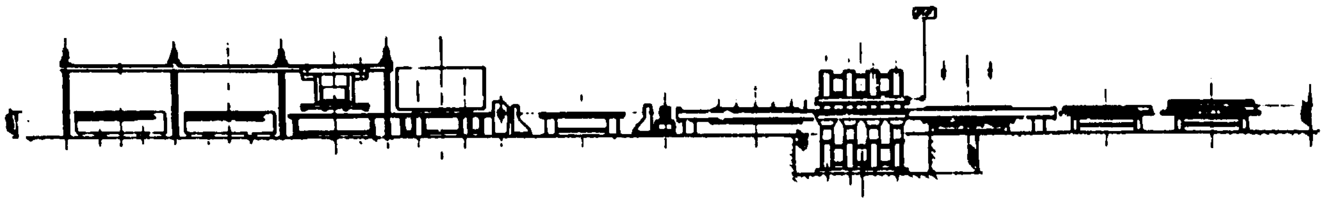


A. *Turbidity time at a temperature of 100°C*

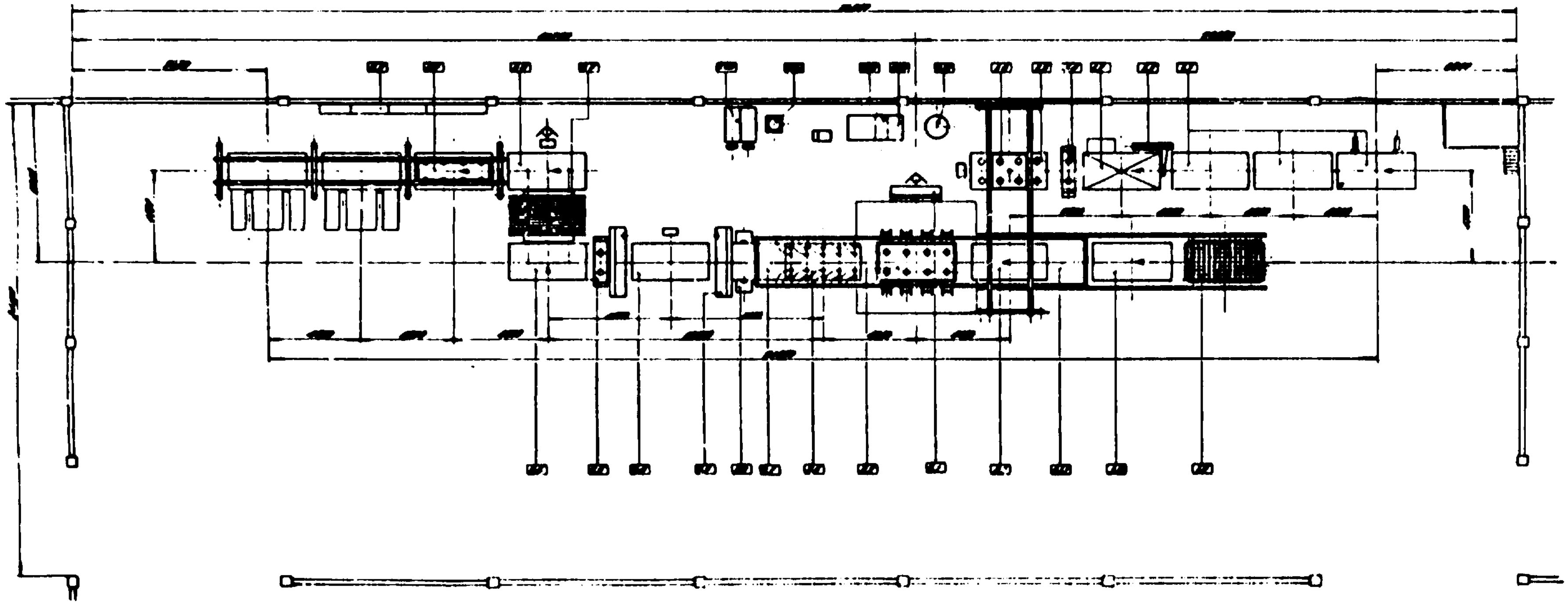


B. *Turbidity time at a temperature of 140°C*

Figure 10. Ultrarapid single opening press with drop loading system



A. Side view



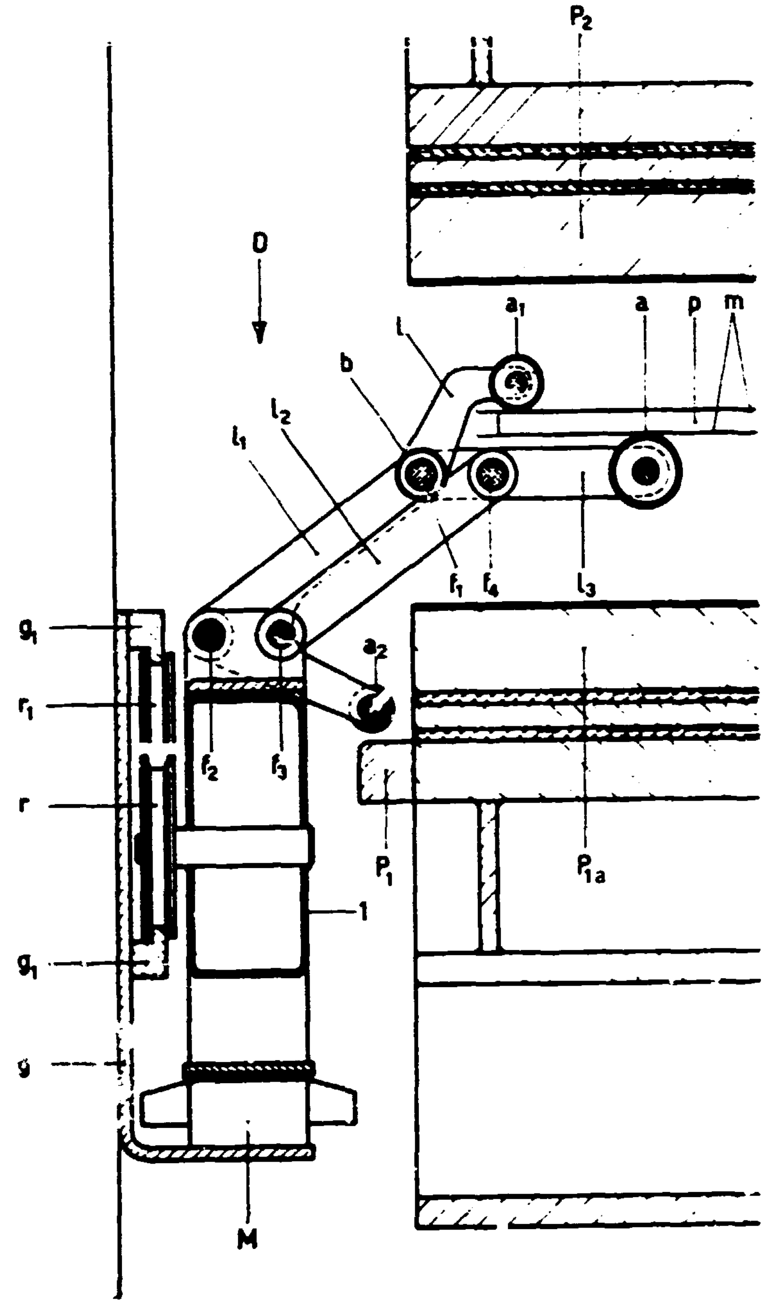
B. Top view

Key: 1.1 Bench with motor-driven rollers
2 Lifting table with motor-driven roller surface
3 Pneumatic pusher
4 Rough paper brushing station
5 Motor-driven roller bench with centring device
6 Board loading vacuum station
9 Paper longitudinal loading vacuum station
10 Micrometric lifting bench

2.1 Loading equipment
2.1.1 Board preparation bench
2.2 Single opening press
2.3.1 Low pressure accumulator
3.2 Centrifugal pump
3.3 High pressure accumulator
3.4 Hydraulic piston pump
3.5 Hydraulic station tank
2.4 Sheet stretching devices

2.5 Extracting truck with vacuum hoists
3.1 Idle roller bench with chain pusher
2 Trimming heads for long sides
3 Moveable trimming heads for short sides
4 Trimming bench with motor-driven rollers
5 Finished board brushing station
6 Bench with motor-driven rollers after brushing station

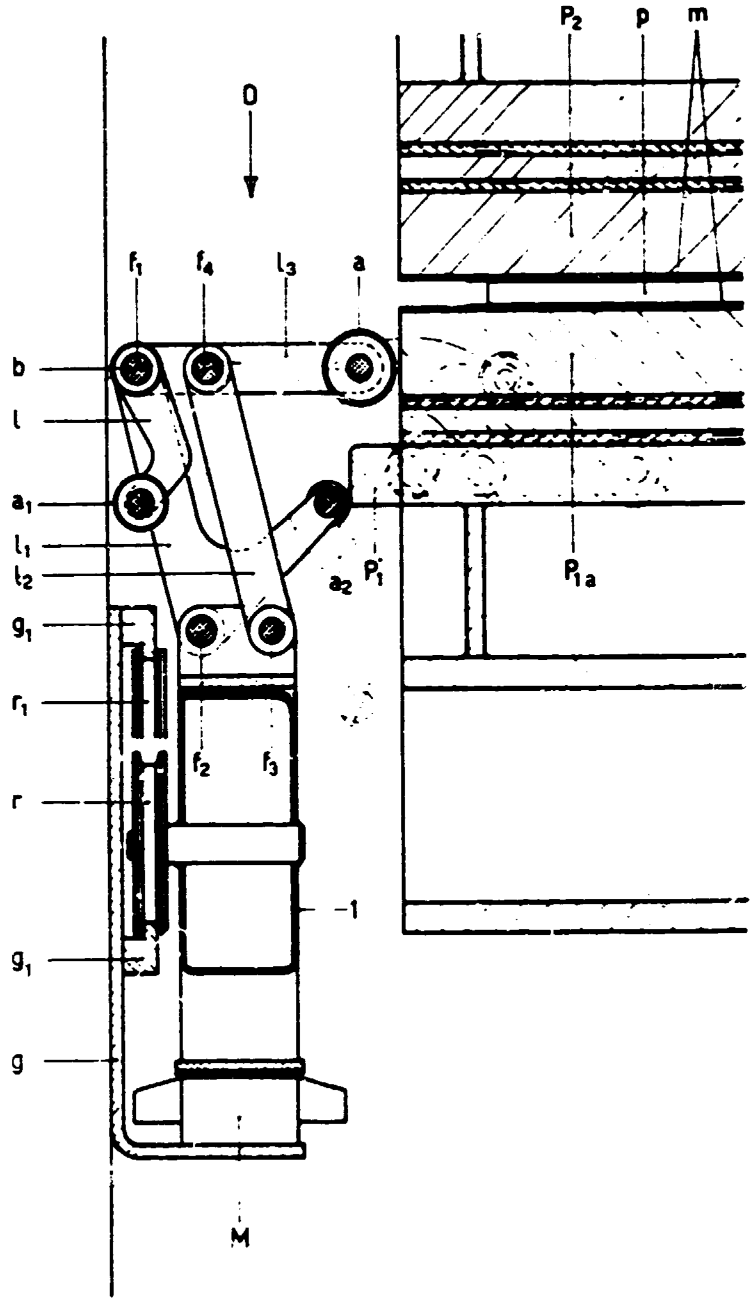
Figure 11. Ultrarapid single opening press with drop loading system while loading



Key:

a	Board supporting rollers	l_1	Lever
a_1	Pressing rollers	l_2	Lever
a_2	Ball bearings	l_3	Pair of levers
b	Rotating cylinder	m	Melamine papers
f_1	Levers pivot	p	Board
f_2	» »	D	Groups of levers
f_3	» »	M	Linear motors
f_4	» »	P_1	Movable locator
g	Guides	P_{1a}	Lower platen
g_1	Truck guides	P_2	Upper platen
l	Lever of rotating cylinder		

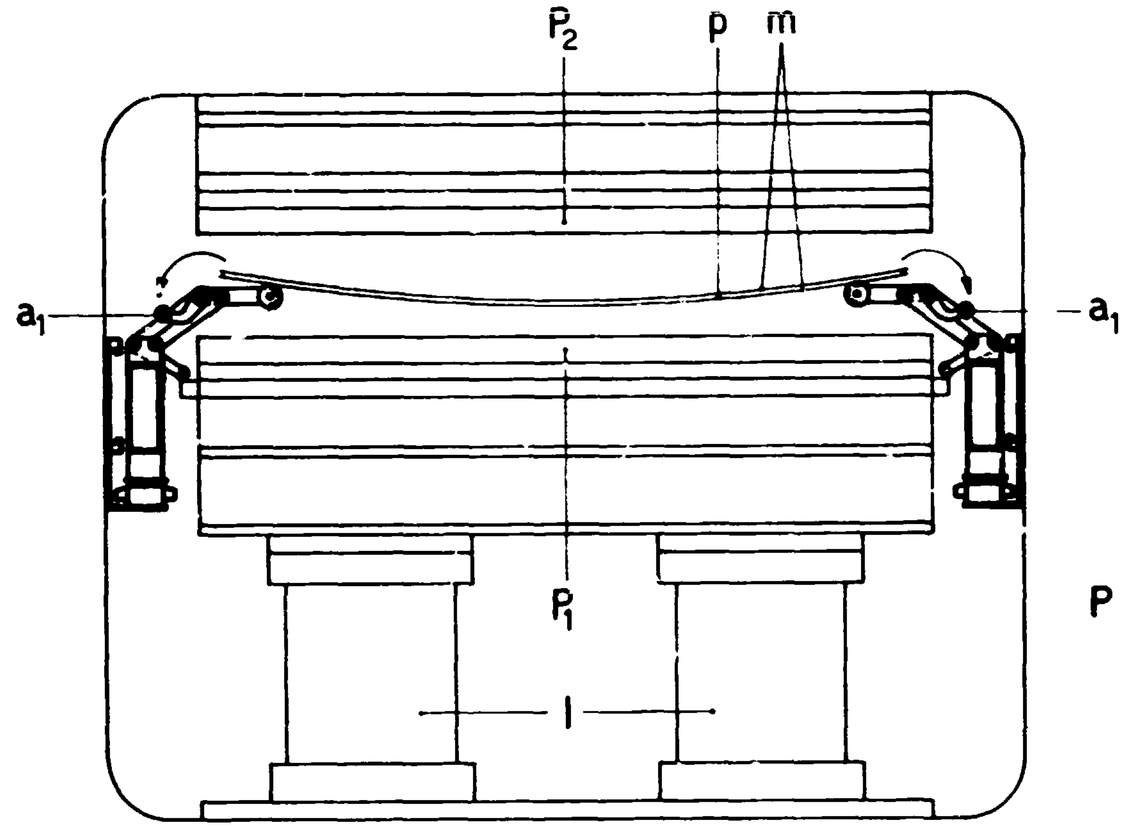
Figure 12. Ultrarapid single opening press with drop loading system showing pressing
(Compare with figure 11)



Key:

a	Board supporting rollers
a_1	Pressing rollers
a_2	Ball bearings
b	Rotating cylinder
f_1	Levers pivot
f_2	» »
f_3	» »
f_4	» »
g	Guides
g_1	Truck guides
l	Lever of rotating cylinder
l_1	Lever
l_2	Lever
l_3	Pair of levers
m	Melamine papers
p	Board
D	Groups of levers
M	Linear motors
P_1	Movable locator
P_{1a}	Lower platen
P_2	Upper platen

Figure 13. Ultrarapid single opening press with drop loading: loading cycle



Key: a_1	Pressing rollers	I	Hydraulic cylinders
m	Melamine papers	P	Press
p	Board	P_1	Lower platen
D	Groups of levers	P_2	Upper platen

Positive features of the hot/cold system include:

(*a*) The ability to obtain the preferred finish (satin or gloss);
(*b*) Superior mechanical surface properties (abrasion, impact, staining resistance);
(*c*) A much easier and safer process.

Negative features in the hot/cold system include:

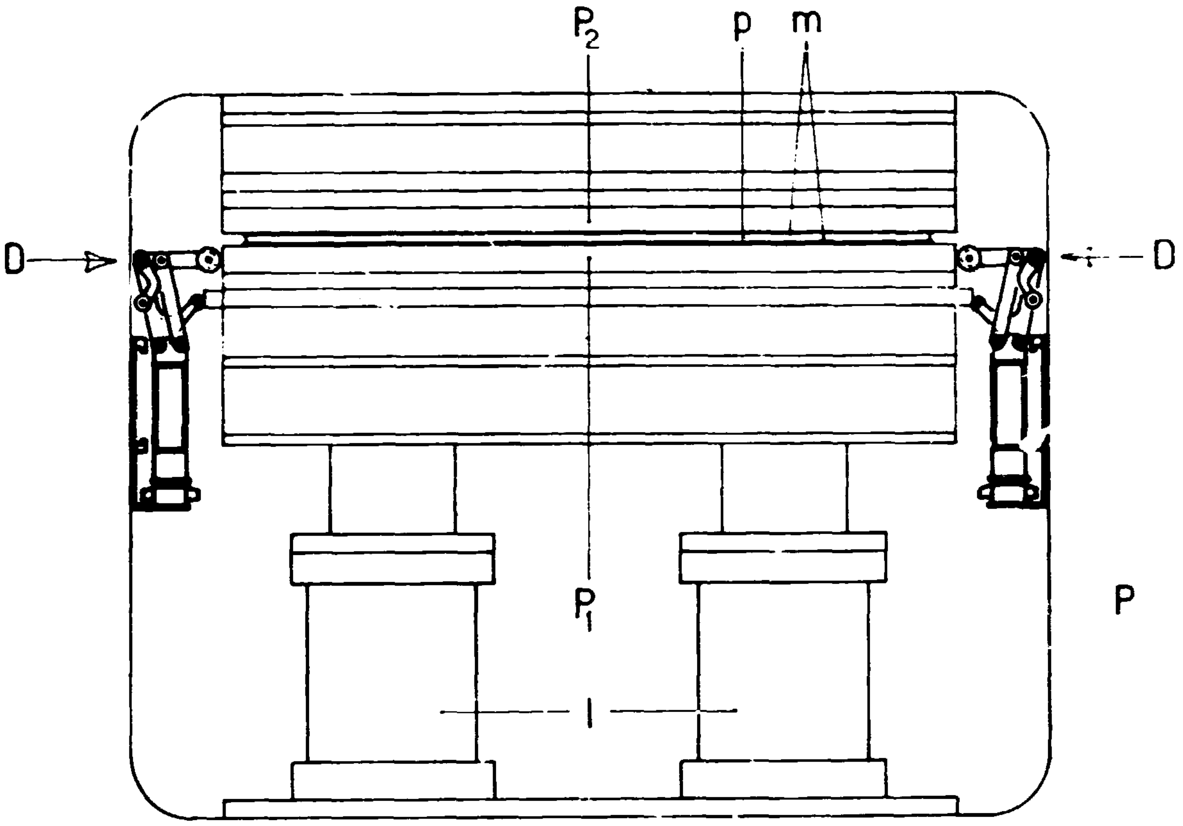
(*a*) Higher initial investment;
(*b*) Higher energy consumption;
(*c*) Greater labour requirements.

Table 2 shows process characteristics for the hot/cold process.

Simultaneous lamination

This laminating system is uneconomical because of the high initial cost and production complications. The system is being further developed.

Figure 14. Ultrarapid single opening press with drop loading: pressing cycle



Key:	m	Melamine papers
	p	Board
	D	Groups of levers
	I	Hydraulic cylinders
	P	Press
	P_1	Lower platen
	P_2	Upper platen

Lamination with "pore filling" papers

Application of urea impregnated papers ensures finished surfaces, with no need of sanding, ready to be printed and lacquered. These may be self-adhesive papers or papers applied on to a board which is usually spread with urea resins.

Other application systems

In addition to the above classic systems other processes have been recently developed, involving variations in raw materials (papers and resins), in paper impregnating methods, even in the same techniques for application. The principle of these new systems lies in paper gluing by the "wet" or more recently by the "dry" method. The "dry" method is somewhat like classic laminating methods. The total cycle length is shorter (about 2 s).

Gluing papers

We can schematically point out the following types:

(a) Impregnated papers suitable for further lacquering, weighing 80-125 g/m². They may be used in veneering presses (figure 3);

Figure 15. Resin content vs. weight per unit area for the hot/cold process

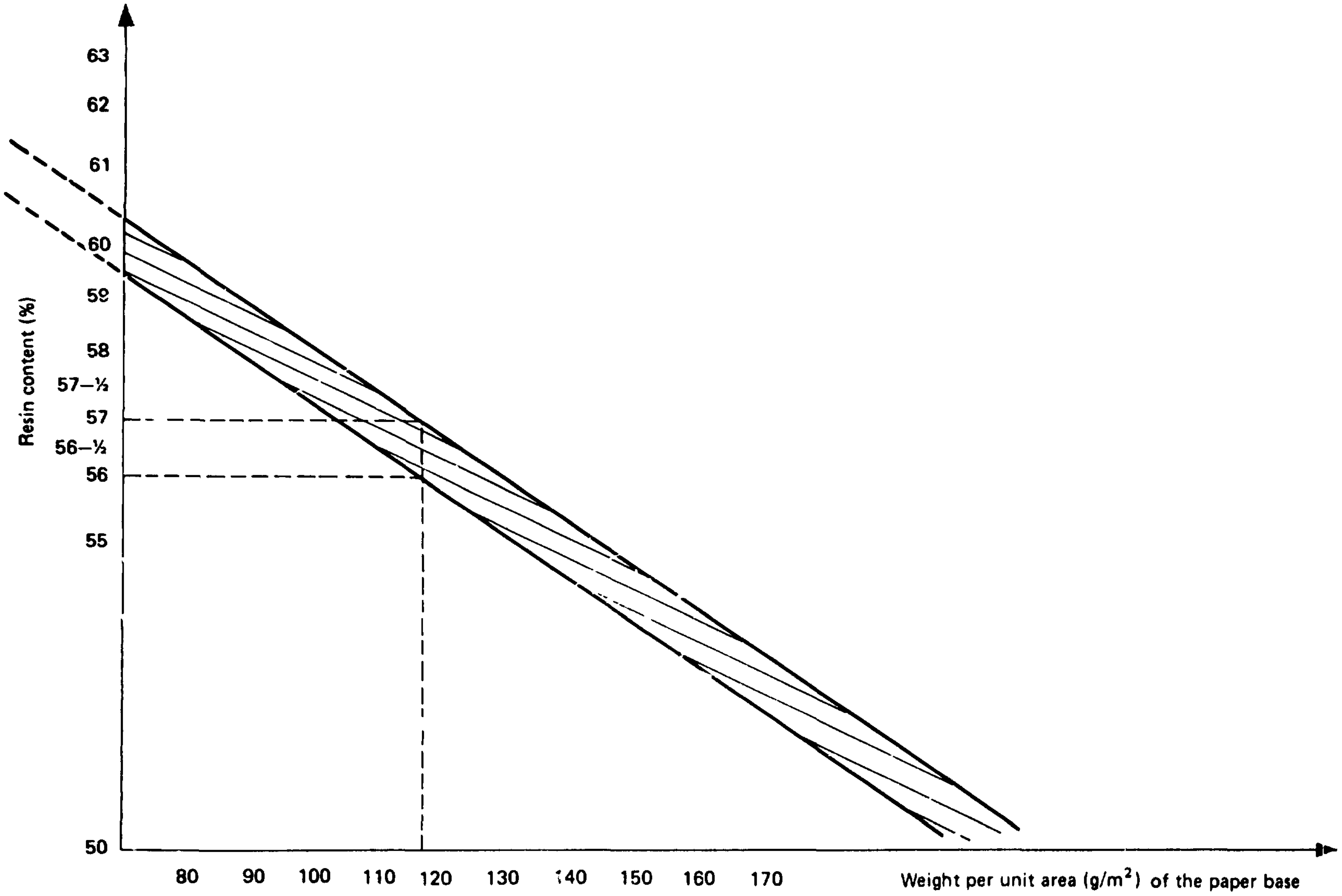


TABLE 2. PROCESS CHARACTERISTICS

Characteristic	*Hot/cold*	*Hot/hot*
Press type	Multi-opening	Horizontal single-opening
Investment	High	Low
1 hour output per press	High: 20 openings—5 pressing cycles = 100 boards	Low: 1 press 70 boards/hour
Energy consumption	High	Low
Mechanical stress during working	Low	High
Area needed	Large	Small
Cooling in press	Necessary	Not necessary
Boards cooling out of press	Not necessary	Necessary (it depends on type of papers-resins)
Sheets and cushion cost	High	Low
Product quality	Very good (gloss surface)	Good (only matt surface)
Resin cost	Low	High
Stability of impregnated papers	High	Low
Required specific gravity of boards	0.65-0.75	< 0.65
Board deflection	Approximately 5 per cent	Almost nothing
Safety	Very high	Low

(b) Impregnated papers, containing a coat of lacquer, weighing 80-150 g/m². They may be used in veneering presses as well as in quick step plants, or in universal type installations;

(c) Semi-finished papers, which may be used immediately after gluing, or being further lacquered. Weight 80-145 g/m²;

(d) Finished impregnated papers, replacing veneers also used for edge-banding (figure 18);

(e) Glue coated finished papers. The glue is applied in a melted state on to their reverse side (hot-melt), or a filling glue is applied on the paper's reverse side as micro-crystals, during impregnating process.

Very light papers (30-45 g/m²) deserve special attention. These are impregnated with urea resins modified with acrylics. They are applied in quick step presses, calenders or universal lines. The board, usually glue coated and laminated on one or both sides with paper, is transported to the press by a conveyer belt. The conveying belt may be provided with a die sheet in synthetic material, to emboss wood grains on to the surface of the impregnated papers. This kind of paper may be used on particle board or fibreboard. Glue content (depending on type of substrate) is about 50-80 g/m² in solution. Indicative pressing times (depending on hardener and wood) are 25 s at a temperature of 100°C and 10 s at a temperature of 160°C.

Due to the lightness of the papers, it is better to use structural die sheets, during the pressing operation, to cover any defects of the wooden surface. In any event, the surface must be polished, smooth and even, without scratch marks which may occur during sanding operation.

A new application system, coming from the thermoplastic materials industry, is the "transfer" method (figure 16) which is usually carried out on a single face of the board. One or more layers (several microns thick) of acrylic or modified acrylic resins are spread on the surface of film, normally a polyester. The reeled film is applied to the surface of the particle board which moves on a conveying belt towards calender rollers. The rollers may be at a temperature of 160°C to 200°C. The upper pressing roller is generally made of silicon-rubber. The surface of the board must be perfect. Under heat and pressure the gluing layer adheres to the board's face, while the substrate-film, bearing the layer, may be torn away or remain as a shielding element against scratches etc. The substrate-film

Figure 16. The plastic laminating system

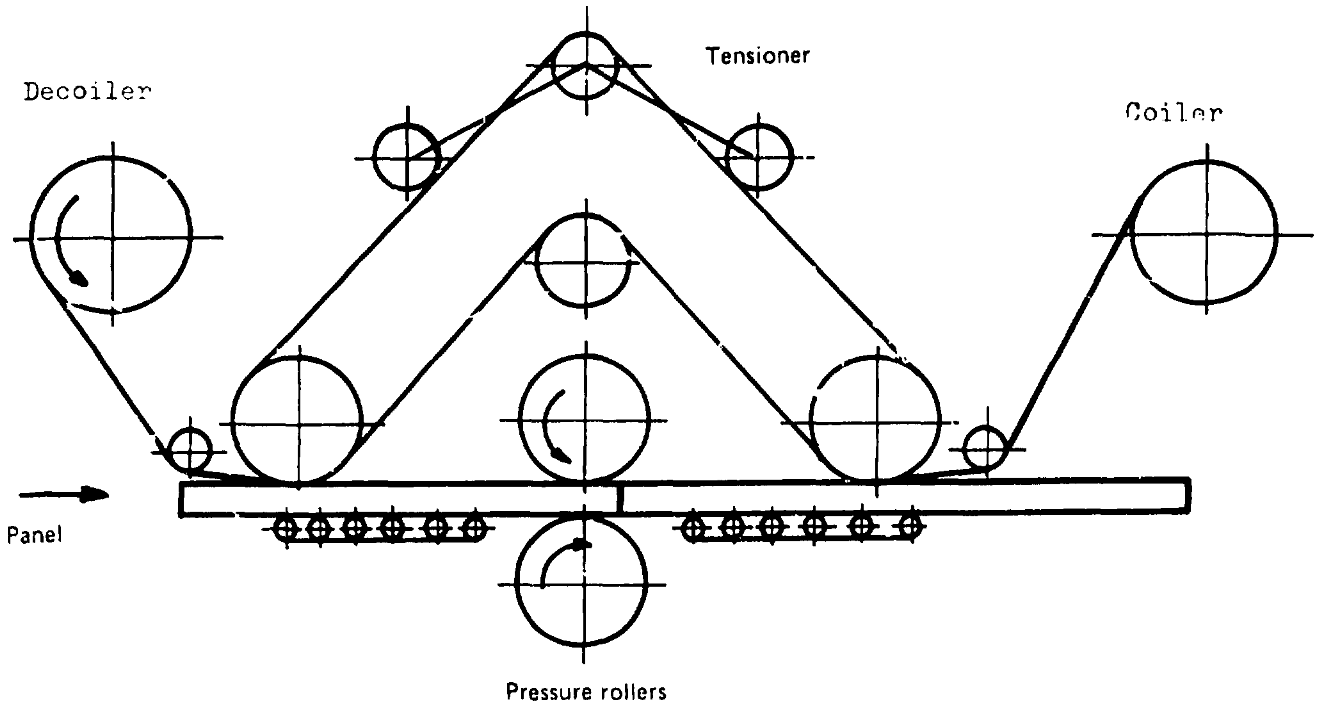
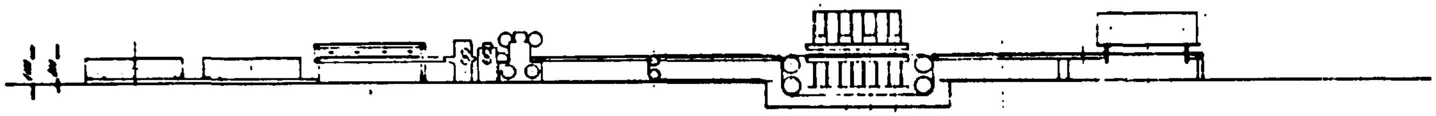
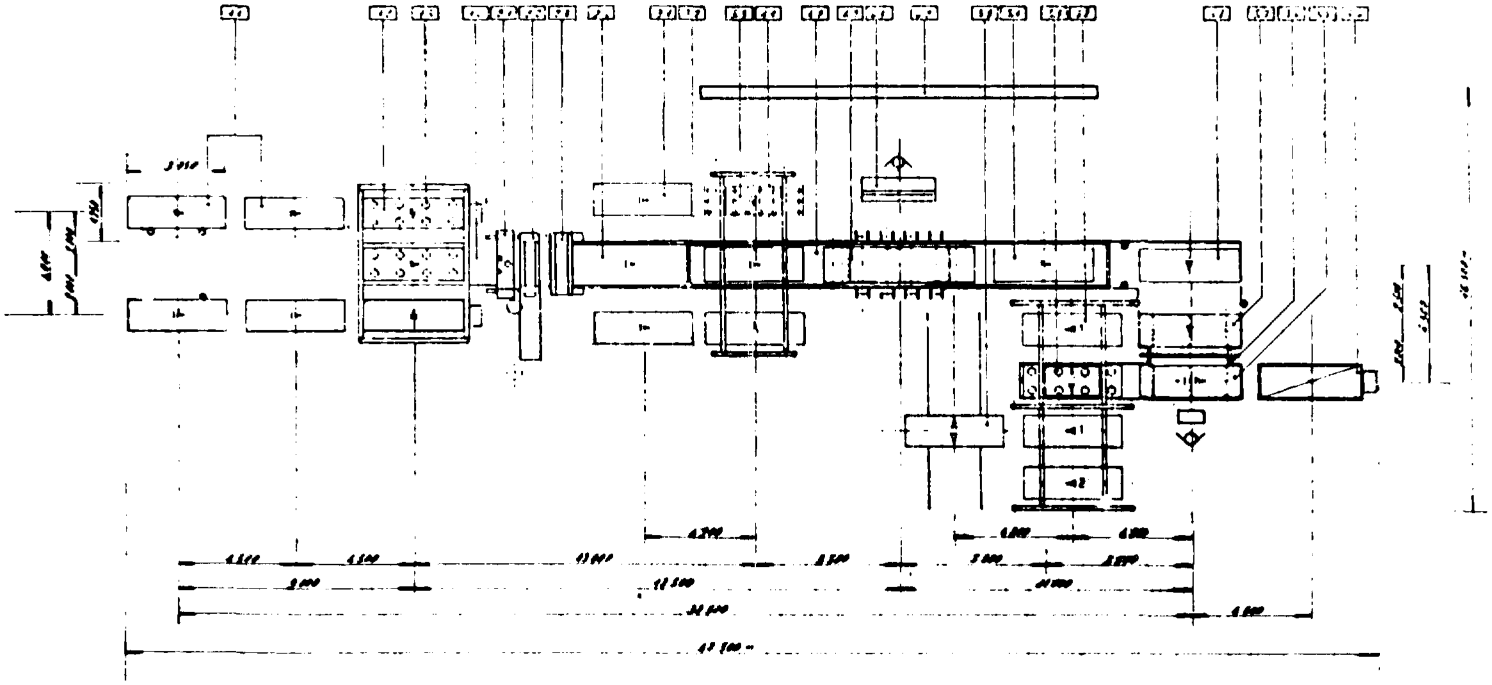


Figure 17. Automatic plant for lamination with light papers



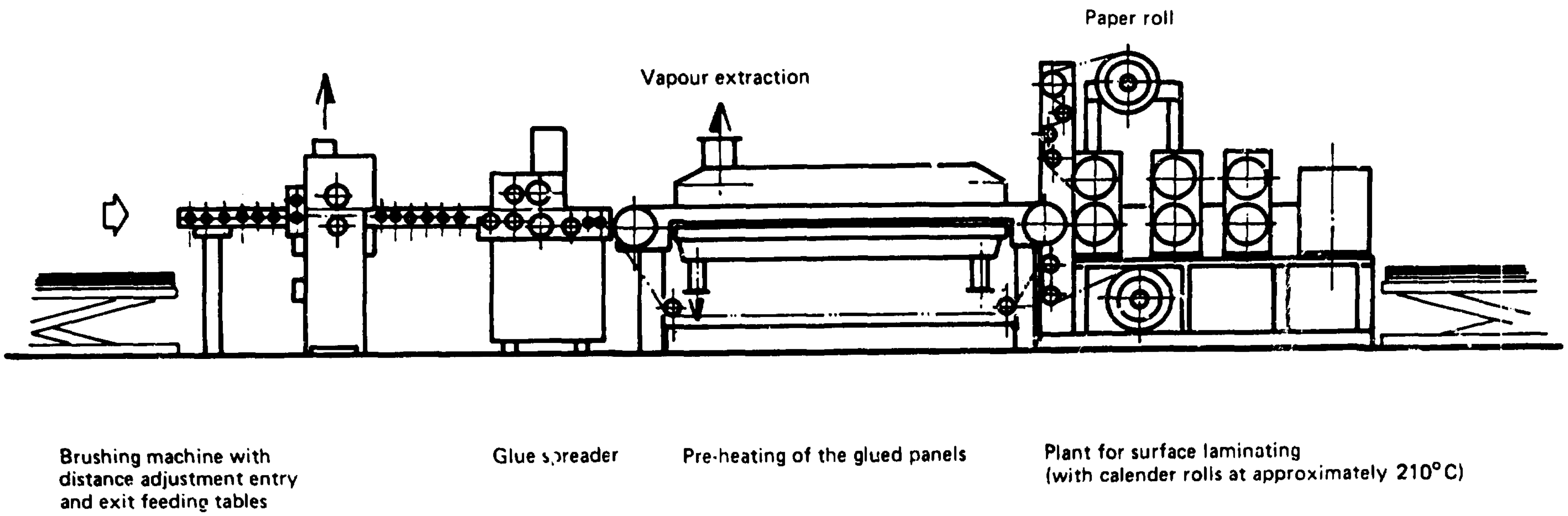
A. Front view



B. Top view

Key: 1.1 Bench with motor-driven rollers
2 Oil hydraulic lifting table
3 Double vacuum hoist for board feeding
4 Belt type conveyer
2.1 Brushing device
2 Gluing machine with four rollers
3 Paper coupling device
4 Bench with motor-driven rollers
3.1 Benches with motor-driven rollers
2 Micrometric lifting bench
3 Vacuum hoist for paper loading
4.1 Set of rollers for board loading
2 Belt type conveyer
3 Single-opening press
5.1 Belt type conveyer
2 Trimming station
3 Bench with motor-driven rollers
4 Board tipper
5 Bench with motor-driven rollers
6 Oil hydraulic lifting table
7 Selecting vacuum hoist
8 Bench with motor-driven rollers
9 Motor-driven truck
6.1 Electric control desk
2 Electric cellular type board
4 Control push button box

Figure 18. Plant for laminating paper sheets on plywood sheets



may be removed from the finished product during other operations, at the end of work or by the user. Unfortunately, physical-mechanical characteristics are not so good, and the board's price per m² is too high.

Lines for paper application

One of the systems is the "quick step", outlined in figure 17. The line consists of gluing machine, winding unit and press, with a conveyer belt, which presses the board with papers. The papers are usually glued and the temperature is between 110°C and 140°C Pressing time, depending on type of glue, is about 8 s. Melamine papers, used in hot/cold system, cannot be used for this method.

By suitable modifications of press capacity and by providing a station for melamine papers and for calenders, it is possible to construct a "universal line" using any type of paper.

The calender system, which has recently been developed, aims to employ light papers in place of PVC coating. PVC has been challenged from the health point of view and because of inadequate physico-mechanical properties. Figure 18 shows the operating principle of this new system. The board, thus laminated, does not meet standard specifications. Undoubtedly the introduction of calenders in pressing lines will improve the finished product. Application speed varies from 15 to 40 m/min. Roller temperature is approximately 210°C. Touch time depends on the speed (assuming 5 mm of touching area, it will be fractions of a second).

Figure 16 outlines the principle of the transfer application system. This system is being studied mainly with regard to the thickness of layers applied to the substrate, and as well for adhesion properties of paper to particle board surfaces.

Selecting plant equipment

Raw materials availability, surfaces and board quality, output quantity (required by the market), and user needs are the determining factors in the plant's product and output. Nevertheless, choice of a specific type of plant, to produce laminated boards, will always be mainly connected with surface quality, productive efficiency and flexibility of the plant. Initial investment is not always a conclusive factor. Classic lamination, that is lamination by hot/cold or hot/hot systems is still the favourite choice. For this reason it is impossible to establish precise rules in plant selection.

No doubt, the total consumption of laminated material in any given country, the availability of energy and type of labour, the possibility of exports and, generally speaking, commercial conditions may influence some investors to prefer either more or less sophisticated plants, with varying numbers of labourers and suitable for manual or completely automatic operation. Each situation must be analysed from time to time. Co-operation strictly with the press manufacturer, who, in addition to the seller, must assume the role of friend and adviser to the purchaser, is of vital importance. Only by doing so, is it possible to ultimately reach satisfactory results, and thereby help industrial growth in the various countries of the world.

XV. Materials for surface finishing and appropriate application equipment*

This chapter discusses methods for the surface finishing of wood products. The various compositions and types of material which can be applied, as well as types of equipment used in application, are considered. The following are useful definitions and descriptions of surface coatings, which have appeared in wood magazines from the United States of America.[1]

Lacquers

The word "lacquer" was derived from the word "lac" which describes an excretion of lac insects. This excretion, when processed, is called shellac. Lacquer has come to be a descriptive term for thin-bodied, hard, clear, colourless finishing materials. Modern industrial usage has almost exclusively limited the term lacquer to coating materials containing nitrocellulose, ethyl cellulose, cellulose acetate, benzyl cellulose and other film-forming chemicals mixed with natural and synthetic resins, or plasticizers dissolved in volatile solvents. Lacquer coatings, in general, are composed of materials that form a surface film by the evaporation of solvents and thinners Varnish coatings involve both the evaporation of solvents and polymerization reactions.

Lacquer application

The use of nitrocellulose lacquers for furniture topcoats was one of the most important factors leading to improvement of production methods for furniture manufacture. The primary advantages of nitrocellulose lacquers were the fast drying due to evaporation and the formation of uniform films with good physical and chemical properties. These latter properties can be controlled for [illegible]ific production requirements. The manufacture and control is straightforward due to the nature [illegible]redients.

The primary disadvantages of lacquers were their low solids content and [illegible]y high cost. A partial answer to the cost and solids content drawbacks has been the develop[illegible] so-called hot spray process whereby spraying viscosity is controlled by temperature and greater thickness can be obtained with fewer coats than with conventional cold lacquers.

Lacquer troubles

There are numerous problems relating to lacquer topcoats that may be the result of faulty application or formulation. Many of these problems are not solely confined to lacquers. They also occur with varnishes. The following problems or troubles are some of the most common encountered in lacquer finishing of furniture.

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* By G. D. Beccaria, expert in surface finishing. (This is an edited version of ID/WG.277/7/Rev.1.)

[1] For additional details on surface finishing see chapter XIV.

Blushing

When a lacquer coat turns grey or white instead of remaining clear and transparent, the film is said to blush. Blushing is caused by:

(a) Too rapid evaporation of solvents, leading to a cooling of the film to a temperature below the dew point of the air. This condenses moisture in the film:
(b) Incompatibility of lacquer ingredients;
(c) Excessive moisture or oil in the compressed air line.

Blushing can be prevented by controlling the temperature and humidity conditions in the plant, by using a higher proportion of less volatile solvents in the lacquer formulation, by using adequate filters and by maintaining drains on the air lines.

Bubbling

The formation of bubbles in the partially dried lacquer film is normally termed bubbling. This condition is caused by entrapping air and other gases in the film and may be due to improper spraying technique or to an improper proportion of solvent in the formulation.

The lacquer may not have a high enough proportion of slow-evaporating solvent. This will cause the surface to dry before the volatile solvents can escape from the film. In addition, if the pressure used is too high, air and solvent bubbles may be entrapped within the film. Further, if the spray gun is held too far from the work, too large a proportion of the solvents may volatilize prior to application, causing poor flow properties.

Blisters

The spraying of heavy coats of lacquer on unfilled or improperly filled woods, or the use of high drying temperatures or any other condition that will cause improper adhesion can result in the raising and separation of the film to form blisters. Proper surface preparation, filling, drying of filler and temperature control of the surface and lacquer will eliminate this problem.

Bridging

The application of a lacquer film over improperly fitted joints and sharp mouldings may form a lacquer bridge which will break or chip during use. Uniform moisture control of parts, proper machining tolerances and careful spraying can eliminate or minimize bridge formation.

Orange peel

When a lacquer coat lacks proper flow characteristics and does not level completely, it appears like the rough skin of an orange and is known as orange peel. Orange peel may be caused by failure to maintain the proper distance between the gun and work, excessive pressure, too rapid solvent evaporation or by use of inferior thinner.

Pinholes

The development of pin-like holes in a lacquer finish may result from improper filling or improper drying of the filler. Pinholing may be caused by the presence of water or oil in the air lines. Since both water and oil are incompatible with the lacquer, they may remain as little submerged globules which are released during rubbing. The use of adequate drains and daily bleeding of lines and tanks can often eliminate pinholes formed from oil and water globules.

Runs or sags

Application of too heavy a film frequently results in sagging or running. Proper spraying technique, which includes spraying beyond the edge of a piece, should help to eliminate this problem.

Wet spots

The presence of grease or oil spots on the wood or the lacquer may result in the formation of small areas which do not solidify properly. Proper screening of the air system and surface preparation will eliminate this problem.

Varnishes

Varnishes may be divided into three primary types. These are oleoresinous or oil varnishes, synthetic varnishes and spirit varnishes. Spirit varnishes are solutions of gum or resin in a volatile liquid which may or may not be mixed with modifying agents. Spirit varnishes are lacquer-type coatings as they do not require oxidation or polymerization, but harden by the evaporation of their volatile solvents.

Clear oil varnishes contain drying oil, resin, driers, solvents and thinners. The drying oils may be of animal or vegetable origin and are mixtures of various triglyceryl esters of fatty acids. The drying of an oil is primarily a curing process involving hardening.

Oils which react most readily and are the fastest drying, are highly conjugated, and give the densest molecular structure. However, these oils discolour during drying to a greater extent than the less highly conjugated oils. Therefore, in clear varnishes drying speed often must be sacrificed to reduce yellowing tendencies.

Varnish troubles

There are many problems that occur in varnish application. Most of these relate to faulty application technique or improper handling of the material. The term v.p. is used to denote a varnish product.

Blistering

The formation of bubbles or blisters may be caused by the use of excessive heat during drying which results in gaseous expansion under the partially cured surface. Blistering may also result if the undercoats or the wood are inadequately dried.

Blooming

Blooming refers to the appearance of a milky or foggy surface. This condition generally relates to excessive humidity in the finishing or storage room. It indicates that condensation has occurred in the film. It may be remedied by rubbing and re-coating. Humidity control in the finishing room or adjustment of solvent mixes are preventive measures.

Checking

Checking is a mild form of cracking and may have the same causes. Individual pieces may be satisfactorily touched up in many instances.

Chilling

A chilled surface caused by solidification of gums, driers or oils may give a varnish film a sandy appearance. This defect is caused when the varnish is stored or applied at low temperatures.

Cracking

A cracked varnish topcoat may have been caused by any of several conditions. The most common causes of cracking are improper drying of the wood or the undercoats prior to topcoat application, severe temperature changes without adequate flexibility in the finishing system, and exposure of varnish films to chemical agents which may cause embrittlement. A varnish film may crack, creating a condition similar in appearance to the skin of alligator. This type of cracking is often termed alligatoring.

Crawling

Crawling or roping is a pronounced wrinkling and generally occurs due to the same causes as running or sagging. It is directly related to the flow characteristics. These might be inadequate because of improper formulation, improperly cleaned surfaces, high or low temperatures or excessive application. An excess of dryer is often the key to improper formulation. Properly cleaned surfaces and proper application temperatures and formulation will eliminate this problem.

Flatting

If the finish coat lacks the normal desired effect and has a somewhat dull appearance, it is described as flatting. Flatting may be caused by re-dissolving inadequately dried undercoats or by excessively high temperature and humidity conditions in the plant.

Pitting

The appearance of little pock marks or pinholes on finished varnished surfaces is referred to as pitting or pinholing. This condition may be caused by inadequate drying of the undercoats and the escape of volatile matter after the varnish has partially dried, or by air currents during drying, or by improper atomization during spraying.

Pigments

A pigment may be defined as a colouring substance which is insoluble in the liquid in which it is suspended or dispersed. Pigments find wide usage in paints, enamels and pigmented lacquers for both metal and wood finishing. In addition, with the present-day trend towards greater colour variation in household furnishings and with the decrease in the availability of traditional furniture wood species, the role of pigments in furniture finishing is increasing.

Fillers

The filler is often considered "the foundation of a fine finish". Many of the principal cabinet woods have large pores and these must be properly filled in order to assure the desired final effect. Conifers and diffuse-porous woods are generally finished without the use of fillers, but occasionally these woods are filled to equalize absorption of different surface areas.

Composition of lacquer coating materials

Lacquer coating products are composed of the following:

(a) The binder. The binder is made up of one or more products, normally resin polymers. Essentially, the mechanical and chemical characteristics of the film obtained depend on it;

(b) The solvents The applicability and uses of the lacquer products depend on the solvents;

(c) The pigments (in the case of pigmented products), which provide colour and covering power to the lacquer product (l.p.). They also affect the mechanical and chemical characteristics of the films applied;

(d) The additives. The additives, when added in small quantities, improve both the characteristics of applicability as well as the chemical and mechanical characteristics of the films applied. For example, zinc stearate improves the sanding of the bottoms, various silicones release air from the film as soon as a sprayed l.p. is applied etc.

Types of lacquers

The lacquer products generally used in the furniture industry in Europe and particularly in Italy are the following:

Polyurethane lacquers
Polyester lacquers
Direct polish polyester lacquers
Urea lacquers with acid catalyst
Nitrocellulose lacquers

Lacquers are mostly non-pigmented transparent coating products. Paints are pigmented coating products.

Polyurethane coating products

Polyurethane coating products normally have two components. The first component generally consists of solutions of synthetic resins in organic solvents. Such resins are mainly a polyester type (alkyd, saturated polyester) but can also be of an acrylic, vinylic or mixed type.

The second component generally consists of solutions of various kinds of polyisocyanates in organic solvents. The most common are the homopolymers of tolueneisocyanate, the copolymer of tolyl isocyanate and hexamethylisocyanate, the biureate of the hexamethylisocyanate. Other types of polyisocyanates may also be used.

Polyester coating products

The polyester l.p.s are normally made of unsaturated solutions of styrene in polyester.

The unsaturated polyester resins are characterized within their own structure, by double or unsaturated bonds. These double bonds are the result of the action of an activator or catalyst (normally organic cobalt salts and organic peroxydes are used for this purpose). They react with the double bonds of styrene thus forming a polymer of styrene interspersed with polyester resin in a three-dimensional, reticulated structure.

Polyester direct gloss coating products

The polyester coating products, referred to in the previous paragraph, when applied normally, are inhibited during the polymerization process by the oxygen of the air (the surface remains sticky and unhardened). The addition of 0.1-0.2 per cent of low-melting point paraffin eliminates such an inconvenience, but makes it necessary for somewhat more toilsome operations later (sanding and, if necessary, glossing). The addition of polyester resin or allylic groups to the mixture allows polymerization to take place in the presence of oxygen. Such allylic groups react, in the presence of suitable activators (cobalt organic salts), with the oxygen of the air to open double bonds and allow the formation of a three-dimensional and reticulated structure.

Urea acid catalysed coating products

Urea acid catalysed coating products are produced in two components. The first component is made of a solution of suitable urea resin and of alkyd resin (although suitable vinylic and acrylic resin may also be used) in organic solvents. The polymerization comes about primarily as the result of a reaction between the methylic groups of urea resin and the hydroxyl groups of the other resin.

At room temperature the reaction is initiated by the addition of a second component, normally a solution of acid substances such as phosphoric acid, acid organic phosphates and so forth in organic solvents.

There are also acid catalysed urea coating products containing a single component.

Nitrocellulose coating products

Nitrocellulose coating products are made with nitrocellulose organic solvents.

In order to obtain good mechanical characteristics of the applied films, it is imperative that other resins (such as alkyd resins) be added to these solutions and that plasticizers (such as butyl phtalate and castor oil) also be added. The formation of the film in this case takes place by means of the simple evaporation of the solvents. No polymerization takes place.

Choosing a coating product

The choice of a coating product depends on many considerations. It is practically impossible to define them and to give an exhaustive and complete description of them. Each situation must be examined in detail to arrive at a tailor-made solution. To better understand the impossibility of having general rules for choosing coating products, it is sufficient to consider the differences among countries in labour costs, fashion styles and of the type of machinery available.

Despite the efforts made to generalize the data available, this discussion reflects the situation existing in the Italian furniture industry. Notwithstanding this, it is believed that the data supplied may provide a basis to begin a discussion on the choice of a coating cycle.

The tables are to be considered in light of present-day industrial practices. Products and systems of application under development are therefore not considered. As shown in table 1, the polyester l.p.

TABLE 1. COATING PRODUCTS AND THE APPROPRIATE APPLICATION TECHNIQUE

Coating product	*Coating equipment*							
	Brush	*Spray*	*Airless*	*Roller*	*Roller curtain*	*Curtain 1 head*	*Curtain 2 heads*	*Electro-static spray*
Polyurethane l.p.	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Polyester l.p.	Yes	Yes	No	Yes[a]	Yes	No	Yes	Yes
Polyester direct gloss l.p.	Yes	Yes	Limited	Yes[a]	Yes	No	Yes	Yes
Urea acid catalysed l.p.	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Nitrocellulose l.p.	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

[a] Only products dryable with ultraviolet (u.v.) heating.

cannot be applied with the airless spraying system, with the curtain coater with one head only and with the roller coater because of the extremely short pot-life (from 5 to 30 minutes at room temperature). This is also true for the direct gloss polyester varnish. In this case, since it is possible to extend the pot-life up to 1 hour and to work with a small quantity of catalysed product, it is possible to use the airless system. For the urea acid catalysed nitrocellulose coating products the use of the two-head curtain coater machine is advantageous in a limited number of special cases.

As shown in table 2, those products which, with suitable additives (e.g. thinners) can be made suitable for use at the indicated temperature, may generally be dried at temperatures between 16° and 30°C. For higher temperatures (see tunnel drying, with air from 20° to 70°C) they should be formulated in a special manner. Low-power u.v. installations are those for which the absorbed power is lower than approximately 1 watt per centimetre of lamp length. High-power u.v. installations are those with lamps whose absorbed power is equal to or greater than 30 watt per cm lamp length.

TABLE 2. DRYING CONDITIONS FOR VARNISH PRODUCTS

Coating product	*Drying conditions*						
	Drying at room temperature			*Air-tunnel drying 20°-70°C*	*Low intensity u.v. drying*	*High intensity u.v. drying*	*I.r. drying - forced air*
	10°-15°C	15°-30°C	30°-35°C				
Polyurethane l.p.	Yes	Yes	Yes	Yes	No	No	Yes
Polyester l.p.	No	Yes	Limited	Yes	Yes	Yes	Yes
Polyester l.p.	No	Yes	Yes	Yes	Yes	Yes	Yes
Urea acid catalysed l.p.	Yes	Yes	Yes	Yes	No	No	Yes
Nitrocellulose l.p.	Yes	Yes	Yes	Yes	No	No	Yes

For infra-red (i.r.) sources, short, medium and long wavelength may be used in most cases. In the case of u.v. and i.r. drying, it is always necessary to have good ventilation preferably with pre-heated air.

As shown in table 3, except for the case of drying at room temperature, one must add 1-2 minutes to the times for the cooling with forced air at temperatures not exceeding 25°C. In the case of u.v. drying it must be remembered that it is practically impossible to use pigmented products. Generally,

TABLE 3. MINIMUM DRYING TIMES TO OBTAIN OPAQUE FINISHES FOR l.p.

Coating product	*Drying conditions*				
	At room temperature (hours)	*With air-tunnel 20°-70°C (minutes)*	*With low-intensity u.v. (minutes)*	*With high-intensity u.v. (seconds)*	*With medium wavelength i.r. (minutes)*
Polyurethane l.p.	4-6	12-16	Unused	Unused	8-16
Polyester l.p.	2-4	12-16	4-5	5-30	8-16
Polyester direct gloss	24-36	Unused	4-5	5-30	Unused
Urea acid catalysed l.p.	4-6	20-25	Unused	Unused	8-16
Nitrocellulose l.p.	2-4	12-16	Unused	Unused	8-16

the faster the drying, the more accurate should be the preparation and more careful the application. Variations in the type and concentration of catalysts or in the dilution in the case of forced drying can cause serious consequences. For forced air drying, although it is possible to work with the indicated times, it is generally advisable to have longer time intervals (at least double those indicated) to allow for a margin of error.

Table 4 shows drying times for the polyester coating products which give glossy finishes. It is necessary to sand with 280-320 paper and then brush polish with abrasive paste and apply a further polish later on. The other glosses may be left as they are; should one wish to remove the small dots caused by atmospheric dust particles, it would be necessary to sand down with 600 paper and then finish with a brush polish.

TABLE 4. DRYING TIMES AND HARDENING TIMES AT ROOM TEMPERATURE FOR GLOSS FINISHED PRODUCTS

Coating product	*Drying conditions*		
	At room temperature (hours)	*Tunnel forced air 20°-70°C (hours)*	*Low-intensity u.v. (hours)*
Polyurethane l.p.	24	—	—
Polyester l.p.	6-8	1 + 3	—
Polyester direct gloss	24-36	—	0.1 + 2
Urea acid catalysed l.p.	—	—	—
Nitrocellulose l.p.	6-8	0.5 + 1.5	—

The figure indicates, in a totally qualitative manner, the influence of thickness, ventilation and temperature on drying times. The diagram highlights the effect of the increase in thickness on drying time. If the thickness doubles, under constant ventilation conditions and at constant temperature, drying time increases 3 to 4 times.

Increased ventilation for constant thickness and temperature reduces the drying time. Doubling the rate of ventilation reduces the drying time by one half to one third.

The increase in temperature, for constant thickness and ventilation, reduces the drying time.

In all these cases, there are limits beyond which it is not convenient to venture. As far as ventilation is concerned, it is advisable not to exceed an air speed of 3-4 m/s, although in the case of the drying of thinly applied products (30-40 g/m^2) one could also use 10 m/s. This is to prevent the air from moving the applied film and giving surface defects.

The limits of the temperature are substantially given by the resistance to heat of the undercoats used. Generally, when using polyacetovinyl glues for gluing edges, the temperature of the air used for the drying should not exceed 80°-90°C.

Although qualitative, table 5 shows that polymerized products generally have far better mechanical and chemical characteristics than the non-polymerized products.

For the yellowing process, one must distinguish between the yellowing of pigmented products and that of transparent products. In the case of pigmented products, it is important that the yellowing due to the binder and to the pigment be minimal. In the case of transparent products, the yellowing of the binder is important only if white woods or white painted woods are used. With non-pigmented varnish products, the protection that the varnish product gives the wood against u.v. rays in sunlight is more important. This protection is obtainable through the addition of suitable u.v. absorbing additives to the varnish products.

The prime coat products (table 6) are in direct contact with the wood. They are applied, according to the filling requested and the type of wood used, with one or more passes. Their purpose is to give support to the finishing coat.

In particular, the two characteristics which clients seek in a prime base are sandability and resistance to overspray. A good sanding allows work to be done rapidly and the attainment of a perfect surface.

A qualitative relationship of drying times vs. thickness, ventilation and temperature

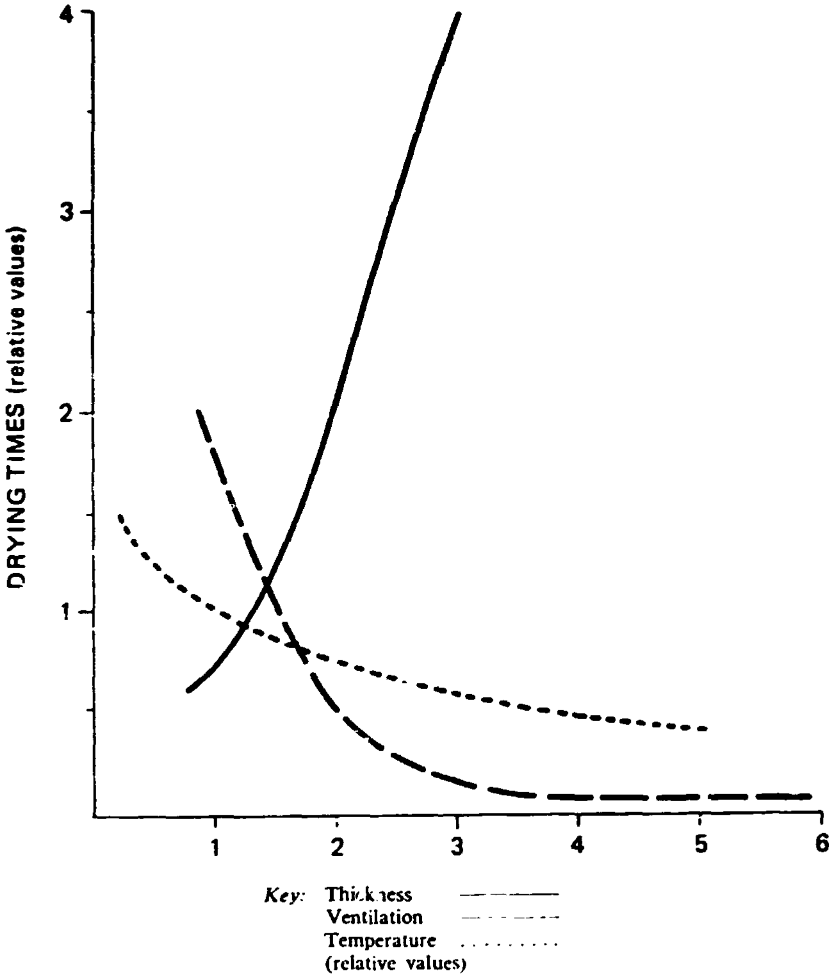

TABLE 5. MECHANICAL AND CHEMICAL CHARACTERISTICS OF COATED FINISHINGS

Coating product	*Characteristics*										
	Adhesion	*Hardness*	*Elasticity*	*Resistance to thermal oscillations*	*Resistance to dry heat*	*Resistance to humid heat*	*Resistance to domestic chemical products*	*Resistance to alcohol*	*Resistance to water*	*Yellowing effect*	*Resistance to cigarette burns*
Polyurethane l.p.	O	G/O	O	G/O	O	O	G/E	E	E	S/E	O/E
Polyester l.p.	G/O	G	S/G	S	O	O	G/E	E	E	G/E	O/E
Polyester direct gloss	O	G	G	G/S	O	O	G/E	E	E	G/E	O/E
Urea acid catalysed l.p.	G/O	G/E	S/G	G/S	S/G	S	S/G	S/G	I/S	G/O	O/E
Nitrocellulose l.p.	G/O	G	S/G	G/S	I/S	I/S	I/S	I/S	G	S/G	I/S

Key: E excellent
O optimum
G good
S sufficient
I insufficient

Good resistance to overspraying prevents the prime coat losing the qualities of flatness obtained by sanding.

For rosewood type of woods it is necessary to carry out tests on the wood to be used. There is too great a variety between one lot of wood and another to be able to know if one or two coats of polyurethane sealer paint would suffice.

TABLE 6. CHARACTERISTICS OF PRIME COATS

Coating	*Characteristics*						
	Elasticity	*Resistance to thermic oscillations*	*Adhesion on wood*	*Inhibition by rosewood*	*Hand sanding*	*Machine sanding*	*Overspraying*
Polyurethane l.p.	O	G/O	O/E	No	G/O	O/E	O/E
Polyester l.p.	S/G	S/G	G/O	Yes[a]	I	G/O	O/E
Polyester direct gloss	G	G	G/O	Yes[a]	S/G	G/O	O/E
Urea acid catalysed l.p.	S/G	S/G	S/G	No	G	G	G/O
Nitrocellulose l.p.	S/G	S/G	G/O	No	O/E	O/E	S/G

Key: E excellent
O optimum
G good
S sufficient
I insufficient

[a] May be applied on rosewood prior to application of a polyurethane sealer.

The data in table 7 indicate the reasons for the success of the polyesters. By using them it is easy to obtain perfectly filled pores with a few coats. The filled pore obtained with polyurethane products is better from an aesthetic point of view and the wood's natural characteristics are still very visible.

TABLE 7. AMOUNT OF v.p. PER COAT

Coating	*Quantity (g/m^2)*	
	Product ready at application	*Dry product*
Polyurethane l.p.	140-180	60
Polyester l.p.	320-380	340
Polyester direct gloss	200-250	180
Urea acid catalysed l.p.	120-140	50
Nitrocellulose l.p.	120-140	45

Table 8 should enable one to approximately determine the amount of l.p. and the number of coats necessary to obtain a given filling.

TABLE 8. AMOUNT OF COATING USED (READY AT APPLICATION)

Wood type	Quantity (g m^2)	
	Closed pore finish	Open pore finish
Very porous wood (e.g. rosewood, mahogany)	270	100
50% porous wood (e.g. locally grown oak)	200	70
Slightly porous wood (e.g. Aniegre)	140	40

Request for finishing operations

The attached form "Finishing operations" (annex I) and the questionnaire (annex II) should enable one to formulate a request for a suitable coating cycle.

For outdoor wooden components, the problems of coating are among the most serious and delicate. For best results, one should follow the instructions provided by a reputable lacquer material producer. For indoor wooden components (doors etc.), the coating cycles are similar to those of furniture.

"Panels to be coated" indicates interior panels. In Europe, panels coated for outside use are rarely used.

The problem of modular case-good furniture is that of the constancy of the finish with regard to colour and artificial ageing. In such a case it is necessary to guarantee both the uniformity of the production from series to series and guarantee that artificial ageing does not alter the colour and aesthetic aspect of the furniture so as to prevent interchangeability of parts manufactured at different times.

Dimensions of the manufactured product

The dimensions are especially important for panel lining and pre-coating panels. Panels a few millimetres (3-5 mm) thick, several metres wide and long (2 m × 3 m; 2 m × 5 m) are common. It is necessary in such cases to give the varnish product finish with above average elasticity as the panels have a tendency to bend and cause considerable demands on the varnish product films during coating and use.

Substrate used

There is a preferred cycle of coating for each substrate. For example, within plywood and laminated plastic covered panels or those of honeycomb construction, there are normally local variations in the thickness which prevent the use of roller-coaters. Normal or thin particle boards generally require calibrating prior to coating.

Type of surfaces to be coated

The coating cycle will vary also in view of the type of surface to be coated. For example, in the case of a rough particle board, it is necessary to first prepare the panel by filling the pores so as to have a perfect surface for later coating.

Part of the form indicates the cycle used and the improvements desired or the machines available.

Conclusion

The preparation of the coating cycle can be extremely simple or extremely difficult. It depends entirely on the relationship between the furniture maker, the lacquer producer and the manufacturer of machines.

It is necessary that all three interested parties communicate with one another and exchange information regarding the desired goals and means necessary to attain them. They should further seek together a reasonable basis for agreement regarding the type of lacquer, the products and the machines to be used, and the production costs of the coated products.

Neglecting this fundamental precaution could lead, in many cases, to improper selection of coating lines and to a non-functioning production line due to lack of suitable machines.

In Italy, the development of furniture-coating material has been, within its own sector, unique. It began with simple craftsmanship and was dominated by the manual application of products and by air-drying. It developed over a span of 20-30 years into a highly automated system without any deterioration in the high quality. This experience is available to help solve problems existing in developing countries.

Lacquer coating equipment

Introduction

The choice of equipment for lacquer coating is not straightforward but depends on many factors. Amongst these are:

(a) The capital available;
(b) The expertise of available labour;
(c) The proposed quality of the products and size of batches;
(d) The available working area;
(e) The nature of the surface to be coated.

It is thus difficult to choose equipment without examining particular cases in depth. Therefore this chapter will review the equipment used for industrial furniture coating in a general way.

The choice of a plant requires careful study and communication between the purchaser, the machinery supplier and coating products supplier. The more complex the coating procedure, the more indispensable the close co-operation among the interested parties. To proceed in a different direction would lead to disastrous results in the quality and in the productivity.

Another point worthy of consideration is that of the speed of production. Generally speaking, the faster the coating, the more precise and accurate the preparation, the conditioning of the substrate, and the care in the selection of coating. One hour's drying less than normal for a product dried in 8-12 hours may be non-critical; but 30 seconds less than normal drying for a product dried in 10-12 minutes could lead to disastrous results. Similarly, an application density of 130 g/m^2 instead of 110 g/m^2 could be unimportant if the drying is carried out at room temperature for at least 8-12 hours. The entire matter would be different if the drying process were conducted with forced air at 25°C to 50°C in less than an hour.

Lacquer coating equipment is divided into two types, equipment for application and equipment for drying.

Selection of coating equipment

Manual coating operations

The manual methods of application of coating products survive only for works of a strictly handicraft nature (restoration and reproduction furniture, small restoration work) and for the maintenance of outdoor woodwork (casings, windows, sashes etc.). These operations usually have a negligible investment cost but require considerable expenditure for labour and have a very low application speed. The manual systems used are application of French-polish, by extrusion and by brush.

The French-polish application is used only in very special cases (restoration). It is applied by pads of cotton or woollen threads wrapped with an outer cloth of linen or cotton. Often nitrocellulose products are used for this type of application. The application requires manual skill and is carried out by carefully wetting the lower part of the padding with varnish and rubbing the surface (which is already treated with a suitable filler) with longitudinal movements. The first movement serves to transport the desired quantity of varnish to the surface. The motion used with the French-polish pad resembles a figure eight.

Application by extrusion is used for coating surfaces of billiard-cues, rods, pencils etc.; that is products with a regular section. Normally, the extrusion is done from a tank fitted with shaped rubber apertures which allow the surfaces to be coated while passing through the opening. The lacquers used are normally high viscous nitrocellulose lacquers.

Application by brush is often used especially for coating fixed or installed surfaces (window frames, roll-shutters etc.). Although very simple to do, brush application does not give a perfect finish. Stretch of the lacquer is always limited. It is easy to have a run-off from vertical surfaces. Brush application is used for lack of anything better where the functional aspect of the coat (resistance to outside factors, protection against humidity and so forth) is more important than aesthetic needs.

Spray coating application

Application is carried out by spraying lacquer from a spray-gun on to the object to be coated. The method with which the lacquer product is atomized distinguishes the various spray-application systems, which include standard and airless spray systems.

The standard spray-guns

Atomizing is accomplished by using compressed, filtered, de-humidified air. No oil is used. The lacquer emerges from the spray-nozzle mixed with air. The air pressure can vary from 2 to 6 atmospheres according to the products applied.

Air consumption for each spray-gun ranges from 3 to 20 m^3/h according to the size of the spray-gun. The types of spray-guns used depend on the type of lacquer feed. Feed may be accomplished by gravity, from a small material container rigidly fixed above the spray-gun. This type of spray-gun is economical, light, easily cleaned and is commonly used for small or medium-duty work where coatings must frequently be changed. Feed may also be accomplished by suction of the coating product from a material container placed below the spray-gun's head and rigidly connected to it. The flow of compressed air through the spray-gun forms a partial vacuum which draws the coating material to the nozzle. Good spray-guns are usually equipped with valves to regulate the quantity of air and lacquer. Thus both catalysed (polyester, polyurethane, acid catalysed) as well as non-cataly (synthetics, nitrocellulose) coatings can be sprayed. The results, which may be excellent, depend largely on proper regulation of the spray-gun. Perfect atomization requires an optimal combination of pressure, air volume and lacquer volume. It further requires application of the coating according to supplier instructions (pressure of air, diameter of nozzle, thinner and viscosity of the product). Also important are the correct distance of the spray-gun from the object to be coated, speed and manner of application. Proper environmental conditions, of temperature, ventilation and absence of dust, are necessary for perfect atomization.

Application of airless spray is done by pressurizing the coating. This is done by compressed air or through a pressure tank or by means of a piston pump. In the first case, compressed air moves a piston pump which gives the varnish product the necessary pressure for vaporization. With the use of such systems greater quantities of varnish products can be applied than by normal spraying.

Spray exhaust systems

Every system of application by spraying must be used in premises equipped with mechanical ventilation both for hygienic as well as for safety reasons. Concentrations of solvents must be reduced below maximum permissible concentration and formation of explosive air-solvent mixes must be prevented. The absence of dust is needed for perfect application work. Therefore, spray-booths are used and these include the dry filter system, the curtain system, automatic systems, electrostatic and other systems.

The dry filter system: includes simple wall ventilation and extracts gases, vapours and smoke generated by the application to filter systems which retain the greater part of solid particles.

The curtain system: by using one or more water curtains and dry filters manages to absorb most of the gas, vapours and solid particles generated by the spray application. The water wash spray-booths are replacing the dry filter systems.

A problem which remains unsolved is that of the disposal of spray-cans for lacquer materials and of the aerosol which are produced. It is advisable that operators use face masks when spraying irrespective of the filter system.

Automatic spray systems are of three types. These include:

(a) Equipment with fixed spray-guns in which the pieces for varnishing or colouring are moved along a conveyer belt and made to pass under 2-3 adjustable spray-guns so that the piece will be completely coated. The spray-guns are controlled by servo mechanisms. Below the conveyer belt and carefully placed below the spray-guns is a collection basin for the excess sprayed varnish. This system is highly popular for colouring and for the varnishing of frames and baseboards;

(b) Equipment with oscillating spray-guns in which the pieces which are to be varnished pass along a conveyer belt right below the spray-gun which has adjustable, hydraulically or mechanically controlled alternative movement at right angles to the movement of the piece. There are servo mechanisms which regulate the opening and closing of the spray-gun in relation to the movement and dimension of the piece. There is a collection basin at the foot of the equipment. This system is used especially for automatic coating of mirrored panels, friezes, handles, frames etc.;

(c) Equipment with rotating spray-guns which consists of a vertical shaft with a series of arms (6 to 12) which rotate. At the extremities of the arms are spray-guns. These spray-guns move perpendicularly to the conveyer belt which is usually of a rolling shutter type and carries the objects to be varnished. Suitable servo mechanisms synchronize the action of the spray-guns with the passage of the objects.

For colouring wood, an electrostatic spraying application is used. The vaporized particles are projected on the object to be varnished through the use of an electrostatic field of force. Wastage of varnish is cut to a bare minimum and there is good coating of the supports. Every electrostatic system uses a high-voltage generator (40 to 90 kV for portable equipment and up to 150 kV for the automatic and fixed-position equipment). The electrostatic systems are of several types.

Electrostatic atomization can be used only with liquids of low resistivity (approximately 10^8 Ω per cm). The system has a high yield but suffers the disadvantage of not adequately filling holes which eventually become visible. It can only be used effectively in dry climates.

Combined centrifugal force electrostatic atomization uses a disc or a rotating cup from which the varnish flows. This allows for an easier electrostatic atomization. This makes possible the use of the products which have a resistivity of 10^8 Ω per cm.

For electrostatic atomization with compressed air, the coating product is atomized by the use of compressed air and special spray-guns. In such a case, the electrostatic field acts to direct the particles to the piece to be coated. The coating material should have a resistivity of about 10^7 Ω per cm. This method is used very much for manual application systems.

Electrostatic atomization in vacuum requires that the coating materials have a resistivity of 10^6 Ω per cm.

For electrostatic lacquer coating, it is necessary to control the humidity and the temperature as well as to use products which can regulate the conductivity of the wood itself. With the electrostatic systems, it is possible to apply practically every type of coating product. Normally, the electrostatic systems are used to coat spaced or round items such as furniture legs, chairs, radio-TV furniture, rifle-butts, billiard-cues etc.

Flood coating systems

Dip coating

This type of application is especially used for objects having a small section or difficult to handle (chair legs, curtain rods, brush handles) or for objects for which it is essential to guarantee the penetration of the wood by preservatives or protective solvents (window frames). The ideal shape to obtain a positive result by dipping is cylindrical or conical. Generally, it is sufficient that the object to be coated not have holes or shapes into which the product will not flow or run well, during and after dipping. This is so as not to leave surplus material which causes the coating to run. In the case of coating a small number of pieces, it is customary to use a sponge or to place the coated product upright to eliminate running. For better results, it is important to use a mechanically operated system for dipping as well as for drip wipe off. Dipping should normally be slow to enable the air, present in the wood and in the cavities of the product, to go out completely. The dipping speed has to be adjusted to the viscosity of the coating material used; the higher the viscosity the lower the outfeed speed. Normally the outfeed speed varies from 1 to 7 cm/min. In order to have a better lacquer flow it is preferable that all surfaces be removed from the basin at the most acute angle possible with respect to the vertical. Dipping can also be done manually by using products having a very low viscosity. However, the resulting quality is only average. Therefore dipping is suitable for pre-treatment or for application of the non-critical prime coats.

The equipment needed for dip coating includes the vat which should preferably be narrow and deep (to avoid excessive evaporation of the thinner and an accelerated oxydization of the wood) with a V-shaped bottom. The vat should be fitted with an agitation system to prevent, as in the case of pigmented products, excessive sedimentation of the pigment. It should be fitted with a filter system to get rid of the solids (e.g., sawdust conveyed by the pieces to be coated) on the coated surface. The agitation and filtering are normally accomplished by the use of a pump which recycles the liquid through filters. The vat also has an overflow wall, a drip-drainer, and a cover. The overflow wall gets rid of floating material (air bubbles, sawdust etc.); the drip-drainer returns excess lacquers which have dripped off the pieces; the cover is for use during non-working hours to avoid fire risks.

Flow-coating

Flow-coating is a method which is little used for coating wood. Often it is carried out by means of a pump and a series of tubes which literally pour the coating material on to the product. A drain vat collects the unused coating material.

Obtaining a good result depends on the form and dimensions of the object to be coated, on the direction of the tubes, the flow of the product and the speed with which the pieces pass through the pouring zone.

Curtain coating

The introduction of a curtain coating about twenty years ago caused a revolution in the coating of furniture, facilitating the finishing of the different parts of the furniture before the final assembling of the parts. Virtually every type of product may be curtain coated. The two-head machine also allows the use of products such as polyesters. The only limitation of the curtain coater is that of the shape and curve of the pieces. Curved pieces with acute angle, such as rods with a round, square or rectangular section cannot be coated in the curtain coater. The major functional mechanism of the curtain coater is a long pouring head, rectangular in shape and with a bottom which opens in the form of a V. The opening of the bottom can be adjusted within an accuracy of 0.5 mm to several millimetres. Flowing material forms a curtain of lacquer which is collected in a trough and recycled to the pump's feed tank. The pump feeds the material through a filter to the pouring head.

The objects to be coated pass along the conveyer belt and through the curtain and thus receive a measured quantity of the coating material. The amount of coating applied is regulated by means of the speed of the conveyer belt (the faster the belt speed the less material is applied) and by the width of the slot in the head (the more it is opened, the more material is applied). It also depends on the material's viscosity. The pump's rate of flow can also be regulated, should be as low as possible to avoid foam and should be adjusted to provide sufficient amounts to the head.

Two-head machines are used for the application of polyesters. Generally, polyester containing a catalyst (peroxide) is poured by the first head whilst the polyester containing an accelerator goes into the second head. The normal hardening process of the coat follows.

The coated film obtained through the use of the curtain coater is far better than those obtained by other systems. In fact, they are outstanding for their spreading, uniformity of thicknesses and satin finish.

The quantity applied may vary from a minimum of 60 g/m^2 to a normal quantity of 80 to 90 g/m^2 to a maximum of 600 to 700 g/m^2 per head. The conveyer belt's speed can be altered from 20 to 150 m/minute; the pump's rate of flow from 5 to 25 litres per minute. The width of the objects to be coated should be normally less than 1,200 to 1,300 mm. Widths of 2,300 to 2,500 mm may be coated by using specially constructed machinery.

Rise and fall adjustment of the head permits the coating of components of different thickness, normally as large as 150 to 200 mm, without any difficulty.

Roll coating systems

Direct roll coating

The direct roll coater applies the coating materials in the direction of the feed. There are three rolls in most roll coaters. The first is the doctor roll, of chromed steel, smooth or engraved; by varying the position to the spreading roll, the quantity of the coating material is regulated; the spreading roll which is a rubber-coated steel drum which spreads the material on the product to be coated; the nip-roll, a rubber-coated steel drum which both guides the piece in conformity with the spreading roll and controls the pressure.

The hardness and the type of rubber used to coat the drums of the roll coater are of extreme importance. Normally, the hardness (measured by Shore A hardometer) should vary according to the type of coating material applied: it ranges from a Shore 30 hardness for colouring materials to Shore 60 for primer polyester materials for u.v. drying. The higher the viscosity of the material, the harder the rubber cover. The type of rubber should be adjusted to the coating material. Elastomers of a neoprene type may be used since they are resistant to all thinners used in coating wooden products, but the high cost of such rolls, and the rapid wear and tear discourage their use at an industrial level. The problem of resistance to thinners may be solved by asking the lacquer producer to indicate the thinners in the product and informing the producer of the machine or the rubber rollers.

From 60 to 80 g/m² can be applied with the roll coater. This amount is related to the viscosity of the product, the pressure exerted by the doctor roll on to the spreader roll, and the feed speed of the product to be coated (the lower the speed the greater the quantity applied).

Problems of roll coating arise in connection with the grade of the substrate flatness. For example, if the panels to be coated are not perfectly calibrated, there could be areas in which there would be an excessive quantity applied and others where there is none at all. For the same reason, there could be some difficulty in applying materials on plywood and laminated plastic panelled products. It is especially difficult to obtain a good flow of the materials applied, if work is carried out with high viscosity liquids and with flash periods of less than 2-3 minutes. Because of these difficulties, the roll coater is generally used for the application of prime coats and of colours.

Reverse-roll coating

The reverse-roll coating machine is similar to the direct roll coater; it is fitted with an extra two rolls, the wiping roll and its counter-roll. The purpose of the wiping roll which turns against feed direction of the panel and is wetted by a suitable thinner, is that of smoothing and perfectly wiping the applied material.

The reverse-roll coater or reverse-roll filler have gained some success in the application of drying polyesters with u.v. rays on very absorbent rough surfaces (e.g., panels of rough particles). This is done in order to prepare the base coat for further applications of prime coats and finishes and eventually for the application of a painted base showing the wood's grain.

The quantity of the material to be applied with a coating machine varies from 10 to 200 g/m². The maximum quantity to be applied for u.v. drying products is from 100 to 120 g/m². Larger quantities prevent perfect drying in depth and have a subsequent lack of adherence to the substrate.

The working width is generally 1,300 mm and the maximum thickness of the products to be coated is of 200 mm.

The feed speed can vary from 2 to 20 m/min. Generally, the length of the workpieces cannot be less than 200/300 mm.

Gravity tumble polishing

Gravity tumble polishing is a system perfectly suited for the application of lacquers on objects which are very small or for application in large quantities.

The equipment consists of a cylindrical (or rarely octagonal) drum which rotates horizontally at 20 to 50 rpm. Holes in the drum's body and cover allow the solvent to evaporate. The operation is carried out by loading the drum with workpieces to be coated and the coating material. The drum is loaded to 50 to 80 per cent capacity. The necessary amount is calculated after several tests have been carried out. The drum then rotates for about 30 to 60 minutes and then the workpieces are removed in a dry state. The viscosity of the materials used (usually nitrocellulose products) is about 60 to 70 on Ford Cup (FC) 4 mm at 20°C. The quantity of coating material is about 600-750 g/m² of surface to be coated.

Centrifugal polishing

In centrifugal polishing a metal-net basket contains the pieces to be varnished. The process is, as is the preceding one, used for very small pieces. The basket is dipped in a low viscosity coating product, usually nitrocellulose, then pulled out. The basket is then inserted in a centrifuge which removes the excess lacquer by high speed rotation, simultaneously drying the coating material.

Grain printing

The machine for grain printing is similar to an offset printing machine. A steel drum on which the grain has been reproduced by a photographic process rotates in a basin to pick up ink. A scraping knife removes the excess ink leaving the correct amount in the drum's etched grooves. Another steel rubber coated drum removes the ink from the etched grooves and transfers it to the panel which is conveyed to it by a conveyer consisting of a series of small rolls. Grain printing on wood is done on two types of substrates:

(a) A low-cost substrate, such as particle boards. In such a case, one or two coatings of polyester filler are applied to the panels by means of a filling machine. The filler is cured by means of u.v. rays After sanding, the base is set with one or two coatings of prime material and, after drying, the printing of wood grain is done with a double printing device. (Two printings are made in order to provide film thicknesses and grain intensity so as to give good shading and a sense of depth.) Later, the cycles continue with an ordinary lacquer coating process;

(b) A substrate veneered with a low-cost species. The only difference between this and the preceding cycle is the use of complete or semi-transparent printing (generally one pass). This is done to leave a certain transparency, the so-called "natural" aspect of the veneering surface. The results obtained with this procedure are excellent.

The printing machine is, however, a machine which demands permanent maintenance by a specialized crew for correct operation and for good results. This explains why the printing process is being replaced by other processes.

Equipment for drying of lacquer coats

Open-air drying

The coating material can be dried by exposure to air. The equipment includes an appropriately covered area and a system of air-conditioning for drying. A ventilation plant is necessary for both health and safety reasons. The rate of air flow should be such as to be maintained below the maximum permissible concentration (M.P.C.) limit and the concentration of solvent required for an explosion. The importance of the uniformity of the ventilation for drying purposes must be stressed here. The differences of air speed at different locations causes different drying speeds generating blooming or blushing effects.

The problem of film uniformity, the air-flow necessary for M.P.C. values, sufficient space and appropriate work conditions restrict this type of drying to individual production, and make it unsuitable for batch production.

Hot-air drying

This drying process is used because of its simplicity. In fact, any type of coating material may be dried with appropriate equipment.

The merry-go-round trolley system has been developed to speed drying of lacquer coats. The trolleys carry the coated products on a continuous chain through the drying area where most of the solvents evaporate during heating and ventilation.

Operation times for this drying process are:

Coating product	*Time for satin finish (hours)*
Polyurethane l.p.	2-3
Polyester l.p.	0.5-1
Urea acid catalysed l.p.	2-3
Nitrocellulose l.p.	0.5-1.5

The merry-go-round drying tunnel is suitable for any type of manufactured items including panels, frames, assembled furniture and chairs. The drying capability of a merry-go-round may be as high as 1,500/2,000 m per day.

The conveyer system is a tunnel-type dryer with roller or belt conveyers and different drying zones. Normally, this type of drying system is divided into three sections: the flash-off zone; the drying zone; and the cooling zone. The temperature and the air speed in all three sections vary with the coating material. Generally, the temperature is varied from 20° to 50° or 70°C depending on the feed speed of the panels to be coated. The drying capacity varies between 2,000 and 3,000 m² per day depending on the shape and dimension of the pieces to be coated. The conveyer type dryers are best used for drying panel products.

Multi-deck drying tunnels are similar to conveyer systems. The conveyer belts are arranged in multi-decks (up to 10) which are usually loaded by a tipple loader. The efficiency is as high as that of the merry-go-round system. However, difficulties have arisen with this type of dryer because of uniformity of the ventilation and therefore variation in the temperatures from deck to deck. These dryers have a capacity of 2,000 m² per day of panel-like products like doors etc. The greatest advantage of this type of dryer is its relatively small size.

The vertical merry-go-round system is equipped with trays which are linked together. Completely automatic loading and unloading is maintained by synchronized conveyer belts which are regulated by servo controls to the movement of trays. The trays are about 3 to 5 m × 1.3 to 1.5 m and are made to pass the flash-off zone, the drying zone (one, two or more zones), and cooling zone in sequence. The number of trays in a furnace can vary from approximately 40 to approximately 140 depending on drying requirements. The daily drying output is around 2,000-2,200 m².

The drying time, with satin finish could be:

Coating product	*Drying time for satin finish (hours)*
Polyurethane l.p.	0.5-1
Polyester l.p.	0.3-0.8
Urea acid catalysed l.p.	0.5-1
Nitrocellulose l.p.	0.3-0.5

The vertical tower dryer is considered suitable for drying of panel-like parts and of squared stock such as frames and rods for curtains etc.

I.r. drying can be carried out by using various i.r. sources. There are three major sources. Each is characterized by a maximum amount of radiation at three different wavelengths: short wave varying from 0.8 to 2 m; medium wave varying from 2 to 3.5 m; and long wave varying from 3.5 to 12 m.

There have been discussions about the advantages of each source. It is possible to maintain a good drying process with all types of i.r. For safety reasons, the short- and medium-wave radiators are used.

In Italy, i.r. drying does not have any advantages but is in use for pre-heating of panels or in cases in which a short and rapid drying is required (colour-drying). Equipment for this, generally, consists of a conveyer belt above which an i.r. ray dryer is installed.

It should be pointed out that i.r. ray drying should be well ventilated because the i.r. rays evaporate the solvents. The vapours have to be removed by an exhaust system.

Insufficient ventilation causes vapour clouds preventing evaporation of further solvent from the coated film. In such a case, the drying process is delayed and the coating could turn out to be imperfect.

U.v. systems are used to apply the prime coats on absorbent substrates such as particle boards and fibreboards. U.v. systems are used to coat interior surfaces. Coating begins with a prime coat of u.v. sensitive material, generally applied by roll coaters. The work is finished with traditional materials.

U.v. systems lost their importance in coated film drying because of lack of flexibility. It is impossible or at least very difficult to dry pigmented lacquer finishes.

Ventilation is also important in u.v. plants, both for avoiding explosive mixtures as well as in certain cases to enable the paraffin of the polyesters to come to the surface.

U.v. drying systems are available in different versions:

(a) Systems with low intensity light. These have been widely used for drying of u.v. polyester materials applied with a coating film of 250 to 280 g/m². Drying times vary from 3 to 5 minutes. U.v. plants are usually equipped with conveyer belts and overhead u.v. lamps in shape of common fluorescent

lights. It is important that the distance between the light and the coated surface to be dried does not exceed 5 to 8 cm and that the distance between the lamps does not exceed 5 cm so that sufficient radiation reaches the surface for guaranteed rapid curing. Cracks in the coated film usually occur along the panel edges after the first pass through the drying tunnel. This defect has been avoided through the use of lights larger than the conveyer belt to guarantee uniform radiation over the entire surface. Such a tunnel could have 12 to 20 lights per metre;

(b) Systems with high intensity light are compact and have been especially used to dry u.v. sensitive products applied by roller coaters. Other applications are faced with the problem of the formation of small bubbles due to overheating of the radiated surface. The drying times are very short and can vary from 10 to 30 seconds. A typical tunnel contains a dozen lights with a total power of 25 kW. In order to obtain a uniform and sufficiently intensive radiation, the lamps have to be placed at distances of about 7 to 12 cm on top of the piece to be dried and the distance between the lights should not exceed 25 cm. The tunnels are generally fitted with a well operating ventilation system which is necessary for safety reasons. Normally, there are three areas in these plants; flash-off zone, a radiation zone and a cooling zone all with heavy-duty ventilation;

(c) Systems with both low intensity and high intensity lights give best results. This is by gelling and pre-hardening under low intensity and final hardening under high intensity lights. Such plants turned out to be less cumbersome than the plants having only low intensity lights. The total drying time is decreased to about 2 minutes;

(d) Systems with very high intensity light are latest developments in this field. The lights have a capacity of about 80 to 100 W/cm, compared with approximate 30 to 40 W/cm of the high intensity lights. This permits further reduction of the curing times to a few seconds (from 4 to 10 seconds). In addition, design has allowed reduction of the maximum temperature of the radiated surface panels. This has permitted the use of the very high intensity plants not only as for the high intensity lights, but also for drying prime and finishing products with good results. An efficient plant is equipped with 2 to 3 lights depending on the speed of the conveyer and the type of material to be dried. The feed speed is an average of 3 to 4 m/min. The plants with very high intensity generally do not need a cooling zone.

Annex I

FINISHING OPERATIONS

Operations	*Amount to be applied (g/m^2)*	*Application concentration*		*°C*	*Drying conditions*		
		%	*With*		*Ventilation*	*Time*	*Machine*
Sanding Colouring							
Drying Stacking							
Printing Drying							
Printing Drying Stacking							
First ink Drying							
Second ink Drying							
Third ink Drying Stacking							
Priming Drying Cooling Stacking							

Sanding
Priming
Drying
Cooling
Stacking

Sanding
Stacking

Colouring
Drying
Stacking

Assembling
Finishing
Drying
Stacking

Assembling
Packing

NOTE

____
Signature

Annex II

QUESTIONNAIRE

Report given by ______________________________ Date ________
Client ______________________________ Address ______________________________

PRODUCTS TO BE COATED

☐ Wardrobes
☐ Bedrooms
☐ Chests
☐ Frames
☐ Kitchens

☐ External casings
☐ Internal casings
☐ Entrances
☐ Marbles
☐ Chairs

☐ Radio TV furniture
☐ Panels to be coated
☐ Precoated panels
☐ Halls, living-rooms
☐ Musical instruments

☐ Tables
☐ Turnings
☐ ________
☐ ________
☐ ________
☐ ________
☐ ________

The products are ☐ modular type ☐ office
☐ individual type ☐ standard

PARTS OF MANUFACTURES TO VARNISH

☐ Internals ☐ Edges
☐ Externals ☐ Rears

TYPES OF COATING MATERIAL

☐ Pigmented
☐ Transparent

DIMENSIONS OF PRODUCTS

Thickness ________ Width ________
Length ________ Depth ________
Height ________

SUBSTRATE USED

☐ Plywood ☐ Honeycomb core laminated plastic
☐ Chipboard ☐ Hardwood (Solid)
☐ Plywood/laminated plastic ☐ Fibre
☐ Blockboard

TYPE OF SURFACE TO BE COATED

☐ Rough ☐ Assembled
☐ Fibre ☐ Veneered
☐ Paper ☐ Coated

Supplying firm ________
____

FILLING

☐ Open pore ☐ Semi-open pore
☐ Closed pore ☐ Semi-closed pore

☐ Gloss
☐ Strongly opaque ☐ Semi-bright
☐ Opaque ☐ Semi-sparkling
☐ Semi-opaque ☐ Sparkling
☐ Calendered
As our product ________

PARTICULAR NEEDS

Is the cycle described in a chapter? ☐ Yes
☐ No
In case of affirmative attach copy of chapter

GRAIN PRINTING

☐ Embossing ☐ Transparent
☐ Printing ☐ Covering
☐ Semi-covering

NOTES ______________________________
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XVI. Industrial production of doors, windows and frames*

The production of interior and exterior wooden shutters is a major contributor to the economy of developing countries. This is due to the vast investment programmes of these countries in the housing field. There is thus a need to produce the more important elements, such as doors and windows, locally. These products, which will have different specifications from one country to another, nevertheless must meet common standards, such as protection against local atmospheric conditions (high humidity, wide thermal ranges, dust etc.) and need to be manufactured in the most simple and efficient manner. The product to be manufactured determines the choice of manufacturing machines. There is the need to study simple models, with adequate mechanical specifications, which are easy to manufacture and assemble. This will reduce the capital investment, curtail expenses during the assembly stage and reduce routine maintenance needs.

It is very necessary to investigate the availability of raw materials which are to be used, and other materials which, unfortunately, sometimes cannot be purchased locally. This is done in order to reduce the importation of those materials and supplies. Imported fittings and supplies should eventually be replaced by others which are manufactured locally, possibly even produced by the company. Those materials which may be replaced by alternatives will be noted later. It is certain, however, that it shall be necessary to forecast and care for all production requirements by ensuring a stock of raw materials and supplies of reasonably uniform specifications so as to avoid technological changes in the manufacturing processes, and technical production problems which could lead to increased manufacturing costs. Further, it is appropriate to underline, at this point, the importance which the daily production output plays upon the choice of manpower, machinery, auxiliary plant services and material handling equipment. Clearly, the low volume production of many different items requires the recruitment of highly skilled labour, since the various manufacturing operations and their good quality depend on the skill of the workers, rather than on the type of machines used. On the other hand, in those plants producing on a large-scale basis, it is obvious that manual skill is needed only in some specific manufacturing operations. With this in mind, the specifications, the manufacturing cycle for large-scale production, the machinery and equipment needed for manufacture of each product will be examined. The timber drying and finishing steps are treated in chapters X and XV respectively.

Doors for interiors

Flush doors

The interior type door consists of a panel "core" built up with a solid wood frame and with reinforcing blocks for locks and hinges, containing a honeycomb core, which may be of cardboard, wood or fibreboard, and by two skins which may be plywood or particle board or even fibreboard panel. The skins of the core may be either flush or have openings for glass inserts. They are laminated with high quality veneer sheets or simply paint coated. The core edges may be rebated or flush, depending on the standard requirements in different countries. Naturally, all the combined

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* By E. Minarelli, expert in joinery production. (This is an edited version of ID/WG.277/9/Rev.1.)

atures which may be given to the outer appearance of the core, in order to impart the door its different finish and quality, do not modify its basic structure. Provided certain conditions of accurate preparation of its components are satisfied, the manufacture of the composite panel is simple. Failure to comply with such conditions may lead to poor results which in turn may give rise to a lot of problems in the succeeding manufacturing stages, particularly during finishing.

As far as the finish and outer appearance of the composite panel is concerned, provided the aforesaid conditions relative to the basic structure remain unchanged, doors for interiors may be classified into two types.

Standard flush doors (second grade)

The standard flush door, which in turn may be rebated, lipped flush or have an opening for glass, is made by using relatively cheap materials. That is to say, the lips or rebates are machined directly on the same wood which acts as the core frame. The particle board, fibreboard or plywood skins are not veneered, but are painted immediately following the thickness sanding operation. The hardware used is generally of average quality, even though its service performance is good.

Veneered flush doors (first grade)

This type of door may also be rebated, lipped flush or have a glass opening. It is made with good quality materials. The lips or rebates are machined directly off the core frame, then edge banded with high quality veneer strips, or obtained after lamination of good quality wood strips on the edge. Prior to laminating the core skins with high quality veneer sheet, the raw skins are thickness sanded. After veneering, they are lacquer coated in semi-gloss or satin finish.

Particular care is given to doors with under cut or applied panels, instead of glass openings, so as to obtain the effect of a continuous sheet of veneered skin taken from the same matrix as the sandwich. The hardware used is of top quality.

The first grade doors are also made from panels of which the skins have been upgraded by surface printing or by melamine or flexible or rigid plastic overlays. However, this type of panel will not be treated here, as its application in today's door manufacturing industry is negligible.

Manufacturing process

The manufacturing process for the two types of doors just described is almost the same; in fact, the process for first grade door differs from that of standard doors in that, as it will be seen further on, it requires a few more machines.

Timber drying is the first working step. The drying process of the sawn timber to be used as internal framing for the panel core and the choice of drying equipment are the subjects of chapter X. Therefore, this step will not be discussed here.

Cross-cutting and multiple ripping of boards follows timber drying. In order to obtain both the core-frame of the panel core and the hinge lock blocks, the dried boards must be cut and ripped into slats of suitable dimensions. To speed up the production rate, particularly when the daily door output is relatively high, it is suggested that the following work sequence be applied:

(a) Trim off defective board ends with a swing or radial cut-off saw;

(b) Cross-cut boards to correct lengths with a similar cut-off saw; in order to obtain from each board lengths equal to the stiles, hinge and lock blocks forming the panel core frame, allowing a small amount of excess wood for the successive trimming operations of the panel sandwich;

(c) Machine the cross-cut boards and if needed the unripped portions of boards into slats of correct cross-sections with the multiple recycling rip-saw.

Very often, during the drying stage the timber is subject to twisting effects making it practically impossible to machine the boards correctly, either with the cut-off or with the multiple rip-saw. To avoid costly rejects, it is good practice to complement the cross-cutting and ripping section with a planer, a thicknesser and a band-saw.

Further, because of the high production output that can generally be achieved during this step and due to the risk of deformation of the slats, it is advisable to have a buffer storage between this step and the next one, with storage capacity equivalent to at least a two-day production run. This not only will allow better balancing of the production departments concerned but will also allow time for the further relieving of the internal wood stresses.

Door frame assembly is done with the panel-core internal framing and the lock and hinge blocks. These must be fastened together in order to form a whole unit with the panel core during the pressing stage. The fastening may be achieved in several ways, but the method most widely used is to use steel or aluminium staples which are shot in by means of portable or automatic stapling machines. The frame components and lock blocks are then laid out on assembly benches, equipped with special templates, or they are simply rested one against the other. In the latter case, assembly relies on the workers' skill to obtain a good matching. It often happens that the internal frame's rails and stiles, during the ripping operations, are subject to twisting and warping effects which might impair the frames. In order to overcome this set-back, it is good practice to install a saw, which may be either a band-saw or circular saw depending on the production requirements, that will make small stress relieving cuts on the rails and stiles. This will ensure greater control of the frame's stability.

Panel sizing is done on sheeting materials which include plywood, particle board or fibreboard panels which will make up the door skins after the pressing operations. It is clear that, to give the plant's flexibility in the production of doors of different dimensions, it is not advisable to purchase these materials pre-sized as this will cause relatively high storekeeping costs. It is, therefore, advisable to have a storage of panel materials of standard door sizes and to take daily from this storage the amount needed to meet the production schedules.

Thus, the panel-sizing preparation section must have the following equipment:

(a) A fork-lift truck which will take the panels to be cut to size, from the general store and store them over a scissor lift bench to facilitate loading the panel-sizing saw;

(b) A panel saw of suitable cutting capacity, to cut sheets to required sizes;

(c) A router to carry out rough cut-out operations on those sheets which will be used as skins for panels which will be used in turn as doors with openings for glass inserts;

(d) A buffer storage unit between the sheeting materials section and pressing section, where all sized sheets and all undercut panels reclaimed during the rough cut-out operation will be stored. These will be kept ready for the pressing operation.

Honeycomb core is preferred to other panel cores. The panel core, as mentioned previously, may be either of cardboard (more commonly called "honeycomb") or strips of wood, plywood or fibreboard. However, in modern door manufacturing in developed countries the "honeycomb" is the most widely used because of its relatively low cost compared with other types of core materials, its greater flexibility in use and because it is commercially readily available. The honeycomb core preparation section requires the installation of only a band-saw to cut to size the honeycomb, which is to be used as core for cut-out doors. This is due to the honeycomb's ability to adapt itself to any geometrical form and to undergo, within certain limits, a fair amount of deformation under pressure. This allows compensation for the eventual slight variations to which the panel core may often be subject, because of the impossibility to control the inner frame component thickness.

Veneer preparation is a manufacturing step which applies only to the production of first grade doors. Veneer preparation requires:

(a) Construction within the plant of a veneer stock storage with controlled temperature and moisture, in order to avoid variable room conditions which cause excessive drying of the decorative veneers, thus ruining their quality;

(b) Installation of a veneer jointer which will enable jointing the veneer in a matching pattern to give the door skins and panels the appearance of a homogeneous single wood board with all its grain patterns oriented in a natural fashion;

(c) The installation of a veneer thread splicer to enable the veneer previously jointed to be spliced both lengthwise and crosswise;

(d) A control bench fitted with a light table having a frosted glass top in order to check the quality of the veneer joints.

Panel to frame assembly occurs when all the elements which go to make up the panel core are available. These elements are the complete inner frame, lock and hinge blocks, honeycomb pre-cut panels, panels for skins and veneer sheets. It is possible to start the sandwich-forming operation by means of hot pressing. This involves the following sequence:

(a) Removal of the skin panels from storage. The panels should have been alternated, face up and face down;

(b) Feeding two panels simultaneously through the roll glue-spreader for spreading urea-based glue on two opposite faces of panels and subsequent feed of the panels to a conveyer along the pressing line;

(c) Removal of the first panel from the conveyer and placing it on to the core forming bench;

(d) Removal of the internal frame from nearby storage and overlaying the frame on to the first skin panel which has been spread with glue and is on the core forming bench;

(e) Removal of the honeycomb from nearby storage and placing it into an internal frame lying on the core forming bench, above the first (bottom) skin panel whose inner side has been spread with glue. Fastening of the honeycomb to the frame is then done with staples;

(f) Removal of the second (top) panel from the conveyer and placing it over the internal frame;

(g) Feeding the core into the hot platen press and repeating the above work sequence for the next core;

(h) Discharge of the pressed panels, at the end of pressing cycle. Storage of the panels for a time sufficient to guarantee their complete cooling and their equilibrium with room moisture conditions is the final step in the sequence.

Door panel calibrating follows the pressing cycle. All core panels, be they used as plain or luxury doors, must be thickness-sanded in order to ensure their constant thickness throughout the production runs to get their faces perfectly smooth throughout, and within acceptable tolerance limits. For this reason every panel is passed through a wide belt contact sander, which may be of the single overhead belt type, or a top-and-bottom belt type. The single overhead belt-type sander involves two machining steps, one for each face of the panel. Each panel, after the thickness sanding operations, is checked to ascertain that its faces are well finished and do not show any streaking, chatter marks, trailing marks, sand troughs or other surface defects. After the thickness-sanding operation is completed all panels to be used as plain doors are stored prior to undergoing sizing or rebating. All panels to be used as first grade doors are moved to the pre-press storage to undergo the veneering operation. Next to the check-up point at the calibrating station, it is advisable to set up a "doctor" section where all surface defects previously mentioned are patched up in order to cut down on manufacturing costs due to eventual work rejects. Generally, this "doctor" section is equipped with a work bench with a pot of filler, a spatula, a splicing knife, glue, a household hot pressing iron, and a belt sander.

Face veneering and laminating section follows calibration. If production runs are relatively low, the veneering and laminating department may be equipped with a panel laminating press. If relatively high production runs are involved, it is always wise to place the veneering and laminating section in line with the calibrating department. At this stage of production both the skin veneering and pockets panel laminating and veneering operations are carried out on first class doors. Veneering of the core skins, which have been thickness sanded, has the following work sequence:

(a) Feeding the sanded core through roll glue-spreader for spreading urea-based glue on both faces followed by subsequent feed of the core to a conveyer designed to minimize surface contact with the wood along the pressing line;

(b) Removal of the first sheet of veneer from the bridge-type storage, located on a frame over the press preparation bench, followed by laying the sheet over the same bench;

(c) Placing the already glued core over the first sheet of veneer;

(d) Removal of the second sheet of veneer from the overhead bridge-type storage and laying it on top of the other face of the glue spread core;

(e) Feeding of the veneered door into the hot press and beginning the work sequence for the next core;

(f) Unloading the veneered door, after completion of press cycle. Storing to allow complete curing and cooling of panels finishes the veneering and laminating process.

Laminating and veneering first grade doors is carried out in much the same way as for the flush panel veneering, that is to say by spreading glue over the faces which have to be laminated and veneered;

and then laying veneer sheets on to the outside faces of pockets and then hot pressing and curing followed by storage.

Door sizing and edge banding is now done to the panel untrimmed doors, sanded and veneered, as they come out of the press. These doors have protruding excess skins. It is therefore necessary to trim and size the rough door panels. The trimming and sizing operation is done on single or double ended automatic machines which do not require highly skilled manpower to control the quality of the work. Once they have been set up, these machines need only manual feeding and out-feeding. Plain doors are sized and rebated at a work station which has:

(*a*) An automatic double end sizing machine to trim and rebate the doors on the stile edge;

(*b*) An automatic panel turner to present the unmachined edges (rail edges) to the second double end tenoner;

(*c*) A second automatic double end sizing machine to trim and rebate the doors at the rail edge.

In addition to the sizing and rebating operations, first grade doors will be edge banded with top quality lipping or veneer bands along the stile edge. This type of door needs a work line composed of:

(*a*) An automatic double end sizing machine to trim or rebate the doors on long sides;

(*b*) A link conveyer between first double end sizing machine and edge banding machine;

(*c*) A double side edge banding machine for the application, on the long sides of doors, of high grade wood lippings and for the machining of rebates. Alternatively, a specially built double side edge banding machine for application of high grade veneer bands on rebated doors may be used;

(*d*) An automatic panel turner to feed the doors into the second double end sizing machine;

(*e*) A second automatic double end sizing machine to trim the doors on the rail edges and to machine the top rail.

First grade flush doors which are to be fitted with overlapping lippings require the same work sequence as for plain doors. However, the overlapping lips are glued onto the door's edges by special clamps after the trimming and surface finishing operations.

The final sizing of glazing cut-outs is necessary to correct all geometric deviations at this stage, so the door, after trimming and rebating will have the correct size. Thus, the cut-out can be accurately centred in relation to the door's outer edges. This is because rough cutting-out operations do not use reference edges. Consequently, during the pressing and sizing operations some inaccuracy of the cut-out arises. This accurate machining or centring operation of the door cut-out is done on an automatic router, which may be either of the type using a template copying device, or a numerically controlled type.

The finish sanding, face and edge coating operations are treated in full as a separate topic, therefore, in the present context only a broad outline of the work sequence involved will be given.[1] The work consists of:

(*a*) Fine sanding of edges and faces;
(*b*) Staining edges and faces;
(*c*) Curing the staining coat;
(*d*) Denibbing the stain-coated edges and faces;
(*e*) Base-coating the edges and faces;
(*f*) Curing the base coat;
(*g*) Top coating the edges and faces with transparent or pigmented coating materials;
(*h*) Curing the top coat.

Assembly of hardware, mouldings and cut-out panels is done at a stage where the door is practically complete. The door needs only to be fitted with hinges, the lock, glass mouldings or cut-out panels and, in the case of doors with overlapping lippings, be fitted with lippings all around. All the above described operations may be carried out either on a transfer line or singly at separate work centres. If the final assembly operations are carried out on a transfer line, provision must be made that each work station along the line be stocked with the hardware and fittings essential to that station's

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[1] For additional details of sanding and finishing, see chapter XVIII.

operations. If the assembly operations are carried out at separate work centres, all hardware and fittings essential to each work centre may be stored nearby each machine or work bench. It is a fact, however, that in spite of their lower flexibility in-line operations are to be preferred to operations carried out at separate work centres. This is because they achieve a considerable saving in material handling in buffer storage, in labour and supervision and, last but not least, they guarantee better product quality. Whether one or the other operational method be adopted, the work sequence does not change and is as follows:

(a) The machining of lock housing and handle bores on the lock mortising machine;
(b) The assembly of hinges on the hinge driving machine.

These two operations may be performed simultaneously by using a combination lock mortising and a boring/hinge driving machine. They are followed by:

(c) The assembly of the lock;
(d) Fitting of the glass fixing mouldings or cut-out panels;
(e) Packing, either with shrink foil wrapping or with corrugated cardboard. The latter method is preferred in that it offers better protection against impact and during stacking, while the former requires the installation of very costly equipment.

Exterior doors

Specifications of exterior doors

The exterior type door differs from that for interiors in that it must satisfy completely different functional specifications. Both types of doors must satisfy the requirements of easy handling, they must allow control and regulation of air flow and they must allow people and objects to pass through. However, doors for exteriors must also protect the house from outside agents. Thus they must prevent water from entering, resist the destructive action of atmospheric agents and have burglar-proof characteristics. Thus the exterior type door must be built of more stable and solid materials and still be easy to construct.

Exterior doors are of two types:

(a) The doubly reinforced door with the interior face sheeting made of panel sandwich;
(b) The door with an outer solid sheet composed of hardwood tongued and grooved boards ed to form a wide board; or with the interior face laminated with plywood.

Manufacturing process

As the manufacturing cycle for the inside face of the doubly reinforced door is analogous to that of the composite panel previously described in the section on interior doors, only those operations which are different for outside doors will be given, with a description, if needed, of those complementary steps which serve to complete the manufacturing cycle.

Timber drying, cross-cutting and multiple ripping of boards is identical to the previously described processes.

Cross-cutting and multiple ripping of matchboard, water-drips and stock frame is accomplished by first cutting the boards to length on the cut-off saw. After this, the boards are ripped to size on the multiple rip-saw to obtain rough sawn matchboard (composed of strips of wood), water drips, rails and stiles for frames.

Stock selection is the next step. All components are sorted out prior to further machining. All slats and boards having knots, deformations and defects of any kind which might influence the appearance and good quality of the doors, must undergo defect removing operations such as knot boring and plugging by means of appropriate machines (knot borer and plugger) and edge and surface straightening on the surface planer.

The machining steps of stock straightening to end trimming and tenoning described above may be best done in a machining line made up of a four-sided moulder in line with a 90° angle transfer unit, equipped with push feeding arm which automatically feeds the workpiece into a double end automatic tenoning machine. This machining line not only guarantees the product's quality, but also results in a great saving of labour:

(a) Stock straightening is done on the surface planer and on the thickness planer;

(b) Match profiling. Both edges of the matchboard stock are machined according to the type of profile required: tongue and groove shiplap or rebated pattern;

(c) Inside profiling of rails and stiles. The rails and stiles of the master frame are machined on the spindle moulder;

(d) End trimming and tenoning. All stiles and rails are end trimmed and tenoned at the combination trimming saw-moulder;

(e) Water drips machining at the spindle-moulder.

Preparation of panel core for interior face sheeting is the same as for interior doors.

Matching of exterior face sheeting is done by matching all boards so as to form a full-size board. This is accomplished by gluing and pressing them in special clamps. The glue is then allowed to cure before undergoing the next manufacturing stage.

Door calibrating is done after glue curing; the matched face is calibrated either by a belt sander or by an automatic wide belt contact sander, depending on the quantity of doors to be produced.

Fixing of the panel to frame is generally carried out on a cold press in order to avoid deformation of the two components. The work sequence is as follows:

(a) Spreading of glue over the contact face of the interior half, either manually or by roll glue spreading machine;

(b) Placing the interior half which was just spread with glue onto the panel which rests on press charging table;

(c) Feeding the doors through cold press platens. The press may be either single or multi-daylight depending on the production quantities required. This step is followed by the unloading of the doors at completion of the press cycle time and their storage to allow for complete glue hardening.

Assembly of doors with matchboard panels may come next. For exterior doors made up of panels or those with plywood inside faces, end trimming and tenoning is followed by the final assembly stage. The operation is done with manual or hydraulic clamps after spreading of glue on the various components by means of gun spreaders or brushes.

It is assumed that all components such as stiles, top, bottom and middle rails and panels have been stored nearby the clamps after the previous manufacturing steps.

Each component, after being spread with glue, is carefully placed in position for the clamps. Then the clamps are tightened and the frame is left under pressure for a few minutes. The clamps are loosened, the door is unloaded and stored for a sufficient time to allow glue curing prior to the next work step.

Calibrating of the door is as for interior doors.

The sizing and rebating work sequence for both types of exterior doors is the same as for door frame assembly. By fitting an extra machining head on the automatic double end sizing machine, it is possible to machine the groove containing the water drip element.

Surface and edge sanding and finishing is as for door calibration.

The assembly of hardware, trims and water-drips work sequence is identical to that described in panel to frame operations.

Windows–louver doors and roller blinds

Terminology

Generally speaking, the window is composed of the following elements:

(a) The sash frame which fastens the window to the building structure and receives the sash or sashes;

(b) The sashes within the sash frame which allow air, light, people and objects to pass through;

(c) The fastening element (hinges, sliding support etc.) which enables the moving sash to open or close;

(d) The locking elements (handles, tie rods, latches etc.) which lock the moving sash in a closed position;

(e) The shading elements (louver boards and roller blind slats etc.) which control the light, protect the window from external agents and increase thermal insulation.

The window may be classed according to three types of closure. The first type is rotation during which the moving components describe a cylindrical path. The rotational class contains windows with one, two, three or more wings, horizontal and vertical centre-hung windows, and tilting windows. The second type of motion is sliding, during which the moving components are parallel. In this class are windows with vertical and horizontal sliding wings. The third class of motion is mixed rotation and sliding. The moving frame component describes a plane, while the other components described a cylindrical path. To this class belong the balanced transom window, folding windows and bellow windows.

Only those windows belonging to the rotation class will be treated, as their manufacturing cycle can be considered to be common to all classes of windows.

Manufacturing process

There is great similarity among the manufacturing processes used for windows, louver doors and roller blinds. This makes it worthwhile to describe the manufacture of all three products at the same time. Kiln drying is covered in chapter X and, therefore, will not be covered in this chapter.

Cross-cutting and multiple ripping of boards is an initial step. Kiln dried boards are removed from the stacks, then cut to appropriate lengths on the swing or radial cut-off saw for the various components to be used for windows, louver doors and roller blinds. The sawn boards are ripped on the multiple rip-saw, which is fitted with a return bench for eventual re-machining of the board portions exceeding the ripping capacity of the multiple rip-saw. Defects, such as knots, are removed at the combination knot boring and plugging machine.

Component moulding and tenoning requires the moulding of components on the spindle moulder; and machining of male and female tenons at the combined trimming and tenoning machine. The two operations may be performed on an automatic machining line consisting of a moulder in line with a 90° feeding unit and an automatic double end tenoner. This line will greatly reduce manpower and floor space requirements. The next steps are end chamfering of louver boards at the chamfering machine; and end trimming of tie rod cover strips and water drips at the double cut-off saw. This is followed by mitre-cuts on water drips.

Slot mortising of louver door stiles requires the machining of louver board stiles on the pneumatic slot mortising machine.

Assembly of "bore in" hinges on sashes is done on the automatic hinge driving machine. This operation must be performed prior to assembly of sash frames, otherwise problems of machine setting and frame handling might arise, especially if many-winged windows were to be produced for which sash frames are very cumbersome. Assembly of sash and window frames is the next operation. It requires:

(a) Spreading of glue on male and female tenons of the sash and window frame components by gun or by glue brush equipment, in either a batch process or by an automatic glue brushing machine;

(b) Matching the frame stiles and rails on the manual or hydraulically operated frame clamps;

(c) Releasing the clamp pressure, unloading and storing the assembled frames to allow complete glue hardening.

Assembly of louver door frames requires:

(a) Glue spreading on male and female tenons as above;

(b) Watching the stiles, rails and louver slats manually or hydraulically with tightening clamps of closing-in pistons;

(c) Releasing of clamp pressure, unloading and storage of jalousie frames as above.

Calibrating of sashes is done either by manually operated belt sanders or by automatic wide belt sanders. For high production runs two automatic wide belt sanders are used in line, linked by a device to present the unmachined edges for further machining and a control station. Alternatively, an automatic wide belt bottom sander and a control station are used.

Sizing and rebating is done for only the sashes. It is possible to tool up machines capable of performing in one pass such machining operations as glass rebates, locking rod groove, water drip housing and latch housing (on louver doors). When small production runs are required only one machine is needed and the workpiece is passed through the machine first along the stiles and then along the rails. In case of large production runs, it is advisable to install a machining line which links an automatic double end sizing machine, a workpiece turner, and another automatic double end sizing machine.

Thus the work sequence is as follows:

(a) Sizing, rebating and machining of the locking rod groove and the latch housing, on the rail edge. This is done in one pass on an automatic double end sizing machine. In the case of louver doors, the sizing and rebating operations are done:

(b) Turning the wing and feeding it into second sizing machine in line, by means of an automatic work turning device;

(c) Sizing, rebating and machining of the glass way and the water-drip housing groove on rails on the second pass through the second automatic double end sizing machine (in line with workpiece turner). In the case of louver doors, only sizing and rebating operations are performed;

(d) Storage of sized sashes in buffer storage.

Pre-assembly follows. Pre-assembly means the assembly of such fittings as water drips, locking rods, cover strips for locking rods and lean-on external strips (if any). These pre-assembly operations usually are done with power driven portable tools such as nailing guns, screw drivers, drills etc. on suitable work benches.

Surface and edge finishing will not be discussed, as it is covered in chapter XV.

Hardware assembly may be done either on single machines or on a specialized assembly line consisting of a suitable number of work stations in accordance with production requirements. The work sequence is as follows:

(a) Drilling water draining holes in the sash with portable electric or pneumatic drills;

(b) Setting the eye-bolts on the sash to engage the locking rod. This is done by means of driving machines or portable tools, depending on the type of locking rod used;

(c) Setting the hinges on sashes by an automatic hinge driving machine, or with a combined automatic or manual hinge boring and driving machine, depending on the type of fastening element used. For example, on the louver doors the fastening element is usually of the wedge-type. This requires a hinge slotting and driving machine, be it semi-automatic or fully automatic;

(d) Assembling the latches, forks and the locking rod in louver doors on the work benches with portable power tools or hand tools;

(e) Assembling the packing strips, if any, in the windows and louver door sashes and sashes at the work benches or work stations;

(f) Testing the fastening and locking elements at the work benches or work stations in order to ensure perfect fit of frames and sashes;

(g) Packaging the finished windows. All handles or protruding hardware are not assembled but are enclosed with the windows for ease of packaging and mounting on site. Packaging of windows is often not necessary. However, if packing is required, it should be done with corrugated cardboard boxes for the reasons already explained in the door manufacturing process.

Frames and interior trim

Terminology

In the door and window manufacturing field, the term interior trim means all those decorative mouldings which enhance the quality of the product as well as those which give the product a greater structural function. Usually, mouldings are made of selected tropical hard woods such as African walnut, mahogany, ramin, etc., because these woods provide an attractive appearance.

Manufacturing process

As the machines which produce lippings, decorative parts, glass holding strips, skirting board and casements have specifications which allow for the machining of any type of mouldings, it is unnecessary to detail their function in this report. Kiln drying is described in chapter X. Cross-cutting and multiple ripping of boards is done to cut out defects and cross-cut on the swing or radial cut-off saw; and to machine cross-cut boards into slats on the multiple rip-saw. Unripped portions of boards in excess of multiple rip-saw capacity are recycled if needed.

Shaping and cutting to length requires:

(a) Shaping of moulds on the spindle-moulder for low production runs or [illegible] the four side multi-spindle moulding machine where high production is needed;

(b) End tenoning of casing jambs and heads on the combination circular saw-spindle moulder (for low production) or on the automatic double end tenoner (for high production);

(c) Mitre-cutting of decorative moulds and glazing mouldings on the single or double head mitre saw.

Sanding and finishing is covered in chapter XV and will, therefore, not be discussed herein.

Assembly steps pertain to decorative mouldings and glazing mouldings. This is because the casings and skirting boards are normally supplied to a customer in running metres. The decorative mouldings and the glazing mouldings are assembled and nailed to the products by portable pneumatic nailing guns. As regards the casings, the jambs and heads of which are normally produced in knocked-down form, the following assembly operations should be followed:

(a) Hinge driving, on the door supporting jamb, by the automatic hinge boring and driving machine;

(b) Machining the latch counter-plate housing, on the jamb opposite the hinged jamb, with a lock mortiser. Followed by fitting the lock counter-plate by means of screws;

(c) Drilling the holes for bolts and bushes, for jambs and heads assembly, on the bush drilling-driving machine or with the drill and hammer on the assembly benches.

Packaging is done in a corrugated carton prior to shipping.

Conclusions

The choice of plant machinery and the amount of its use with respect to required production is of prime importance to a company's cost structure and efficiency. In other words, where a company plans a set production figure, providing the equipment usage remains constant, the optimum use of a production unit will be that unit's designed capacity. This means that each piece of equipment must be carefully selected so that it may cope with the planned production of the overall operation. Take, for example, a unit which is required to produce doors, windows and mouldings. This unit will consist of a variety of machines, including some automatic lines. Such a unit can only be justified economically if annual production of less than 40,000 units is anticipated. Over this level it is essential for management to consider the pros and cons of providing more sophisticated equipment to avoid bottlenecks in the operation.

Because of the importance of adhering to careful planning during the early stages of setting up a plant, a company needs to examine all possible situations. These include availability of power, water, the local work-force (both skilled and unskilled), transportation systems, materials and shipping. The latter is particularly important where export markets are involved. To sum it all up, it is important that proper planning be carried out to ensure that an operation will be viable. It must be kept in mind that initial production targets can change, hopefully upwards, in a very few years time.

XVII. Production of chairs and other wood components*

This report considers chair production from several viewpoints including machining chair components, production flow-charts, and the application of adhesives, coating material and hardware. Production operations on both single and multi-purpose machines is compared. In addition, staining and lacquer coating equipment for chair frames, including equipment dipping, spray coating, flow coating and coating by means of electrostatic systems is considered. Finally, the report presents a machinery and equipment list for a chair factory of fifty employees.

The furniture industry makes use of a variety of raw materials, each one of which poses different technological and production problems. However, a general distinction can be made between products manufactured from solid wood and those made of wood derivates such as wood-based panels. The machinery and equipment used in the manufacture of chairs does not differ substantially from that required for other forms of wood manufacture. Therefore, this is applicable to numerous forms of wood processing.

General features of the Italian chair industry

Furniture is a major industry in north-east Italy, particularly in the Friuli Venezia Giulia area. Approximately 650 firms with 12,000 employees have an annual cash turnover of approximately 2 billion Italian lire ($US 2,340,000)[1] coming mainly from export business. All these firms are located in an area of about 300 km^2 around Manzano, San Giovanni al Natisone and Corno di Rosazzo. These companies, the oldest of which were formed at the end of the last century, are involved almost exclusively in a particular type of industry. These are "light technology" industries, with a low level of investment per employee, and a high degree of specialization which is typical of this region. Because of this, these industries enjoy a high degree of manufacturing flexibility since they can make use of sub-suppliers.

Considering the relationship between the products and the market in which the chair industry operates, the following alternative relationships are possible:

(a) Standardized and consistent production models; production for stock, low quality standards, competition merely based on price;

(b) Varied but reasonably consistent production models; fairly large mass production (same models for different clients), competition based on price and quality;

(c) Very large selection of production models and timber species; limited mass production, manufacture exclusively by order, competition based on quality of products and services.

Alternative *(a)* offers the possibility of establishing highly automated and productive manufacturing lines using specialized machines. This is also possible for alternative *(b)* though not to the same extent, because the various models are technically compatible but less productive. In the last case, *(c)*, which

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[1] The amounts given in lire (Lit) are for April 1978. At that time the value of the lira in relation to the United States dollar was approximately $US 1 = Lit 850 (Lit 1,000 = $US 1.2).

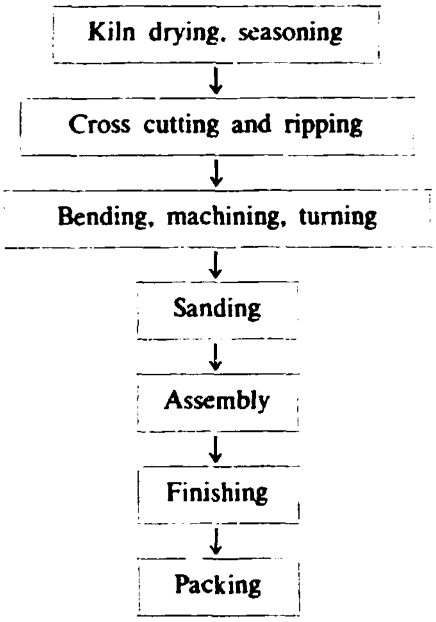
is probably the most common case at present, the impossibility of using the same manufacturing techniques for a wide range of different products, requires versatile machinery. This machinery must be ideally capable of being used for the production of a large number of different models.

Theoretical production cycle

Let us consider the "integral cycle" plant for the production of chairs. This is a plant where production starts with the sawn timber and ends with a fully finished and packaged product. We will not consider the upholstering of chairs and the bending of wood by steam because these are specialized operations carried out by specialized firms. The choice of machinery is based first of all on its versatility as this is a major requirement of this type of plant, which supplies sub-components to the furniture industry. More sophisticated types of adaptable machinery for mass production are not considered in this chapter.

A major role in the solid timber industry is played by fairly straightforward machinery, and the human element is still of great importance. The machinery can easily be adapted to a number of different operations required by rapidly changing chair models.

A production cycle applicable to most types of chairs and also suitable for other solid timber components is shown below.



Kiln drying can be carried out on planks or on rough sawn components. Machining has been divided into three groups since both bending and turning require special equipment and are often carried out by specialized firms. Finishing includes all the operations affecting the appearance and protection of the component against physical, chemical and mechanical agents.

Adhesives

Glued joints have several advantages over mechanical joints. These advantages include better appearance and better uniformity of load distribution, and ensure better performance. Adhesives currently used are based on synthetic resins because of both their improved strength characteristics and their ease of application. The most widely used adhesive is a (PVA) polyvinyl acetate based emulsion. This is easy to apply and fairly strong although it has a few limitations and disadvantages. The ambient temperature and the timber temperature must not be less than 10°C during adhesive application. The moisture content of the timber must be not more than 15 to 16 per cent. The final product is not water resistant.

Stains and lacquers

Both these items are covered more fully in chapter XV and therefore are only being mentioned briefly. Stains commonly used are either water or organic-solvent based. Special emulsions known as "penetrating stains", in which pigments are diluted with a solvent, are also used. These have the advantage of producing a base coat for subsequent lacquering. Three types of lacquers are applied for the finishing treatment; in order of preference they are polyurethane, nitrocellulose and acid catalyst varnishes. The second type is based on a single component and dries out by evaporation of the solvent.

Other materials

Other materials used in the timber industry include abrasive belts and papers for sanding raw and finished components, hardware for jointing, upholstery and paper and cardboard for packaging. Choice of equipment will depend on production needs.

The manufacturing process

Kiln drying

Timber can either be seasoned in the open air lumber yard or dried in kilns by means of special equipment capable of controlling and decreasing the moisture content of the timber. The kiln drying process can be applied both to sawn lumber or rough sawn components prior to their final machining, depending on the individual production requirements. Three kiln drying systems are currently available; the traditional hot air system, the vacuum and the de-humidifying systems. The advantages and disadvantages of each system are dealt with in chapter X. It is important to stress here, however, that the vacuum system has had considerable success in the chair industry, particularly with certain wood species and components in stick form, due to its simplicity and speed.

Cross-cutting and ripping

Sawn, kiln-dried lumber can be rough sawn by cross-cutting and ripping to size for rails, legs, back posts, splats, stretchers, armrests etc. Boards are first cross-cut and then ripped to obtain pre-sized components ready for subsequent machining. Cross-cutting is usually carried out on a pneumatic or manually operated circular parallel swing-saw to give various cutting widths and thicknesses. A width of 140 mm and a thickness of 60 mm are sufficient for chair components. The simplest alternative to this machine is obviously a band-saw. A standard band-saw is also frequently used for cutting the rough boards, cross-cut as previously described, into stocks or into contoured components after manual ripping. This machine is indispensable in a factory processing solid timber. It is very versatile and its performance relies greatly on the ability of the operator. A multi-rip saw can produce more cut components at one time but it is only suitable for parallel cuts. The multi-rip saw has a number of circular blades spaced on the same shaft at pre-set distances. Several sticks can be obtained simultaneously, all from the same rough sawn board. The use of one or more band-saws does not eliminate the need for a multi-rip saw which can cope with all types of straight-edged components.

Planing

In order to obtain perfectly flat surfaces, rip-sawn components must be planed. This operation can be carried out with the old-fashioned, but still widely used plane. Today, however, the plane has been replaced by the surface planing and jointing machine and the thicknessing machine.

The surface planer planes two surfaces at right angles to each other and the thicknessing machine planes the other two surfaces. These are very basic woodworking machines, very simple to operate and to maintain. The planing and moulding machine is an alternative to these and offers greater flexibility as it can perform several operations at the same time. It has a number of spindles, normally from four to seven, each carrying a cutter-block for planing the four faces (four-cutter). The remaining cutter blocks are used to mould the piece to the required profile. Timber is fed into the machine at constant speed by rollers or is "pushed" by chains at variable speeds which may exceed 30 m/min. The roller feed is normally used for small pieces of non-uniform length. The planing and moulding machine has an extremely high capacity and can be equipped with automatic feeding and stacking devices so that it can be operated by one man. Setting the machine up is a fairly complex task. This machine is very profitable for long production runs of the same component. It can also be coupled with the multi-blade saw to make a mass production line, operated by as few as three operators.

Calibrating wide-belt sanders have been used over the last few years, for certain timber species, to reduce thicknesses by a few millimetres. This is commercially viable, although expensive, when processing timber that is difficult to plane and of high unit price.

The simplest and most versatile machine for planing irregular profiles is the moulding machine. Its spindle is so designed that it can be fitted with a number of tools and cutter blocks.

The copy-moulder is a more complex machine that allows greater productivity and is less dangerous than the moulding machine. It consists of two vertical spindles fitted with cutter blocks and a "tracer roll" copying the required profile. The complementary heads reproduce the p e-set profile on the rough components, suitably fixed over the templates. This machine can be equipped with two additional spindles for sanding. It only requires one unskilled operator.

Shaping

A wide variety of contours and profiles can be obtained on the spindle moulder fitted with the appropriate tools. As previously stated, the machine is very versatile, is suitable for various operations, needs only one operator and can be equipped with automatic feed. The maximum spindle speed is 10,000 rpm. The high-speed router complements this machine. The router can make internal and concave mouldings by using a guide pin located on the table in alignment with the spindle and a template. The router speed can exceed 24,000 rpm, giving a very good machine finish. High-speed routers became very sophisticated during the past few years and numerically controlled models are now available on the market. Obviously, the cost of this equipment is very high and can only be justified in the case of large mass production of, for example, furniture door panels.

Turning

Rounded components can be obtained by turning timber on a lathe. Components of pseudo-circular section can be machined on the moulder or the planer-moulder. Lathes range from those where the tool is handled by the operator while the piece rotates between centres, to the very complex ones, fully automated and equipped with loader, wer feed saddle and finishing tool slides, capable of copying a pre-set profile. There is a great deal of design sophistication in the field of timber turning.

Cutting to length

This is the operation during which the component is cross-cut to its final longitudinal dimension. It can be carried out with an adjustable circular saw. A double end cross-cutting machine is used for large production runs. The cross-cutting machine can cut both ends to length simultaneously. Consideration should also be given to the widely used multi-purpose machine. It is easy to operate and to set up and it can cut to length, contour shape and drill in a programmed sequence. It is particularly useful for machining rectangular section components to be jointed to rounded section components.

Boring and mortising

Boring and mortising operations are designed to bore round holes or to bore mortises in timber. Drills are used for the former and oscillating mortising machines for the latter although these can also drill round holes. Two or three parallel axis holes are usually required for joints. The holes can be obtained by using multi-spindles or heads with multi-bits capable of boring various patterns. Multi-spindle boring machines can also have independent boring heads. This is also true for the mortising machine for which the different spindles can oscillate on a plane through their axis. Many specialized machines are available for these operations but a complete list cannot be given here. The following, however, are worthy of mention:

(a) An automatic boring machine for seats;

(b) An automatic boring and dowel driving machine. It bores, applies the glue and drives the dowels;

(c) An automatic gang mortising machine. It can drill and mortise at once in different planes and at different angles and it is particularly suitable for the machining of backposts with non-rectilinear profiles.

Tenoning

Tenons can have a rectangular section or, in the case of chair joints, rounded edges. Tenons with rectangular cross section can be machined on a spindle moulder or, for larger production runs, on a single end tenoner, equipped with special cutter heads. A well-established practice, however, is that of using a tenoning machine with rounding-off attachment. This can produce a tenon which fits tightly into the mortise and gives a joint with good mechanical strength. Tenoning machines can have one or two tables. They can produce as many as 16 tenons per minute, machine tenons to various angles and machine circular sections also. The tenoner always machines perpendicular to the face which has been processed initially on the single end tenoner. The automatic double-head tenoner with rounding-off attachment has an even higher production rate. The two heads can be moved so as to machine components of different length and can thus produce two identical or different sized and angled tenons at the same time. This machine can be supplied with automatic loader and can produce more than 1,200 tenons per hour.

Sanding

This operation is carried out to eliminate the cutter marks left by previous machining operations and to obtain the final shape and a smooth surface. Abrasive papers or cloths are used for this purpose and the operation can be carried out manually or by special machines where the sanding belt is driven by an electric motor. The best results on flat surfaces are achieved by using automatic calibrating wide-belt sanders with single or multiple belts. The belts can be positioned above or below the feed table and if both are operated on the line, two parallel faces are sanded at the same time. These units, to operate satisfactorily, need a ducting system to carry away the sanding dust. Best results are obtained with twin-belt sanders, where the first belt is coarser than the second.

Assembly

During assembly, the various components are put together to make up the final product. Very simple tools are required for this operation: clamps and rubber mallets. Better production can be obtained with pneumatic clamps which, with pistons, assemble the components of the chair or other products rapidly. The clamps are mounted on a sufficiently rigid frame which can be easily modified as required.

Finishing

This stage includes all the operations for improving the appearance of the timber and providing mechanical, physical and chemical protection. A generally accepted finishing system for timber is based on one coat of primer, two undercoats and, after sanding, one top coat. Priming is usually carried out by dipping the component in a tank of the proper size which contains either undiluted primer or primer mixed with a low solids-content emulsion. Finishes can also be applied by more sophisticated methods such as manual spray-gun and flow coating. The use of the gun requires a high rate of material consumption, gives a better quality of finish but a slower finishing rate. Flow coating generates problems of shade variation with time, but has the advantage that the equipment can be installed on a continuous finishing line. Primed components can be left out to dry naturally in the workshop or fed through heated tunnels on trolleys or hung from a conveyer chain.

Prime coats and top coats are usually applied by spraying. Compressed air directed into the material stream atomizes it and forms a spray. The equipment is simple to use and to maintain and can be very fast if operated by a well-trained operator. Paint can be fed into the system by gravity or from containers under pressure. This equipment can be improved upon with respect to material consumption and time required, particularly in the case of components with large cut-outs (chairs, frames etc.), by using an electrostatic spraying system. The finish is automized in an electrostatic field where the gun constitutes one pole and the component to be painted the other. This method decreases spray losses. Theoretically, all coating material flows to all the component surfaces, including the hidden surfaces. The coating material has to be adjusted to this system and the moisture content of the wood must be controlled. It operates less efficiently in conditions where the air is humid than when dry. Another finishing alternative, particularly on large surfaces, is to use airless electrostatic guns. High pressure atomizes the finishing material. The airless electrostatic gun, equipped with special nozzle, has recently been used for painting chairs with further savings in operation time and material consumption. During the past few years, these electrostatic systems have been introduced to automatic finishing plants, solving coating problems faced during the continuous automatic painting of chairs.

Whatever the application technique, excess solvents and spray particles must be removed by special exhausts. These exhaust systems form part of the spray booths and are separated from the painting area simply by a metal grill, filter systems or by a water curtain consisting of a special water-wash spray booth. Paints can dry out naturally or in hot air tunnels of the type described for the drying of primers. The ends of the component should be kept at a lower temperature than the centre part to allow curing and cooling of the paint film. Maximum temperature should not be higher than 50°-60°C to prevent problems in the assembled components.

Another system for the finishing treatment of chairs and other similar products is the electrostatic disc. This system has been used on completely automated production lines. The system consists of a metal disc rotating about its axis and sliding along its length with a traverse approximately equal to the height of the object to be painted. The latter describes a looped path around the disc, presenting four faces in succession. An electrostatic field is created between the disc and the object so that all the finishing material should reach the component in a succession of thin film applications. Supplemental guns are used to touch up the paint film where necessary.

Notwithstanding these attempts of automating the finishing process, one operation still needs to be carried out manually, that is the sanding of the prime coat. This is normally carried out by hand or, sometimes, with small electric or pneumatic orbital sanders. In a chair factory this operation requires more than 10 per cent of the labour employed on the entire production line.

Other operations related to chair production

Dowels are made on a machine which produces various lengths of circular section grooved or plain dowels or pins of various diameters.

The shaping of the glue blocks (triangular section reinforcements) is carried out on the profile shaper, capable of automatically machining several pieces at the same time. This alleviates the need for this operation to be carried out on the hand-operated spindle moulder, which is unsafe. The same machine can be used for edge profiling solid or framed seats.

The production of small plywood panels is carried out on a cold press or a hot platen press. The combination of a radio frequency heating system (RF) and a press can be adopted for large-scale production. This system greatly reduces the curing time for the adhesive applied to the veneer sheets of plywood. RF-heating systems are widely used for the production of panel components, glued-up stock and in wood bending. The adhesive applied for RF-curing must be specially formulated for this purpose.

The maintenance section must include a few machine tools for metal work such as a drill press, a grinding machine and an electric welder. A tool maintenance room has to have a sharpening machine for bits, cutters and saw blades, saw setting equipment and welding machines for band-saws.

In the case of mass production of only a few model types, chair components can be processed into their final shape and made ready for assembly by a single multi-head machine capable of planing, shaping, boring, sawing, tenoning, sanding, etc. Each operation is carried out by a different unit which is easy to remove and replace. The machining is computer controlled and a single operator is required.

Outline of plant equipment

Below is a list of machines and equipment required for a modern chair production plant with approximately 50 employees. The machines chosen are particularly suitable for very diversified production and are simple to operate.

(a) Production of straight-tenoned components:

1. Pneumatic circular swing-saw for cross-cutting
2. Multi-blade circular saw, 300 mm working width for rip sawing
3. Moulding machine, 170 mm working width, with seven cutterheads
4. Automatic double-head tenoner with rounding-off unit

(b) Production of non-contoured components and other operations:

5. 2 band-saws, 900 mm diameter wheel
6. Surface planer, 520 mm working width
7. Thicknessing machine, 630 mm working width
8. 2 spindle moulders, 5 speeds, 10,000 rpm maximum
9. Double-end sawing machine
10. Automatic sawing, boring, shaping machine
11. Automatic double-head mortising machine
12. Automatic gang mortising machine with three independent units
13. High-speed router with floating head
14. Automatic lathe with centring device
15. Wide belt sanding machine with belts above feed table, 1,100 mm working width
16. 4 horizontal sanders with a 4,900 mm long belt
17. Brush sander with abrasive holder
18. Bench sander
19. Dust exhaust system for twelve sanders
20. Automatic dowel shaping machine
21. Automatic shaper for corner blocks and panels

(c) Assembly and finishing:

22. Pneumatic clamps for pre-assembly
23. Clamp for assembly
24. Electrically heated hydraulic two-platen press, size 2,500 × 1,300 mm
25. 4 dip tanks
26. 2 water wash spray booths, 4,000 × 2,200 × 2,000 mm
27. 3 electrostatic spray guns
28. 4 airspray guns
29. 3 glue guns and glue container

(d) Pattern and template making department:

30. Spindle moulder
31. Single table mortising machine
32. Automatic double table tenoning machine with rounding off unit
33. Band-saw
34. Moulding machine with seven cutter heads

(e) Maintenance room:

35. Grinding machine
36. 3 kW portable welders
37. Drill press
38. Knife sharpener
39. Universal tool sharpener
40. Band-saw sharpener with setting attachment
41. Band-saw butt welding machine

(f) Power plants:

42. Chip and dust exhaust system with 2 collectors, 1 silo (capacity 315 m^3), 2 electric exhaustors, filter system
43. Compressor station consisting of a rotary compressor (capacity 1,000 l/min) air cooling system
44. Transformer unit and distribution station
45. Hydraulic hoist, capacity 4 tons

(g) Tools and accessories:

46. Various tools for the setting up of machines, tool maintenance, assembly and sanding tables, benches and bench support for components.

On the foregoing basis one can calculate the total investment for plant and machines and also the investment per employee, using prices which were in effect at the end of 1977. The investment for technical assets could be around Lit 450 million ($US 530,038) and therefore the investment per employee would be approximately Lit 9 million ($US 11,000).

XVIII. Technology and machinery for the production of casegood furniture*

The production of casegood furniture, a modern reflection of the image of the traditional cabinet maker, is an attempt at industrialization that was always considered the prerogative of the craftsman.

Figure 1 is a generalized drawing of components which can be used as sides, bottoms, tops and backs of doors and drawers or shelves and other special parts. The individual components have suitable finishes and technical characteristics to enable the assembling of a finished product. Assembly is achieved with suitable hardware or simply with wooden dowels and polyvinyl acetate (PVA) glue. In order to give as much realism as possible to descriptions of production processes and machinery, the three following quantitative production levels are taken as references:

(*a*) Level A is that of small daily output, craftsman production techniques and a few employees;
(*b*) Level B is that of medium daily output and a few dozen employees;
(*c*) Level C is that of high output, industrialized production, and more than 100 employees.

Panel material

There are usually three initial processes in the production of casegood furniture. These initial processes are sawing panels to size, preparing hollow-core board and preparing the veneer. These may be reduced to two or even one depending on the type of board material used. The components can be made of:

(*a*) Hollow core board;
(*b*) Particle board;
(*c*) Blockboard or laminated board;
(*d*) Particle board coated with melamine laminates;
(*e*) Particle board for coating with paper or polyvinyl chloride (PVC);
(*f*) Plywood;
(*g*) Other bonded panels.

Panel sizing

As already mentioned, the panel is selected according to its end use. It must be sawn into oversized pieces with up to 15 mm average allowance for squaring up operations. Panels on the market in developed countries can vary from 120 to 250 cm wide and 240 to 600 cm long. Panel sizing circular saws for workshops of each level of production are discussed below; layouts for panel sizing are shown in figure 2.

For production level A it is sufficient to have a circular saw with a sizing carriage supporting the panels while sawing. Three operators will operate the machine. The production rate is 5-10 m^3

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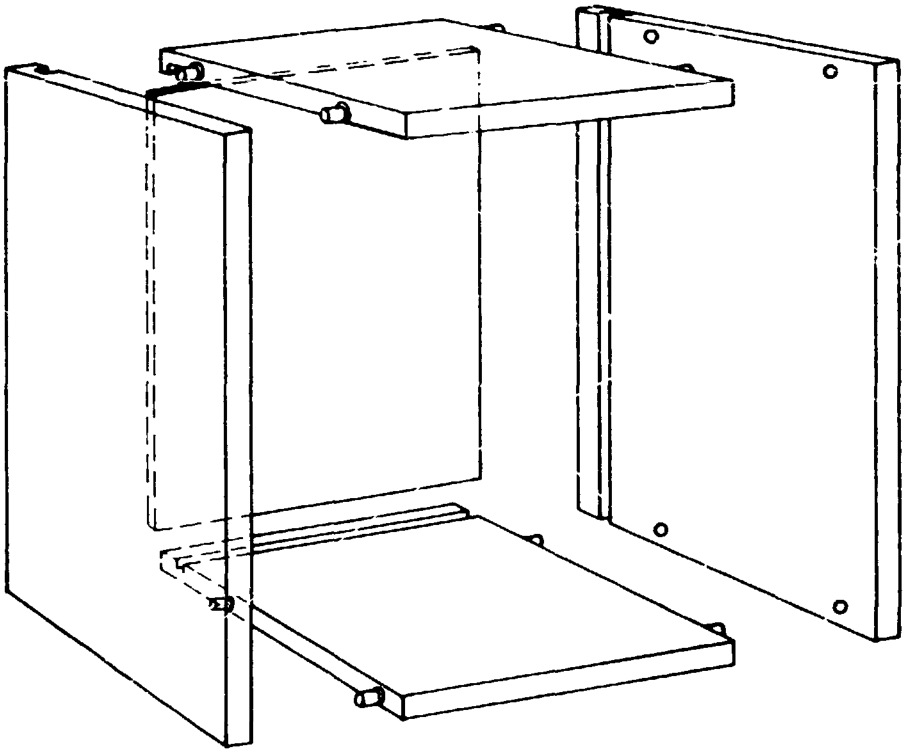
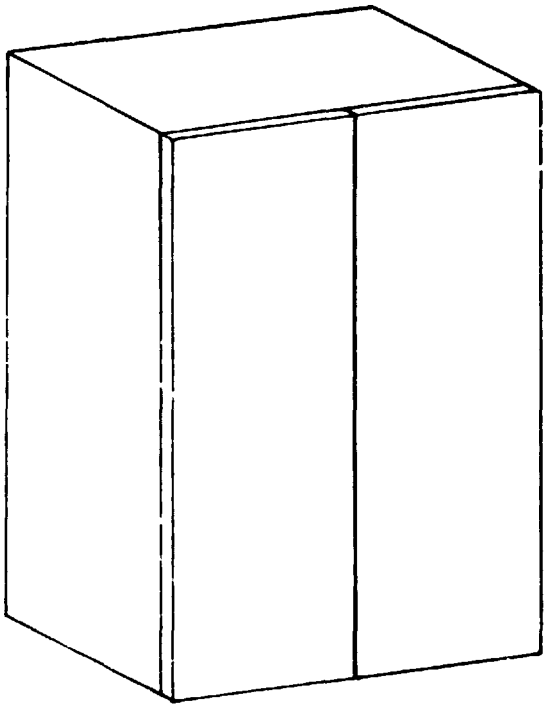
* By A. Schiavo, industrial management/planning consultant, expert in the furniture sector. (This is an edited version of ID/WG.277/8/Rev.1.)

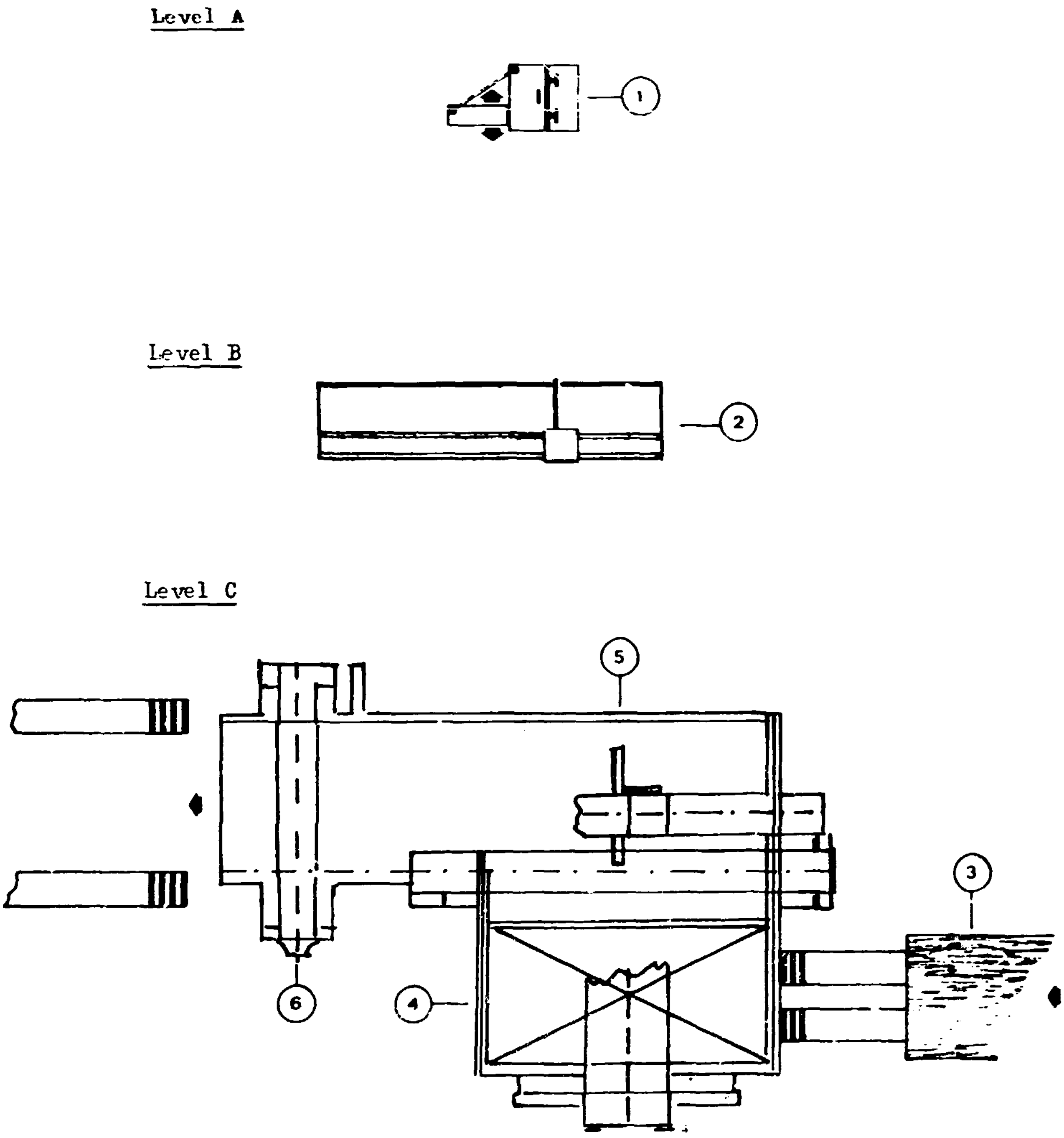
Figure 1. Assembling of carcase components





Assembled piece of panel furniture

Figure 2. Layout for panel sizing



Key:
1 Circular saw with sliding table
2 Vertical single blade panel saw
3 Panel storage infeed
4 Automatic loader
5 Panel rip saw
6 Panel crosscut saw

of panels in eight hours. In some cases the machine may also be used for other operations. It is preferable that the machine be equipped with a scoring saw, to avoid splintering.

For production level B production, the machines used for sawing panels are the vertical single blade type. These machines have a structure to support the pack of panels (positioned edgewise) and a blade, guided by a suitable arm, for both lengthwise and crosswise sawing. To pick up the single panels and position them on the machine, a vacuum grip travelling on an overhead hoist could be used. The production rate is 8 to 15 m^3 in eight hours.

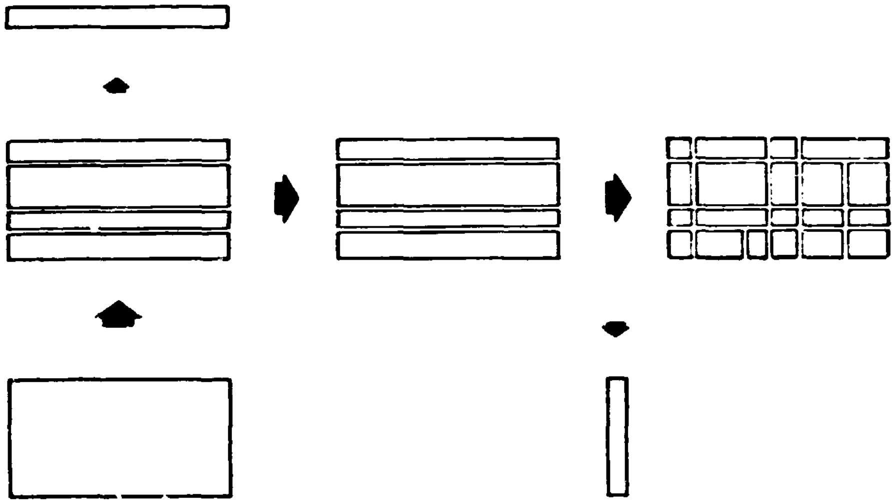
For production level C sizing large quantities of panels requires high production machines with one or more sawing units. The sawing panel packs are positioned on a fixed table or a travelling table moving in two directions transversally. There are three well known systems:

(*a*) A machine equipped with multiple blades for lengthwise sawing of panel packs; a top sawing unit is placed for crosswise sawing;

(*b*) A machine with a single blade sawing unit swivelling by 90° for lengthwise and crosswise sawing;

(*c*) A sizing plant of two units. The first machine has one saw and a bottom scoring blade, to saw the pack of panels lengthwise. Crosswise sawing is then done on a second machine. This is shown in figure 3. The entire pack or the single strips are moved by a conveyer. On all plants of level C both lengthwise and crosswise sawing can be controlled mechanically or by numerical programme. Automatic loaders and unloaders can be used for the packs of panels.

Figure 3. Flow diagram for multiple sizing of boards for a large scale plant



The number of operators can be from one to three while productive capacity, which varies considerably according to the type of sizing operations and batch size, can be from 20 to 100 m³ in eight hours.

Preparation of hollow board

Hollow core boards are built up on a frame of low-cost softwood which must be dried to avoid twisting the rails and stiles. Wood or paper can be used as core material. The covering panels can be plywood, particle board or other wood-based panels.

The machining operations of rails and stiles for the frames are:

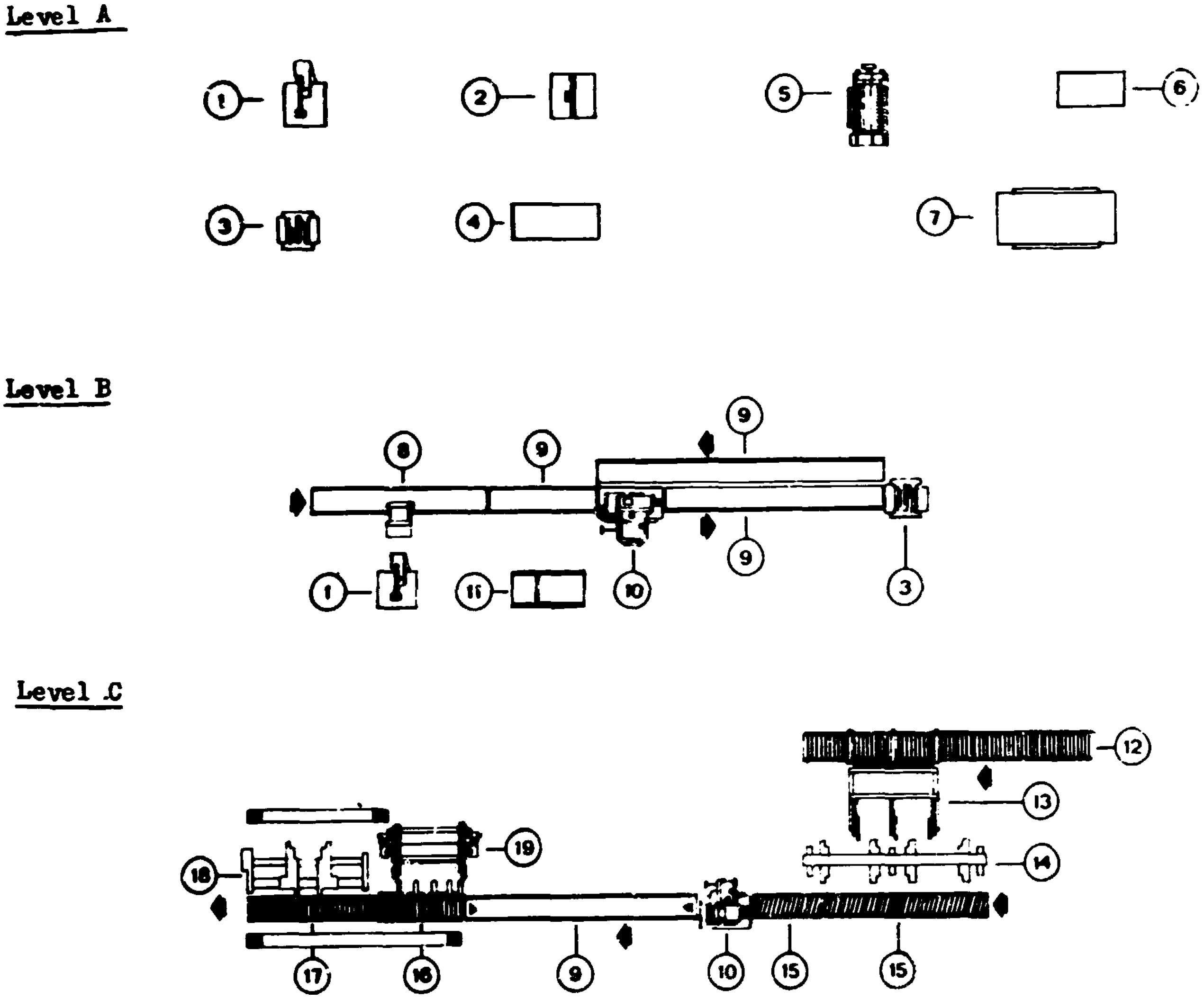
(*a*) The boards are ripped with the thickness of the board equal to the width of rails and stiles;

(*b*) The board is planed to the proper thickness of rails and stiles, and sawn to the proper width.

The types of plant vary considerably according to the quantity of panels to be produced. Layouts for the preparation of hollow core boards are shown in figure 4.

For production level A, the boards are purchased already dried. The first operation is sawing to the required length with a band-saw. The boards are ripped on a circular saw and planed on a thicknessing machine. A stapler is used to join rails and stiles to form the frame. The filling material (honeycomb) is then inserted and held with a few staples and the frame is passed through the glue spreading machine for application of urea formaldehyde glue on both sides. The covering panels are applied and curing follows in a one opening hot press.

Figure 4. Layout for preparation of hollow core boards



Key:
1 Band saw
2 Circular saw
3 Thickness planer
4 Frame assembly table
5 Glue spreading machine
6 Disc conveyer
7 Hot platen press
8 Cut off saw
9 Conveyer belt
10 Multi-blade rip saw
11 Surface planer
12 Roll way storage
13 Automatic stacker
14 Automatic board sizing
15 Multi-blade saw roll way feeder
16 Turning unit (90°) for feeding cut off saw
17 Roll way linked to unloader
18 Automatic unloader
19 Automatic cut off saw

The temperature of the water circulating in the platens is 90°C. The length of the curing cycle depends on the thickness of the covering panels and can vary from 5 to 7 minutes. Cooling and conditioning follows before the next machining operation starts.

For production level B, the same operations as in level A are used but with the following machines:

(a) A single blade cut off saw;
(b) A multi-blade circular sawing machine for ripping;

(*c*) A thickness planing machine if necessary;
(*d*) A band-saw for cutting the cross members and any dowels required for the inside of the frame;
(*e*) A bench with a hand stapler for joining rails and stiles;
(*f*) A double side glue spreading machine;
(*g*) A multi-daylight hot press;
(*h*) A disc conveyer linking the glue spreader and the press.

For production level C, a large quantity production of panels is involved and therefore much more complex and sophisticated machines and equipment are used.

It is necessary to begin with drying the raw material in suitable dryers.

Stock is automatically unstacked and fed to the multi-blade cut off saw. The boards, whose rail and stile lengths represent the lengths of the members of the frame, are conveyed to the multi-blade rip sawing machine. In this way stile and rail stock has the length required and can be checked as it passes along a conveyer. Stile and rail stock are placed in position on the assembling frame. Frame assembling can be done on a machine which carries out the entire stapling operation automatically . Stiles and rails can be joined (automatically) either by staples or gluing. Panel to frame assembly follows in multi-daylight presses as described in level A or B.

Preparation of veneer

Preparation of veneer begins with the selection of the purchased packs, trimming the packs to length, joining to the required width and then splicing. The success of these operations is dependent on the ability of the operator. The qualitative choice of material and the technique used to splice the sheets is of major importance. After being spliced the sheets are inspected and numbered. The machines used in each level are as follows:

Production level A (low level):

(*a*) Veneer pack trimmer and jointer;
(*b*) Paper tape splicing machine.

Production level B (medium level):

(*a*) Veneer pack trimmer;
(*b*) Veneer pack jointer;
(*c*) Splicing machine;
(*d*) Inspection table.

Production level C (high level):

According to the required capacity a varying number of machines used for level B production must be installed. Layouts for the preparation of veneer are shown in figure 5.

Panel coating

As mentioned before, oversize panels are machined to size. Assembled hollow core boards or particle boards are processed by veneering, or by the application of finished materials (papers or PVC) or by the application of fillers or prime coats.

Veneering

After glue spreading,[1] the veneer is normally applied to the panel, pressed and cured. Machines and equipment vary according to the production level. A possible layout for veneering is shown in figure 6.

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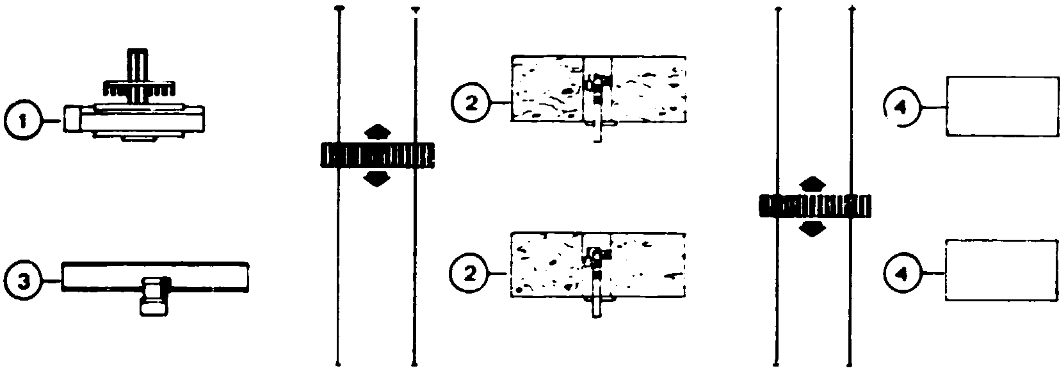
[1] For additional details on application of glue see chapter XIII.

For low level production, after preparation, the glue is applied to the panel with a roller glue spreader and the sheets of already prepared veneer are positioned at both sides of the substrate. The substrate is then placed in a single daylight hot press (90°). The pressing cycle varies considerably according to the type of veneer used, its thickness and the type of glue hardener used. However, usual cycle times are about 2 to 3 minutes. Pressure is about 3.5 kgf/cm².

Figure 5. Layout for preparation of veneers

Level A

Level B



Key: 1 Trimmer
2 Splicer
3 Saw
4 Inspection tables

For medium level production, as the panels have to undergo successive operations on precision sanding machines,[2] it is necessary, before applying the veneer, to calibrate the panels on a sanding machine equipped with coarse abrasives.

The machine can operate only on one side of the panel. For double side sanding the panel has to pass the sander twice. Glue spreading and pressing can be as for production level A, using single or multi-daylight presses according to the required production capacity. Furthermore, it is necessary to provide a panel disc conveyer after the glue spreading operation. The lower part of the disc dips into a water basin (to keep the discs clean). The panel is supported from the time it leaves the glue spreading machine until its assembly by the operator. Glue mixing equipment will facilitate the preparation of the urea formaldehyde glue mix.

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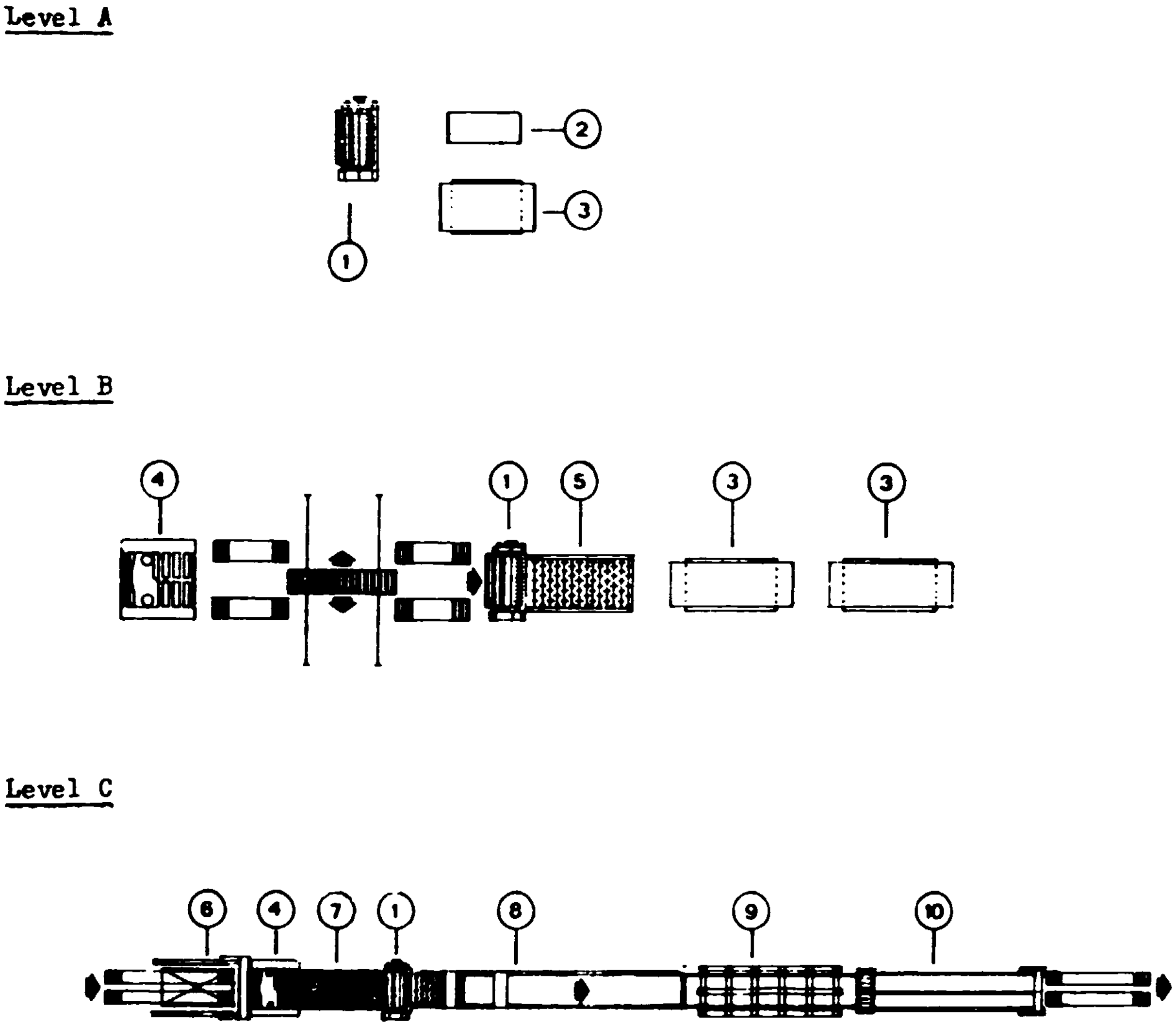
[2] For additional details on sanding see chapter XVI.

Figure 6. Layout for veneering



Key:
1 Glue-spreading machine
2 Preparation table
3 Hot press
4 Sander
5 Disc type conveyer
6 Automatic loader for pressing line
7 V-Roller conveyer
8 Conveyer belt
9 Automatic press
10 Outfeed conveyer belt

For high level production, an automatic pressing plant is installed by linking different machines so that a panel is processed in one pass. The equipment for automatic pressing is:

(a) An automatic press loader (can be of the thrust type);

(b) A linking element;

(c) A double-sided sanding machine;

(d) A double-sided glue spreading machine;

(e) A bench on which operators arrange the sheets of veneer on glue covered panels;

(f) An automatic one daylight press. This machine is linked to a loading conveyer on which the various panels are laid in front of a single opening press with an endless belt. All the pressed panels leave the press while, simultaneously, those laid up at the loading conveyer are fed in. The conveyer on the outfeed end also acts as an automatic unloader.

Laminating synthetic materials

Due to the high cost of plant involved, the laminating of synthetic materials is only of interest for levels B and C. There are two main groups of synthetic laminating material, papers treated in various ways and thermoplastic foils. A layout for the application of synthetic materials is shown in figure 7.

PVC papers can be used as substitutes for wood veneers and the panel therefore must undergo a coating operation after paper application. Alternatively the paper can be impregnated and therefore used directly as the decorative finish of the panel. This technique is also possible with thermoplastic films also made from polyvinyl chloride.

In the two latter cases the production cycle is substantially reduced because all the sanding and coating phases are avoided. By using sheets of PVC it is possible to coat panels on both faces and edges with the same sheet. It is also possible by using certain machines described later, to obtain the body of a furniture unit from a single PVC coated panel.

The plant for applying PVC at production level B (medium level) contains a panel loading element with:

(a) A top and bottom brushing machine;

(b) A top and bottom unreeling machine for the rolls of PVC with a roller pressing unit for stretching the film on the panel and clipping;

(c) A conveyer belt and final roller press.

Due to the application of PVA glue the panels must be carefully stacked and conditioned. The plant for applying PVC at production level C (high level) is the same as that for level B with the addition of automatic panel loading and unloading equipment. The plant is equipped with a hoist to bring PVC rolls from stores to the unreeling unit.

Application of fillers or prime coats

The application of fillers or prime coats is done on panels (hollow core board or particle board) to provide a base on which to apply the final decorative laminating or coating. The aim is to obtain the grain effect of a particular type of wood by printing during coating, or to obtain coloured finishes with pigmented varnishes. The filler used must be polyester based and is applied according to the panel type which can vary in weight from 200 to 500 g/m².

For production level A (low level) it is advisable to purchase panels already treated by the supplier due to the very high cost of suitable equipment.

For production level B (medium level) a single face sanding machine, a filling machine, and an ultraviolet (u.v.) dryer is required for applying fillers. Drying time for the coat (10 s to 30 s) varies according to type of u.v. light used, and is of the same order as for veneered panels.

For production level C (high level) the level B plant must be complemented with an automatic loader, a linking element, a sanding machine, a brushing machine for removing dust and wood particles before applying filler, a filling machine, another linking element, a dryer and an automatic unloader.

A floor plan for the application of fillers is shown in figure 8.

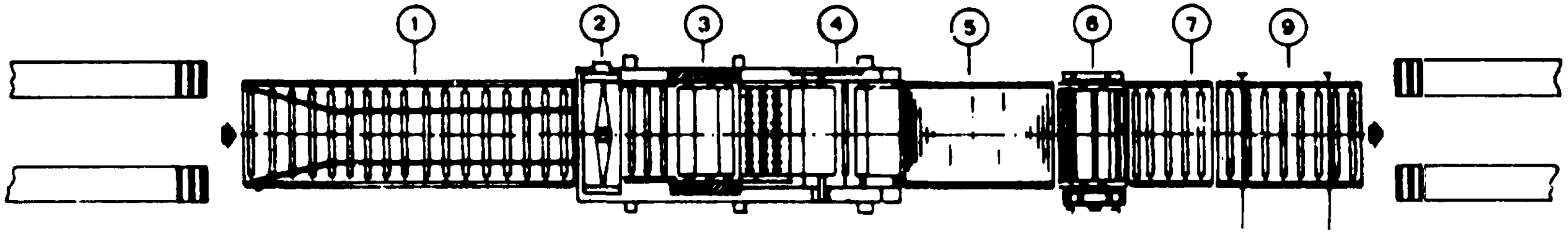
Sizing, edge banding and boring

We have so far dealt with manufacturing processes, machines and plant installations which differ from each other, depending on the type of panel and coating material used. Sizing, edge banding and boring, on the other hand, are processes common to all types of basic panels. This topic will be treated without any particular subdivisions except for quantitative production levels and for the exceptional case of PVC laminated panels, the description of a special processing technique.

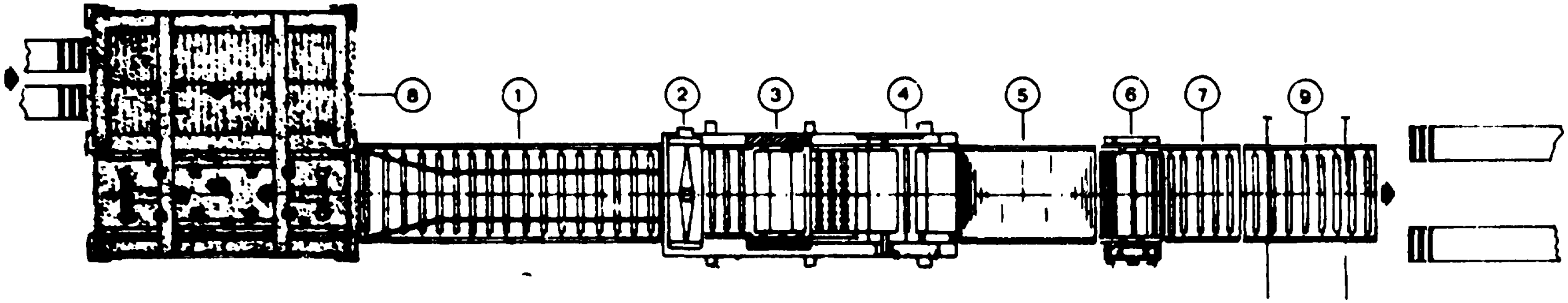
For production level A (low level) category, the sizing (both longitudinal and transverse) of panels is carried out with a simplified twin-blade panel sizing saw and, if required, with an automatic or manual panel feed. Sizing must be very accurate to obtain surfaces suitable for edge banding with veneer or thermoplastic bands. Edge banding can be done on a single head machine using hot melt glue; the

Figure 7. Layout for application of synthetic materials

Level B



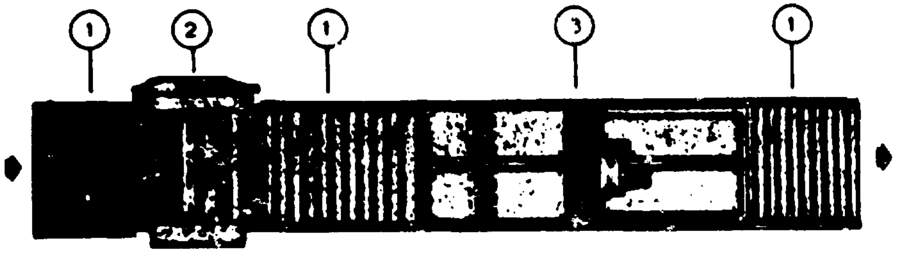
Level C



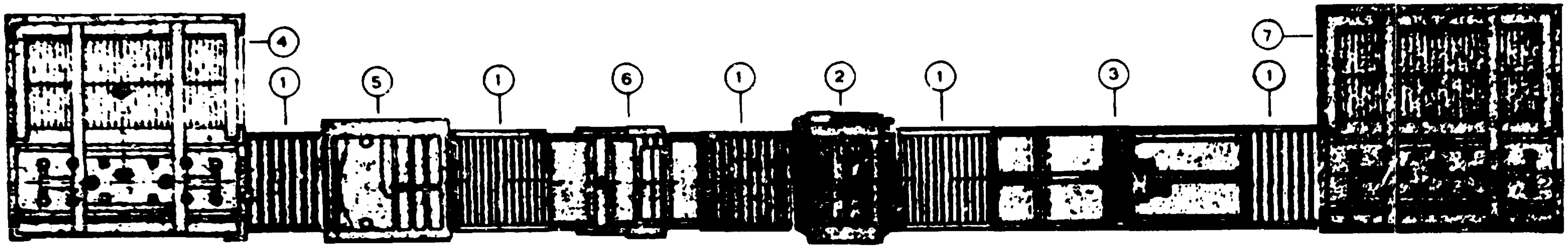
Key:
1 Infeed unit
2 Brusher
3 Unreeler
4 Clipper
5 Conveyer belt
6 Roller press
7 Outfeed conveyer
8 Automatic loader
9 Conveyer slide

Figure 8. Layout for application of filler

Level B



Level C



Key:

1 Linking element
2 Filler machine
3 Ultraviolet dryer
4 Automatic loader
5 Sander
6 Brusher
7 Automatic unloader

edges are of veneer or other material in strips or on reels. On this type of machine, only one edge can be applied to the panel during each pass. Sizing and edge banding is followed by the boring operation. The panels must be bored to take all the hardware required and for the final assembly of the unit. A machine with a single mobile boring head can be used for both horizontal and vertical drilling. For various auxiliary operations it is important to have other machines available such as high speed routers.

For production level B (medium level) in order to mechanize and automate handling and greatly reduce floor to floor times three basic machines, which can be used in line, are indispensable. The machines would, however, have to be positioned so that they could be used individually. The machines are:

(a) A double end tenoner/panel sizing machine with machining units arranged both for sizing and moulding operations. With this machine longitudinal sizing precedes transverse sizing;

(b) A double edge banding machine grouped with the panel sizing machine and linked by a driven conveyer which can be removed to use the two machines independently. The two heads of the edge banding machine must be exactly the same and capable of being used with edges of wood or thermoplastic materials either in strips or on reels. In the case of wood edges the plant must use automatic sanding units;

(c) An automatic multi-spindle boring machine for horizontal and vertical top and bottom boring. The number of heads will depend on the number of boring operations. The machine will also be grouped with the panel sizing and edge banding machine so that, when transverse sizing and edge banding is carried out, all the boring operations required can be done in one pass.

For other successive operations on the panels, the necessary auxiliary machines are a high speed router, an edge banding machine for contoured edges, a single-head boring machine and a circular saw with scoring attachment.

For large-scale production, sizing, edge banding and boring are done on a completely automated line consisting of:

(a) A loader;
(b) A panel sizing machine;
(c) An edge banding machine;
(d) A board turning unit;
(e) A panel sizing machine;
(f) An edge banding machine;
(g) An automatic boring machine;
(h) A dowel driving machine (when working on finished products coated with melamine and PVC);
(i) A board turning unit;
(j) A double station unloader.

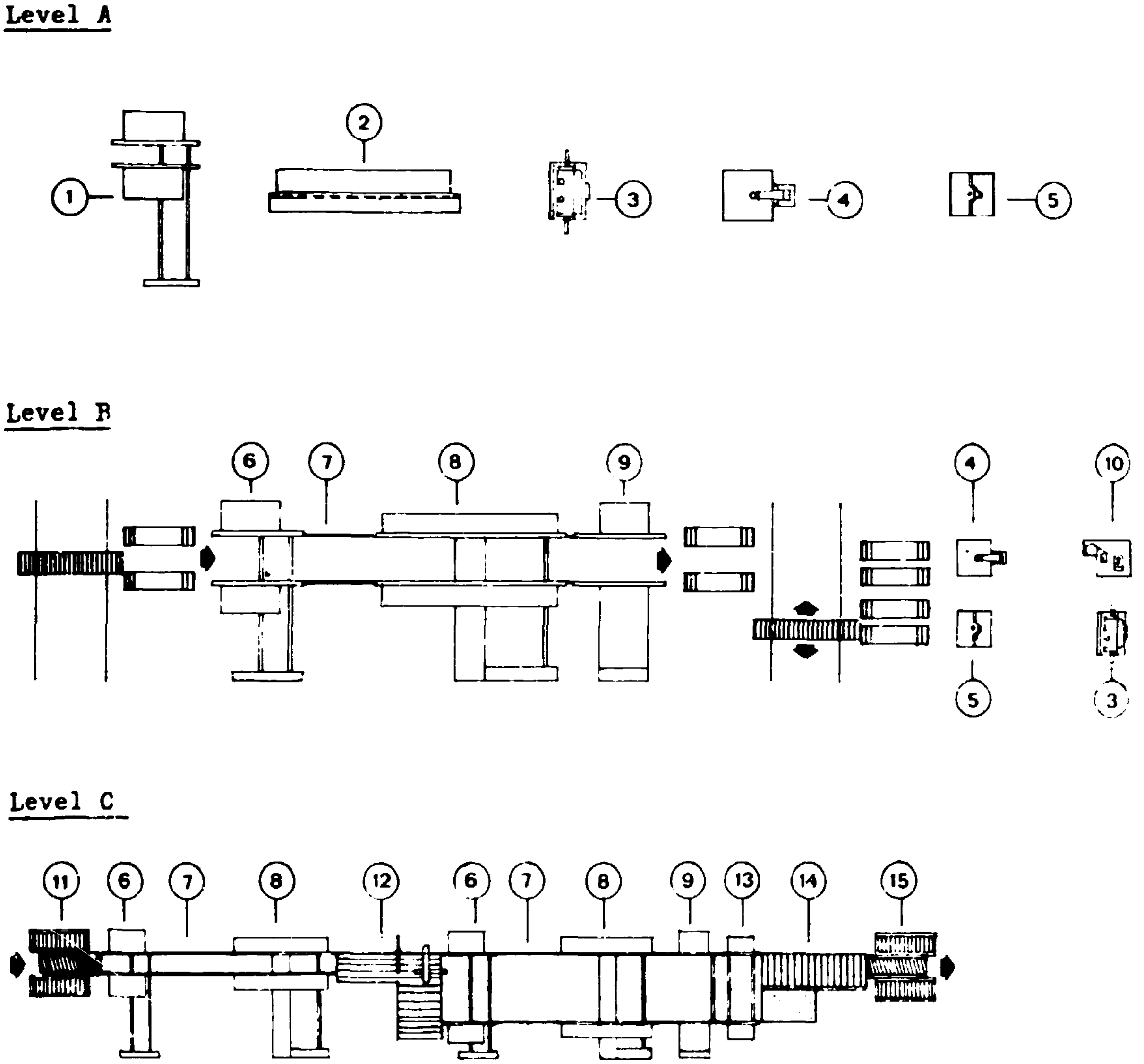
Layouts for sizing, edge banding and boring are shown in figure 9. Very careful thought should be given in choosing this plant by evaluating the quantity and type of production involved. One of the more important considerations to be borne in mind is that the output of a complete sizing/edge banding line is closely tied to the quantity of identical parts fed into it. In fact, as shown in figure 10, empirical data indicate that production rate is optimized for production of more than 1,000 identical panels. It is therefore obvious that, if the quantity of panels to be produced is well below the figure given above, the complete production line is not efficient and is uneconomical for very small quantities (100 to 200). In this case it would be well to split the line into two single production lines with independent boring units.

The two main advantages of the single line are that tooling up time (most of which is taken up by the borer) is reduced by removing the boring machine from the line. This gives productivity advantages of up to 50 per cent empirical results. In addition, stoppage of the whole line due to mechanical or production troubles of a single machine is eliminated.

Another important consideration is that whenever a line is automated (with automatic loading and unloading) and the sizing/edge banding operation is done on machines where dimension changes are programmed electronically, a considerable increase in productivity will result. Figure 11 indicates the effective production obtainable (linear metres per minute) as a function of the length of the workpieces.

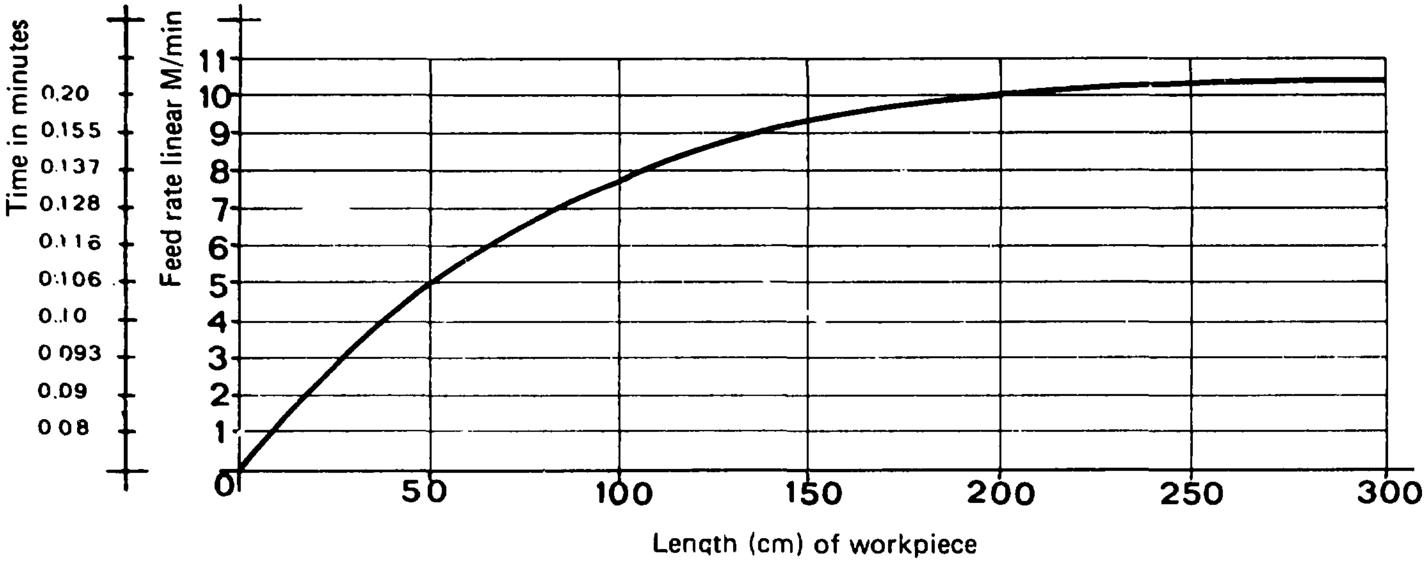
This curve demonstrates that productivity does not vary greatly for workpieces over 150 cm long. Below this value productivity decreases sharply. Evidently this consideration is fundamental because production capacity changes considerably as a function of the type of furniture unit produced. Therefore the choice of machines and their characteristics must be evaluated very carefully in view of the above considerations. As already mentioned, some machines outside the line are indispensable for carrying out certain auxiliary processes after the sizing/edge banding operations. It is interesting to consider the separation of the boring machine from the automatic line (although the line could, with advantage, be equipped with an automatic boring machine only for horizontal boring operations). This allows for rapid tooling and, furthermore, avoids the condition where the line feeds up to the limit of the borer. Special boring

Figure 9. Layout for sizing, edge banding and boring



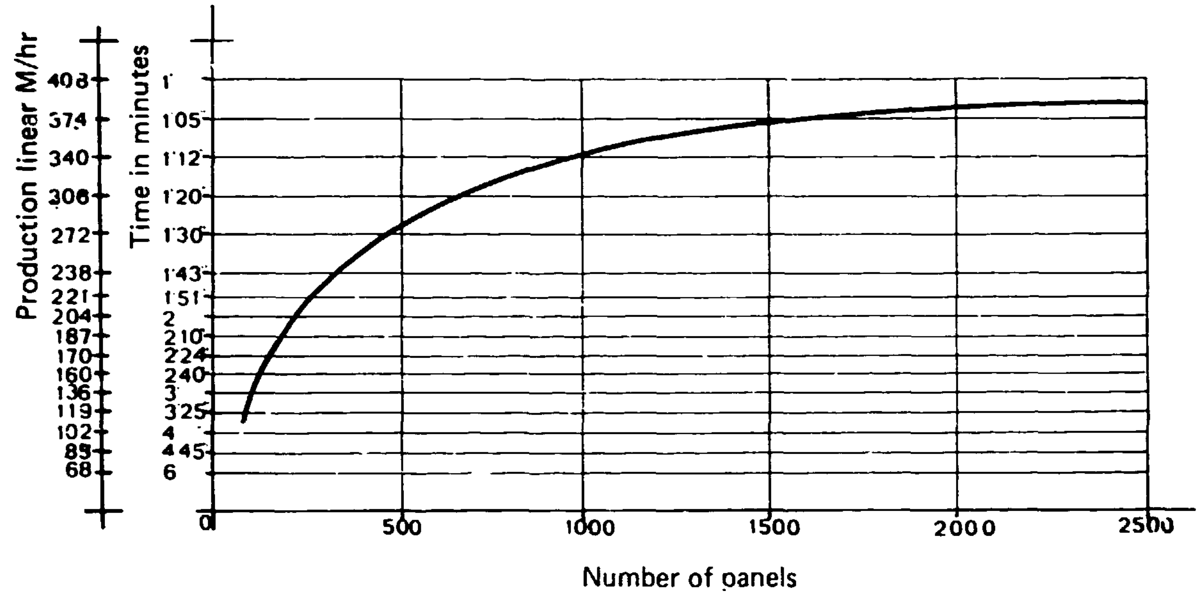
Key:
1 Plain panel sizing machine
2 Single-end edge banding machine
3 Single-end boring machine
4 Router
5 Spindle moulder
6 Automatic panel sizing machine
7 Linking element
8 Automatic edge banding machine
9 Automatic boring machine
10 Contour edge banding machine
11 Double station loader
12 Board turning unit
13 Dowel driving machine
14 Board turner
15 Double station unloader

Figure 10. Production rate of a panel sizing line as a function of the number of panels



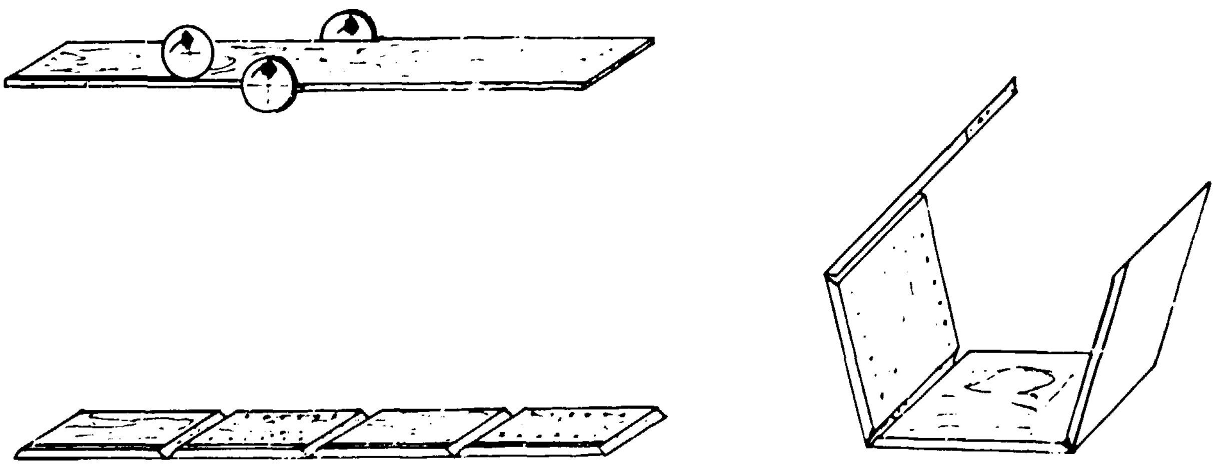
operations in which the parts to be machined are identified at the pre-assembly stage, can be done on a special machine being programmed for many dimension changes and arranged to carry out many different boring operations.

Figure 11. Production diagram of a panel sizing line as a function of panel length



For the processing of melamine and, above all, PVC laminated panels into folding boards, the sizing and edge banding is only done lengthwise. The length of the board is the same as the total outside dimension of the body of the furniture unit. The board is passed to an integrated linear system for simultaneous boring and V-grooving to prepare the board for folding to form a shell as shown in figure 12.

Figure 12. Sizing and edge banding (done lengthwise only). The board is passed through an integrated linear system, is bored, grooved and folded to emerge as a furniture shell



Lacquer coating

All panels which have been veneered or treated with filler have to be sanded on faces and edges before lacquer coating. As will be described later, lacquer coating of the panels before assembly can be avoided. For certain types of finish it is possible to sand the faces and edges and to assemble the unit before staining and lacquer coating. For the three levels so far referred to, systems and plant vary considerably according to capacities required. In particular, they vary according to the type of coating material. The problem will be dealt with here only as far as the three quantitative production levels are concerned. The individual application system is treated in chapter XV.

For production level A (low level) the sanding of the raw faces and edges can be carried out with a manually operated belt sander. The same machine is used for sanding the coated faces and edges. Staining and coating the faces and edges with prime and finishing products is done in a spray booth with a filter wall and exhaust system to eliminate all the air-borne residues from the compressed-air spray-guns. The panels are then placed on suitable supports and the spray left to harden in free air.

For production level B (medium level) the sanding of raw and coated panel surfaces can be done with a separate automatic machine chosen according to type of veneer or coating material used. The sanding of rough edges, mentioned previously, will be done on the edge-banding machine equipped with sanding units. Curved wood edges on panels are sanded on a single-head contour sanding machine, the number of passes being equal to the number of edges to be treated. Coating of edges is done on stacked panels by spraying in the spray booth. Drying is in the open air. For surface treatment a semi-automatic plant can be used. The plant has the following equipment:

(a) A brushing/staining machine for applying one coat of stain;
(b) A stain dryer (infra-red or hot air);
(c) A roller coating machine for application of the prime coat;
(d) A lacquer dryer (infra-red or hot air) according to type of coating material;
(e) A lacquer sanding machine for denibbing raised grain;
(f) A curtain coating machine, with one or two heads;
(g) A rack trolley with chain feed.

After curtain coating the panels are loaded on rack trolleys which, coupled to the chain conveyer, pass through a drying tunnel. Heating systems and fans are arranged in two different zones, one at low temperature for the evaporation of the solvents and one for drying the coat at a higher temperature. Finally the panels can be cooled in open air or in a forced ventilation zone. A single-head edge sanding machine is used for smoothing the coated edges. The finish coat can be applied with the same plant described above or, as explained later, on the assembled unit. A layout for lacquer coating for levels A and B is shown in figure 13.

For production level C (high level), after edge coating of the stack in a spray booth and subsequent drying, the panels enter an automatic surface lacquering plant. The prime coating plant contains:

(a) A double automatic loader for two lines of panels;

(b) A sanding machine, with two or three cross-belt sanding units for finishing the veneered surfaces;

(c) A staining and prime coating machine with rollers, as explained for production level B, the only difference is that there can be more coating machines and dryers. The aim is to obtain a better finish with fewer coating films. The size and capacity of the dryers is proportional to the feed rate of the line to allow complete drying of the panels;

(d) An automatic sanding machine for the intermediate sanding of the coat;

(e) A brushing/cleaning machine for making surfaces perfectly clean;

(f) An automatic lining-up unit preceding the curtain coating machine;

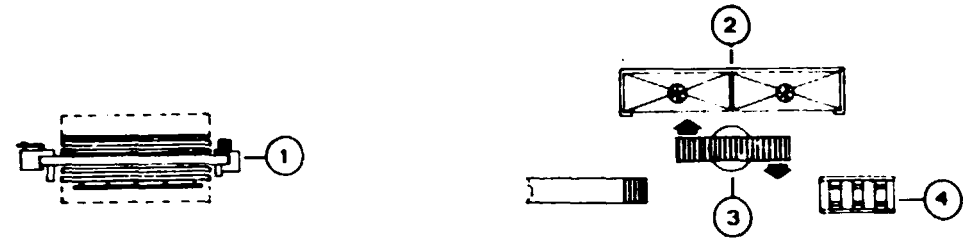
(g) A curtain coating machine with special conveyers to allow coating to be synchronized with a complete load for the dryer;

(h) An automatic loader for the dryer, if needed;

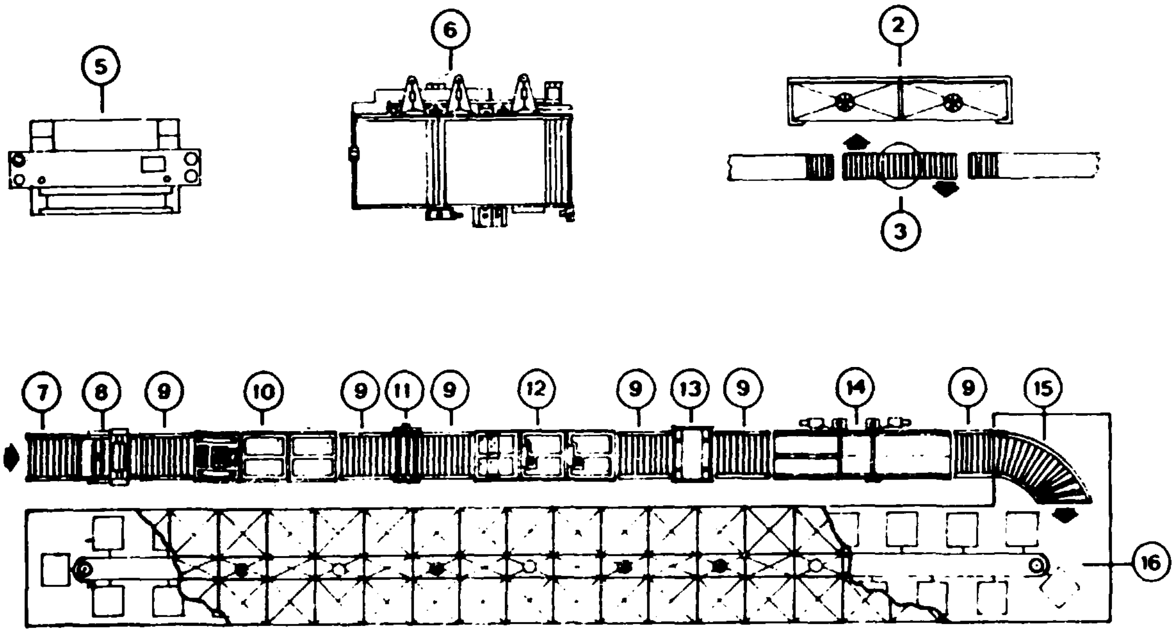
(i) A multi-deck dryer with variable temperature control, located in the two drying and flash-off zones. The exact location depends on the type of coating material. The dryer also includes a cooling zone and automatic unloading device.

Figure 13. Layout for lacquer coating

Level A



Level B

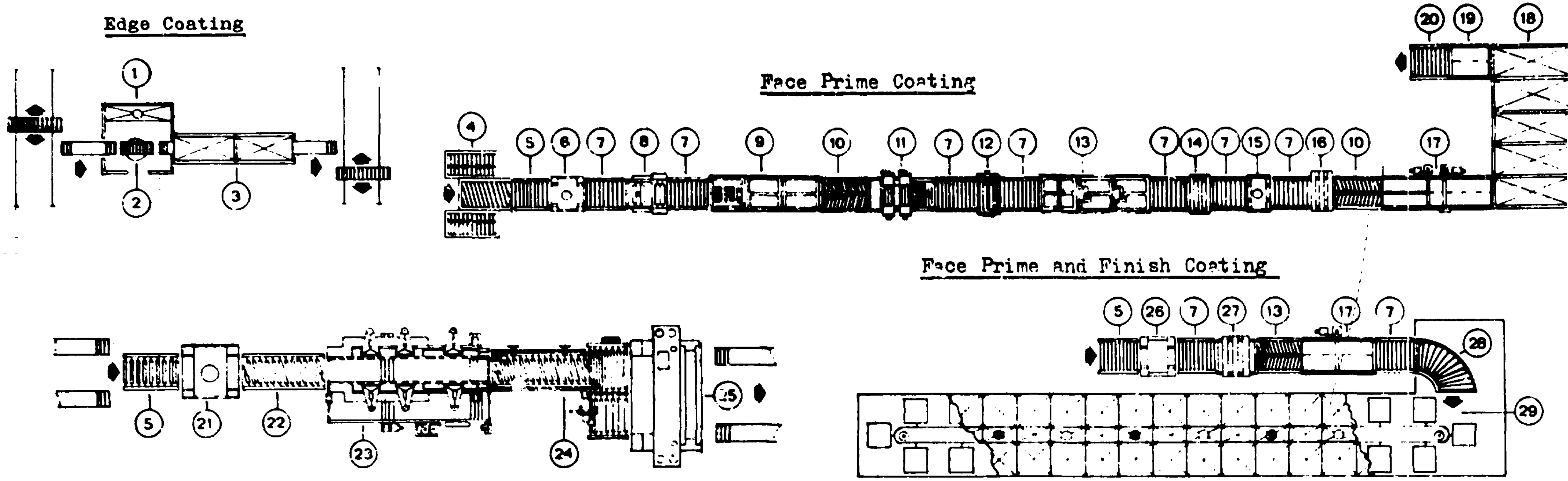


Key:	1	Manual belt sander	9	Linking element
	2	Spray booth	10	Hot air dryer
	3	Rotating table	11	Coating machine
	4	Trolley	12	Ultra-violet dryer
	5	Automatic sander	13	Sanding cleaning machine
	6	Single-head edge sander	14	Curtain coating machine
	7	Infeed unit	15	Curtain coater unloader
	8	Brusher	16	Rotary type dryer

The panels then enter a line for sanding the coated surface. The line may be a linked line for cross sanding operations with double automatic sanders (in line) for edge sanding. Panels can be coated with a finishing material on a separate line containing a vibrator unit to remove dust and any small scratches on the coated surface. There is also a panel cleaning unit, a single-head curtain coater, and a dryer (linear or rotary).

For both production levels, B (medium level) and C (high level), it is possible to insert in the coating line, after the staining phase, a printing machine which prints a good reproduction of wood grain on to the stain. This process can be carried out on panels having polyester coated fillers or, for a better effect, on panels veneered with low-cost (plain) veneer. The great advantage of this system, besides considerable cost reduction, is that of giving the panels a uniform surface; a feature much appreciated in large-scale production of modular unit furniture. The application of the first prime coat on the printed surface is possible after a short flash-off cycle and is a completely automatic operation. A layout for high production level (level C) for lacquer coating is shown in figure 14.

Figure 14. Layout for lacquer coating (level C)



Key:
1 Spray booth
2 Rotating table
3 Dryer
4 Double station loader
5 Infeed unit
6 Belt sander
7 Linking element
8 Brushing/staining machine
9 Hot air dryer
10 Herringbone element
11 Printing machine
12 Coating machine
13 Ultraviolet dryer
14 Brushing/cleaning machine
15 Automatic sanding machine
16 Cleaning/brushing machine
17 Curtain coating machine
18 Multi-deck dryer
19 Inspection table
20 Unloader
21 Transverse sanding machine
22 Inclined roller linking element
23 Double edge sanding machine
24 Board turning unit
25 Longitudinal sanding machine
26 Vibrator unit
27 Cleaning machine
28 Curved infeed roller way for dryer
29 Chain fed rack trolley dryer

Pre-assembly — assembly — packing

We have so far dealt with the processing of the panel to prepare it for final assembly into a finished furniture product. Independently of quantities, the basic concept for programming the whole manufacturing process can be described by a flow diagram for five different types of manufacturing, starting with a work order, and ending with delivery. The types are:

(a) A work order with an integral flow for the whole manufacturing process including assembly and inventory control of the finished product;

(b) A work order with integral flow for the whole manufacturing process including carcass assembly only. The front of the furniture is varied according to market demand. This is followed by inventory control of the finished product;

(c) A work order with integral flow up to pre-assembly. Assembly is according to delivery requests with cycle programming and inventory control of the semi-finished product;

(d) A work order for components with inventory control of the semi-finished product. Assembly is according to delivery requests with cycle programming;

(e) An integral work order with assembly according to delivery requests with cycle programming.

These flow diagrams are shown in figure 15.

It is evident from the above that assembly systems and methods can be quite diversified. The assembly and packing of units with finished panels having completely finished surfaces (laminated with PVC or coated with lacquer finishing material) differs according to production level. For production level A (low level), all the hardware (frames, accessories, drawer guides) must be applied to the panels at the work bench with manual tools (screwdrivers, drills, staplers). After the fitting of hardware and wooden dowels the panels can be handled in two different ways. They may be packed loose (with cardboard, polyester and polystyrene protection) so that assembly may be done by the end user; or they may be assembled. In this case, the carcass will be assembled by first using PVA glue and then a pneumatic clamp to square up the carcass. Doors and drawers (previously assembled) will then be fitted to the body on a work bench and the units packed in cartons with suitable protection. For production levels B and C (medium and high levels), special machines and equipment are required for medium- and large-scale production and for their choice certain rules must be observed. Among these rules are:

(a) To eliminate all unnecessary material handling;

(b) To store all semi-finished parts close to the assembly line and to use space so as to permit easy pick-up;

(c) To avoid conveying parts on the floor and picking-up semi-finished parts once they have been put on the assembly line;

(d) To carry out all pre-assembly, assembly and packing operations (manual and mechanical) during the progress of the unit along the production line;

(e) During pre-assembly, to carry out the boring not previously done according to the established assembly programme.

The assembly plant can include the following machines and equipment:

(a) Automatic dowelling machines;

(b) Machines for auxiliary boring and automatic application of some types of hardware as required;

(c) Mat type or slotted conveyer belts, operated by variable speed motor drive reduction gears for pre-assembly, with structures for holding the equipment; and with overhead pneumatic tools and hardware containers so that the operator has, within reaching distance, the right piece of hardware and the right tool for the operation involved;

(d) Clamps for squaring up the units;

(e) Automatic tippers;

(f) Slotted conveyers, variable in height (even automatically variable), for applying doors, drawers or other parts to the units as they advance at a pre-established rate.

At the end of the assembly line the units must be suitably protected from damage (in stacking and transport to stores) up to final delivery. In particular, veneered furniture must be protected to prevent alteration to the wood's shading by exposure to light. The product is normally packed in cartons.

Figure 1: Main flow diagrams

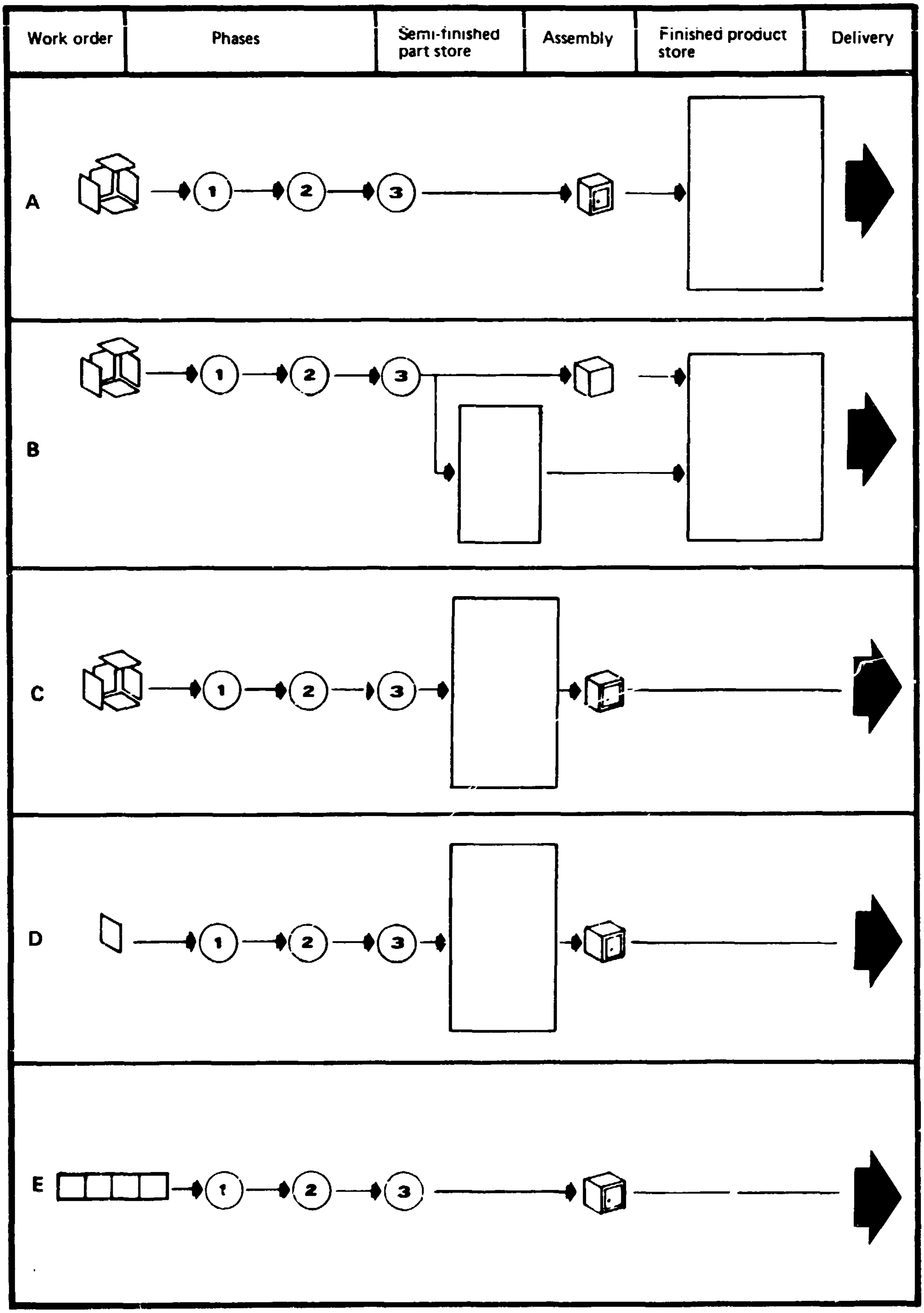
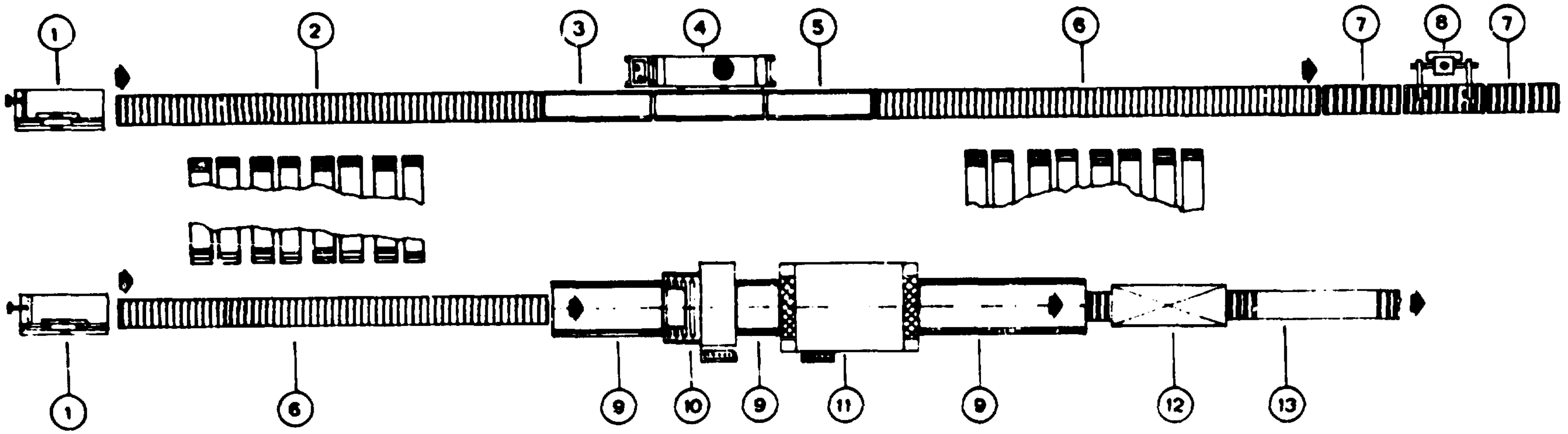


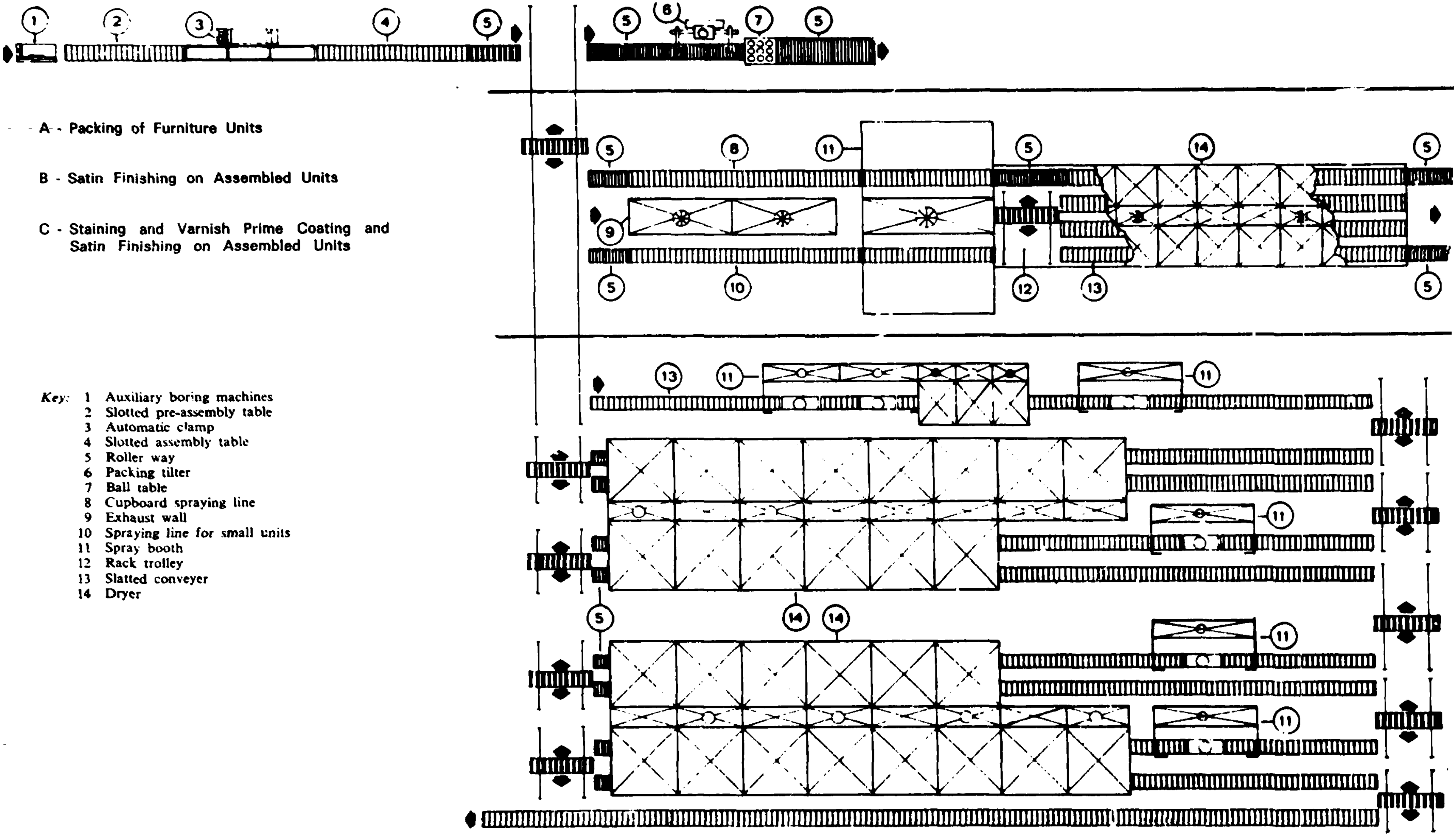
Figure 16. Layout for assembly and packing (furniture units with finished panels)

Levels B and C



Key:
1 Auxiliary boring machine
2 Slotted conveyer for pre-assembly
3 Infeed unit
4 Automatic clamp
5 Loading conveyer
6 Slotted assembly conveyer
7 Dead roller way
8 Packing tilter
9 Conveyer belt
10 Reeler for shrinking foil wrapping
11 Electric dryer
12 Lift
13 Unloading roller conveyer

Figure 17. Layout for assembly of furniture units with unfinished panels



A - Packing of Furniture Units

B - Satin Finishing on Assembled Units

C - Staining and Varnish Prime Coating and Satin Finishing on Assembled Units

Key:

1	Auxiliary boring machines
2	Slotted pre-assembly table
3	Automatic clamp
4	Slotted assembly table
5	Roller way
6	Packing tilter
7	Ball table
8	Cupboard spraying line
9	Exhaust wall
10	Spraying line for small units
11	Spray booth
12	Rack trolley
13	Slatted conveyer
14	Dryer

Corners are protected with polystyrene and delicate surfaces with tissue paper. The cartons can be closed at the end of the line with automatic strapping or taping machines. For all those units with uncoated surfaces, and particularly unassembled units, packing with shrinkable film may be useful. The film is applied by a machine consisting of an automatic unreeler of the shrinkable film rolls, a splicer and an electric oven which, at a temperature of about 200°C, shrinks the foil which wraps tightly around the surfaces to be protected. Layouts for the assembly and packing of furniture units with finished panels are shown in figure 16.

The unfinished panels can be divided into two categories. They may be veneered panels, which are given a prime coat after having been sanded on faces and edges. These are assembled as described above. On the same assembly line the assembled units enter a pressurized booth where the finishing coat is applied with a spray gun. The units are then conveyed automatically to a dryer. Packing is as described before.

The unfinished panels may also be veneered and sanded panels, which have not been stained and coated. These are assembled to obtain raw units. All the operations for staining, various prime coats, sanding and finishing prime coats are done on the assembled unit, thereby obtaining special finish shadings such as antique etc.

For large-scale production, all the above operations take place in succession as the unit moves forward on a conveyer belt a given speed and passes through the spray booths and dryers as shown in figure 17. On leaving the plant the units are packed in the normal manner.

After assembly, the furniture units can be stored for delivery against orders and dispatched to the customer. Alternatively, they leave the assembly and packing lines ready to be sent to the customer.

Conclusion

An attempt has been made to deal in a detailed way with the various cycles and processes for the production of casegood furniture. In view of the extent of the problems involved, the subject should certainly be covered more thoroughly; however, it is hoped that the foregoing comments and explanations are sufficient to give a guide to those interested in the choice of machines and in the production processes for a particular type of furniture.

XIX. Selection of equipment for parquet production*

A plant for manufacturing wooden flooring must take many social, environmental and technical factors into account.

The following technical factors are particularly important:

(*a*) The availability of raw materials for a 10, 20 or 30 year period;
(*b*) The sizes and characteristics of the available raw materials;
(*c*) The climatic conditions of both the production plant and the countries where the flooring will be used with regard to humidity and changes;
(*d*) The type of flooring, such as matched flooring or mosaic parquet.

The initial training of technicians and machine operators in the use of the equipment should be provided by the machinery manufacturer. This will ensure continuous production by keeping the equipment in good working order

The following discussion of the establishment of a plant for the production of parquet flooring in tropical countries will assume a plant of the following nature:

The plant is a mixed production plant (i.e. matched flooring and mosaic parquet)
No premanufacturing is necessary
The climate is tropical
The material available is sawmill trim-ends or boards not suitable for high quality lumber
The medium lumber grades of hard-woods or wood available contain silicon which requires special toolings
The annual output is approximately 250,000 m² for the mosaic flooring and 500,000 m² for the matched flooring
The technical consultants for training local staff to operate the plant at full capacity are available

Production facilities

Rough mill

When the plant produces parquet-sized flooring from sawn lumber it should be equipped with:

(*a*) A standard ripsaw machine for single edging of the boards;
(*b*) One or more cut-off saws for cross-cutting the boards according to the lumber grading rules for parquetry and production line requirements.

These saws may be manual, semi-automatic or automatic. The high-grade lumber will be selected for match flooring and mosaic parquet. Band saw machines will be used to rip boards for

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* By G. Gazzotti, consultant in the manufacture of parquetry. (This is an edited version of ID/WG.277/15.)

high capacity production. Naturally multi-blade circular sawing machines are used. These require less manpower than single blade machines; however, they create more wastage of wood. A multi-blade twin shaft circular sawing machine can cut boards up to 120 mm in thickness.

Kiln drying

If the rough sawn parquet stock does not attain the moisture content necessary for final machining it has to be piled under a roofed area for seasoning. As the air-seasoned parquet-sized stock will be kiln dried, it should be stacked on pallets and be transported to the drying kilns. These kilns may consist of prefabricated units or be constructed from concrete or brick materials.

Some companies save considerable manpower by loading the wood into metal baskets which are then transported to the drying kilns. This system is especially useful for handling lumber for pattern type flooring. Each species of wood has its own drying cycle, which varies in accordance with the type of equipment used. The drying kilns are normally heated by boiler systems which can be fired with sawdust, chips or mill refuse to generate hot air, hot water or steam. Once the moisture content has been decreased to the desired level, the wood is stacked for storage at ambient temperature for conditioning for a period of one to two weeks. The length of time depends on the species of wood and the amount of internal stress. Additional information on kiln drying may be found in chapter X.

Parquetry machinery for mosaic parquet

The selection of machinery for mosaic parquetry depends on price and the characteristics of the lumber to be machined. Some systems use four-sided moulding machines for surfacing and thicknessing sawn material. Other systems use planing machines with special cutterblocks. Sometimes the wood is cut to length before planing, and various cut-off systems are used to cut it to length after planing. Output for each plant may vary from 200 to 800 m^2 per day depending on the different size of the work-force and assuming more or less a full supply of the lumber. The length of the strips, which vary between 120 and 160 mm, will affect the plant output.

After machining, the strips are assembled by using 16 squares which are glued to a coated paper or plastic web. When the production facility is designed due consideration must be given to the degree of automation. Occasionally, the equipment which is selected is too sophisticated. Output is higher and less manpower is required, but the problems connected with technical assistance are too expensive, even in developed countries.

Production of matched parquet flooring

The selection of machinery required for manufacturing matched parquet flooring depends on the level of investment and lumber grade as well as lumber characteristics such as hardness, presence of mineral inclusions, resins and other features. For example, even though it may not seem important the quantity of lamella required to produce tongued and grooved strips of 23 mm thickness will affect the choice of machinery. These factors influence the system, with regard to special machinery, the required motor, as well as the necessary rated horse power for the machine. To reduce labour costs standard parquet machines are equipped with a hopper feed; a truing-up unit for straightening the rough-sawn lumber; a moulding machine with at least four spindles (two horizontal and two vertical); plus a double trim circular sawing machine.

Packaging

Either corrugated cardboard boxes or shrink-wrap foils are used for packaging the mosaic flooring, although in some instances both systems are used.

For the standard strips and lamellas, the most widely used system is wire or steel strapping. On some occasions, plastic bands (which may be reinforced), shrink-wrap foils and even corrugated cardboard boxes are used. Packaging is done at the end of each production line, which simplifies transport inside the factory. In special packaging departments modern machinery can be used to reduce labour costs.

It is worth bearing in mind, that the moisture content of parquet flooring material which is strapped and packed in cardboard boxes gradually changes to conform to the temperature and humidity of its ambient environment. Shrink-wrapping flooring materials avoids this problem. Thus, the moisture content of material that is to be shrink-wrapped can be adjusted by kiln drying to suit any export requirement.

Glossary

SIMPLE WORKING DEFINITIONS OF WOODWORKING TERMS USED IN THIS PUBLICATION

The following simple working definitions are intended for those who may not have thorough familiarity with the English language. The terms selected are those whose primary or usual definition, in English, differs from the commonly accepted woodworking definition; it further includes terms which have different definitions in American and British usage, and specialized terms which come from the study of the biology and biochemistry of trees and wood-based products.

Terms whose primary definition, in English, differs from the commonly accepted woodworking definition

calibrating. (In board manufacturing) accurate thicknessing within a prescribed tolerance.

carriage. Device used to support, position and hold a log.

cell. A general term for the structural units of plant tissue.

centre-ripping. Cutting a wide board in the centre.

dog. Hook iron fastening a log or flitch in working position, e.g., on a carriage.

ends. Timber less than 8 ft (2.4 m) in length.

flitches. Pre-cut log selection mainly used for veneer manufacture.

grain. Lines of fibre in wood, giving a pattern.

hardwood. Wood from broadleaved tree (commercial terminology).

heartwood. Dead inner core (as against younger, outer core-sapwood) of a woody stem or log.

hog. (noun) Reducing machine making coarse particles; (verb) to produce coarse particles.

joinery. Interior fitments of a house.

pith. Primary tissue found at the centre of stems and logs.

shakes. A separation along the grain.

size. Gelatinous solution used to stiffen, glue or glaze laminates.

slab. The outermost slice, cut from a log which is being squared.

softwood. Wood from coniferous trees (commercial terminology).

square. (noun) Square sectioned timber with sides from 1 in. to 6 ins. (verb) Obtaining a given shape from an irregularly shaped model.

waney-edged wood. Partially squared logs or planks with corners not wholly cut out.

Technical or biological terms

ambient humidity. Humidity or percentage moisture content of air (in contact with wood).

ambient temperature. Temperature of air.

anisotropic. Exhibiting different properties when tested along different directions.

annual growth ring. A ring on transverse surface resulting from yearly growth increment of the tree.

atomization. Reducing liquids to a fine spray.

busbar. System of conductors to carry electrical power *calender.* A machine in which fibreboard or a particle-board mat is pressed between rollers (as against platens).

cambium. Growing layer of the tree.

capillary attraction. Physical phenomenon by which liquid is drawn into pores and spaces (in wood).

cellulose. Carbohydrate forming main constituent of cell walls and tissue.

conifer. Cone-bearing tree; the wood is commercially known as softwood.

cross-cut saw. Saw used to cut across the grain of wood.

dado. Groove in lumber (American usage).

deciduous. (Of tree) shedding leaves periodically, not evergreen; commercially known as hardwood.

dowel. Short cylindrical piece of wood used as a pin to secure a joint.

duramen. See *heartwood.* The inner core of a stem.

earlywood. See *springwood.*

figured veneer. Veneer with decorative design or distinctive markings due to irregular grain formations.

frame-saw. Saw having several tensioned blades in a frame at fixed intervals; operates with a reciprocating up-and-down movement.

gang-saw. See *frame-saw.*

lamella. Thin plate of wood (wood anatomy: plate of cells).

latewood. See *summerwood.*

lignin. One of the principal chemical constituents of woody cell walls.

lumber. (American usage.) See *timber.*

mortise. A recess formed in wood to receive a projection of another piece.

mullion. The vertical or horizontal divisions in window frames.

polymerization. The chemical process of producing a large molecule (polymer) from many subunits (a hardening of glues or paints).

rabbet. A rectangular recess formed on the corner of a piece of timber, to receive a door, sash or other piece of timber.

rebate. See *rabbet.*

sapwood. Outer (younger) portion of a stem (or a log).

spindle moulders. A precision machine with one vertical-spindle taking moulding or shaping tools.

springwood. Also earlywood; that portion of the annual growth ring produced during the early part of the season.

summerwood. Also latewood; produced after springwood; it is usually denser and mechanically stronger than springwood.

template-controlled shaping. Process used to obtain a given shape from an irregularly shaped model.

timber. (British usage.) Wood prepared for carpentry, building etc.

tenon. The end of a piece of wood, reduced in thickness so that it can be inserted to a recess (mortise).

The following studies on various uses of wood have been prepared by the United Nations Industrial Development Organization and some have been issued as United Nations sales publications:

ID/10	*Production Techniques for the Use of Wood in Housing under Conditions prevailing in Developing Countries.* Report of Study Group, Vienna, 17-21 November 1969 United Nations publication, Sales No. 70.II.B.32
ID/61	*Production of Prefabricated Wooden Houses* Keijo N. E. Tiusanen United Nations publication, Sales No. 71.II.B.13
ID/72	*Wood as a Packaging Material in the Developing Countries* B. Hochart United Nations publication, Sales No. 72.II.B.12
ID/79	*Production of Panels from Agricultural Residues.* Report of an Expert Working Group Meeting, Vienna, 14-18 December 1970 United Nations publication, Sales No. 72.II.B.4
ID/133	*Selection of Woodworking Machinery.* Report of a Technical Meeting, Vienna, 19-23 November 1973
ID/154	*Low-cost Automation for the Furniture and Joinery Industry*
ID/180	*Wood Processing for Developing Countries.* Report of a Workshop, Vienna, 3-7 November 1975
UNIDO/LIB/SER.D/4	*UNIDO Guides to Information Sources No. 4: Information Sources on the Furniture and Joinery Industry*
UNIDO/LIB/SER.D/6	*UNIDO Guides to Information Sources No. 6: Information Sources on Industrial Quality Control*
UNIDO/LIB/SER.D/9	*UNIDO Guides to Information Sources No. 9: Information Sources on Building Boards from Wood and other Fibrous Materials*
ID/214 UNIDO/LIB/SER.D/31	*UNIDO Guides to Information Sources No. 31: Information Sources on Woodworking Machinery*
ID/234 UNIDO/LIB/SER.D/35	*UNIDO Guides to Information Sources No. 35: Information Sources on the Utilization of Agricultural Residues for the Production of Panels, Pulp and Paper*
ID/236 UNIDO/LIB/SER.D/36	*UNIDO Guides to Information Sources No. 36: Information Sources on Industrial Maintenance and Repair*

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