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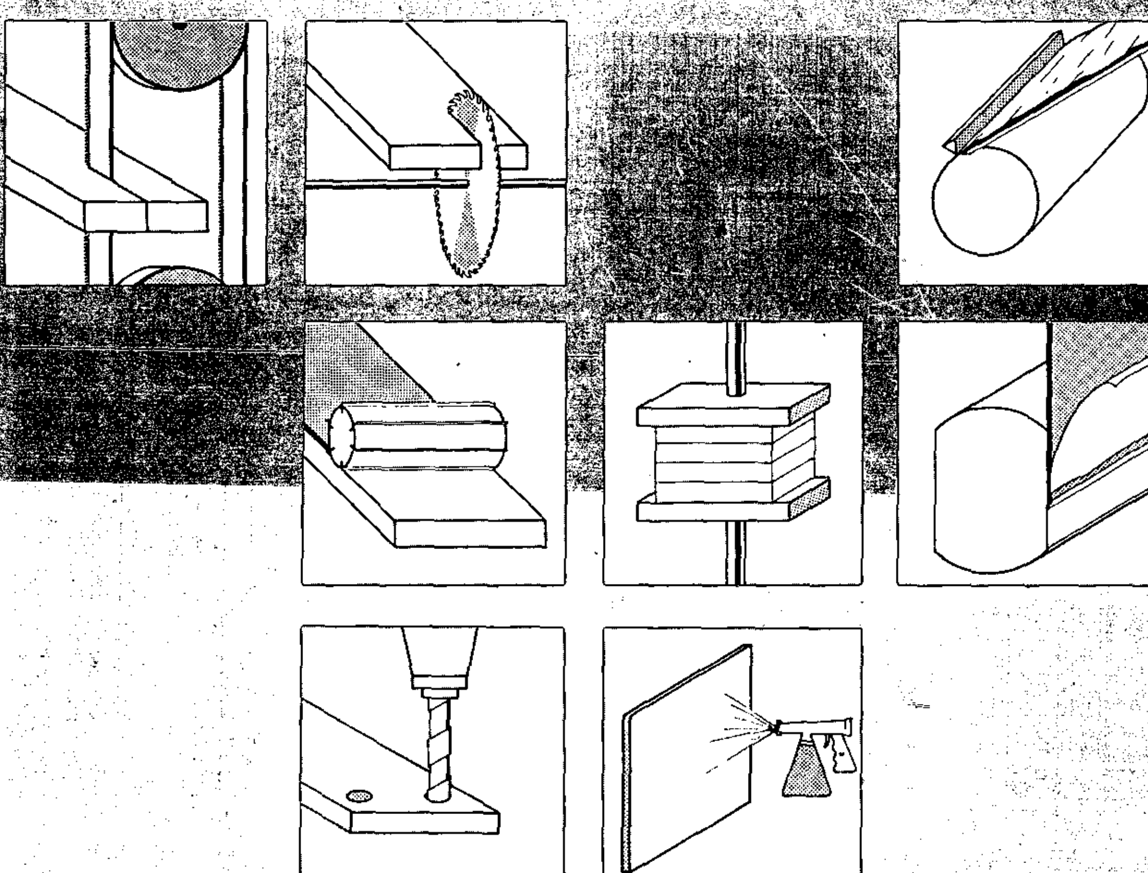
GENERAL STUDIES SERIES

Technical criteria for the selection of woodworking machines



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

TECHNICAL CRITERIA FOR THE SELECTION OF WOODWORKING MACHINES

GENERAL STUDIES SERIES

TECHNICAL CRITERIA FOR THE SELECTION OF WOODWORKING MACHINES

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 1991

Note: This is a revision of a document that appeared in 1981 under the symbol ID/247.

ID/SER.O/11

UNIDO PUBLICATION
Sales No.: UNIDO.91.5.E
ISBN 92-1-106257-8
02500P

EXPLANATORY NOTES

Reference to dollars ($) are to United States dollars, unless otherwise stated.

The monetary unit in Italy is the lira (Lit). The following exchange rates are used in the conversion of lire to United States dollars:

Date	*Exchange rate per US dollar*
April 1978	Lit 850
April 1982	Lit 1,315
September 1983	Lit 1,620

The following symbols have been used in tables:

Two dots (. .) indicate that data are not available or are not separately reported.

A dash (—) indicates that the amount is nil or negligible.

A hyphen (-) indicates that the item is not applicable.

Parentheses round a figure indicate a negative amount.

Totals may not add precisely because of rounding.

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

CBN	cubic boron nitride
dB	decibel
DC	direct current
HM	hard metal (or Hartmetall)
hp	horsepower (1 hp = 746 W)
HRC	hardness (Rockwell scale C)
IRR	internal rate of return
kcal	kilocalorie (1 kilocalorie = 4.186 kJ)
kgf/cm^2	kilogram force per square centimetre (1 kgf/cm^2 = 9.807 x 10^4 Pa)
l.p.	lacquer product
LPG	liquid petroleum gas
MARR	minimum attractive rate of return
MC	moisture content
MDF	medium-density fibreboard
MIG	metal inert gas
mm Hg	millimetre of mercury (pressure)
MPC	maximum permissible concentration
PF	phenol formaldehyde
PVA	polyvinyl acetate
PVC	polyvinyl chloride
RF	radio frequency
RM	relative moisture
rpm	revolution per minute
TIG	tungsten inert gas
UF	urea formaldehyde
v.p	varnish product

Other abbreviations

ACIMALL	Association of Italian Woodworking Machinery Manufacturers
AWF	Ausschuss Wirtschaftliche Fertigung
DIN	Deutsche Industrie Norm (Federal Republic of Germany)
ECE	United Nations Economic Commission for Europe

EUMABOIS	European Association of Woodworking Machinery Manufacturers
FEPA	Fédération Europeenne des Fabricants de Produits Abrasifs
FAO	Food and Agriculture Organization of the United Nations
FESYP	European Federation of Associations of Particleboard Manufacturers
ICOTERMS	International Rules for the Interpretation of Trade Terms
INTERBIMALL	International Fair for Woodworking Machinery and Accessories (held at Milan, Italy)
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, the purpose of which was to explain the various processes that 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 should prepare technical manuals and conduct training courses for industrialists and officials responsible for the approval of investments in the woodworking industry. In carrying out this recommendation, UNIDO held five technical courses on criteria for the selection of woodworking machinery at the Fifth to Ninth Biennial International Fairs for Woodworking Machinery and Accessories (INTERBIMALL) at Milan, Italy, during the month of May 1976, 1978, 1980, 1982 and 1984.* 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 185 participants from industry and Governments of 56 developing countries. The courses were financed from special-purpose contributions of the Government of Italy to the United Nations Industrial Development Fund. In view of the great interest shown in the courses, and the subsequent responses from many developing countries, UNIDO published, in 1981, the lectures given at the second course in Technical Criteria for the Selection of Woodworking Machines (ID/247).

This publication is a revision of ID/247. It includes the text of lectures given in subsequent courses as well as three papers that were not discussed during the courses but distributed to participants. These are: "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), which was prepared for the 1973 meeting; a paper for the furniture seminar held in Finland in 1977; and a paper dealing with guidelines for the selection of options in establishing wood-based panel industries in developing countries (ID/WG.335/16) prepared for the Seminar on Wood-based Panels and Furniture Industries, held at Beijing, China, in 1981.

*Documents originally prepared for the seminars bore the symbol numbers: ID/WG.226/-; ID/WG.277/-; ID/WG.320/-; ID/WG.369/-; and ID/WG.432/-.

CONTENTS

Part three

TOPICS OF COMMON INTEREST IN THE PRIMARY AND SECONDARY WOOD-PROCESSING INDUSTRIES

Part four

SECONDARY WOOD-PROCESSING INDUSTRIES

Part one

TOPICS OF GENERAL INTEREST

I. Wood characteristics influencing equipment selection and machine operations*

In order to select any machine tool, it is first necessary to consider the properties of the raw material that is to be worked. Wood is not a material with homogeneous properties; the conditions of growth can affect the hardness of the wood, its resistance to tools, the amount of wear caused in tools etc. The most important properties are the density, moisture content, the direction in which the log will be cut and the diameter of the log.

The characteristics of timber from countries with temperate climates are fairly well known because working conditions are well-established and experience has been gained over the years in using such timber. Because these characteristics are known, the effects of varying conditions of machining on log breakdown at the heat saw can be evaluated. 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. In tropical countries, however, growth conditions change frequently, there is a wide variety of wood species, and the logs are of large size. Parameters to evaluate such wood must of necessity be a broad average of the variables involved.

Persons who select 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 and 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—trees that grow in temperate regions. The average tree size in tropical regions is larger than the average tree size in temperate regions, however. In 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 felled when they are 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 primary species of high volume and first-grade quality that bring the maximum return for the investment costs of felling, logging, transport, yard handling etc. Trees to be considered in this category are all in the large-diameter class, ranging from 50-60 cm minimum diameter to 1.5-2 metres maximum diameter.

*By G. Giordano, Professor of Wood Technology and Forest Utilization, University of Florence, Italy. (Originally issued as ID/WG.277/1/Rev.1.)

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 that can be handled by mobile or stationary cranes, fork lifts, trucks and other powered units.

Internal stresses

Few foresters and technicians are aware of the importance of internal stresses. They are extremely important, however, because of the negative consequences that 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). A list of some of the more common tropical wood species is given in the table.

Tropical wood species

Geographic location	*Common name*	*Scientific name*
African species	Azobé	*Lophira alata*
	Emien	*Alstonia congensis*
	Homba	*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.

In the cross-section of a tree, there is a tensile stress near the periphery and a compressive stress near the centre. These forces are in equilibrium in the standing tree. When the tree is felled and sawn, these forces become unbalanced; consequently, the periphery tends to contract and the internal part to expand. The final result is cracks in the shape of crow's feet starting from the pith. Often these cracks reach the periphery and open the log into four or five independent sectors, and the log cannot be further processed economically. Even if there are not such large cracks at the time of sawing, the boards are stressed at their ends and can open or become badly deformed. Internal stresses are often accompanied, in tropical species, by so-called "brittle heart", which is a central area devoid of any fibrousness and with lower mechanical resistance. Throughout the entire brittle heart area, successive cross cracks can be found in the wood on the internal side of the log. 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 wood. In ligneous tissues, it is possible to find two other types of substances in the cell sap: soluble substances called "extracts" and 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 tools, damage steel kiln fittings, stain steamed wood or cause eye, skin and lung irritations to workers exposed to dust generated during machining and sanding operations.

A rubber resin or sticky substance can be troublesome in 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 that are like irregular stones, sometimes as large as a human fist. They may be distributed throughout the wood of certain species, such as iroko or some meranti. The substances can 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 may be scattered in crystals or granules of smaller diameter (0.02 to 0.05 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 the machining of these woods is both difficult and expensive. Among the 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.) While this factor has nothing to do with the power or type of machine to be selected, removal systems for sawn off-cuts, planer chips and sawdust must be carefully studied.

Fibre and tissue peculiarities

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

Log and lumber conversion

Log yard operations

Log handling equipment for lifting and transport must be rigid, high-powered, and capable of several operational uses. If it is not possible to store logs in log ponds, a log concentration yard must be created. 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 if the weather is extremely hot and dry.

The log yard must be provided with a set of appropriate cross-cut saws. The ones normally used are of the chainsaw type, which can be moved manually or 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 metal splinters may be imbedded in the logs (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. Some of these topics are treated in more detail in chapters IX and XVII.

Sawing

Before selecting the head rig, it is necessary to prepare the log conversion plan, which includes the species available and the 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 sawing techniques such as feed speeds, shape of teeth etc. will not be examined in this chapter, it is necessary to dwell briefly on the problem of internal stresses and to examine the following sawing techniques to determine which is the most advantageous:

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

(b) To 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) To 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 are sawn with a spray system, which sprays a solvent onto the blade so that sticky spots do not form on the tool. A scraper or a similar device should be used to remove the caked sawdust from the sawn surface.

Boards are cross-cut or trimmed using circular saws with special teeth shapes and suitably set. 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, causing health problems, it is recommended that a chip and dust exhaust unit should be installed. In addition, workers should use protective masks and gloves.

It is important to study the material flow in a sawmill in order, to decide on conveying and transport equipment for sawn wood and waste material such as slabs, edgings, trim ends, off-cuts etc. which should be chipped and stored in silos. These topics are covered in more detail in chapters IX and XX.

Peeling, slicing and production of plywood

The size of the logs is a factor that determines the power needed 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 brittle heart may be present, the veneer peelers must be constructed in such a way as to be able to use chucks with different diameters.

It must be possible to adjust parameters of cycles of steaming vats to any quality of wood (i.e., steam temperature and length of treatment). It is very difficult to establish a general rule for wood species that have not been completely studied; in such a case it is necessary to collect data to determine steaming parameters (see chapter XIV for more detail).

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

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

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. The various factors affecting these processes should therefore be recognized from the start up of production. These topics are covered in greater detail mainly in chapters V, XI and XII.

Gluing, laquering and finishing

The equipment required for gluing, laquering and finishing is the same 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 that cause problems in bonding and coating operations. Finishing is treated in chapter XXIII.

Kiln drying

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

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

Introduction

The quality control of woodworking machines involves a sequence of tests that make 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 wood-processing machines has made it necessary to adopt criteria in the form of performance tests or standards that are agreed on by the manufacturers and users of machine tools.

These 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:

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

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

(c) 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.

The purchaser should be aware of the current technical standards for each of the woodworking machines in order to be able to 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 machines that remove chips or particles. These constitute the majority of the machines used in the woodworking industry. They are listed in annex I;

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

The figures in this chapter, which generally refer to tolerances, were in line with the norms and standards in force in countries with highly developed wood industries and advanced woodworking machine-tool sectors in the early 1970s.

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 indicators of geometrical precision.

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, and 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 deviations do not lie solely in the machine. Deviations may occur because of the geometrial 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

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

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
- The operator (who can make 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 that 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, it is necessary, first of all, *to determine the main 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. The tests and the parameters to be checked must also be carefully selected.

In addition to checking for geometrical precision with the machine stopped, machines should be subjected to tests during idle running (no load) and under full load.

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

(a) The machine must be mounted 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 0.02-0.04 mm per 1,000 mm length is used for this purpose;

(b) The measuring instruments used for testing purposes should be of an accuracy (owing to design inaccuracies) that does not exceed 1/3 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 coaxility, 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 coaxility 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 an axis (or of an axis with respect to planes) and the 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 is 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 and sanding machines (drum sanders, wide-belt sanders, contact sanders);

(b) Machines of precision class 2, the basic class, which includes most woodworking machines, such as planing machines, moulding machines and spindle moulding machines etc.;

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

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 machines 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", above). 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 that act on the guideways and tool-holders in a direction perpendicular to the machined surface when the machine is in operation. 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 that may develop when the machine is operating under the most unfavourable conditions.

Procedure for geometrical checks

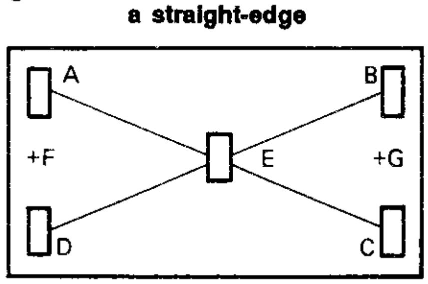
The most common methods for checking geometrical and machining accuracy are presented below, with an indication of the devices used in the tests and the tolerances for each type of machine.

The flatness test

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

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 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*) on 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



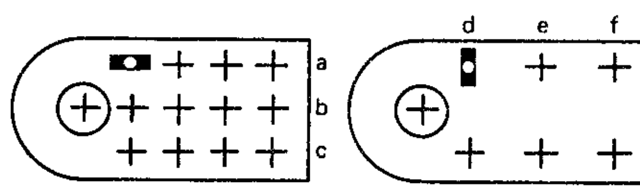
Points *A, B, C* and *E* are all in the same plane. The straight-edge is then placed on *B* and *E;* an adjustable block is placed at point *D* and its upper face is brought into the plane defined by the upper surfaces of the blocks already in position. As a result, the upper surfaces of the blocks at 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. Testing flatness with a spirit level

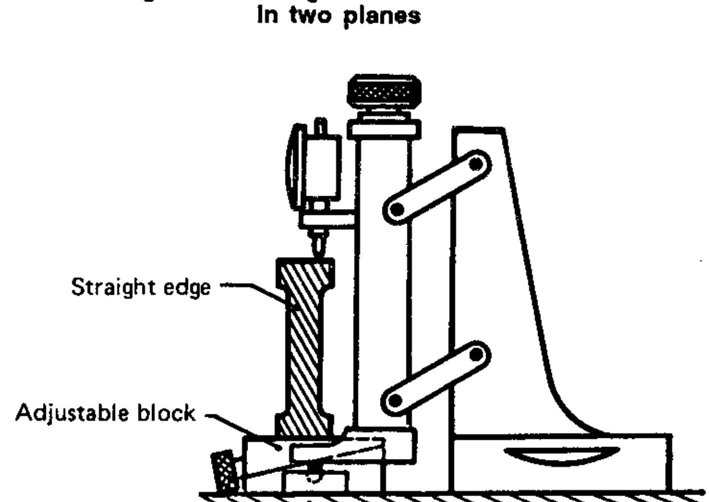


The straightness test

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", above).

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, a straight-edge is laid on two blocks located at points corresponding to the minimum deflection. The measurement is made by moving a rider along the straight-edge; one point of the rider 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. This test is not commonly used for woodworking machines, however.

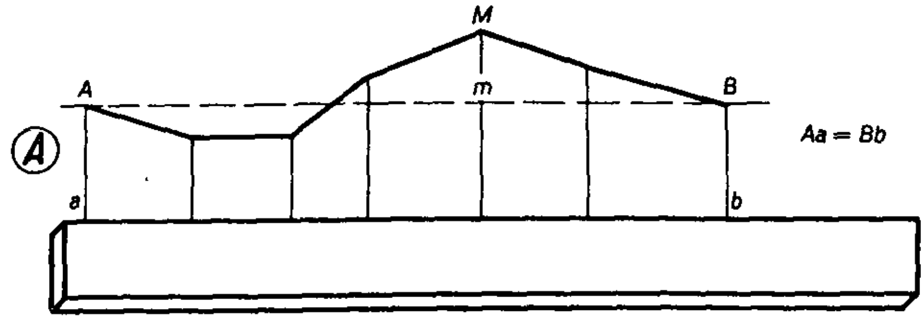
Figure 3. Straightness test of a line in two planes



[1]Important only when small components are machined.

Using the method shown in figure 4, the distances from the different points along the line *AMB* to the straight line *AB* can be read directly, with identical readings at the end of each line.

Figure 4. Straightness test result with identical readings 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, are checked in relation to the straight line *ab* (figure 5).

When measuring with a spirit level, the reference plane is the horizontal plane as defined by the level. The measurement is made by sections (figure 6). The general direction of the line to be measured (*AB*) is plotted on the diagram of values measured; *xy* is the reference line. The distance *MN* measured perpendicularly to this direction should not exceed the specified tolerances.

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

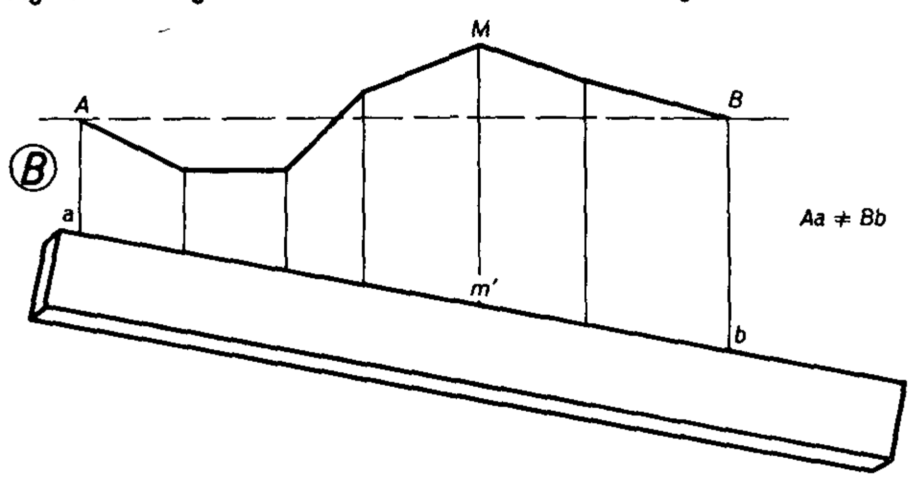


Figure 6. Measuring straightness on a horizontal plane.

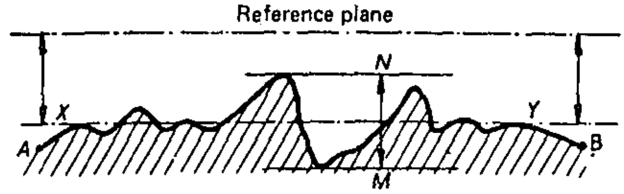
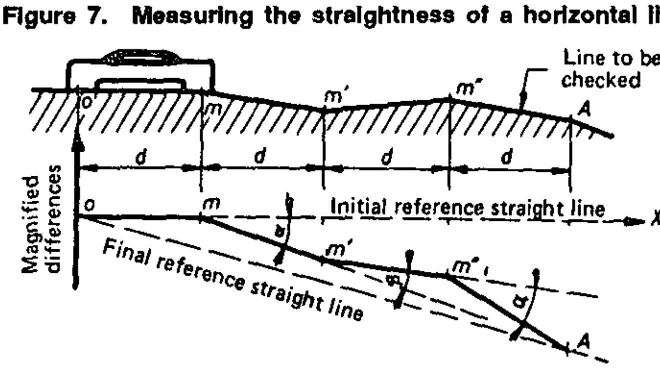


Figure 7. Measuring the straightness of a horizontal line



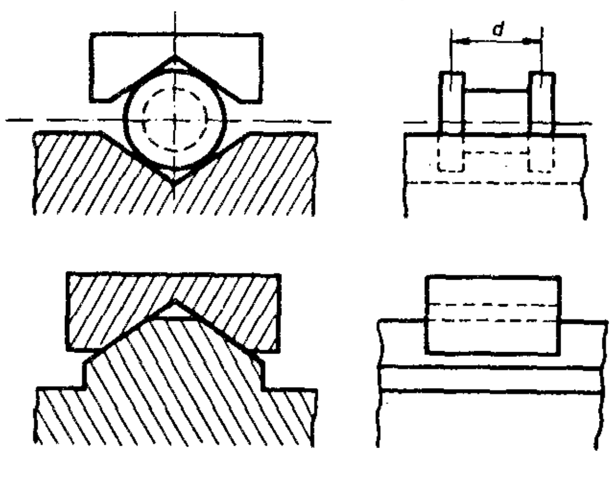
The level is placed successively on *om*, *mm'*, *m'm''* etc. The distances *om*, *mm'* etc. are equal to a value "*d*", related to the total length *oA*, which is to be checked (usually, *d* is between 100 and 500 mm). The readings of the level on *mm'*, *m'm''* etc. are compared with the reading at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

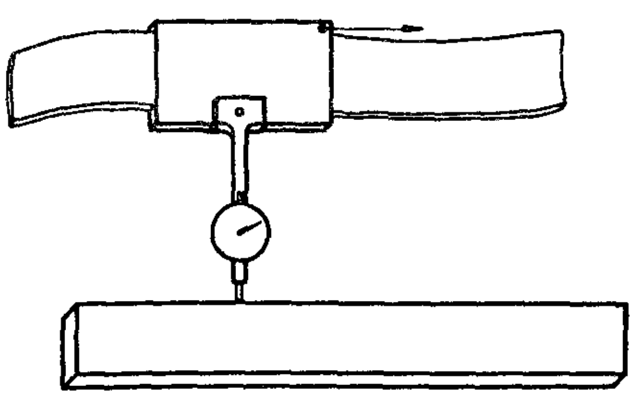
Checks for straightness of a component relate mainly to slideways of machine tools. Flat slide-ways are checked with a straight-edge, as in the case of lines, while V-slideways are checked with a level laid on a cylinder or some intermediate part made to the shape of the slide-way (figure 8).

Figure 8. Checks for straightness of a V-slideway



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).

Figure 9. Checks for straight-line motion



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".

Checking for coaxiality

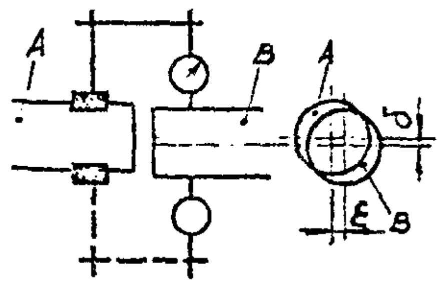
Coaxiality is checked by the following methods:

(*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 extension 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.

Figure 10. Opposite-points measurement method



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 $2\,\delta$, representing the maximum value of the discrepancy.

In this method, however, the inherent sources of errors must be considered in relation to the degree of accuracy required of the machine tool undergoing acceptance testing. These errors are the following:

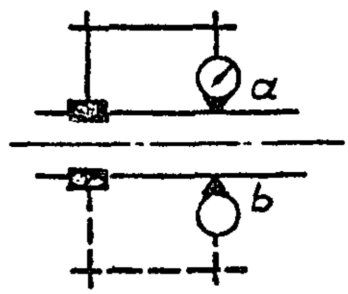
(*a*) Error due to the weight of the plunger, which in the upper position increases the pressure exercised and in the lower position decreases it;

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

(*c*) Error due to lack of rigidity in the mounting arm of the dial gauge.

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

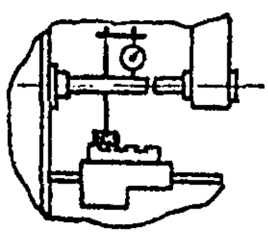
Figure 11. Opposite-points method to measure inherent deformation for errors



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.

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).

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

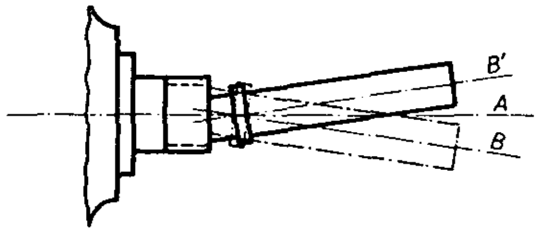
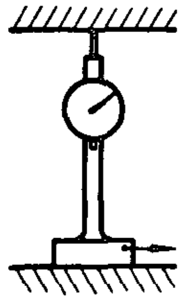
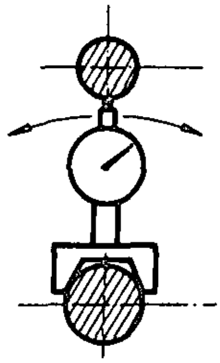


Figure 14. Checking parallel levels (planes)



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.

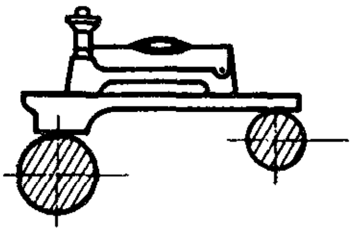
Figure 15. Dial gauge for checking parallelism of aligned spindles



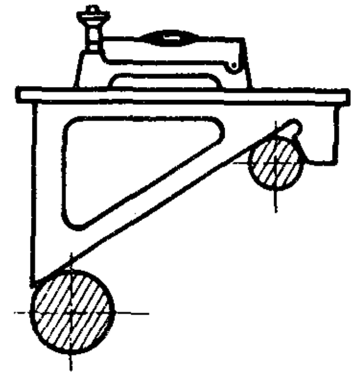
For the check in the second plane, an additional plane is needed, perpendicular to the plane that passes through the two axes. If this additional plane exists by virtue of the fact that the two axes are parallel to a surface of the machine, the parallelism of each axis, considered separately, should 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 level is set so that the air-bubble is at 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

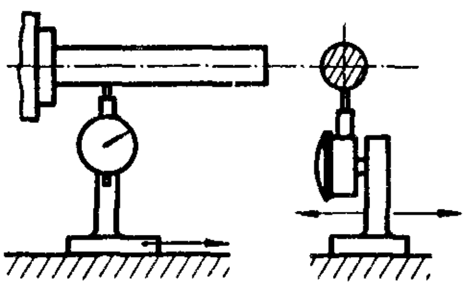


B. Square for testing parallelism

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 a 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.

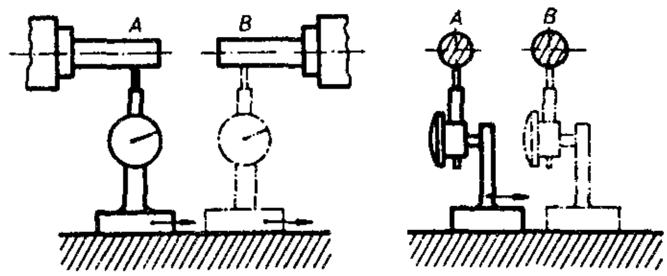
Whenever tests involve movement of the measuring instruments, the instrument should be fixed to the moving component, which takes the place of the supporting base of the dial gauge.

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.

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 the 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 to one another should be checked by means of a precision square placed on one of the planes. Using a dial gauge with a flat base placed on the second plane, a 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).

The 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 19. Squareness testing using a dial gauge

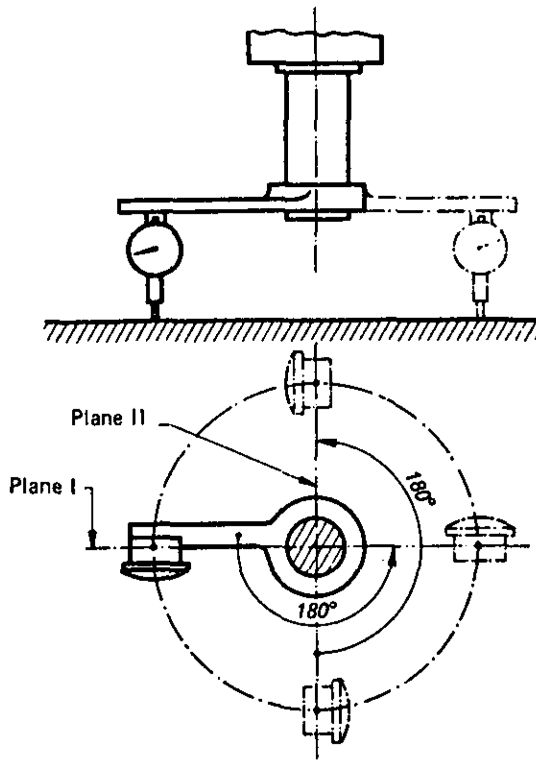


Figure 20. Checking the squareness of two planes to one another

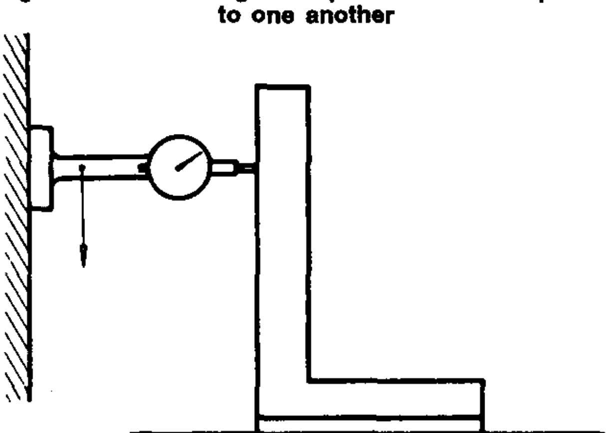


Figure 21. Checking the squarenes of two axes to one another

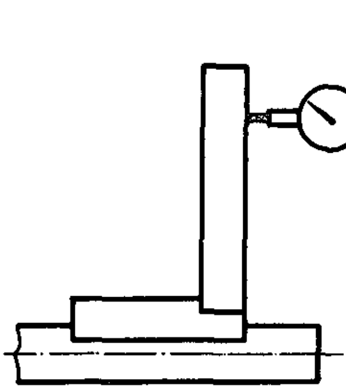
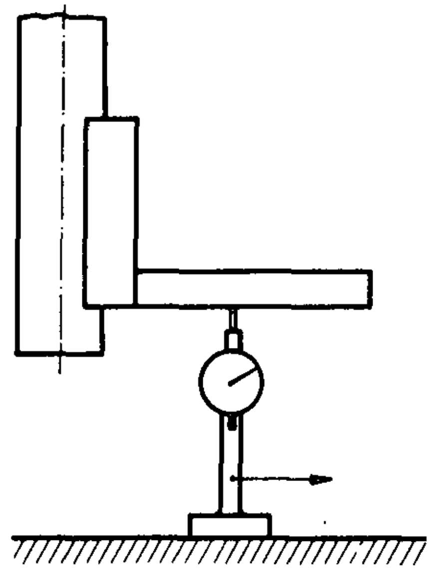


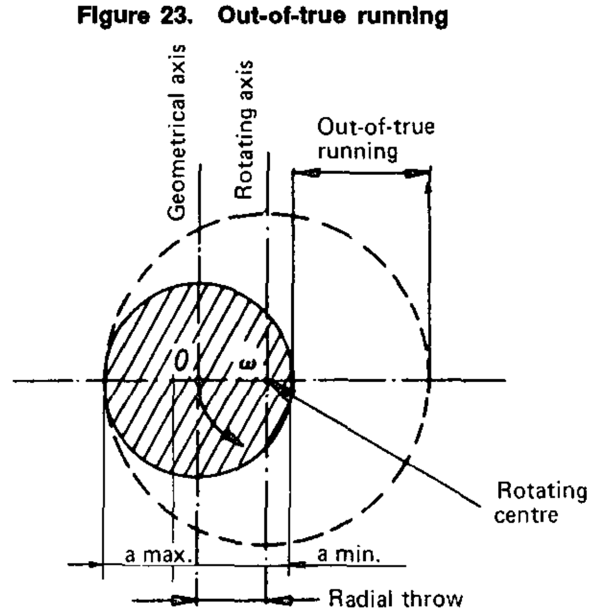
Figure 22. Testing the squareness of an axis to a plane



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 result of the radial throw of the axis, the out-of-round of the component and the errors of bearings.

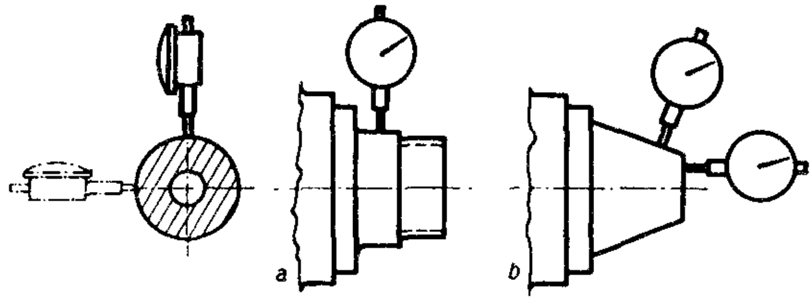
Figure 23. Out-of-true running



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).

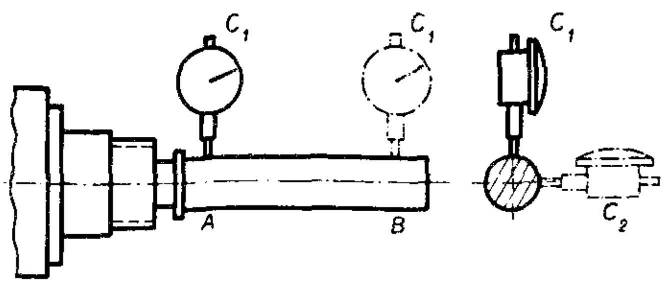
Conical surfaces, especially those with a steep taper, *require a preliminary check for axial slip, as this will* affect the measurement results in the test for run out.

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



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).

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

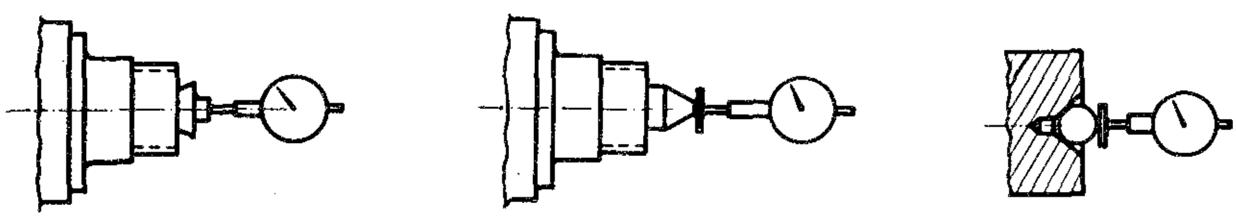


To make up for for any lack of accuracy in inserting the mandrel into the bore, these operations should be repeated four times, at 90° intervals with respect to the bore; the average of the readings so obtained is the final result.

The tolerance on run out is not preceded by a sign. It includes errors in the shape of the revolving surface and the movement and the lack of parallelism of the axis of a 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 26) 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.

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

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).

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 27).

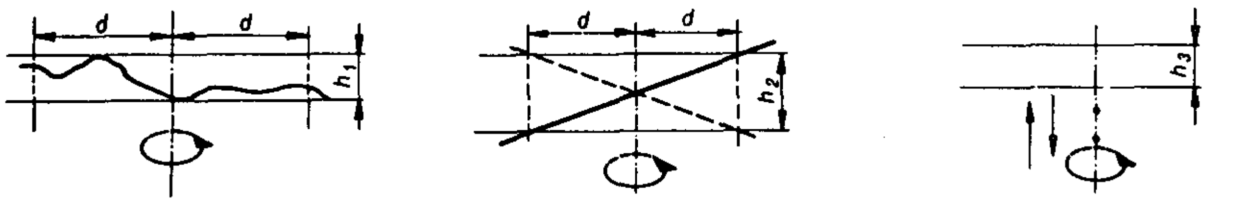
Camming may be examined over the entire test surface or only at a distance "d" from the axis.

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

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

Figure 27. Camming procedure

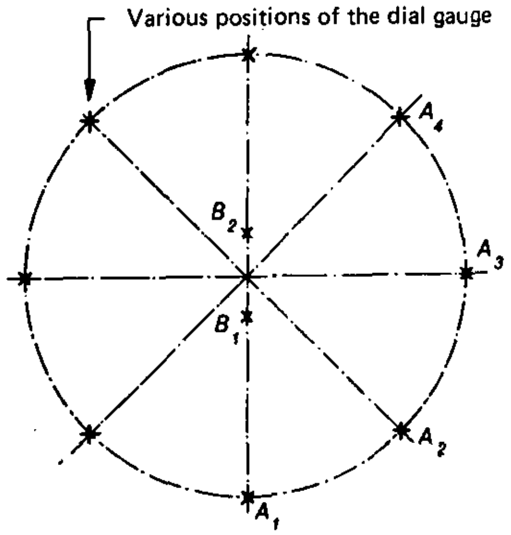


A. Camming where the surface is not flat

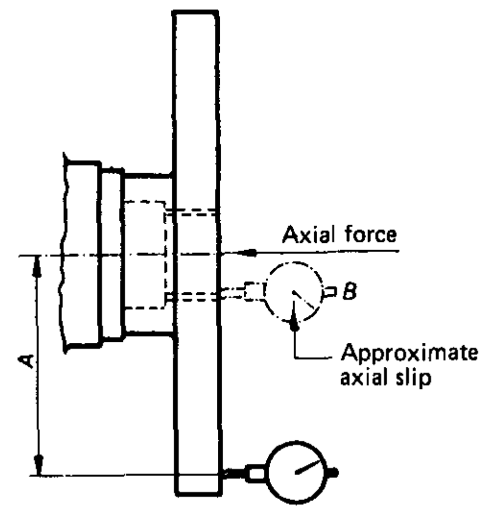
B. Camming where the surface and axis of rotation are not perpendicular

C. Camming due to axial displacement of the axis

Figure 28. Measuring camming



A. Positions of dial gauge during camming measurement



B. Measuring axial slip

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 (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.

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

Relationship of frequency to permissible noise*

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

*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 the 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.

Testing the geometrical and machining accuracy of representative types of woodworking machines

For each representative type of woodworking machines 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 annex III. The application of these standards should be based on an agreement between the manufacturer and the purchaser. The testing methods included in the standards 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 annex III should be adapted, 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 annex IV. These values are indicated in the technical data sheets for each representative type of woodworking machines operating by chip or particle removal.

Annex I

MACHINE TOOLS FOR WOODWORKING MACHINES 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 (narrow) 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

III.1. 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 axis	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	

III.2. Specifications for the precision of band sawing machines for joinery and cabinet making (with pulleys up to 1,000 mm in diameter)

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
	A. *Geometrical checks*	
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 }	$\frac{0.4}{1\ 000}$	
(*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	0.6	
(*b*) Transversely	0.4	

III.3. Specifications for the precision of manual-feed circular sawing machines

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
	A. *Geometrical checks*	
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). circular saw blade). Straight-edge, slide calipers

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

III.4. *Specifications for the precision of mechanical-feed circular sawing machines*

Purpose of the test	*Permissible tolerances (mm)*	*Remarks and recommendations*
	A. *Geometrical checks*	
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 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 tests	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

III.5. 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 *(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. 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

III.6. *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 and, in the case of *(c)*, the diagonal) 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 workpiece 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

III.7. *Specifications for the precision of planing machines for two-sided 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	*(a)* 0.15	
(b) Same, from 400 mm to 800 mm	*(b)* 0.25	

Purpose of the test	*Permissible tolerances (mm)*		*Remarks and recommendations*
	A. *Geometrical checks* (continued)		
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	
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	*(a)*	0.2	
(b) Transverse	*(b)*	0.1	

III.8. 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	

Purpose of the test	Permissible tolerances (mm)	Remarks and recommendations
	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. 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	$\frac{0.2}{1\ 000}$	

III.9. Specifications for the precision of spindle moulding machines

Purpose of the test	Permissible tolerances (mm)	Remarks and recommendations
	A. Geometrical checks	
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-parrallel 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

III.10. 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 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 an 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

III.11. 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	0.15	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 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 *(b)* Parallelism between the lower support surface and the base surface of the sample	$\frac{0.15}{100}$	Slide callipers accurate to 0.05 mm
2. Hole boring	+0.13 H 11 according to ISO standard	Hole gauge. Boring bit diameter 20 mm

III.12. 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			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 on each member along the machine *(a)* and over the width of the work surface *(b)*
(a) in the direction of feed	*(a)*	$\frac{0.15}{1\ 000}$	
(b) in a transverse direction	*(b)*	$\frac{0.1}{1\ 000}$	
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 support		0.04	Dial gauge graduated in units of 0.002 mm with the 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) with 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: $b \times 1\ 500$ mm, where b = machining width.			
1. Flatness of the sanded workpiece		$\frac{0.01}{1\ 000}$	Straight-edge, feeler gauge

III.13. 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 $\frac{(0.02)}{(1\ 000)}$
(*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

IV.1. Data sheet for vertical frame sawing machines

(Basic parameter: Inside width of saw blade frame)

Specifications	*Units*	*Parameter*[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)

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.

[a]These parameters were valid at the time of the original paper ID/WG.151/25 issued on 29 October 1973. In the intervening years, technological advances have been made.

IV.2. Data sheet for log band sawing machines

(Basic parameters: Pulley diameter and feed rate)

Specifications	*Units*	*Parameter*
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 tropical hardwood provision is made for 2-3 cutting speeds)
Power requirement (according to pulley diameter)	kW	60[a]-80[a]-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 tropical hardwood species, specially designed band saws.

IV.3. Data sheet for horizontal band sawing machines

(Basic parameters: Pulley diameter and feed rate)

Specifications	*Units*	*Parameter*
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
Adjustment of blade tension		Electric

IV.4. Data sheet for band resawing machines

(Basic parameters: Pulley diameter and feed rate)

Specifications	*Units*	*Parameter*
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

IV.5. Data sheet for double edging circular sawing machines, mechanical feed for resinous wood

(Basic parameter: Maximum edging width)

Specifications	*Units*	*Parameter*
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

IV.6. Data sheet for multiple blade circular sawing machines, or ripping, mechanical feed

(Basic parameter: Maximum width of workpiece)

Specifications	*Units*	*Parameter*
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

IV.7. Data sheet for surfacing and jointing machines

(Basic parameter: Width of cut)

Specifications	*Units*	*Parameter*
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

IV.8. Data sheet for thicknessing machines

(Basic parameter: Maximum edging width)

Specifications	*Units*	*Parameter*
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

IV.9. Data sheet for planing and moulding machines for three- or four-side dressing

(Basic parameter: Machining width)

Specifications	*Units*	*Parameter*
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

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:

IV.10. Data sheet for spindle moulding machines

(Basic parameters: Maximum thickness of workpiece and maximum cutter speed)

Specifications	*Units*	*Parameter*
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 requirement	kW	3-4.5

IV.11. Data sheet for routing machines

(Basic parameters: Maximum width of grooves and recesses, maximum speed of tool head, and throat)

Specifications	*Units*	*Parameter*
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

IV.12. Data sheet for chain mortising machines

(Basic parameters: Maximum width of mortise and length of mortise (travel of carriage))

Specifications	*Units*	*Parameter*
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

IV.13. Data sheet for horizontal slot mortising machines

(Basic parameter: Maximum diameter of cutter bit)

Specifications	*Units*	*Parameter*
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

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.

IV.14. Data sheet for wood turning lathes

(Basic parameters: Maximum swing over gap and maximum distance between centres)

Specifications	*Units*	*Parameter*
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

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.

IV.15. Data sheet for sanding machines with two and three top drums

(Basic parameters: Width of machining and maximum feed rate)

Specifications	*Units*	*Parameter*
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

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).

IV.16. Data sheet for wide-belt sanders, bottom sanding unit and top sanding units

(Basic parameters: Width of machining and feed rate)

Specifications	*Units*	*Parameter*
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 driving the sanding belt	kW	9-22

Note: The specifications refer to fine-sanding machines.

IV.17. Data sheet for twin wide-belt sanders with top and bottom sanding units

(Basic parameters: Width of machining and feed rate)

Specifications	*Units*	*Parameter*
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

Note: The specifications refer to machines for panel calibrating.

IV.18. Data sheet for horizontal stroke sanders with sanding pad or with pressure bar

(Basic parameters: Width of belt and speed of belt)

Specifications	*Units*	*Parameter*
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 conveyor 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*

The 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. The 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 and quality control, and the judicious choice of capital-intensive woodworking machines. When, why and how to purchase woodworking machines that are used for log processing are discussed in the present chapter.

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 the 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-based panel industry, whereas it is an input 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 that will affect:

(a) The rate of production;

(b) The 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.

Factory size and location

The 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 power, 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, hold-ups 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. One of 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 turnovers, 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, the numbers of which is decreasing, these techniques have always been used. At this stage in the development 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 the analysis of production flow patterns of the various parts and subassemblies. The design stage is critical in the optimization of production output. The design must take into consideration the rate of production, the organization of

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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 also possible to have a layout that is obtained by shifting the production equipment from time to time in the configuration most suitable for the 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 the location of machines, layout involves the location of various production departments, stores, buffer stock areas, auxiliary facilities and other related installations. Annex III shows a relationship chart analysing the importance of the 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 computer numerically controlled.

It is best to try to select a machine that 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) Versatility and excess capacity (possibility of multiple or increased production utilization);

(c) Useful life of the machinery with regard to foreseeable technical advances that 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.

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 features. 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 owing 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 available hours to 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. The 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 is characterized by a breakdown rate that 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, 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.

Efficiency is the percentage of time during which the machine should function without breakdowns. It can be represented by:

$$E\% = \frac{(T)}{(T+F)} \times 100$$

where:

T is the average time interval between breakdowns
F is the average duration of the breakdown

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 and 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 hold-ups during breakdown.

Technological features

Important technological features of machines are:

(a) Overall machine dimensions;

(b) Machine weight (useful for judging rigidity 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 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 (sawing machines, planers etc.) and coating (spreaders, automatic roller painters, sprayers etc.). The 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 the 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 the expansion of infrastructures, such as electric, hydraulic or pneumatic systems etc.;

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

(i) Testing and commissioning costs;

(j) Costs for training of personnel;

(k) Depreciation rates (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 the workpiece;

(f) Rejection rates;

(g) Characteristics of waste and losses (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 Economic Commission for Europe (ECE) (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, 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, standard terminology is used in defining all woodworking machines. The Technical Classification of Woodworking Machines and Auxiliary Machines for Woodworking was prepared by the European Committee of Woodworking Machinery Manufacturers (EUMOBOIS) (see chapter IV, annex III).

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 the purchaser 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 the proper sequence for installation. If such a programme is not properly adhered to, pieces of equipment or machinery may arrive well in advance of the scheduled installation time. These items may be subject to damage if they have to be stored, either crated or uncrated, for a long period of time. Such damage could be the result of rusting, dust particles, pilferage or the effects of local weather.

General terms of delivery

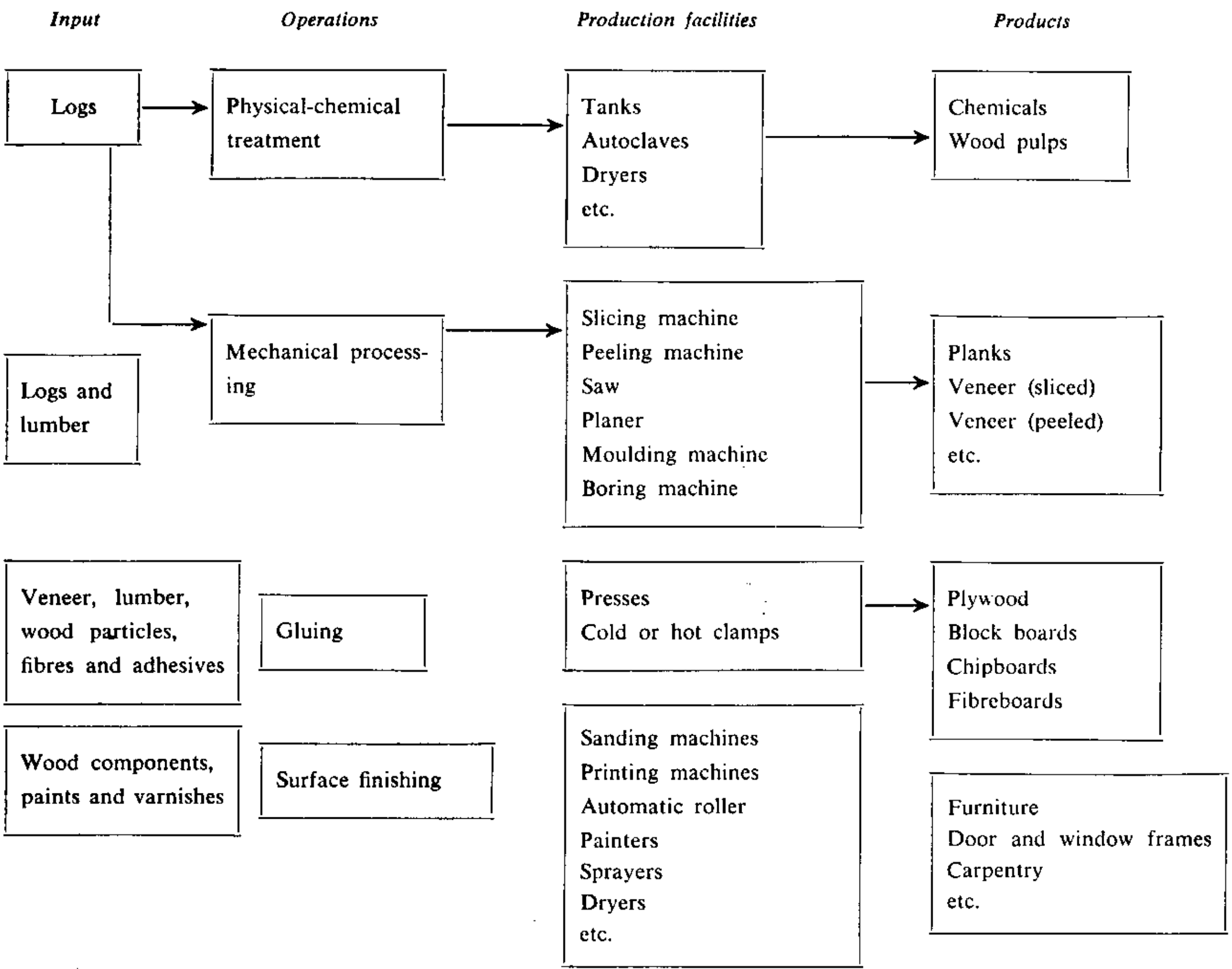
Annex VI includes a supplementary document which refers to "General terms of delivery". This document, has been drafted with reference to Documents Nos. 188A and 730, published and recommended by the ECE. It is a document that has been amended up to 1 January 1977 and is applicable where contracts are 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. It is considered advisable for developing countries to pay particular attention to the contents of the supplementary document when they become involved in purchasing of machinery or equipment.

As a supplementary document, which refers to the "General conditions for the supply of plant and machinery for export", is included as annex III. This document was prepared under the auspices of ECE.

Annex I

WOOD PROCESSING OPERATIONS



Annex II

PRODUCTION LAYOUT AND PRODUCTION FLOW DIAGRAMS

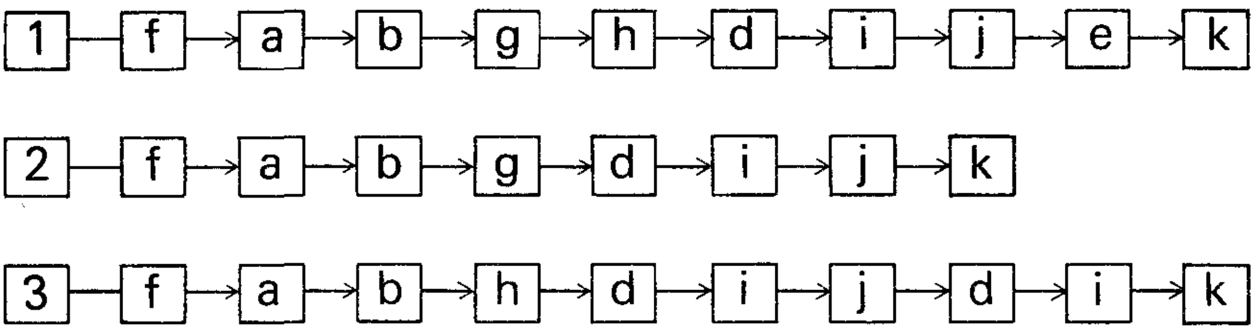
Layout types include:

(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.

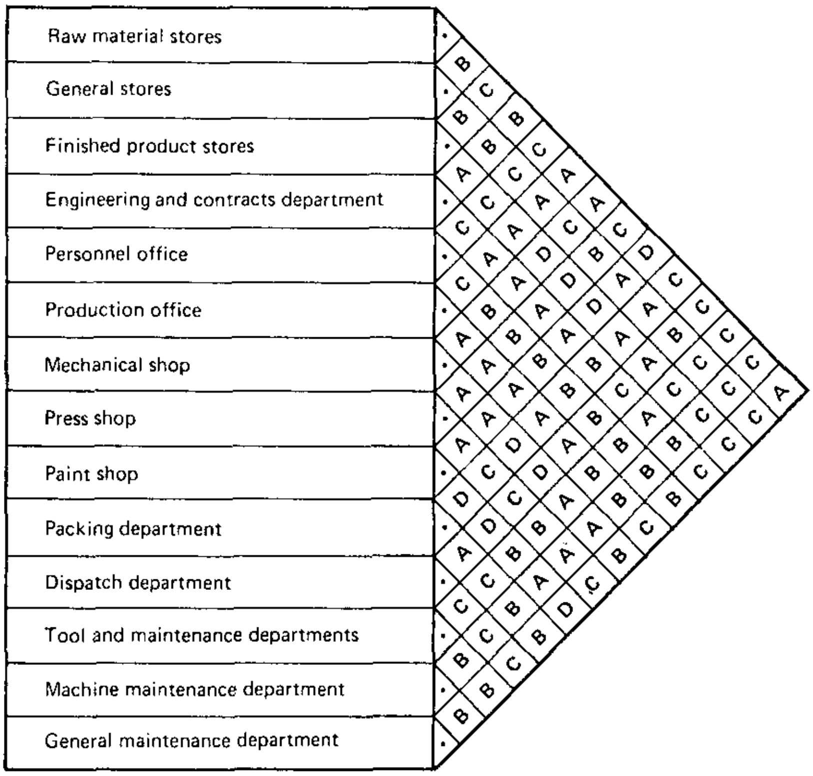


Key:

a	Press	1	Carcass (exterior frame of panel furniture)
b	Tenoning	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-SIZED 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

RECORD OF MACHINE CHARACTERISTICS AND POSITION

(Description) *Descrizione*	(Services) Servizi	(Location) *Dislocazione*
Macchina (Machine)	(Main motor) *Motore principale*	(Factory) *Fabbrica* ____ (Floor) *Piano* ____ (Bay) *Campata*
Marca (Make)	____ *V* ____ (Phase) *Fase*	
Modello (Model)	____ *Hz* ____ (HP) *CV*	
Num. catal. (Cat. No.)	(RPM) ____ *giri/m*	
Capacità (Capacity)	(Control gear) *Apparecchiatura di comando*	
Lista attrezzi (Tool list)	____ *V* (AC) (DC) *CA-CC*	
N. invent. (Inventory No.)	(Intake) *Aspiraz.* / *Gas*	
Disegno N. (Drawing No.)	(Water) *Acqua* / (Coolant) *Refrig.*	
Modifiche (Changes)	(Outlet) *Scarico*	
	(Steam) *Vapore*	
(Cost) *Costo* ____ (Date) *Data* ____ (Condition) *Condizione* ____	(Foundation) *Fondazione* (Yes) ☐ *Si* (No) ☐ *No*	
(Length) *Lunghezza* ____ (Width) *Larghezza* ____	(Drawing No.) *Disegno N.*	
(Height) *Altezza* ____ (Weight) *Peso* ____	☐ (Grouting) *Cementata*	(Notes) *Note* ____
(Special features) *Dati caratteristici* ____	☐ (Anchor bolts) *Bulloni d'ancoraggio*	
	☐ (Dampers) *Antivibranti*	
	☐ ____	(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[a] 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 referrable 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.

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;

*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.

[a] 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.

(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 connection 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 cirumstances 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 Plan, 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 connections to the Plant (whether such connections 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 an error or omission in the drawings or information mentioned in paragraph 1 hereof which appears before taking over shall be borne by the Contractor. Any such error or omission which appears after taking over shall be deemed 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 for 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 hereinafter 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 subparagraphs *(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 subparagraph *(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 subparagraph *(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 subparagraph *(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 subparagraphs *(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 impeded 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 of 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. and 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. and 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]

[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.

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 ($b_1 + b_2 \ldots + b_n = b$).

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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[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. 188A 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 or 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.

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 manfuacture 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.

*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.

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 13, 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 Vendor 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 despatched 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 ensure, 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 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.

10.6. For the purpose 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 Vendor's expenses shall be deemed to be that 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 deducations 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 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 ($b_1 + b_2 \ldots + b_n = b$).

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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.

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 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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[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, they may 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, the selection of equipment. 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, is the subject of the present chapter.

There are too many cases in the developing countries of the wrong pieces or the wrong assortment of machines being purchased. Once this is done, scarce foreign currency—from the point of view of the national economy—has been misspent. In addition, 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.

Other reasons that the wrong machines are chosen are:

(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 representatives of the firm 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;

(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

*By the secretariat of UNIDO. (Originally issued as ID.WG.256/26.)

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 component 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 techiques 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 the location 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, in order to avoid 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 plain 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 life 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 the 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 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 can be manufactured in the developing countries.)

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

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

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 several European countries 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, conveyors 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. Needless to say, 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;

[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).

(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 (litres per minute and pressure required);

(q) The need for special auxiliary equipment in the tool room or maintenance workshop to operate the machine;

(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, or cost of modifying the existing dust extraction installation;

(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(s) in a locally understood language for installing and operating the machine;

(h) The currency of payment;

(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 many 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, 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, even years

Annex II

CLASSIFICATION SYSTEM

The classification system, devised by the late 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 many of the considerations listed are technologically obsolete. However, the method is valid. Thus the specific considerations must be updated and a similar list devised for every processing line.

	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
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

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

	Number of points
Manufacture of particles	
System proposed	
Separate manufacturing lines for surface and for core particles and separate storing of sawdust, shavings and particles 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	
Large, over 100 m^3	3

	Number of points
Medium, over 50 m^3	2
Small, below 50 m^3	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 m^3 with level indicator on several points of the bin	3
Capacity below 25 m^3 with indicator for "full" and "empty"	2
Low capacity without level indicator	1
Dosing of particles	
Continuous quantity control	3
Discontinuous quantity control	2
Volume dosing	1
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

	Number of points
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 admitted, of course, that a multi-opening press has a certain advantage in the potential possibility of increasing the capacity.

	Number of points
Working pressure	
Min. 35 kgf/cm^2	3
Min. 30 kgf/cm^2	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 slides	3
With tools processing once two slides	2
With tool processing one side only	1
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 at one point	1
Not proposed	0

	Number of points
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

	Number of points
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

Annex III

TECHNICAL CLASSIFICATION OF WOODWORKING MACHINES AND AUXILIARY MACHINES FOR WOODWORKING*

Introduction

The European Committee of Woodworking Machinery Manufacturers was founded on 22 January 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

*Neuilly-sur-Seine, European Committee of Woodworking Machinery Manufacturers, 1980.

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, gluing room equipment, tool maintenance equipment etc.

1 Cutting machines change the shape or dimensions of a work piece:

(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.

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 from an independent machine.

8 Multi-purpose machines using working methods covered by group 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
12.131.35 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 sawblades
12.132.332 with adjustable distance of sawblades
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 dressing, adjustable table, fixed upper horizontal cutter blocks:
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 workpiece:
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 lathes
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 or 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 press
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, clamp and dowel pin driving machines, basket stapling machines)

32.2 Machines for assembling by means of wire (e.g.: fire wood 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 spreading 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 assembling 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
61.26 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 assembly:

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 lathes
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
82.29 Others

84 Multi-purpose 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 huttles 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. Rates of return on investment as a basis for the economic choice of machines in the field of wood processing and manufacturing*

Introduction

An industry is viable and produces at profit if it manages to optimize the use of its resources (raw materials, manpower, plant and machinery and capital). The raw material must be obtained at the best possible price; it must be of a quality corresponding to expectations; it must not generate excessive scrap or waste; it must not be used in excess with respect to the function of the finished product; and it must be on stock in sufficient quantities, but not in excessive quantities, which would cost a lot to maintain. The second factor in industrial production, manpower, includes skilled and unskilled workers, supervisors, department heads, sales staff, top management and the owners. All manpower has a cost, a level of efficiency and a direct influence on the profitability of an enterprise. Plant and machinery are indispensable and decisive in every industrial activity. It is essential for plant and machinery to be carefully selected and well-utilized and maintained. Capital must finance the industrial process and is therefore an essential facet in the life of a business.

There are many interrelationships between these four resources, and they have extremely different consequences, depending on the type of business and on the country where it is located. In this chapter, emphasis is placed on the relationships between plant and machines and capital, i.e. the rates of return on investment. There are many ways in which capital can be obtained (underwriting by shareholders, bond loans, loans at facilitated rates normally set up by Governments, medium-term loans from financial institutions and short-term credit from banks), but this subject will not be discussed in the present chapter.

The concepts presented are general and not specifically related to woodworking machines. Reference has been made, however, to a detailed economic study on the woodworking machine sector, which is characterized by a lower intensity of fixed capital compared to metalworking and the machine-tool sector. There is, therefore, ample opportunity for valid investments by manufacturers of woodworking machines.

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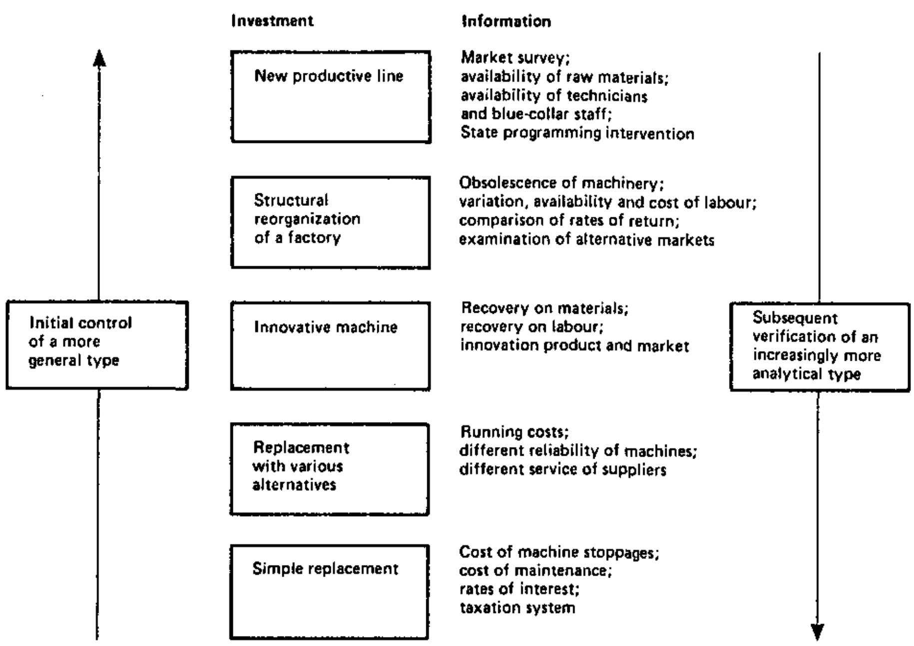
Investments

Before discussing the criteria and formulae to evaluate an investment and presenting examples, it is necessary to define an investment. The types of investment and the information that should be obtained before making an investment are shown in figure 1.

The establishment of a new production unit of a factory to produce planks, for example, would involve significant investments of capital, the construction of sheds, the installation of a sophisticated plant and the purchase of many machines.

Figure 1. Types of investment



Another type of investment might be for the restructuring of a factory, for example, in order to renew, update and considerably increase production or to diversify products

Investment in an innovative machine to replace another type of machine leads to economies through savings on materials and labour; for example, a edge-banding machine would make it possible to enhance less valuable materials, with excellent results in terms of appearance and quality.

Another type of investment would be for the replacement of a worn-out or out-of-date piece of equipment with a different piece of equipment. There might be a number of machines from which to choose, differing in cost and capacity.

The simplest type of investment would be for the replacement of a worn-out machine. In this case, management would have to decide whether to replace an equipment part immediately or to continue incurring high maintenance costs and postponing the investment of capital.

The classification in figure 1 is not a strict one and could also be modified to include other types of fixed assets.

For all the above-mentioned types of investment, evaluating the rates of return on investment is important. The basic mathematical formula is the same, although, in some cases, the application differs.

Before presenting the mathematical formula that compares an "initial investment" with a continuous flow of "revenue" and of "costs", it should be pointed out that, in the various cases indicated, the types of costs and of revenue may be different. Even greater differences may exist in the manner in which the extent of these monetary flows is evaluated.

When establishing a new industrial unit, it is indispensable to have a good knowledge of the market for the finished product, an analysis of the absorption in the regions or countries in which the unit is to be constructed and a survey on import and export flows. Just as important is information on the availability of raw materials and local labour and their relative costs and the possibility of finding qualified technicians. In addition, the level and type of government support for the type of activity in question are decisive. On the basis of this input, a cost evaluation of all the production factors (materials, manpower, capital, machines) can be made, and the yield for every unit produced and the output that can be sold can be calculated. If all the analyses are carefully made, it is possible to foresee trends in various areas.

In case of a structural reorganization of a factory, other variables must be considered: the obsolescence of the machinery, the availability and cost of labour compared with its worth at the time the factory was founded, changes in the raw-material and finished-product markets and the availability of innovative methods of work and machines. In this case, a comparison must be made of the rates of return of the existing factory and the modified production unit.

If management wishes to evaluate the advisability of investing in a machine that would modify a specific operation considerably, it is necessary to estimate *a priori* the economy that can be obtained on materials and labour, but it is also necessary to identify to what extent the quality of the finished product would be improved and how that would affect the selling price and the quantities that can be sold.

If, when replacing an item of equipment, there is a choice between new machines having different features, the running costs for each machine have to be evaluated. It is also necessary to include in the calculation reliability, the services rendered by the suppliers, for example during start-up in terms of technical assistance, and the availability and cost of spare parts.

The decision to replace a worn-out machine with a similar machine involves research into the cost of machine stoppages and maintenance and an evaluation of rates of interest and the influence of the taxation system on taxable business profits.

This classification of the various types of investment is purely formal. In effect, the information necessary to take an investment decision is important for all investments. Even for the simple replacement of a machine, for example, all the information that would normally be gathered when a new production unit is studied should be available.

An example might be the case of a door and window frame business that must replace one of the three tenoning machines. A study of the door and window frame market is likely to show that the tenoning machine cannot be replaced with another of the same kind. If the market is expanding, a machine with more production capacity should be examined; if it is beset by a crisis, an attempt should be made to work with the two installed machines.

If a new production unit is to be set up, a certain need for machines must be assumed in a first general analysis, and the machines would have to be chosen on the basis of general criteria. Once it has been decided to establish the new factory, every machine must be studied in detail. In some cases, it will be necessary to verify the advantage of an innovative machine for a certain operation as an alternative to other traditional machines. In other cases, a comparison of similar machines will have to be made on the basis of their reliability and of the services offered by the suppliers.

The cash-flow trend

Whether a new production unit is to be installed or a machine is to be replaced, the principle is always the following: an investment of capital that produces an income (or a saving on costs) for a long period of time is made on a short-term basis. The fixed asset has a useful life, at the end of which it is sold at a recovery value (frequently very low). By plotting on a graph the progressive monetary flows in relation to time (that is cash flow), a curve like the one in figure 2 is obtained and various phases can be identified: phase A, a period of initial cash outflows (for example, the payment for the project); phase B, during which there is a rapid and concentrated outflow for the purchase of machines and plant; phase C, representing the start-up of production, with very limited incoming cash; phase D, in which there is a constant increase, corresponding to the maximum income; phase E, during which the income gradually decreases (even if it remains very high) owing to the effect of wear and tear on the plant and various external conditions (increased cost of labour, increased competition etc.); and, finally, upon termination of the useful life of the fixed asset, an income for the sale of the plant and machinery. With an initial investment equal to I, the initiative has led to the total recovery of the initial cost and has generated an income equal to $G(i,n)$:

$$G(i,n) = -I - \int_0^n c(t)(1+i)^{-t}\,dt + \int_0 p(t)(1+i)^{-t}\,dt + V_f(1+i)^{-n} \qquad (1)$$

Where:

- i = annual rate of interest
- t = time function
- n = useful duration
- I = overall investment, in this formula considered instantaneous, that is with a duration of phases A and B equal to zero
- $c(t)$ = variable running costs in the period 0 to n
- $p(t)$ = variable gross revenue in the period 0 to n
- V_f = value of recovery of the investment sold at moment n
- $G(i,n)$ = updated economic result—function of the rate of interest i and the useful life n.

The advisability of the investment should then be evaluated in economic terms. At this point, it is necessary to introduce the concepts of interest and devaluation: if \$100 is lent and \$110 is repayed in a year, the apparent earning is \$10. But, if in the course of that year the cost of living has increased by 10 per cent, the \$110 can be used to purchase exactly the same goods that could have been purchased with the \$100 the previous year. In other words, nothing was earned.

Shown mathematically, there is an outflow of \$100 and an income of $\frac{\$110}{1+i}$, i representing the interest. If the interest is i = 10 per cent, the updated economic result is

$$G = -\$100 + \frac{\$110}{1 + 0.10} = 0 \qquad (2)$$

In figure 2, it can be seen that by outlining an instantaneous investment I, the curve changes in the AB zone in a line descending perpendicularly, while with the introduction of the updating coefficient $(1+i)^E$ the curve takes an even more accentuated descent since the cash inflows further forward in time are influenced more negatively by inflation.

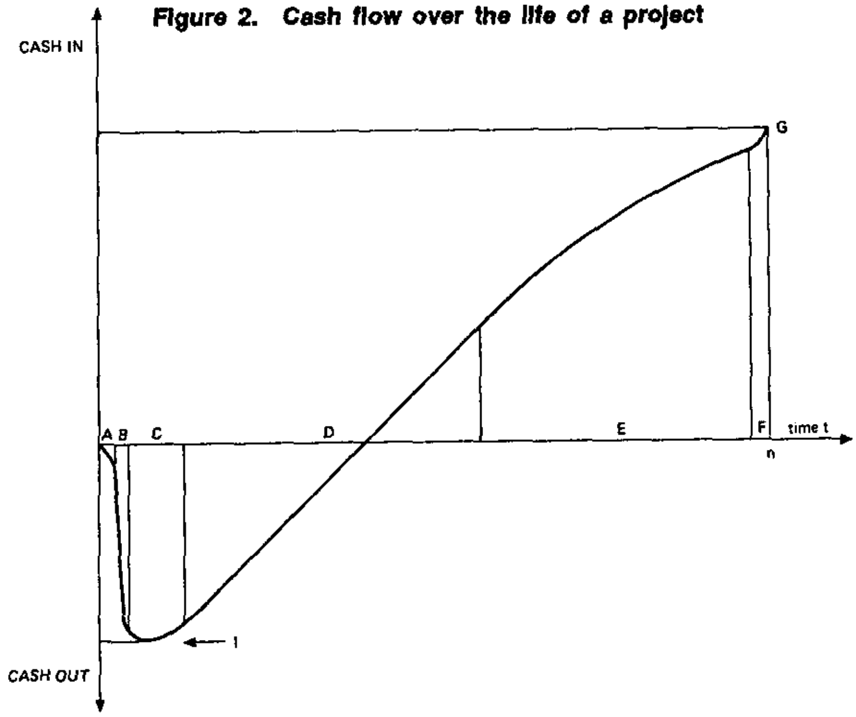


Figure 2. Cash flow over the life of a project

Unfortunately, the mathematical formula, even though exact, and the figure, even if very explicit, do not permit easy calculation of the updated economic result. In fact, the problem is to "foresee" the trend in costs and gross revenue over time; the longer the duration of n, the more difficult and uncertain this becomes. The difficulty of forecasting the future and the absence of general rules for the trend of costs and revenue over time would, at this point, make it impossible to go any further in solving the problem.

It is interesting to note that many engineers, for example, may be actively engaged in the analysis of investments; experience, instructions and knowledge of the machines and plant enable them to identify, in the various cases, the rules to be applied for evaluating the advisability of an investment. Ample literature has thus become available and many parameters have been identified and defined, which can be adopted in individual cases in order to judge the benefits of investments.

Formulae for the calculation of the rates of return on investment

Many simplified formulae for the evaluation of advisability arise out of the general mathematical formula (1). The search for simplified formulae presupposes knowledge of the various parameters. In some cases, and especially in the past when the value of money was relatively stable, there was a tendency to neglect the test of devaluation "i", and the values were therefore not updated. A simplification that is frequently used is to calculate the difference between revenues and costs and even the sole improvement in revenue between two different solutions (for example calculations are made of the savings generated by a new machine as compared with manual processing); mathematics show that this procedure is permissible, if given rules are complied with. Again for the purpose of facilitating calculations, a consistent trend in revenue is assumed, with constant savings for all the years of life of the investment. A notable simplification, finally, is dividing the useful life into homogeneous periods, for example into years, and considering the monetary income to accrue at the end of every financial year.

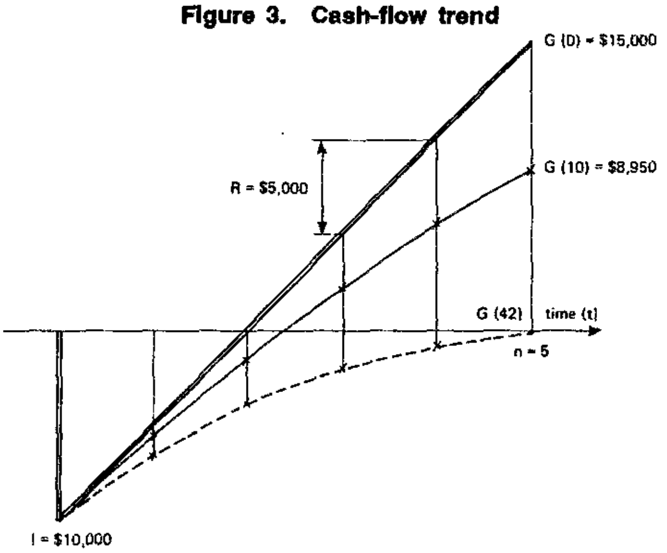
An analysis of the cash-flow trend can be made using simple formula. In figure 3 it is depicted graphically. (The cash-flow trend is indicated by a double line.)

Figure 3 can be interpreted using two concrete examples:

(a) A truck is to be purchased at $10,000 for the transport of logs to the port, which makes it possible to save on railway tariffs. It is assumed that this saving, less the cost for the use of the truck, is equal to $5,000 per annum and that the truck has a useful life of five years;

(b) A machine is to be purchased at a value of $10,000 for the recovery of the veneer from the rounding-off operations, with a consequent greater production of plywood valued at $5,000 per annum. This example is not very precise because the plant in question has a useful life of much more than five years; it is sufficient, however, to change the abscissa of the time (*t*) and to repeat the calculation in the event of a longer lifetime.

Figure 3. Cash-flow trend



At the end of the five years, the earnings, at an interest rate of zero, are $15,000.

The main indices that are analysed in the evaluation of the investment are the following:

Recovery (pay-back) period
Rates of return on investment, per annum and not updated
Current value or updated economic result
Index of benefit
Discounted cash flow, per annum and not updated
Equivalent cost per annum

The recovery period (pay-back) index is used a great deal, especially for short-term investments, usually with a high rate of return. It does not take the rate of interest into account. It is expressed by the formula:

$$P_r = \frac{I}{R} = \frac{10{,}000}{5{,}000} = 2 \qquad (3)$$

The formula expresses the time in which the invested capital is paid back. In the example, the recovery period is two years and is shown in figure 3 at the intersection of the double line with the axis (*t*).

The rates of return on investment, per annum and not updated, are calculated using the formula:

$$T = \frac{n\,R - I}{n\,I} = \frac{G\,(0)}{n\,I}$$

$$= \frac{5 \times 5{,}000 - 10{,}000}{5 \times 10{,}000} = 30\% \qquad (4)$$

The formula expresses the rate of return on the investment in a simple manner without taking the interest into account. If, at the end of the life of the investment, $15,000 has been earned, $3,000 have been earned per annum with an initial investment of $10,000. The rate of return is therefore 30 per cent.

In the current value or updated economic result index, the interest is taken into consideration. As already indicated, future income is updated taking into account a rate which, in the example, has been set at 10 per cent (per annum, i.e. compound interest). In figure 3 the trend of the updated revenue is indicated with a continuous dotted line. The formula is the following:

$$G\,(10.5) = R\,(P/A\ 10.5) - I = 5{,}000 \times 3.79 - 10{,}000 = 8{,}950 \qquad (5)$$

In this formula the coefficient $(P/A\ 10.5) = 3.79$ represents the current value, at compound interest, of a temporary revenue at constant deferred instalments of $1 and can be found in actuarial mathematical tables. The pay-back period would be 2.5 years.

The calculations have been based on an arbitrary interest rate of 10 per cent. In figure 3, the value G (10.5) is indicated on the right-hand side.

The index of benefit is calculated starting, as in the previous case, from a pre-set value. The formula is:

$$\psi = \frac{R\,(P/A\ 10.5)}{I} = \frac{5{,}000 \times 3.79}{10{,}000} = 1.895 \qquad (6)$$

The formula expresses in updated value how many times the investment is paid back during the entire life of the plant. Like the previous index, this one is based on an arbitrary rate and therefore gives a conditioned indication of the actual rate of return on investment. Also, in formulae (3) to (6), constant incoming cash flows have been assumed over the life of the project. Other formulae, which lead to the same result but are more complicated, are used if income varies.

The discounted cash-flow index is more complicated than the others, and in order to discuss it, a number of other concepts need to be defined.

The internal rate of return index (IRR) is expressed by $i^{\wedge\wedge}$ and is calculated using the following formula:

$$G\ (i^{\wedge\wedge}\ 5) = 0$$
$$R\ (P/A\ i^{\wedge\wedge}\ 5) - I = 0$$
$$(P/A\ i^{\wedge\wedge}\ 5) = \frac{I}{R} = 2 \qquad (7)$$

Using interest tables it can be seen that the interest is equal to: $i^{\wedge\wedge}$ = 42 per cent. This type of calculation is widely used in the evaluation of investments and represents, in the opinion of the author, the most appropriate methodology.

The IRR cannot be likened to the indices examined previously. According to a mathematical demonstration which is too long to present in the present chapter, the incoming cash flow of each year can be divided into two parts, one for the reimbursement of the capital and the remainder to pay the interest $i^{\wedge\wedge}$ for one year on the capital that is still to be repaid. For this reason the index IRR = 42 per cent is higher than the non-updated rate $T = 30$ per cent illustrated in formula (4). In order to understand how the interest $i^{\wedge\wedge}$ should be evaluated, it is necessary to introduce a new index, the minimum attractive rate of return (MARR).

MARR can be defined as the rate at which an enterprise is interested in investing, since it has other possibilities for producing a return. MARR must not be confused, as often happens, with the cost of the capital that the enterprise receives from shareholders and banks. MARR must be substantially higher than the average weighted rate from the sources of business financing because it is not advisable to invest in projects that expect earnings equal to the cost of the capital, owing to risk elements present in many projects and the uncertainty of the future.

If, therefore, a business sets a MARR equal to 20 per cent, for example, it expresses its availability to invest in all initiatives that have an IRR>MARR. The capital invested in the various initiatives will have a return cash flow and can gradually be invested in other activities, always with IRR>MARR.

At this point the validity of the system is evident. The investment is examined and calculated completely on the basis of the foreseeable cash flows, without inserting external hypotheses for the rates; in the end, the IRR index is compared directly with the MARR set by the business.

A number of factors determine the rate at which MARR is set. If, inflation is low in a country, for example at a level of 5 per cent, the average rates payable by a business may be of the order of 8 per cent and MARR will be fixed at around 10 to 15 per cent; if inflation is for example 20 per cent, the business must fix MARR at a level of 25 to 30 per cent. To give another example, if a business has average rates payable of 10 per cent, it can fix MARR at 15 per cent; if another business in the same country has mainly short-term financing and therefore pays rates of 15 per cent, it would have to fix the MARR at 20 per cent.

While the discounted cash flow system is undoubtedly better than others in the evaluation of a new investment, some supplementary steps must be taken when more than one alternative for investment exists, for example the purchase of two similar machines, with different initial costs and annual returns. The equivalent cost per annum system may be used in this case. The formula applied is the following:

$$CE = R - \frac{I}{(P/A\ 10.5)} = 5{,}000 - \frac{10{,}000}{5{,}000} = \$2{,}361 \qquad (8)$$

Examples

In order to make the methods of evaluating investments and the formulae presented above more clear, two examples are given below: one for the purchase of a new machine, the other for a new production unit.

Innovative machine: lipping machine for doors

A business produces internal doors for houses at a rate of 500 pieces/day. The doors are of the veneered type, with the frame made of high-quality wood and the leaf of plywood veneered with the same wood species. The technical manager of the business had considered the possibility of adopting a much more economical species for the leaf frame. At a trade fair, the technical manager examined a machine that glued a wooden lath along the whole of the rabbet of the door and that could make the use of more economical wood species possible. This case would fall under the heading "innovative machine", as shown in figure 1.

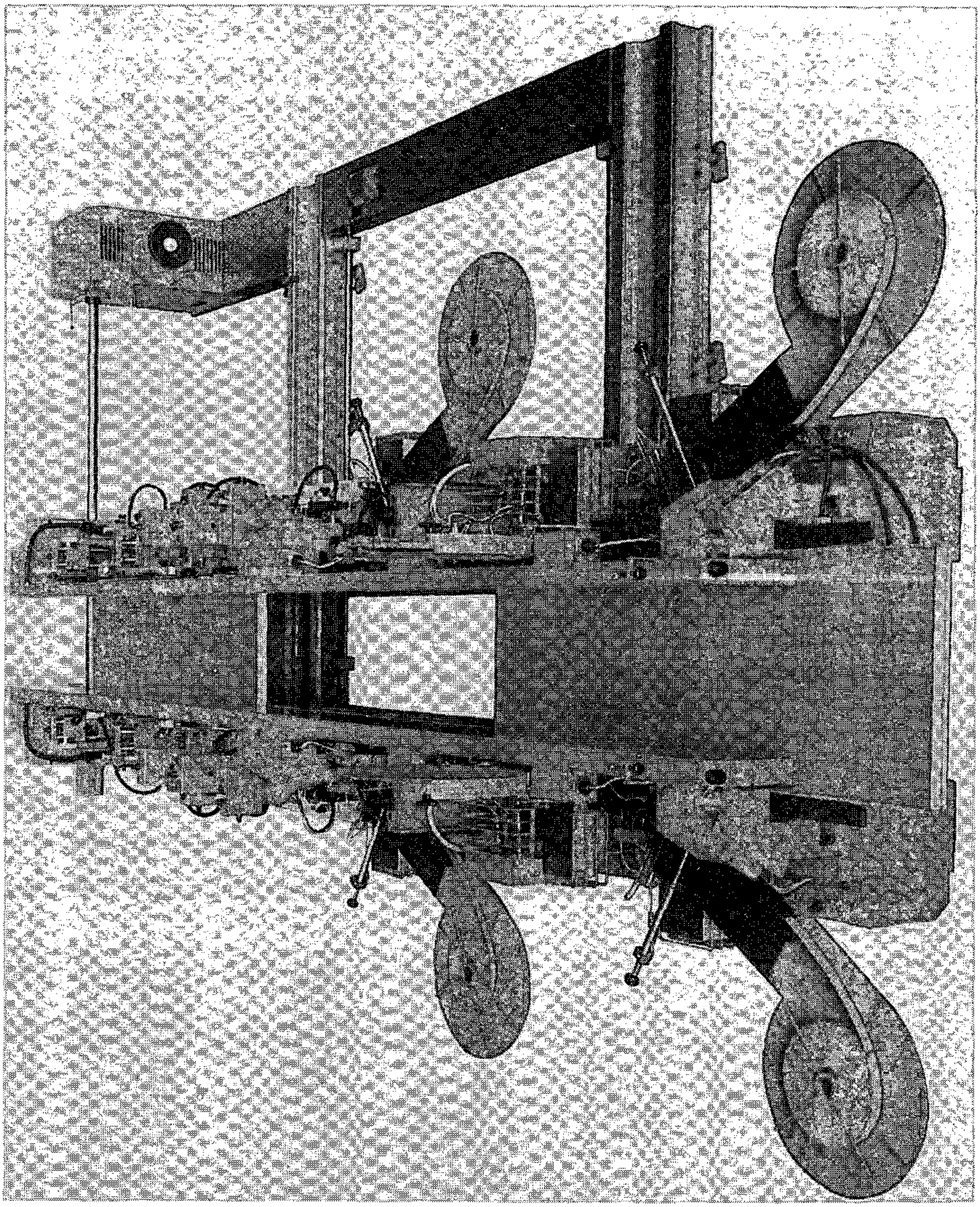
Considering the market for the wooden door industry, the technical manager estimated that the current production of 500 doors per day was a suitable quantity and that it would not be reasonable to expect increases in sales or to examine machines with higher capacities. The most economical wood species would be widely available, and its price was expected to remain competitive for more than 10 years. Existing personnel would be capable of running the new machine, and the limited extra labour that would be necessary could be hired easily.

The machine is like the one in figure 4, except that it is operated on only one side, which is amply sufficient for the production of 500 pieces per day. The operations performed by the lipping machine are illustrated in figure 5.

After making this preliminary analysis, it is necessary to evaluate the economic benefits of the investment and, for this purpose, the technician must select all the cost elements that are necessary. The economic evaluation below is based on an examination of the "economic components" illustrated in chapter III.

The values and the information necessary for the evaluation of the fixed asset are shown in table 1. The values refer to 1982, and it is assumed that the machine entered into operation on 1 January 1983.

Figure 4. Lipping machine for doors



The economic values for each year during the expected life of the lipping machine is shown in table 2. It is useful to comment briefly on the hypotheses adopted in the example:

(a) The country in which the business has its headquarters is an exporter of timber. For this reason the difference in value between a high-quality wood and an economical one is limited to \$65 per cubic meter; in Europe such differences are much higher and always justify the purchase of the lipping machine, since the rate of return is much greater;

(b) All the values have been assumed for the total duration of the investment. The values increase over the years according to the medium-term plan set up by the business. On the basis of these calculations, it is foreseen that the cost of timber would rise on average by 6 per cent

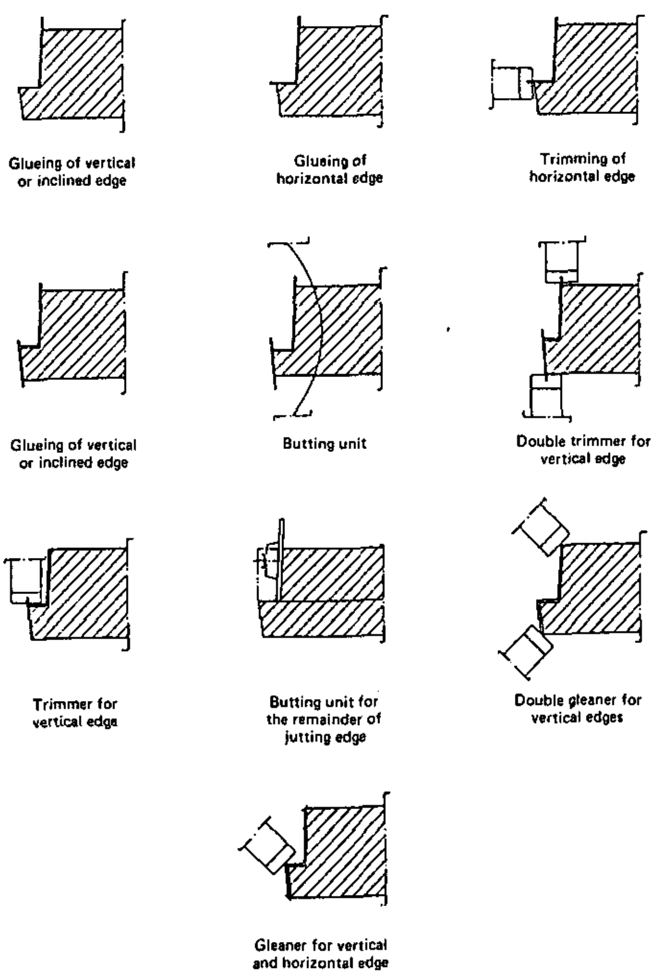
per annum, labour by 9 per cent and power by 9 per cent; these values give an idea of the inflation in force in the country examined;

(c) The additional cost for labour is calculated for three workers needed for manual loading and unloading of the machine;

(d) The cost of the non-recoverable scrap has been indicated for a general case; with the machine under examination, the scrap can always be reconditioned; the time for recovery is amply absorbed by the hypotheses already set forth;

(e) The cost for maintenance includes the spare parts purchased for approximately two years which were purchased initially and have not been included in the calculation of depreciation; in the subsequent years a progressive increase in costs for spare parts, is foreseen, taking the aging of the machine into account.

Figure 5. Manufacturing cycle of a lipping machine



The incoming capital for the years from 1983 to the end of the useful life of the machine is shown in table 3. It should be noted that the calculation of taxes foresees that the additional earning achieved by using the machine is normally subject to taxation and that the relative tax is paid the subsequent year. It should also be noted that, although a limited saving on the cost of the timber was assumed, over the financial years the business has incoming capital that varies between $11,000 and $32,000. As can be seen, it is very important to make a correct forecast of the revenue and costs, and it is not possible, therefore, to consider that the incoming capital is constant solely in order to simplify the calculations.

Table 1. Calculation of capital invested and related values for a lipping machine (one side only)

Item		*Amount of production/cost*
Theoretical production		800 doors/day
Actual production		500 doors/day
Purchase value f.o.b. (value indicated)		$40 000
Transport-insurance taxes (27%)		$10 800
Complementary equipment		—
Base, link-up, power etc.		—
Start-up and testing; Staff training	(8%)	$3 200
Commercial value of area occupied for new manufacture	12.5 m² × $80/m²	$1 000
		$55 000
Useful life of machine		8 years
Residual value at end of life		$8 000
Fiscal depreciation		8 years
Accelerated fiscal depreciation		5 years
Depreciation desired by business		5 years
Initial purchase of tools and spare parts for two years		$7 000

Note: The values have been chosen to provide a typical example. They do not, therefore, necessarily represent reality and are not to be considered binding.

All the formulae shown previously have little true relation to reality. The calculation of the discounted cash flow is shown in table 4.

The internal rate of return IRR = i ^^ that would reduce the earning indicated in the following formula to zero is easily found by attempts and by interpolations. The formula, taking non-constant annual quotas of recovery into account, is the following:

$$G(i\text{^^}\, n) = 0$$

$$I = R_t(1 + i) - t + V_f(1 + i) - (n + 1) \qquad (9)$$

According to the methodology illustrated earlier, the following two parameters necessary for evaluation of the investment are obtained:

rate IRR = i^^ = 41.1 per cent
pay-back period = 2 years, 3 months

If the company that is studying the investment has headquarters in a country with a rate of inflation of 6 to 9 per cent and therefore established a MARR equal to 17 per cent, it easily verifies the benefits of the purchase of the lipping machine, since 41.1 per cent is very attractive. From the financial point of view, the pay-back period indicates that the monetary savings permit the return of capital in two years and three months. The investment is, therefore, extremely advisable.

New production unit: plywood factory

The second case is a company that wishes to construct, in a timber-producing country, a factory for the manufacture of plywood (see figure 6). On the basis of a detailed study by the purchaser, who surveyed all the local features, the project was to be carried out by an Italian engineering firm.

Table 2. Estimated savings and additional costs resulting from the purchase of a new lipping machine

(Dollars)

	1983	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*
Savings									
Savings on price of timber ($/m³)	65	65	75	75	75	85	85	95	—
Total saving[a]	110 500	110 500	127 500	127 500	127 500	144 500	144 500	161 500	—
Additional costs									
Labour ($/h)	3.0	3.4	3.8	4.0	4.4	4.8	5.1	5.7	—
Supplementary labour[b]	*16 200*	*18 400*	*20 500*	*21 600*	*23 800*	*25 900*	*27 500*	*30 800*	—
Special technician	900	1 000	1 100	1 200	1 300	1 400	1 500	1 700	—
Wood edging	54 000	54 000	60 000	60 000	65 000	65 000	73 000	73 000	—
Glue and other materials consumed	4 000	4 200	4 400	4 800	5 100	5 300	5 600	5 900	—
Cost of residue not recovered[c]									
Maintenance	7 000	500	4 400	4 900	5 500	6 200	7 000	8 000	—
Power	2 300	2 500	2 700	3 000	3 300	3 600	4 000	4 400	—
Total supplementary costs	84 400	80 600	93 100	95 500	104 000	107 400	118 600	123 800	—

Note: The values have been chosen to provide a typical example. They do not, therefore, necessarily represent reality and are not to be considered binding.
[a]Assuming a constant consumption of 1,700 m³/year.
[b]Assuming 5,400 hours a year for loading and unloading the machine.
[c]Not relevant.

Table 3. Trend of incoming capital

(Dollars)

	1983	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*
Savings	110 500	110 500	127 500	127 500	127 500	144 500	144 500	161 500	—
Supplementary costs	(84 400)	(80 600)	(93 100)	(95 500)	(104 000)	(107 400)	(11 600)	(123 800)	—
Margins	26 100	29 900	34 400	32 000	23 500	37 100	25 900	37 700	—
Payment of taxes	—	(6 050)	(7 550)	(9 350)	(8 400)	(5 000)	(14 850)	(10 350)	(15 050)
Realization value	—	—	—	—	—	—	—	—	8 000
Incoming capital	26 100	23 850	26 850	22 650	15 100	32 100	11 050	27 350	(7 050)
Margins	26 100	29 900	34 400	32 000	23 500	37 100	25 900	37 700	
Fiscal depreciation	(11 000)	(11 000)	(11 000)	(11 000)	(11 000)	—	—	—	
Taxable profit	15 100	18 900	23 400	21 000	12 500	37 100	25 900	37 700	
Calculation of taxes (40%)	6 040	7 560	9 360	8 400	5 000	14 840	10 360	15 080	

Table 4. Calculation of discounted cash flow

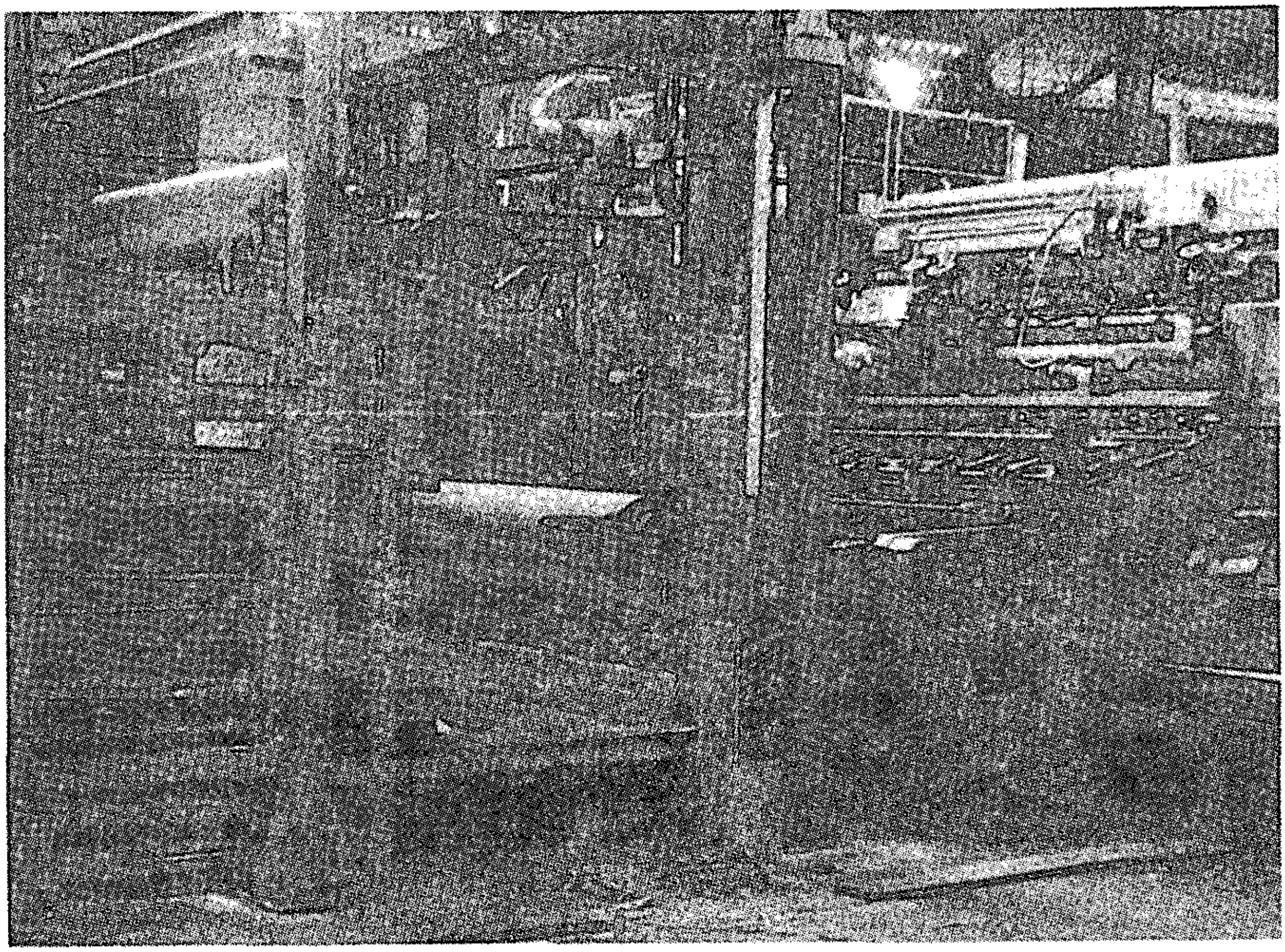
Years	*Flows of incoming capital capital ($)*	*Cumulative process income ($)*	*Rate of 40%*		*Rate of 45%*	
			Table	*Updated value ($)*	*Table*	*Updated value ($)*
1983	26 100	26 100	0.714	18 635	0.690	18 009
1984	23 850	49 950	0.510	12 164	0.476	11 353
1985	26 850	76 800	0.364	9 773	0.328	8 807
1986	22 650	99 450	0.260	5 889	0.226	5 119
1987	15 100	114 550	0.186	2 809	0.156	2 356
1988	32 100	146 650	0.133	4 269	0.108	3 467
1989	11 050	157 700	0.095	1 050	0.074	818
1990	27 350	185 050	0.068	1 860	0.051	1 395
1991	(7 050)	178 000	0.048	(338)	0.035	(247)
Total	178 000			56 111		51 077

Note: Calculation of rate by interpolation:

$$\left.\begin{matrix} 56{,}111 - 55{,}000 = 1{,}111 \\ 55{,}000 - 51{,}077 = 3{,}923 \end{matrix}\right\} \text{IRR} = i^* = 40 + \frac{1{,}111}{1{,}111 + 3{,}923} \times 5 = 40 + 1.10 = 41. \text{ Pay-back period} = 2 \text{ years} + \frac{55{,}000 - 59{,}950}{26{,}850} \times 12 = 2 \text{ years} + 2.3 \text{ months.}$$

Table of coefficients $(1 + i) - n$.

Figure 6. Plywood factory (reeling system and reel stores)



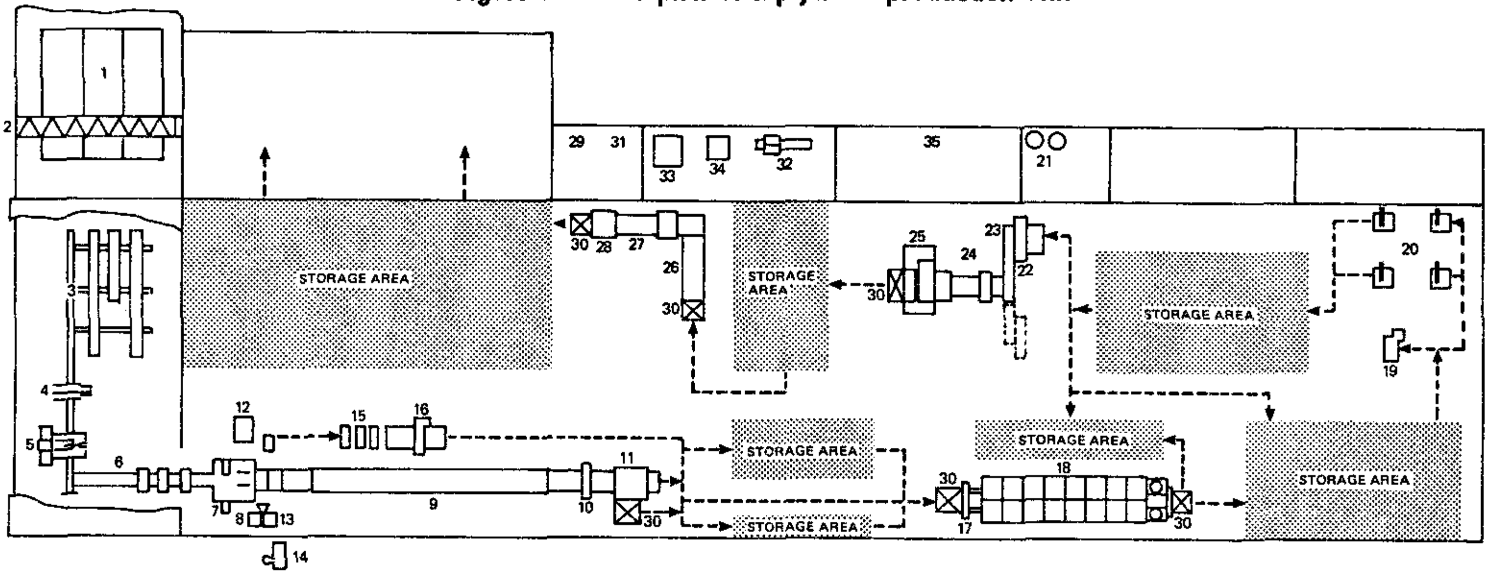
The factory whose layout is illustrated in figure 7 has been designed. The characteristics of the unit and the investments necessary (in 1982) are indicated in table 5.

Table 5. Characteristics of and investments for a factory to produce plywood

Item	*Production characteristics/cost*
General features	
Wood used	Okoumé
Covered surface	-7 500 m^2
Timber processed	15 200 m^3 per annum
Plywood produced	8 000 m^3 per annum
Labourers	67 people
Managerial, technical and administrative staff	8 people
Days worked	300 days per annum
Shifts	2 shifts
Investments necessary	$
Plant and machinery, f.o.b. value[a]	1 000 000
Transport, insurance and taxes (27%)	270 000
Base, link-up etc. (5%)	50 000
Start-up and staff training (10%)	100 000
Total value of plant	1 420 000
Buildings ($80/$m^2$)	600 000
Operating capital (estimated)	500 000
Total financial requirement	2 520 000

[a]The value is actually higher but has been rounded to $1,000,000 for ease of calculation.

Figure 7. Floor plan of a plywood production unit



Key:

1 Steaming bins
2 Electrical gantry crane, 10 tonnes
3 Chain conveyor deck for logs
4 Chain saw
5 Log debarker
6 Chain conveyors for charger
7 Automatic lathe charger
8 High-efficiency telescopic veneer lathe
9 Tray deck system or reeling system and reel stores
10 High-speed pneumatic clipper
11 Fully automatic veneer stacker
12 Core chain conveyor with pneumatic ejector
13 Waste belt conveyor
14 Waste veneer chipping machine
15 Device for recovery of roundings
16 Automatic clipper for recovery of roundings (option: Zig-zag tray is best)
17 Automatic veneer loader for dryer
18 Jet veneer dryer with cooler
19 Veneer jointer assembly
20 Veneer splicers (other systems possible)
21 Glue mixers
22 Four-cylinder glue spreader
23 Pre-press
24 Press loading and unloading devices
25 Hot press
26 Four-side panel squaring unit with automatic transfer
27 Transfer conveyor
28 Wide-belt sander
29 Suction plant for sizing and sander
30 Hydraulic hoisting platforms
31 Air-compressor unit
32 Automatic precision knife grinder
33 Grinder for circular blade of squaring unit
34 Grinder for chain saw
35 Heat-generating plant
▒ Storage area

In addition to the investments indicated in table 5, the company has a series of revenues and costs, which are arrived at based on an analysis of market conditions, the experience of technicians and the experience of a similar plant.

The plywood is of a high quality for export and therefore has a high selling price; the cost of the personnel is very low, as occurs in some countries (in this example it has been set at $3,600 per annum, different from the case examined previously); most of the thermal power can be produced by the company from residues, while 15 to 20 per cent is obtained using other fuels; and no calculation is made for taxes because a government exemption to facilitate investments is assumed.

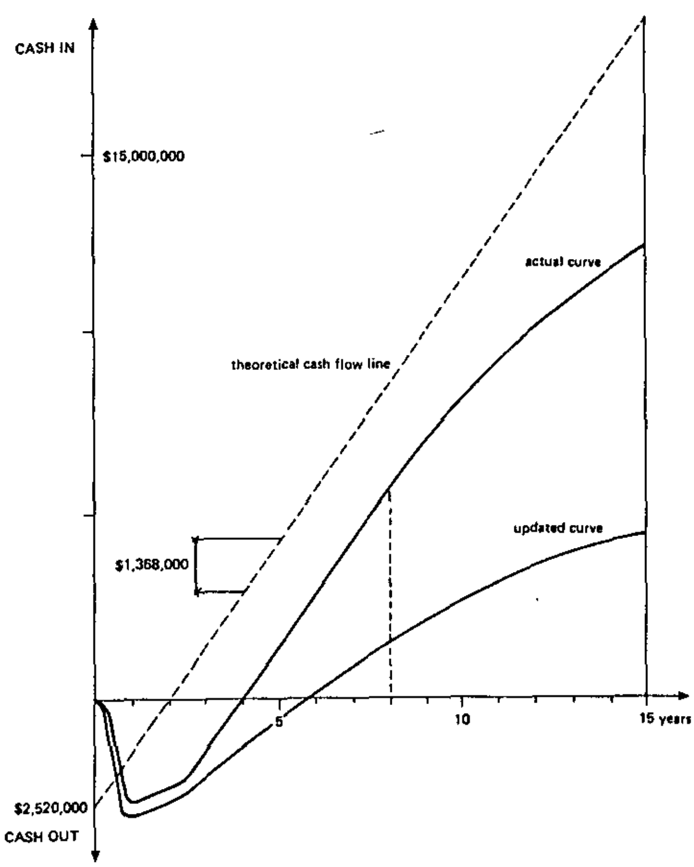
As can be seen from table 6, against annual sales of $3,400,000, there are costs of $2,032,000 and a gross margin of $1,368,000. By deducting the depreciation and the necessary interest on capital, the net profit is obtained.

The application of the classical formulae to evaluate the rate of return on investment does not have much significance in this case. In fact, by again taking the indices set forth previously, the following values are achieved:

I = initial investment	$2 520 000
R = gross annual margin	$1 368 000
(P/A 10.15) = coefficient obtainable from the tables in the case of interest on capital at 10 per cent and useful duration of the factory of 15 years	$7 606
$P_r = \frac{I}{R}$ = recovery period (payback)	1 year, 10 months
$T = \frac{nR - I}{nI}$ = rates of return on investment, per annum and not updated	51%
G (10.15) = updated economic result considering i = 10% and n = 15 years	$7 885 000
= index of advantageousness	4.13
IRR = $i^{\wedge\wedge}$ = rate of return, updated and per annum	54%
CE = equivalent annual recovery	$1 037 000

The investment apparently has an extremely high rate of return. It should be recalled that, at the beginning of the analysis, the formulae used were said to alter reality by introducing simplifying hypotheses. In figure 8 the simplified (theoretical) cash flow, on the basis of which the formulae are fixed, is indicated with a dotted line. Especially for an investment in a very complex factory, the simplifications adopted previously are no longer acceptable. In particular, reference should be made to the start-up period. The installation of production units takes, in reality, almost a year; upon completion of the factory, maximum production is not reached at once because it is necessary to train personnel, set up the machines and begin sales. It has been assumed that this period lasts for approximately 1.5 years. In addition, after about eight years of activity, a lower rate of return must be expected on account of wear and tear and obsolescence of the plant. The curve of the cash flow which emerges from this hypothesis is indicated in figure 8 by a continuous line ("actual curve").

Figure 8. Cash-flow for a plywood production unit



The major uncertainty in the present example is due to inflation: it is difficult to foresee the trend of all the prices and costs over 15 or more subsequent years. Thus in the next calculation in the example inflation is not considered but interest is set at 10 per cent. The curve goes down further, as indicated in figure 8 ("updated curve").

Graphically, the initial curve has diminished considerably. Given these conditions is the investment still economical? Yes, it is. Even at an interest rate of 15 per cent of the capital, at the end of 15 years the updated earning is more than $4,000,000. Moreover, at the end of the 15 years the business is still efficient and valid and, with a suitable programme for renewal of the machines, can still generate a notable profit.

It is necessary to pay attention to the pay-back period on the capital, which actually is about six years. If it is assumed that a loan was taken out, it is necessary to foresee quite a long time for the repayment.

The findings in figure 8 can be calculated using a cash-flow table that takes into account, in the most exact manner possible, the forecasts that have been made. This is done as was shown in the first example.

The importance of a further index commonly used by project engineers, the break-even point, should be emphasized. The plywood factory has a break-even point corresponding to 40 per cent of maximum production (see table 6). If, and especially in the start-up phase, production reaches only 50 per cent (for example with one shift), a positive cash flow still exists, as has been assumed in this example. But if the break-even point is much higher, the factory would have a lower coefficient of certainty and in the initial phase would lose rather than recover cash.

It is now necessary to go back a little. In explaining figure 1 (types of investment), it was noted that, after an initial general examination, it was necessary to analyse in greater detail all the machines and all the alternatives. It will be assumed that the purchaser, on the basis of the calculation that has been verified, decides definitely to construct a production unit that assures a good return on the capital invested.

As in the case of the structural reorganization of the factory, it is necessary to evaluate the alternative and complementary markets. It may emerge as being advisable to modify the initial project partly as a result of the following hypotheses:

(a) The possibility of selling dried rotary-cut veneer to local industries that produce sheets with particle board cores (in this case it is necessary to increase the peeling and drying capacity);

(b) The possibility of producing enhanced plywood with veneer faces purchased from other companies;

(c) The possibility of expanding the factory to produce sheets, which would be used internally as well as sold;

(d) The possibility of installing the factory at a different location, where the waste can be sold at a higher price.

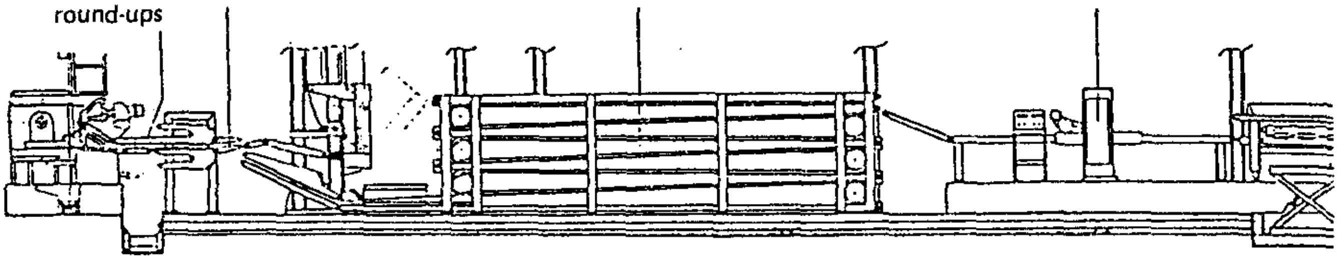
Even if none of these possibilities is accepted, it is necessary to consider other controls. It may be advisable to examine some innovative machines or machines that would increase productivity. This would be the case in the plant for the recovery of the rounded-off veneer pieces, illustrated in figure 9. This line permits a much better utilization of raw material (around 3-4 per cent). The rate of return of this supplementary investment would be calculated and the capital required and revenues and marginal costs would be examined. If the investment is considered to be advantageous, the final project would also include this line.

Table 6. Revenues and costs for a plywood factory

Item	Consumption (per m³ of plywood)	Unit price ($)	Unit values ($/m³ plywood)	Total[a] ($/annum)
Plywood sold (8,000 m3/annum)	1	425/m³	425	3 400 000
Timber	1.9 m³ (yield, 53%)	75/m³	142.5	1 140 000
Glue	100 kg/m³	0.4/kg	40.0	320 000
Electric power	150 kWh/m³	0.05/kWh	7.5	60 000
Fuel (estimate)	100 kg/m³ × 15%		3.8	30 000
Tools	3% on import value		3.8	30 000
Maintenance	4% on import value		5.0	40 000
Total variable costs			202.6	1 620 000
Wages	20 h/m³	12/day	30.0	240 000
Technical and administrative staff	8 people	4 500/annum	4.5	36 000
Overheads and selling expenses				136 000
Fixed costs				412 000
Total production costs				2 032 000
Gross margin				1 368 000
Depreciation				172 000
Interest only on loan				126 000
Net profit				1 070 000
Sales variable costs			222.4	
Fixed costs				710 000
Break-even point			3 192 m³/annum	
Percentage of capacity			40%	

[a]Rounded to the nearest $1,000.

Figure 9. Plywood factory: line for the recovery of roundings



Conclusions

It has been shown in the present chapter that:

(a) No single and perfect criterion exists for the evaluation of the rate of return on investment;

(b) It is quite easy to know and to use some formulae, but *it is indispensable to make forecasts of* the quantities and prices with a great deal of precision in order to anticipate effectively the future reality;

(c) Capital should not be invested thoughtlessly.

All the control elements must be considered in the most careful manner.

VI. Power supply and auxiliary installations in woodworking industries*

The technological facilities of industrial plants play a major role in the cost effectiveness of factory management. On the one hand, machine tools and, most notably, woodworking machines determine both the quantity and quality of production; on the other hand, all ancillary systems are designed to provide flawless operation and cost-effective management of the productive processes.

The aim of the present chapter is to highlight the technical relevance of the various elements of common technological facilities in woodworking industries (power supply, steam, water, compressed air) and to present criteria for choosing the most suitable system. The first thing to be borne in mind is that there are always many solutions to a given problem, and from a strictly technical point of view they all are equally acceptable. The designer's task is to identify the most profitable technical solution in order to achieve the best possible performance.

The first step in this connection is establishing an order of priorities among the various parameters to be considered. Of equal importance is envisaging the possibility of modifying or enlarging the plant equipment over the years, bearing in mind that it should have an economic life of at least 20 years. These are the fundamental considerations that apply in the majority of cases. Before discussing the best solution, from a qualitative point ov view, it is necessary to focus on the essential elements of major ancillary plants.

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Electric energy

General

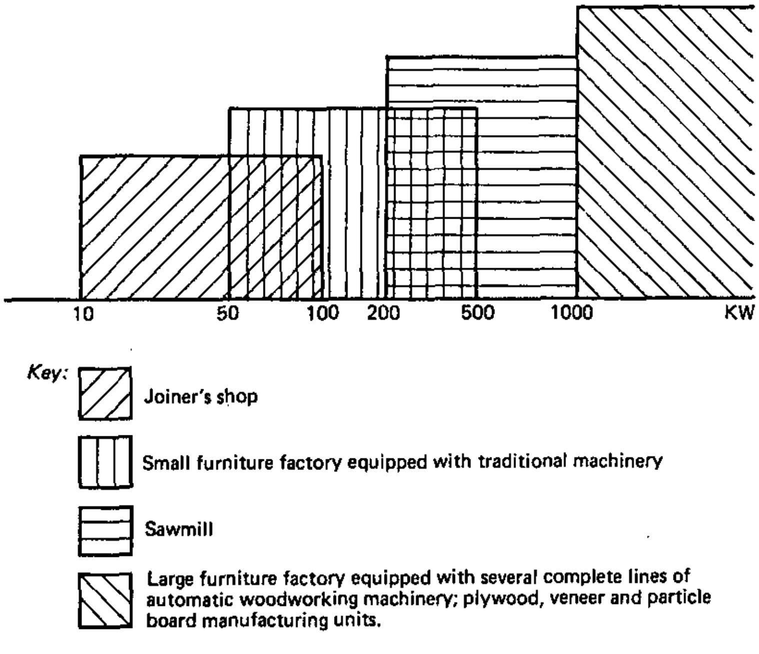
The power plant is fundamental to all machine-operated productive units. It affects technological systems and facilities and the driving and regulation stages. The advantages of having an electric power supply are that transmission is simpler and the size (volume) of the motor is smaller than that of other sources of energy (internal combustion or turbines).

Power generation

In the woodworking industry, it is normally not worthwhile for a company to generate its own power supply, especially if the power can be provided by an existing network. A subtransforming station can be connected to the supply mains and the line voltage can be stepped down to the desired voltage for various uses.

The ranges within which the power supply installed in various woodworking plants is allowed to vary, from a quality viewpoint is shown in figure 1. Should connection to the power mains turn out to be impossible, electric energy will have to be generated by a power unit.

Figure 1. Power requirements of woodworking plants



Power units are usually driven by a diesel engine which is connected to a corresponding alternator.

Supply

There are two major power supply systems:

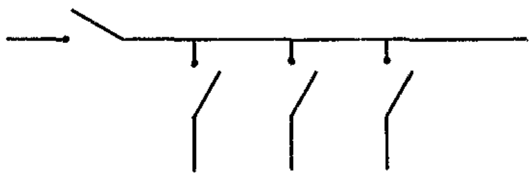
(*a*) A radial system;

(*b*) A ring system.

With the radial system, the machines to be supplied with power are arranged in subgroups in the shape of an "upside-down tree". There are three different types of radial systems, namely:

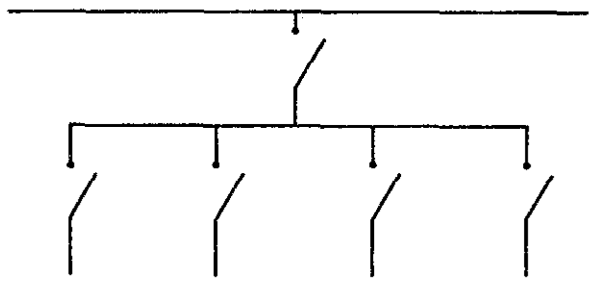
(*a*) Power supply at mains end and shunts along the mains (figure 2);

Figure 2. Radial power supply system with power supply at mains end and shunts along the mains



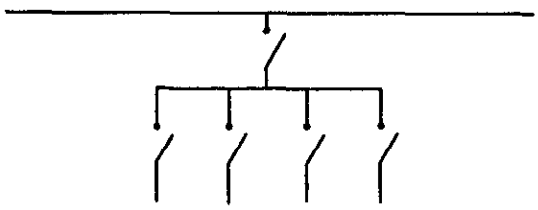
(*b*) Power supply at mains centre and shunts along the mains (figure 3);

Figure 3. Radial power supply system with power supply at mains centre and shunts along the mains



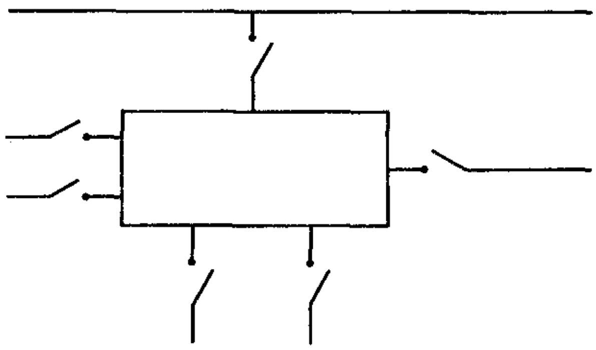
(*c*) Both power supply and shunts in one single point on mains (motor control centre) (figure 4);

Figure 4. Radial power supply system with power supply and shunts in one single point on mains



The ring system is "closed" and allows access to the power supply from two different points of origin (figure 5).

Figure 5. Ring power supply system



Woodworking plants frequently adopt the closed-ring type distribution system. The advantage is that it provides a two-way power supply, thereby making the plant highly reliable. On the other hand, there are more installation-related problems with respect to lead laying. Leads sometimes need to be very long, especially in the case of very large factories.

The most common types of conductors (leads) are protected copper conductors and insultated copper cables that can be laid underground or put in suspended raceways.

The lead cross-section area has also to be designed with a view to its having to carry the maximum installation current. Since all machinery units are arranged in series, they are not separated.

In the absence of any adverse side-effects, laying conductors in suspended raceways allows for the rapid connection or disconnection of mains, easy maintenance operations (which can be performed on sight) and work to be carried out under the floor without running the risk of damaging the supply mains. However, the surrounding air must not be too warm in order to prevent conductors from reaching unacceptable temperatures. If conductors are to be laid underground, either because they cannot be laid in suspended raceways owing to technical reasons or just to protect them from weathering, pipelines or raceways will have to be used to protect them from any damage resulting from impact or infiltration.

Applications

Asynchronous motors are, almost invariably, the final "users" of the power supply in woodworking plants. The working mechanics of this type of motor are shown in figure 6. The static torque is almost equivalent to the pull-in torque and it decreases constantly as speed increases. This type of motor is therefore suitable for machine tools, since it is self-regulating and it can be set on the desired operating point, varying its speed accordingly and keeping efficiency values close to peak values in a wide range of applications.

As for the electric installation, the only drawback is that the power factor decreases very rapidly down to low load values, as can be seen from figure 7 below.

Figure 6. Working mechanics of an asynchronous electric power

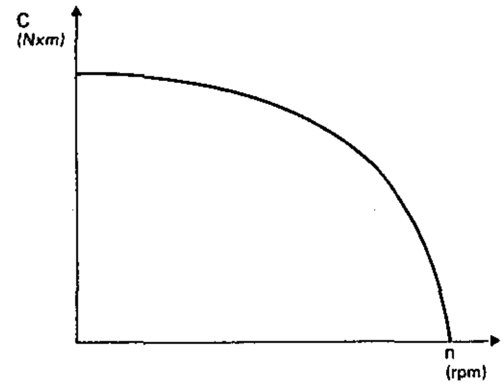
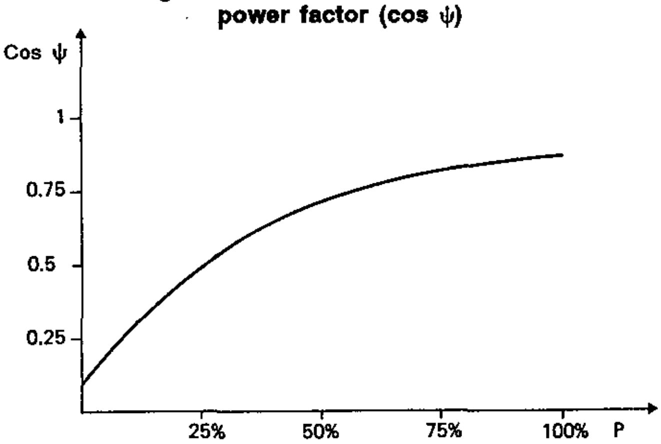


Figure 7. Effect of load value on power factor (cos ψ)



Special systems should therefore be envisaged that generate reactive power to be fed into the mains so that the overall power absorbed is reduced and the load factor increased. Suitable static capacitor banks would therefore have to be provided for power factor correction.

Protection and safety measures

Safety measures should be applied to all feeder lines, machinery and, more generally, to sections of the plant that need to have devices for immediate power supply cut-off in case of malfunctioning. But, most of all, protection must be provided for all workers likely to come in contact with live pieces of equipment or installations.

It is important to note that the strength of the current passing through the human body is the cause of injuries, and even death. Even at a low intensity, the danger of major physiological damage increases with the length of time that current passes through the body. A *100* mA current can prove lethal in a few seconds (see figure 8).

There are two major instances in which workers come into contact with live pieces of equipment or installations:

(a) Accidental contact, usually with hot parts (figure 9), which is a common event during ordinary maintenance operations;

(b) Contact with parts that have become live owing to mechanical failures (figure 10).

Figure 8. Danger curve (according to Dialzel) and danger area (according to Bodler) of current passing through a human body

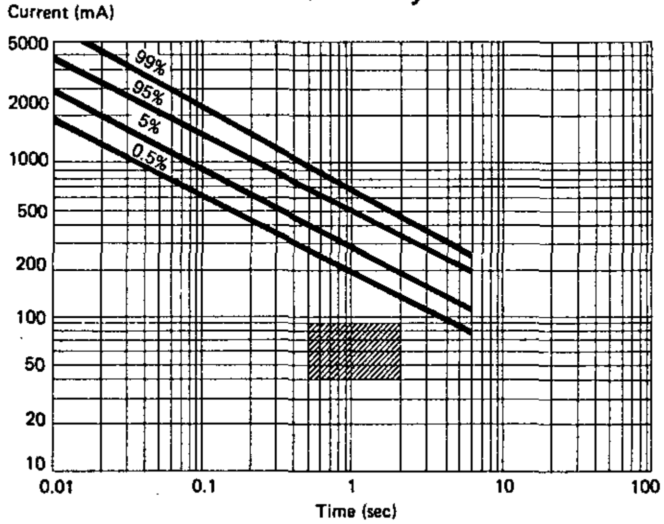


Figure 9. Accidental contact with hot parts during maintenance

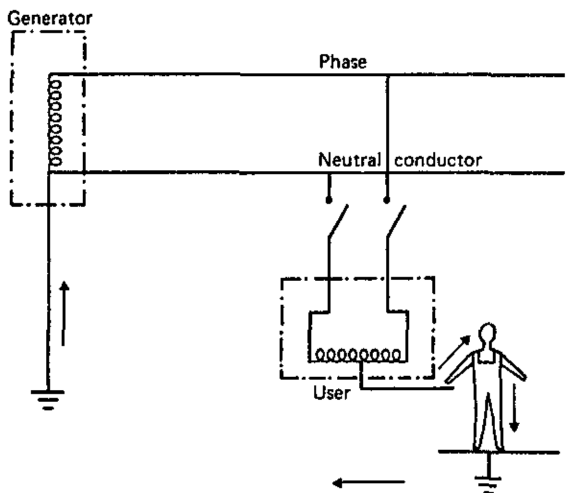
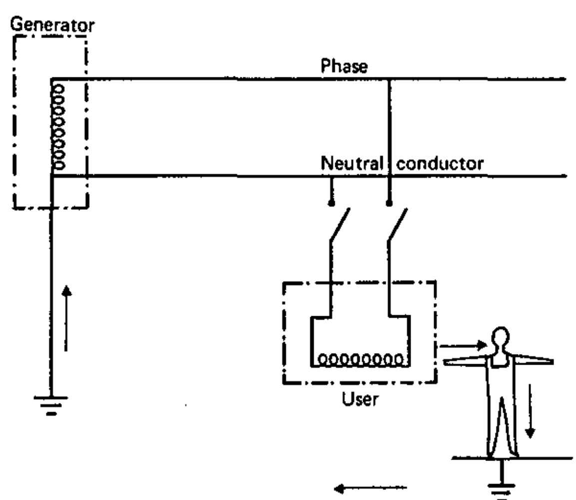
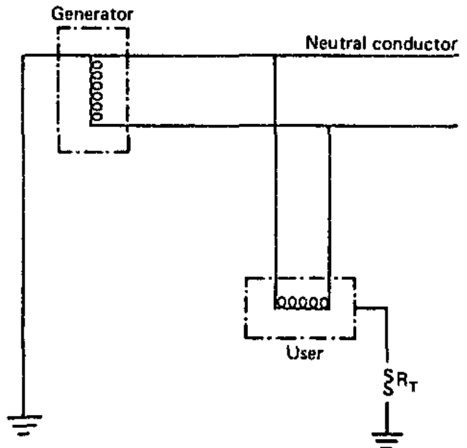


Figure 10. Contact with live parts



In the second instance, the danger is larger and more frequent since such accidents are not due to disregard of safety rules but to bad electric connections that tend to deteriorate with time. Consequently, if accidents are to be averted, suitable protective measures must be envisaged. For the same reason, the ground power grid has to be correctly designed and accurately sized so that it closes the current circuit in a loop, thus preventing current from passing through a body that has come in contact with hot metal parts (figure 11).

Figure 11. Correct ground power grid



Compressed-air system

Compressed air is one of the most largely used forms of energy in woodworking industries owing to its unique qualities, which are essential in such processes as clamping of workpieces, piece handling, lacquering, conventional and portable tool operation and part adjustment and positioning. This is true despite a relatively low overall efficiency; the ratio between the pneumatic power supplied to the various machines and the energy absorbed by compressor-driving motors is low.

The most outstanding advantages of compressed air are:

Easy handling of pneumatic motors
Easy adjustment by simply opening or closing nozzles
Protection from processing overloads
Two parameters express the pneumatic power supply of a plant, namely:
Actual working pressure required (kg/cm^2)
Air flow rate required at full load (Nm^3/h)

In most cases, the pressure required is some 7 kg/cm^2, while consumption varies depending on the use. The major parts of a pneumatic system are compressors, distribution lines and actuators. These are described below, together with a brief account of the necessary fittings (suction filters, coolers, separators and steam traps, pulsation dampeners and buffer tanks).

Compressors

The four main types of compressors are:

Reciprocating compressors
Rotary positive displacement blowers
Turbine compressors (axial or centrifugal)
Screw compressors

The criteria to be considered when choosing a compressor are:

Maximum delivery pressure
Required capacity
Isothermal and adiabatic efficiency
Expected machine life
Vibrations produced

An example of an evaluation of the four types of compressor using these criteria is given in the table. The type of compressor that is most largely used in woodworking industries is the reciprocating compressor, which can be driven by a motor, or an internal combustion engine or a diesel engine.

Evaluation of four types of compressor

(Approximate values at 7 kg/cm^2)

Type of air compressor	*Pressure (kg/cm^2)*		*Maximum airflow (m^3/min)*	*Weight/power (kg/kW)*	*Economic life (h)*	*Vibrations and plant complexity*[a]	*Compressed air contamination*
	Maximum	*Utilization*					
Pistons	350	7	500	40-70	20 000	A	Oil
Rotary blades (volumetric)	30	7	100	27-35	10 000	B	Oil
Centrifugal	12	7	160-2 000	20	20 000[b]	C	—
Rotary screw	30	7	300	15	25 000[b]	C	(oil)

[a]A = maximum; B = medium; C = minimum.
[b]Approximate values.

It is suggested that single-action compressors should be used for up to a power of 25 hp and double-action compressors over 100 hp. Either compressor can be used for the intermediate power range.

If the distribution network is of the proper size and has been accurately serviced, pressure drops will tend to be low, so that it is advisable to provide a delivery rate that is about 40 per cent higher than the actual requirement and to allow for air leakages that become more frequent with the passing of years. Screw compressors are the latest and, therefore, most advanced compressors. They have been made far less complicated than previous versions, but their installation costs have obviously risen.

Compressor regulating devices deserve special attention, since the machines of woodworking plants mainly run at a lower capacity than peak capacity, and compressor-utilization values are relatively lower than steady-state values. Hence, in order to have low operating costs, regulating devices will have to be designed in such a way that they do not excessively undermine efficiency when operating conditions depart slightly from optimal working conditions. The compressor/motor (or engine) coupling can be of three different types:

Direct
With reduction unit
With driving belts

Direct coupling makes the whole system extremely compact. However, it requires motors with a low number of revolutions and a highly accurate system assembly so as to prevent the motor shaft and the compressor from being misaligned. The coupling with a reduction unit and gears allows high-speed motors to be used and the unit to remain quite compact; however, the reduction unit cost is quite high.

The belt-driven system is much more flexible in case of abrupt changes in the rotation speed. It also makes it possible to vary the gear ratio by replacing pulleys. Its installation, however, calls for a larger room, and the power it absorbs is greater than in the previous two cases. The compressor units will also have to be properly fed with a suitable coolant, which is usually water flowing in a closed circuit. Compressors must be cooled for three major purposes:

(a) To lower the final temperature of the air so as to avoid putting the material under intolerable stresses;

(b) To achieve an isothermal type of compression to the greatest possible extent, with a resulting higher efficiency;

(c) To cause vapour to condense so that it can be exhausted on line.

The design of the suction system will have to combine two major elements: simple construction features and the possibility of feeding pure air at a low temperature. The reduction of compression is proportional to the temperature of the air taken in. Growing impurities cause filters to produce unacceptable head losses, although their efficiency is enhanced.

Delivery and distribution systems

Compressor units have to be placed in an explosion-resistant area. The distribution system starts from the flange of the on-off valve, which should be positioned outside the partition wall.

If the tank is located at a distance from the compressor, the diameter of the delivery piping should be the same as for the compressor outlet; the piping storage capacity should be expanded by increasing its diameter by some 20 per cent.

As in the case of power plants, the distribution network may be equipped with:

A single manifold and its branches
A double manifold and its branches
A ring circuit

Because the current of main and branch devices is reliable, distribution through a single manifold is common since it also allows remarkable savings in terms of installation costs. An "upside-down tree" type of distribution system is nonetheless recommended in which various operating sub units upstream are divided by the branching-off points of the line. With this type of system, all the operating units will not be cut off in case of failure, if the failure does not occur upstream from the point where shunts branch out. Ring circuits permit the shutting off of small portions without starting machines downstream, since they are supplied from the other end of the ring.

Rigid pipelines have a smooth surface and are jointed with head flanges, welded, or threaded. Threaded pipes are easier to assemble but are likely to leak air. Pipe fittings of flexible rubber or synthetic materials have to be used for connecting parts that are in motion. The correct pipe size should allow for a 0.3 to 0.5 kg/cm^2 pressure drop owing to the distances in order for distribution systems to maintain 7 kg/cm^2 pressure.

Use of the system

The major tasks fulfilled by the pneumatic system are piece handling and tool driving. During the piece-handling operations, pneumatic parts perform the following tasks: control the workpiece position, machine feed, on-line machine linkage and piece clamping. Conversely, tool-driving operations are almost solely designed to provide the tool-feed motion, while the cutting motion is carried out by electric energy.

In figures 12 and 13, two different pneumatic systems similar to those used in ordinary woodworking machines are shown. Accumulators (storage cylinders) have to be located upstream from pneumatic actuators and serve as regulators (equivalent to a fly wheel for rotary motion). Indeed, since operating levels are not always steady, a storage unit must be provided in order to regulate the air flow and to avoid having to design the network based on the sum of peak loads of each machine.

Thermal plant

Thermal energy is necessary in any plant for technological purposes (presses, driers, lacquering equipment etc.), for factory facilities, for people's comfort (sanitary facilities, heating etc.) and for air-conditioning of the work sites.

Generating plant

The potential of the power-generating unit is calculated on the basis of the peak simultaneous load coming from the various operating units. Hence, it is of utmost importance to have a power-generating unit that is also highly efficient in conditions other than the rated operating conditions. The current trend towards making optimal use of all processing waste materials should lead to increased use of boilers that can be fed with wood chips, sander dust, sawdust, bark, wood off-cuts and edgings and any other processing waste. Since the heat value of these materials is generally insufficient to cover the required thermal energy alone, a feeding system based on traditional fuels needs to be installed and used as a stand-by.

In addition to traditional water-tube and smoke-tube boilers, woodworking plants can also resort to diathermal fluid boilers that are largely used to convey heat to platens of presses used in the wood-based panel industry. The economic advantage of shifting from a smoke-tube boiler to a water-tube boiler is of the order of 25-29 kJ/h (6-7 million kCal/h).

Figure 12. Pneumatic units

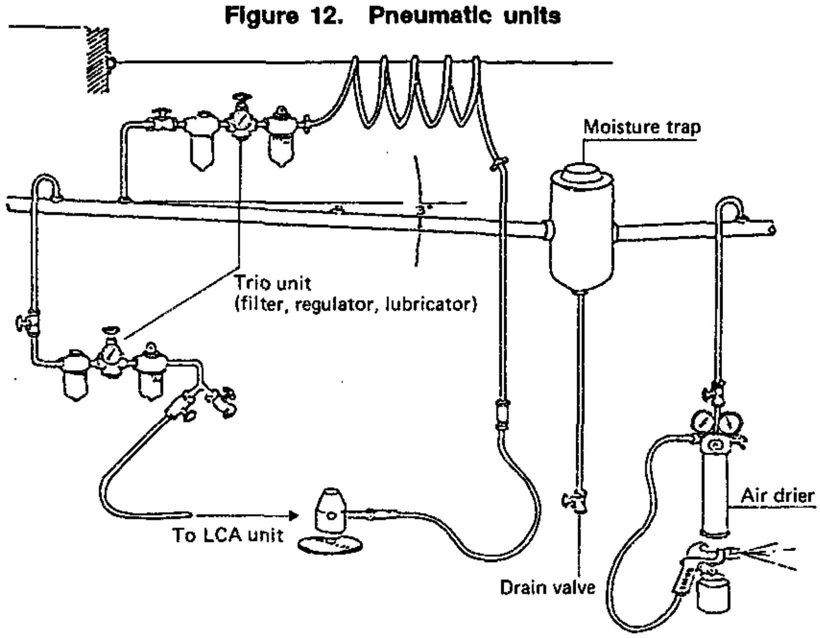
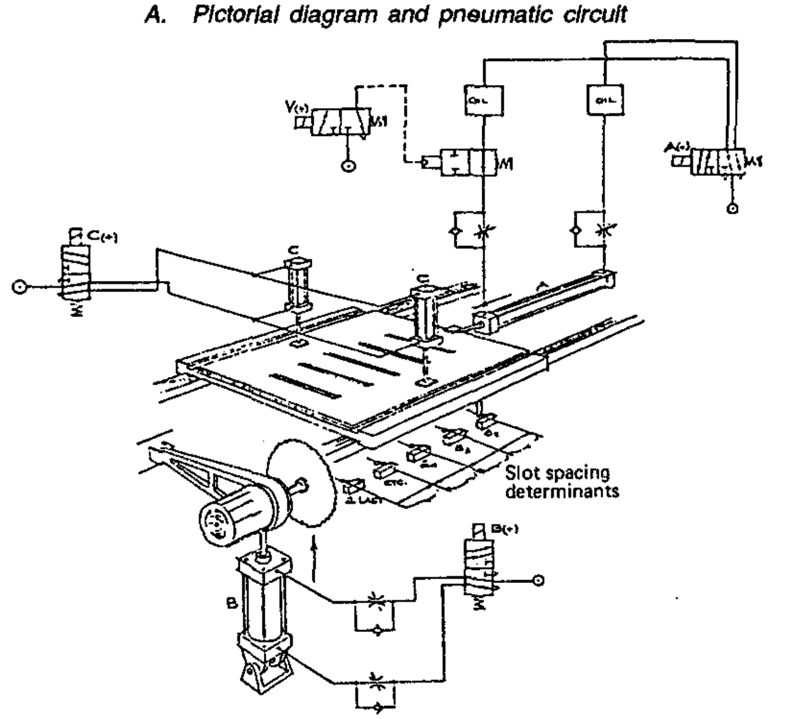
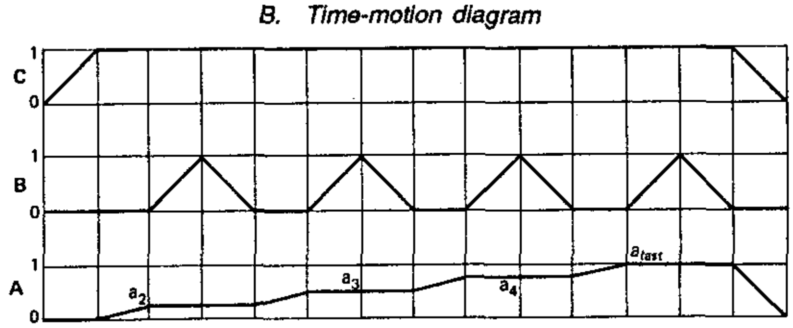


Figure 13. Pneumatic system for a radio-TV cabinet slotter

A. Pictorial diagram and pneumatic circuit

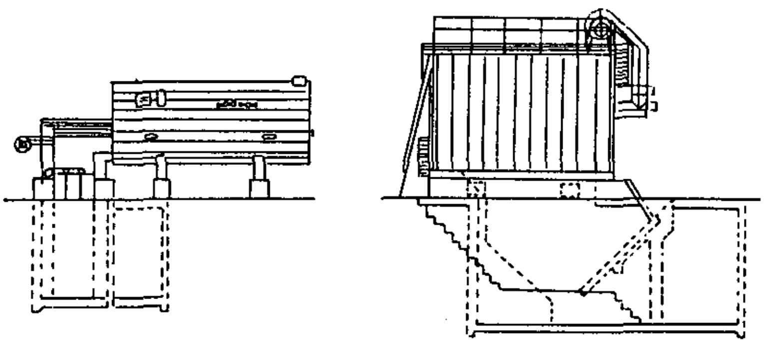


B. Time-motion diagram



The construction diagram of a smoke-tube boiler is shown in figure 14 (diathermal fluid boilers have construction and operation features similar to those of pressurized-water boilers). Steam or water boilers have to be equipped with a treatment plant for filtering and purifying the feed water to make it absolutely pure.

Figure 14. Smoke-tube boiler



Distribution

Distribution systems differ remarkably depending on the type of fluid used for carrying energy. In the case of steam boilers, costs are higher owing to the need to use larger pipes and a material that can withstand mechanical and thermal stresses as well as corrosion. Special attention should also be given to studying pipe geometry to minimize localized head losses which would eliminate the formation of condensate under pressure-drop conditions.

Hydrostatic or hydrodynamic steam traps should be envisaged in order to have the steam phase only within the pipe. A centrifugal or positive displacement pump supplies the energy necessary for conveying the mass. The pump is used to return water in the liquid phase.

The regulating system must ensure that the head necessary for the various machines is transferred at the required temperature and must therefore interact with the combustion process. For this purpose, it first acts upon the water-steam balance in the boiler and then on the burner, metering the fuel flow.

Pipe sizing is easier when the energy carrier is in a liquid phase (pressurized water or diathermal oil), although the system thus has greater inertia when working conditions vary.

In order to get an instant response from the plant to load changes, mixing the fluid between the boiler's inlet and outlet with three- or four-way valves is recommended. The operation's efficiency can be further improved through precision regulation of the fuel entry into the boiler.

Use

A major distinction must be made between machines and factory facilities that have to be provided with thermal energy (heating, sanitary facilities, water etc.). The two major woodworking plant units that need thermal energy are driers and presses.

Peeled and sliced veneer driers need to be supplied with large amounts of steam, whereas for lumber kiln drying thermal energy is often obtained through hot air that is produced by unit heaters. Other sawn-lumber kiln drying processes (condensation, vacuum) consume little energy given the efficiency of the thermodynamic cycle that determines the process parameters.

Hot presses that are used to produce and upgrade wood-based panels require an amount of heat that is proportional to:

The weight of hot-pressing surfaces
The thermal capacity of the material they are made of
The maximum temperature reached

The heating fluid can be steam, super-heated water or diathermal oil. Diathermal oil has an advantage because it does not cause plate corrosion and no skilled personnel are needed to operate the generator.

Technical and economic criteria for assessing plant parts

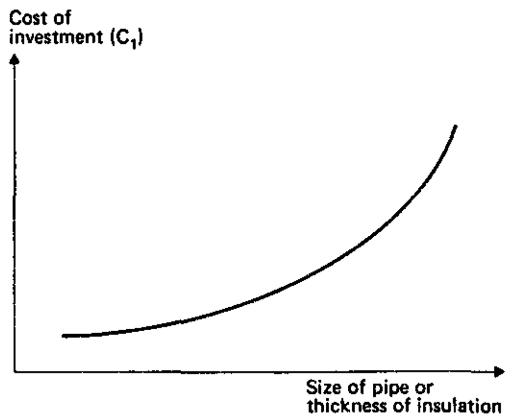
The major concern of a designer is minimizing production costs. To do so the designer, in considering the wide range of technical solutions, has to choose those solutions that will make it possible to achieve the greatest cost effectiveness in the production process. The traditional approach to studying the various solutions is to break down costs into capital and running costs. Capital costs relate to all preliminary activities that have to be performed in order to set the unit into operation (design, construction, materials, manpower, machinery etc.). Once the plant starts operating, its running costs will have to be assessed. There are two kinds of operating costs: fixed and variable costs.

The analysis of these aspects makes it possible to determine the cost per unit of output, which is the basic parameter to be cosidered when making a production plant highly competitive. This criterion applies in the majority of cases and should also be adopted in selecting every single part of the plant. An approach for the qualitative solution of two problems based on these concepts is presented below

Pressure losses

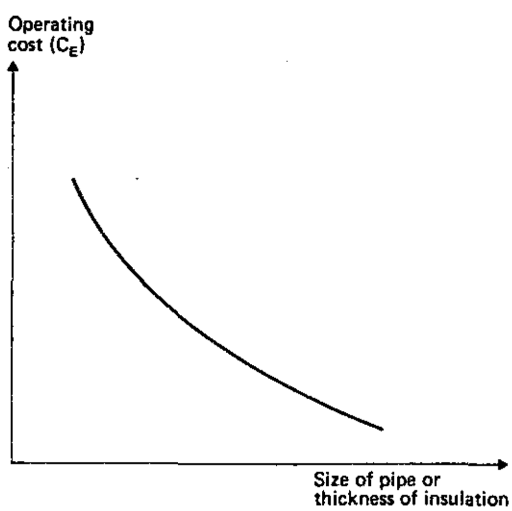
The fluid circulation under pressure is provided by water power, using a driving force which is usually a centrifugal or positive-displacement pump. This power determines the flow rate to the various machines under a certain given pressure. The flow rate is determined by combining the area of the section through which the fluid flows with its speed. At this point, the major problem is minimizing the energy cost caused by pressure losses caused by friction along the pipe walls. In this case, capital cost is accounted for by the piping system and can be illustrated as in figure 15.

Figure 15. Capital cost



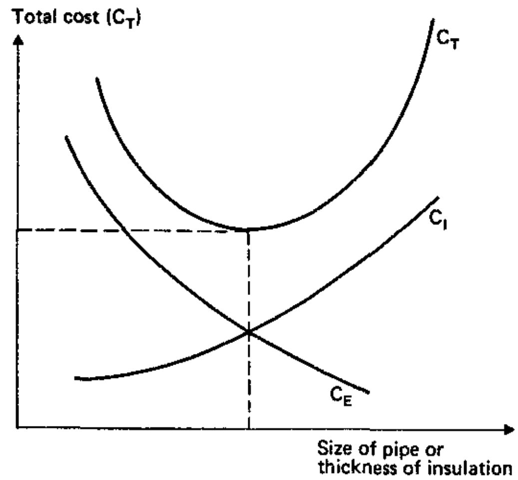
Indeed, the larger the diameter, the higher the costs, since the material weight will be heavier per unit length, and such parts as valves, pipe fittings, flanges etc. will have to be larger in size. Conversely, the speed necessary to deliver the required flow rate increases with smaller pipe diameters and thus smaller flowing areas. Since the upward trend of pressure losses is a function of speed, the operating cost trend involved in recovering the lost power can be illustrated as in figure 16.

Figure 16. Operating cost



The overall cost of the plant is a combination of the capital and operating costs. The curve can be seen in figure 17.

Figure 17. Total cost



Heat loss

The second case is that of piping that contains the heating fluid of a press surface. During the shift from the heat generator to the machines, a certain amount of heat is transmitted outside the piping system and is therefore lost. This amount of heat, in addition to the quantity of heat actually needed, has to be made up for by the thermal energy generator. As a result, heat losses have to be minimized so as to curb the costs involved in extra energy requirements. This is achieved by coating the fluid pipe with an insulating material that has low thermal conductivity. The cost of insulation rises as the thickness of thermal insulation increases (see figure 15). This virtually accounts for the capital cost. Conversely, operating costs rise with a decrease in the thickness of insulation (see figure 16). The sum of the resulting curves is the overall investment cost (figure 17). The optimum thickness value can be read at the curve minimum.

The same approach can be applied in solving any other technical problem, always with a view to achieving the highest cost effectiveness.

Part two

PRIMARY WOOD-PROCESSING INDUSTRIES

VII. Choosing forestry equipment*

Introduction

Forestry exploitation is the felling and logging of wood directly in the forests. It may be the final felling of trees that have reached maturity, thinning cuts or felling to improve plantation standards. These operations can be carried out in forests whose function is of a protective nature or in forests that supply timber. Exploitation must be carried out in such a way that the environmental balance of the forest is not disturbed, however.

Forest exploitation can be carried out either manually or mechanically. Before the advent of mechanization, men with a great spirit of adaptability were needed, as they had to live far from home or towns for many months; they also had to possess considerable physical strength. Today, through the help of machines, the sawyer-lumberjack's job has become less tiring, and, because of the high wages paid, it has come to be considered an interesting job, even by the younger generation.

Access to the forest is a very important factor in rational exploitation. Logging paths and roads must be accessible to heavy trucks and be connected with the country's road network, thus enabling timber to be transported easily to industry, railway stations and sea and river ports. Another important consideration is the need to have specialized labour to make efficient use of the machines, and this requires the creation of special schools and professional training courses.

Phases in forest exploitation

A phase is a particular operation that is carried out with the same equipment. Forest exploitation is subdivided into the following phases:

(a) *Felling of trees.* The trunk is detached from the tree stump. In certain countries, this is still done using an axe and a two-man saw. In the majority of cases, it is carried out with a mechanical chain-saw (see figure 1), with hydraulic shears (see figure 2) or with tractor-driven disc or chain saws;

(b) *Limbing and cutting of tree-tops.* Limbs and tree-tops are cut from the felled trunk. This can be done using an axe or mechanical chain-saw that is less heavy and cumbersome than the saw used for felling. In certain cases, this phase also includes bucking or stacking branches, depending on whether these are to serve as fuel wood or pulpwood;

(c) *Bucking.* The felled trunk is cross-cut into several parts. The length of these parts depends on market requirements and on the timber-cutting system used as well as on transport limitations. This phase can also be carried out at the roadside;

Figure 1. Felling with a mechanical chain-saw

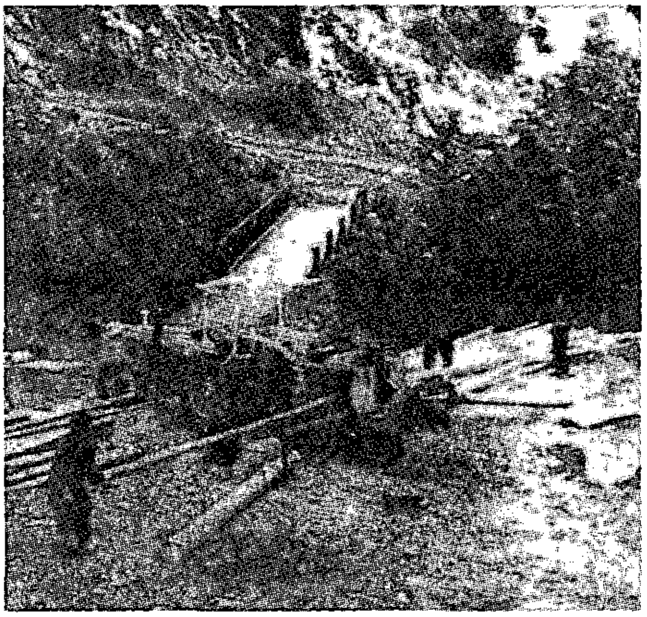
Figure 2. Tree felled with hydraulic shears

*By Sanzio Baldini, Director, Wood Research Institute, Florence, Italy. (Originally issued as ID/WG.432/3.)

(*d*) *Stacking*. This takes place at the roadside or in clearings and includes possible bucking operations;

(*e*) *Debarking*. This is carried out with manual equipment, such as hatchets, or with machines such as the one shown in figure 3. Mechanical debarking is usually carried out only on softwood logs;

Figure 3. Mobile ring debarker



(*f*) *Transport*. This phase is split up into three sub-phases, namely loading, transport and unloading, which is the last phase of exploitation unless trans-shipment occurs at a railway station, river or sea port.

Felling is always the first phase of exploitation; some of the other phases may not be necessary or are carried out in a different sequence. Thus, in the case of small-sized trees felled during thinning cuts that will be used for the production of chips, the limbing and bucking phases are not needed; they will be replaced by the chipping process, by which the tree is reduced into chips.

Types of exploitation

Work characteristics vary according to the type of forest exploitation and should be closely related to the type of forestry regeneration methods applied. Selective felling implies the existance of a large concentration of wood in the area being exploited. This type of felling is characterized by the selection of a few trees; when these are large, work must be carried out in such a way that the surrounding trees as well as seedlings are not damaged. This is not always possible, especially if the forests are serviced by few roads. In the case of thinning cuts, a small percentage of the growing stock is felled and the trees are often small in size. This creates great technical difficulties in exploitation, and the solutions for overcoming these difficulties are often uneconomical.

The choice of a working system and exploitation costs are influenced by various parameters that must be kept in mind, especially by the person planning systems for moving the timber from the forest.

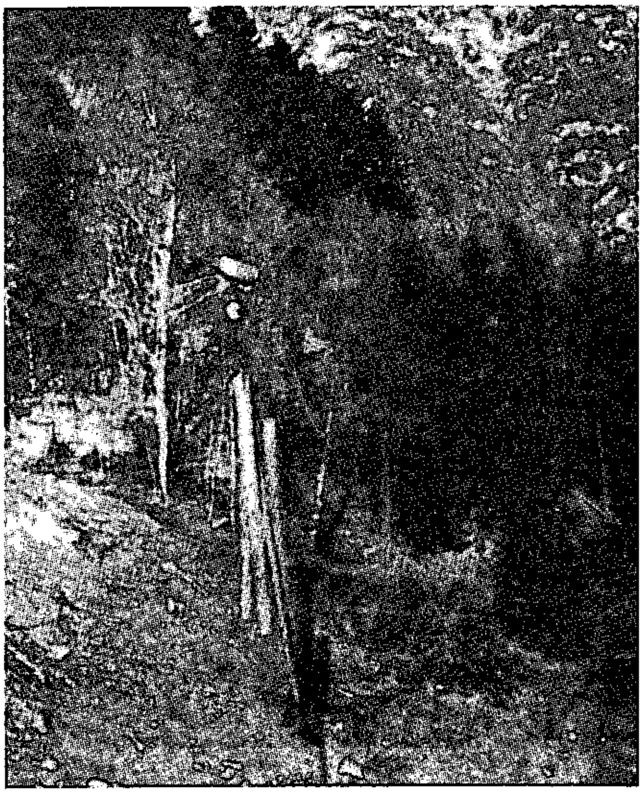
Topography

The choice of logging method to be used depends, among other things, on the gradient or slope and irregularities of the terrain. The gradient is a determining factor in the choice of the logging method. For terrain with a gradient of less than 20 to 25 per cent, all types of tractors (including farm tractors) can be used for hauling a load whether going uphill or downhill (see figure 4).

Figure 4. Two-drum winch used on a farm tractor

The 20 to 25 per cent gradient is the minimum limit for working a cable-way system. Terrain with a 40 per cent gradient can be logged, as long as the ground is dry, using four-wheel drive forest tractors (skidders) not hauling a load. Caterpillar-track tractors can be used on gradients of up to 50 per cent, as long as they go along the lines of maximum gradient. Logging by tractors along these gradients can only take place downhill. This gradient is the minimum limit for collecting all the wood by gravity using hand-operated tools. Ground with a 40-60 per cent gradient allows logging both uphill and downhill with cable-way systems (see figure 5).

Figure 5. Cable crane with semi-automatic carriage



In this particular case, uphill logging is preferable, as lower lines are needed than for downhill logging. Saw horses can be lower or may not be necessary, as it is sufficient to lift the log heads clear of the ground. Up to these gradients it is easy to create proper road conditions for logging and for material haulage without having to build any special supporting walls and bridges. On steeper ground with a gradient of 60-80 per cent, forests are generally of a protective nature and cable-way systems, helicopters or balloons are used.

Irregularities may hinder the exploitation of forests. Obstacles such as stones, holes, rock ledges etc. can hinder work on the ground. Irregular ground makes logging and road construction difficult: with the same gradient, a more expensive logging system may be required.

Soil composition

Unlike farm soil, forest soil is very superficial, and the rock stratum is covered with leaves, which often hide traps such as holes or cracks which are extremely dangerous for machines. When choosing forestry equipment, the type of soil must be taken into consideration. The main types and their characteristics are described below.

Clay-rich soil. This type of soil has low water permeability and is very hard when dry and very slippery when wet. With this type of soil, it is essential to plan logging and transport during the dry season.

Damp or fresh soil. This is the most common type of soil. Above the mineral layer of soil, there is a layer of leaves, which encourages wheels to sink in. For this reason, it is advisable to use machines with wide caterpillar tracks or to equip tractors with wheels, with special chains or special caterpillar tracks, allowing a ground pressure of 100 g/cm^2.

Sandy soil. Machines with wide tyres and low pressure must be used on this type of soil. Caterpillar tracks are very quickly worn down by the silica.

Rocky soil. This type of soil is a result of the heavy passage of vehicles or can be due to soil erosion. It is not advisable to use caterpillar-track tractors, in view of the low grip this type of soil offers. Low-pressure tyres should be used.

The "capacity" of the soil is the resistance limit above which soil becomes deformed when loaded with a given force. Resistance varies from a few grams to a few dozen kg/cm^2. It can be measured with a special instrument that is inserted into the soil.

Machine rolling friction or feed resistance

Wide-diameter tyres with high pressures meet with less feed resistance but also have less traction. The resistance value *(R)* is:

$$R = K \times P \qquad (1)$$

where:

K = rolling friction coefficient

P = weight of the vehicle

The value of K varies according to the type of route and to whether the machines are equipped with tyres, caterpillar tracks or steel wheels, as can be seen in table 1.

Table 1. Rolling friction coefficient

Type of route	*Low-pressure tyres*	*Caterpillar tracks*	*Steel wheels*
Dry road	0.03-0.04	0.03-0.04	0.02
Dry, clay-rich soil	0.05-0.08	0.05-0.06	0.06
Sandy, loose soil	0.08-0.15	0.06-0.10	0.09
Muddy soil	0.10-0.20	0.08-0.12	0.15

Sliding friction is the force needed to make an object or body slide along the soil. It depends on the type of soil and the shape of the object or body. In the case of logs, it is very important for the butt ends to be lifted off the soil as this reduces the drag friction coefficient.

The friction value for trunks whose butt ends touch the soil and therefore meet with obstacles can be higher than 1. When the tops are kept clear of the soil, the coefficient is 0.2-0.3.

Maximum tractive force *(F)* of a machine is given by the equation:

$$F = K \times P \qquad (2)$$

Adherence or grip coefficient is given by:

$$K = \frac{F}{P} \qquad (3)$$

Where:

F = maximum tractive force of the machine at the hook expressed in kg

P = total weight of the machine expressed in tonnes

This coefficient depends not only on the nature and humidity of the soil but also on whether rubber-tyred or caterpillar-track machines are used (see table 2).

Table 2. Adherence or grip coefficient

Type of route	*Tyres*	*Metallic wheels*	*Caterpillar tracks*
Gravel, road dry or wet	0.7		1.2
Compacted dry path, clay-rich soil	0.5		0.9
Compacted wet path, compact soil	0.4		0.7
Loose, wet soil	0.2		0.5
Loose, dry soil	0.4		0.3
Frozen or snow-covered soil	0.1		0.1
Metallic wheels on sandy soil		0.4	
Metallic wheels on roads		0.5	

Climate

Climate is a very important factor and must be taken into consideration when choosing equipment and work systems.

Thus, in northern countries with very long winters, it is important to plan the first phases of exploitation during summer, while logging can be carried out in winter by sliding logs along snow-covered paths (see figure 6). In tropical countries, it is impossible to carry out this type of work during the monsoon season, therefore this phase will have to be planned for a season when the soil is dry.

In some climates, wind may cause problems for the remaining trees. Work must be planned with great care to avoid damages as far as possible.

Other considerations

Two other points should be considered. One is the diameter and height of the trees to be extracted. The other is the condition of the forest, which can be:

(a) A virgin forest, in which case a rational road network must be studied;

(b) A forest where exploitation has already taken place in compliance with a management plan, in which case only marked trees should be felled. Road conditions are likely to be excellent;

(c) A forest that has been exploited without a management plan and where, generally speaking, conditions are somewhere between the two conditions mentioned above.

Figure 6. Logging on snowy paths (Logs are joined together by chains and the hooks are towed by a farm tractor)

Economic aspects

The economic aspect is extremely important for the preparation of a forestry exploitation plan. The price of standing trees will be more or less high, depending on whether the owner of the forest is an administrative body or a private person and on economic conditions in the country. The price also depends on the ease of extraction and transport of the timber to industry, seaports or railway stations.

If there are no roads in the forest, heavy capital investments will be needed for their construction, and this must be taken into account by the firm concerned. Sometimes road construction is carried out directly by the State or other administrative bodies, as it is in the interest of the whole community.

To evaluate exploitation costs, the company must add all costs that it will have to sustain during the various work phases. Social welfare costs, costs for accident insurance and salaries, wages and possible overtime work are also extremely important factors.

Social aspect

With a qualified labour force and the possibility of using the same people on the job for many years, a higher degree of accuracy and better machine maintenance can be achieved. Unfortunately, it is not always possible to have regular labour because, for example, the climate often does not permit continuous work, e.g. rain in the tropics and prolonged winters in northern countries. There are countries with a high population density, where labour is cheap and even competitive with machines. In other countries, labour is badly paid and a lumberjack's job is very hard. In this case, mechanization can contribute towards improving the qualifications of personnel, even if training courses and even years of experience are necessary to obtain good machine drivers and qualified maintenance personnel.

In many cases, it is more expedient to pay people according to their productivity. When a team is well organized and highly professional, there is less than 4 minutes down-time per hour. This figure goes up to 10 minutes with badly organized teams. Insofar as work management is concerned, 3 to 7 minutes down-time per hour of work must be calculated for industrialized countries and 6 to 14 minutes for developing countries. Generally speaking, when a yard's efficiency is over 0.85, it can be considered excellent, and it is acceptable, if it is between 0.85 and 0.60. Should efficiency be below these values, the yard has inadequate organization.

It is important to bear in mind each country's work traditions and customs, otherwise the introduction of a new system will not always give the anticipated results.

Equipment and machines used in forests

Manual equipment

The various types of manual equipment used in forests are described below.

Axe. The axe is, without doubt, the most ancient cutting tool. It is used for limbing, debarking and wood cleaving.

Reaping hook, sickle or bill hook. This tool has different shapes, depending on the country or region where it is used. One of the best (because of its beak) is the one made in Italy. Besides cutting, it can also be used for limbing and for pruning standing trees.

Wedge and sledge hammer. The wedge is very useful, as it facilitates the felling of trees during the cutting phase. It is also very useful for cleaving wood. The wedge is hit by the sledge hammer. Lately, iron or wood wedges have been replaced by a pad that inflates by means of the exhaust gas from the mechanical chain-saw.

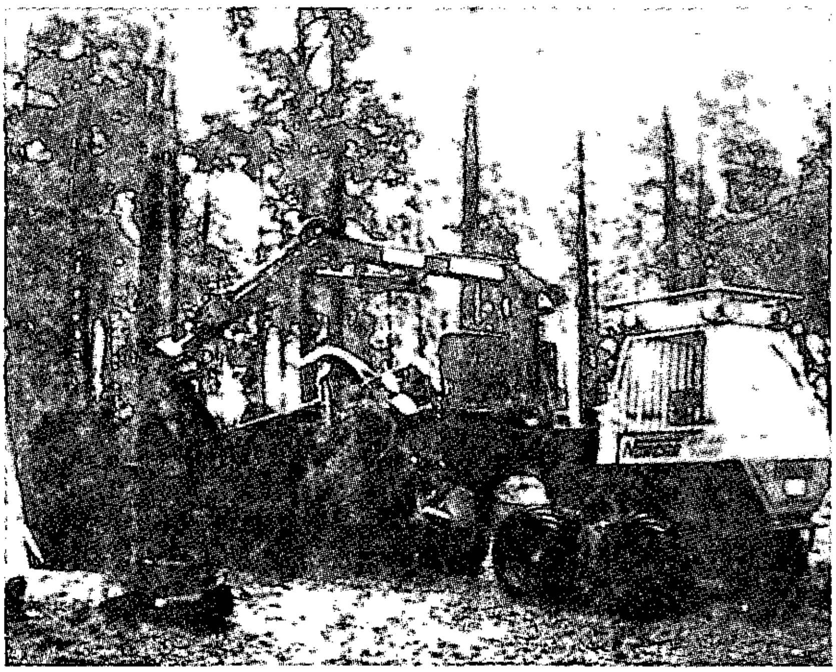
Debarkers. The debarker can be knife-shaped, with two handles on the sides and used by pulling, or shovel-shaped, used by pushing.

Small saws. Small saws are mounted on an aluminium shaft and allow the cutting of branches 4 to 6 metres from the soil.

Mechanical chain-saws. Wood cutting takes place by means of a chain with sharp teeth. The chain, activated by a pinion, runs along the slot of the guide bar. Engine power varies from 2 to over 5 kW, and the length of the guide bar can vary from 32 to 92 cm. These parameters vary according to the specie of wood to be cut, its diameter and whether felling and limbing operations have to be carried out. To safeguard the health of the person operating the mechanical chain-saw, the saws should be equipped with vibration-damping systems, a chain brake, a security accelerator and, for better comfort, especially for those people working in northern countries, with heated handles.

Cutting and rigging machines. These machines can be used for softwood trees located on soil with a gradient not exceeding 20-25 per cent. The cutting tool is made with hydraulic shears or with a sharp-toothed chain. They are equipped with a special part that directs the tree's fall. There are also machines that load felled trees directly onto their rear train for logging (see figure 7).

Figure 7. Felling with hydraulic shears and loading the tree, complete with foliage



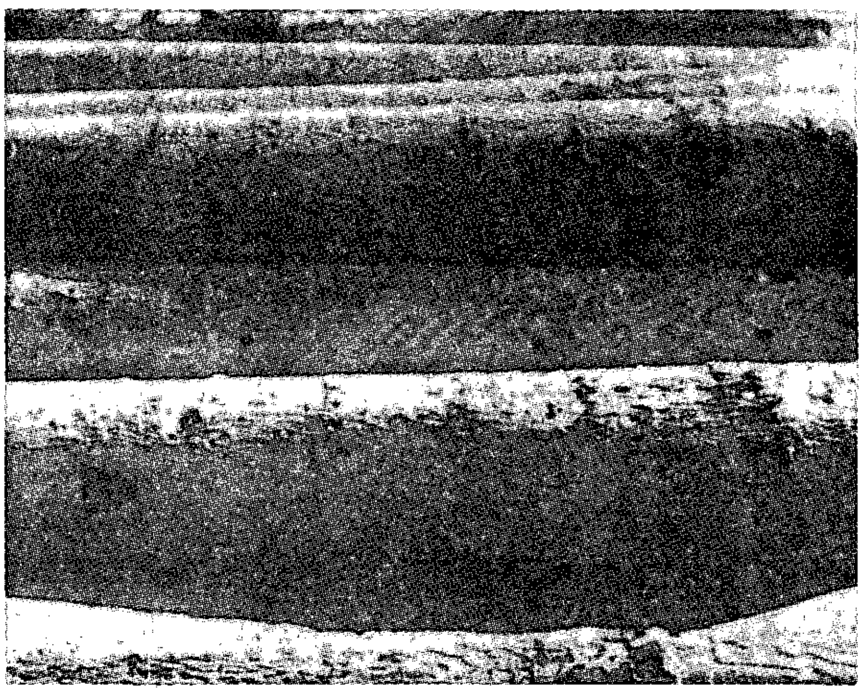
Limbing, bucking and sorting machines. Other machines are used for limbing and bucking of the logs into pieces of desired length. In Scandinavian countries and the United States of America, where mechanization is very advanced and planning is rational, machines sort logs for quality, diameter and length by means of electronic instruments.

Debarking machines. Debarking can be done in the forest or at the mill, depending on the type of machinery selected and the assortment of timber. In forests, mobile debarkers powered by tractors are used, whereas in mills, debarkers have electrical motors.

Ring debarkers are most commonly used, with knives fitted onto the rotor. The log is fed axially through the ring, and the knives remove the bark by working in a spiral direction. The knives can reach a debarking speed of 40 metres per minute and strip bark off logs of up to 80 cm in diameter.

A second type of debarking machine is the cutter debarker. The log moves forward and rotates, so that the cutter can remove the bark. These machines sometimes also remove part of the wood. Debarking speed with these machines can reach 6 metres per minute; the diameter of the logs can be over 100 cm. More modern machines have a multi-knived head, the knives being of a small size. Such knives have the advantage of giving a cylindrical shape to the log, but they also partly remove the last growth rings (see figure 8 below).

Figure 8. Logs debarked with ring debarker
(Part of the last growth rings has been removed)



Another type of debarking machine is one with knives assembled radially on a disc. This is used for so-called white debarking, because it removes part of the wood. This type of machine is used for billets for paper mills and also, because of its limited size, for operating along forest roads.

Chipping machines. Chipping machines (see figure 9 below) are either mobile or fixed, with either a disc or a drum that chips the material introduced through a feed hatch. The cutting plane is slanted with respect to the axis of the material introduced. After passing through a bottleneck, chips are blown into the trailer-truck bins or into containers on the soil. With the chipping process, 20-25 per cent of the crown's biomass is recuperated. These chips can be used in the production of particle boards.

Combined machines. These are machines of considerable size that carry out many exploitation phases. During the research that led to the conception of these machines, emphasis was placed on the limbing operation, which represents up to 30 per cent of the cutting and rigging work. Debarking represents 50-70 per cent of the total time, while felling only represents 5-10 per cent. Since debarking is generally carried out in the mill, limbing is the most important function of a combined machine.

Over the last few years cutting machines have been used with increasing frequency in Scandinavian and American forests. The machine also loads the tree with all its branches onto its rear train and takes them to log yards (see figure 7 above). At this point, a limbing and bucking machine completes the preparation of the log (see figure 10). During this operation, the trees are lifted by the stem with a hydraulic crane. The stem is squeezed between two rollers which, by their rotating motion, allow the stem to slide along. Four to six bow-shaped knives press the stem and cut off the branches. A disc saw or a chain-saw is lowered by the operator and completes bucking. If necessary, the machine also carries out sorting.

A very sophisticated type of combined machine, which should only be used on soil with a slope no higher than 20-25 per cent, carries out all phases, from felling to limbing and sorting, directly in the forest (see figure 11).

All these combined machines are operated by a single person and have given excellent results in coniferous forests.

Figure 9. Chipping machine with direct loading of chips into the truck's bins

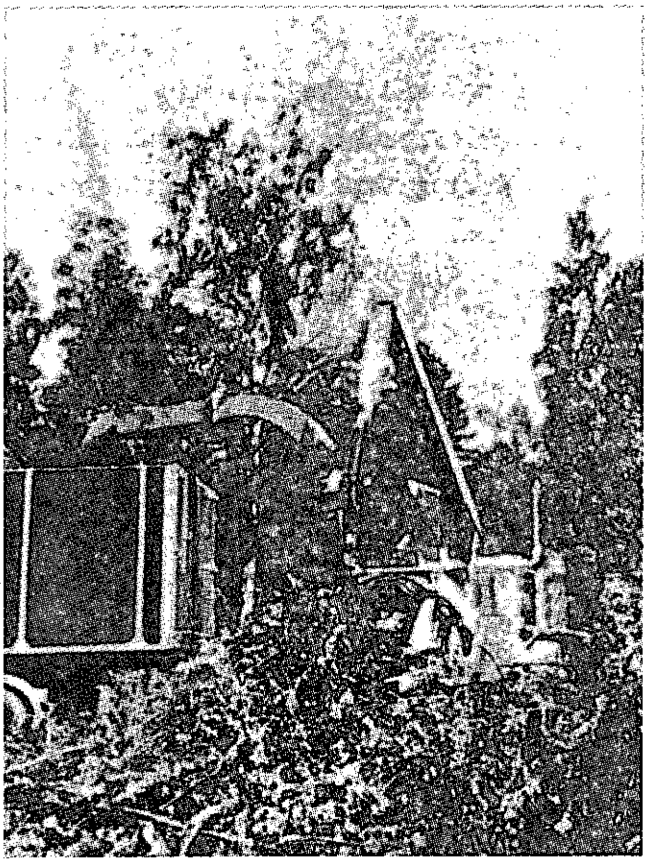


Figure 10. Limbing and bucking machine

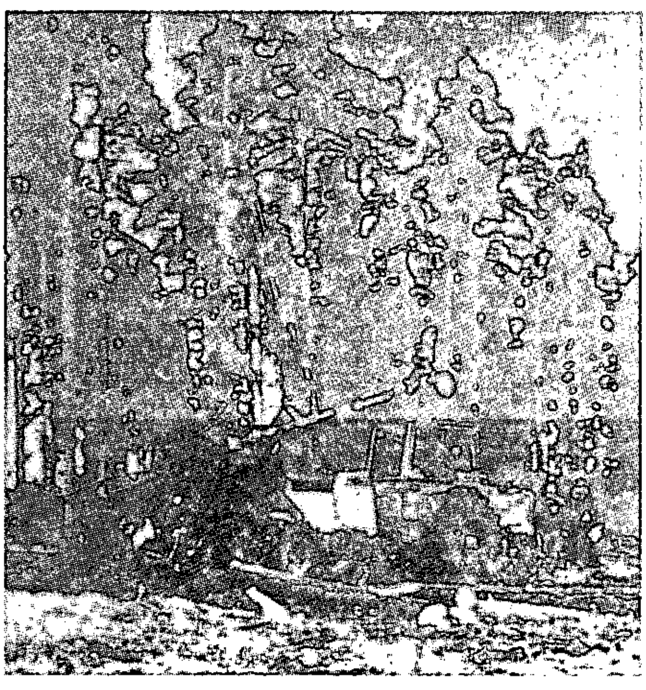
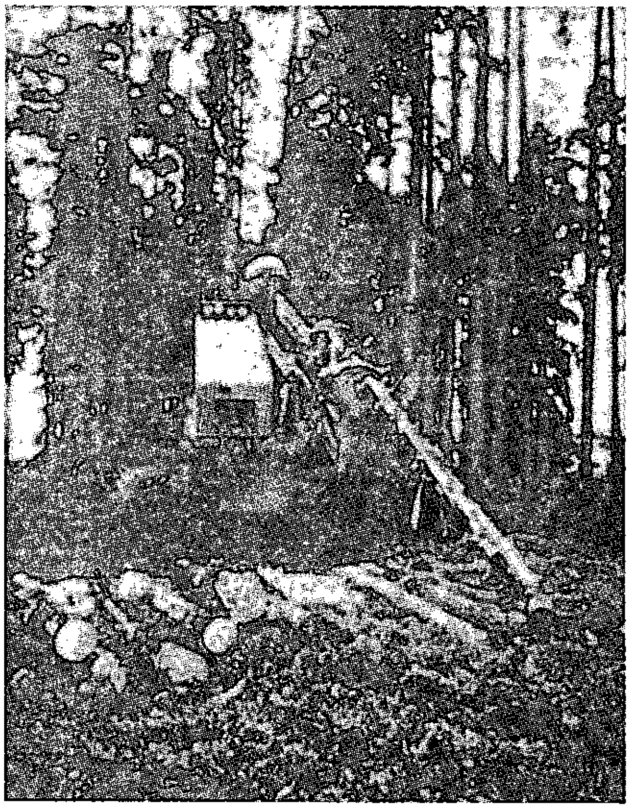


Figure 11. Sophisticated type of combined machine



Tractors

Various types of tractors can be used in the forest. They are described below.

Tractors with self-steering wheels. All of the wheels on these machines have the same diameter and all are power-driven. Their turning circle is smaller than that of farm tractors.

Articulated tractors. The front and rear trains of articulated tractors are held together by a hinged pivot. This allows tractors to have a very small turning circle, and, therefore, they are very manageable in forests. They have four-wheel drive, and the wheels are of equal diameter, which allows for considerable stability and permits their use on slopes with a 30-35 per cent gradient. These characteristics have contributed to the widespread use of this type of tractor. Usually, these machines have a winch with one or two drums or hydraulic grabs assembled on their rear train (see figure 12). At the front, they are equipped with a bulldozer blade, which is also used to move stones, to level logging paths and for the preliminary stacking of logs.

Carrier tractors with semi-trailers. The rear train of carrier tractors is formed by a platform provided with a crane with hydraulic grabs for loading and unloading logs (see figure 13). These tractors are very easy to handle, which is why they are widely used throughout the world for the transport of both logs and by-products to be used for energy generation.

Crawler tractors. Crawler tractors are rigid machines that are used for opening roads in virgin forests. They can also be used for logging, if they are provided with a winch.

Figure 12. Articulated wheeled tractor with winch

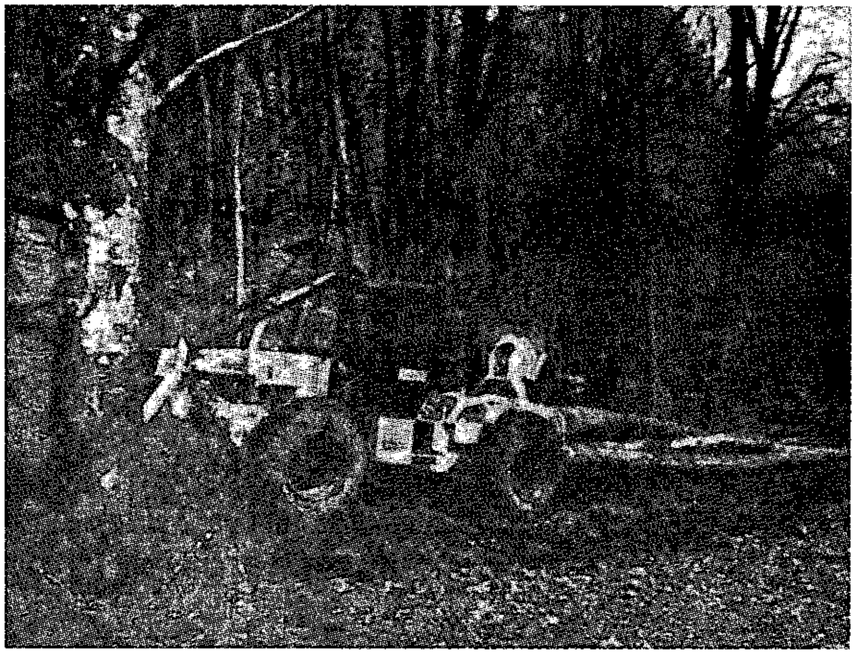
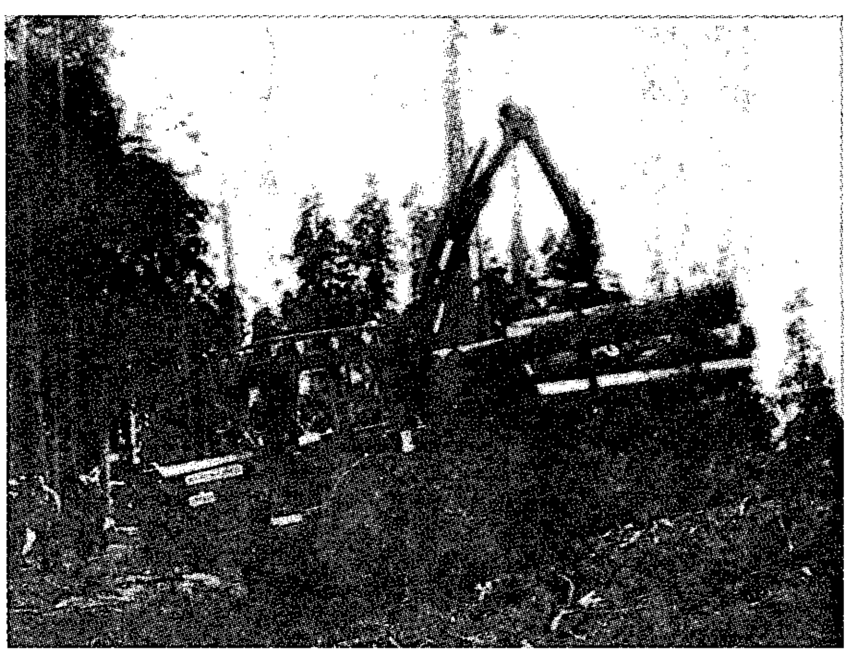


Figure 13. Carrier tractor with semi-trailer



Crawler tractors with oscillating wheels. Unlike the tractors described above, oscillating wheels allow these tractors to overcome obstacles more gently. They can be found especially in Canada and the Union of Soviet Socialist Republics.

Crawler tractors with semi-trailers. These tractors couple the advantage of having a trailer with that offered by the crawler track. They are very useful machines on marshy or snow-covered land.

The accessories necessary for forest tractors are listed below.

Winches. Winches are usually placed on the rear trailer and can be with one or two drums. With winches of this type, the tractor can be used as an engine power station for a small cable aerial. It is useful to attach a small winch to the front part of the tractor, to help the machines get out of marshy land.

Inlet hatch for logging. The inlet hatch is formed by four rollers placed on the sides of a rectangle. The winch rope passes through the hatch. The hatch allows ends of trunks to be kept clear of the soil, thus avoiding spoiling the wood or damaging the roads. Less friction allows for machine operation with less powerful engines and, therefore, savings on energy consumption. The logging hatch reduces engine effort by 25-40 per cent.

Semi-trailers. Semi-trailers have a two-wheel axle. Trunk tops as well as tops of whole trees are placed along the axle-bar.

Trailers. Trailers are used for loading logs. They can be with a single or double axle. It is very important for an axle-bar to be power-driven as, besides making it easier to overcome extreme gradients uphill, this makes going downhill safer because the trailer, within certain limits, holds back the tractor. Forest trailers are provided with a crane with hydraulic grabs for loading and unloading materials. When they are equipped with a double axle on a pivot pin system, obstacles can be overcome gently.

Angle dozers. These blades are attached to the front of tractors and are used to level soil that is to be reforested or to open roads in virgin forests.

Harrow ploughs. Harrow ploughs are used to till the soil for reforestation. They can be attached to farm tractors.

Stumpers. Stumpers are shaped like shears, for cutting, with two over-riders to enable the tree stump to be uprooted. They are attached to big tractors and excavators. This system is very widespread in Scandinavian countries. It allows the yield of the wood mass to be increased by 15-20 per cent. The wood, after having been washed, is then chipped and mixed in a ratio of 10-15 per cent with other wood material. It is used by the paper industry.

Timber loading and means of transportation

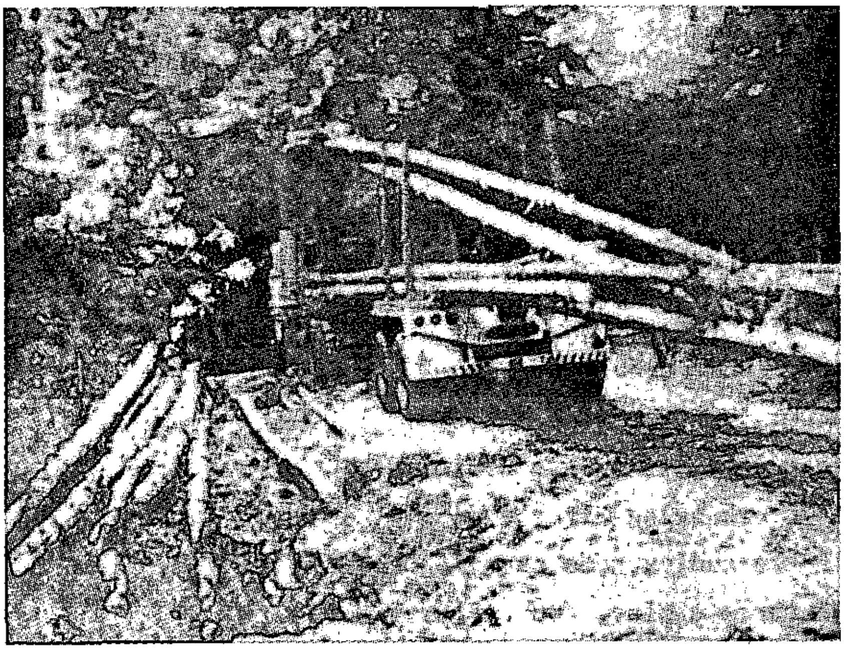
Timber loading

The manual loading of wood is disappearing in favour of loading with hydraulic cranes, which has been described above. Filling containers directly in the forest with chips and small logs for the paper mills has proved to be very practical: these small logs can be loaded with conveyor belts, which can also be used to feed chipping machines. Trailer tractors provided with large hydraulic grabs have proven very useful for the loading and unloading of trailer trucks.

Transport

Land transport. For timber transportation, trucks with or without trailers, tractor semi-trailers and trucks with semi-trailers are used (see figure 14). When transport takes place on sandy roads, the vehicles should have more than one rear axle so that weight is more evenly distributed on the soil.

Figure 14. Truck and trailer used for transport



These vehicles must be equipped with low gears and extra brakes if they have to go down steep gradients with a full load. In addition to hydraulic cranes, they can be equipped with special devices, known as the multi-lift system, for loading containers (see figure 15).

Aerial transport. Aerial transportation can be carried out with a cable crane and/or cable-cars. These can be:

(a) With one single mobile cable, a "lasso" or fixed cable or cable with overhanging wire;

(b) With two cables, one carrying and one towing;

(c) With three cables, two carrying and one towing, forming a closed ring. With three cables, one can be carrying, one towing and one a recall cable, allowing the platform to also work horizontally (see figure 16).

Helicopters. Helicopters are very useful when there are no access routes into the forest. Their carrying capacity varies depending on altitude, on whether the material is seasoned or not, on whether transportation is to be carried out going up or downhill and obviously on engine power.

Balloons and airships. The use of these means of timber transportation is currently in the experimental phase. They are particularly used in the United States.

Water transport. Floating of timber is the most ancient form of transportation in countries abounding in rivers or lakes.

Figure 15. Multi-lift system

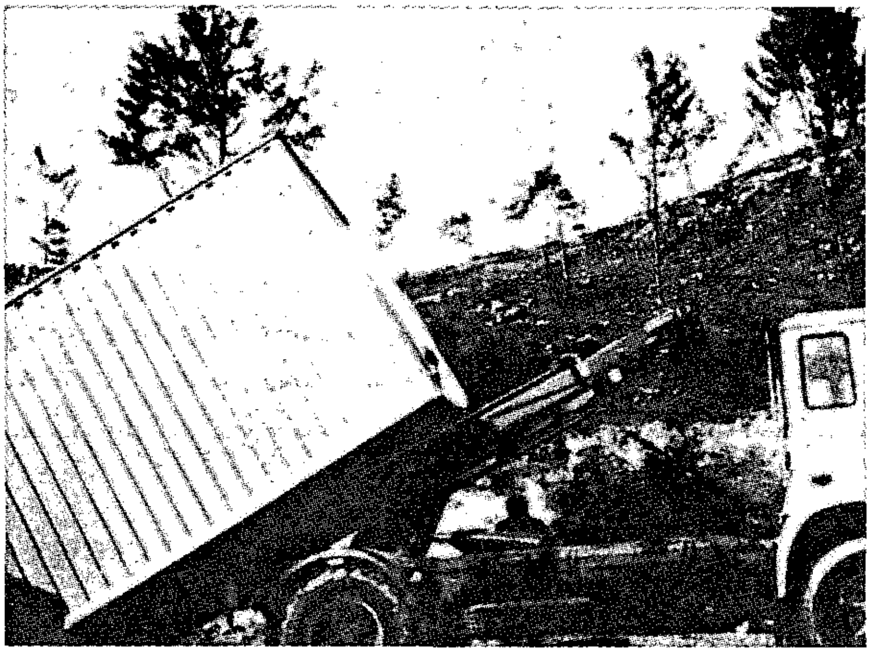
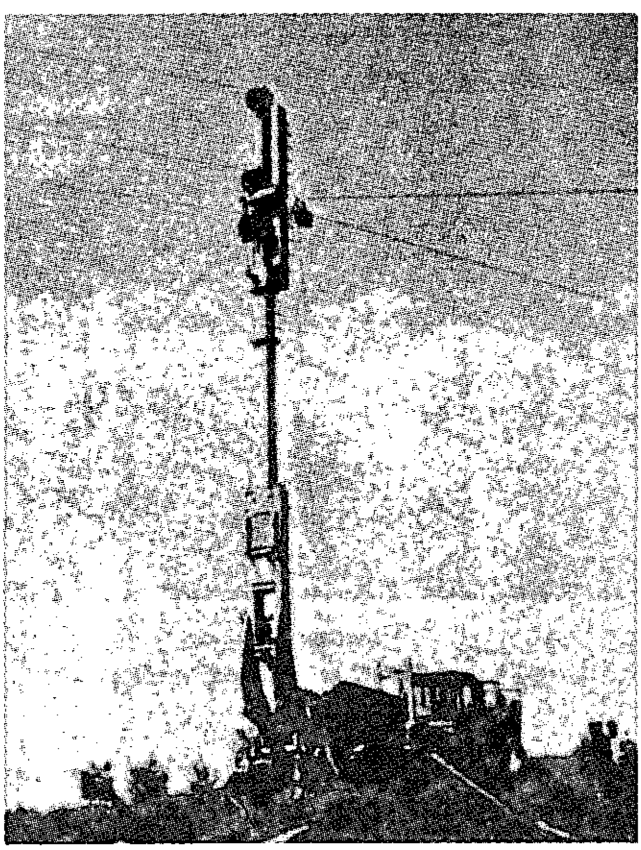


Figure 16. Mobile extendable mast with three cables



The material (composed of single logs or logs bound together to form huge rafts) is singled out by means of a small plate, affixed to the single logs. When they reach the mill downstream, they can be sorted out, either manually or electronically, also according to timber characteristics (see figure 17). Often, this material is stored on frozen lake surfaces, and it is only when thawing sets in that the logs will start their journey. It is normal for a certain number of logs not to arrive at their destination, because they remain entangled or trapped along the way and cannot always be recovered.

Boat transport. Wood material, logs or chips are transported by boats with larger or smaller capacities. These boats, usually made of steel, are equipped with all accessories for the loading and unloading of the material.

Railway transport. This form of transportation was particularly used until the middle of the twentieth century. In certain countries it is still the most commonly used form of transportation. With the construction of roads open to heavy traffic, the use of railway lines has been greatly reduced.

Cost of machines

To calculate the cost of machines, fixed and variable costs must be taken into account.

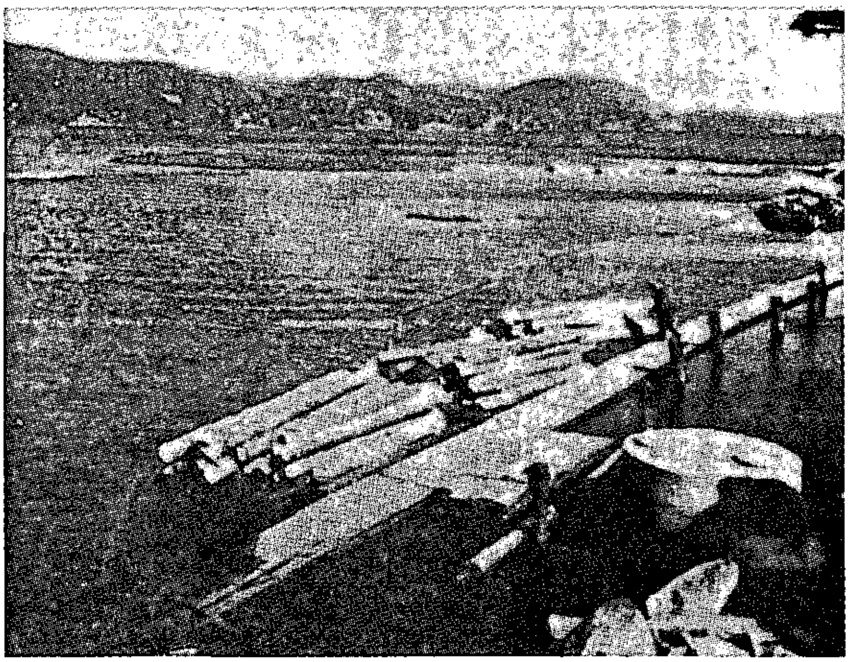
Fixed costs

Fixed costs (depreciation, interest on capital, insurance, remittances etc.) exist whether the machine is operating or not.

Depreciation

It is very important to define depreciation costs, thereby allowing an owner to find the necessary capital for replacing a machine when it becomes unserviceable. The calculation is made by dividing the cost of the machine by the presumed number of working hours if proceeds from the sale of the second-hand machine are not foreseen. If the machine is to be sold, the proceeds must be subtracted from the original cost of the machine. In practice, it is advisable to follow the first procedure. The number of hours varies according to the type of machine and the work required from it. Even if a machine is still in working order, after a few years new, more efficient, and higher-yield machines are available. In this situation, the machine therefore depreciates (the phenomenon of obsolescence).

Figure 17. Sorting of rafts



The depreciation period almost never corresponds to the technical endurance of the machine, which is always longer, as the machine can be profitably used for secondary types of work. For example, a forest tractor can be used to operate a debarking or chipping machine or can be used for shifting timber in log yards. Technical endurance is the number of hours a machine can work before wear and tear results in very high repair costs, that is, the number of hours that allows the amount between fixed costs per hour and repair costs per hour to be reduced to a minimum.

It can be more profitable to calculate depreciation costs separately for various parts of the machine if, for example in the case of crawler-tracks, they wear out rapidly.

Interest on capital

The rate of interest on capital varies greatly according to whether the capital was supplied by banks or by local development boards.

Insurance, remittances etc.

Generally speaking, these rates have an incidence ranging from 0.5-1 per cent on the machine's price.

Variable costs

Variable costs depend on the machine's working hours and on repairs, power, lubricating oils and the need for spare or replacement parts.

Repairs

To calculate the variable costs of repairs, the accessories the machine is equipped with, such as the winches, logging arches, blades etc., must also be taken into account.

The formula used for calculating repair costs is:

$$\text{Technical endurance period (hours between repairs)} \times \text{real daily working hours} \times K \qquad (3)$$

Where:

K = repair coefficient

K becomes higher for a machine that breaks down and has a high repair cost. This coefficient usually varies from 0.4 to 1.2.

Machines are never under constant working pressure all day long. Tractors, for example, in the case of logging actually work five to six hours out of every eight; cable cars work four to five hours, and motor saws five to six.

At the beginning of the technical endurance period, repair costs will be low; at the end of this period, repair costs will be equivalent to double the calculated value. This must be kept in mind when the depreciation period does not correspond to the technical endurance period but is shorter because of obsolescence.

Fuel, lubricating oils, electricity

The calculation for fuel consumption is made on the basis of consumption diagrams supplied by the engine builders. Data obtained must be correct in relation to actual working hours. Consumption is in the region of 200 to 240 g/hp/h (petrol) for gas engines and 160 to 210 g/hp/h (fuel oil) for diesel engines. Lubricating oils and other lubricants necessary for good machine operation must also be considered. The costs can be evaluated at 10 to 20 per cent of fuel cost.

Parts subject to rapid wear

These include cables for winches, tyres, limbing, debarking and chipping knives etc. These costs are calculated by dividing the purchase cost by the hours of use.

By adding fixed costs to variable costs, the hourly cost of the machine is obtained.

Exploitation costs

Once the machine costs are known, the cost per cubic metre of material used can be calculated. Various costs can be represented graphically, thus permitting an evaluation of: different systems and their theoretical suitability; advantages of constructing roads versus those of logging by helicopter; or the desirability of bucking the tree in the forest itself or in log yards. All the data can be inserted into a computer, which will rapidly give the desired answers. Nevertheless, the labour force must be taken into consideration (availability, qualifications, wages etc.)

Conclusions

A machine can be chosen and purchased in a few days, but a good tractor or cable-car driver needs years of training. Evaluation errors are often the reason for the failure of an exploitation project. People are not machines, and traditions cannot be wiped out by turning a key. In spite of this, mechanization along with adequate training can solve many social and economic problems in developing countries.

VIII. Mechanization of forest operations*

Logging operations begin with the selection of a 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 countries that have large forested areas.

In planning logging operations, it is 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 that are involved in expanding and upgrading agricultural lands may co-operate and jointly regulate land usage, be it for growing trees, for agricultural crops or for grazing.

Thus, it is no longer possible to exploit forested land at will. Instead, it is necessary to first learn about 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 possible to proceed in a businesslike manner with logging operations by selecting the type of equipment best suited for the work. Over the past 50 years, machinery and equipment for logging, land development and road building etc. have been improved and have become more productive. At the same time, safety features for the protection of the operator have been developed.

One type of machine that 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, manoeuvrability 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 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.

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 increases the operator's control. 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.

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.

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*By M. Caselli, expert in forestry equipment. (Originally issued as ID/WG.277/5/Rev.1.)

[1]For additional details on logging, see chapter VII.

Figure 1. Raised fairlead used as an accessory to the winch

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 with diameters under 60 cm. 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 for felling trees:

(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 mould-board, 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;

(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 saw-teeth. Converging protective brush racks are welded to the upper extremity of the blade to cast the vegetation to 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;

(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 2. Angle shear blade used for tree felling
(The trees are pushed to one side)

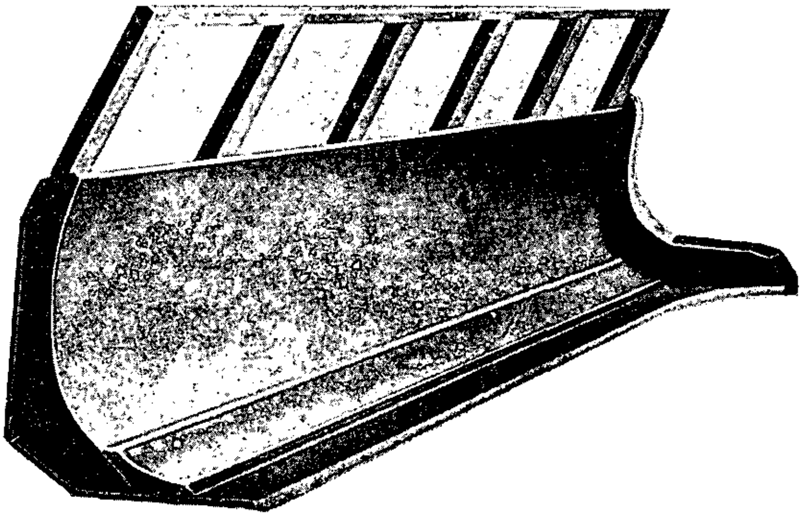


Figure 3. Felling "V" blade for rough tree felling

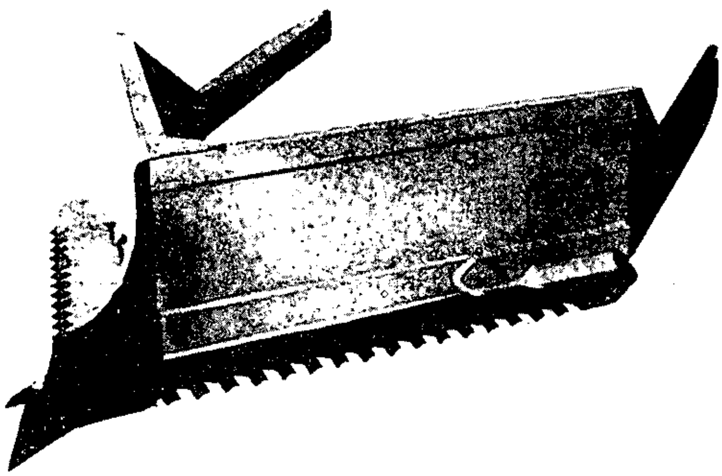


Figure 4. Tree-pusher blade

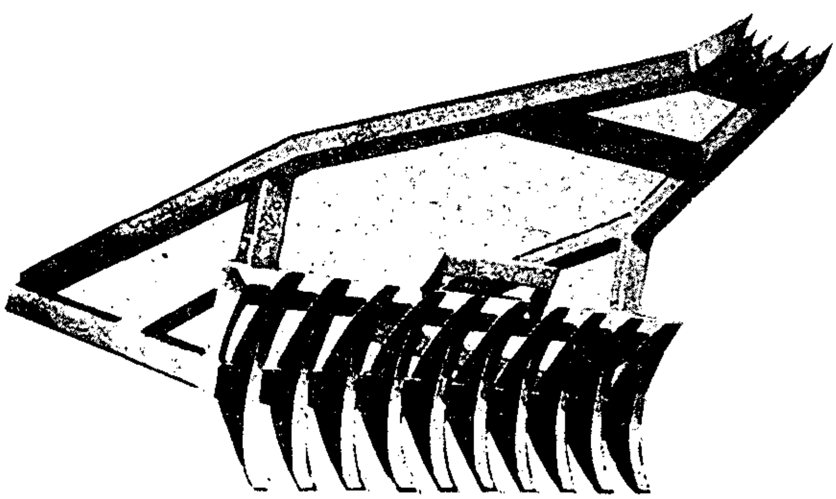
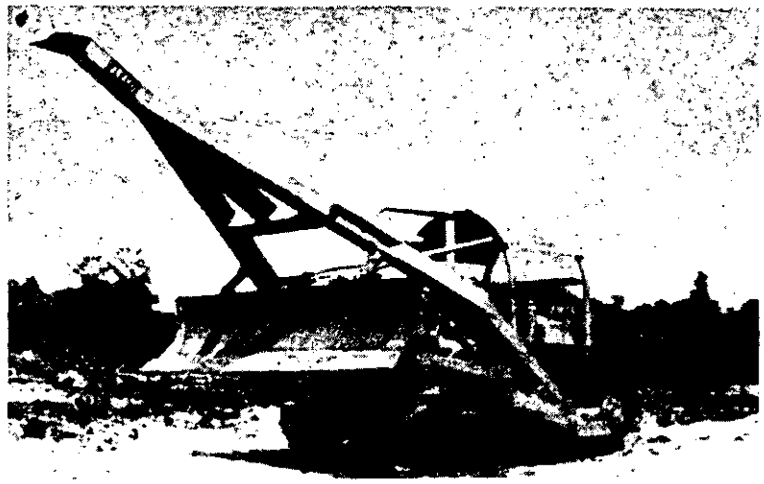
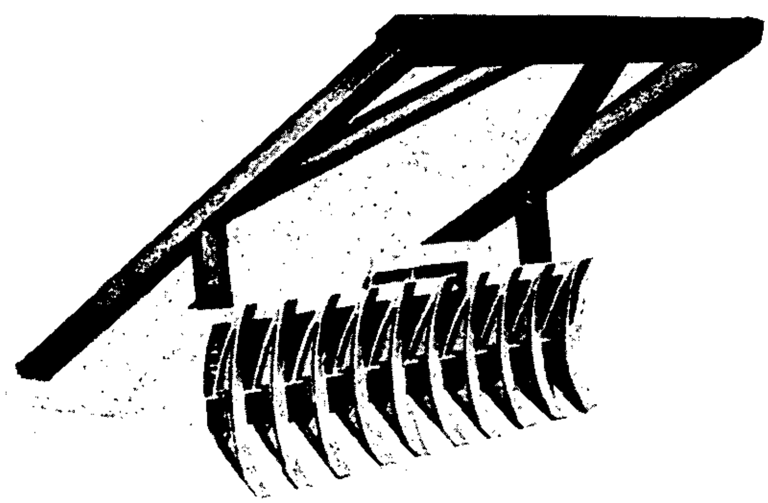


Figure 5. Tree pusher



(*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 6. Tree boom



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 1/3 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 50-80 mm, 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 tonnes. In chain clearing, it is preferable to pass twice over the same area in perpendicular directions.

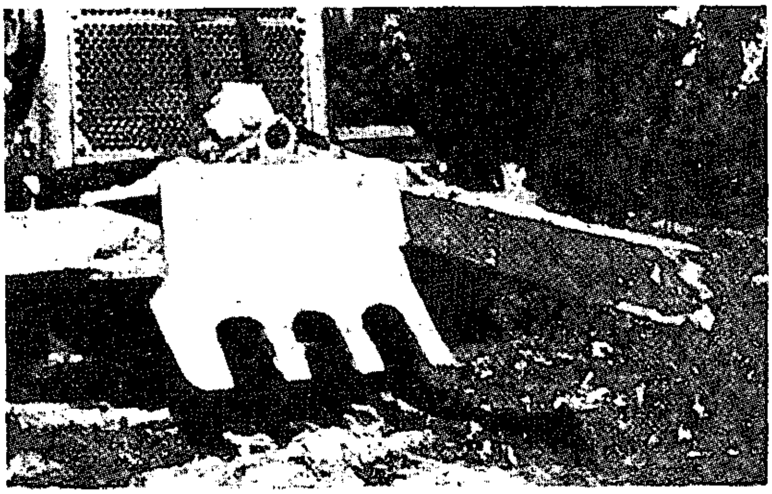
Stump digging

The stumps that 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. Stump-digging stumper



In order to root out the stumps of large trees that 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.

Figure 8. Stump-digging stumper, showing the raking-shore for stump removal

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.

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.

Figure 9. Traction stumper

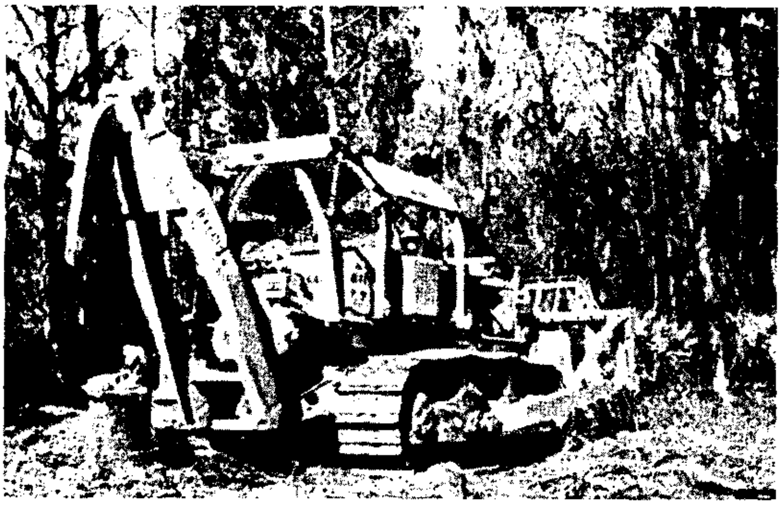


Figure 10. Blade rake

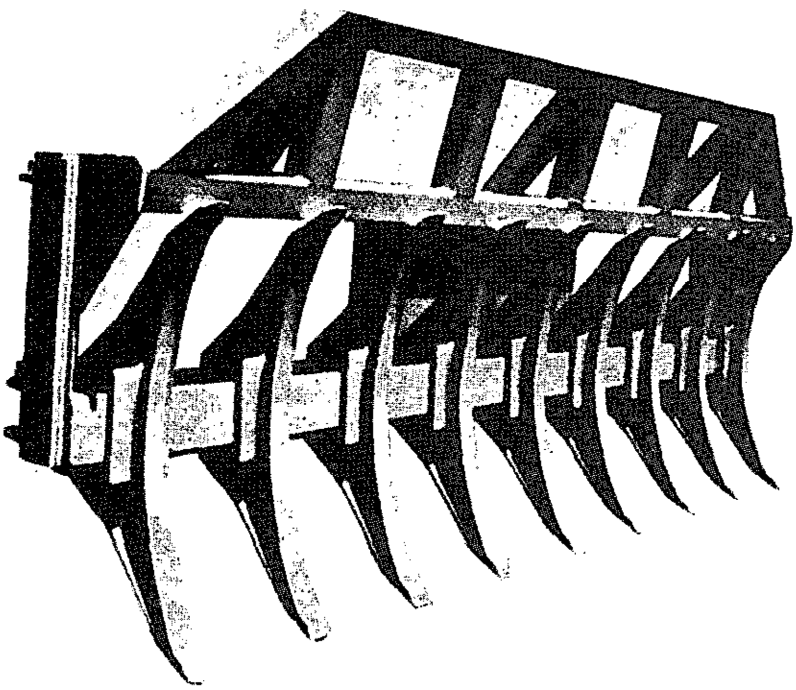
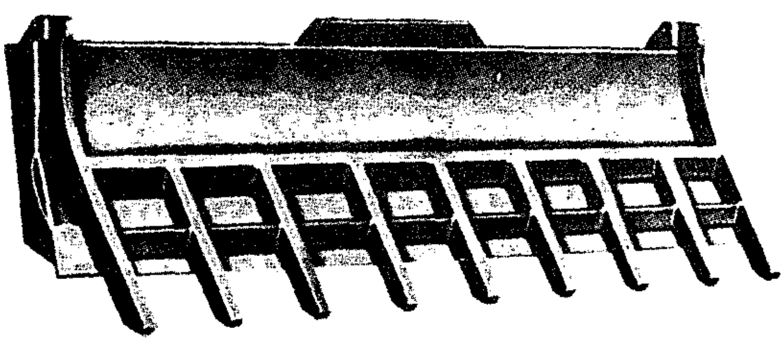


Figure 11. Blade rake for angle-dozer



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).

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.

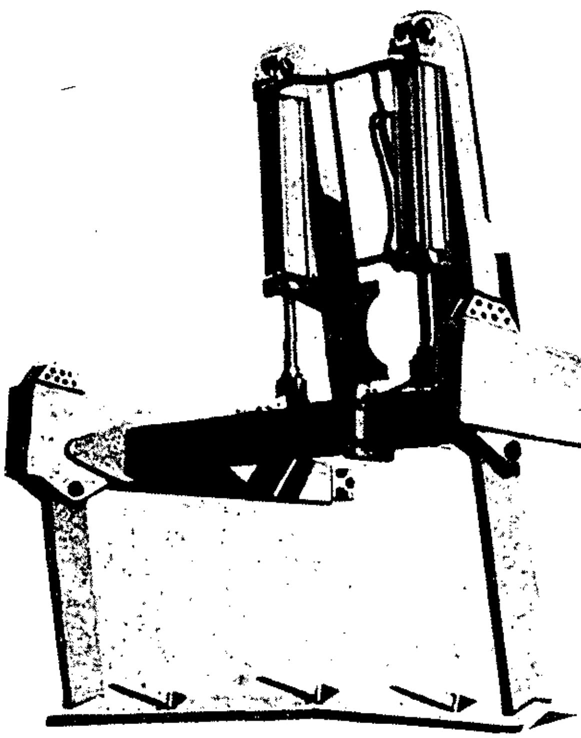
Surface clearing and smoothing

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



(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 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 that 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 or at an angle to the direction of the dozer's motion. If the frame is a V-shape, the harrow acts on the soil surfaces on both sides. The frame of the V-shaped harrow may be rigid or flexible and, in this case, its setting may be manual, cable or hydraulic.

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 re-opened 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 section on land clearing are used. If the undertaking is particularly simple, even the land-clearing angle-dozer may be used.

Figure 13. Rolling chopper

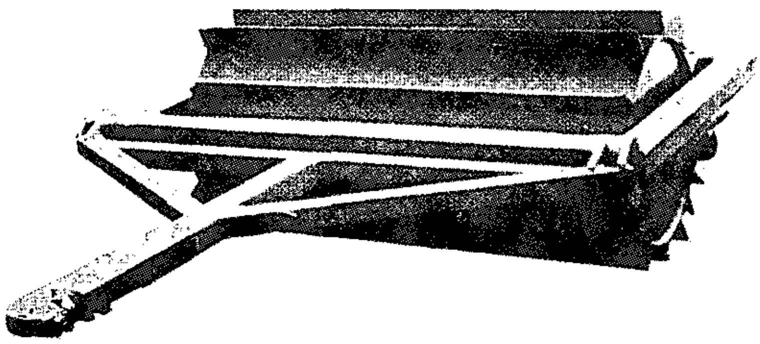
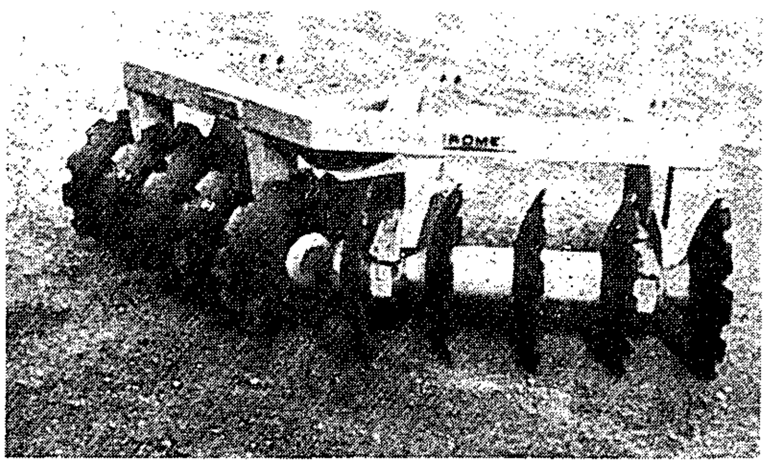


Figure 14. Disc harrow for land clearing



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 manoeuvre 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 the construction of logging roads. 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 manoeuvrability of the load-skidding tractor.

Ripper

The 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) depends largely 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, 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 and 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*

History of sawmilling equipment

Sawing is the key phase in the set of operations known as wood breakdown or primary conversion of wood. Because of its importance, it deserves to be studied in detail.

Archaeological findings have served to prove that already during the Palaeolithic and the Neolithic ages rudimentary stone tools with a roughly straightened and toothed edge were used. The first metal blades appeared during the Greek and Roman civilizations, and further improvements were made, such as the change from copper to iron, the setting of the teeth and the use of a frame to hold the blade.

It seems that already in the fourth century a rudimentary hydraulically driven machine was employed to operate the saw blades. The use of hydraulic energy is reported in various documents. One of these, dating back to the fourteenth century, contains mention of a water-operated sawmill. By the end of the fifteenth century, the use of this source of energy must have become quite common in Europe, so much so, that among Leonardo da Vinci's drawings there is a diagram of a hydraulically driven gang saw. This type of saw was later used in other European countries, and was called a Venetian saw. In a document from the beginning of the seventeenth century, specific mention is made of a hydraulic sawmill in North America. Because of building requirements, such plants began multiplying, and, at the same time, new and different types of machines were designed and constructed.

The reciprocating motion of a toothed blade of limited length was replaced by the circular motion of a disk with a toothed edge (beginning of the nineteenth century) or with the linear motion of a toothed band pulled tight between two pulleys, one of which was motive. An attempt was then made to apply the principle governing the band-saw to mobile equipment. The first patent for a machine of the latter type was granted in the United States in 1858 and the second in the United Kingdom of Great Britain and Northern Ireland in 1900. Nevertheless, this tool began to be commonly used in the 1930s.

Sources of energy began developing concurrently. During the past century, steam was the undisputed source of energy; by the beginning of the 1900s, it was joined and later replaced by electricity. The continuous increase in labour costs was a reason for the rationalization and mechanization of all working phases. This led to large-scale automation and, more recently, to the adoption of highly complex electronic equipment.

These recent technical advances are certainly interesting. In the opinion of the author, however, the use of complex equipment is as yet unadvisable in developing countries in which the technical training of manpower requires further improvement and electronics and computer science specialists are still not commonly available.

Phases of work in a sawmill

The following phases lead to the transformation of raw material, logs, into lumber:

Taking the logs from the stockyard and feeding them into the processing line
Trimming the ends and debarking
Sawing
Edging and, if required, trimming
Grading and stacking
Preservative treatment
Storage

Before each phase is examined in detail, some aspects concerning the material to be machined must be mentioned. Most developing countries are situated in tropical areas where a sawmill must answer one of two distinctly different requirements:

(a) Machining of logs from natural forests with large diameters (rarely with medium diameters) and often irregular in shape;

(b) Machining of logs from plantations with small diameters (less frequently with medium diameters) and regular in shape.

Transporting the logs from the stockyard and feeding them into the processing line

In modern sawmills, there is always a suitably equipped yard, with passageways and travelling gantry cranes for stacking logs. Strong angle irons deeply anchored in concrete bases need to be placed at the four corners of log stacks, otherwise logs can roll off and cause the stacks to collapse. Lift trucks are normally used to transport logs to the stacks and then from the stacks to the machining line. There are various types of lift trucks: fork lifts, side-loaders, front-loaders etc. The choice is influenced by the size and shape (regular or irregular) of the logs to be moved.

Cutting the ends and, if required, bucking at fixed lengths

Cutting the ends

The cutting operation is usually carried out immediately before the logs are fed into the machining line. It may be carried out in two different ways, depending on the availability of labour and the quantity of logs to be processed daily. If labour costs are low and if the volume

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of log throughput is not excessively high, chain saws of sufficient length may be used. If the log diameter is very large, the chain saw has to be very heavy and therefore has to be placed on a very low carriage. The latter facilitates transport of the chain saw to the log and at the same time acts as a fulcrum during the rotation of the guide along which the chain slides.

If the quantity of logs to be machined daily is large and labour costs are high, it is best to carry out this phase mechanically. Large circular saws are required, arranged in different ways according to the direction which logs are fed to them. If the logs are fed to the saw by means of ascending chains with axes parallel to the rotation axis of the blades, two blades are required; they act on a plane and are set at the distance prescribed for bucking.

If the logs approach the saw by means of a channel conveyor with an axis perpendicular to the cutting plane of the blades, the blade axis cannot be fixed. It must be possible to lift it or lower it by rotating the arm on which it pivots.

If a single blade is available, each log has to be sawn twice consecutively; if there are two blades that act simultaneously at the distance required, machining times are halved.

Debarking

Complete debarking of the logs to be sawn cannot be considered as a complementary operation that can be dispensed with. Not only is the bark of most species hard and abrasive, it also contains impurities and grains of sand that accelerate the wear of blade teeth. For good plant management and in order to save energy, waste bark should be concentrated in a given area, where it is possible to organize its recycling or removal.

Debarking methods differ widely, according to whether the logs come from natural tropical forests or from plantations. In the former case, logs are large in diameter and generally irregular in shape. Moreover, because of felling and logging operations, the bark has often been partially removed from the logs, in which case the manual completion of debarking may be economically more advisable than using a debarking machine.

If it is essential to use a debarking machine because of log diameter, one with a milling head/cutter head should be chosen. The machine consists of a small mill assembled on one end of an arm that pivots at its other end; the mill exerts continuous pressure onto the edge of the log, thereby following any irregularity on its surface. For complete debarking of the whole of the log's surface, the milling head must run over the entire surface of the log spiral-wise; the log must therefore be rotated and, simultaneously, a relative axial displacement between log and the milling head takes place. The log is rotated on its axis either by clamping the log between two spindles centred in the end sections or by means of a geared disk system, in which the disks are placed with the axes parallel to the log axis, forming a sort of cradle or channel in which the log lies. The rotation of the disks (all moving in the same direction) causes the log to rotate in the opposite direction.

There is another possibility for relative axial movement: axial displacement is obtained by causing the log to advance under a milling head on a fixed base or when the frame holding the arm on which the milling head is assembled shifts parallel to the axis of the rotating log.

When the wood to be machined comes from plantations, the diameter of logs rarely exceeds 60 cm and the shape is generally regular. Moreover, the bark of both eucalyptus and coniferous trees adheres rather closely to the log. Hand debarking is therefore always difficult, while machine debarking offers various possible choices of equipment. In addition to the milling-head barkers mentioned previously, ring debarkers are also available. With these, the log is passed through a ring rotating at high speed; 4 to 8 cutters are assembled along the outer rim of the ring. By means of spring devices, cutters with specially shaped tips exert pressure on the log, thereby cutting and removing the bark. Because of the synchronization of the two movements—that of the log being fed into the ring and that of the ring-knife system—the bark is cut and removed spiral-wise.

Sawing methods

The layout of the working line of a sawmill requires the careful study; the characteristics of both the material to be machined and the processed lumber to be produced must be taken into account. No plant layout is suitable for all cases; on the contrary, there are various solutions, according to the different parameters that have to be taken into account. It is impossible to review all the possible parameters, but some general information is presented below for developing countries that wish to produce commercial grades of lumber.

The basic elements of machines for log breakdown—gang saws, band-saws, circular saws etc.—and the criteria for chosing them have been examined in detail in chapter VII and are discussed only briefly here. The headrig that is most widely used for large diameter logs (most tropical species) is the band-saw, which is more versatile than the gang saw and does not cause as much wood loss during sawing as two circular blades coupled on the same axis would.

The simplest procedure would be parallel sawing, thereby obtaining a set of parallel boards which, if put back close together, would once more form a log. This would be an advantageous cutting procedure, insofar as it requires only one machine and does not require the log to be shifted once it has been clamped to the carriage. However, from the practical standpoint, it has a series of negative aspects: the board direction can cause maximum warping; the board width varies, and boards consequently requiring edging; there are difficulties in making regular stacks etc. There are ways of solving these problems, however, depending on whether only a head band-saw or both a head band-saw and a resaw are available.

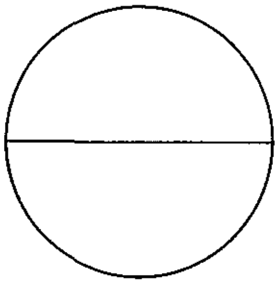
Head band-saw

Method 1. If the only machine available is the head band-saw, it may be best to cut large logs into two halves lengthwise and to cut a thick slab to be successively resawn from each half. Parallel sawing of the half log is then continued without changing the half log's position, thereby obtaining thick boards with one perfectly straight edge. The two parts that are cut off at the beginning are placed on the carriage and sawn into boards of smaller width (see figure 1).

Figure 1. Sawing large-sized logs (more than 110 cm in diameter)

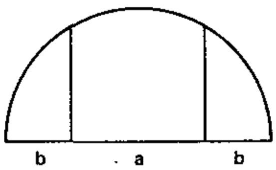
A. Sawing log lengthwise (middle-thick slabs)

A



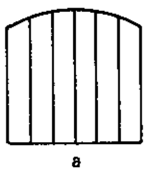
B. Sawing thick slab (a) *(edgings* (b) *stored temporarily)*

B



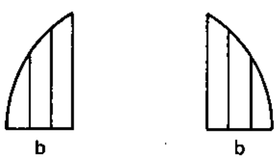
C. Parallel sawing wide thick boards

C



D. Sawing narrow boards from edgings

D



Method 2. For medium-sized logs (of a diameter of 90-110 cm), the terminal slab is separated, together with a limited number of boards, by effecting a number of carriage runs. The log then has a flat surface of sufficient width. The log is then turned 180°, and the operation is repeated, thereby obtaining a flitch. The flitch is then turned 90° and is sawn in parallel; by ripping, boards of a constant width are obtained (see figure 2).

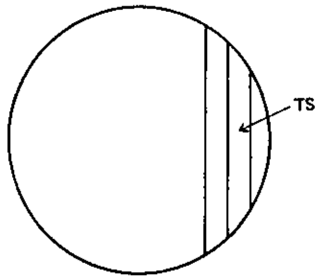
Head band-saw and a resaw

Method 3. If the machines available include a head band-saw and a resaw, a thick slab is separated from the log with one run of the carriage and is then resawn, for logs with average to large diameters (70-100 cm). The log is then turned 180°, and the operation is repeated; the second slab is treated like the first one. Without shifting the log's position, it is then separated into two halves, which will be converted into edged boards by means of both the head saw and the resaw (see figure 3).

Figure 2. Sawing of medium-sized logs

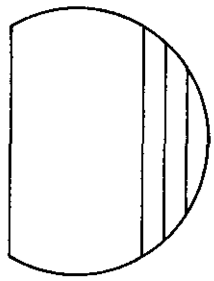
A. Separation of terminal slab (TS) and some boards

A



B. Log rotated 180° and operation repeated to get flitch

B



C. Ripping the flitch

C

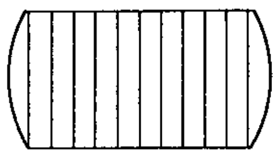
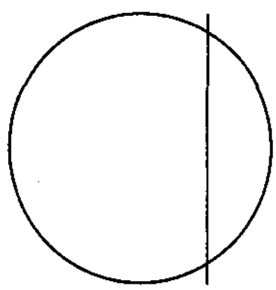


Figure 3. Sawing logs of average to large diameters (70-100 cm) on band-saw and band resaw

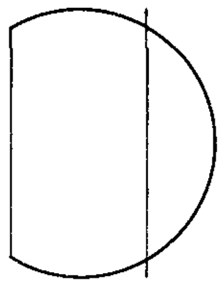
A. Sawing of thick slabs (slab resawn on resaw)

A



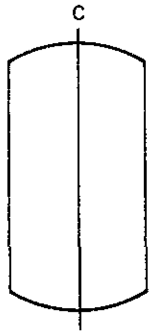
B. Log turned 180° sawing second thick slab (slab resawn on resaw)

B



C. Sawing into two halves

C



D. Two halves converted into edged boards on both saws

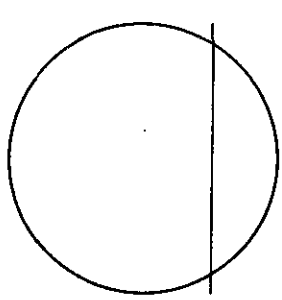
D

Method 4. For logs with diameters between 50 and 70 cm, instead of cutting two slabs on two opposite sides, the log is turned 90° after the first slab has been cut off, and the second slab is then cut. Without changing the log's position, parallel sawing of the boards is then carried out until the remaining slab is reached. This may be sawn on the same headrig or on the resaw (see figure 4).

Figure 4. Sawing of smaller diameter logs (50-70 cm)

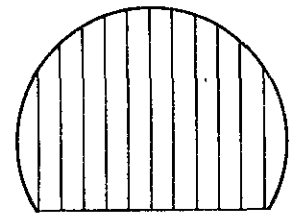
A. Sawing slab (stored for further resawing)

A



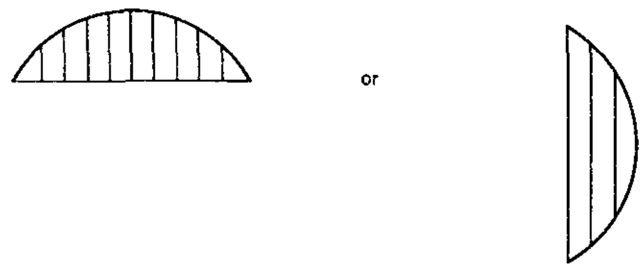
B. Log rotated 90° sawn into boards

B



C. Sawing of two slabs (on heading or re-saw)

C



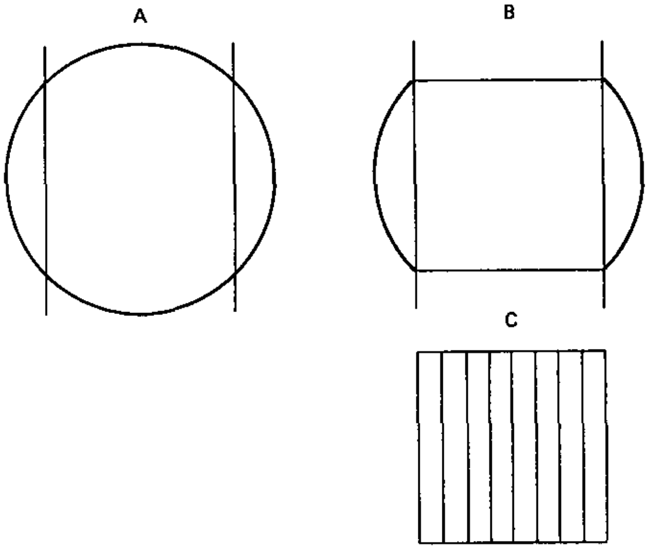
A fault that often occurs in the largest logs of tropical species, or in eucalyptus trees from industrial plantations, is the occurrence of internal growth stresses, which lead to a remarkable decrease in the yield of processed lumber with respect to bole volume. The cause of this problem is found in the standing tree, where a set of forces tend to shorten the peripheral part of the trunk with respect to the inner part, which tends to lengthen. If these logs are sawn according to method 1, the fault will immediately become obvious because the two halves will curve with the concave part towards the outside. It will consequently be impossible for them to lay flat along the whole length of the carriage, and the boards obtained with the various sawing rounds will have a curved edge instead of a straight one. The other sawing methods indicated, especially method 2, partially reduce the effect of these stresses, but, in order to have fully satisfying results, it would be necessary to eliminate the whole of the log's peripheral part. The following solutions are possible:

(a) If a single-blade band-saw is available, four successive runs should be made to eliminate four slabs all around the log. After the fourth slab has been cut off and without changing the log's position on the carriage, the flitch (with a square or rectangular section) can be sawn parallel (see figure 1);

(b) A much more rational solution, both because of the better results obtained and because it is time-saving, is the use of a pair of twin band-saws (see figure 5). The first run cuts off two slabs on opposite sides (5a); the piece is then turned 90° and brought back for a second run (5b), as a result of which the log section is square. The square is then passed through a single band-saw (5c), e.g. a resaw, so as to obtain processed lumber of the desired thickness. This solution is obviously more expensive than the previous one because of capital investment required for machinery; however, owing to an improvement in the yield (i.e. the ratio between the original bole volume and the processed lumber volume), it becomes profitable after some time;

Figure 5. Sawing pattern for twin band-saws used as a headrig

a and b on twin band-saws (slab rotated 90° for b); c sawn on single band resaw

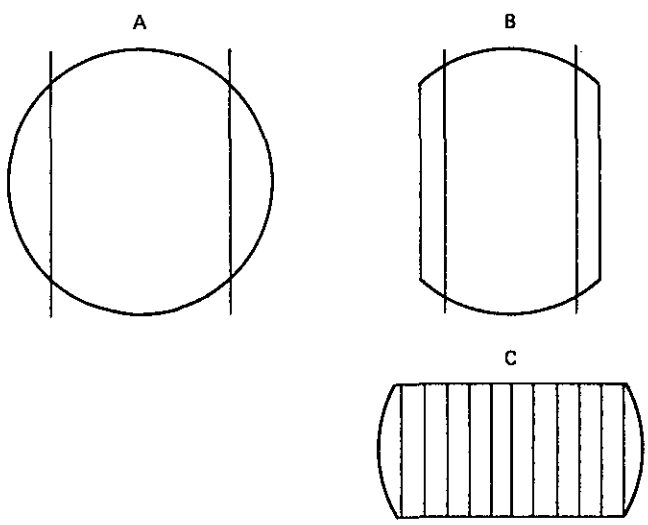


(c) A variation of solution *(b)* implies placing a second pair of twin band-saws on the same machining line after the first pair. In this case, the log does not have to be returned to the headrig, thereby saving time. Moreover, the distance between the blades of the second pair of saws may be different from that of the first pair, which offers a wider selection of flitch sections. Capital investment in this case is much higher than for the previous solutions;

(d) When the board width required is small, the solution illustrated in figure 6 can be employed. The headrig includes two pairs of band-saws (6a), followed on the machining line by another pair (6b), which results in a rectangular flitch. This is then cut into boards in the usual way (6c) (preferably on a resaw).

Figure 6. Sawing pattern for two pairs of twin band-saws

First twin band-saw heading (a); second twin band-saw heading (b); flitch resawn on resaw (c)

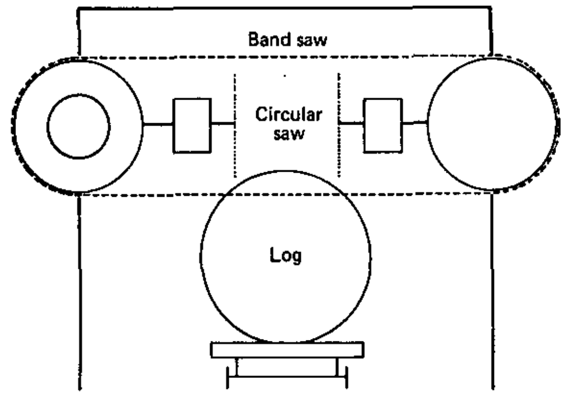


If thick beams with a square or rectangular section are required instead of boards of average thickness, an accurate study of the direction and distance between the cuttings must be made, with drawings. In these drawings, attention must be paid to "oversizing" in order to take into account shrinkage that takes place when the wood is dried.

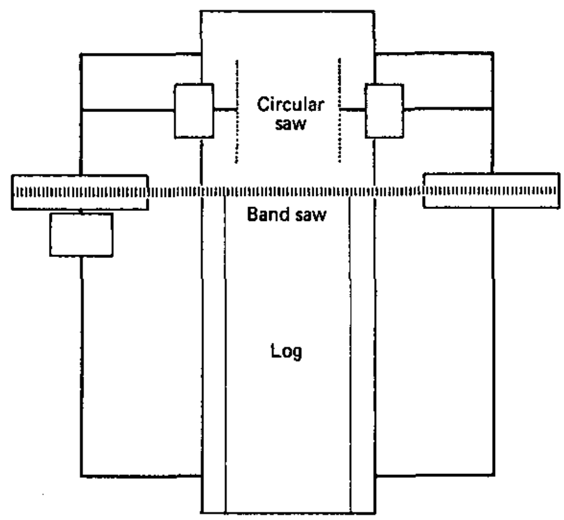
A way to reduce end splits that are due to internal stresses on boards is to use a horizontal band-saw (see figure 7) on which two circular saws are assembled at right angles to the band-saw very near the blade. As the board is cut off from the log, the circular saws eliminate the lateral strips, which contract and cause end splits.

Figure 7. Sawing on a horizontal band-saw with two circular saws for edging

A. End view



B. Top view

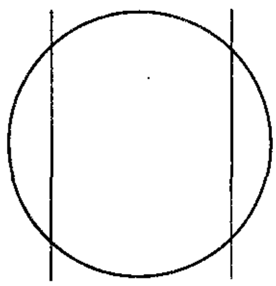


Other techniques must be used if the logs to be sawn are not of large diameter but are rather homogeneous in size and all smaller than 50 cm in diameter. This situation is typical in northern and central European sawmills, where large quantities of softwood are machined and where boards of constant width and thickness are required. These boards are ripped to a constant width. In this instance, a single headrig is not suitable, and other solutions must be sought.

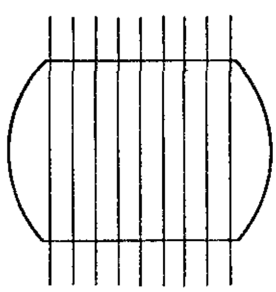
In the past, the sawing line began with a frame-saw with two blades set apart at a distance so as to allow boards to be cut to the required width (see figure 8). The result was a flitch and two symmetrically opposite slabs. The flitch was turned 90° and boards of the required size were cut by a second gang saw with many blades.

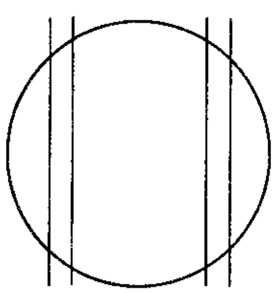
Figure 8. Sawing on a frame-saw

A. Log passing through first frame



B. Flitch passing through second frame





When the log diameter is larger than the diagonal of a square whose sides are equal to the board width, it is best to assemble four blades on the head gang saw instead of two, so that the first pass (a procedure similar to that in figure 6) will result in a flitch having two parallel sides, two non-edged boards and two slabs. The two boards are sent to the trimmer and the slabs to the resaw, in case some small-size lumber can be obtained from them. The flitch continues along the machining line on to the next gang saw (multi-blade), where the boards of required width are cut.

In another, more modern, process, the first four-blade gang saw is replaced with two pairs of twin band-saws, followed by two more pairs. This layout results in a squared log, which then passed through a third set of twin band-saws. The first two pairs of twin band-saws may be integrated with chippers that immediately transform the slabs into particles, which can then be used to produce particle board or cellulose. This process is rather complex and is certainly rational, but it is very expensive and not suited to sawmills in tropical countries.

Small logs with a diameter not exceeding 24 cm come from thinnings, plantations or coppices and may be used to obtain small boards for pallets, packaging purposes or flooring. The procedure (see figure 9) involves a first run through two twin band-saws, which will turn the bolts into flitches; these are then sent on through two sets of circular saws, set in pairs on the same plane.

Sawing machines

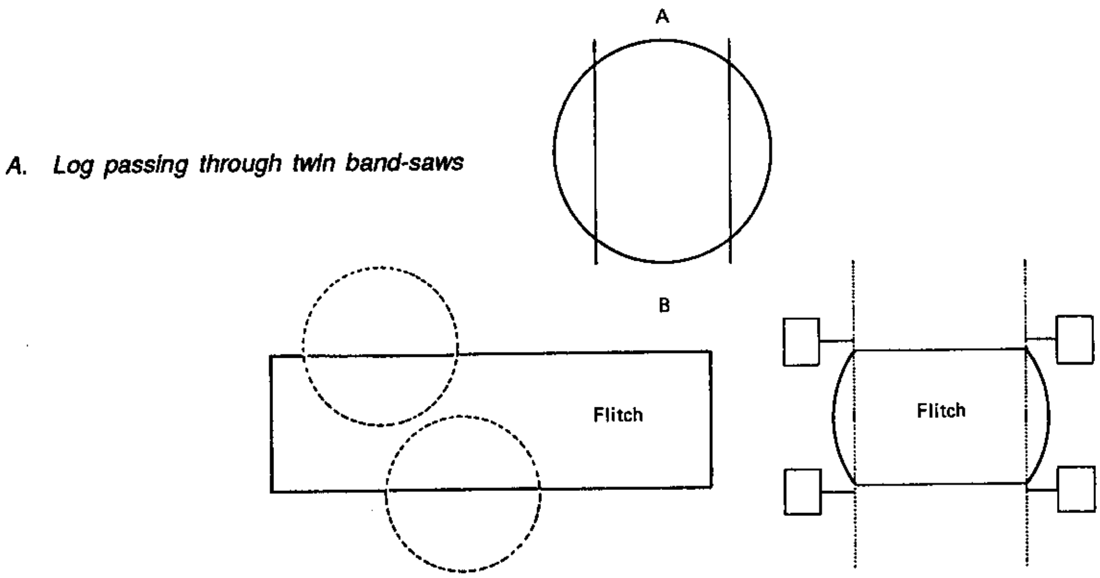
Mistakes are often made in respect of log diameter, because machine purchasers think that a machine intended for log diameters of, say, 1.20 m can give satisfactory results for logs of larger diameter too, for instance 1.80 m, if the distance between the axes of the two pulleys is increased enough. If the free length of the blades is increased without increasing the thickness of the blades accordingly, however, blade resistance against the forward thrust of the log by the carriage will decrease noticeably. Consequently, the operating speed will have to be reduced. Therefore, if logs of large diameter represent a significant percentage of the number of logs to be sawn, it would be best to have two head band-saws, one for large diameters and the other for average diameters.

If, on the other hand, large diameter logs only amount to 6-8 per cent in terms of number of logs (20-30 per cent in terms of volume), it is best to carry out the first cut through the heart with a large chain-saw assembled on a frame, with a rail for access of carriage, or by means of two large-diameter coplanar circular saws on the same plane.

While prior knowledge of the diameters of the logs to be sawn is necessary to define machine size, it is also important to predict what the assortment of the main production will be. The majority of plant layout and internal transport arrangements, including those relating to wastes, depend on this factor. If, for example, the boards to be produced exceed 40 cm in width (very wide boards), it is best to use head saws directly, rather than cutting big flitches on the resaw, while for board widths under 30 cm, the opposite is true, considering the higher speed of the resaw compared to that of the head saw. If maximum recovery of boards and strips from the slabs is required, some experiments should be made with the material available, since the peculiar characteristics of each wood species make it impossible to find a working method that applies to all species. A method that gives excellent results with one species may give negative results with another.

With reference to frame-saws, the frame size must be related to the actual log diameter if the logs are to be flat sawn. This is impossible, however, in the case of very large logs, which must first be halved lengthwise. In cases where there is an abundance of raw material, it is best not to waste time by running the flitches through the frame-saw one at a time. Two or more flitches put in contact with one another can be fixed to the carriage; they can then all be sawn in one run.

Figure 9. Sawing pattern for small diameter (plantation) logs



B. Flitch passing through two superimposed sets of circular saws

Coplanar circular saws are very useful for obtaining large squared logs, especially in sawmills where the operating times are short. Such saws do cause high wood losses in sawdust because of their thickness; they are therefore not always advisable.

If the logs to be used have small diameters (as shown in figure 9), excellent results may be obtained by using circular blades of reduced diameters, assembled staggered one on top of the other; the percentage of sawdust is thus more than acceptable, since the blades will be very thin because of their small diameter.

Edging and trimming boards (if required)

Edging machines are essential in all sawmills, since there are always boards with wane on one or both edges because of the cylindrical shape of the logs. Edging is always carried out with circular saws with a diameter not exceeding 300-350 mm. Two types exist: with the blade axis fixed and the board on a movable carriage; or with the board fixed on the table and the blade travelling along its length. Boards are generally held in position with a set of rollers and flat tracks with a milled surface; the tracks are interlinked so as to form a ring with articulated elements. If the blade operates from below, the tracks are on both sides of the board (top and bottom), while if the blade operates from above, the tracks are along the whole width, with a depression where the blade passes.

Edging takes place as follows: the raw board, the shape of which is trapezoidal, is fed to the tracks from its narrowest side so that the central area of the tracks, along which the blade will cut, touches one of the board's margins. At the end of the run (during which the board is led by the action of the track chain), the board is returned to its initial position on the opposite side. If boards with parallel edges are required, a guide bar must be placed at right angles to the plane on which the board is set. In this way, the board being cut is guided in a straight direction.

Single-blade edging machines only work along one of the board edges; edging machines with two coupled circular blades can, in a single run, cut two parallel edges. One of the blades is fixed, while the other can be shifted parallel to the first. It is both time-consuming and uncertain for the operator to assess the board's width; therefore, the so-called "shadow" system can be used. The shadow system involves lighting equipment above the working table (a lamp), under which a long frame runs. Along the inside of the frame, many parallel wires are drawn, and the farthest of these projects its shadow along the extension of the path of the fixed axis blade. All the other wires project straight parallel shadows on the boards, so that the operator can determine with accuracy the maximum width obtainable and thus set the second blade, which can be shifted by means of a special pointer and scale. In technologically more advanced plants, the wire shadow system has been replaced by a laser device that projects a brilliant red line on the boards.

A circular trimmer (cross-cut) saw should be introduced on the working line if: the logs have not already been cross cut to the required length of the boards; after sawing on the head saw the boards are discovered to have faults that must be eliminated; or short boards recovered from resawing of small slabs must be adjusted in length. Its position will depend upon the number of working lines. If, for example, few boards require trimming, it is possible to locate the trimmer at the end of the working table where the edging machine is located. If, on the other hand, all the boards require trimming, the circular trimmer should be on a working table of its own, with its own storage area.

The trimmer can operate in different ways: it can emerge vertically from the working table (pedal control); or it can be moved as a pendulum or a pantograph. Since this machine is very dangerous, suitable protection must be foreseen when designing it in order to avoid accidents.

Equipment for transport along the working line

The logs are transformed into the various dimensions required by the market by being passed through different machines; this is called the working, or machining, line. The wood must therefore be transported along a certain route, and this transport route should not be manual, except in special cases.

A wide choice of possibilities exists for meeting transport needs. There is, however, a set of basic requirements, namely: the transport route must be as short as possible, thereby avoiding any uselessly long passages; the means of transport chosen must not force the operator to abandon a working position to either pick up or accompany the logs along their route; and movement by gravity must be exploited whenever possible. This latter point is very important; it means that the first sawing of the logs should take place at a higher level than that of the logyard. In other words, the log will have to be lifted once, at the beginning of operations.

Since the material is always transported longitudinally with respect to the machines, the best direction for moving logs towards the machines and for stacking logs beside them is transversal. Therefore, the exploitation of the force of gravity will take place most often at right angles with respect to the general direction of the machining lines (for the greater part by means of tilted planes).

Transport in the sawmill generally takes place according to any of the following methods: trolleys on rails; automotive trolleys (usually complete with lifting apparatus); longitudinal conveyors; belt conveyors; roller conveyors; chain conveyors; lateral travelling lifts; hoists; monorails; and knockouts.

The logs are moved from the stockyard to the entrance of the machining hall by means of trolleys on rails or longitudinal chain conveyors. The latter consist of ducts with a trapezoidal section that is wider in the upper part, with walls and bottom made of closely interconnected boards. There are longitudinal irons on the bottom, along which metal crosspieces with protrusions run. The crosspieces are fixed at regular intervals onto an endless chain that causes the system to move in a continuous fashion, thereby feeding the logs forward in the direction of their axis. Once the logs are near the head saw, they must be clamped onto the carriage that will feed them to the blade. To do so, the logs are lifted onto a table with a tilted plane by means of endless conveyor chains with short arms that pick up one log at a time. Each log is then turned over and falls into a canal or duct composed of grooved rollers that are either arched or bi-truncated cones. This duct must enable perfect log orientation towards the saw blade, either by means of tongs at the end of the carriage or by means of retracting levers that act on the sides of the logs, thereby allowing partial rotation movement.

The boards leave the head saw on a roller conveyor with rollers that are assembled on ball bearings and are kept in rotation by means of an endless chain with its own motor. When the boards reach the areas where they must be shifted from a longitudinal to a transverse position (e.g. where they must be fed to the edging machine or to the trimmer), the roller surfaces are no longer smooth but have helical-shaped protrusions that cause the change of direction. If the change of position is not compulsory, i.e. where it is only to be made occasionally for example to remove faulty pieces from the line, a system of transversal chains can be set up. When in rest, these do not emerge above the rollers, while during operation they emerge just enough to lift the board surface from the rollers and to convey the board in a transverse direction. Boards that have been removed from the main machining line in this fashion can then be shifted onto tilted roller rails towards a working table from which they continue moving towards further machining or, in case of waste products, towards a storage area.

For the longitudinal transport of boards it is always advisable to use roller conveyors, but for wastes an endless belt conveyor is often more appropriate, since waste material of small size and low weight does not impose excess stress upon the material of the belt and thus does not unduly shorten its operating life.

Some sawmills may employ trolleys on rails for their internal transport systems (for passage from one rail line to another parallel one). In that case rotating platforms must be foreseen for the exchange of the lines.

When displacement to the sides can be effected by means of simple inclined or arched rails, pneumatic knockouts or tipper levers can be used to shift the pieces from the longitudinal rollers to the rails themselves.

Hoists and overhead monorails are used to shift heavy pieces of material or when lack of space makes ground shifting impossible. Vacuum lifting equipment is very useful for the overhead transport of material.

Choice, grading and stacking of boards

In technologically more advanced sawmills, fault detection is entrusted to complex electronic equipment. In most cases, however, board grading is still carried out by specialized and highly reliable operators who watch the boards passing in front of them on a special table and assign the proper grade. Other operators then pick up the boards manually from the transverse chain and put them in the appropriate compartment, or this operation can be carried out by means of ejection equipment situated along the line and controlled by the operator in charge of grading the boards.

Once the boards have reached their destination, they must be stacked. There are various machines available to stack the boards (which are all the same length) in regular layers, placing stickers between each layer. These machines even bind the stacks with metal or plastic straps into packages.

Preservation treatment (if required)

If the boards have been stacked complete with stickers and tied up well, preservation treatment can be carried out by immersing the whole stack in a tank full of preservative. A hoist with a movable arm is employed for this purpose. If the sawmill lacks the mechanical equipment necessary for stacking with stickers, it is better to dip the boards into the tank one by one.

If the boards are dried artificially and not in the open air, the preservation treatment is carried out after drying.

Storage

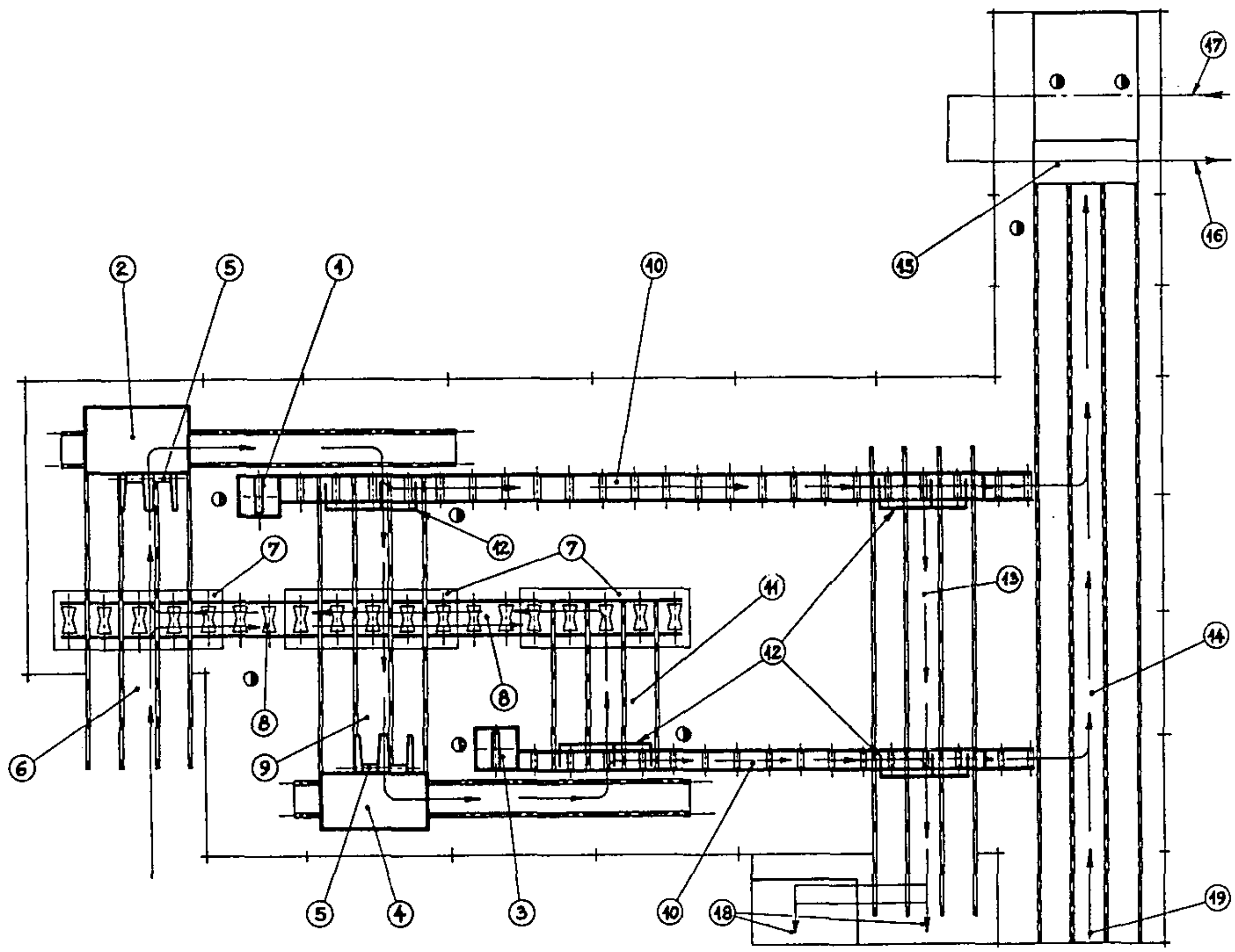
Lift trucks pick up the stacks from the grading sections where they have been prepared or from the exit of the drying kiln and carry them to the storage rooms, which must always be dry and airy. The stacks can be piled to a height of 8 m using pallets or separating beams that allow for the necessary space to insert the fork-lift arms. Fork-lift trucks with sufficiently long masts must therefore be chosen.

The stacks of boards must never be put directly on the floor; they must be placed on concrete cubes at least 40 cm high. To ensure good airing, the roof should be designed with two separate sections, with the upper section at least 30 cm higher than the other. If the storage area has poor ventilation, a series of fans should be installed.

General layout of machines and transport systems

Three layouts and flow diagrams are shown in figures 10 to 12.

Figure 10. Layout of a sawmill (GIMM)

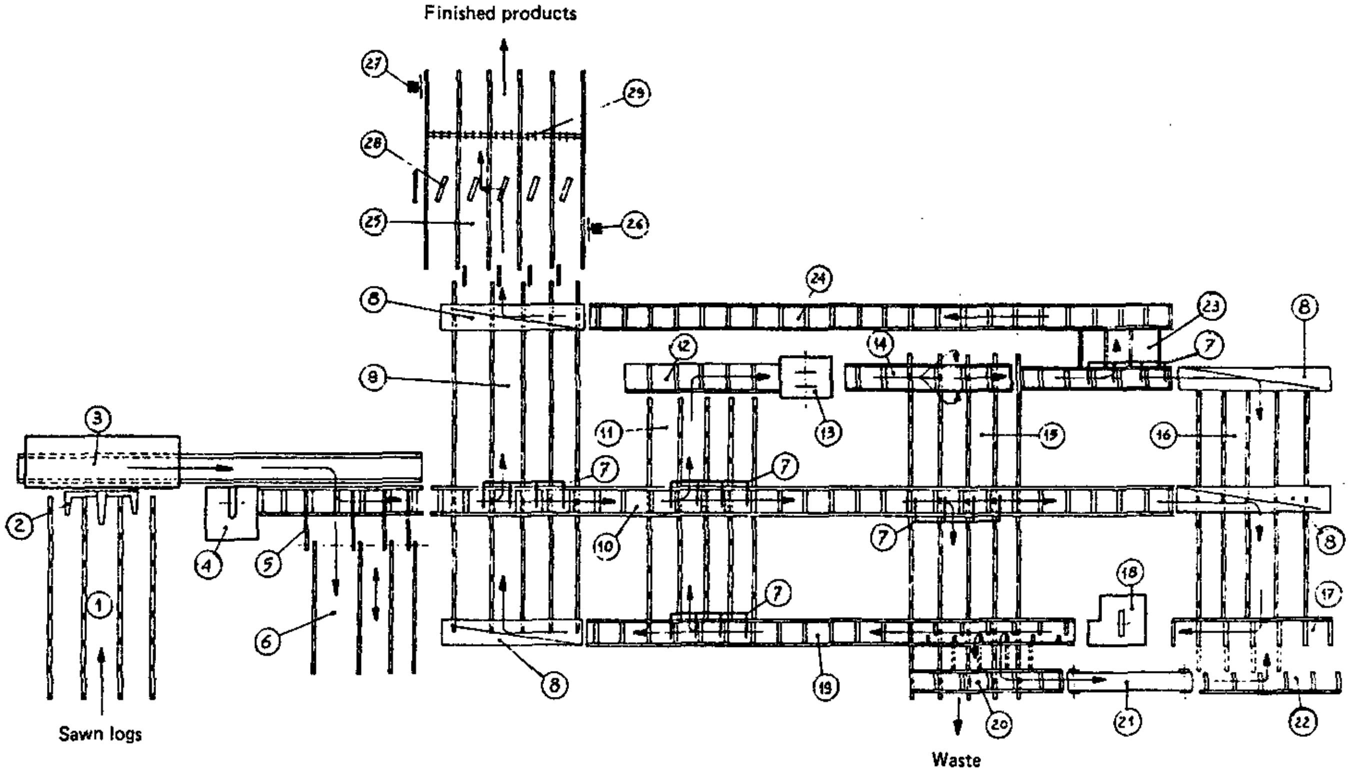


Key:

1 Band-saw No. 1, 2.10 m in diameter
2 Carriage with a withdrawal of 1.8 m
3 Band-saw No. 2, 2.10 m in diameter
4 Carriage with a withdrawal of 1.5 m
5 "Simonson" type log turner
6 General feeding conveyor
7 Retractable fluted conical roller conveyors
8 Fluted conical roller conveyors
9 Lateral conveyors for feeding band-saw No. 2
10 Smooth roller conveyors for sawn boules
11 Lateral chain conveyors
12 Ejecting arms
13 Lateral chain conveyors
14 Conveyor for feeding the lath piling device (roof-top type chain)
15 Stacker "in stick"
16 Exit of stacked sawn wood "in stick"
17 Return of laths
18 Sorting station for boules of different thicknesses
19 Direct entry to the stacker "in stick"
◑ Work station of labour force

Source: J. Froidure "La scierie du GIMM à Nantes-Chevire", *Revue Bois et Forêts des Tropiques*, No. 126, 1969.

Figure 11. Layout of a sawmill (SEPC)

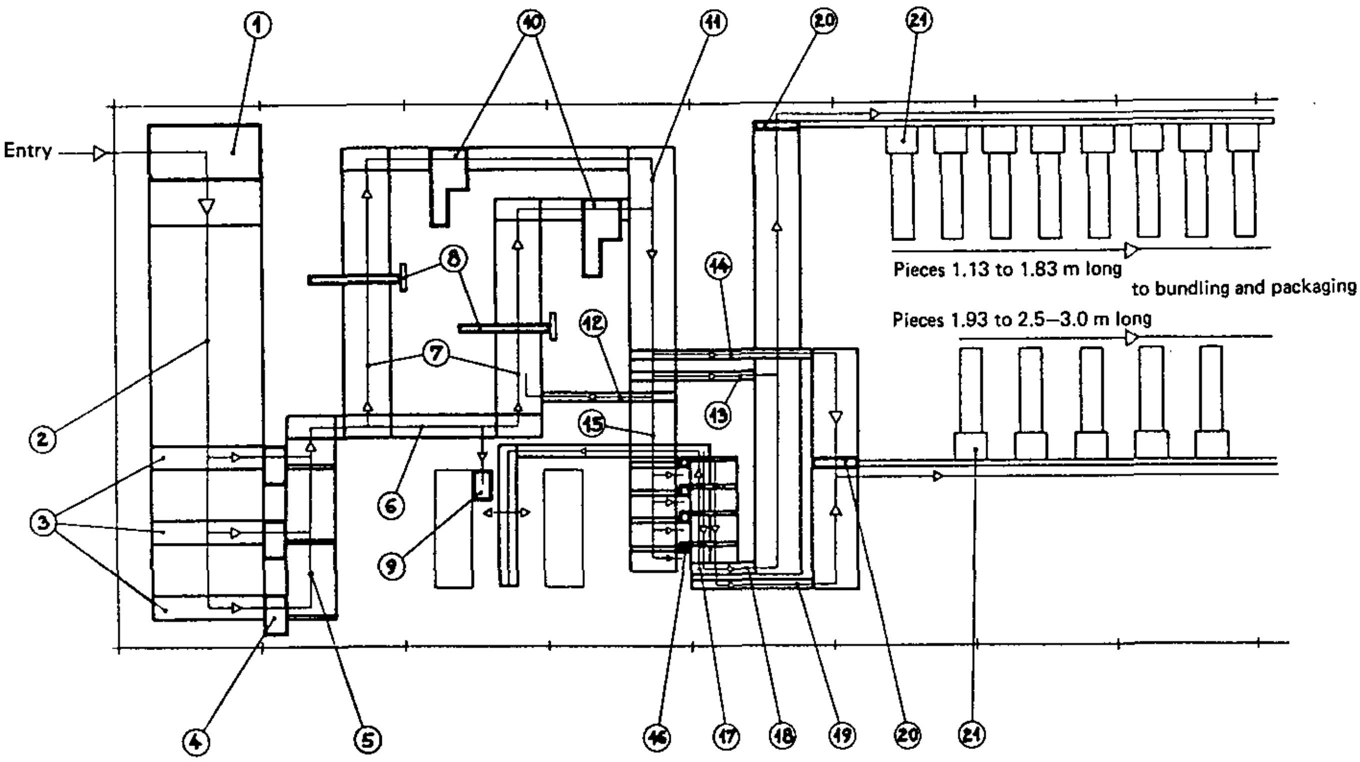


Key:

1 Log transport line
2 Log loader and turner (Simonson)
3 Log carriage (Brenta)
4 Log heading 2.4 m (Brenta)
5 Retractable transfer conveyors
6 Storage and transfer conveyor
7 Automatic ejectors
8 Deflectors
9 Conveyor to transport finished products
10 Main table with rollers
11 In-feed conveyor to the edger/ripper
12 Entry table to the edger/ripper
13 Multi-blade edger/ripper
14 Exit table from the edger/ripper
15 Conveyor for removal of offcuts and slabs
16 In-feed conveyor to the band-resaw
17 Entry table to the band-resaw
18 Resaw 1.5 m (Brenta, murimatic type)
19 Table with rollers
20 Table with rollers to return flitches to the band-resaw
21 Conveyor belt
22 Receiving table (with rollers)
23 Ramp
24 Table with rollers
25 Cross-cutting and trimming line
26 Right-side cross-cut saw
27 Left-side cross-cut saw
28 Automatic transfer station
29 Measurement of lengths

Source: A. Legras, "La scierie de la S.E.P.C. à Greg ben (Côte d'Ivoire)", *Revue bois et forêts des tropiques,* No. 140, 1971.

Figure 12. Layout of a resawing plant



Key:

1 Destacker
2 Feeding chains for cut-off saws
3 Feeding device for cut-off saws
4 Cut-off saws
5 Belt conveyors for cut-to-length products
6 Smooth rollers
7 Feeding conveyors for ripsaws
8 Shadow device for positioning prior to sawing
9 Single blade ripsaw for wide boards
10 Fully automatic four-blade ripsaws
11 General collector of edged material
12 Device for returning pieces with defects to ripsaws
13 Transporter for short top-grade pieces, after checking
14 Transporter for long top-grade pieces, after checking
15 Transporter of pieces with defects to the cut-off saws
16 Set of four cut-off saws
17 Possibility for return of products to the single-blade ripsaw
18 Transporter for short pieces after removal of defects
19 Transporter for long pieces after removal of defects
20 Photo-electric cells to determine the length of the pieces
21 Bins for sorting according to length

Source: J. Froidure, "La scierie du GIMM à Nantes-Chevire, *Revue Bois et Forêts des Tropiques*, No. 126, 1969.

X. Guidelines for the selection of options in establishing wood-based panel industries in developing countries*

Introduction

UNIDO and the Government of China convened the two-week Seminar on Wood-based Panels and Furniture Industries at Beijing from 20 March to 4 April 1981. One week was devoted to wood-based panels, the other to furniture. Following the first week there was a three-hour panel discussion with the theme: "Guidelines for the selection of options in establishing wood-based panel industries in developing countries". The panellists were: Wang Feng Shang, Director and Chief Engineer, Shanghai Wood Industry Research Institute; Ba Ru-You, Beijing Woodworking Plant, expert in particle board production; Chian Ying-Lin, Associate Research Fellow, Institute of Wood Industry, Chinese Academy of Forestry; Xia Zhi-Yuan, Associate Research Fellow, Institute of Wood Industry, Chinese Academy of Forestry; H. P. Brion, consultant in low-cost automation; J. L. Carré, consultant in the production of particle board; G. Heilborn, consultant in the production of plywood; R. Vansteenkiste, consultant in surface finishing of panels; P. Wiecke, consultant in the production of medium density fibreboard; and a representative of UNIDO. The discussion was based on lectures that had been presented on various wood-based panels: plywood;[1] particle boards (including cement-bonded board and oriented strand board and waferboard);[2] fibreboard (including medium-density fibreboard);[3] the surface finishing of wood-based panels;[4] and low-cost automation in the wood-based panels industries.[5]

The discussion enabled the participants to assess better the relative merits and limitations of the products and the problems to be overcome in establishing such industries in developing countries. Comparative tables on raw material, market and technological considerations were filled out during the discussion by members of the panel and the participants (tables 1, 2, 3 and 4). Non-compressed fibreboard ("softboard") was not considered in this comparative study because of its limited potential in developing countries.

Wood-based panels (plywood, particle board and fibreboard and their more specialized variations) are to a large extent interchangeable for many potential end-uses. Most of them are composed of raw material that could also be used to produce any other type of wood-based panel. Many developing countries, however, have not established wood-based panels industries in spite of the fact that the main raw materials (wood or other ligno-cellulosic material) are available.

Raw material considerations

Availability of raw materials

Form of ligno-cellulosic material

Plywood. The production of plywood calls for ligno-cellulosic material in the form of good-quality logs. The diameter of the logs can vary considerably: tropical countries may peel logs of very large diameter, while in Scandinavia diameters of less than 20 cm are peeled. (The equipment needed is similar but quite specialized.)

Fibreboard (hardboard), medium-density fibreboard (MDF) and particle board (with synthetic adhesives or mineral binders). The raw material for these types of board can be in any form (logs, offcuts or chips of wood or agricultural residues). If only chips are used, their size and other characteristics (bark) may affect the properties of the end-products.

Range of species that can be used

Plywood. Most timber species may be used for plywood, provided that they can be peeled (or sliced). In many cases the peeling characteristics can be improved through steaming or other heat treatment: only wood can be used for plywood.

Fibreboard (hardboard). The raw material base for fibreboard can be comprised of a mixture of species, but they should have a limited density range. Wood or ligno-cellulosic material from agricultural residues can be used.

MDF. The raw material for MDF is similar to that for fibreboard, except that the limitations to the range of density are stricter. So far MDF has been produced from wood only, but it could be produced from certain agricultural residues.

Particle board. All wood species in conjunction with synthetic adhesives are acceptable for producing particle board. A wide range of agricultural residues have also been found suitable for this use. Ligno-cellulosic material

*This chapter is based on a panel discussion held during the Seminar on Wood-based Panels and Furniture Industries, Beijing, China, 20 March-4 April 1981. (Some of the Assessments have been updated.) (Originally issued as ID/WG.335/16.)

[1]Wang Feng Shang, "The process of plywood manufacture" (ID/WG.335/7/Rev.1) and Gotthard P. Heilborn, "Recent developments in plywood production" (ID/WG.355/9).

[2]Ba Ru-You, "The manufacture of flat-pressed particle board in the Beijing Woodworking Plant" (ID/WG.335/5) and J. L. Carré, "Recent developments in particle board production" (ID/WG.335/15).

[3]Chian Ying-Lin, "Technology and equipment of a small-scale wet-process hard fibreboard (hardboard) plant" (ID/WG.335/3/Rev.1) and P. H. Wiecke, "Production of medium-density fibreboard" (ID/WG.335/14).

[4]R. Vansteenkiste, "Surface treatment of wood-based panels" (ID/WG.335/10/Rev.1) and Xia Zhi-Yuan, "Decorative laminates" (ID/WG.335/6).

[5]H. P. Brion, "Mechanization and automation possibilities in the wood-based panel industry" (ID/WG.335/4).

used in conjunction with cement should have a low tannin and sugar content.

Chemicals required

Plywood. Urea formaldehyde (UF) is used for interior types of plywood and phenol formaldehyde (PF) for exterior types. In both cases the requirements are roughly 4 per cent by weight of the weight of the timber.

Fibreboard (hardboard). No chemical additives are required if fibreboard is produced by the wet process; approximately 3 per cent phenol formaldehyde (PF) (by weight) is necessary using the dry process.

MDF. MDF calls for the addition of about 9 per cent (by weight) of urea formaldehyde (UF).

Particle board. Between 8 and 10 per cent (by weight) UF is necessary for particle board bonded with synthetic resins. (PF is sometimes used, but it is far less common.) Cement is used as a binding agent for two types of boards; low-density boards (of the wood-wool or wood-chip type) require about 50 per cent (by weight) of cement, while the high-density (smooth surface) boards require about 300 per cent (by weight) of cement.

Cost of raw materials

Cost at source

Plywood. The cost of the veneer logs at the source is always very high compared to the raw materials required for other wood-based panels.

Fibreboard (hardboard), MDF and particle board. The cost of the wood raw material is always low for these boards. If agricultural residues are used, their cost varies and should be determined in each particular case.

Transport and handling costs

Plywood. Transport and handling costs for veneer logs are always high compared to those of the raw materials used for the other wood-based panels.

Fibreboard (hardboard), MDF and particle board. The transport and handling costs are low in all cases where wood is used. If the raw material is an agricultural residue, its cost varies and should be determined in each particular case. Transport and handling costs of timber used for low-density cement-bonded particle board (wood-wool or wood-chip boards) are medium.

Cost of chemicals

The unit costs of the synthetic adhesives (UF or PF) are the same for all types of wood-based panels. By and large, the costs are high in all developing countries, since chemicals often have to be imported. On the other hand, the cost of the cement required for producing cement-bonded particle boards is low.

Need for research and development

Plywood. No further research and development work is considered necessary before introducing the plywood industry in developing countries, other than developing equipment to peel logs of smaller diameter or down to a smaller core.

Fibreboard (hardboard) and MDF. If the raw material is wood, no further research and development is needed. If, on the other hand, it is an agricultural residue, some research and development work will most probably be needed.

Particle board. When using wood and synthetic resin, no further research and development work is needed. The tannin and sugar content of the wood raw material might have to be tested before using it for cement-bonded particle boards. As in the case of fibreboards, if agricultural residues are used, some research and development work will most probably be needed.

A synopsis of the raw material considerations is presented in table 1.

Market considerations

Size of the market in developing countries

Present and potential markets

Plywood. Local markets for plywood are generally good in countries with abundant raw material (wood) in the early stages of development of a panel industry, although the potential must be considered less good owing to the eventual encroachment by other wood-based panels when plants to produce them are established.

Fibreboard (hardboard). Both the present and potential local markets are considered good.

MDF. Although the present market is limited, the potential market for this product is considered to be very good.

Particle board. The present market is considered to be good, while the potential of the market is rated very good.

The present and potential export market

Plywood. The present export market for plywood is considered to be good. It is believed that the potential export market for this product is even better (very good).

Fibreboard (hardboard). The present export market is limited, and the potential export markets for fibreboard are rated very low.

MDF. MDF is a relatively new product, and at present production facilities are small. The present export market is small, and it is estimated that export potential is limited.

Particle board. Both the present and potential export markets for all types of particle board are limited.

Promotion requirements

Plywood and fibreboard (hardboard). No promotion is required to develop local or export markets for these products.

MDF. Since this is a relatively new product, serious promotion campaigns must be planned and carried out to develop both local and export markets.

Particle board. Both synthetic adhesive-bonded and cement-bonded particle boards need to be promoted on the local market. Synthetic adhesive-bonded particle board needs no promotion on export markets.

Table 1. Raw materials considerations

Aspect	Plywood	Fibreboard (hardboard)	Medium-density fibreboard	Particle board
Availability				
Form of ligno-cellulosic material	Logs	Logs, offcuts and chips	Logs, offcuts and chips	Logs, offcuts and chips
Range of species	Most species	Only a limited density range	Even more limited than for fibreboard	All species
Chemicals needed	UF or PF: ± 4%	Wet process: 0 Dry process: 3% PF	UF: + 9%	UF: 8-10% Cement: 50% for low-density 300% for high-density board
Cost				
Cost at source:				
Wood	Very high	Low	Low	Low
Agricultural residue	n.a.	Depends on local conditions	Depends on local conditions	Depends on local conditions
Transport and handling:				
Wood	High	Low	Low	Low
Agricultural residue	n.a.	Depends on local conditions	Depends on local conditions	Depends on local conditions
Chemicals:				
UF and PF	High[a]	High[a]	High[a]	High[a]
Cement	n.a	n.a.	n.a.	Low
Need for R and D				
Wood	None	None	None	None for UF bonded boards
Agricultural residue	n.a.	Further R and D often needed	Further R and D often needed	Further R and D often needed for cement-bonded boards

Note: n.a. = not applicable.

[a]In most developing countries.

Range of applications

Markets for panels as produced

Plywood. The range of applications for plywood is very large.

Fibreboard (hardboard). The range for this type of panel is limited owing to the panel's properties and characteristics.

MDF. The range of applications for MDF is special and is broader than for both hardboard and particle board.

Particle board. The range of applications is large.

Markets for panels in vertically integrated plants

Plywood. The range of applications is even larger than if raw sheets are marketed.

Fibreboard (hardboard). Although the range is enlarged through integration, it is still limited.

MDF. The range of applications is improving and could be very good.

Particle board. Vertical integration improves the range of applications which is even larger than that of MDF and thus very good.

Versatility

Plywood. Plywood is the most versatile wood-based panel, since it can be used both for interior and exterior applications.

Fibreboard (hardboard). Fibreboard is the least versatile wood-based panel. It can be used only for interior applications.

MDF. Although MDF can be used only for interior applications, it is more versatile than hardboard and as good as particle board.

Particle board. UF-bonded particle board can be used only for internal applications. These nevertheless are quite varied. The applications for cement-bonded particle board are more limited. Although it is an "exterior" type of board, it can only be used for construction.

Price range

Plywood. Plywood is the most expensive type of wood-based panel.

Fibreboard (hardboard). In countries with a surplus of timber, hardboard is the second lowest wood-based panel price-wise (after low-density cement-bonded boards). In timber deficient countries where no cement-bonded boards are usually produced, hardboard, although selling at higher prices, is still the lowest priced wood-based panel.

MDF. In countries with a surplus of timber, MDF is the second most expensive wood-based panel (after plywood); in timber deficient countries where no plywood is produced, it would be the most expensive type of wood-based panel.

Particle board. In countries having a surplus of timber, synthetic resin-bonded particle board would be priced between hardboard and MDF. In timber deficient countries the position of particle board remains unchanged but prices would be higher. Low-density cement-bonded particle board is the lowest priced wood-based panel. On the other hand, the price of high-density cement-bonded particle board is higher than that of UF-bonded board and of the same order of magnitude as MDF.

A synopsis of market considerations is presented in table 2.

Table 2. Synopsis of market considerations

Aspect	*Plywood*	*Fibreboard (hardboard)*	*Medium-density fibreboard*	*Particle board*
Size of market				
Local market:				
Existing	Very good	Good	Limited	Good
Potential	Good	Good	Very good	Very good
Export market:				
Existing	Good	Limited	Low	Very low
Potential	Very good	Very low	Limited	Very low
Promotional requirements				
Local market	None needed	None needed	Needs promotion	Needs promotion (for all types of panels)
Export market	None needed	None needed	Needs promotion	None needed
Range of application				
Panels as produced	Very good	Limited	Medium	Good
Improved panels	Better than normal panels	Better than normal product, but still limited	Good	Very good
Versatility	Most versatile type of panel (interior and exterior use)	Least versatile (only interior use)	Better than fibreboard, but not as versatile as particle board (interior use only)	UF-bonded board: varied applications (only interior use) Cement-bonded board: only construction (interior and exterior use)
Price range[a]				
Timber surplus countries	5	2	4	UF-bonded boards: 3 Cement-bonded boards: Low density: 1 High density: 4
Timber deficient countries	—[b]	3	5	UF-bonded boards: 4 Cement-bonded boards: —[b]

[a]Rated from 1 (lowest) to 5 (highest).
[b]Unlikely to be produced locally.

Technological considerations

Wood raw material yield[6]

Plywood. Plywood has the lowest yield among the various wood-based panels, of the order of 40 to 50 per cent. Furthermore, the raw material used is the most expensive.

Fibreboard (hardboard). The yield is relatively good, of the order of 75 per cent.

MDF. The yield is very good, of the order of 90 per cent.

Particle board. The yield for synthetic adhesive-bonded particle board and high-density cement-bonded particle board could also be 90 per cent. For low-density cement-bonded particle board, it varies considerably, depending on the type of raw material used. It could be as low as 50 per cent for some types of wastes.

[6]It is impossible to give yields for non-wood raw materials (agricultural residues), as these would vary considerably from material to material.

Technological level

Stability for developing countries

Plywood. The technology for producing plywood is simple. It is most suitable for developing countries.

Fibreboard (hardboard). Two technological processes exist: the wet and the dry process. There are two manufacturing systems for the wet process: the batch (or Deckle box) system, a simple process suited to all developing countries; and the continuous (conventional process) system, which might be considered too advanced for countries at an early stage of development. The dry process is more sophisticated and recommended only for more advanced developing countries.

MDF. The MDF process is relatively new. It would only be suitable for more advanced developing countries.

Particle board. The flat-pressed, synthetic-bonded and cement-bonded processes (for high-density boards) are suitable for almost all developing countries. (The extruded particle board process has been superseded. It is used only for very specific applications, e.g. in construction of partitions.) On the other hand, the process for producing low-density cement-bonded boards is very simple and suited for all developing countries.

Maintenance of equipment

Plywood. The equipment is simple and easy to maintain.

Fibreboard (hardboard). The equipment used in the wet process is relatively unsophisticated, and its maintenance is considered to be of a medium level. That used in the dry process is more sophisticated and hence difficult to maintain in most developing countries.

MDF. As in the case of the dry process fibreboard, the process is sophisticated and the equipment would be difficult to maintain in most developing countries.

Particle board. The equipment used to produce low-density cement-bonded particle board is very simple and hence easy to maintain in all developing countries. On the other hand, that used to produce synthetic resin-bonded particle board and high-density cement-bonded particle board is relatively sophisticated, and its maintenance is of a medium level.

Industrial infrastructure

Plywood. Only simple industrial infrastructure, which is available in almost all developing countries, is needed.

Fibreboard (hardboard) and MDF. A medium level of industrial infrastructure is needed for these types of wood-based panels.

Particle board. The production of flat-pressed, synthetic-bonded or high-density cement-bonded boards calls for a medium level of industrial infrastructure. On the other hand, the production of low-density cement-bonded boards calls for only minimal industrial infrastructure.

Need for research and development

The production of plywood in developing countries calls for limited research and development work. The production of the other wood-based panels calls for a medium amount of research and development if the raw material to be used is wood and a high level of research and development if it is an agricultural residue (depending on the type of residue to be used).

Operation of the process

Plywood. It is possible to produce plywood on a one-shift basis.

Fibreboard (hardboard). One-shift operation is possible only if the wet discontinuous (Deckle box) process is used. The other processes (conventional and dry) call for the continuous operation of the plant.

MDF. Production calls for the continuous operation of the line.

Particle board. The production of low-density cement-bonded particle board is the only type of particle board that can easily be produced on a shift basis. The production of synthetic resin-bonded and high-density cement-bonded particle board on a one-shift basis, although feasible, is technically difficult and should be avoided if at all possible.

Minimum economic capacity

For all wood-based panels, two levels of minimum economic capacity exist: one is for a plant to cater for the local market, enjoying a certain amount of protection, and the other is for a plant that would be competitive on the world market.

Plywood. The minimum economic capacity in the first case would be of the order of 7,000 m^3 of finished product per year, while in the second case (producing from tropical hardwood logs) it would be of the order of 42,000 m^3 of plywood.

Fibreboard (hardboard). The minimum economic capacity would be 15 to 20 tonnes per day and 75 tonnes per day, respectively.

MDF. The minimum economic capacity would be 50 to 75 tonnes per day and 150 tonnes per day, respectively.

Particle board. The figures for low-density cement-bonded particle board are very low (1,000 to 2,000 m^3 per annum); exports of this product are unlikely. The corresponding figures for the other types of particle board (synthetic resin-bonded boards and high-density cement-bonded boards) are 20 to 30 m^3 per day for plants catering only for the local market and approximately 150 m^3 (approximately 200 tonnes for cement-bonded board) per day for plants that will export.

Energy requirements

Electric power requirements

Plywood. The power requirements to produce plywood are low.

Fibreboard (hardboard). The power requirements are high (more than for particle board, but less than for MDF).

MDF. The power requirements are the highest for the wood-based panels, but not considerably more than for hardboard.

Particle board. The power requirements are about medium, i.e. less than for fibreboard but more than for plywood, for all types of particle boards except low-density cement-bonded board. The power requirements for that type of panel are very low (less than plywood).

Fuel (heating) requirements

Plywood. No external fuel is needed if the plant burns its waste.

Fibreboard (hardboard). Fuel requirements are high for both the wet and the dry process, being higher for the latter than for the former.

MDF. Fuel requirements are high.

Particle board. Fuel requirements are about medium for synthetic adhesive-bonded particle board and high-density cement-bonded particle board. No fuel is needed to produce low-density cement-bonded particle board.

Water requirements

Plywood. The production of plywood requires only very small quantities of water.

Fibreboard (hardboard). The wet process has a very high water requirement (unless the technologically sophisticated closed circuit is used, in which case an average amount of water would be needed). Water requirements for the dry process are small.

MDF. Water requirements for this product are also small.

Particle board. Water requirements are rated small for synthetic resin-bonded particle boards; they are average for cement-bonded particle board.

Ecological considerations

Plywood. The production of plywood causes only small ecological problems, that are easy to overcome.

Fibreboard (hardboard). The production of hardboard by the wet process poses very serious ecological problems. The dry process poses fewer problems.

MDF. Ecological problems exist in the production of MDF; however, they are considered to be only of medium severity.

Particle board. There are problems if synthetic resin-bonded particle board is produced, but there are few problems if the binding agent is cement.

A synopsis of the above considerations is given in table 3.

Table 3. Synopsis of technological considerations (from the point of view of developing countries)

Aspect	*Plywood*	*Fibreboard (hardboard)*	*Medium-density fibreboard*	*Particle board*
Wood raw material yield	40-50%	75%	90%	Resin-bonded and high-density cement-bonded: 90% Low-density cement-bonded: 50-70%
Technological level				
Suitability for developing countries	Simple. Most suitable	Wet process, batch: simple, suitable; wet process, conventional: suitable for many countries; Dry process: suitable only for more advanced developing countries	Suitable only for more advanced developing countries	Synthetic resin-bonded board and high-density cement-bonded board: suitable for most developing countries Low-density cement-bonded: suitable for all countries
Maintainability of equipment	Simple	Wet process Medium dry process: sophisticated Medium	Sophisticated	Synthetic resin-bonded board and high-density cement-bonded board: medium Low-density cement-bonded board: very simple
Industrial infrastructure required	Simple	Medium	Medium	Medium, except for low-density cement-bonded board: very simple
Research and development needed	Limited	Wood raw material: medium; agricultural residues high	Wood raw material: medium; agricultural residues high	Wood raw material: medium; agricultural residue: high
Operation of process	One shift operation possible	Process must be continuous (except the Deckle box process)	Process must be continuous	Synthetic resin-bonded and high-density cement-bonded boards: one-shift operation difficult; low-density cement-bonded board: one-shift operation easy
Minimum economic capacity (finished product)				
Local market Export market	7,000 m³/year 42,000 m³/year	15-25 tonnes/day 75 tonnes/day	50-75 tonnes/day 150 tonnes/day	Synthetic-bonded and high-density cement-bonded boards: 20-30 m³/day and 150 m³/day Low-density cement-bonded boards: very low
Energy requirements				
Electric power	Low	High	Higher	Synthetic resin-bonded boards, high-density cement-bonded boards: medium Low-density cement-bonded boards: very low
Fuel (heating)	None (if waste material is normally used)	Wet process: higher; dry process: high	High	Synthetic resin-bonded boards and high-density cement-bonded boards: medium Low-density cement-bonded boards: none

Aspect	Plywood	Fibreboard (hardboard)	Medium-density fibreboard	Particle board
Water	Very small amount	Wet process: very high amount; Dry process: small amount	Small amount	Synthetic resin-bonded boards: small amount Cement-bonded boards: medium amount
Ecological considerations:	Small problems	Wet process: very serious problems Dry process: medium problems	Medium problems	Synthetic resin-bonded boards: medium problems Cement-bonded boards: few problems

Manpower and capital requirement considerations

Manpower requirements

Plywood. Skilled personnel are needed to operate a plywood plant; they could be trained on the job. Unskilled personnel would pose no problem. Expatriates are normally not needed.

Fibreboard (hardboard). All the skilled personnel, except for electricians and mechanics, could be trained on the job. Unskilled personnel would pose no problem. A few expatriates would be needed to operate initially a wet-process plant, and a larger number would be needed to operate initially a dry-process plant.

MDF. The situation is similar to that described for the dry-process fibreboard (above).

Particle board. The situation for plants producing synthetic resin-bonded boards and high-density cement-bonded boards is similar to that described for the wet-process fibreboard (above). For low-density cement-bonded boards, skilled workers could be trained on the job. Unskilled workers pose no problems, and no expatriates would be needed.

On-the-job training of skilled workers is necessary, but there is no need for any training abroad for any of the plants.

Capital requirements for a minimum-capacity plant

Plywood. Capital requirements are relatively low, broken down approximately evenly between local and foreign currency.

Fibreboard (hardboard). Capital requirements are rated medium, broken down approximately into 30 per cent in local currency and 70 per cent in foreign currency. This applies to both the wet and the dry processes.

MDF. The situation is similar to that of hardboard. Capital requirements are higher (because of the larger minimum capacity).

Particle board. Capital requirements for synthetic resin-bonded board are rated low to medium. The breakdown is approximately 30 per cent in local currency and 70 per cent in foreign currency. For high-density cement-bonded boards, the capital requirements are rated medium to high, the breakdown being along the same lines as for resin-bonded boards. Low-density cement-bonded boards require very low investments by wood-based panels standards. The breakdown is approximately 20 per cent in local currency and 80 per cent in foreign currency.

A synopsis of manpower and capital requirements is given in table 4.

Table 4. Manpower and capital requirements

Aspect	Plywood	Fibreboard (hardboard)	Medium-density fibreboard	Particle board
Manpower requirements				
Local:				
Skilled workers	Could be trained on the job	Could be trained on the job (except for electricians and mechanics)	Could be trained on the job (except for electricians and mechanics)	Could be trained on the job (except for electricians and mechanics)
Unskilled workers	No problem	No problem	No problem	No problem
Expatriate requirements	Normally not needed	Wet process: few needed; dry process: some needed	Some needed	Synthetic resin-bonded board and high-density cement-bonded board: few needed Low-density cement-bonded board: none needed
Training:				
On the job	Needed	Needed	Needed	Needed
Abroad	Normally not needed	Not needed	Not needed	Not needed
Capital requirements				
Total value	Relatively low	Medium	Medium	Synthetic resin-bonded boards: low to medium

Table 4 *(continued)*

Aspect	*Plywood*	*Fibreboard (hardboard)*	*Medium-density fibreboard*	*Particle board*
Capital requirements (continued)				
Total value *(continued)*				High-density cement-bonded board: medium to high Low-density cement-bonded board: very low
Local currency	± 50%	± 30%	± 30%	Synthetic-bonded board and high-density cement-bonded board: ± 30% and ± 70%, respectively
Foreign currency	±50%	± 70%	± 70%	Low-density cement-bonded board: ±20% and ± 80%, respectively

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 that are normally used for furniture, furnishing components and doors. The second category comprises those that 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 (for on-site and do-it-yourself construction).

The characteristics of various types of panels

Particle boards bonded with synthetic resin

Wood is transformed into chips, which are mechanically broken into particles of the required size and dried. A synthetic resin usually urea formaldehyde-based, thermosetting binder and other complementary substances are added and mixed, and a small quantity of water-repellent material (mineral wax) is generally added to provide a limited amount of waterproofing. If furniture and other products may be subject to biological degradation (fungal and insect attack), a suitable protective chemical agent may be added.

Panels are formed, compacted and bonded in heated presses. Using modern equipment, these panels can be made as large as 30-50 m^2, and panels of any length can be produced by a continuous process. They may be cut to size as needed, and result in smaller offcuts. Panel thickness can be from 2.5 to 400 mm, thereby satisfying a wide range of requirements. Density can vary from 350 kg/m^3 to 800 kg/m^3; the least dense panels are made from wood or other cellulose-based materials and are generally thicker than 15 mm. Elastic-mechanical characteristics are relatively as good as those of better-quality plywood and denser particle boards. The large panel is gaining worldwide 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.

Particle boards bonded with synthetic resins having high resistance to humidity and water

The physical structure of particle boards bonded with water-resistant resins and the production facilities are identical to those containing ordinary resins. The only difference is in the bonding synthetic resins and additives used; they are phenol and formaldehyde based or belong to the melamine group and are thermosetting. Once they have polymerized, they do not react with water. Other synthetic resins have been studied, but they are still in an experimental stage.

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: *(a)* to limit, as far as possible, the swelling of the wood particles by adding water-repellent substances; *(b)* to prevent biological degradation, particularly by mildew and fungal agents, by adding protective chemicals; and *(c)* to fireproof the panels in many cases.

Medium density fibreboards manufactured by a dry process

Medium-density fibreboard (MDF) panels are an alternative to resin-bonded boards, 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 from 600 to 700 kg/m^3. These panels can be produced in very large sizes, but no continuous production plants have been established. Elastic-mechanical characteristics are similar to those for particle board. Owing to the greater amount of energy required to defibre the wood and because more raw material is used for a given panel thickness, as well as for 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

As in the case of MDF, the first processing step is to defibre the wood; fibres may then be processed into boards by either a wet or a dry process. In the wet process, lignin contained in the wood acts as a binder. Limited amounts of added synthetic resins act as additional binders. For the dry process, fibres are bonded with synthetic resins similar to those used for particle board.

Very large hard and semi-hard boards can be produced by the dry process. As far as is known, no continuous production plants have been built. Minimum thickness is usually 2.5 mm, and maximum thickness is 7-8 mm, for

*By M. Bermani, engineer, technician, expert in the production of fibre panels. (Originally issued as ID/WG.277/4/Rev.1.)

both hard and semi-hard boards. The weight is greater than that of an equally thick normal type particle board. Production facilities are similar to those for the two types of boards previously described.

Mineralized wood-wool boards

Bonding ingredients are Portland type or magnesium cement and a loose mass of wood wool or shavings. Thicknesses ranges from 20 to 100 mm and density from 360 to 570 kg/m^3. The panels are extremely porous and therefore fairly light. The main advantages are good heat and sound insulation; high permeability to air; resistance to mildew, fungus and insects; and resistance to moisture and fire. However, mechanical strength is low. These panels 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 attics.

Cement wood-chip boards

Relatively large wood particles are prepared, partially dried and, after undergoing a "mineralizing" treatment, 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 can be from 500 to 700 kg/m^3. The mechanical strength is higher and the field of applications wider than for mineralized wood-wool panels. 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" or "lost" 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 false ceilings, floor foundations, internal and external facing on perimeter walls, internal partition walls etc.

Particle boards bonded with lyes of lignin bisulphite

Production of this type of board is relatively recent. It can be produced economically only if there are pulp or paper mills located close by that 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 like 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. It can be shortened by adding thermosetting phenolic resins to the lyes and by heating the panels under pressure with high-frequency electric heating equipment. 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 used 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, which have gone into industrial production in the last 10 years, have many applications in modern building. Their cost may be less than synthetic resin-bonded particle board panels, manufacture is somewhat easier, and weatherproofing is 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 owing to humidity changes. 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 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. 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, when 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, partitions and perimeter walls (combined with other materials) etc., owing to their excellent resistance to fire, humidity, atmospheric agents, mildew, fungal agents, insects and chemicals. Sound-deadening properties are high and, although inferior to that of normal panels, heat insulation is satisfactory. The boards may be used to advantage for built-in shuttering for normal concrete and reinforced concrete casts. 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 MDF and hard and semi-hard fibreboards, the wood must be defibred and bonded by wet processes. Natural ligneous substances are used as binders. Owing 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 good heat insulation. The boards are used for all 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 is available over a long period of time 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 the 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 billets 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 used mainly 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 MDF. 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 and machining harder.

Characteristics of the six types of panel that 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 that 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.

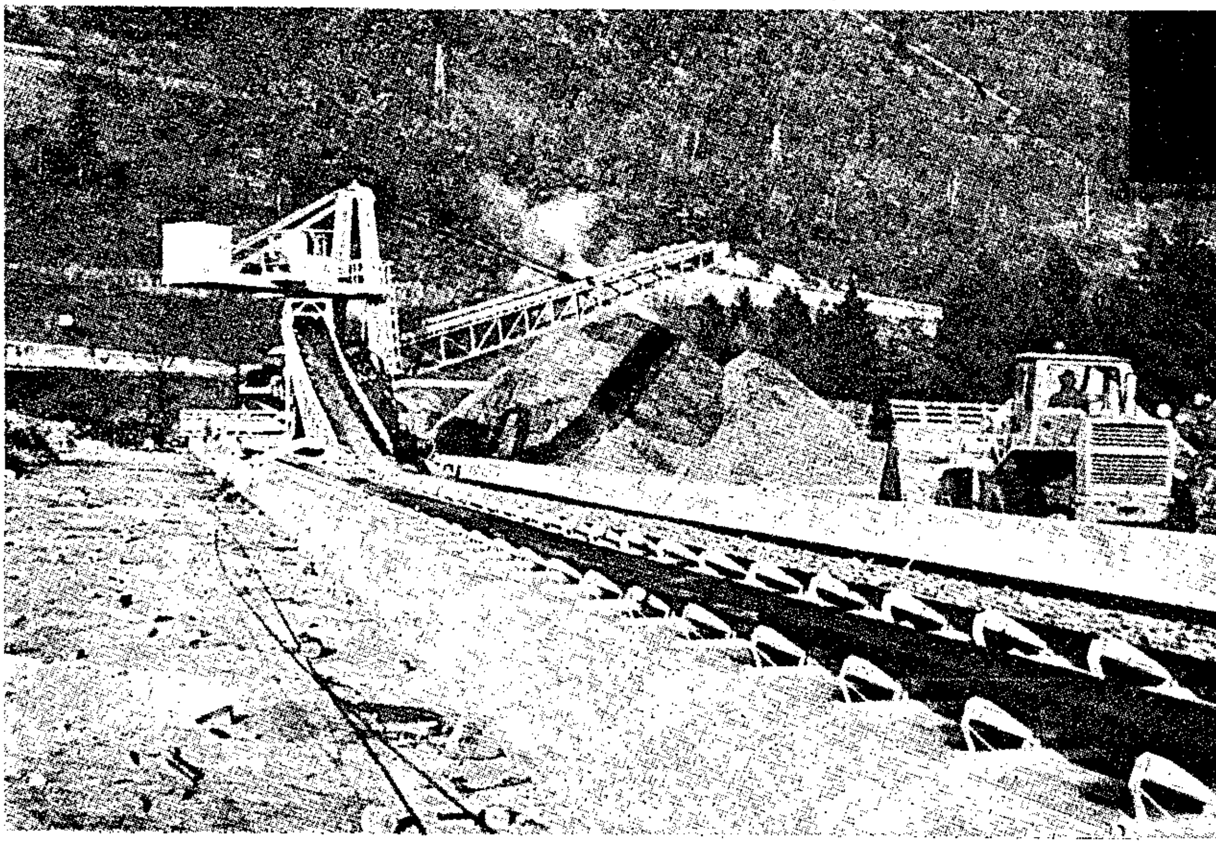
Raw material may be of only one type or may consist of different materials to be used concurrently, in fixed proportions, in the initial production step. In the case of sawdust obtained from other operations, storage in silos is feasible. Other raw materials are normally stored in the open.

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, stocks 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 that will arrive at the factory. It is also important to consider the 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. Weather-proofing 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 a 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 raw material received is shown in figure 1. For raw material in the form of small billets or branches, stacking is normally done by a vehicle with a hydraulic scoop. Manoeuvrability 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 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 conveyor system may be useful for stocks that cover a small area, when withdrawals are carried out in a continuous process and where stocks are situated close to the factory.

Figure 1. Equipment for storing and transporting raw material



For piling small pieces or bulk materials, mechanical loading shovels may be used. If the material is sufficiently small and uniform, belt conveyors (bucket or hydraulic types) may also be used for transport to the factory. Details are given later in this chapter 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. By-products of plants from which textile fibres have already been extracted, such as hemp stalks and flax straw, and from which all fibrous residuals must be removed mechanically, are also not considered (nor, for that matter, are aspects covering the de-pitting of bagasse).

For the production of panels having three or more clearly differentiated layers, the process begins with separating the raw material used in the core from that used for the faces. 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, billets not yet debarked can be used for external layer particles, while lower-grade assortments such as branches or faggots are chipped for use in the core (figure 3). In these cases, each group of materials is stored separately with its 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 the particle size decreasing from the centre to the 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. Particles are produced in two or three successive phases. Raw material can be purchased in the form of edgings, offcuts, slabs, or branches etc. or in chip form for ease of transport; these chips are never delivered with the final geometrical requirements and have to be given the geometric characteristics prescribed by the technology used. This production of relatively coarse material is done with knife hogs or knife clippers, as shown in figures 5 and 6. For small logs (billets) or saw mill by-products (slabs and off-cuts), disc-type chippers can be used. The material is conveyed, at a predetermined angle, to a rotating disc fitted with a series of blades, which cut the material into lengths varying from 20 to 40 mm. The disc diameter varies from 1,000 to 2,000 mm, and production can exceed 150 m^3/h.

Figure 2. Chip-handling equipment

Figure 3. Sorting different species for core and face layer chips

A drum type chipper is more advisable, however, particularly because it can handle a wider variety of forms of woods. It is also suitable for veneer off-cuts, small diameter brush wood or other materials that 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 conveyor belt followed by a set of toothed rollers, the lower ones being fixed and the upper ones oscillating to adapt to the thickness of the material involved being chipped. Important requirements for chippers are strength and simplicity as well as wear resistance for the parts that 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 conveyor 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 conveyor 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 that 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.

Figure 4. Infeed conveyor for chipper line

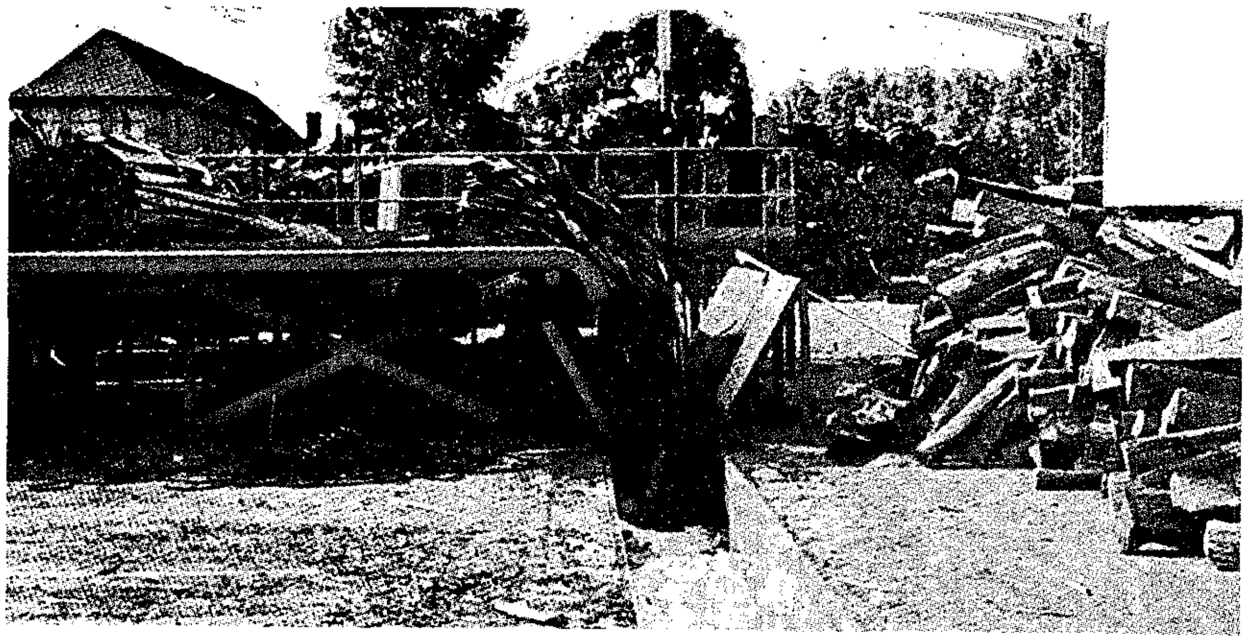
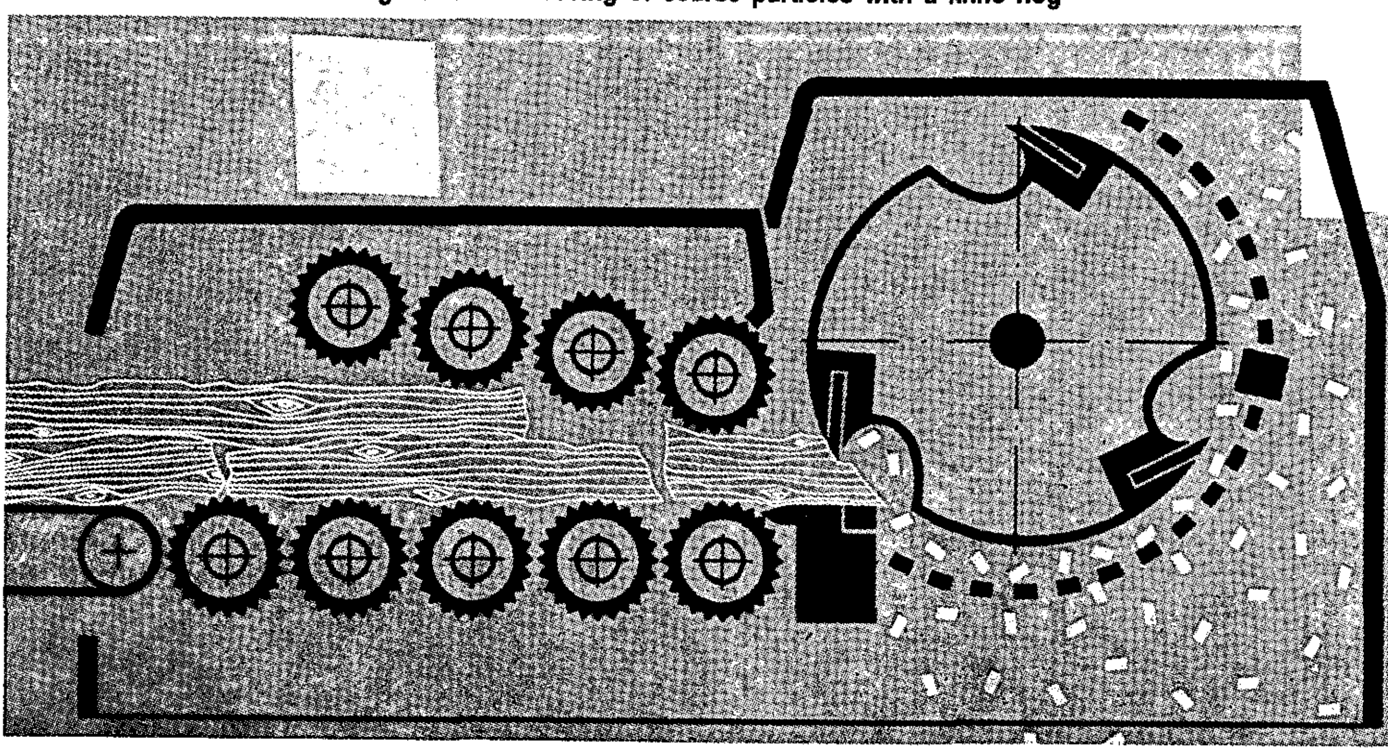


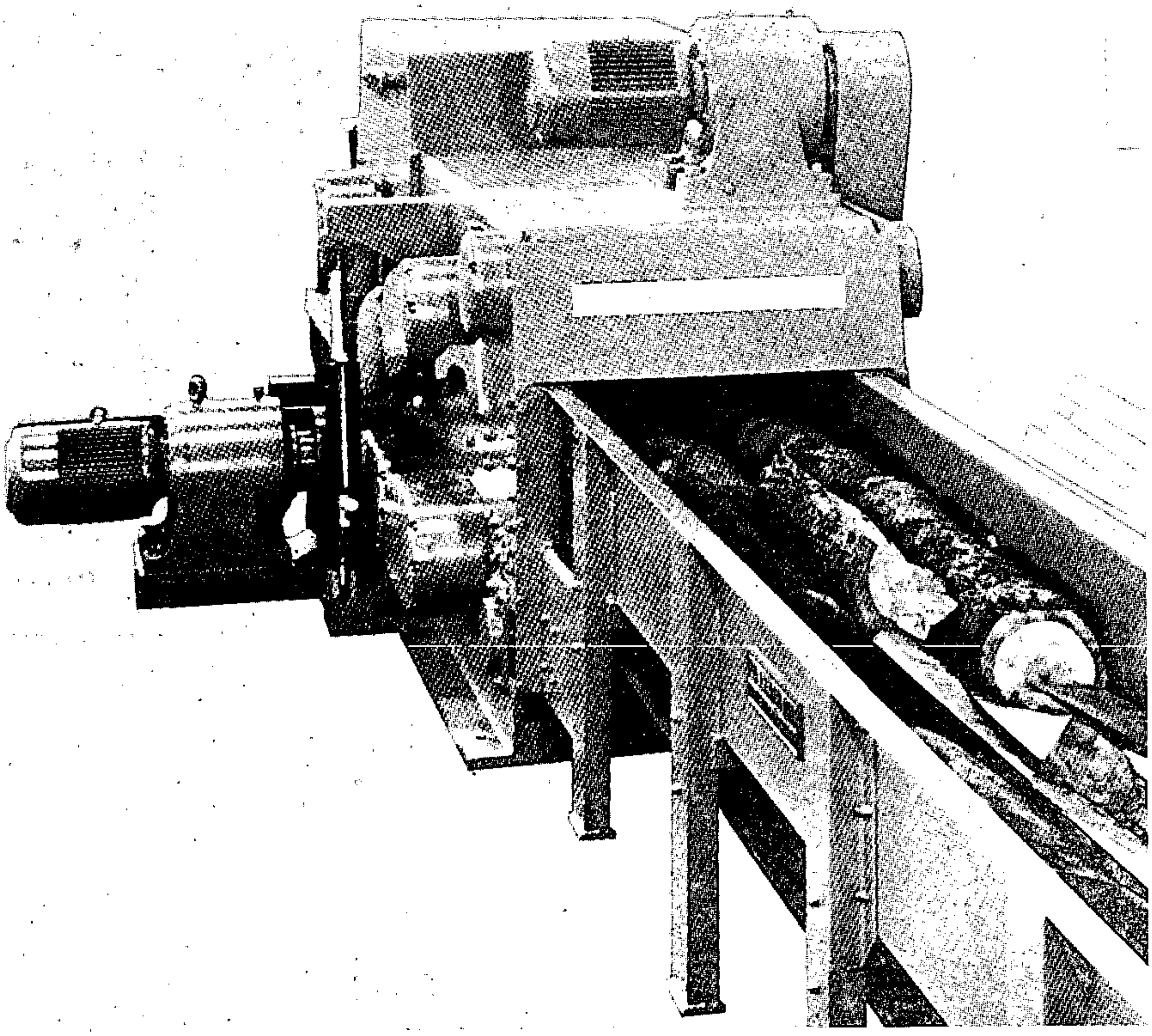
Figure 5. Processing of coarse particles with a knife hog



The arrangement of the counter-blade relative to the characteristics 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 the 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 life 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 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 replaced. Blade projection must be accurately set. The preferred system is one that 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. The 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 make lubrication difficult. For this reason, of all the systems for driving the conveyor belt and the feed rollers, one 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 6. Heavy-duty knife chipper with infeed chute



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 wood in many different forms, it must be solidly built throughout and require minimum maintenance, it must have minimum downtime 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 (see figures 8 and 9). 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. 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 7. Chipper drum with wedge system

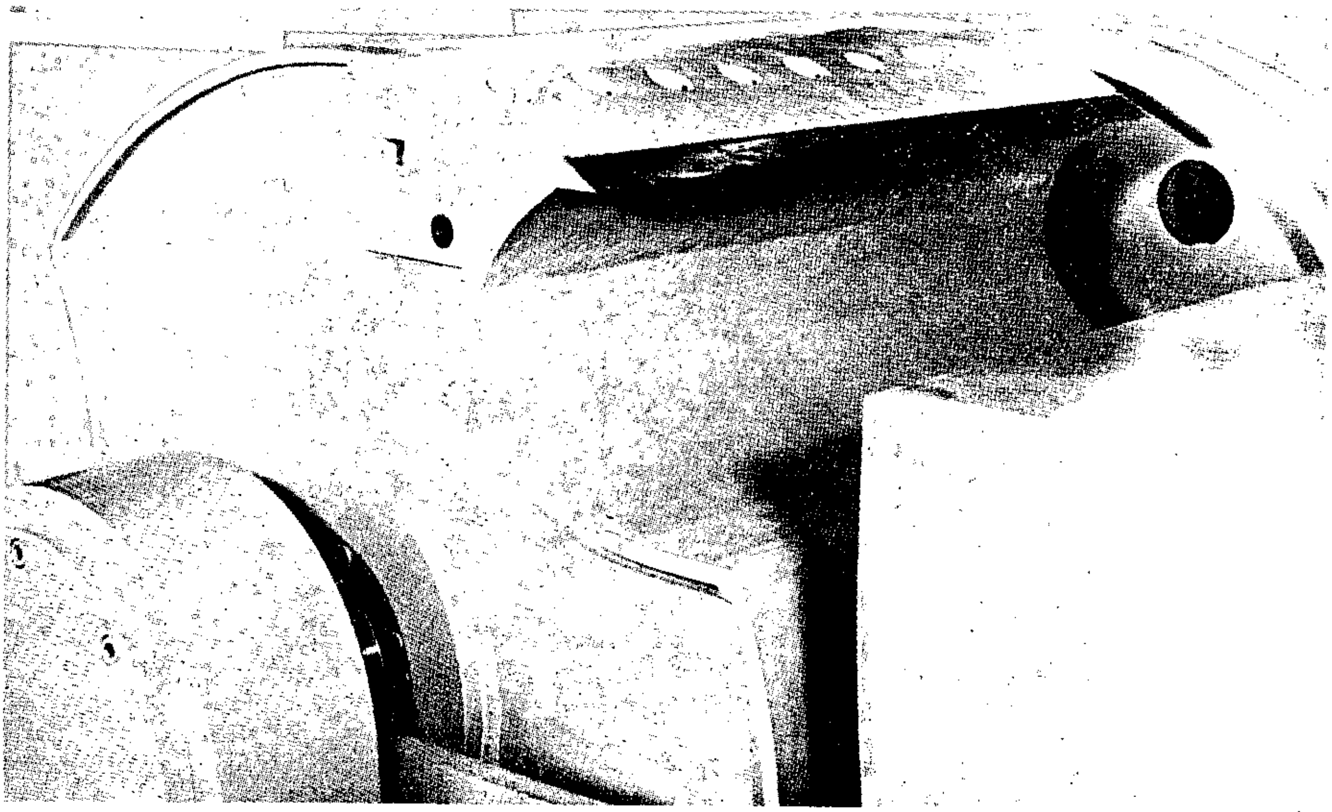


Figure 8. Chipper for short lumber and waste material

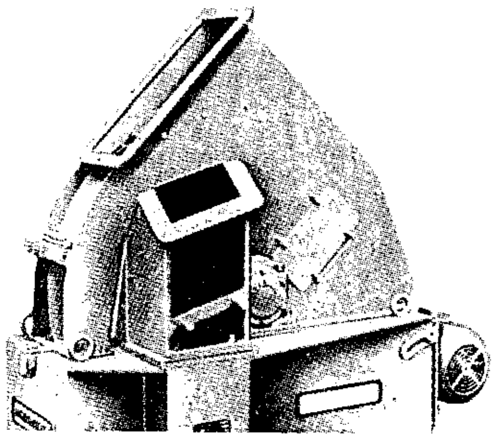
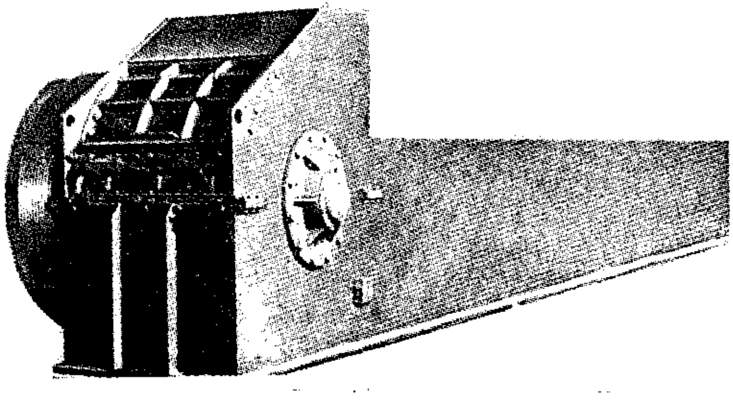


Figure 9. Chipper for processing bales of agricultural by-products



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 that operate on chips (either purchased or prepared on the machines described above) or already broken up material; and those that operate only on relatively long pieces, albeit pieces of small cross-section. In the first category are flakers with a rotating knife holder cage (figure 10). The one most often recommended is the double-flow type (figure 11). This is composed of an internal rotor with vanes and an 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. The 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

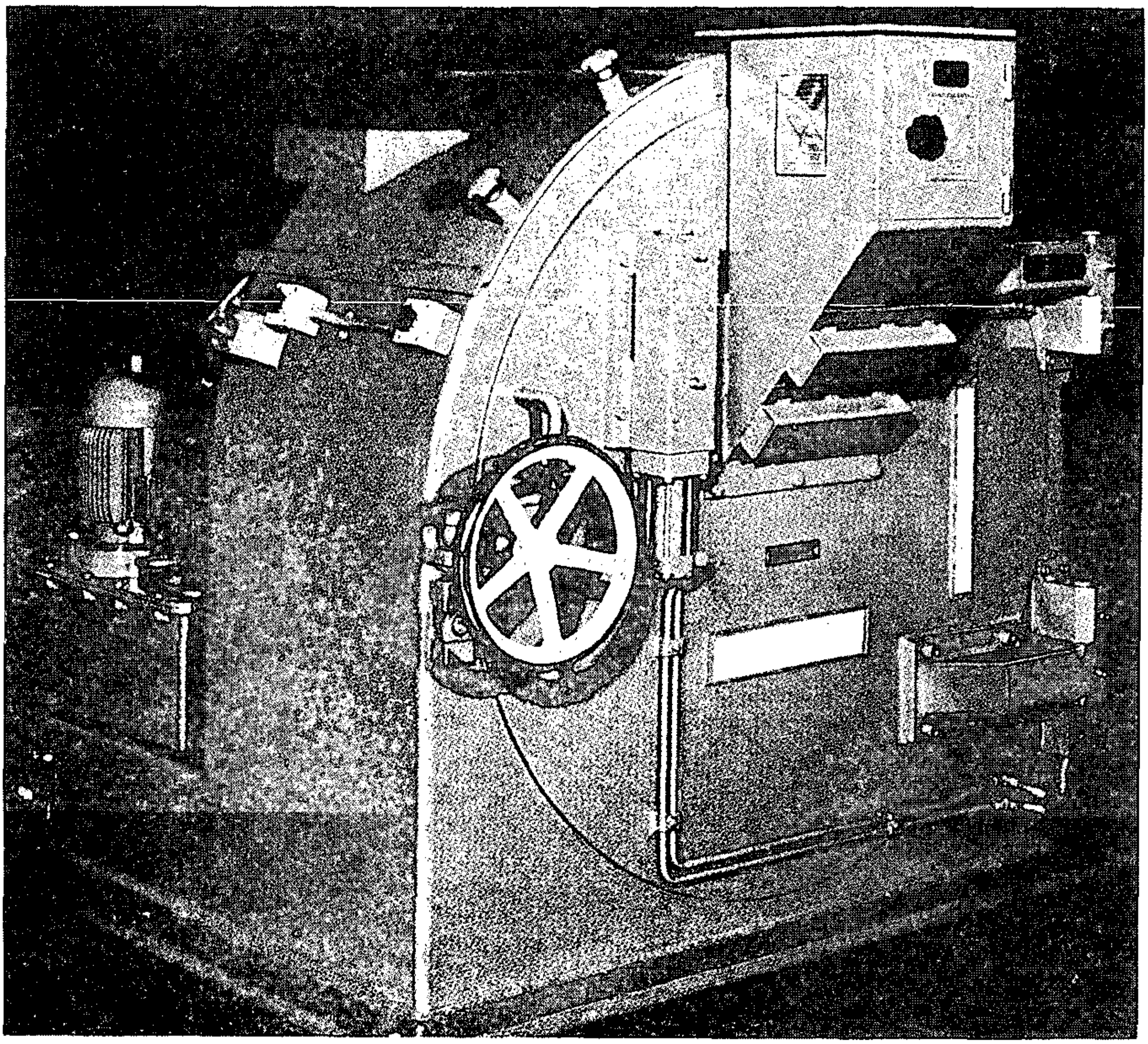


Figure 11. Schematic drawing of the flaking process

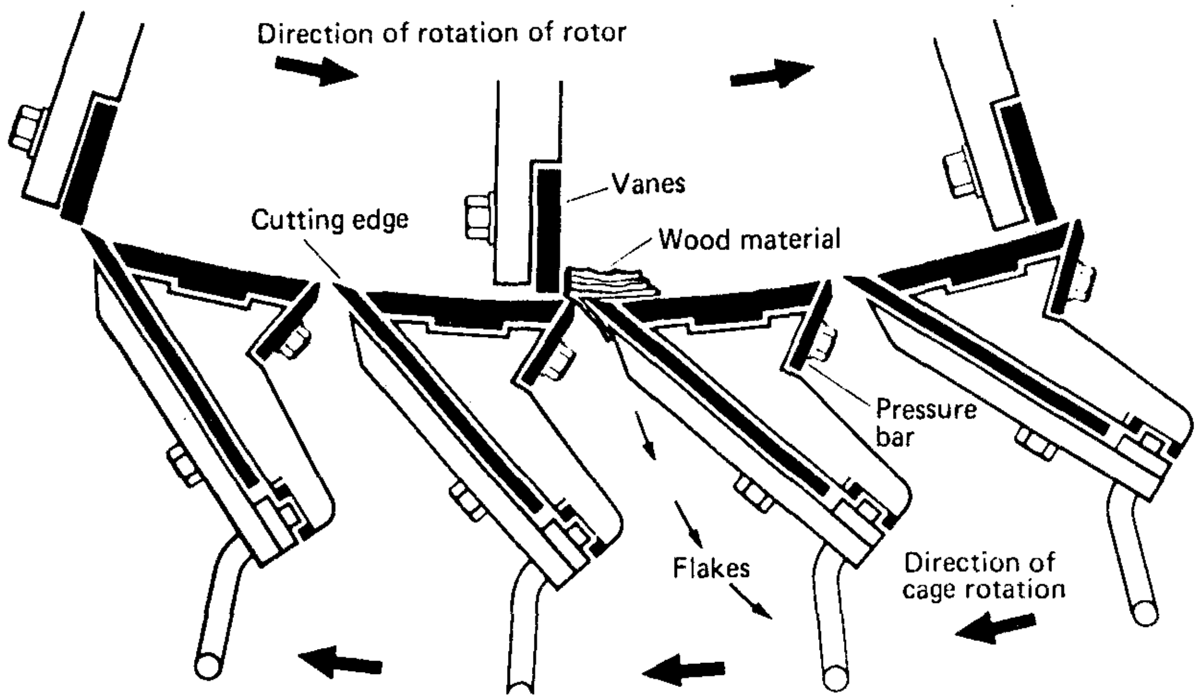


Figure 12. Push-button controlled hydraulic system of the flaker

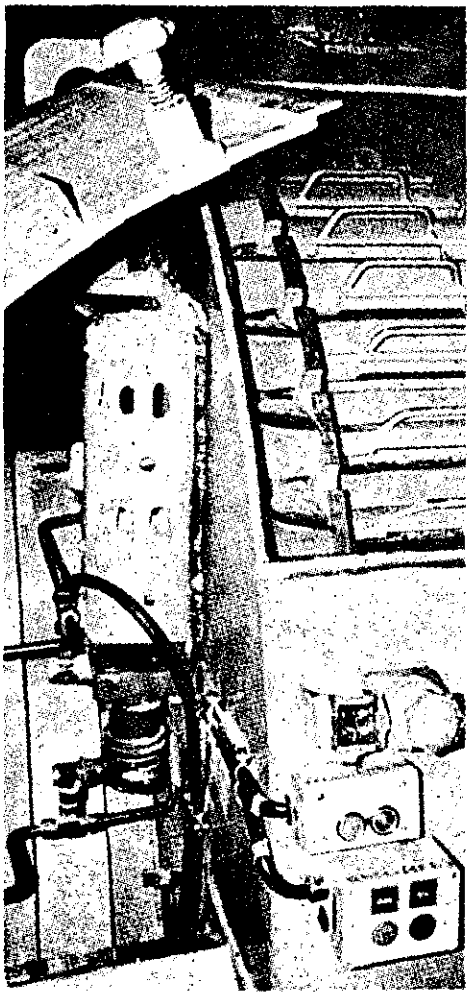


Figure 13. Replacement of the knife units and knife clamps

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.

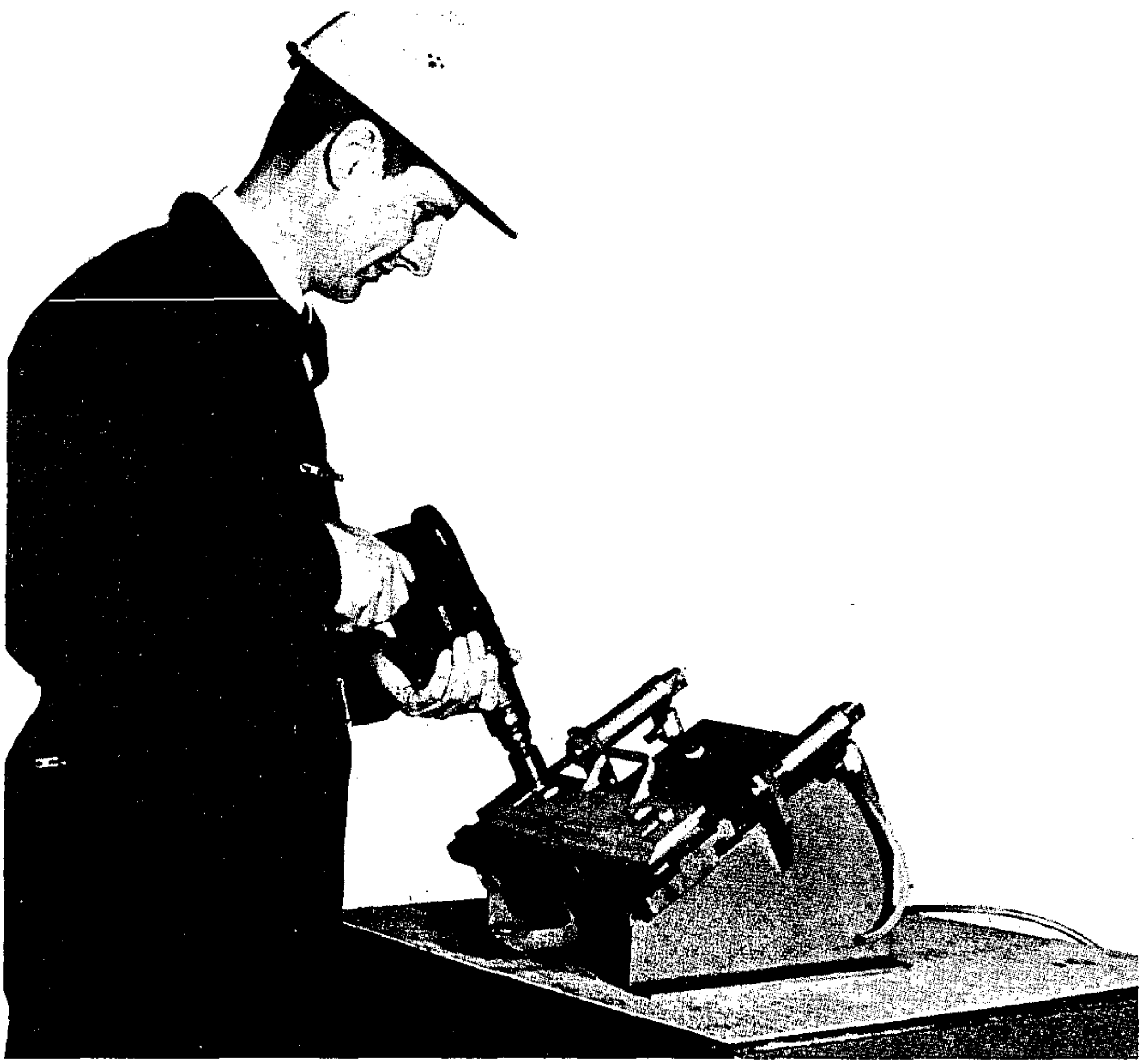
One of the most important factors in a flaking machine is the quality of the knives. Even if top-grade materials are used, sharpening is frequently necessary if the characteristics of the flakes are to be maintained and energy losses avoided. The ability to rapidly change blades, with consequent short down-times, is an important consideration.

Flakers on which the entire rotor has to be dismantled to change the knives are not recommended. Machines on which each knife and counter-knive unit is interchangeable and can be removed and replaced through an opening in the periphery of the casing are more practical.

The 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.

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).

Figure 14. Electromagnetic setting device for accurate adjustment of knife

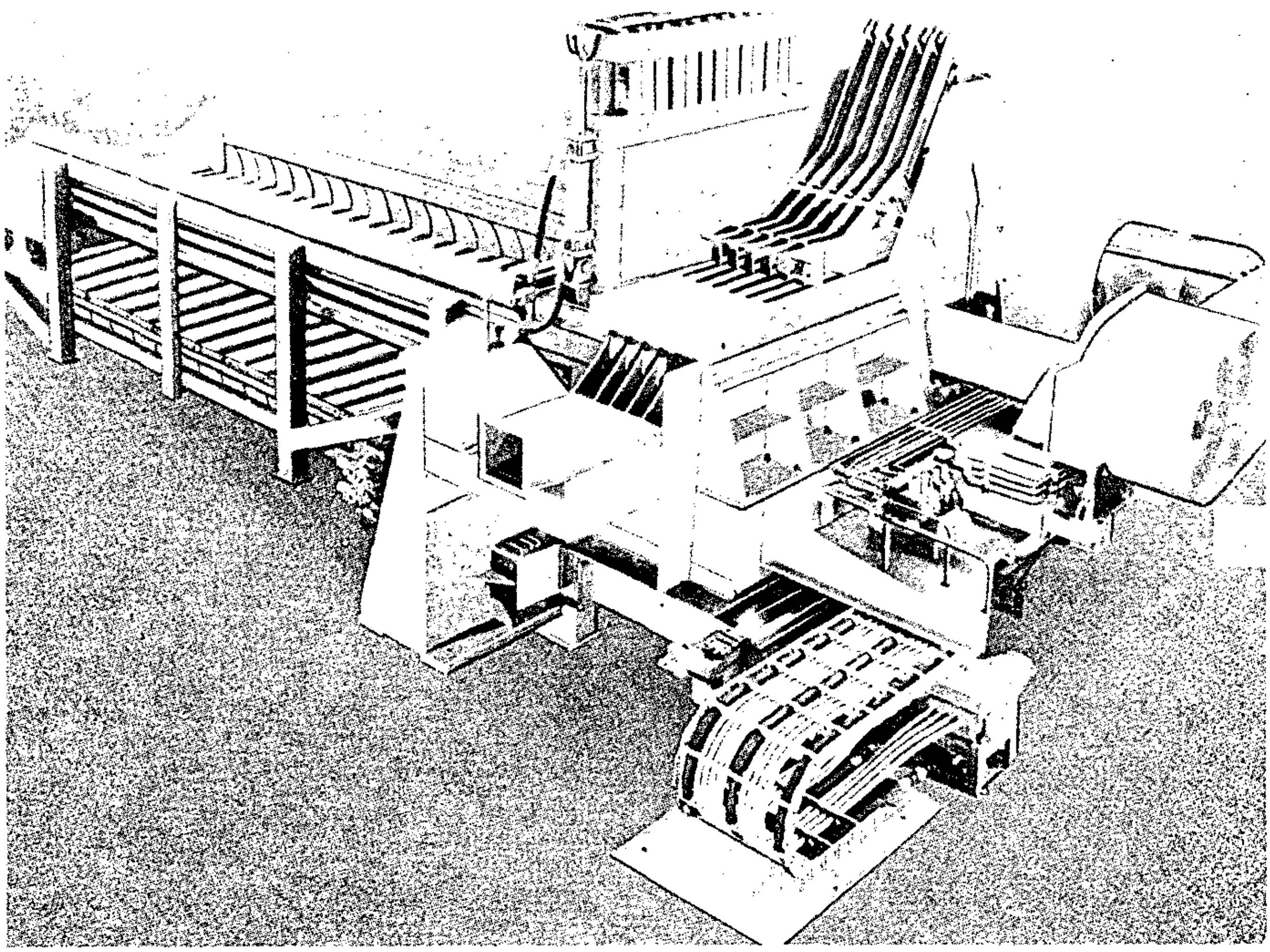


Flakers that have the internal surface of the cage lined with hard steel wear plates fixed into the side so as to be easily withdrawn for grinding or, if really necessary, for replacement are highly recommended.

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 bolt-driver is used to tighten the fixing bolts (figure 14). A lamp illuminates a reference line which corresponds to the pre-set position of 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. 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/h of flakes 0.4-0.5 mm thick (dry weight).

Figure 15. 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.

Figure 16. Alignment of the knives of the universal flaker

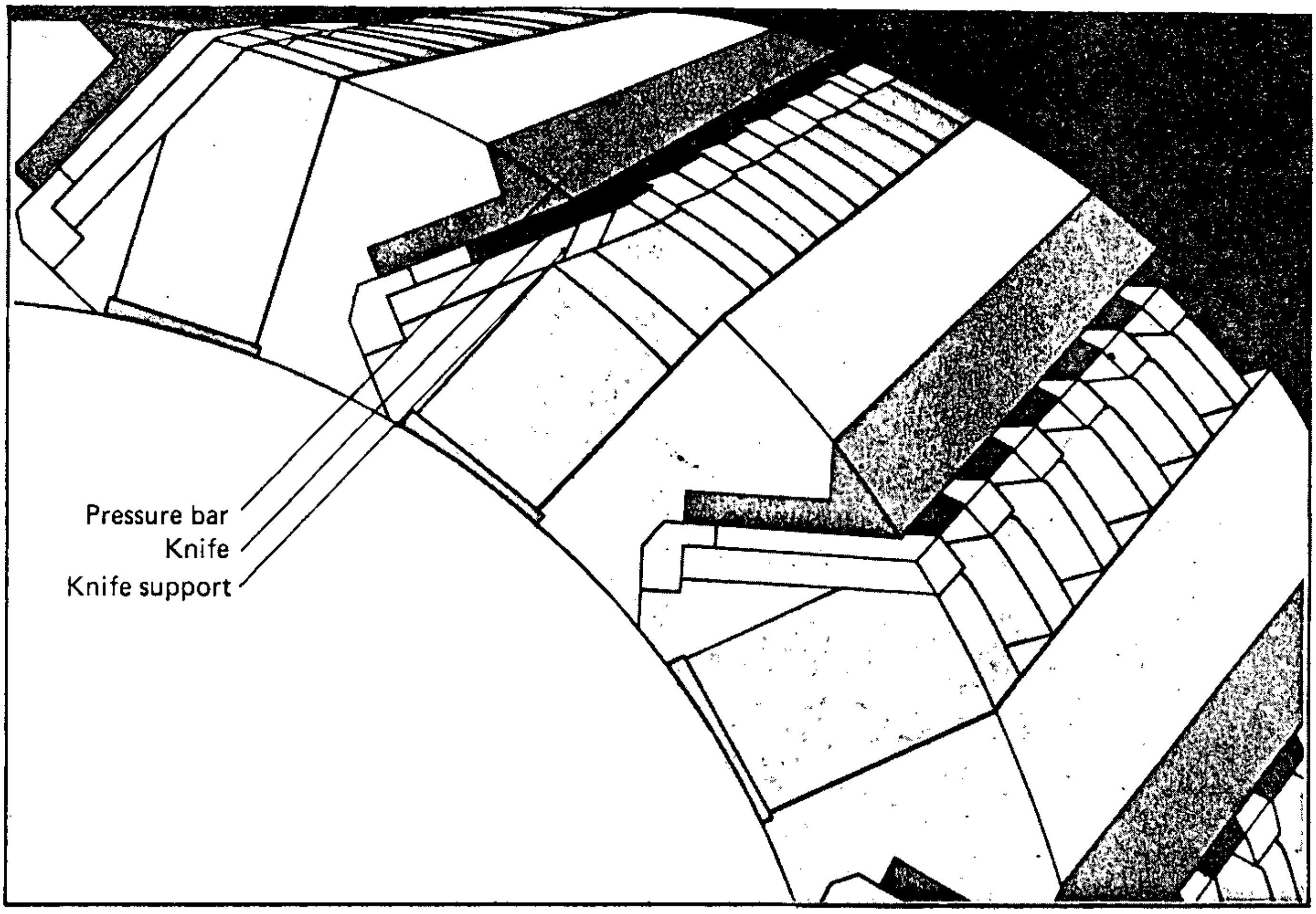
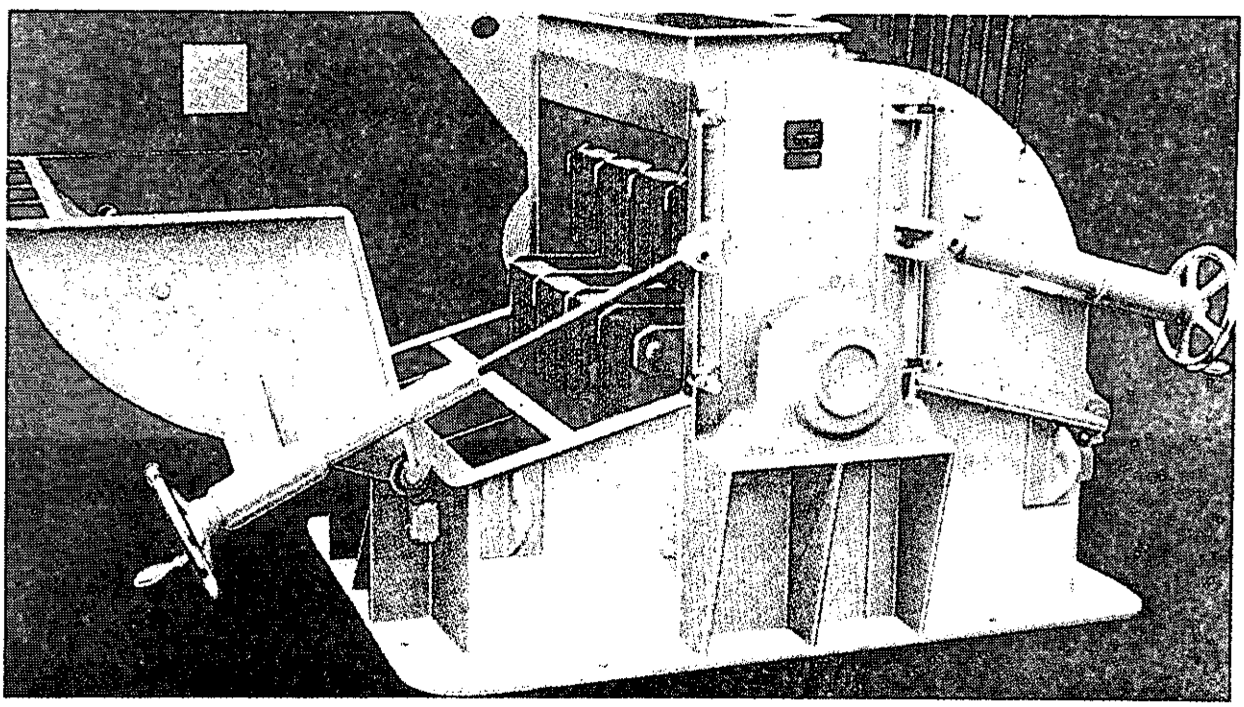
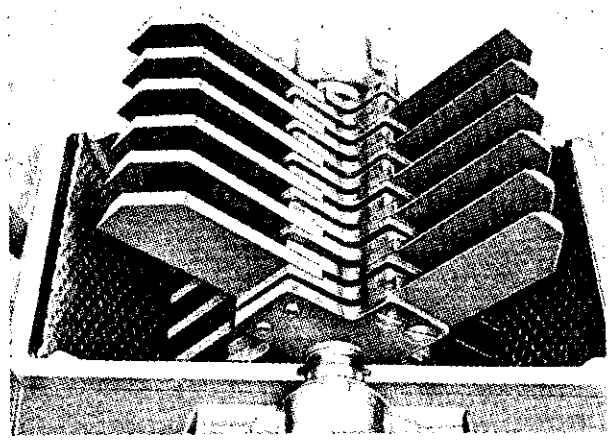


Figure 17. A hammer mill with wing beaters



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 knifeless 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). The particle size is determined by the size and shape of the holes in the screen. The inside diameter of the mills varies from 600 to 1,200 mm and screen width from 200 to 600 mm, depending on machine capacity.

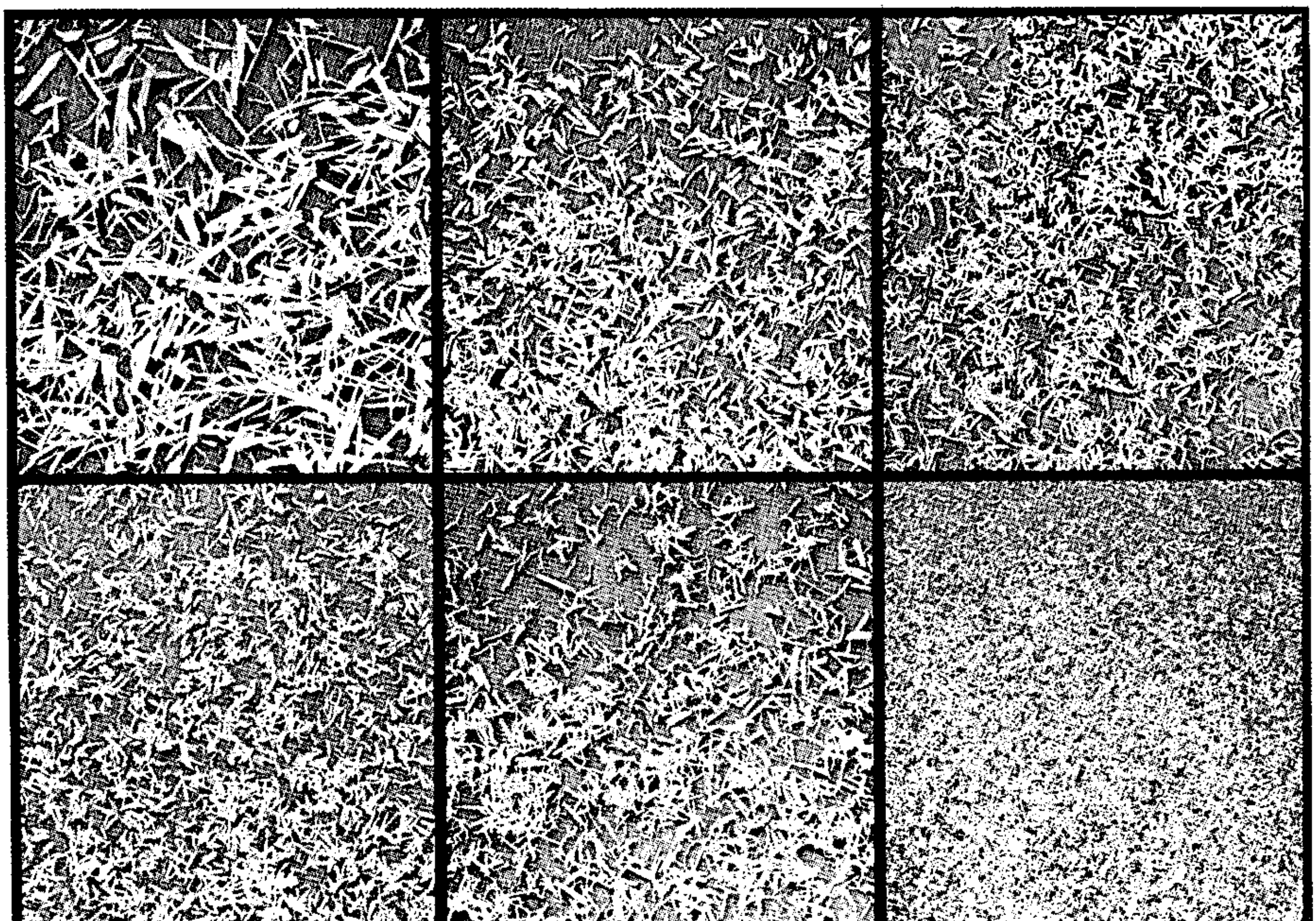
Figure 18. Knifeless hog with fixed beaters



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 19. Particle sizes produced in special mill

Final product



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 the two profiled segmental discs, one fixed and one rotating. The distance between the 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 20. Refining mill

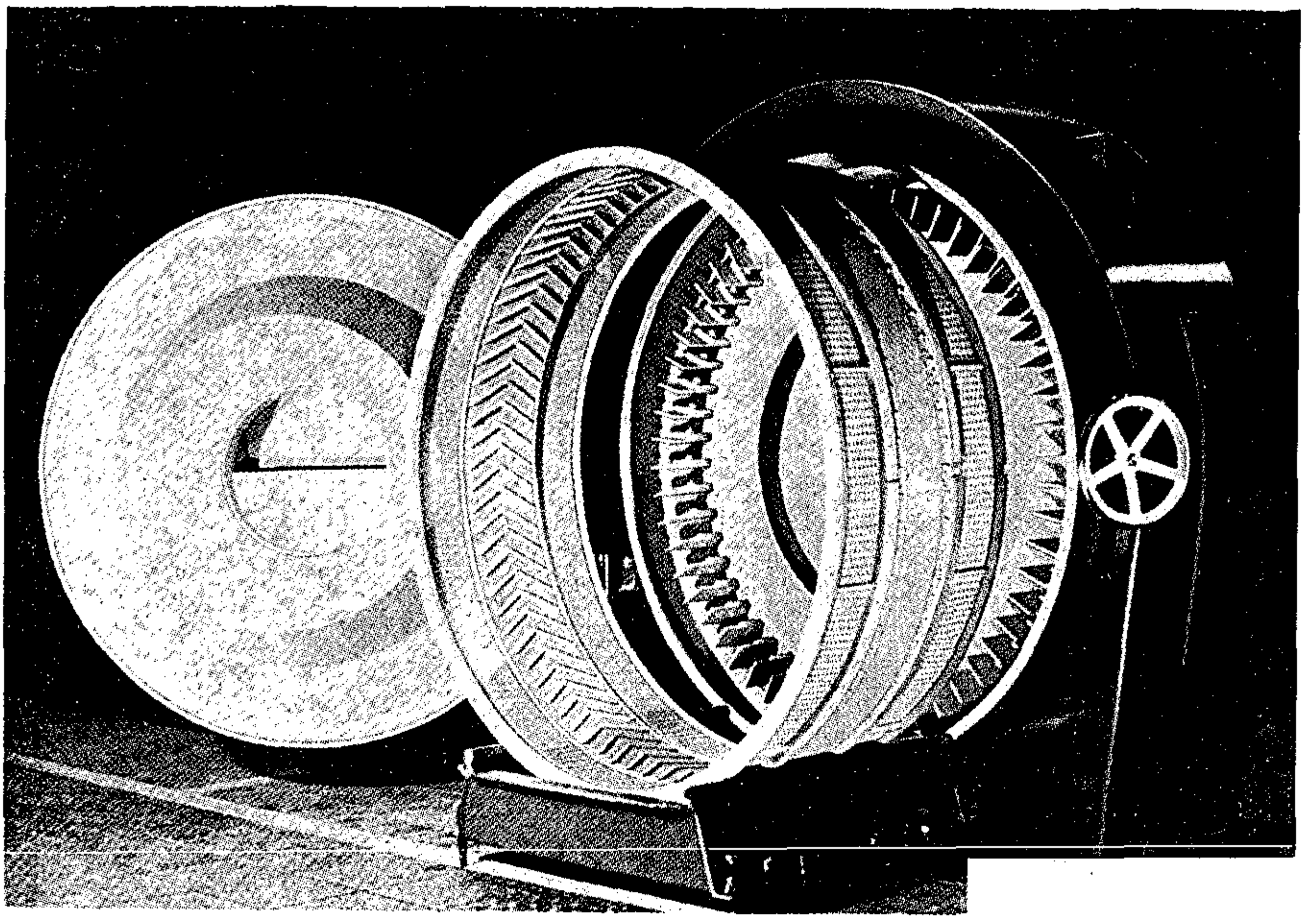
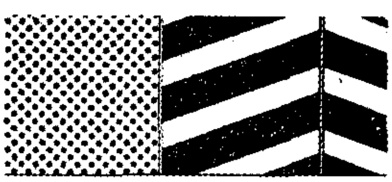
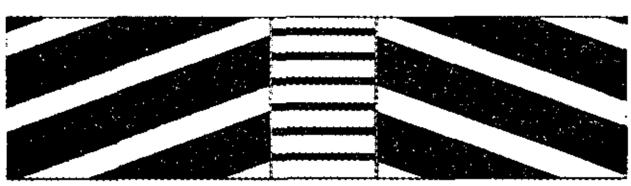


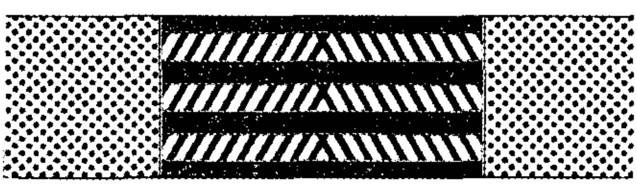
Figure 21. Chip paths during grinding and screening



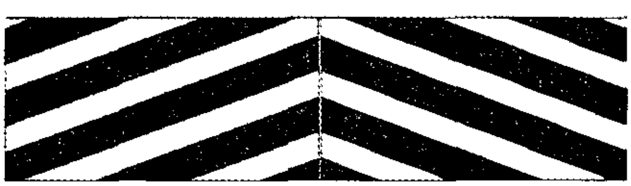
V-ledges with screen



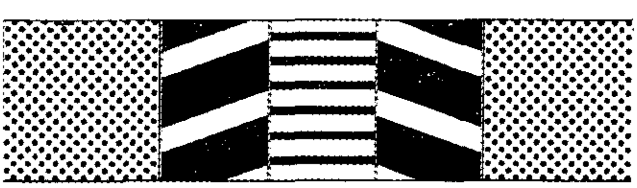
Chip grinding path, wide, without screen



V-grooved ledges with screen



V-ledge grinding path, wide, without screen



Chip grinding path with screen

Figure 22. Different grinding-profiles for refining machines

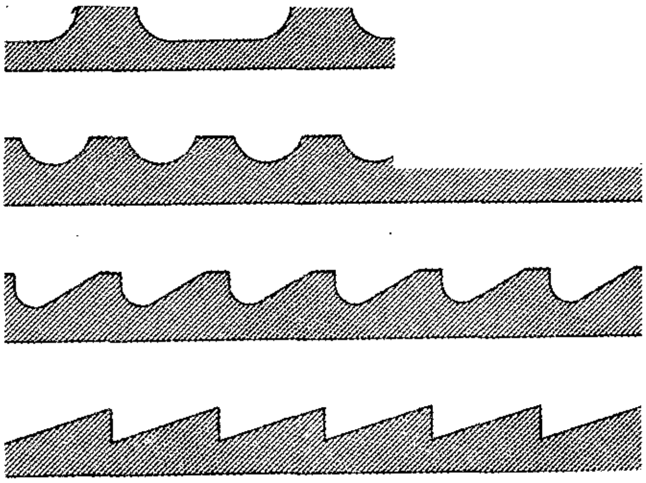
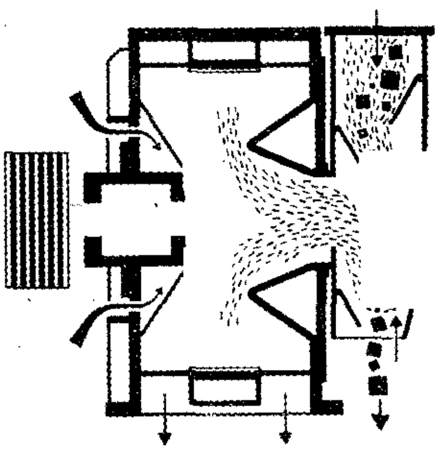


Figure 23. Chip flow direction in a refining machine



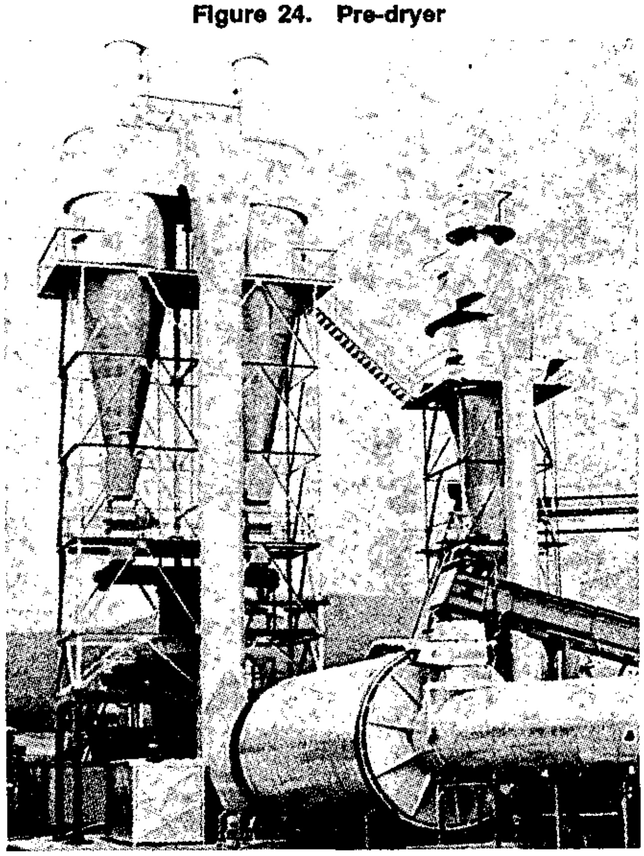
Dryers

Drying is a delicate process. Difficulties may be caused by poorly designed dryers and by fires and explosions that 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 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 the 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 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.

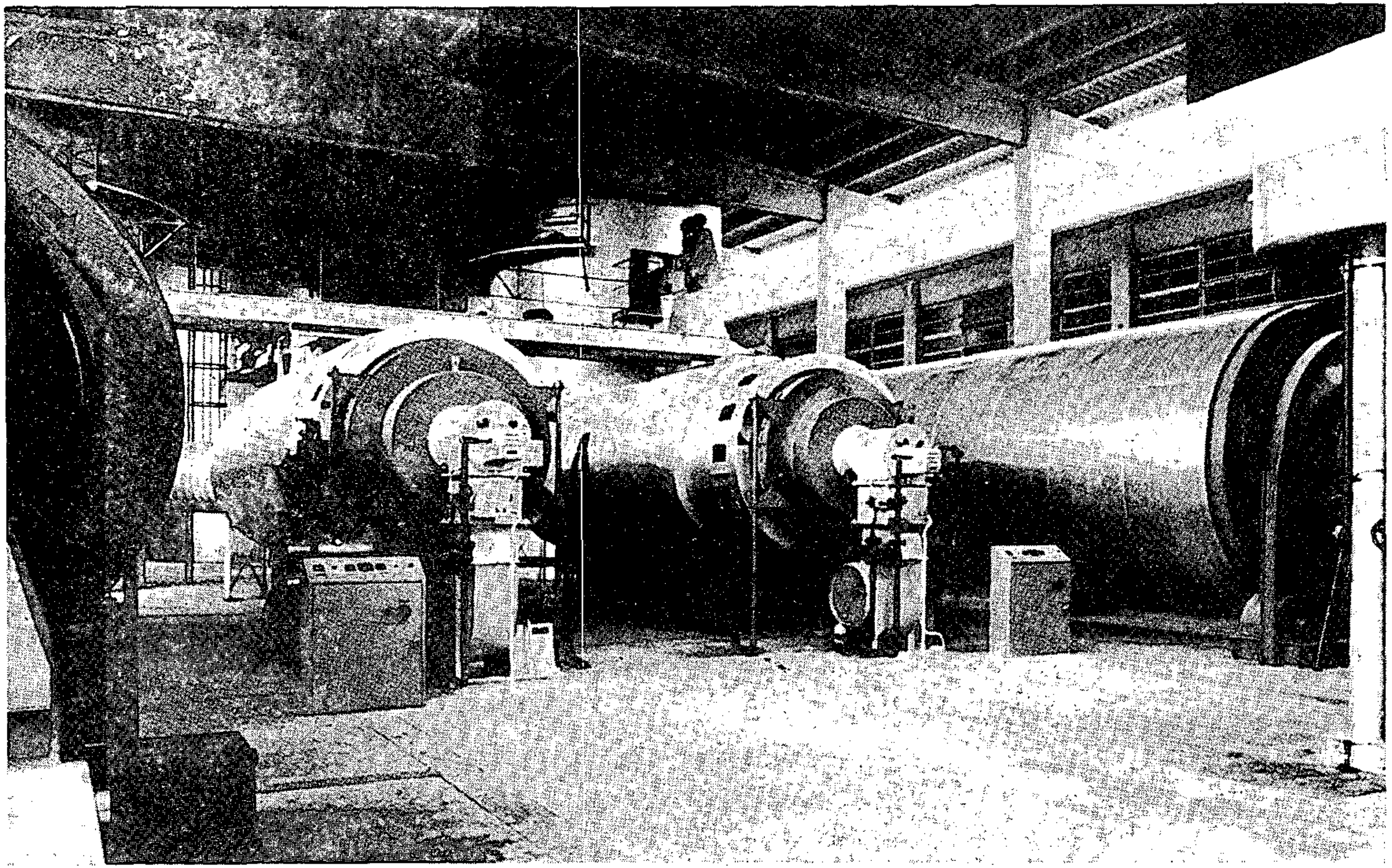
The dryer that has proved to be the most functional and is most widely used is the type with a rotating horizontal cylindrical body consisting of three concentric solidly united cylinders. This gives three passes, in alternating directions, to the particles before they are ejected. The heat is uniformly distributed to the particles. The 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. 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.

Figure 25. Close-up view of kiln drums for chip drying



Silos

A certain number of silos must be provided for each production line for the storage of particles that 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 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 26. Storage silos for particles

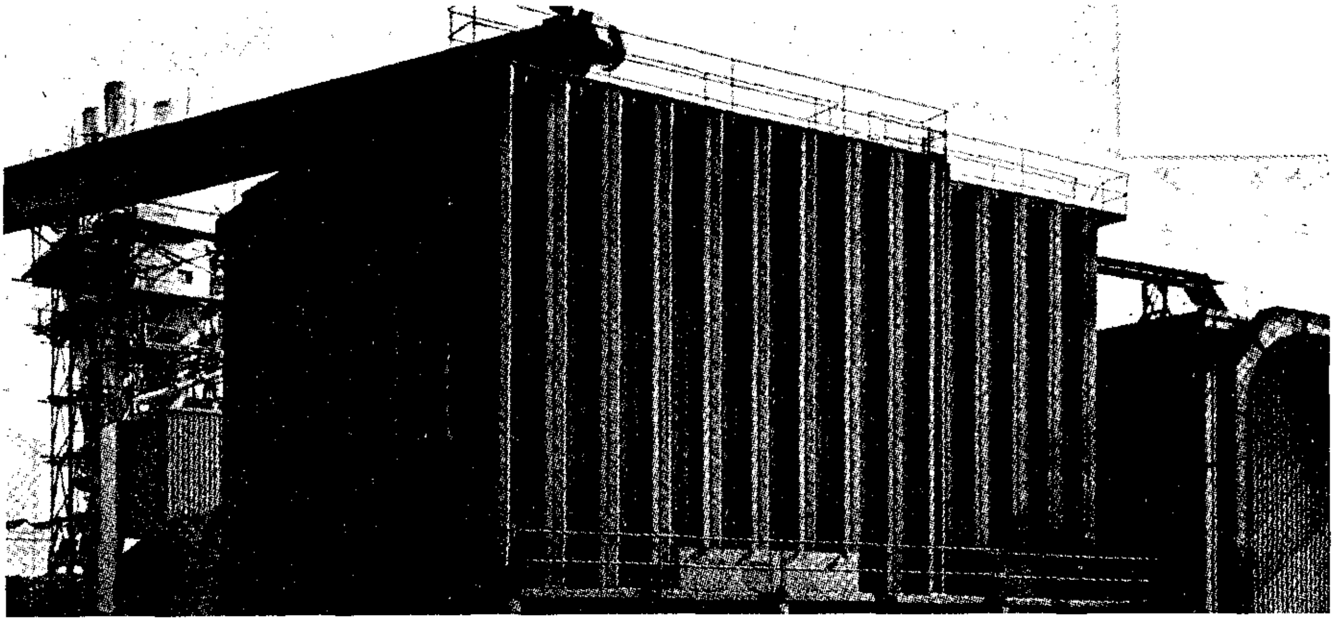
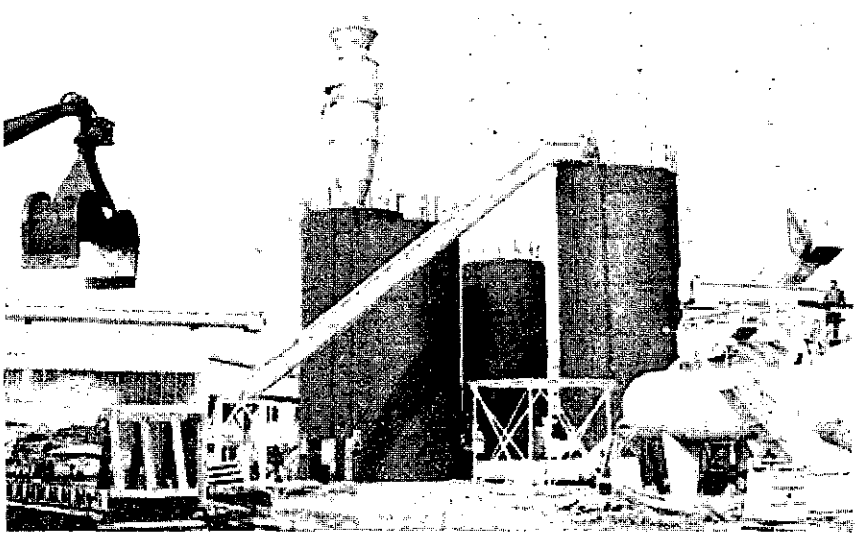


Figure 27. Storage silos with screw feeder



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.

Figure 28. Chip-feeding unit

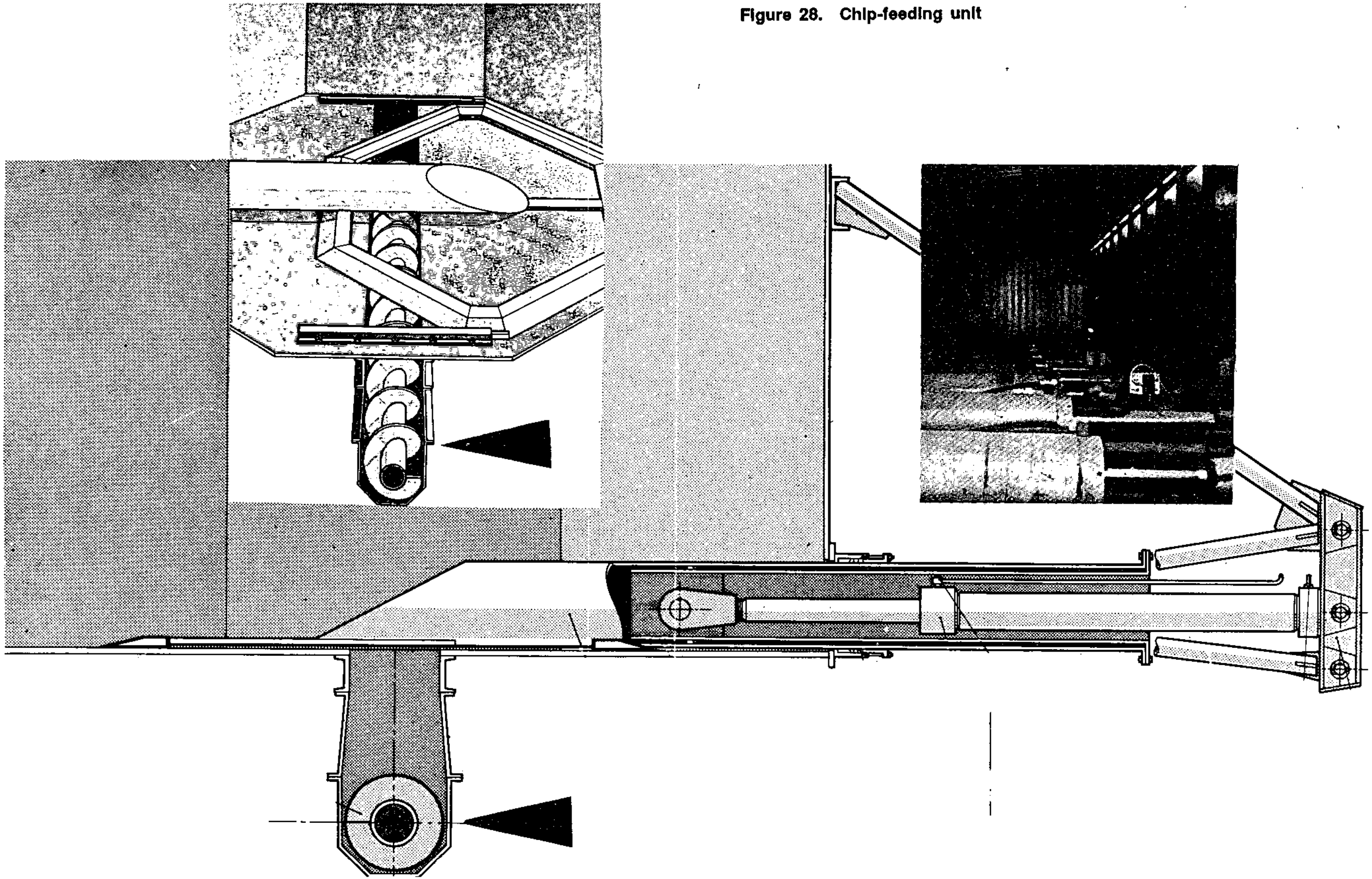
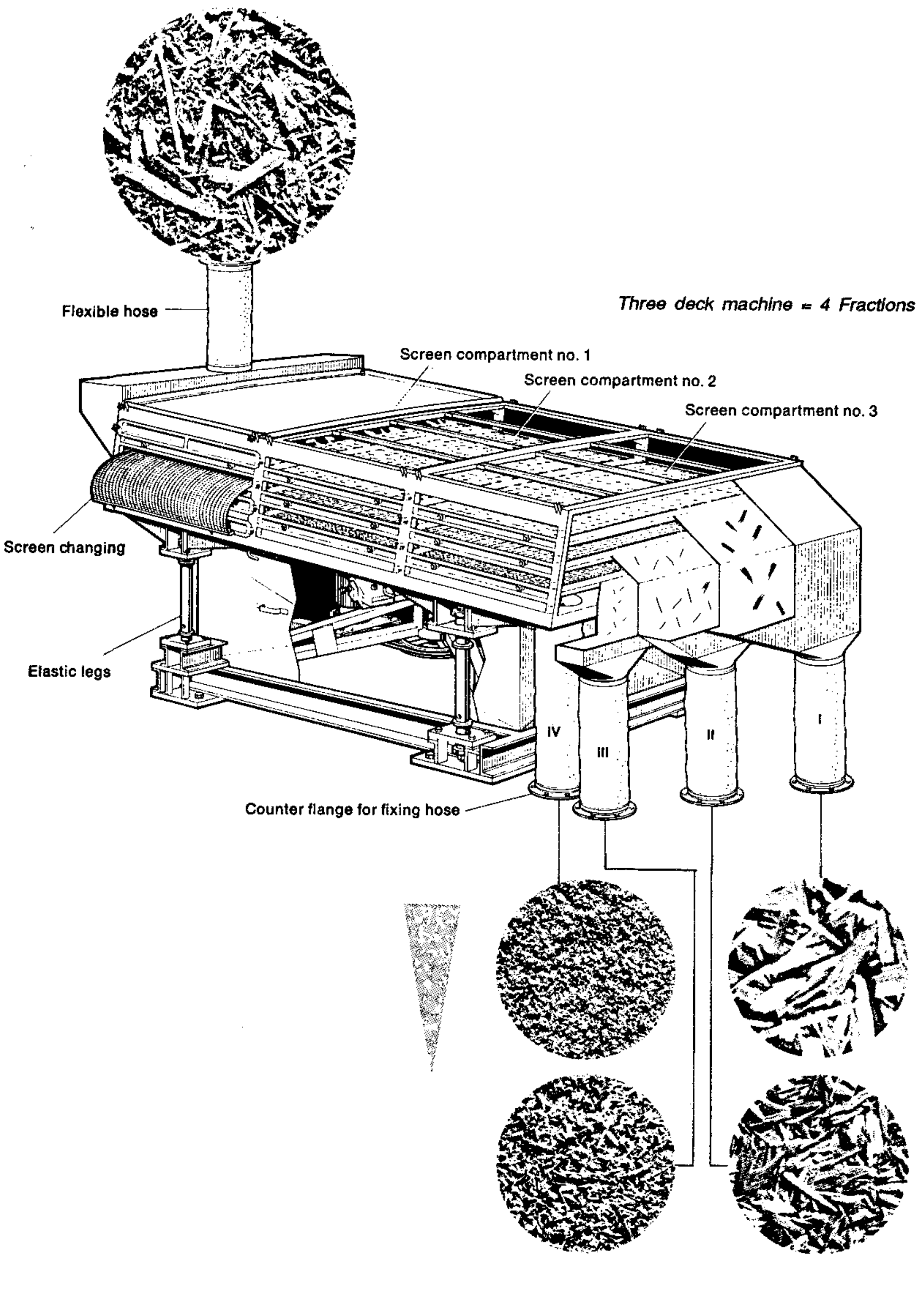


Figure 29. Schematic drawing of the orbital chip grader



Particle grading

After drying, fine particles must be separated from the larger ones that will be used to form the internal core 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.

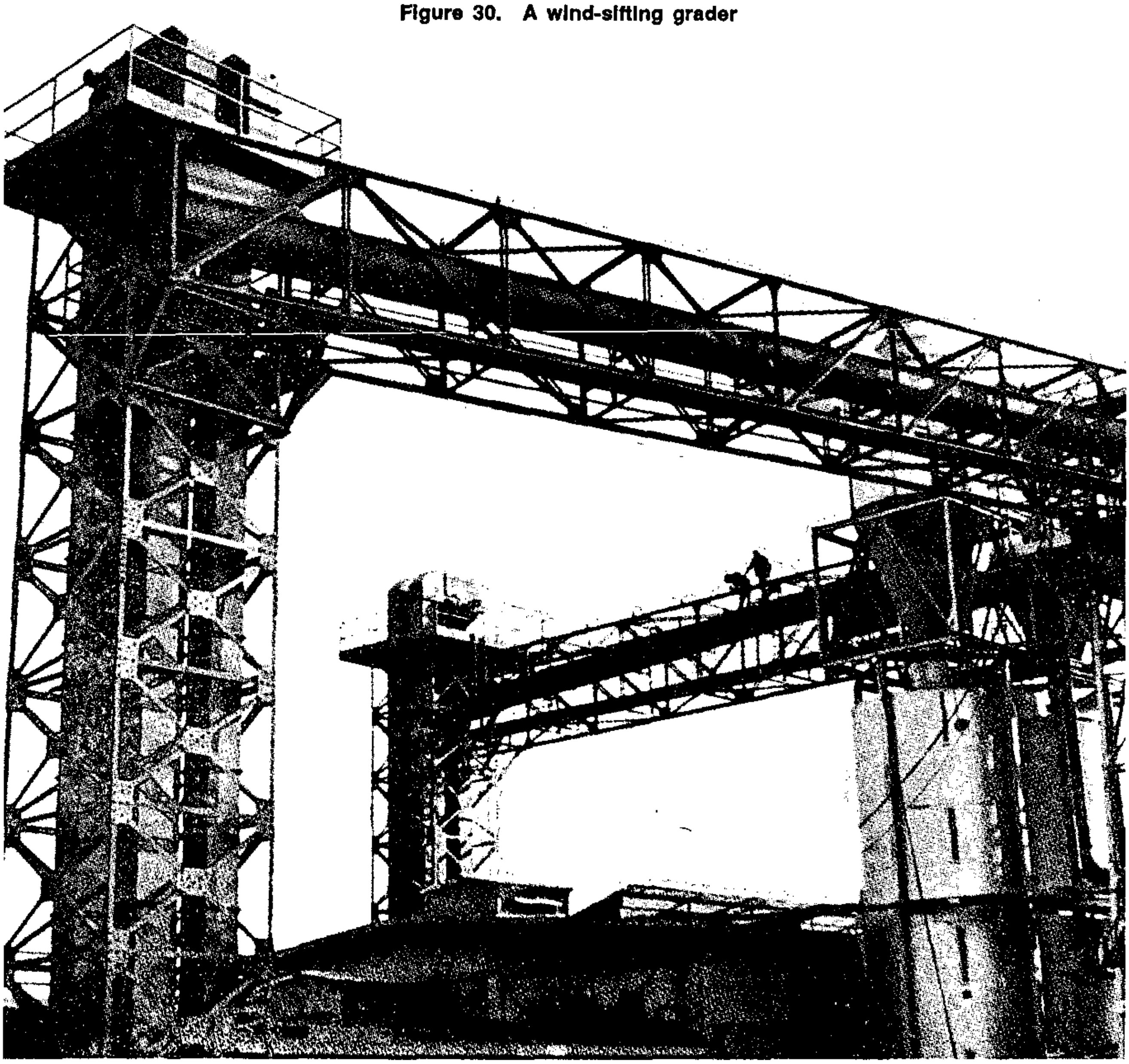
Grading can be done both by multi-sieve graders and by air-blast separators. The best results are obtained by combining the two systems. Graders can be oscillating, vibrating or orbital (rotating in a plane around an eccentric axis) types. The latter system is preferred for wood particles because it 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 m^2. This gives a total area of 21-24 m^2 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.

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 that 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



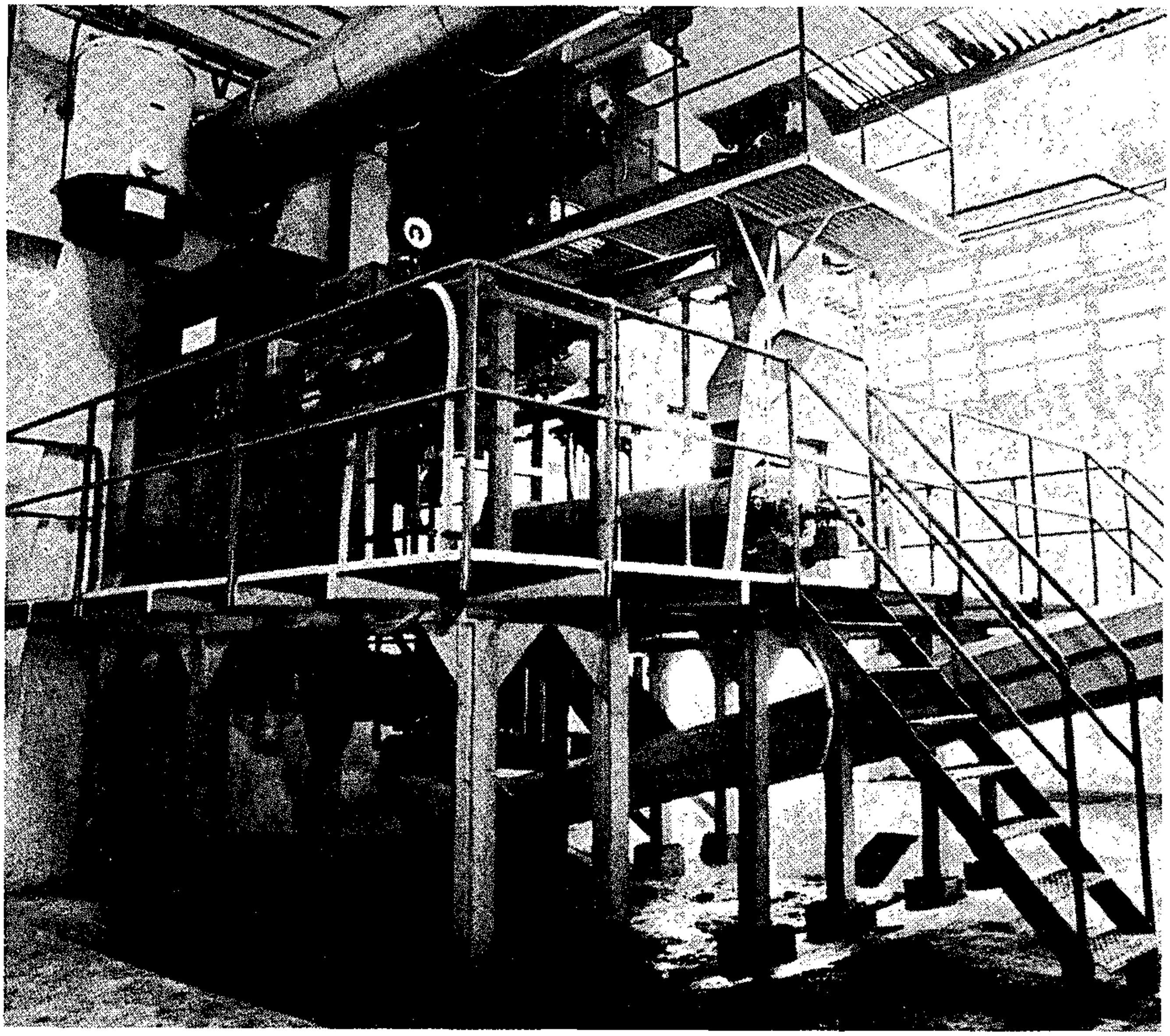
Preparation of binding agents and their addition to particles

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; a 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 that 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 insecticides or fungicides can be included in the mixture. A good plant has functional simplicity and provision for component metering and mixing; it is also 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.

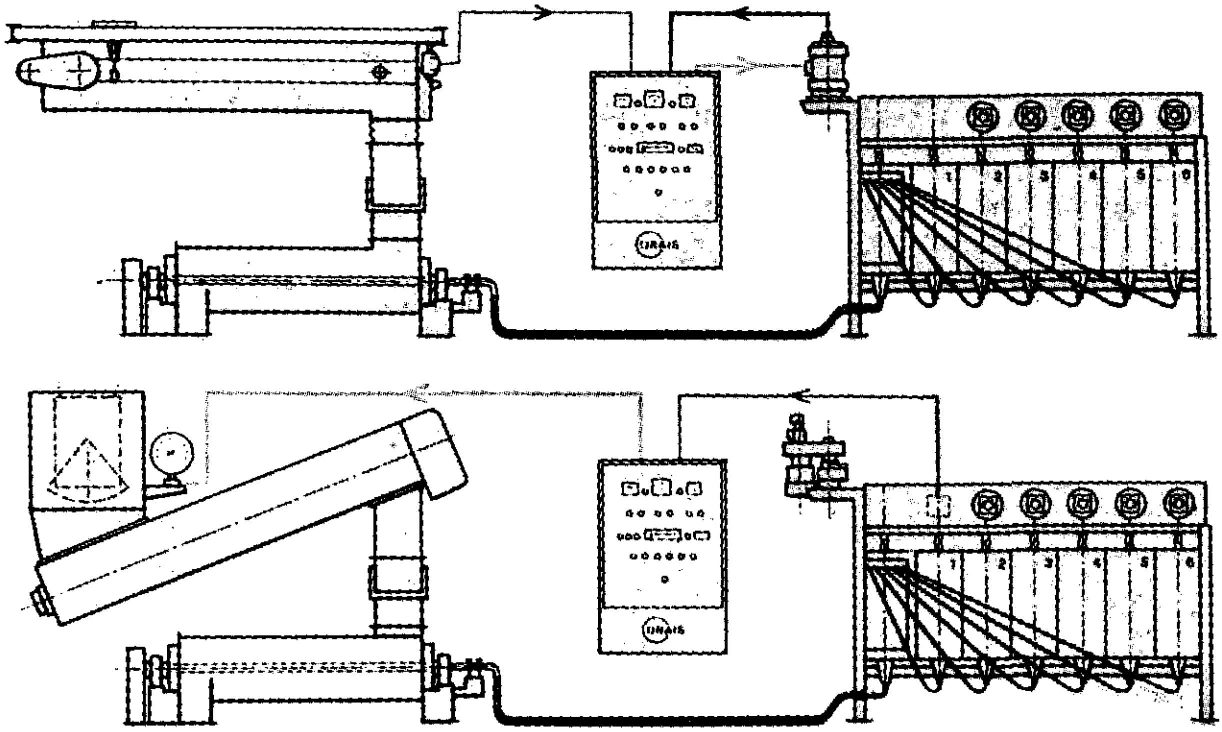
A rapid mixer mixes and homogenizes the chemicals. The mixture is then conveyed to a chemically resistant tank of appropriate size. Normal metering and mixing plants are made to supply up to 7,000 kg/h of mixture.

Figure 31. Automatic adhesive/additives metering station



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 the power supply. They must be capable of handling high-peak belt loads.

Figure 32. Schematic plan for the automatic metering of binder materials

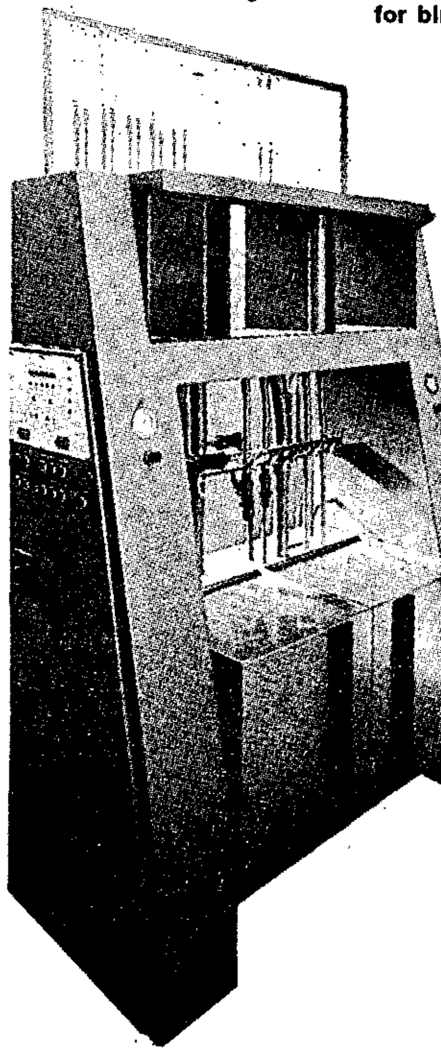


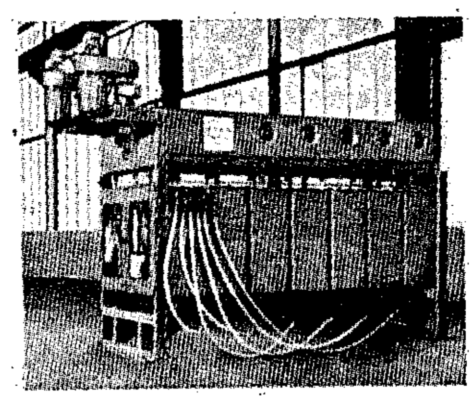
High-turbulence continuous gluing machines are widely used. The mixture enters through the hollow shaft and is thrown by centrifugal force through rotating nozzles on the shaft onto the particles. Besides uniform binder distribution, features of these machines are high productivity (over 30 t/h of treated 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 the 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 the 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 are wear-resistant and interchangeable and that bearings are strong and well-fitted. A machine of this type is shown in figure 36. The 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, which is applied to the particles. The next set of nozzles is used to introduce water to the mix. As there is little friction, there is no need for cooling. Owing to the abrasive action of cement, it is essential that the extremities of the arms and the internal wall of the cylindrical body are wear-resistant.

Figure 33. An automatic metering device for binder infeed





Mat-forming lines

In most plants, boards are formed on a mechanical conveyor 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: the 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 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 produces a uniform thickness. This is true whether or not the boards will be sized.

Figure 34. Automatic belt type weighing machine (glue/chip blending)

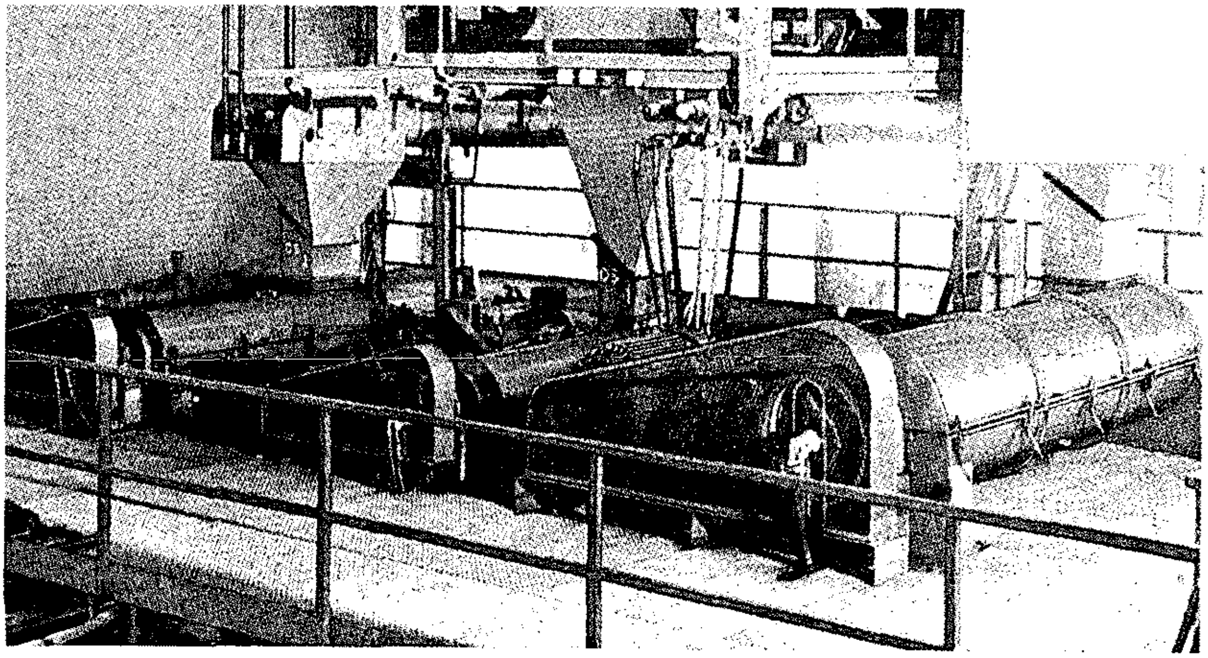


Figure 35. Glue spreading with staggered times to prevent clogging

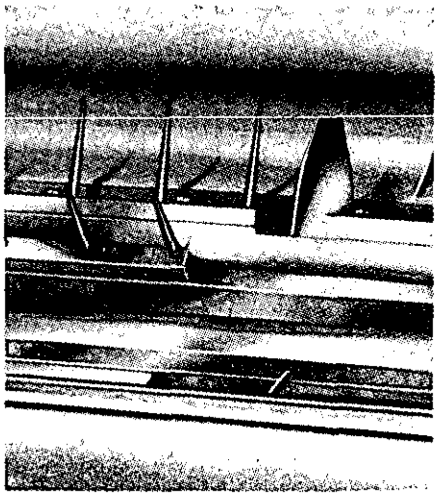


Figure 36. Glue-spreading machine, showing spraying/mixing arms

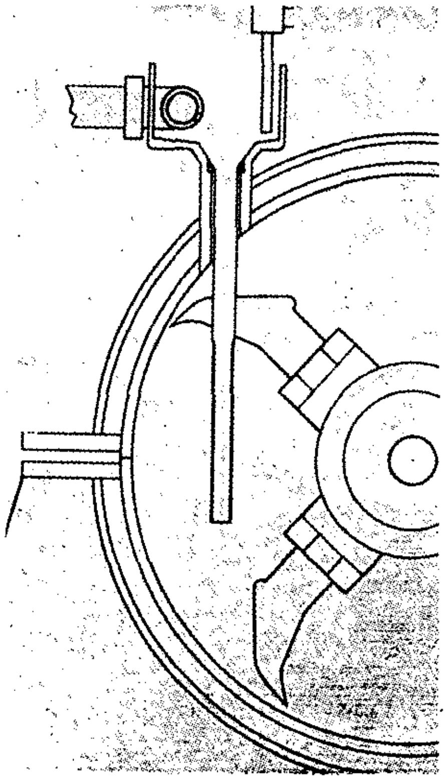
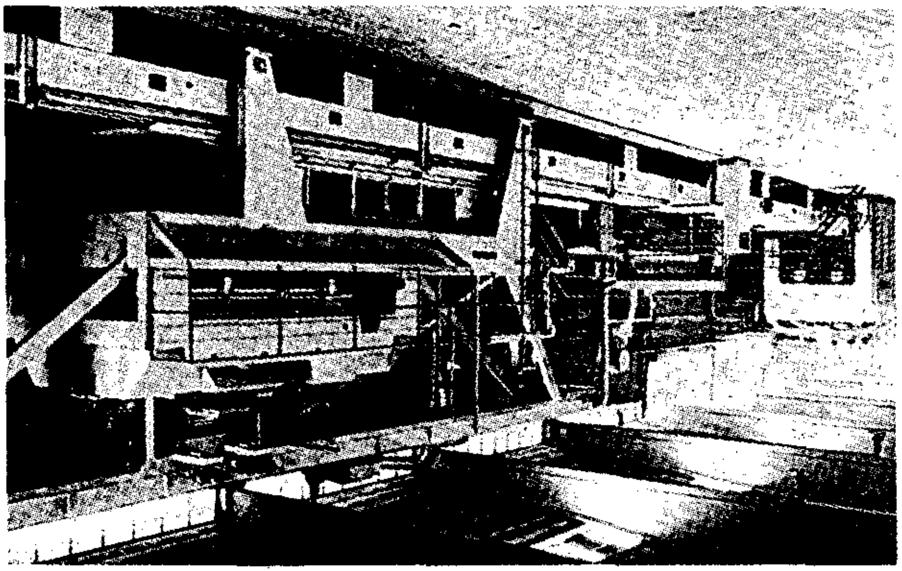


Figure 37. Mat-forming machine for chip spreading

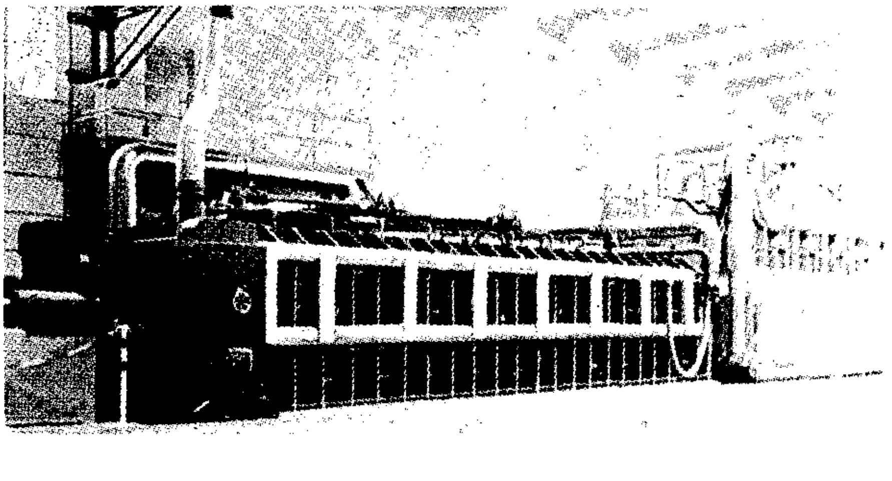


Forming machines either remain stationary as the belt moves underneath them or have reciprocating motion and the belt remains still during particle distribution. For graded particle boards, one forming machine is sufficient. It is sometimes used in combination with a mechanical or air-blast distribution system. The particles are distributed at distances proportional 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, with respect to both 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.

Mat pressing

The installation of a pre-press (figure 38) for densifying particles provides considerable advantages, even if it complicates plant organization and has a 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. Subsequently 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 conveyor 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. The recommended specific pressure is approximately 20 kgf/cm^2, even though good results can be obtained with lower pressures.

There are also calender-type preliminary presses (which cannot be heated). The rolls are covered with double-strength rubberized canvas. While this particular type is more economical and faster than platen presses, the specific pressures that it can exert are relatively low. Thus, its 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 that 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 produced recently. The experience gained so far is not sufficient to establish whether or not they are the best system for pressing bonded wood boards, bearing in mind quality and cost of production. The particle board process is shown schematically in figure 40.

Continuous particle board presses are the best choice for processing thin 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 that 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 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. The 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 the 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. The drum diameter is 3,000 mm, and the belt width allows boards of 2,500 mm and over to be produced. The productive capacity of a calender press that is pressing boards of maximum width 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 (over 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 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 a specific working pressure (which it is convenient to limit to 30 kgf/cm^2); closing speed; the accurate distribution of hydraulic pressure; structural ruggedness (whether steel plate or column type); the 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 the 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); and heat insulation between platens and the press structure to avoid all heat transmission that would cause expansion and distortion.

All these measures and the high platen temperature (normally over 200° C) reduce pressing time by approximately 10 seconds 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, thickness gauges and weight checking units are placed 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.

Figure 39. Schematic layout of a board-forming line

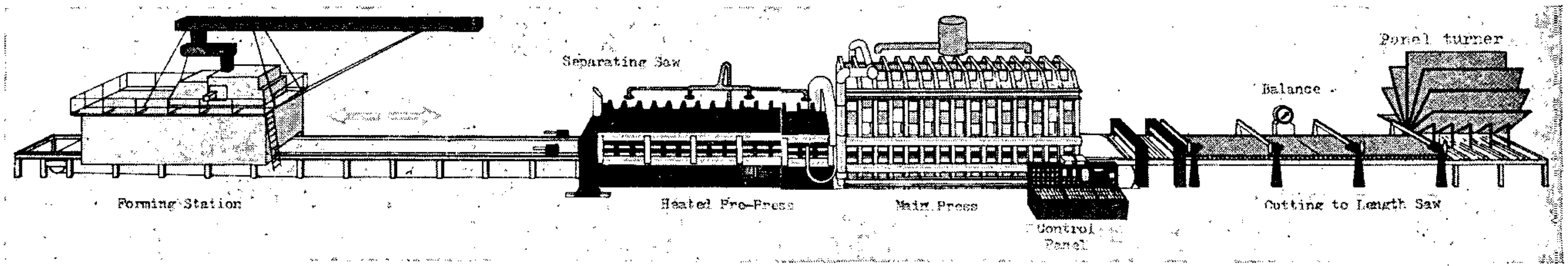


Figure 40. Schematic drawing of the particle board process

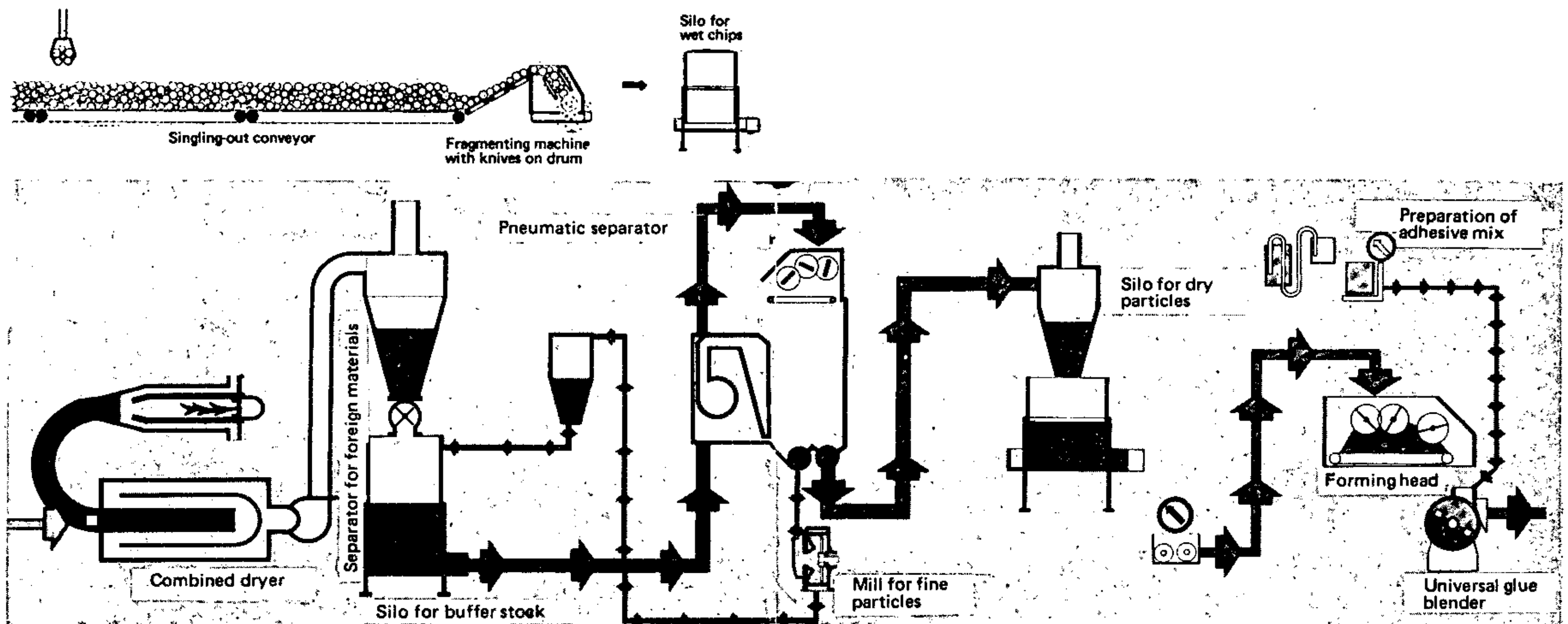


Figure 41. Continuous particle board press

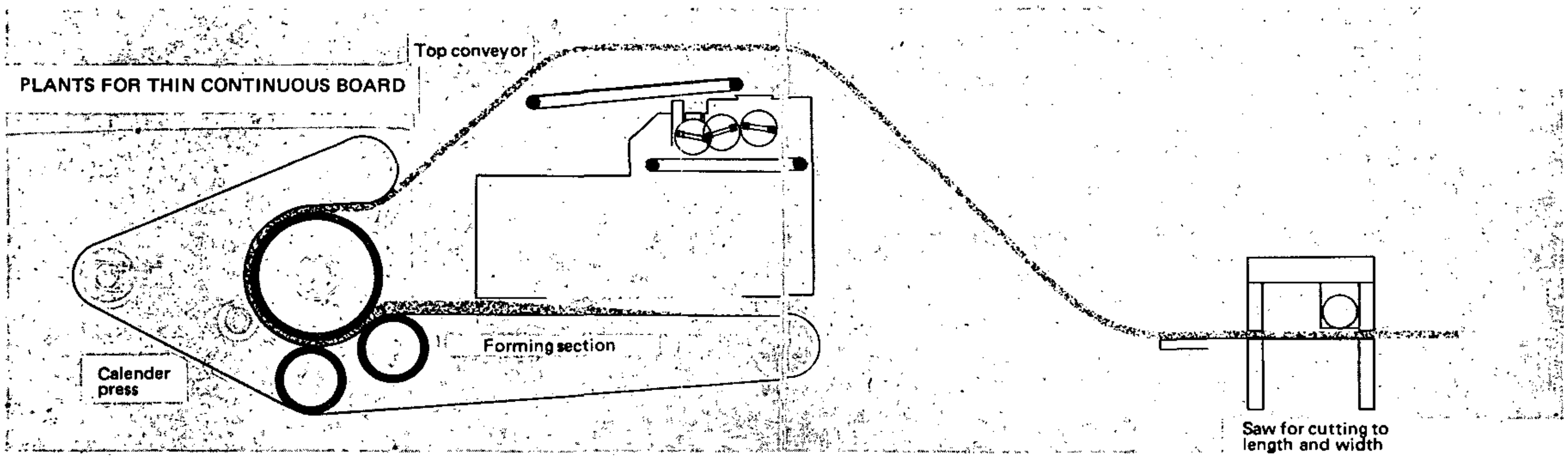


Figure 42. Sizing saw for the outfeed end

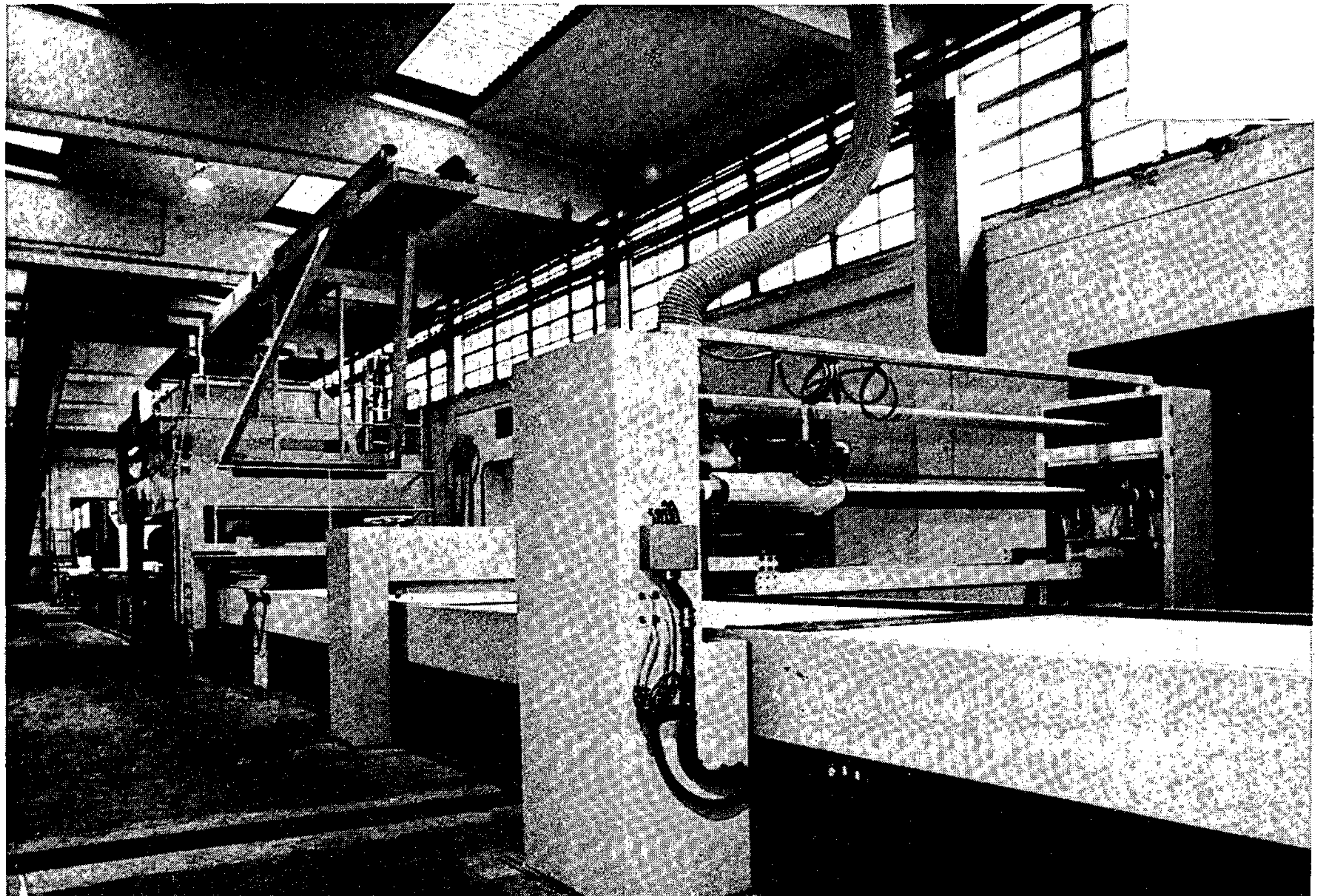


Figure 43. Hot platen presses with control panel in front

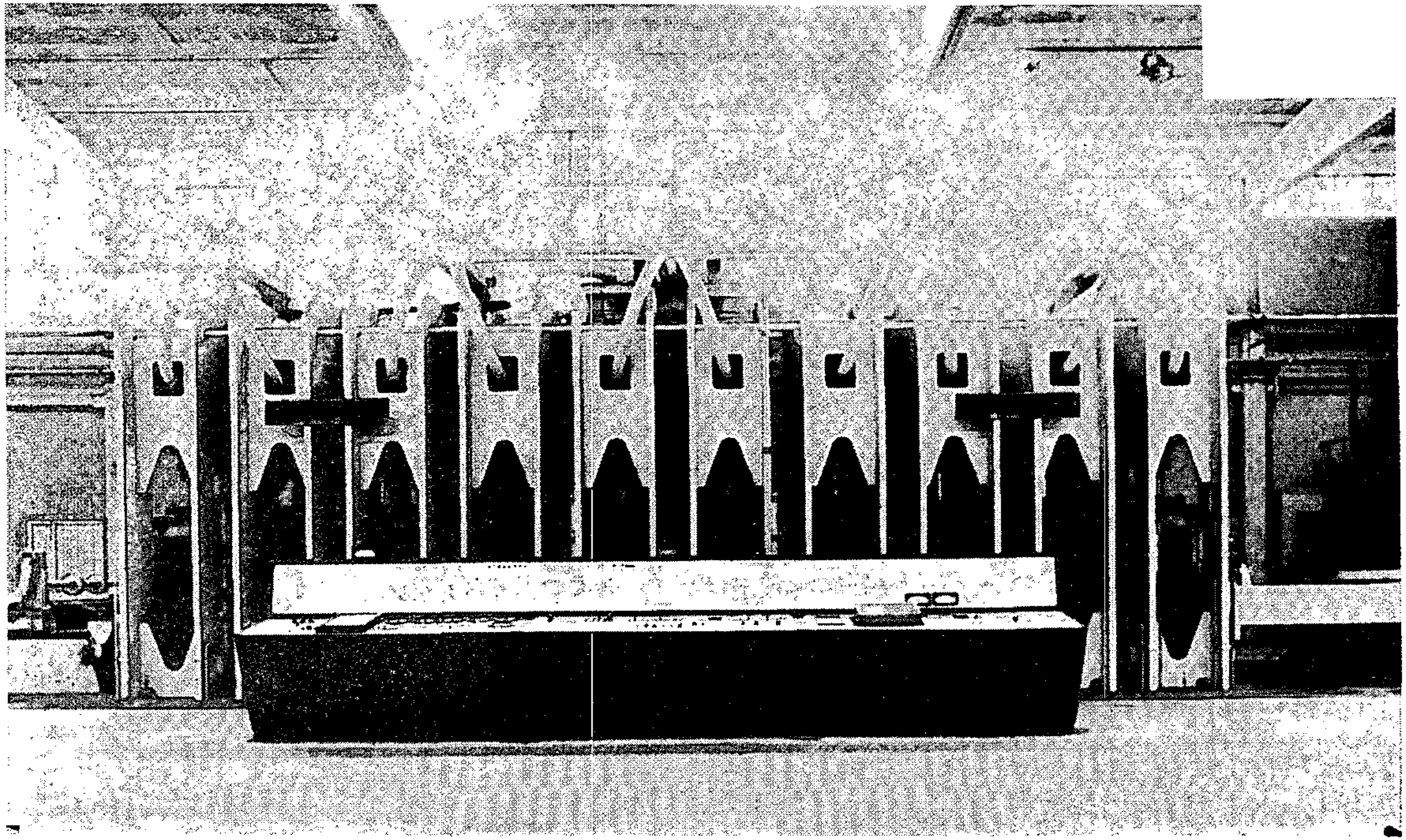


Figure 44. Schematic layout of the entire MDF process

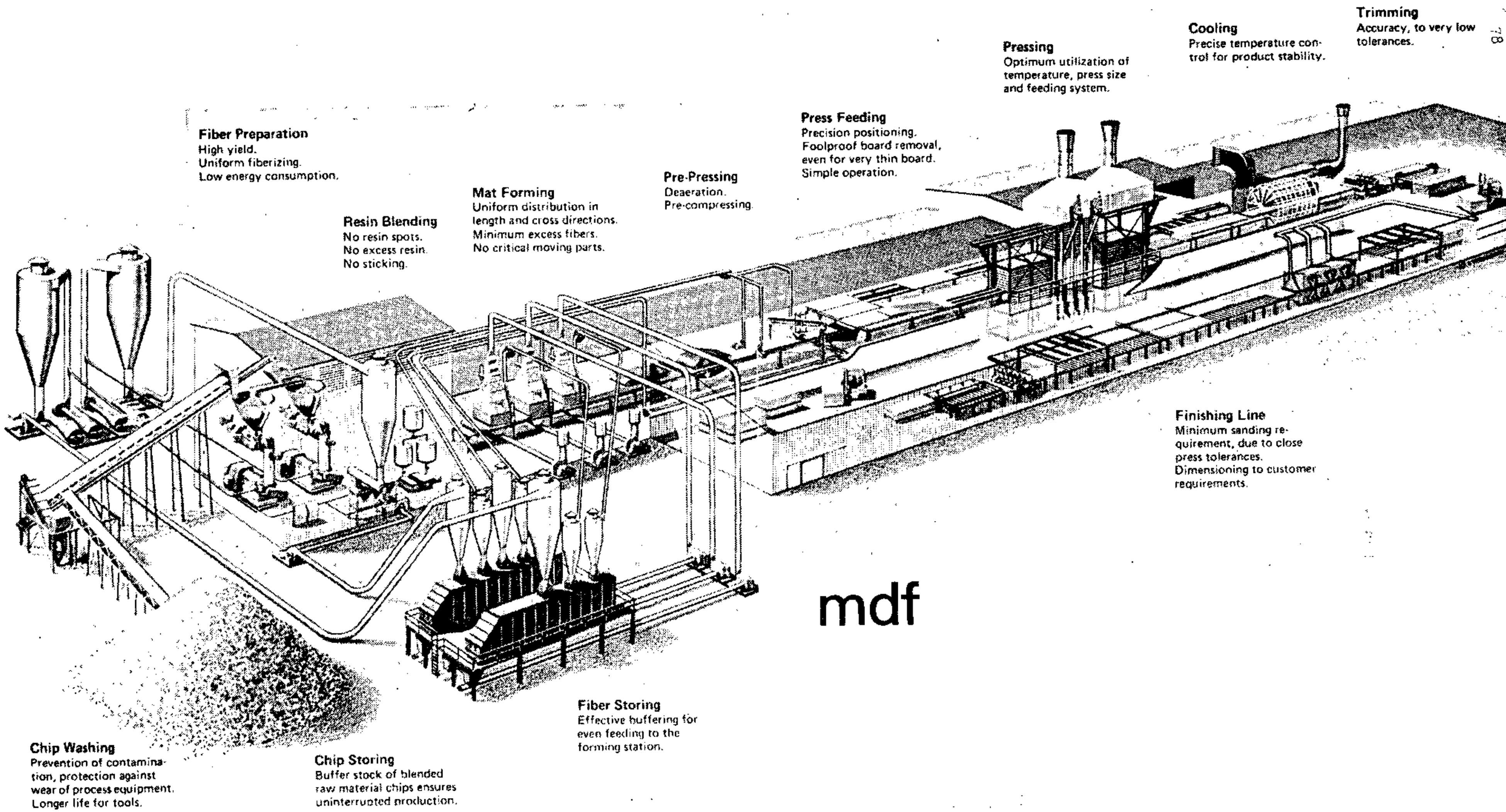


Figure 45. Board cooling system with rotating conveyor

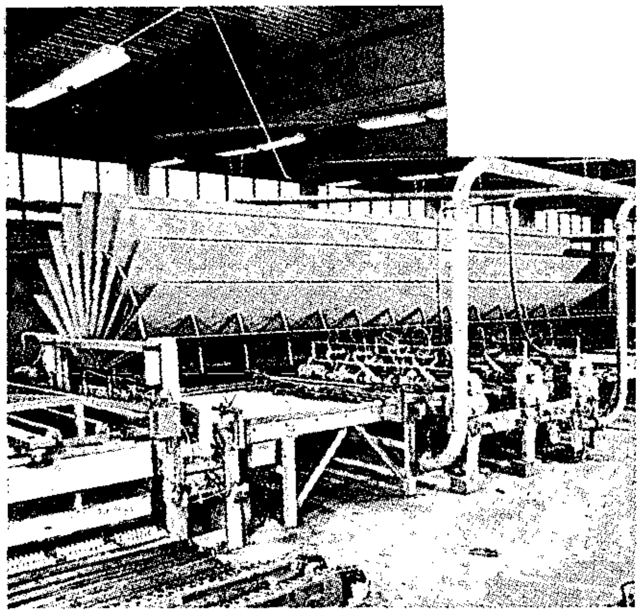
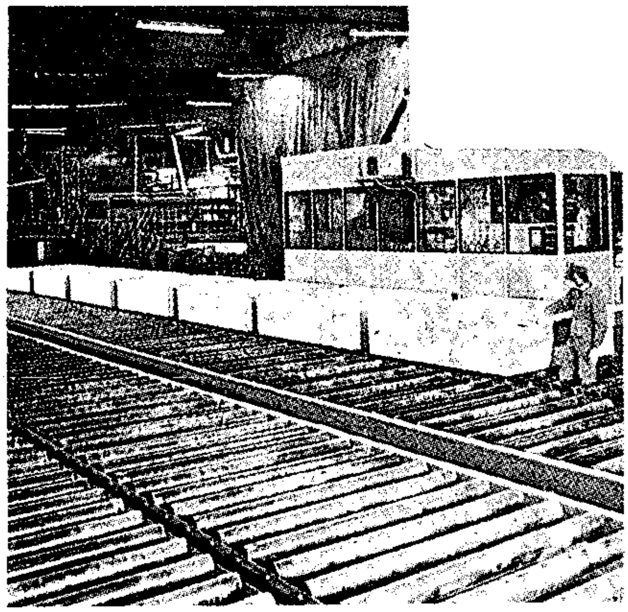


Figure 46. Board storage on roller ways prior to sanding



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 tungsten carbide teeth are used, thereby considerably reducing the frequency of sharpening. Transverse sawing is 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 that 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 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, in particular the bobbin type, have been superseded. Sanding machines are shown in figures 47 and 48.

Figure 47. Top and bottom wide-belt sander

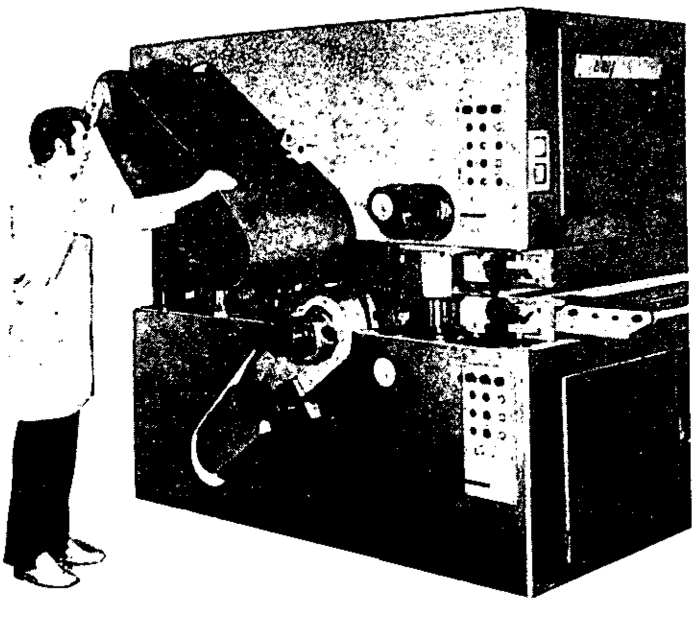
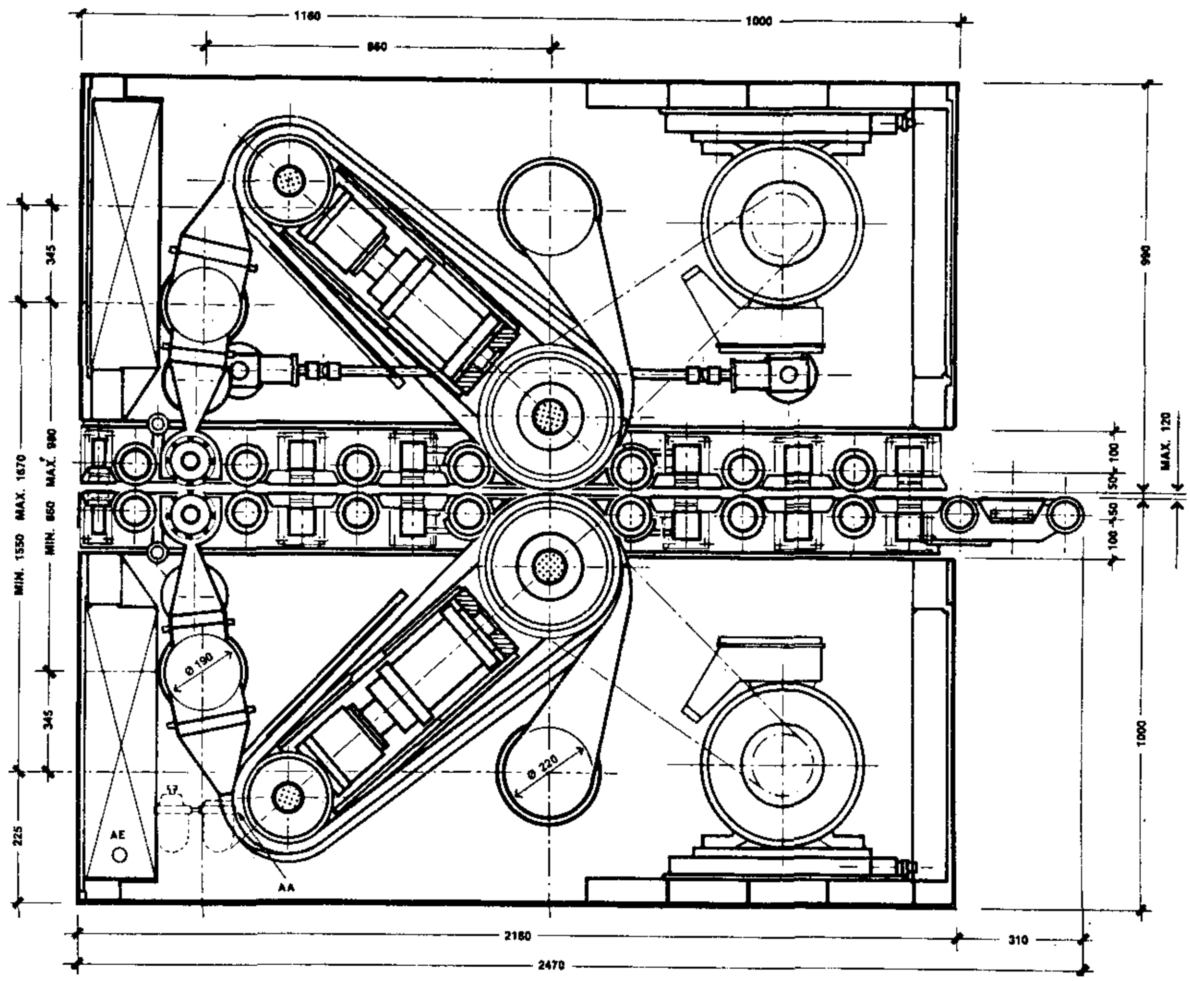


Figure 48. Cross-sectional drawing of a wide-belt sander



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, the 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, technical data on plants with calender presses for the continuous production of particle boards (synthetic resin bonded) as well as on plants for cement-bonded boards are presented below.

Plants for the 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 the width, 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 fom 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 base instead of plywood; and for the packing industry.

The 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 the boards 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 owing to limited flexibility;

(c) Irregularity of surface absorption when painted, varnished or glued, owing 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 rigid plastic foils or of very thin laminates. It is generally considered that a more careful study of particle size and shape, binders and 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. The weight is proportional to the 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 aims 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 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; compressive strength is approximately 150 kgf/cm^2; and tensile strength, perpendicular to panel faces, is 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 that is 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, $m^{-1} \cdot h^{-1} \cdot °C^{-1}$ (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). Weather-proofing is excellent (even for freezing conditions), as it is fire-resistant. The panels are impervious to biological degradation. These features make the panels particularly suitable for building applications. Surfaces are smooth and compact and ideal for all types of finish, whether water-based paints, varnish or any other kind of coating material. Owing to the 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}.

The 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. Economic considerations in the choice of plant and machines for the production of particle board*

A country wishing to set up a particle board industry must: *(a)* take into account certain general considerations; *(b)* determine the total capacity of the plant and the size and type of board to be produced; and *(c)* choose the best machinery.

General considerations

Three main considerations generally affect the decision to produce particle board:

(a) The need to develop the building trade or the furniture industry as well as to meet special requirements in the packaging and plywood industries;

(b) The amount of raw material available (wood and agricultural by-products);

(c) Local and export market potential.

Even if there is a need to develop the building trade, local markets may not be large enough to justify even a very low production level of about 30 m³ per day (22 hours), unless the client is official and the industry is supported by the Government. The availability of infrastructure, technology and skilled workers are also important considerations. A country that lacks wood but is rich in other natural resources could consider purchasing a plant and importing round wood for various uses; the waste wood could be used for the production of particle board. The glue, when dry, represents about 10 per cent by weight of the dry product. Thus the availability of glue and other additives must also be considered. The prospect of placing the product on the local market and possibly abroad, either directly (raw board) or indirectly (processed board), is another very important consideration when examining the advantage of establishing a particle board industry.

*By T. F. Slodyk, Technical Director of SAP Pagnoni, Milan, Italy. (Originally issued as ID/WG.369/3.)

Output

Once the needs and markets have been analysed and the availability of raw materials, infrastructure and labour have been ascertained, it is necessary to calculate the most advantageous output for a new plant. The following considerations must be taken into account:

(a) The number of factories of the same type already in the country;

(b) The real urgent needs and future needs;

(c) The availability of spare parts.

Table 1. Growth of the particle board industry, by economic grouping, selected years

Group	*1950*	*1960*	*1970*	*1975*	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*Percentage of total world production, 1984*
	(million m³)										
Developed market economies	0.02	2.6	14.7						29.0		66.6
Northern America	0.01	0.6	3.4						8.9		20.5
Western Europe	0.01	1.9	10.5						17.8		41.0
Oceania	—	—	0.3						0.8		1.8
Others	—	0.1	0.5						1.5		3.5
Developing economies	—	0.1	0.6						2.7		6.2
Africa	—	—	—						0.2		0.5
South America	—	—	0.4						1.6		3.7
Asia	—	—	0.2						0.9		2.0
Centrally planned economies	—	0.4	3.8						11.6		26.6
World total	0.02	3.1	19.1						43.5		100.0

Source: Food and Agriculture Organization of the United Nations, *Yearbook of Forest Products*, various years.
Note: Figures are rounded where appropriate.

International data

Data on wood-based products on the international market in past years can be helpful in deciding whether to set up a plant. The growth of the particle board industry by economic grouping from 1950 to 1984 is shown in table 1. The growth in the production of various wood-based panels over the same years is shown in table 2.

The production of wood-based panels more than doubled in the decade from 1960 to 1970 (from 30 to 70 million m³). According to estimates of the Food and Agriculture Organization of the United Nations (FAO), production is expected to reach a minimum of 140 million m³ by 1990 and 170 million m³ by the year 2000.

Since over 38 million m³ of particle boards were produced, it can be assumed that growth will be at least the same over the next years, reaching 56 million m³ by 1990.

The production of wood-based boards in the European countries from 1972 to 1978 is shown in table 3.

Data on the plants producing wood-based panels in Western Europe are presented in table 4.

Table 2. World production of wood-based panels and sawn wood, selected years

(Million m³)

Type of panel or wood	*1950*	*1960*	*1970*	*1975*	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*
Face-veneers	—	1.2	3.2								
Plywood	6.1	15.3	33.1								
Particle board	0.02	3.1	19.1								
Fibreboard	5.4	11.0	14.4								
Total boards derived from wood	11.5	30.6	69.8								
Sawn wood	265	344	413								

Table 3. Wood-based board production in European countries, 1972 and 1978

	Year		*Increase or decrease*	
	1972	*1978*	*Thousand m³*	*Percentage*
Particle board	14 245	17 793	3 548	24.9
Plywood	3 420	2 420	(1 000)	(29.2)
Hard fibreboard	1 960	1 530	(430)	(21.9)
Insulating board	1 045	760	(285)	(27.2)

Source: European Federation of Associations of Particleboard Manufacturers (FESYP).

Table 4. Production capacity of wood-based panel plants in Western Europe

Production capacity	*Number of plants*	*Percentage of plants*
0 to 20,000 m³/year	27	11.2
20,000 to 50,000 m³/year	55	22.8
50,000 to 100,000 m³/year	74	30.7
100,000 to 200,000 m³/year	51	21.2
Over 200,000 m³/year	34	14.1

Total productive capacity, about 23,000,000 m³

Real output, about 18,000,000 m³

Extra capacity margin: 27 per cent

Source: European Federation of Associations of Particleboard Manufacturers (FESYP).

Only 11 per cent of the existing plants produce under 20,000 m³/year while over 35 per cent produce more than 100,000 m³/year. The plants with small capacities are rather old and are no longer profitable. These data are significant in choosing plant capacity.

In the United States, productive capacity increased from 7.5 million m³ in 1972 to 9.5 million m³ in 1978, an increase of 26.7 per cent, while production increased from 5.49 million m³ in 1972 to 7.6 million m³ in 1978, an increase of 38.4 per cent (equal to 6.4 per cent per year). The number of factories increased from 58 to 85.

In the last six years, particle board production in Japan more than doubled. World-wide particle board production reached 38 million m³ in 1978, as opposed to 3.1 million m³ in 1960.

It is unlikely that any further increases will occur in European countries, since wood is not as readily available as it was in the past and costs of raw material, power and labour are rising. Therefore, developing countries that are rich in wood and that export large quantities of unprocessed wood should consider the establishment of processing facilities, and countries that import wood for processing into plywood should set up facilities for the exploitation of wastes. Malaysia, Papua New Guinea and the Philippines currently export logs; these countries could become important plywood and particle board manufacturers in the near future and pave the way for new plants and investments.

Table 5 shows the destination of log exports from Indonesia. Assuming a 50 per cent conversion factor, at best, for plywood and sawn wood, some 20 million m³ per year of Indonesia's logs could be recovered. The price of wood doubled in one and a half years, both for coniferous and non-coniferous species (from $55-$60 per m³ in 1978 to $105-$120 per m³ in 1980). Full exploitation of wood could be achieved through a programme of wood conversion and investments in suitable technologies.

Table 5. Destination of Indonesian exports of wood

Destination	*Log volume (million m³)* 1983	Percentage[a]	1984	Percentage[a]
Japan	1.726	57.6	0.906	57.8
China	0.585	19.5	0.320	20.4
Republic of Korea	0.179	6.0	0.084	5.4
Hong Kong	0.101	3.4	0.060	3.8
Singapore	0.283	9.5	0.154	9.8
Others	0.118	4.0	0.043	2.8
Total	2.992	100.0	1.567	100.0

Source: Food and Agriculture Organization of the United Nations, *Yearbook of Forest Products* (Rome, 1984).

[a]Rounded up.

Note: Export figures represent almost half of the total Indonesian exports (about 40 million m³/year).

The wood that could be processed in Indonesia, the Philippines, Sabah and Sarawak and other countries of the region is about 35-40 million m³ per year, and market demand (Japan, Republic of Korea, Taiwan Province and Europe) is almost the same (35 million m³ per year). Comparing the production of these countries with their percentage of particle-board production (only two per cent of the total world production), it becomes obvious that the possibilities for setting up plants of various capacities in that region must be investigated.

Plant and investment alternatives

An accurate study of the different markets in the world can be helpful in choosing the most economic plant for investment.

Wood-based panel production can be expected to grow to only about 140 million m³ by 1990. If particle-board production remains at 40 per cent of total wood-based panel production, particle-board production will increase at a rate of 1.7 million to 2.2 million m³ per year to reach a level of 55 million to 65 million m³.

In Europe, which accounts for about 49 per cent of world particle-board production, market demand should rise at least 1 million m³ a year; thus, in 1990, European production should become about 28 to 30 million m³.

The low per capita consumption in countries such as Italy, Portugal and Spain will probably rise to account for this increase in production surplus. This increase can probably be met by countries that are major consumers through the full exploitation of production capacities (plants now exploit only 80 per cent of their capacity) or by modifying or modernizing existing plants. Relatively small expenditures for the purchase of machinery can increase plant capacities by 30 per cent or more.

The situation is different in Latin America, Africa, Asia and Oceania, where growth is expected to be much greater because of the rate of development and the abundance of forests.

Determination of plant capacity

Productive capacity and board type

Industrialized countries

There are general rules for determining plant capacity since prices of wood, power and finished products are more or less alike in all countries (except in Finland and the United States). If manpower remains constant and production is doubled, for example from 150 m³ to 300 m³ per day, the percentage for labour costs and other expenses will be reduced.

Some examples of cost calculations are found in table 6. In addition to production costs, the cost of the plant site will also have to be considered. The ease of access to the plant (roads etc.) can be vital when deciding to set up a new plant or to increase the production of an existing one. In any case, a plant should be studied for the use it can make of different types of wood, wastes and annual plants.

The type and size of boards depend mainly on the market situation, the boards' end-uses, the consumers' requirements, the climate of the country and international standards and building regulations.

Developing countries

In developing countries, plant capacity must be analysed case by case. Countries rich in wood but lacking

Table 6. Production cost breakdown—three actual cases in Italy

(Percentage by input) (1978)

Input	*Case I—300 m³/day (board thickness, 18 mm; specific gravity 0.65)*	*Case II—120 m³/day (board thickness, 14.5 mm; specific gravity 0.68)*	*Case III—140 m³/day (board thickness, 15.5 mm; specific gravity 0.64)*
Wood (1,000-1,280 kg/m³ at Lit 50-70 kg)	47.2	49.2	44.4
Glue (100-110 kg/m³ at Lit 290-300 kg)	23.9	18.8	27.6
Labour	4.8 (54 workers)	7.4 (26 workers)	8.1 (20 workers)
Fuel (burners, driers, transporters, heating)	7.2	3.2	4.5
Electric power (about 150 kW/m³), lighting, heating etc.	4.6	4.5	7.2
Various working materials (abrasive materials, knives etc.)	3.9 }	6.2 (for both rows)	0.9
Maintenance and repair	5.2 }		1.8
Overhead	2.9	9.8	1.8
Depreciation	2.6	1.7	3.6

facilities should choose plants of rather small capacities located near the sources of supply. Countries with a large unskilled labour force should choose small-sized plants, with little mechanization.

Assuming that wood and labour are relatively cheap, the total cost of boards should not be high. Investment will depend on the local demand for boards and on the care taken to recover and exploit all wastes generated when preparing the raw wood for export. Any type of waste, when turned into boards, represents a form of capital (if it cannot be used as an energy source). With this in mind, it would be better to choose small plants, with the possibility of modifying them in order to increase production in the future.

Determining the main features of boards to be produced in developing countries is rather complex. In the case of small and simple plants, the board size could be 1,220 × 2,440 mm, which is more or less the standard dimension for plywood. On the other hand, if the intention is to export, these measurements do not comply with European market standards very well. The type of board to be manufactured also depends on the ambient conditions (resistance to humidity, mould or insects). It should also be noted that the more simple and less mechanized a plant is, the more difficult it is to obtain a three-layer board with faces suitable for lamination. Problems of relatively higher formaldehyde emissons also preclude exports to many of the developed countries.

These considerations are vital in the choice of a plant. A good-quality board is always an advantage, so purchasing good quality machines is normally profitable.

Choice of machinery

The machinery chosen should correspond to the capacity required. A diagram of a typical plant appears in the figure. This type of automated plant, with a press size of 2,000 × 11,600 mm, can produce about 160 m³ in 22 hours, with a board thickness of 20 mm. A small plant with a press size of 1,220 × 2,440 mm will produce about 23 m³ in 22 hours.

For a plant with daily outputs of 25 and 30 m³, the arrangement of machinery is wholly different, although the flow sheet would be similar to the one of a plant having an output of 160 m³. A plant producing 25-30 m³ should be designed for a future expansion of its capacity up to 55-60 m³. A small-size plant can be almost entirely manually operated, while a medium-size plant (160-400 m³) must definitely be automated. In the figure, all parts marked in black represent components of the plant that can be removed from the line of 160 m³ per day.

Comparative investments

Approximate costs for plants producing boards measuring 1,220 × 2,440 × 19 mm and 2,000 × 11,600 × 19 mm are given in table 7.

Economies of scale play a very important role, and total production costs can vary according to production increases, approximately as follows:

From 25 to 150 m³ per day: decrease of about 37 per cent

From 25 to 50 m³ per day: decrease of about 21-25 per cent

From 50 to 150 m³ per day: decrease of about 6-9 per cent

Considering rough production costs in plants for 25 to 50 m³ and 150 m³ per day, the resulting returns on investment have been reported as shown in table 8.

Table 7. Cost of machinery and equipment in plants of three different sizes

(Dollars) (1978)

	Average output per year[a]		
	6,750 m³ (20-25 m³ per day)[b]	*13,500 m³ (45-50 m³ per day)*[b]	*46,000 m³ (150-160 m³ per day)*[c]
Imported machinery including all expenses, transport and insurance	1 250 000	1 500 000	5 400 000
Local supplies	100 000	250 000	1 400 000
Assembly, foundations, vehicles	350 000	350 000 }	1 300 000
Other	100 000	100 000 }	
Totals	1 800 000	2 200 000	8 100 000

[a] Based on 300 working days per year.
[b] Board size: 1,200 × 2,440 × 19 mm.
[c] Board size: 2,000 × 11,600 × 19 mm.

Table 8. Return on investment for plants of three different sizes

(1978 prices)

	Average output		
	25 m³/day	*50 m³/day*	*150 m³/day*
Cost ($/m³)	145	135[a]	105
Selling price ($/m³)	170	170	170
Excess ($/m³)	25	35	65
Gross return on capital per year (average output × excess)	168 500	472 500	2 990 000
Investment (machines only)	1 800 000	2 200 000	8 100 000
Return on capital as a percentage of investment	9.4	21.5	37

[a] In particularly favourable conditions, this figure could be as low as $115/m³.

For plants with capacities ranging from about 150 m³/day to 500 m³/day, proportions do not change so much; therefore, the main factor is the amount of wood available. For developing countries, the principles can be completely different. Where capital is lacking, local consumption is low and labour is largely unskilled, a small-size plant (25-30 m³/day), designed to be extensible, can definitely be justified.

Other components of plants with the capacities as described above are shown in tables 9 to 12. It can be seen from the tables whether small- and medium-size plants are profitable.

Layout of a typical plant

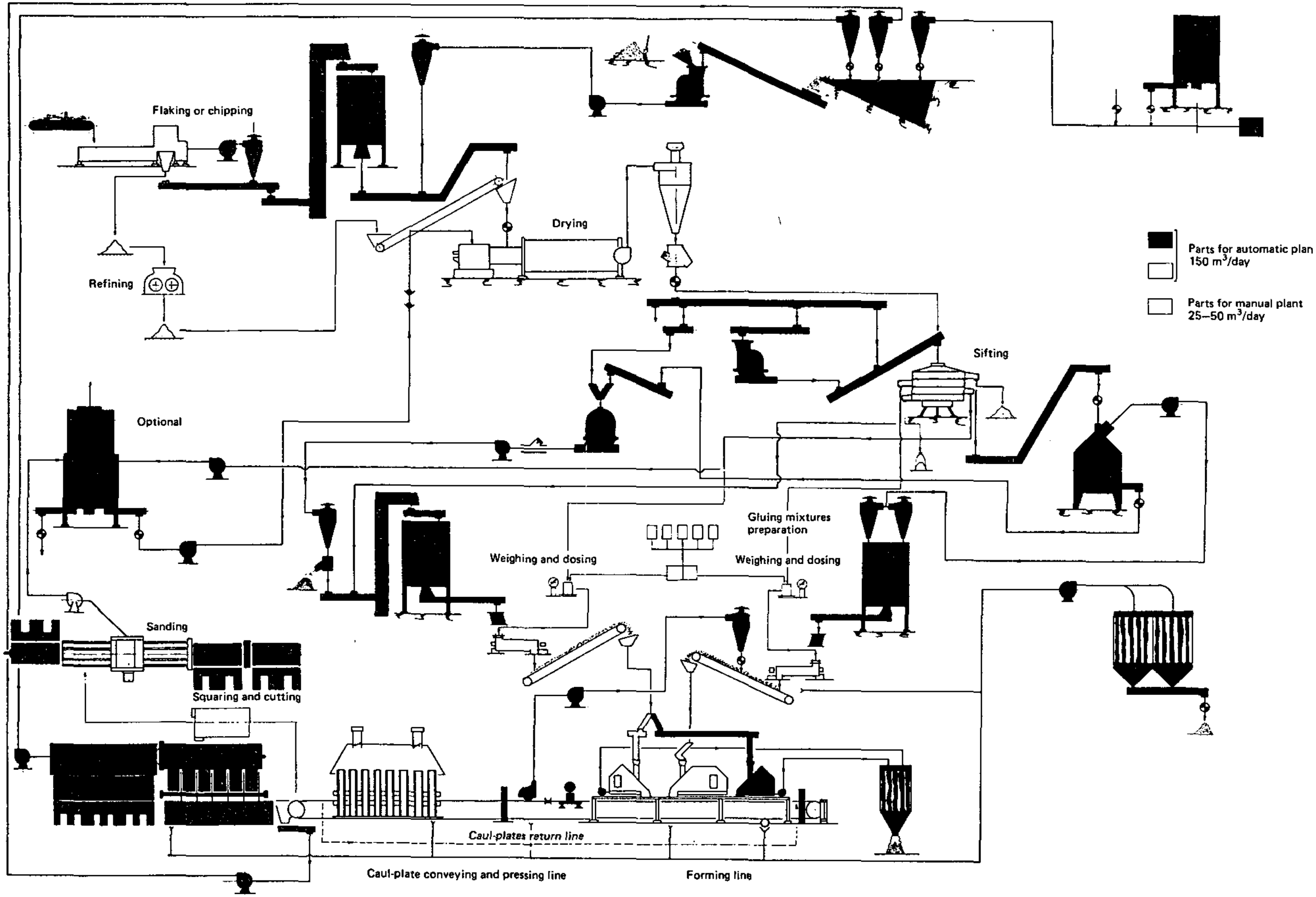


Table 9. Gluing plant

(Dollars) (1978 prices)

Cost	Daily capacity 25-30 m³	50-60 m³	100-120 m³	200-250 or more m³
Glue spreading machine, lateral type, and electric plant	8 000 000	12 000 000	15 000 000	30 000 000[a]
Setting unit of five components, bonding mixture, pumps	6 000 000	8 000 000	8 000 000	15 000 000[b]
Dosing, feeding screw of glue spreading machine discontinuous balance	10 000 000	14 000 000	14 000 000	46 000 000[c]
Total	24 000 000	34 000 000	37 000 000[d]	91 000 000

[a]Two machines.
[b]Automatic.
[c]Two electronic dosing machines.
[d]In the case of two glue-spreading machines, add Lit 15,000,000 for glue-spreading machine and Lit 14,000,000 for dosing.

Table 10. Flaking and refining machines

(1978)

	Capacity 25 m³/day	50 m³/day	100 m³/day	150 m³/day	200 m³/day
Centrifugal flaker					
Model	80/30	100/30	120/45	100/30 (2 units)	120/45 (2 units)
Power	180 hp + 15 hp	220 hp + 25 hp	140 hp + 30 hp	220 hp + 25 hp	140 hp + 30 hp
Price (millions of Lit)	60	75	100	150	200
Flaking machine					
Model	150/DM	150/DMS	180/DMS	150/DMS (2 units)	180/DMS (2 units)
Power	180 hp	220 hp	340 hp	220 hp	340 hp
Price (millions of Lit)	120	130	170	260	340
Refiner					
Model	STL/800	STL/1000	STL/1000	STL/1002	STL/1500
Power	75 hp	150 hp	150 hp	220 hp	270 hp
Price (millions of Lit)	11.1	19.5	19.5	30.5	41

Table 11. Sifter

(1978)

Capacity	Grading quantities	Dimension	Power	Price (millions of Lit)
3 500 kg/h dry	4	2 × 4 × 1.60 m	4.5 kW	10
7 000 kg/h dry	4	2.5 × 5 × 2 m	5.5 kW	15

Table 12. Dryer

(1978)

Production (kg/h of dry raw material)	kg/h of water evaporated	Power	Burner (kg fuel)[a]	Price (including control and fuel burner, excluding dust burner (millions of Lit)
1 500	1 250	60 kW	200 kg/h	70 000 000
3 000	2 500	95 kW	300 kg/h	105 000 000
4 500	4 000	135 kW	500 kg/h	175 000 000

Production (kg/h of dry raw material)	*kg/h of water evaporated*	*Power*	*Burner (kg fuel)*[a]	*Price (including control and fuel burner, excluding dust burner (millions of Lit)*
8 000	7 000	168 kW	750 kg/h (maximum about 1 litre = 840 Kcal)	240 000 000
10 000	8 500	180 kW	900 kg/h max.	280 000 000

Note: For 1 m^3 of exhaust air, the dust content is 150 mg.

[a]Burner can be fed partly with dry wood dust.

When choosing machines, apart from their cost and size, the most important consideration is quality. In the woodworking industry, all machines are generally good; nevertheless, if they are particularly cheap, there will be a risk of shorter machine life, of frequent halts in the course of production and of longer assembly time. If local repair and maintenance are particularly difficult and spare parts are scarce, it would be worthwhile to spend a little more in order to assure continuity in operation and to avoid production losses and lost revenue.

All plants must be well kept, and small problems should not be neglected, since they might endanger future operations. Any plant, although expensive, eventually becomes profitable if easy production without problems is possible, there is a good safety level for the operators and good-quality products can be produced. On the other hand, a simple and cheap plant might become unprofitable from the economic viewpoint if at least part of the production must be of a better quality for lamination and export to industrialized countries.

Investment advantages

Developing countries that have wood, lack pecuniary resources and facilities but normally have ample unskilled manpower, should set up small-sized plants. From the economic point of view, plant output should never be lower than 50 m^3 per day. Plants should be able to achieve at least this output and an even greater one in the future. Meanwhile, it is necessary to provide operator training so that skilled technicians will be available in the near future.

It is advantageous to exploit wood wastes and board finishing dust, either as an energy source or as raw material for the production of new boards. It is advisable that dust under 0.15 mm mesh should not be used or reused since glue consumption will increase (even with the addition of a third gluing machine), the board's mechanical properties will be reduced and the tools used will wear out faster (depending on the amount of glue added and on the board's faces). This use is justified in countries where energy is very cheap and wood and panels are very expensive, as in oil-rich countries. As for the utilization of dust as an energy source, the dust heat value at different moisture contents must always be considered, as shown in table 13.

Table 13. Heat value of wood dust of different moisture content

Moisture content (percentage)	*Kcal/kg wood*	*Kcal/kg fuel oil*
50	2 100	about 10 500
30	3 200	
10	4 300	

In most countries (except the oil-rich countries), it is profitable to use wood waste as an energy source. Wastes should be as dry as possible, as can be seen from table 13. In order to dry them, solar energy could be used or, failing that, a plant for dust drying could be set up, thus allowing the prompt utilization of dust in boilers or particle dryers. In case the dust to be dried is wet and considering all heat losses, about 900 Kcal will be required per kg of evaporated water. For this operation, too, it would be preferable to use wood dust from wastes.

The above considerations, however, refer to small- and medium-size plants for the production of particle boards. They do not apply to plants of a capacity above 500 cubic metres.

XIII. Medium-density fibreboard panels*

Introduction

Medium-density fibreboard (MDF) panels obtained by the dry process are one of the products manufactured with forest material that have enjoyed the most amazing increase in output in the last few years. Manufacture of this panel began in the United States in 1966; its production probably did not exceed 40,000 tonnes. During the period 1966-1971, world output of MDF panels increased from 200 tonnes per day to 1,000-1,100 tonnes per day. During that period, several technical difficulties had to be overcome in order to obtain panels with satisfactory features. At the same time, marketing these panels was difficult because their introduction on the market challenged established uses and habits.

From 1971 onwards, world output increased at rates that varied from 25 to 55 per cent a year. At the end of 1975, output exceeded 3,800 tonnes per day.

The reasons for the success of MDF panels are many. The first is that it will eventually be possible to use by-products of deforestation: large and small branches; branch tops; brushwood; scraps from other wood processes such as stock butts, sawmill trims, sawdust and chips; and waste wood from other wood industries (from plywood, veneer planing, joinery etc.).

As in the production of other particle-based panels (although to a lesser degree and with some limitations as regards the nature and type of the materials used), it is theoretically possible to manufacture MDF panels starting from agricultural by-products (stems of plants that give textile fibres such as cotton and hemp, bagasse). This feature can be particularly interesting for countries that are agricultural and do not have considerable forests or that have only limited amounts of wood available. It should also be borne in mind that MDF, with specific features, represents real "re-made wood"; it offers, more than any other type of panel, the possibility of using the price advantages and the prerogatives of solid wood.

The density (or specific weight) of natural wood depends on the number of fibres that make up a unit volume and on the density characteristics of the fibres, whereas the weight and density of fibreboard panels are practically independent of the values of the timber or other raw materials of the ligno cellulosic family from which they are manufactured. Even using very hard and heavy wood species, it is possible to manufacture fibreboard panels with high mechanical resistance and with a specific gravity of between 600 and 700 kg/m^3. MDF panels can be machined easily and uniformly in all directions; surface finishing operations of any kind (coating and enamelling, veneering and laminating etc.) are also easy and cheap.

An advantage of all types of wood-based panels is that they can be produced in large sizes, which makes such panels easy and economical to use. It is now possible to make panels in sizes in excess of 2 × 20 m, i.e. with an area of more than 40 m^2. The thickness varies in general between 8 mm and 25 mm, but there would be no technical difficulties in manufacturing panels with a thickness as small as 6 mm or as large as 30 mm.

The demand of furniture industries in countries manufacturing wood-based panels exceeds the availability; nevertheless, MDF panels are more expensive than competing panels, i.e. particle boards. The higher cost of MDF panels can be justified, however, because of the lower processing expenses and the better quality of furniture produced. They are also of interest to the building industry where they can be used for fixed and movable partitions or floor underlays etc.

The features and elements of a typical plant with medium output rates are described in the present chapter, and information is given on principles of operation, the overall area necessary for an industrial factory, the energy requirements (heat and steam, electric energy) and the weight of the machinery and mechanical installations. It has been assumed that, in this typical plant, the basic raw material is timber in the form of small-diameter stock (from 8 to 15 cm) and branches (from 5 to 8 cm in diameter), both of which are by-products of deforestation, and industrial waste such as sawmill trimmings, chips of various types, shavings and sawdust.

Manufacturing MDF panels using the "dry" process

Storage

The materials that are fairly regular and in large pieces (stocks and branches, trimmings and offcuts) should be stored in regular piles of up to 4-5 m in height in special factory yards; the piles should be placed on supports off the ground in order to avoid biological degradation of the materials. Fork lifts and front loaders with diesel motors can be used to pile the materials. The smaller sized materials (chips and sawdust) can be conveniently stored in bins if the quantity to be used is relatively modest, if supplies are continuous or if processing takes place continuously; otherwise it is necessary to create large bulk stacks. If the climate is hot and moist, the problem of preservation may arise, because materials may deteriorate owing to fungi and bacteria attacks.

To prevent degradation, a system can be set up to blow in a mixture of air and combustion products at low pressure and through special channels that are equipped with slots and are on the ground. This gaseous mixture at moderate temperature (35-40° C), or even less, creates an unfavourable environment for the development of parasites inside the stacks; it prevents rain water from penetrating the material when protective coverings are not

*By M. Bermani, engineer, technician and expert in the production of fibre board panels. (Originally issued as ID/WG.226/12.)

available; and it reduces the moisture content in the timber, which makes the subsequent converting operations easier and more economical.

Processing

Large-size timber is lifted with front loaders onto trucks and conveyed to the first converting stage. In this stage the timber is reduced into chips in powerful and robust machines (chippers).

Chips of various types and materials from the storage silos are mixed in a general-feed hopper equipped with a hydraulically controlled extraction device. The mixture is then moved to a belt conveyor with the aid of an intermediate screw. The conveyor belt introduces timber into a washing plant in which any foreign matter (sand, mould etc.) that might damage machines or affect the quality of the finished product is eliminated. The washing plant consists of a deep container, into which the chips are forced, and a tilted screw stirrer, at the bottom of which water is recovered and filtered and introduced once again into the cycle.

After washing, the material is conveyed to other hoppers (dosing hoppers) with smaller dimensions. The hoppers are located above the grinders and equipped with hydraulic extraction and proportioning devices, which also break up the "vaults" or buildup of chips between the hoppers' walls that would hamper descent towards the vertical outlet canals.

Beginning with grinding and up to the mat-forming station (from which the panel is obtained by hot pressing), the material is treated in two separate preparation lines.

The material is conveyed from the dosing hoppers through a hermetic screw to the pre-heater. The screw is conical, which allows a material "plug" to build-up at the heater's inlet. The pressure inside the pre-heater can reach up to 12 atmospheres, and the material plug can stand up to such pressure, while allowing regular and uninterrupted feeding.

Under the effect of heat and steam, lignin, which is the natural binder of wood fibres, becomes soft; thus, fibres can be separated from one another with a minimum amount of energy and without deteriorating them. By means of another screw, material coming from the pre-heater is introduced into the disk grinder; the material is forced to pass between a static disk and a rotating disk, which causes the separation of fibres.

Under the steam pressure inside the grinders, the fibres are blown through a valve and a blowing nozzle into the dryer. A special deviation valve is located at this point, which allows the fibres to be conveyed to a centrifugal separator. The separator separates them from steam and recycles them if the moisture content is too high (as is the case, for example, when starting the plant).

The drying of fibres is carried out in two stages in blow-type dryers, in which hot air is used both as a dehydrating vehicle and as a means of transport. Each dryer is equipped with a combustion chamber that uses fuel oil or gas. Combustion gases are mixed with outside air in order to reduce the temperature to the degree suitable for dryer operation. In order to reduce the risk of fire, this temperature is kept at a relatively low level, especially in the first stage when the smallest fibres may settle on the walls and become overheated.

The first drying stage consists of a vertical drying tower. The fibre material is introduced into the lower part of the tower and extracted from the upper part. Fibres are then separated from drying gas and steam; they are moved by the same fan that introduces the gaseous mixture into the tower by means of a centrifugal separator. The second stage consists of a vertical tower into which another fan introduces the hot gaseous mixture from the corresponding combustion chamber. A centrifugal separator again separates the fibres. The material can then be stored in a hopper or passed through an extraction system to the resination treatment, where a catalysable and thermosetting synthetic resin is applied.

In order to obtain sufficiently water-repellent panels, it is necessary to apply a small quantity of mineral (paraffin) wax to the fibres; this process and resination can be carried out simultaneously by mixing wax in an emulsion with the solution of synthetic resin. The melted wax can also be introduced onto the fibres before resination. Experience has shown, however, that the best results are obtained when a fossil wax such as "ozocerite", which is brought to melting in tanks with a heating jacket, is applied directly into the grinders through proportioning pumps and spraying nozzles, which in turn are heated and kept at a considerably higher temperature than the melting temperature of the wax.

The fibre leaving the second centrifugal separator goes into a storage hopper; it is kept as reserves for the first sections of the plant and the resination and panel formation sections. The air discharged by the centrifugal separator is in its turn conveyed into a secondary high-performance centrifugal separator, which separates the fibre fraction that might have escaped the first separator. This fraction is collected and reintroduced into the cycle.

The resin that is usually used for MDF panels is an aminoplastic product, based on urea and formic aldehyde, or melamine. It can be purchased as a concentrated solution (approximately 65 per cent) and stored in tanks that are protected against excesses of temperature if the chemical industry that manufactures it is at such a distance as to make its transport in solution form convenient. If the chemical industry is not located nearby, the resin has to be purchased in the form of powder and dissolves as and when needed. A catalyser, or hardener, must be added to the resin; it is generally purchased in powder form. A special appliance is available to automatically and continuously proportion the two components, dilute them with water and mix them.

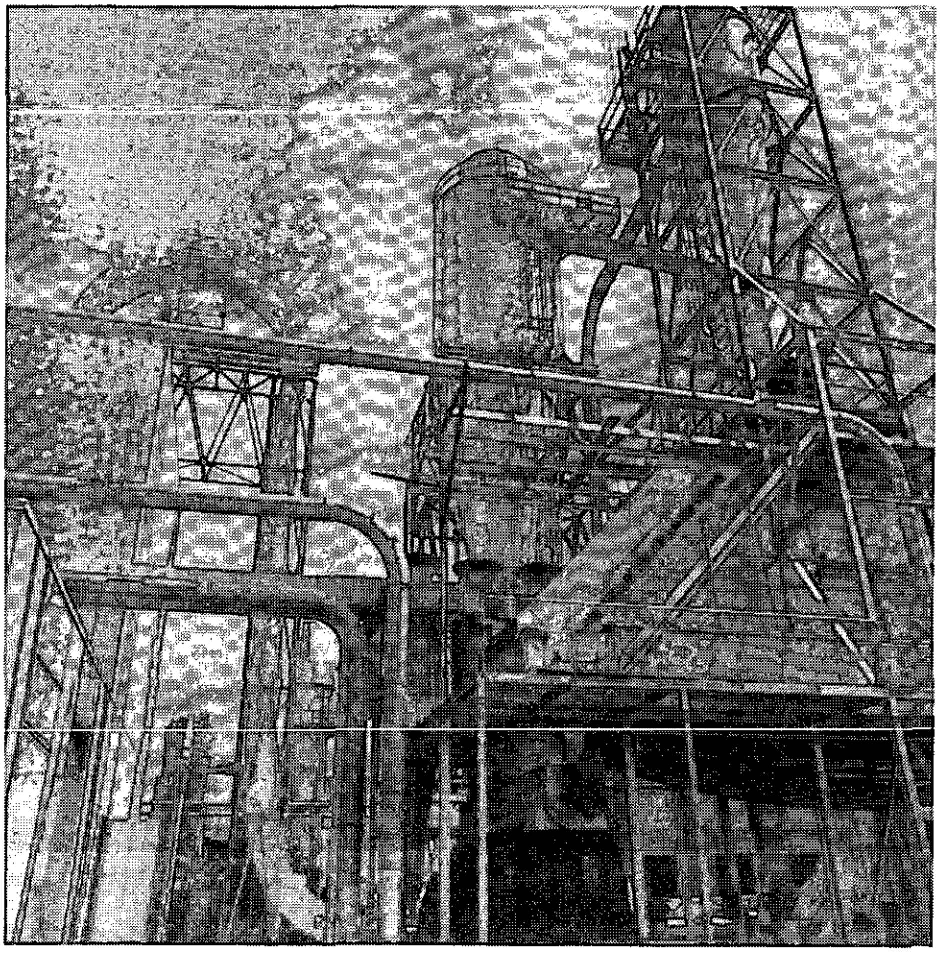
The fibre is carried on an oscillating weighing conveyor belt. Special precise metering pumps with scales weigh the fibres so as to keep the percentage of resin and material scrupulously constant. This mixture is then introduced into the gluing machine.

Almost all manufacturing companies now use the same type of gluing machine. It consists of a horizontal cylinder that can be opened, and it has a double wall within which water circulates to cool the machine. Owing to the cooling, resin and fibre deposits are avoided and therefore cleaning and maintenance operations are reduced to the very minimum. The cylinder has a feed inlet and an outlet hole with a counterweight lock; a rotating hollow shaft in the cylinder is equipped with three series of arms having different shapes and purposes.

The gluing mixture is introduced under pressure into the shaft cavity, and it passes to the intermediate series of arms, which are straight and hollow and have a spraying nozzle at the end. The first series of arms ends with helical blades; its purpose is to distribute the fibre and to project it forward. The third series is in the shape of a robust spatula, with reinforced ends to reduce wear owing to abrasion; this series of arms distributes the resin uniformly in the fibrous mass.

The fibrous mass is then deposited in a hopper equipped with a conveyor-scraper, which spreads it uniformly. It has an extractor-proportioning unit, which transports the mass towards a series of disintegrator rollers which eliminate any clots. An Archimedean screw with two outlet screws separates the material into the required number of portions, which are then pneumatically conveyed to the station where the felt that is to be pressed is formed. The pneumatic transport system in a MDF panel factory is shown in figure 1.

Figure 1. Pneumatic transport of the fibres



When applying the pre-prepared adhesive and auxiliary additives mixture to the dry fibres, through drum glue blenders of the type already described, it is difficult to prevent the creation of clots. This obviously results in defective panels, since the clots appear on the surfaces of the panels.

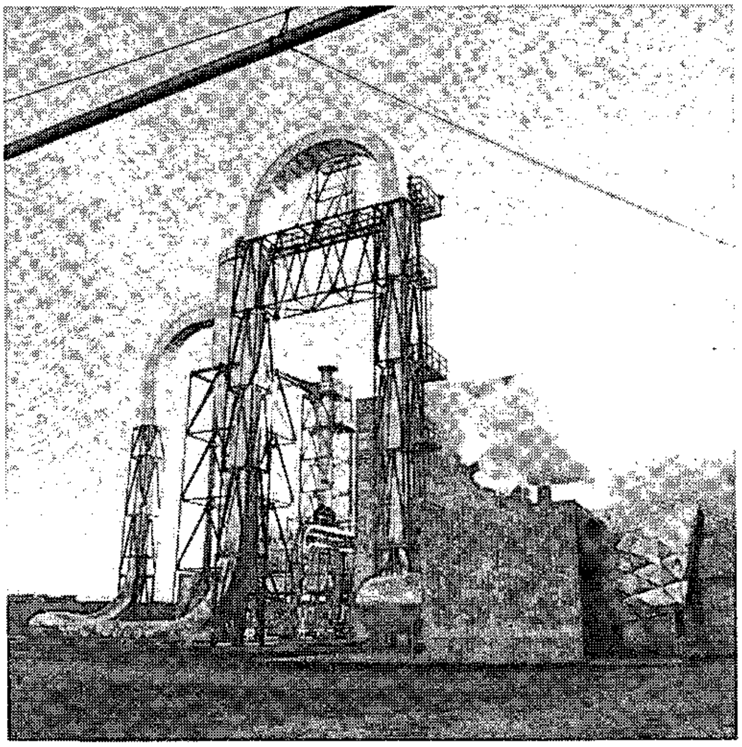
Even if sophisticated technologies are used for blending and preparing the adhesive mix, it would be preferable to use a "revolutionary" system, known as the "glue line", in which the mixture of adhesive and other components (in particular the wax) is injected directly into the defibrator of the chips, either as an emulsion or fused. A separate fibre dryer is used, permitting the glued fibres that emerge from the defibrator to be brought to the required level of humidity in the pneumatic transport duct that transports the fibres to the panel-forming station. A current of hot air, introduced into the ducts, dries the fibres. The end portion of this duct is designed to cool the glued and dried fibres.

Both the "glue line" and the "portal frame" portion which functions as a cooling section are shown in figure 2.

The formation of clots can thus be fully prevented; the equipment used is simpler and less costly; and the mixing of the adhesives with the fibres is as complete as possible. However, control is needed to ensure that the adhesive resin does not pre-polymerize and thus no longer gives the panel the desired cohesion in the subsequent phase of the process (pressing). This is certainly no easy task, but such control can be achieved.

A high-efficiency cyclone separator (figure 3) separates the glued fibres from the transport air. The glued fibres move downwards to feed the forming station (figure 4), which includes three distribution heads that uniformly spread the mass on the whole length. A continuous conveyor, made of filtering cloth, slides below the forming station and the proportioned fibre falls onto it; fibre forms the felt in this way. There are three vacuum boxes below the conveyor, one for each distribution head; vacuum is achieved with three vacuum pumps. Fibre adheres to the belt during passage below the station; after passing the station, felt that has been formed is levelled by a special roller.

Figure 2. Cooling arch of the "glue line"



The excess fibre, which is separated by the roller, as well as the fibre recovered by the air coming off the centrifugal separator and the fan of the first vacuum box (the air coming from the other two fans does not need to be filtered) is reintroduced in the cycle.

The conveyor belt transports the felt towards a press for preliminary pressing, which reduces its height to 1/3 or 1/4 of the original thickness. The press has a low-pressure section, which lets most of the felt contained in the fibre out, and a second high-pressure section, for definite pre-pressing.

The felt leaves the filtering belt and is moved to another compact belt, made of plastic reinforced with cloth, along which edges are ground and a transverse cut is made (by means of a circular saw which moves diagonally) to the length of the finished panel. The wastes from the longitudinal and transverse cuts are recovered and recycled. (The mat-forming and cross-cutting line are shown in figure 5.)

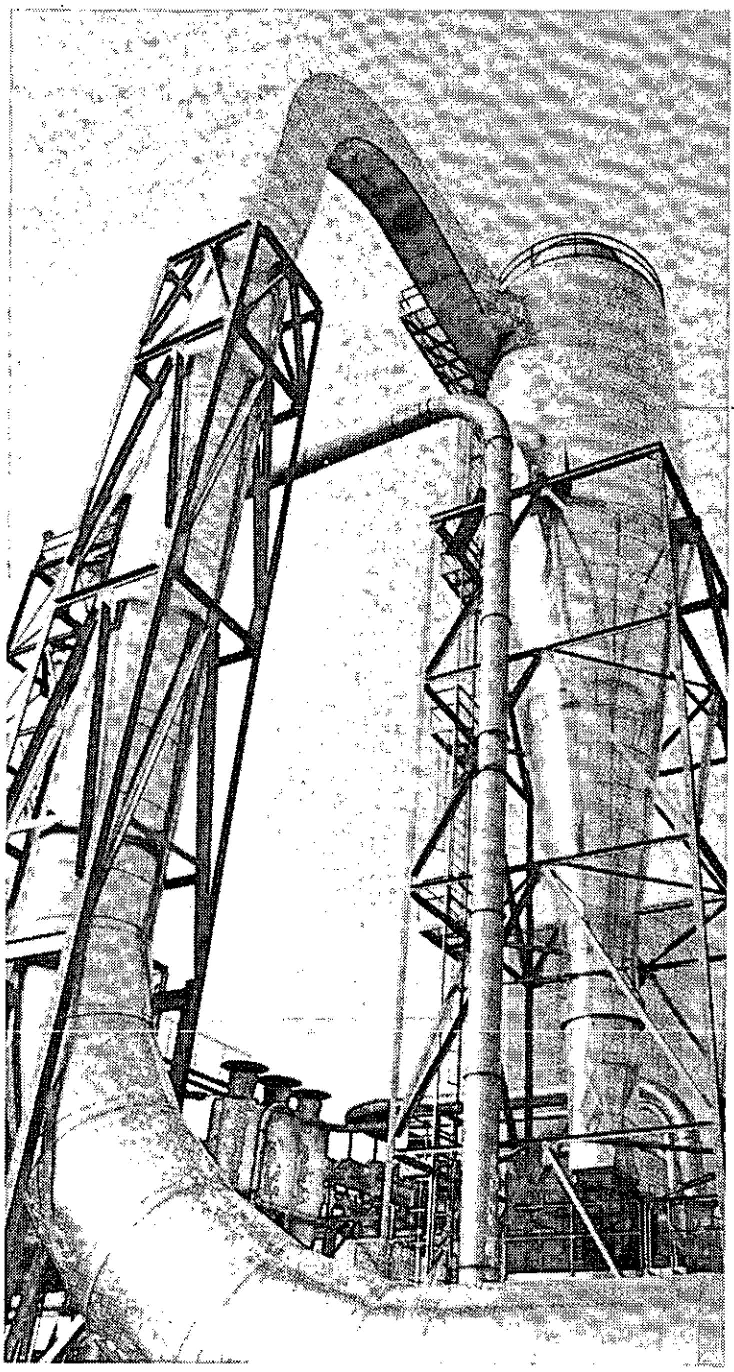
Before being introduced into the high-pressure section of the preliminary press, the fibre felt passes through an electromagnetic appliance to spot the accidental presence of metallic matters. The parts of the felt containing such foreign matter must not be forwarded and are automatically eliminated after passage under the fractioning saw. After this operation, the felt sections are forwarded at higher speed towards three conveyor belts arranged in series and then onto a steel belt synchronized with the last accelerating belt, which passes through the heated-platen press. The steel belt is used to charge felt into the press and extract the pressed panel simultaneously.

The press is the most important machine in the plant, the heart of the plant itself. The plant has only one pressing room, and its size can vary depending on the desired output. The lower platen of the press is fixed; the upper platen, which is driven by many hydraulic cylinders, is adjustable in height according to the desired panel thickness. Each cylinder is equipped with a stroke adjuster, which also adjusts pressure. This press can replace the traditional system, involving metal spacers, which was inconvenient and was not able to ensure the greatest accuracy of calibration.

The heated platens are 90 to 120 mm thick, depending on the press dimensions, with a perfectly flattened surface and a system of inside canalization through which the heat is circulated, thus ensuring a uniform temperature. In order to avoid any overheating of the lower and upper platens, which would lead to deformation and consequent incorrect gauging of the panels, the plates are accurately insulated from the platforms and, to avoid any possible heat passage, a special device for refrigerating the circulated water is placed between the platens and the platforms. To prevent possible differences in temperature between the lower part and the upper part of any platform, the same water is also circulated outside the platens themselves.

The temperature of the platforms is kept at around 200 °C, and the specific pressure exerted on the felt reaches 34-35 kg/cm^2. Mineral oil is preferred at present for starting the press, and diathermic oil is preferable to overheated water under pressure for heating because the former allows automatic boilers to be installed operating at atmospheric pressure and does not necessitate qualified staff.

Figure 3. High-efficiency cyclone to separate the glued and dried fibres

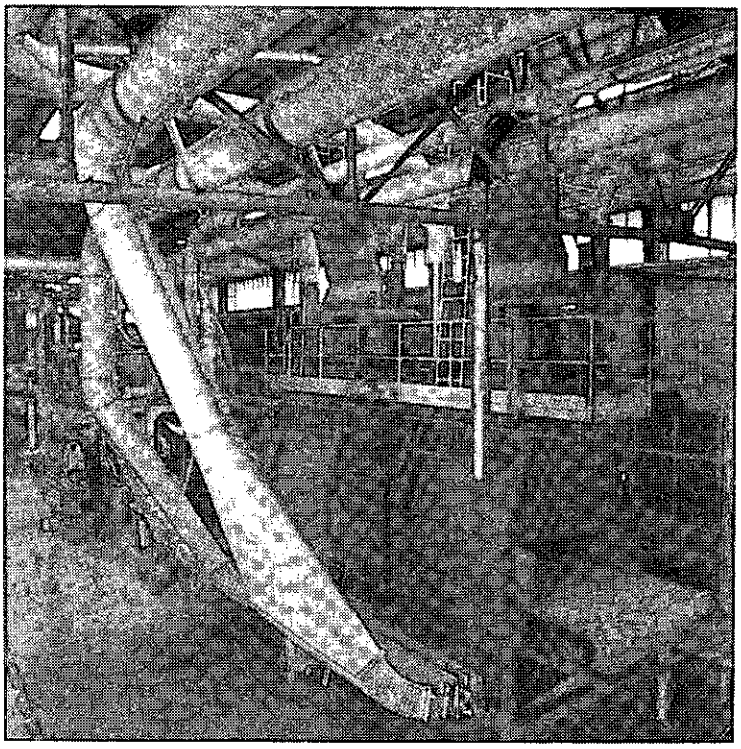


In order to reduce pressing times and to heat the fibre mat as homogeneously as possible during the pressing phase, certain American and European manufacturers of MDF panels have invested in presses (which, for technical reasons, can only have one or two daylights) in which the indirect heating, through thermal oil or superheated water, is generated by a high-frequency electric generator which heats the entire thickness of the panel evenly. These presses, however, are very costly, difficult to operate and maintain and have other shortcomings. It is advantageous to rely on conventionally heated presses, and the duration of the pressing cycles should only be reduced through a careful selection of adhesive resins and their catalysts.

At the press outlet, panels are forwarded to a rotating rack, where they are allowed to cool adequately. They are then passed to the squaring-up section, along which automatic saws grind the edges, and then to the fractioning section, in which the panel is sawn into parts that are multiples of its original length and width. Both sections are arranged in series. Panels are then conditioned in a special room, where they are left in piles for a few days to allow the gluing resin to stabilize and the moisture that has remained in the panel after pressing to spread uniformly.

The last operations before the panel is stored are calibrating and sanding. Panels are passed through wide belt sanders, which have two or three pairs of sanding belts arranged above and below and which therefore operate on both sides. Finally, panels are graded into the various quality levels and trademarks are applied.

Figure 4. Double mat fibre-forming station



The sanding dust, eliminated through suction and separated from the air in a sleeve filter, as well as trimmings from the squaring-up operation and sawdust are not used again in the working cycle but are fed into the boiler.

The physical and mechanical properties of the completed MDF panels are shown in the table.

Physical and mechanical characteristics of MDF panels of various thicknesses

	Thickness[a]		
Characteristic	*6-10 mm*	*12-22 mm*	*25-40 mm*
Density (kg/m³)	800-750	750-730	730-690
Modulus of rupture (kg/cm²)	300	280	250
Modulus of elasticity (kg/cm²)	30 000	28 000	25 000
Internal bond strength (kg/cm²)	7.5	7	6
Thickness swell (%)	10	7	6
Water absorption (%)	20	16	20
Screw holding face (kg)	—	180	160
Screw holding edge (kg)	—	140	130
Moisture content (%)	8	8	8
Thickness within panel (mm)		± 0.2	
Standard size (mm)		3 660 × 1 870	

[a]The board is produced in thicknesses of 6, 8, 10, 12, 14, 16, 19, 22, 25, 30, 35, 38 and 40 mm. They have been grouped in this table for simplicity.

Typical plant for the manufacture of medium-density fibre panels

A typical plant for the manufacture of MDF panels is described below. It has been assumed that the plant has a medium output capacity and produces panels of 19-mm thickness with a specific weight of 700 kg/m³. The total output is 140 tonnes per working day (24 hours), or 200 m³. The panels, 1,830 × 18,300 mm, are to be divided into five panels of 1,830 × 3,660 mm. Panels with thicknesses ranging from 8 to 25 mm and a specific gravity from 600 to 650 kg/m³ may also be produced.

Preparation of fibres

Processing begins with the transformation of the timber material into large chips by means of a milling chip former with a double head and a feeding belt that is 2 m long and that needs 150 kw power. The chips are laid near the first feeder on the manufacturing line, next to the material that is already in small pieces, as mentioned in the previous section. Both raw materials are inserted into a concrete silo with a capacity of approximately 60 m³. Two hydraulically driven automatic feeders are located on the bottom of the silo. Downstream from the silo, a 6 m screw moves the material on a tilted belt conveyor that is 60 m long and 650 mm wide. Another conveyor (5 m long and 800 mm wide) follows. It is equipped with a magnetic detector for spotting and eliminating metallic matter.

The washing plant includes a system for the elimination of sand and mud, the timber extraction plant and the water recycling plant. The conveyor-scraper (10 m³ capacity), which adjusts the quantity of material that is inserted into the hoppers, is equipped with a hydraulic device for feeding the grinders.

The total weight of the metal parts that compose the appliances mentioned above is approximately 40 tonnes; the total installed power is 100 kw.

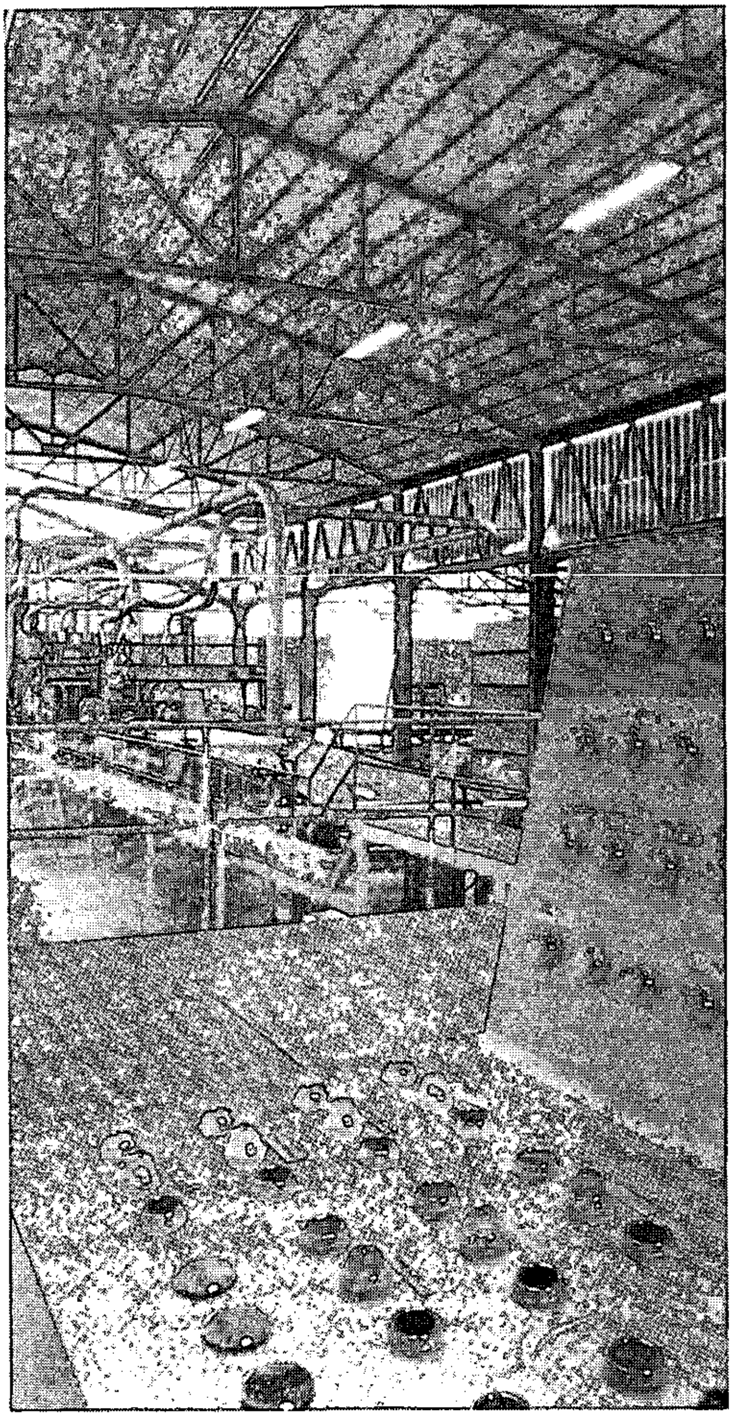
The preheaters, together with the relevant screw-feeding system and the grinders, are built of stainless steel or acid-resisting steel. A small plant under the grinders melts and injects pre-determined proportions of ozocerite into the grinders themselves; from these, the mixture of fibres and steam passes through a special valve to the drying units, or, in the starting phases, it is temporarily deviated to the centrifugal separator.

Fibre drying, application of gluing resin (bonding agent)

Combustion oil tanks, oil preheaters and primary air fans are located at the side of the burners of the two dryers' stages. In the subsequent two drying phases there are: a screw conveyor, which introduces the fibres into the store hopper (not always necessary); an oscillating conveyor belt; a proportioning unit, enclosed into an airtight metal chamber, which feeds the gluing machine (as described in the previous section); and the appliances for the preparation of the resin mixture and for pumping it into the gluing machine.

The total weight of the machines and relevant devices, from preheaters to gluing machines, is 85 tonnes, and the necessary installed electrical power is 2,120 kw.

Figure 5. Mat-forming and cross-cutting line, seen from the control panel of the pre-press and the hot press



Pneumatic transport of resinated fibre, its metering and storage, and forming and pre-pressing of fibre felt

A pneumatic device, a fan, a centrifugal separator and a fibre-extracting device for the transport from the gluing machines to the proportioning silo are located in this part of the factory. The proportioning silo is of iron and steel plate. Its upper part is a scraping unit for levelling, in which the fibre is distributed along the whole length, and the bottom part is a variable-speed conveyor that conveys the material towards a line of disintegrating rollers, which constitute the front of the silo itself.

A screw situated below the silo receives the material, divides it into two fractions and introduces it into two pneumatic conveyors which, through centrifugal separators, feed the forming station. The forming station may have up to three fibre-distribution heads (of the "pendistor" type); it allows a felt to be formed with a rated width of 1,830 mm. Three levelling rollers are placed before the heads, and vacuum boxes with suction fans are situated along the heads and under the forming belt.

The levelling rollers located after the first and the third head of the forming station send the extracted material back through pneumatic conveyors to the centrifugal separator, which is situated above the central head, while the roller located after the second head sends the material to a centrifugal separator, which sends it into the proportioning silo again.

The forming station is followed by the preliminary press, which has low-pressure and high-pressure sections. The detector, placed between the two, intervenes if foreign matter such as metal is present. The pressure is exerted hydraulically by the rollers of the preliminary press; rotating brushes keep the rubber carpets of the press clean.

Saws for the longitudinal trimming of the pressed felt and for transverse cuts are located further on along the line. The material from trimming and transverse cuts is brought back to the first and third head through pneumatic belts.

The total weight of these installations is 160 tonnes, and the installed electrical power is 1,015 kw.

Transport of fibre felt, hot pressing, cooling, squaring up, sectioning and stacking of panels

The felt conveyor belt operates at accelerated speed. Two other sections that operate at an even higher speed are located upstream from the belt. The first section adjusts the spacing between felts; the second high-speed section is equipped with a deviator that sends irregular felt sections to a disintegrator.

The one-station hot press, through which a continuous steel belt passes, feeds the felt to be pressed and extracts the pressed panel; it can exert 11,900,000 kg of pressure, which is equivalent to a specific pressure of 34 kg/cm^2. The hot platens are 120 mm thick, the maximum opening between them is 300 mm, and 44 cylinders control the upper platen.

Another deviator with a disintegrator is installed after the press; it allows faulty panels to be eliminated. This is followed by a rotating rack in the cooling chamber, with 12 rays and with roller devices for automatic charging and discharging, and by 8 saws for squaring up panels and cutting them into sections (two saws for longitudinal cuts, equipped with mills for the disintegration of trimmings; two for head cuts, also with disintegrating mills; and four for intermediate cuts). The sectioned panels are forwarded to a device that automatically stacks panels; it includes a hydraulic lifting table, a series of motorized roller plates and a device for aligning the panels arranged in a pile.

The weight of these machines and equipment is about 500 tonnes; the installed electrical power is 770 kw.

Conditioning warehouse, calibration and sanding, inspection and grading

Panels are stored in the warehouse and left for the time as necessary to complete the cooling of piles, the polymerization of the binding resin and the uniform spreading of moisture inside the panels. From the warehouse, the panels are forwarded to the thickness-calibrating and smoothing sander (of the wide belt "contact" type), with one or several pairs of belts. For the automatic feeding of this machine there are: a roller conveyor on which a fork lifts piles of panels; and a hydraulic lifting table with a pneumatic device and with a motorized roller system for feeding each panel. Another gliding plate is placed before the machine.

The grading plant, in which panels are classified into first and second quality, receives panels directly from the thickness-calibrating and smoothing sander. It includes: a testing conveyor, with a mirror system for the simultaneous examination of the upper and lower sides of the panels; a shifting section with two outlets, each equipped with a hydraulic lifting table; an extractor and alignment device for panels; and gliding plates on rollers, with notches for picking up piles by means of fork lifts.

The total weight of these machines and appliances is about 100 tonnes; the installed electrical power is 460 kw.

Heating plant

A boiler is installed in the heating plant to produce the steam needed for the wood-grinding plant and for other ancillary services; the total quantity of steam needed is 6 tonnes per hour, corresponding to about 16,736 kJ (4,000 kcal) per hour. Operating pressure in the boiler is 15 atmospheres.

The installation of an oil-operated boiler is foreseen for press heating; its power is 10,460 kJ (2,500 kcal) per hour, and it is able to attain a temperature of about 220 °C.

Protection against fire

The danger of fire in plants like the one described here must obviously be taken into consideration, and fire prevention must be extremely scrupulous. Such a plant would use water to extinguish fires; at the most dangerous points, the action of water is supplemented by the introduction of halogen gases, which choke the flames.

At the points where fires might begin in the plant, automatic infra-red "Firefly"-type detectors are installed.

Technical data

Raw material, energy, air and water

The following quantities are needed to manufacture panels having a thickness of 19 mm and a specific gravity of 700 kg/cm (per tonne of panels produced):

Timber (anhydrous weight)	1 tonne
Steam	1 tonne
Energy	400 kWh
Fuel for dryers	120 kg
Binding resin (urea formaldehyde) (anhydrous weight)	90 kg
Fossil wax	20 kg
Hardener	2 kg

The following would also be needed:

Water (900 l/min are needed for cooling plants)	1,000 l/min
Compressed air (7 atmospheres)	10 m^3/min

Staff

The following staff are needed:

Management and administration

Factory manager	1
Sales manager	1
Chief engineer, production	1
Chemical engineer	1
Mechanical engineer	1
Electrical engineer	1
Assistant manager, production	1
Accountants	2
Sales personnel	2
Administration manager	1
Technicians	2
Secretaries	2
Shorthand-typists	2
Employees	2
Shop foremen	3
Chief of the yard	1
Store manager	1
Chief engineer, maintenance	1
Chief electrician	1
Spare-parts shop foreman	1
Total	28

Workers

Timber yard, 3 workers × 3 shifts	9
Fibre preparation, 2 workers × 3 shifts	6
Glue department, 1 worker × 3 shifts	3
Forming station, 1 worker × 3 shifts	3
Press section, 3 workers × 3 shifts	9
Trimming and grinding, 2 workers × 3 shifts	6
Panels selection, warehouse, packing, internal transport, boiler	15
Mechanics, 1 worker × 3 shifts	3
Electricians, 1 worker × 3 shifts	3
Helpers for mechanics and electricians, 1 worker × 3 shifts	3
Lubrication, 1 worker × 1 shift	1
Cleaning, 3 workers × 2 shifts	6
Janitors, 1 worker × 3 shifts	3
Maintenance, 4 workers × 1 shift	4
Electric plants, 3 workers × 1 shift	3
Conditioning warehouse, 1 worker × 1 shift	1
Joiners, 2 workers × 1 shift	2
Drivers, 2 workers × 1 shift	2
Total (about half of whom are specialized and one third qualified or semi-specialized)	82

Conclusions

Technology for the production of MDF panels is in a phase of evolution, and it can benefit from all the experience acquired by the particle board manufacturing industry over the last 20 years.

The number of workers for the size of plant taken to serve as an example (200 m^3 per day) is bound to be reduced through increased automation and an increase in the use of closed-circuit television in the more important sections of the production line.

The increased mass of raw materials in MDF panels (when compared to particle board of the same thickness and density) is at least 10 to 15 per cent more (see the table). This results in increases in the consumption of raw materials, adhesives and energy inputs. To this must be added increased costs of investments resulting from the fact that the price of MDF panels, per cubic metre or square metre, is considerably higher than that of particle boards of the same thickness. MDF panels have a number of characteristics and properties, i.e. homogeneity, compactness and ease of machining the edges in all directions and over its entire thickness (see figures 6 to 12), that are advantageous in industries and crafts that use reconstituted boards. Thus, demand for MDF panels for the manufacture of a number of products, especially reproduction (period) furniture, is expected to increase.

A further advantage of the MDF panel over particle board is that it can use a wider range of timber species, offcuts and wastes and also ligno-cellulosic agricultural residues.

In the coming years there will be a continuous increase in the production of MDF panels. Their use will also extend not only to the developed countries but also to developing countries, above all to countries that have a shortage of sawn wood.

Notwithstanding the above, total global capacity will always remain a fraction of that of particle boards. This will certainly be the case if research to improve the quality of particle boards is successful. The scope for improvements in particle board is theoretically limitless, while it is certainly finite for MDF panels.

Figure 6. Picture frames made of MDF

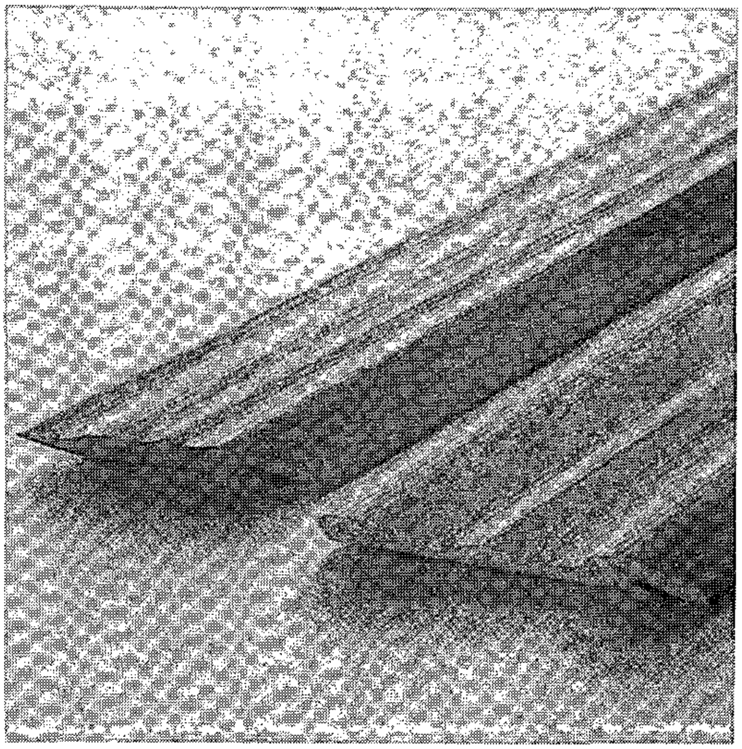


Figure 7. Machined and veneered edge of an MDF panel

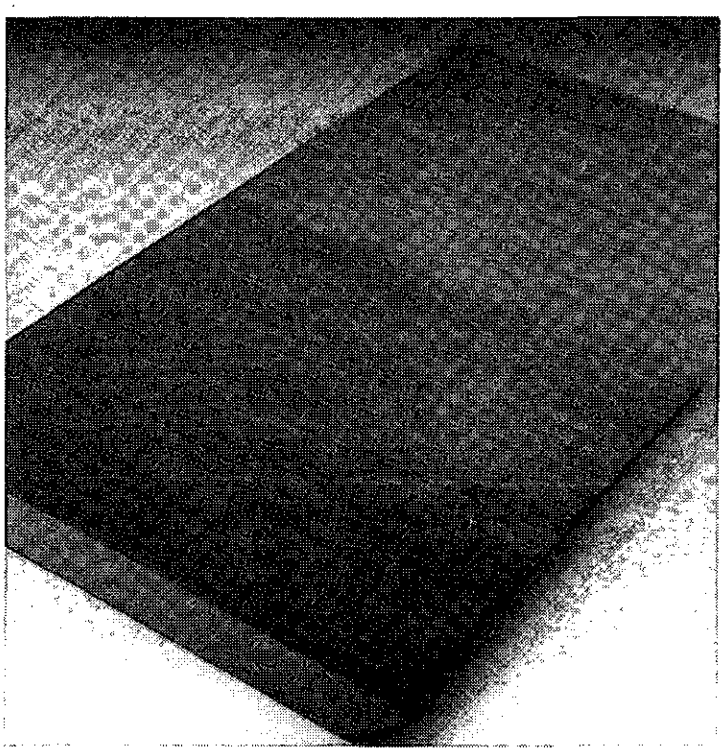


Figure 8. Machined edge of an MDF board used in a composite panel for a top of a reproduction piece of furniture

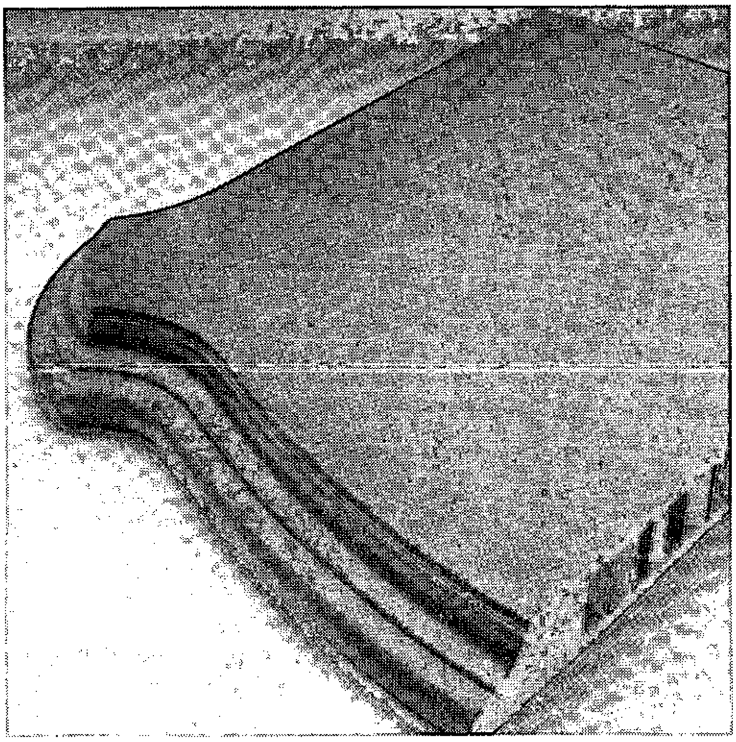


Figure 9. Squared and turned leg made of MDF

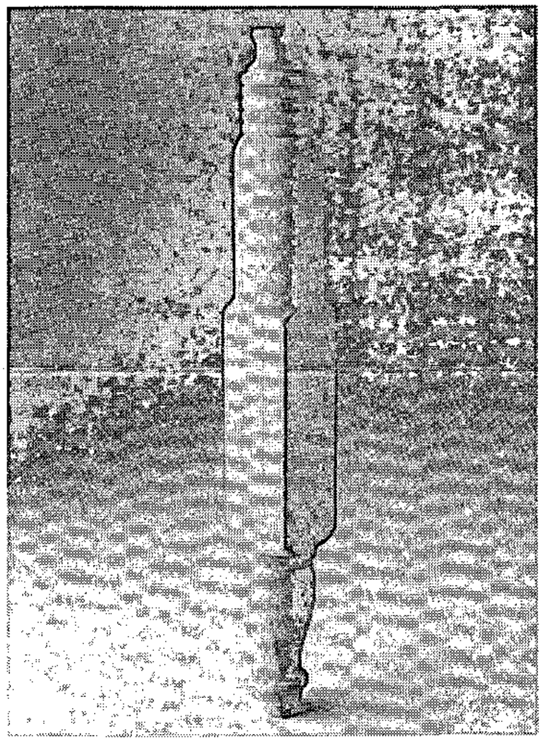


Figure 10. Routed and moulded door panel

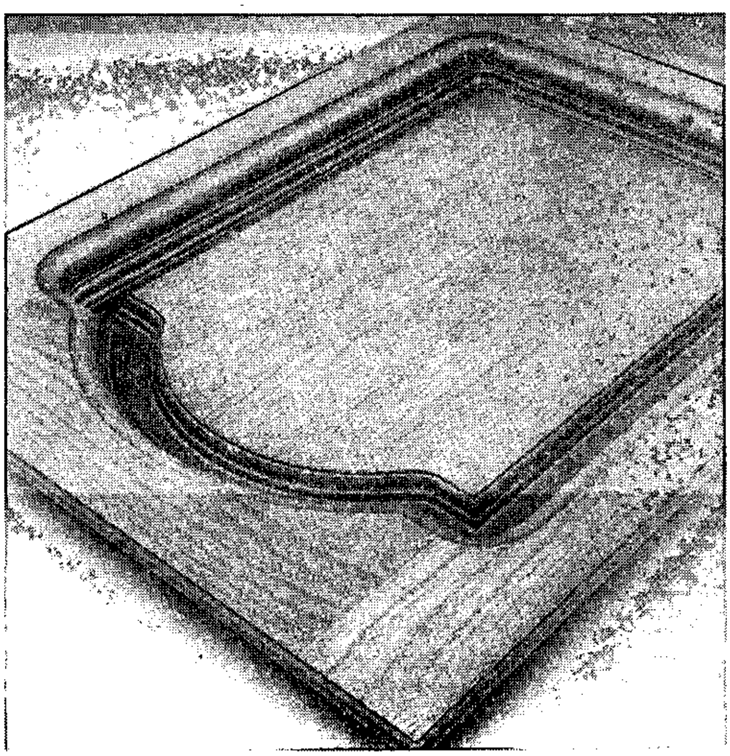


Figure 11. Weather-board effect machined from an MDF panel

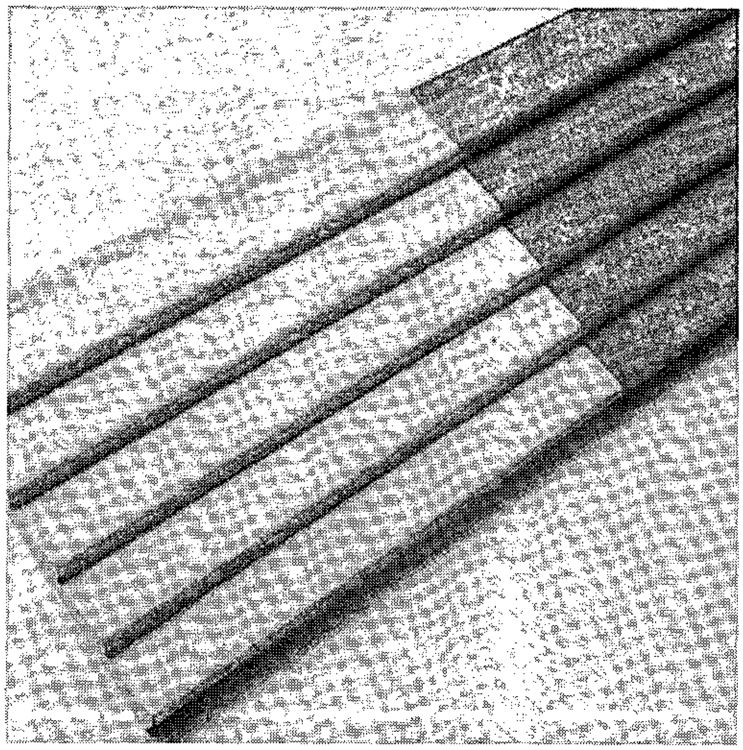
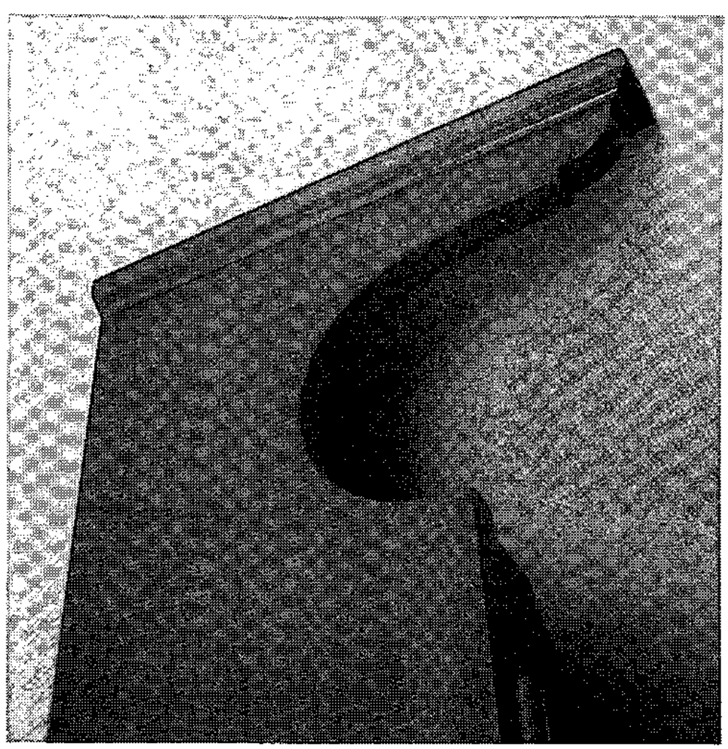


Figure 12. Moulded side panel



XIV. Criteria for the selection of machinery for sliced veneer*

The word "veneer" is used in the present chapter to denote thin sheets of high-quality wood species, 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 phase consists 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 market 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-ordinating 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 the layout is to some extent determined by existing installations;

(b) Efficient internal and external handling. Care should also be taken in selecting the correct location of lifting gear. The apparatus should also be adequate with respect to capacity and speed;

(c) Efficiently designed plant and services 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.

Operation sequence

Log cutting to length

The first production operation consists of sectioning the logs to the required length. Owing 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 portable electric 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).

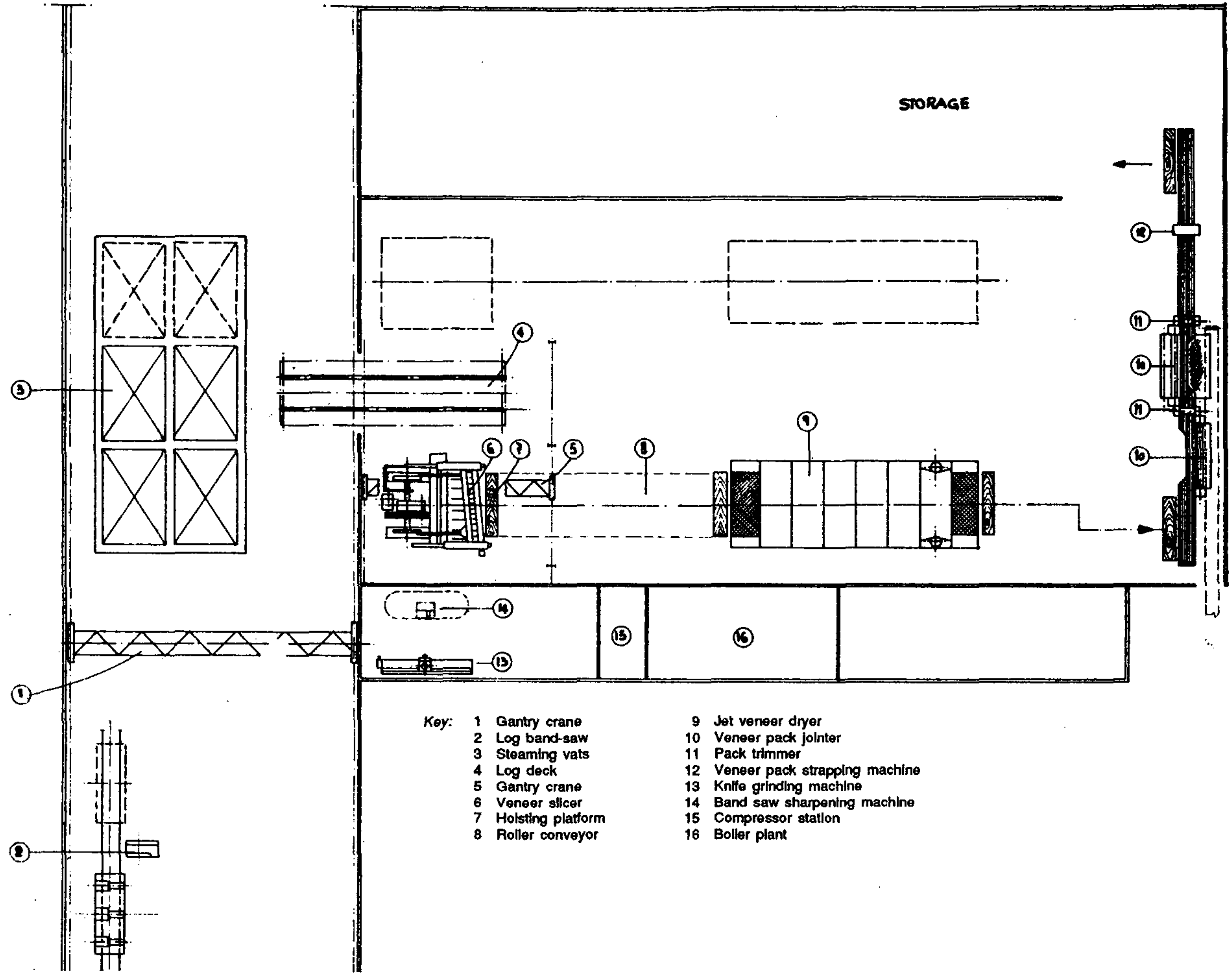
Log debarking[1]

The operation immediately following log cutting to length 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.

*By A. Colombo, consultant in veneer and plywood production. (Originally issued as ID/WG.277/12.)

[1]For additional details on log debarking, see chapter VII.

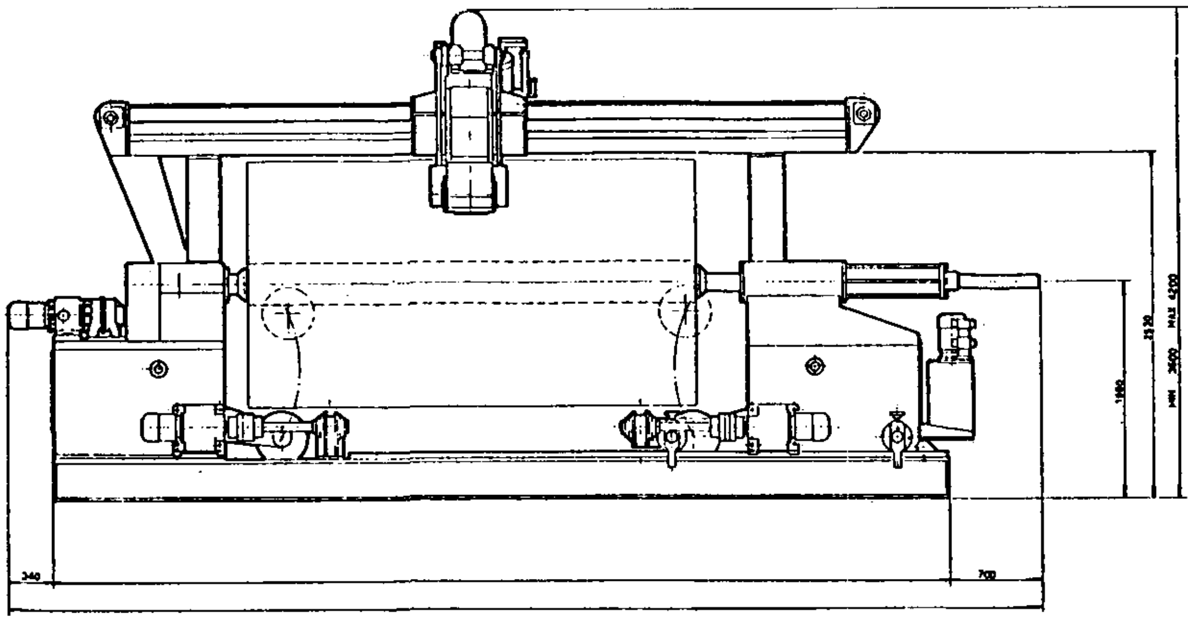
Figure 1. A Veneer slicing plant



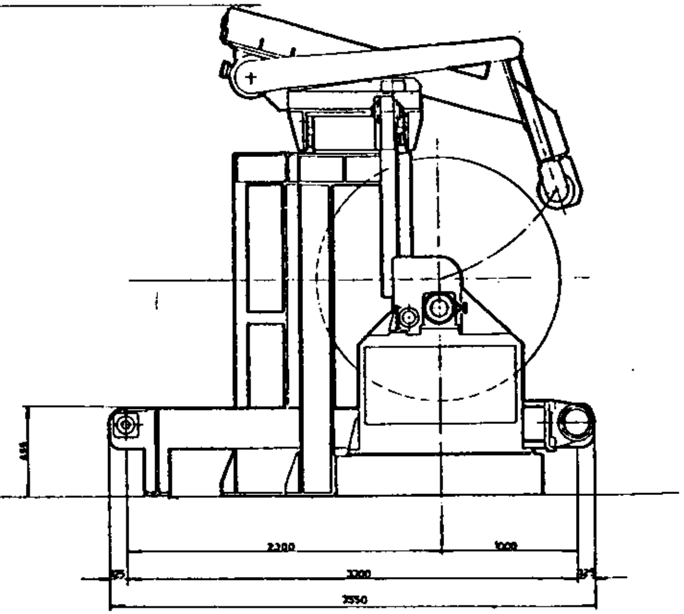
Key:

1 Gantry crane
2 Log band-saw
3 Steaming vats
4 Log deck
5 Gantry crane
6 Veneer slicer
7 Hoisting platform
8 Roller conveyor
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

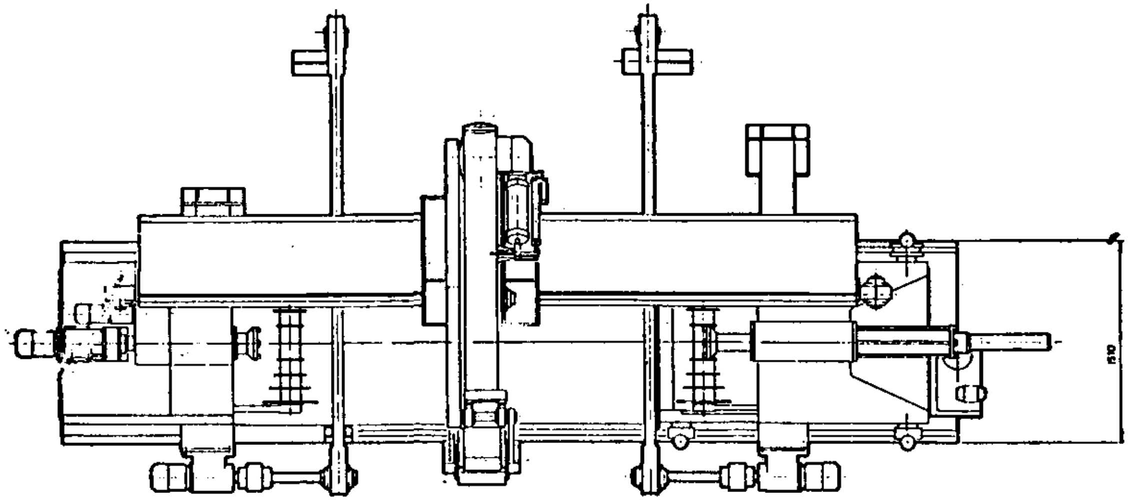
Figure 2. Debarking machine



A. Front view

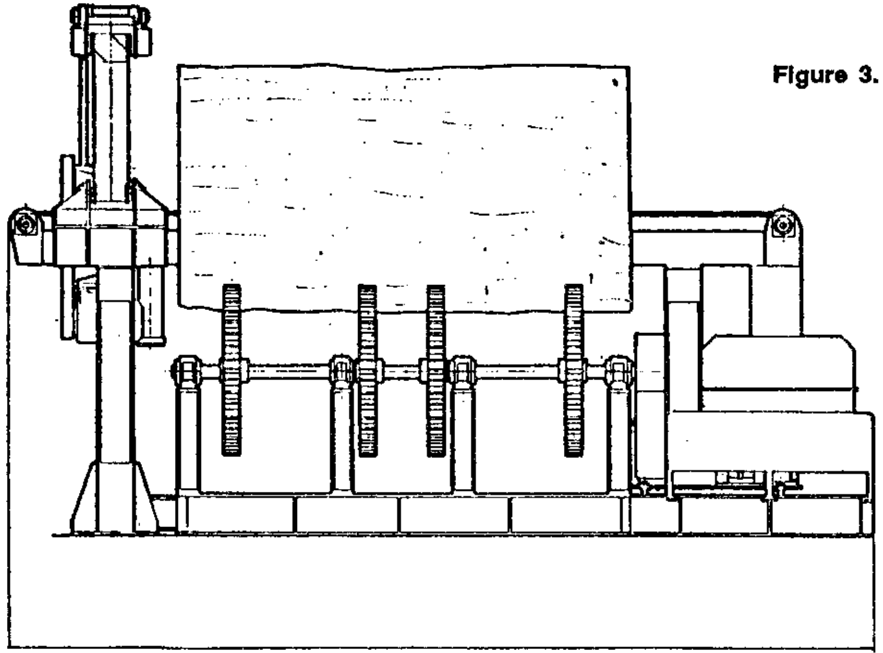


B. Side view

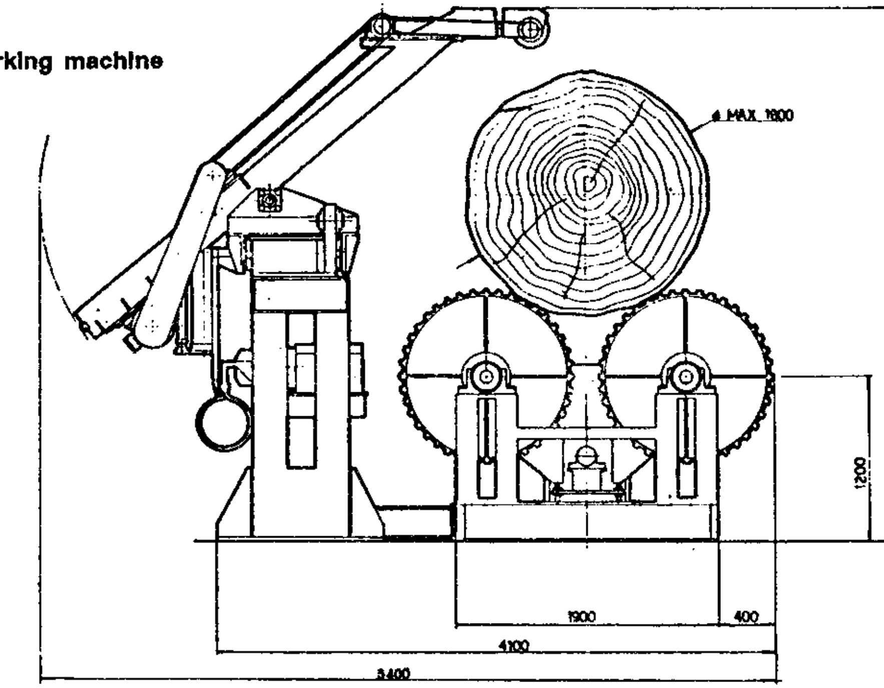


C. Top view

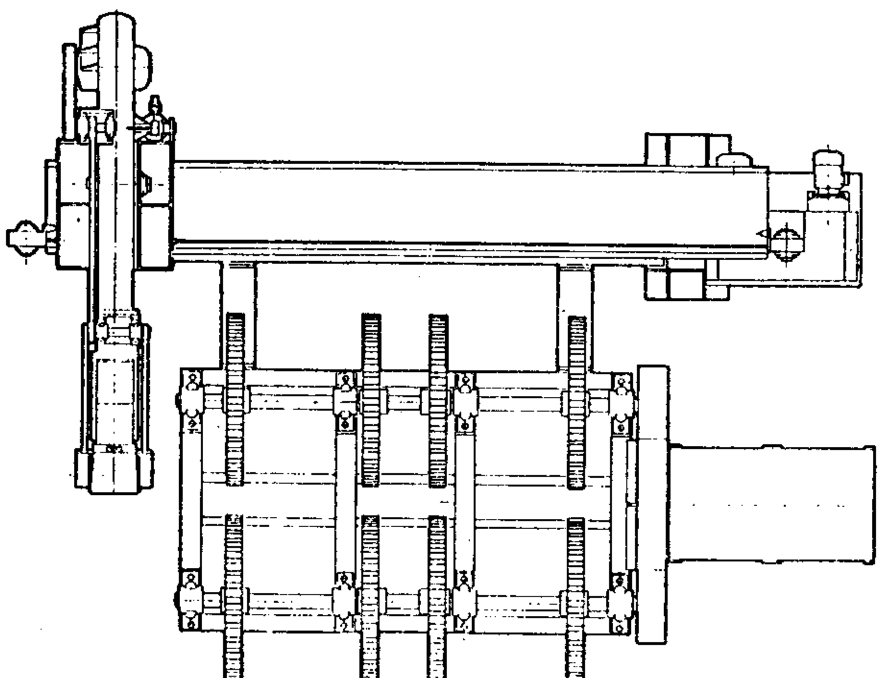
Figure 3. Debarking machine



A. Front view



B. Side view



C. Top view

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 flitch 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 longitudinally into three parts. The log is placed longitudinally on a mobile carriage and can be rotated to allow it to be cut radially at three positions 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 appropriate vats or boiling in hot water. The vats are made of masonry or concrete 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 heat the water and generate the necessary steam for the treatment of flitches.

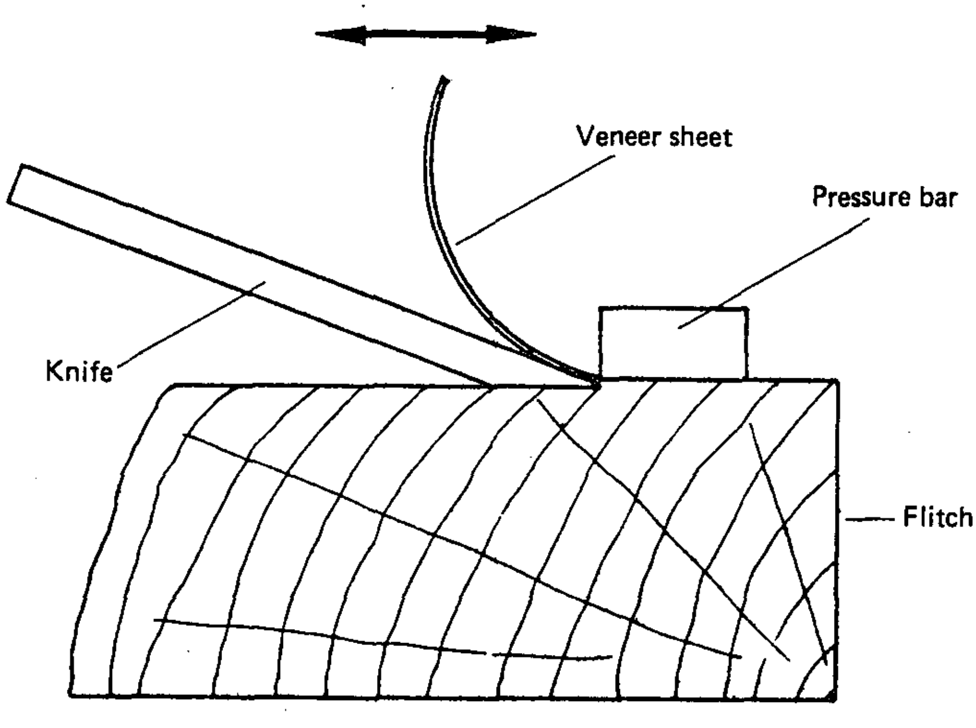
Heating done by immersion in boiling water is generally used only when resins or other substances must be exuded.

The temperature of hydrothermic treatment is normally between 80° and 90° C in order not to damage the mechanical properties of the wood. The duration of this treatment is important and varies depending on species and diameter of the log from 10 to 80 hours. Accumulated data and suitable tables are used to choose the appropriate durations. 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 in the production of veneer is the slicing operation. The 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 the feed equal to the slicing thickness at each feed or return stroke.

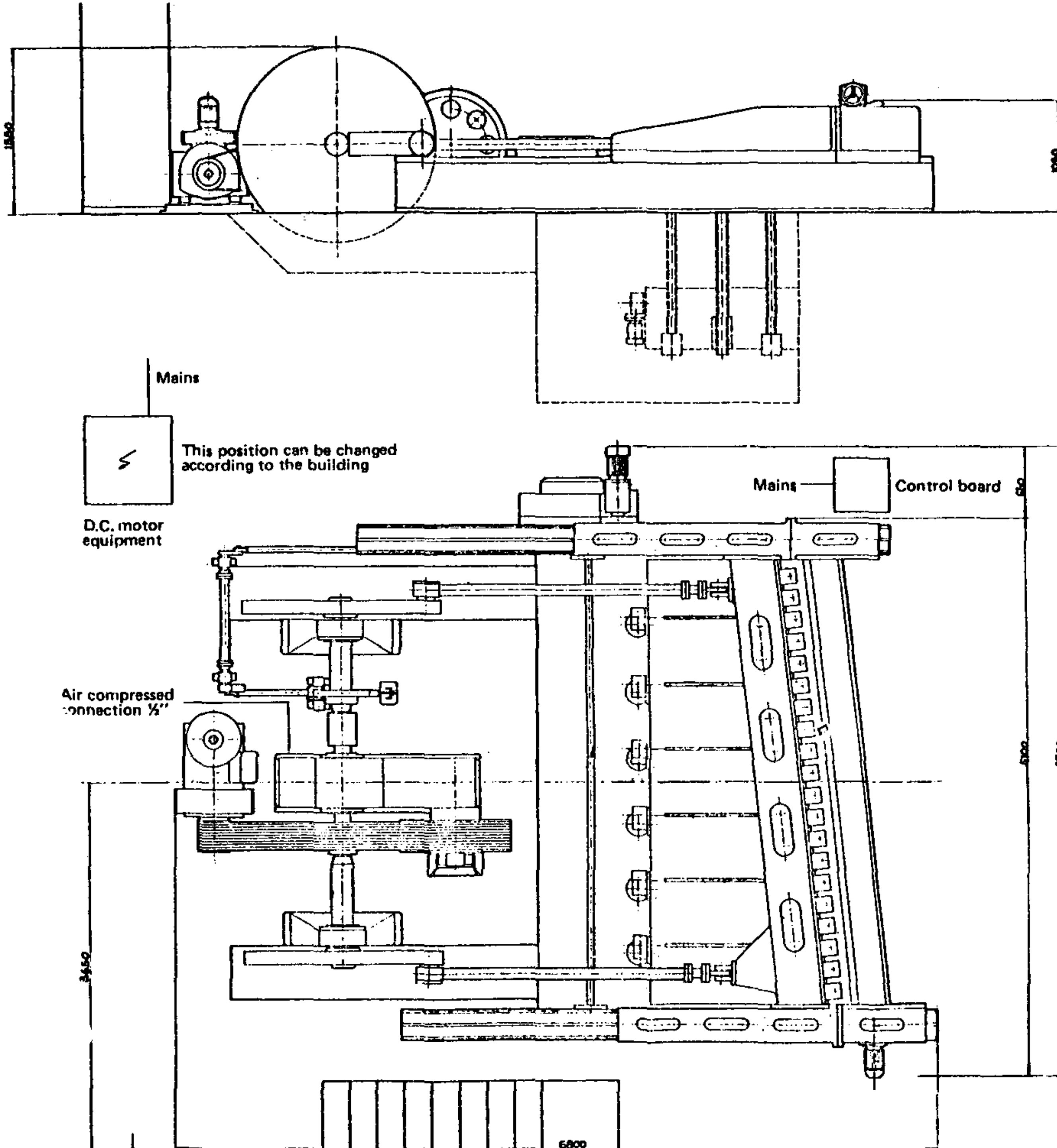
Figure 4. Horizontal slicing



Various configurations have been developed around this basic slicing principle. These include: the log in a fixed position and the 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 predominated in practice: horizontal slicing and vertical slicing.

[2]For additional details on veneer slicing equipment, see chapter XV.

Figure 5. Specifications of a veneer slicer



Volume	m^3	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

Horizontal slicing machines

This is the standard machine and is the most widely used and is 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 the inspection of the flitch and the 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 conveyor 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 a suitably designed 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.

The automatic bolting and releasing of the knife and nosebar on the pressure bar for assembly and cleaning, substituting all manual operations by motorized movements, have made horizontal slicers much easier to operate. They are also highly productive, assuming that the features of rigidity, versatility and precision are incorporated in the design.

In some of the more modern slicers a second set of flitch dogs (front and rear side) have been mounted. Dogging is therefore possible between the front and rear dogs, in addition to the standard dogging against the front part of the slicers. This allows the best inclined position of the flitches to be chosen, which is sometimes necessary for the best slicing operations. It is also possible to find the best incident angle between the knife and the flitch. Any friction between the flitch and the 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 vertical slicing machines, the flitch reciprocates vertically and the slicing unit is stationary. At the end of each stroke, the flitch is advanced by the thickness of the veneer to be produced. A vertical machine is shown in figure 8. Compared with the horizontal machine, there are a few advantages and disadvantages. One advantage is in the higher slicing speed. However, this advantage pertains only to flitches that 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 owing 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).

Automatic handling of veneers

Various systems have been developed to automate handling from the slicer to the veneer dryer in order 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, conversely, the dryer can run idle during the loading and unloading of the slicing machine, during the cleaning of the flitch or when turning the flitch or during down times, thus justifying manual handling and "buffer stocks".

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 need to reduce labour is not of prime importance. An automated line is therefore advisable only as an auxiliary line to another line on which one or more 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 conveyors 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 permitting a reduction in overall size.

Figure 6. Horizontal slicer

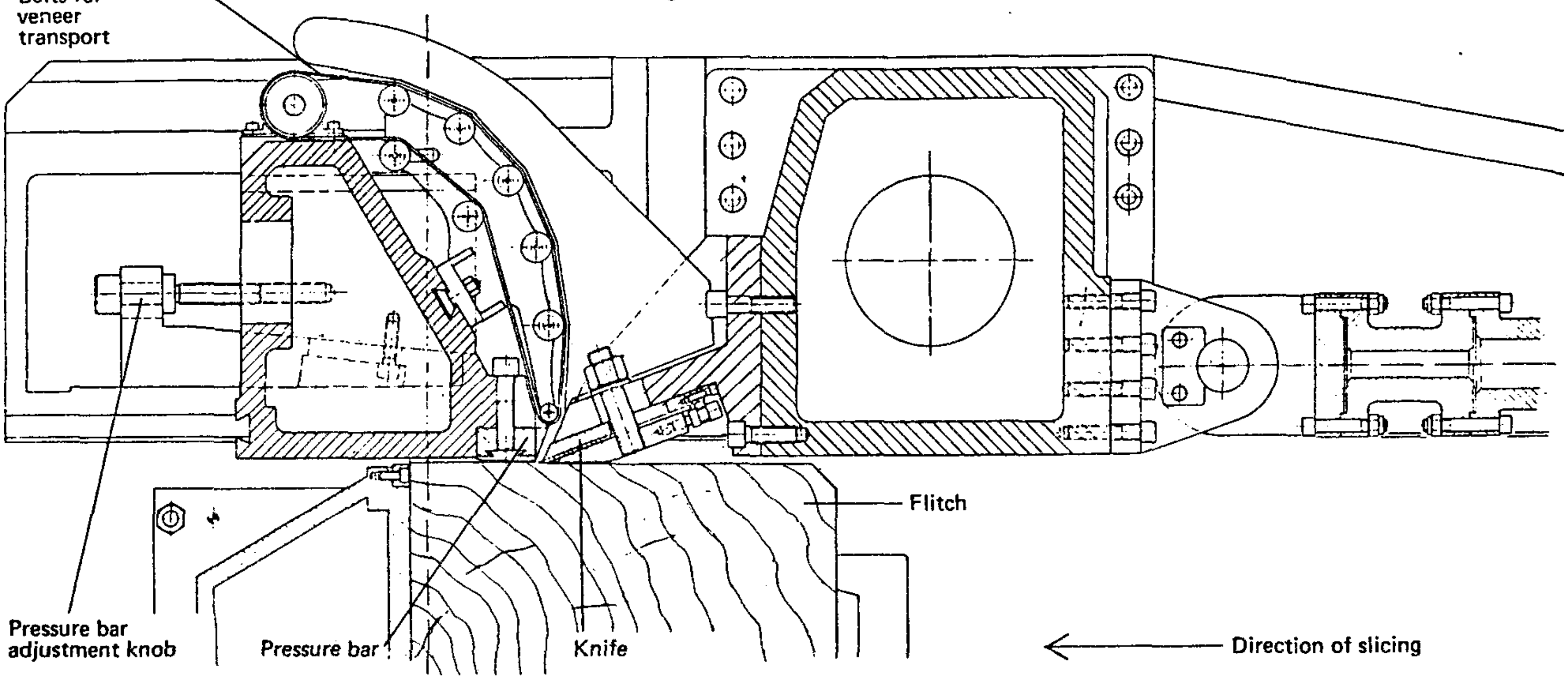
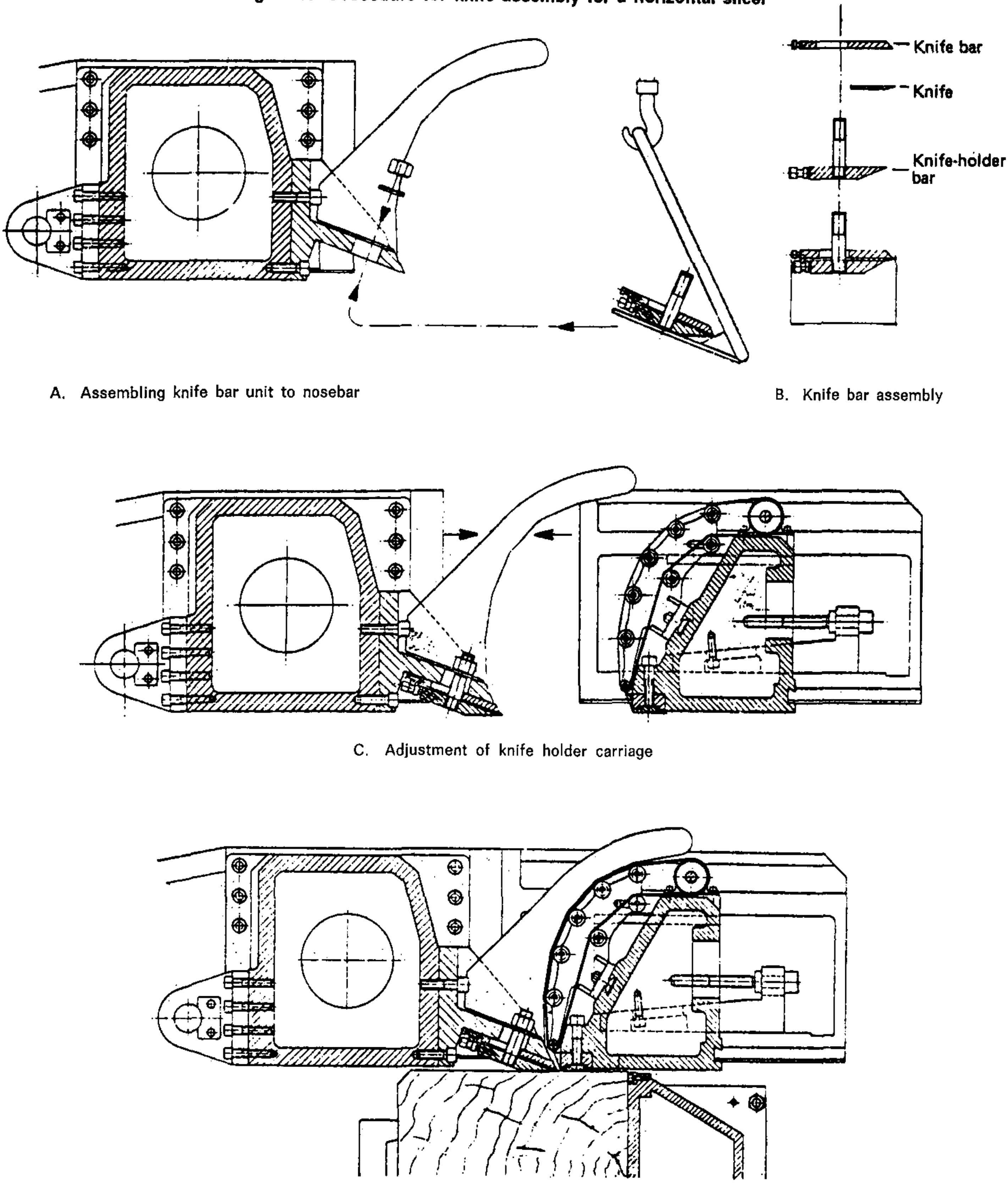


Figure 7. Procedure for knife assembly for a horizontal slicer



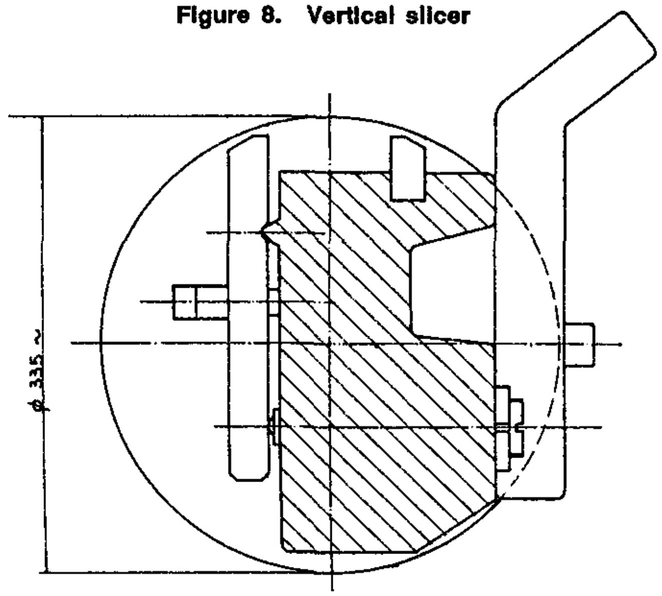
A. Assembling knife bar unit to nosebar

B. Knife bar assembly

C. Adjustment of knife holder carriage

D. Complete assembly

Figure 8. Vertical slicer



The choice of the dryer must take into account the 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.

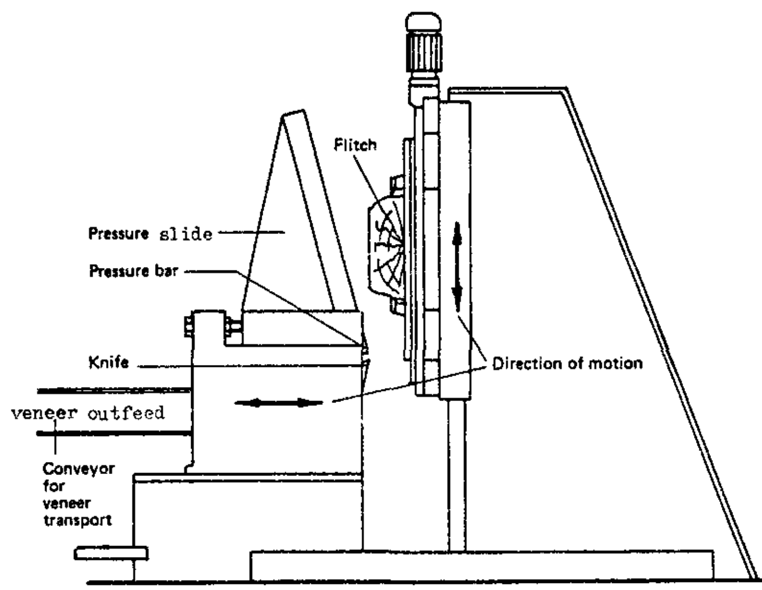
Veneer pack jointing and trimming machines

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 the 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 the automatic strapping of the packs. Machines have recently been installed that automatically measure 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 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 essentially a rod rotating between the spindles 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 that has been appropriately cut at both ends. The results of these operations are equivalent to slicing but allow the 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 owing to the ease and rapidity of loading, the high working speed and lower labour requirements. Owing to the high stresses involved with eccentric peeling, the machine must be very rigid in design and equipped to take into account the considerable eccentric loads that the system generates.

Figure 9. Peeling lathe for eccentric peeling (end view)



XV. Production lines for plywood and veneer*

Over a century has gone by since modern plywood panels were first manufactured in 1884. The industrial production of plywood began around 1910, and it became an important product during the following decades. In the last 20 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 entrepreneurs. FAO experts estimate that in the year 2000 world plywood requirements will be twice that of the production of the 1980s. Increases in requirements will stimulate progress in woodworking technology. This is a constant process, which has accelerated noticeably during the last 10 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. 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 that use a large quantity of plywood have become common in the suburbs of the big cities in the United States. Prefabrication is a good method of building homes that 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 Trans-Siberian 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 countries where the building industry is less advanced, wood is generally used for making forms for concrete and reinforced concrete. Sawn boards may be reused 3 or 4 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 for wooden packaging. Making plywood packages involves less work than the traditional method of making packages by nailing a number of boards and cross pieces together; owing to the large surfaces, there are no cracks; and plywood packaging is lighter than traditional packaging. 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.

Panel classification

Plywood panels may be classified according to use and type of wood as follows:

(a) Classification by composition:
- (i) Three layer plywood from 3 to 8 mm thick;
- (ii) Plywood with more than three layers, from 8 to 40 mm thick;

(b) Classification by use:
- (i) Normal or "interior" plywood is used when moisture resistance is not required;
- (ii) "Exterior" plywood is resistant to moisture;
- (iii) "Marine" plywood resists all atmospheric agents, immersion in cold water (both fresh and sea water), attack by fungal agents and insects;

(c) Classification by form:
- (i) Flat panels;
- (ii) Curved, convex, corrugated or three dimensionally shaped panels.

In the following discussion on criteria for selecting machines for manufacturing plywood, the most important sector will be examined: 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 decorative face 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 selection of machines in the various sectors of a plywood panel plant:

*By E. Mabini, expert in plywood and sliced veneer production. (Originally issued as ID/WG.277/14.)

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, a plant can be divided into sectors, according to the step-by-step transformation of the raw material. Assuming that the raw material has already been checked and that the low grade logs are eliminated, 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
Composing the panel
Pressing
Trimming 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 a suitable 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 that have been selected are piled in the log yard. These logs must be kept in good condition and free from cracks. The size of the log yard depends on the plant size and the frequency of delivery. If space and water are available, the logs can be kept in a pond or vats.

Sometimes it is impossible to 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 the vats, which are closed with special covers so the logs are surrounded by steam.

Today gantry cranes are widely used for handling logs. These cranes replaced the overhead and derrick cranes because they are more versatile, more efficient and safer. The logs usually have different sizes, shapes and lengths; thus some preliminary operations must be carried out before they can be peeled. The first operation 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 conveyors, 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. Logs that 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.

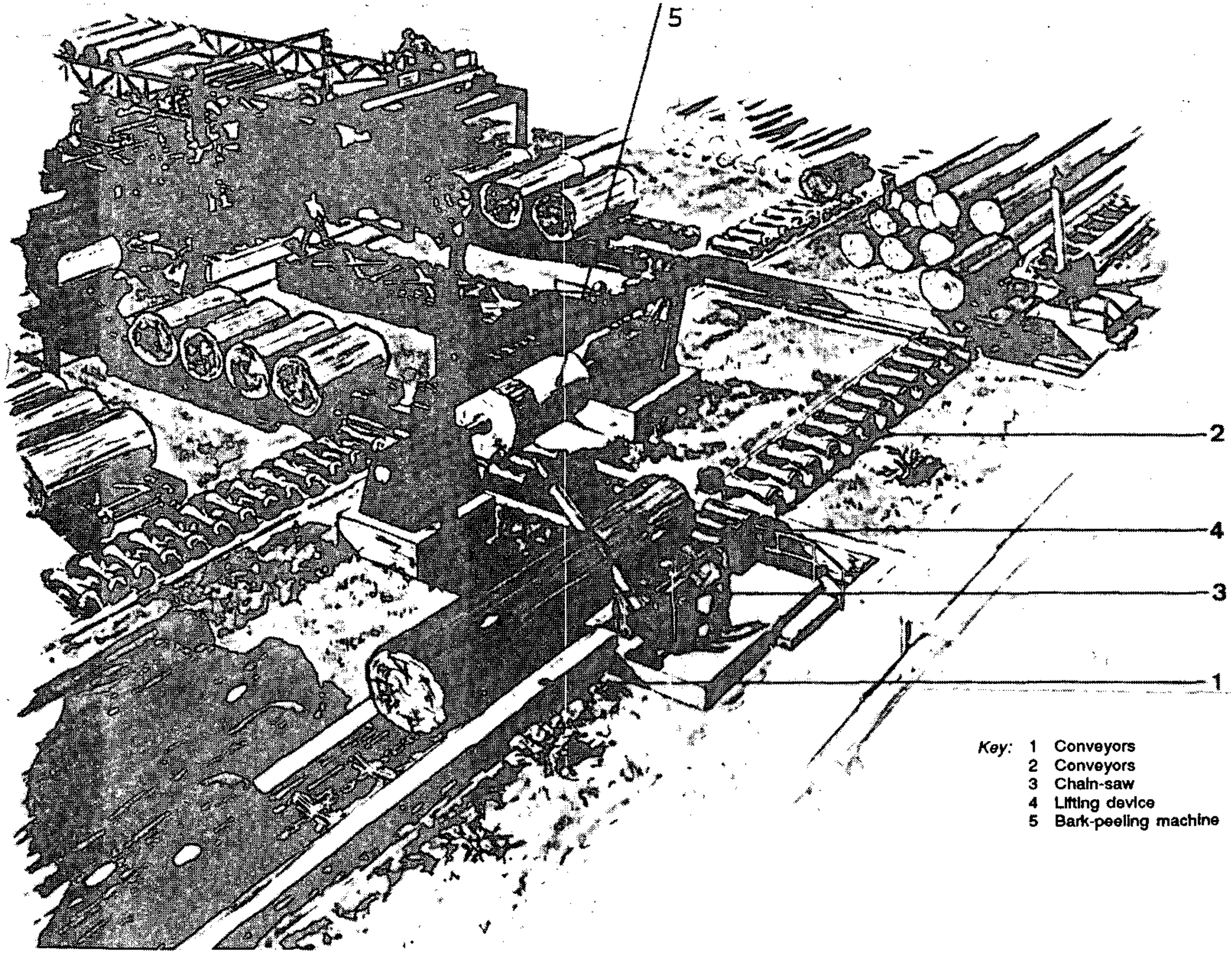
For logs less than 70 cm in diameter that are green or steamed and have rather thick bark, rotor debarking machines are best. These are automatic machines with a sturdy frame that supports two chain conveyors (one on each side). Each conveyor is equipped with feed rollers or discs. The conveyors feed the log and centre it with respect to the rotor. The rotor is a ring rotating around its centre. Adzing tools are mounted on the 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 into 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 effect 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 debarking 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 conveyors are installed. Unfortunately, when the logs are irregularly shaped or have holes, the cutter cannot debark the log completely; it has to be done manually.

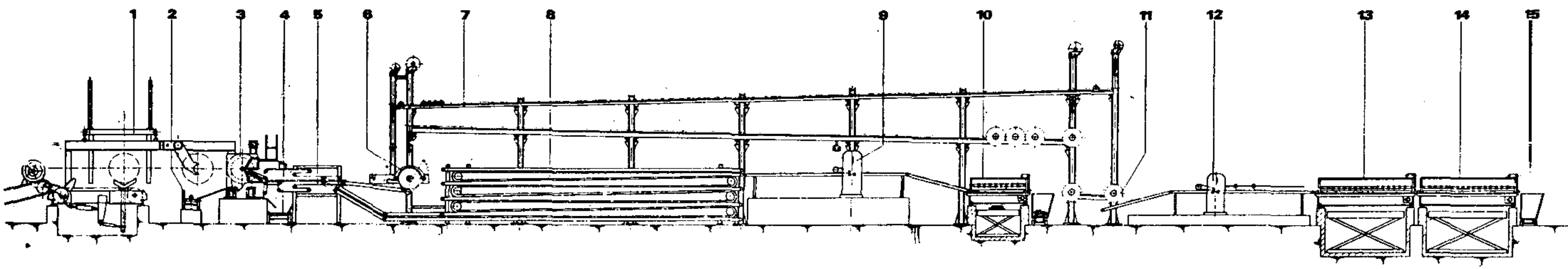
Debarking cutters may also be used for small and medium diameter logs with thin bark, such as beech. Both rotor and cutter debarking machines have a high capacity so that one machine can operate for several production lines, especially when the plant has a good conveyor and bark collection system.

Figure 1. Plant for cutting logs to size and debarking



Key:
1 Conveyors
2 Conveyors
3 Chain-saw
4 Lifting device
5 Bark-peeling machine

Figure 2. Continuous production line to produce wet peeled veneer sheets from logs



Key:

1 Automatic centring and loading device
2 Conveyor for rounds, where cores are unloaded
3 Peeling lathe with double telescopic spindles and operator controls
4 Conveyor for unutilizable round-ups
5 Conveyor for peeled veneer
6 Automatic reeling device
7 Reel store
8 Multiple conveyor 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

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 for the 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. Layouts 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 usually around 10 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 that 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 the operator 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 lathe. This feed rate is faster than the rate at which the veneer peeling lathe 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 lathe 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 lathe; 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; and 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. It is possible, however, 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 lathe 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 lathe 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 DC 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 conveyor belts and the reeling equipment so that these three operations all proceed at the same rate. Automatic reeling can be compared to unreeling a roll of paper (which represents the log), transporting the strip of paper and reeling 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 it;

(c) Thickness control. At least two different thicknesses are needed. Furthermore one larger thickness is 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 changed automatically every time the thickness is changed;

(d) A device for the rapid withdrawal 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 sheet 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 lathes for medium and small diameter logs must be equipped with

devices that press against the whole length of the log. On the larger peeling lathes, this device is required only for the central 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 lathe needs instruments that assist the operator. For example, an ammeter connected to the main motor shows how much energy is being used 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 rpm etc.

The whole peeling lathe 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 lathes 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 lathe—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. 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 conveyor (figure 2 (4)) transports this waste material to the knife hogs 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). Often, in three-layer panels, the centre layer is twice as thick as the top layer. This peeled veneer is placed on a belt conveyor (figure 2 (5)) and transported to a storage container, which is a series of conveyors, 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 conveyors 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. These sections can be activated individually or as a group by the operator either at the peeling lathe or at the clipper, which is a machine placed after the storage container. This entire process is simple because the peeling lathe produces round-ups periodically only, whereas the clipper works full time. While the peeling lathe sends the peeled veneer to the first section of the storage container, which is set at the same speed as the peeling lathe, the second section feeds the clipper (figure 2 (9)) at a lower speed.

When the log has become cylindrical and the continuous sheet of peeled veneer is being made, the first section of the storage container is connected to the second section and is used to feed the clipper. The plant in figure 2 is equipped with an automatic clipper (figure 2 (9)) for clipping irregular pieces of peeled veneer into parallel sheets 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 conveyor at the back of the clipper transports the veneer to the storage area. 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 chipper. The operator on the clipper just has to adjust the conveyor speed according to the amount of waste material. Occasionally, the operator has to speed up the conveyor belt to the clipper when the pieces of peeled veneer are of particularly bad quality.

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 movable 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 conveyor that transports the wood from the peeling lathe to the reeling station is synchronized with the peripheral speed of the log. Two tapes of glue 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) and (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 stored or to keep the reels with different thicknesses of peeled veneer separate.

The plant suitable for processing logs less than 50 cm in diameter is shown in figure 3. 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 that 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 conveyor. 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 the flap position, are used to adjust the belt speed to either the peeling rate or the feed rate of the clipper. The clipper is driven by compressed air, and the conveyor 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 size sheets. 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.

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 dryers (figure 5) may be used. In the first case, the peeled veneer is fed through the dryer in band form with the grain perpendicular to the direction of feed and the veneer is clipped to size after drying (figure 4); 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 have been used more frequently because of their economic advantages. Production quality may be lower, however. 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 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, the 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 the use of different species 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 species of the 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 indicate the moisture content continuously. They can be used to automatically regulate the dryer temperature and feed rate. The sheets that are not sufficiently dry are automatically sprayed with a 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 and quality of wood used. These two dryer 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 species 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 that raw materials account for about half of 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. There are two splicing methods. In the first case, a glue string is placed in zig-zag form, across the joint; in the second case, thermoplastic adhesive spots cover the joints. The most modern machines are equipped with a conveyor belt. The bands of peeled veneer are laid side by side on the 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 adhesive

This section of the plant works independently, and its operation differs from plant to plant depending on the recommended adhesive formulation. 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 spread with adhesive; core ply, with adhesive spread on both sides, third ply, not spread with adhesive 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 adhesive spreading machines are the roller-type double-side adhesive spreaders. Sometimes "curtain" type spreaders—where a thin adhesive curtain drops through a calibrated slot—are used. The sheet of wood passes underneath this slot, and the amount of adhesive deposited on the surface depends on the feed rate of the sheet.

This type of adhesive spreader can only spread adhesive 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 adhesive 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 adhesive 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 adhesive at room temperature. The adhesive may be either urea or phenol based. As modern plywood plants have high production rates, the hot presses have a minimum of 16 openings, and they may have as many as 40. Bonding pressure varies from 10 kgf/cm^2 for softwood plywood to 25 kgf/cm^2 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.

The most modern presses are also equipped with devices that open and close all the platens simultaneously. These platens are chrome-plated to eliminate corrosion. They improve the appearance of the panel surfaces and facilitate heat transmission. For 4-mm panels, press time can be as low as three minutes.

Today, high-temperature water is used to heat the platens in the presses. The 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".

With single-opening 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 presses 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) A larger portion platen area is used 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 conveyor belt passing through the press;

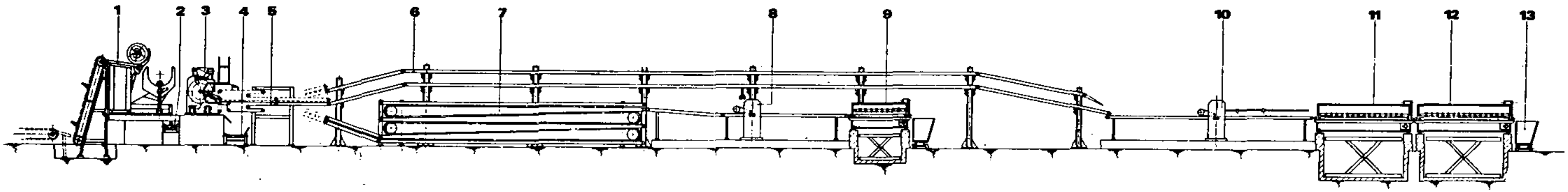
(c) The single-opening presses are easier to build and operate, and they can easily be applied to manufacture special types of panels.

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 and ensuring a perfect right angle. Two trimming saws 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.

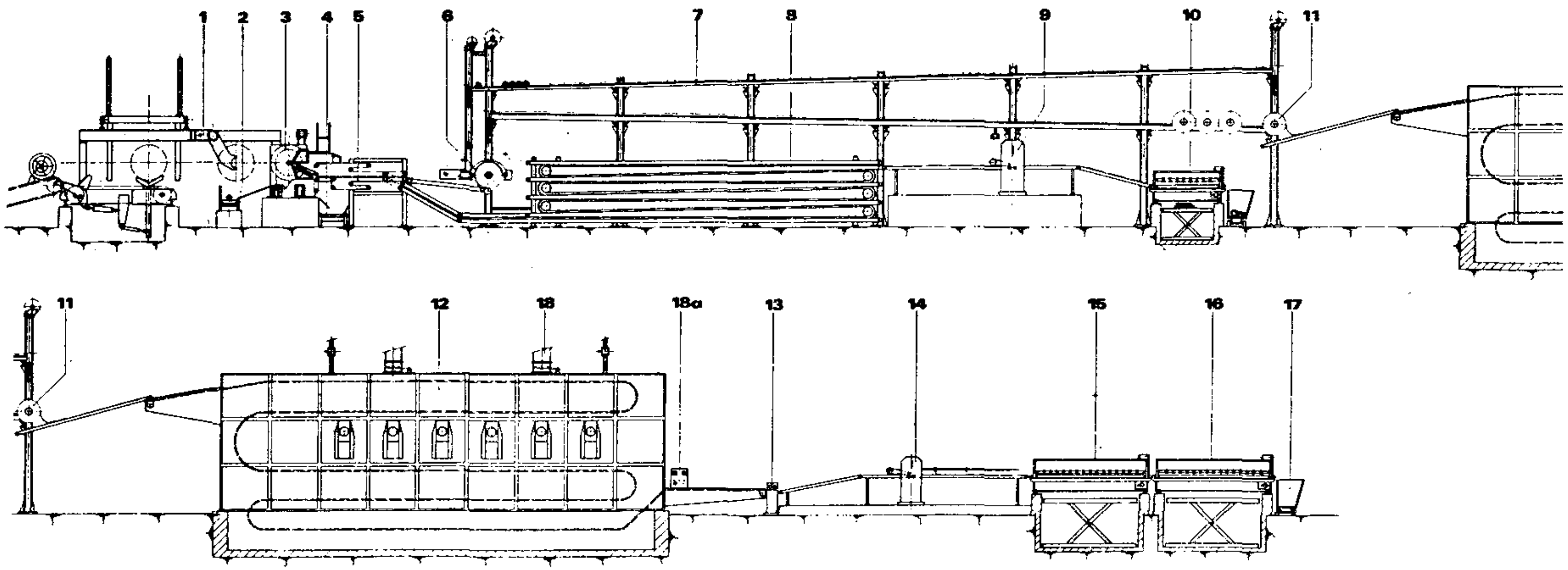
Figure 3. Continuous line for processing logs of less than 50 cm diameter into wet peeled sheets (deck system)



Key:

1 Automatic geometric centring and loading device
2 Round conveyor
3 Peeling lathe with double telescopic spindles
4 Conveyor for peeled veneer
5 Conveyor for peeled veneer
6 Peeled veneer multiple conveyors (deck system)
7 Multiple conveyor 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

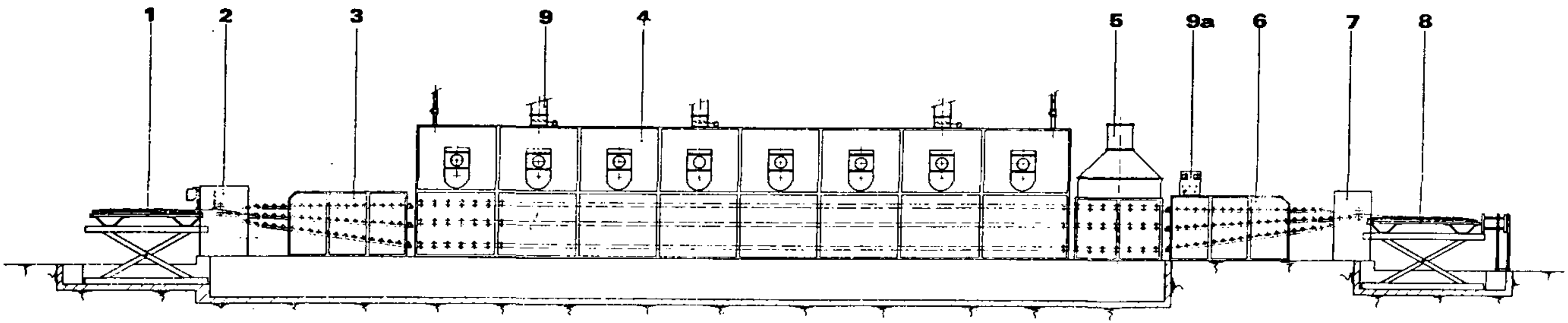
Figure 4. Continuous line for the transformation of logs into dry peeled sheets



Key:

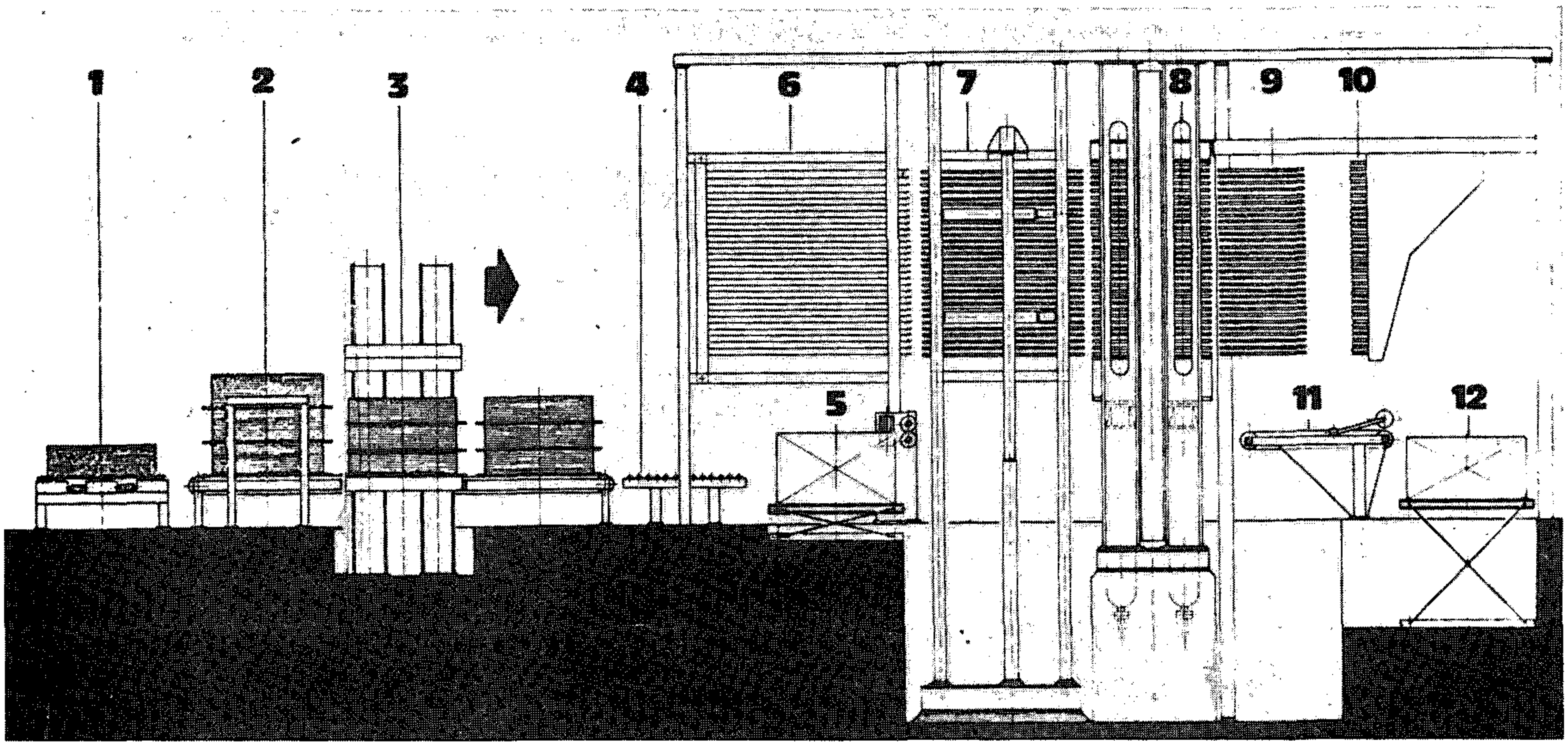
1 Automatic centring and loading device	10 Piling-up device for undersized sheets
2 Conveyor for rounds, where cores are loaded	11 Automatic unreeling device
3 Peeling lathe with double telescopic spindles and operation controls	12 Continuous dryer
4 Conveyor for unutilizable round-ups	13 Metering device for residual humidity
5 Conveyor for peeled veneer	14 Automatic clipper
6 Automatic reeling device	15 Piling-up device for entire sheets
7 Reels store	16 Piling-up device for undersized sheets
8 Multiple conveyor for round-ups	17 *Picking-up device for wastes*
9 Automatic clipper	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 Conveyor
4 Dryer
5 Cooling chamber
6 Conveyor
7 Automatic ejecting and piling-up device
8 Elevating platform
9 Chimney with adjustable flow
9a Control of air moisture in the dryer

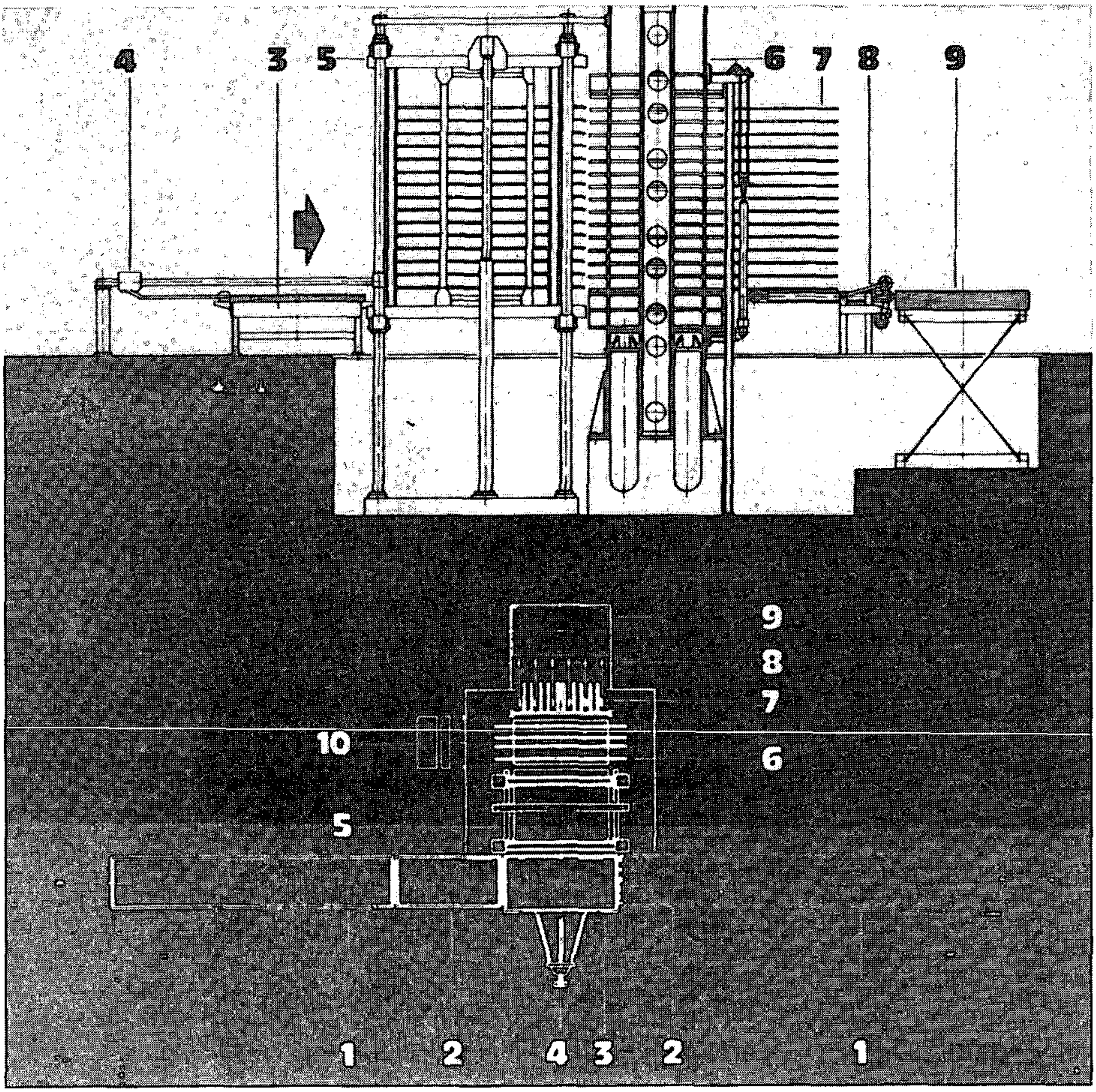
Figure 6. Automatic pressing lines with pre-press



Key:

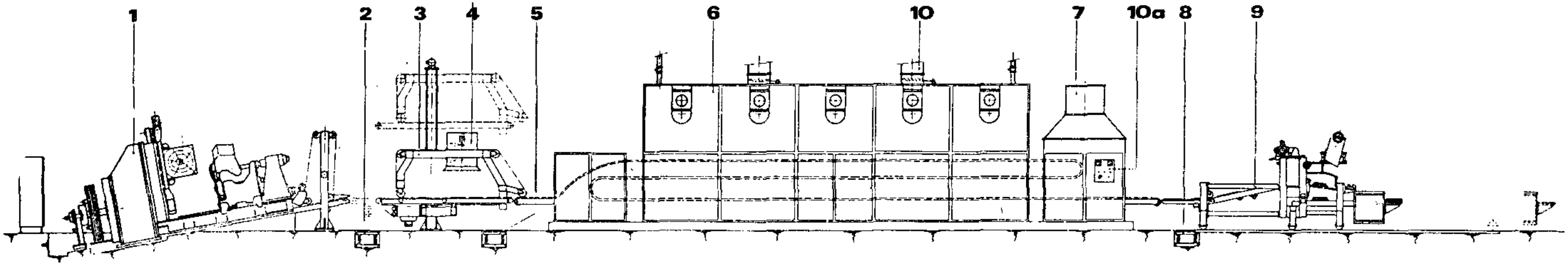
1 Book building conveyor
2 Pre-press conveyor
3 Oil-hydraulic pre-press
4 Intermediate conveyor
5 Board loading device
6 Pushing arm in the press
7 Loading lift
8 Multi-opening hydraulic press
9 Unloading lift
10 Press extracting unit
11 Board ejecting unit
12 Piling platform

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

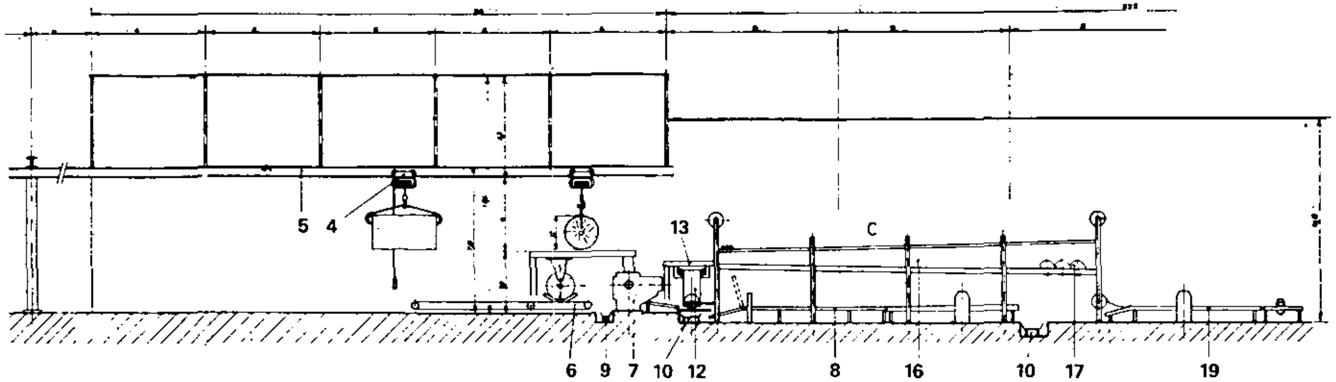
Figure 8. Continuous line for the transformation of logs into dry sliced veneer



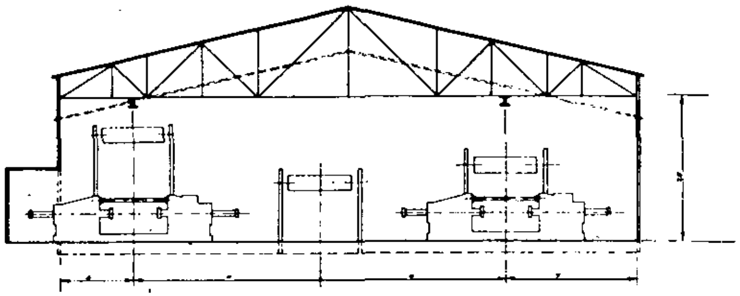
Key:

1 Vertical veneer slicer
2 Elevating platform
3 Auxiliary connection conveyor
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 fry dryer

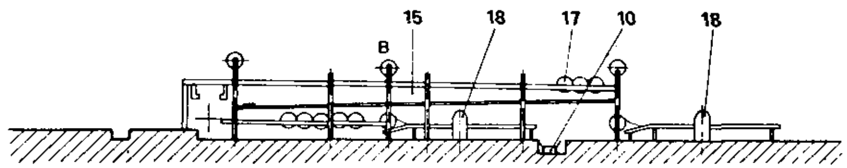
Figure 9. Plywood plant



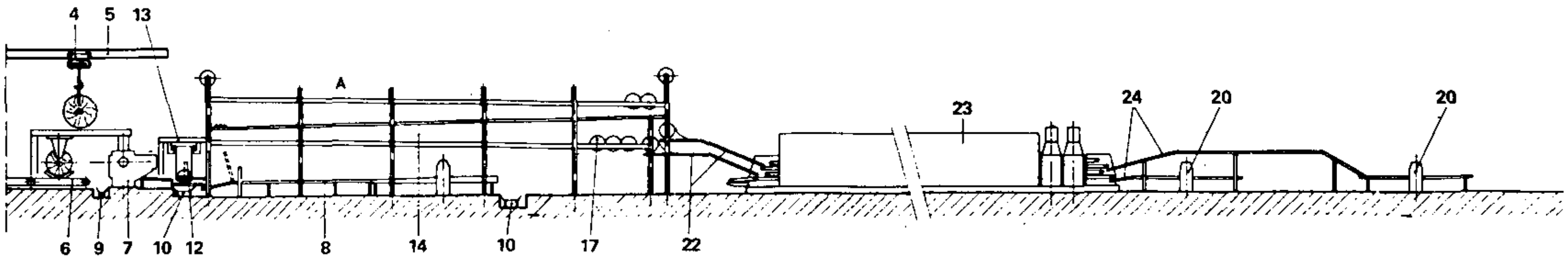
A. Front view showing peeling operation



B. Side view

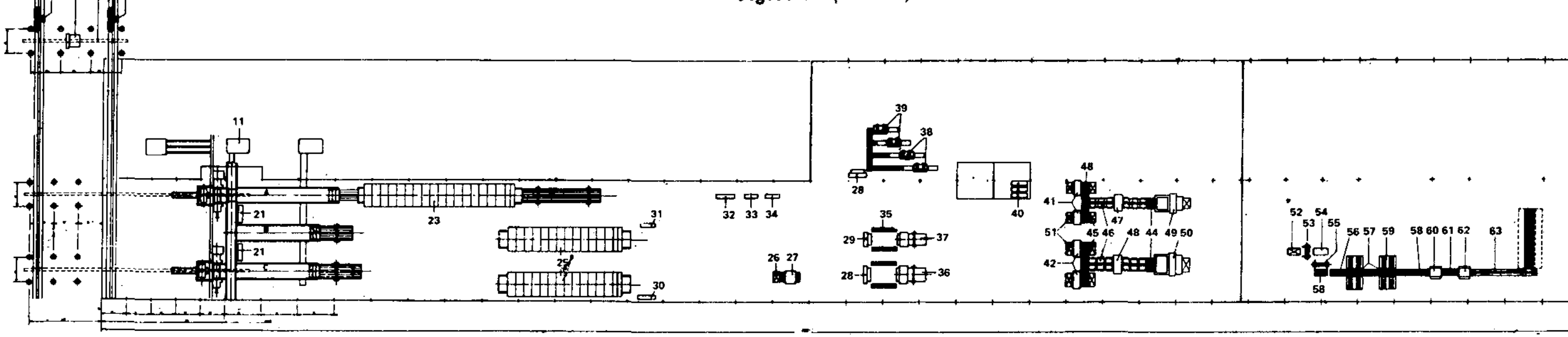


C. Expanded-front view showing reeling equipment



D. Expanded-front view showing feed to dryers

Figure 9. *(continued)*



E. Top view

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 conveyor for rest rolls
10 2 conveyors 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 conveyors
23 1 continuous dryer with cooling chambers
24 2-floor belt conveyors
25 2 roller dryers with cooling chambers
26 1 electrohydraulic elevator
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 conveyors
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 ejectors 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 circular saw blades are usually 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 only 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 on both top and bottom.

Veneer slicing

Some plywoods are face veneered. The 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, the peeling lathes and presses operating on a double-shift basis, with the dryers, clippers, veneer splicing machines and finishing line is shown in figure 9.

XVI. Selection of equipment for panel surface improvement through lamination*

The direct use of such wood-based panels 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). "Surface improvement" is the process of improving the physical-mechanical characteristics. The surfaces of plywood and fibre and particle boards that are used in the building trade and furniture and transport industries are usually laminated. "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 scratches, abrasion, moisture and heat and to some household chemicals. Surface improvement depends on the substrate material, the laminating material (papers and resins) and on the system adopted for lamination.

The lacquering and coating of boards using polyvinyl chloride (PVC) foils is not referred to in this chapter, as the process is not a true lamination.

Materials for lamination

The substrate materials are:

- Plywood
- Fibreboard
- Particle board (which, owing to its wide use in the building and furniture industries, will be emphasized in this chapter)

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—lacquering or printing and lacquering—is carried out. Lamination is done with diallyphtalic urea and modified urea impregnated papers. Light papers (about 40 g/m^2) may be glued with PVC or polyvinyl acetate (PVA) copolymer based glues or urea glues. For this process several kinds of papers, which will be described in the section dealing with particle board lamination, are available.

Plywood, bonded with phenolic resins (marine use)

Plywood 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 owing 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 the wood species, of about 15-18 kgf/cm^2; and a temperature of about 146° 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/cm^2;

(b) The hot/hot process. This process is done on the multi-opening press (or rarely in a 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 owing 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

*By F. T. Slodyk, consultant in wood-based panel industries. (Originally issued as ID/WG.277/16.)

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/m^2). 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 a resin content at the surface of not less than 12 per cent.

Owing 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 out 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 g/m^2;

(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/m^2;

(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/m^2. The temperature used is about 120° C, the pressure 18 kgf/cm^2, and the time required about 120 s. The weight of the self-adhesive paper is 90-200 g/m^2. The temperature used is about 160° C, the pressure 12-18 kgf/cm^2, and the 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/m^2;

(e) Light papers impregnated with urea or urea modified with acrylic resins, which may or may not be intended to have polyester resins spread on to the surface. These papers are applied to the surface to be laminated, and may be lacquered. The weight of the paper is about 30-40 g/m^2;

(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/m^2, and pressure is about 10 kgf/cm^2. The temperature depends on the "hot-melt" type, but usually it is about 15° C;

(g) Papers impregnated with urea/acrylic resins and micro-pearls of acrylic resins, applied according to a vacuum penetrating system. The weight of the raw paper is 90-120 g/m^2 (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, either by 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 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

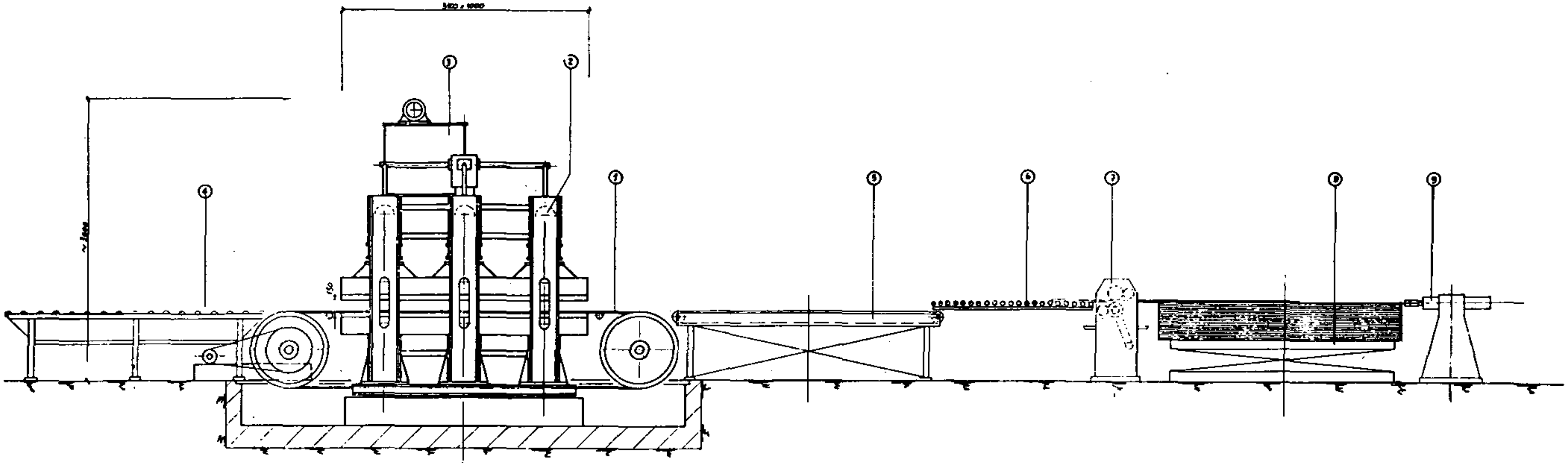
System 4

Manufacturing of impregnated or spread papers
Manufacturing particle board
Coating with impregnated or spread papers

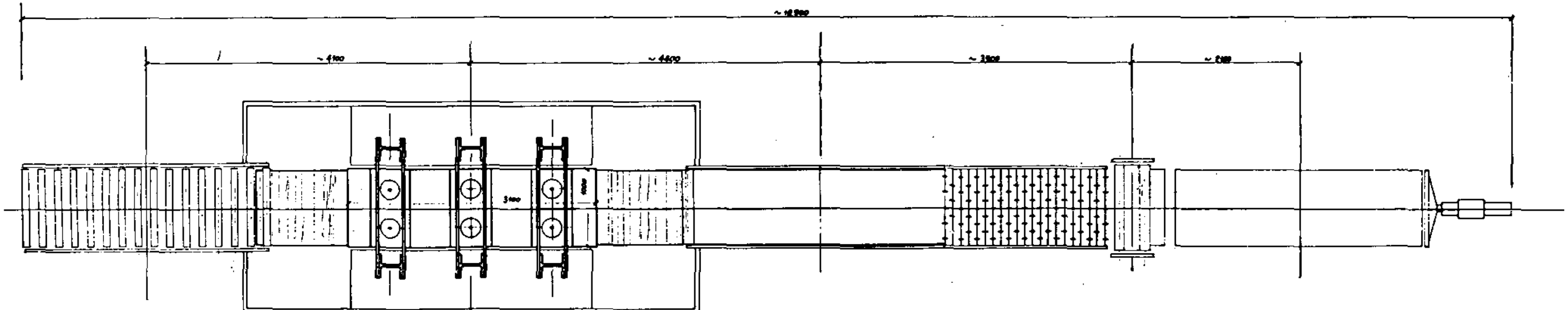
Lamination with decorative laminates (system 1) must be done almost without exception on flat surfaces, owing to the high operating cost. Simultaneous lamination (system 3) is developing slowly, owing to technological difficulties, and rejection is common. However, lamination with impregnated papers 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.

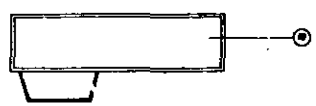
The ever-growing need for laminated products in many fields has required changes in the standards for surface properties. Some of these (DIN 68754) are still not yet observed. The need for definitions of quality and of price and quality expected are strongly debated with regard to end-use. Actually, only the market-place will decide the matter, and technicians will establish new standards concerning surface characteristics and developments in the industry.

Figure 1. Pressing line with single-opening hot-press



A. Front view

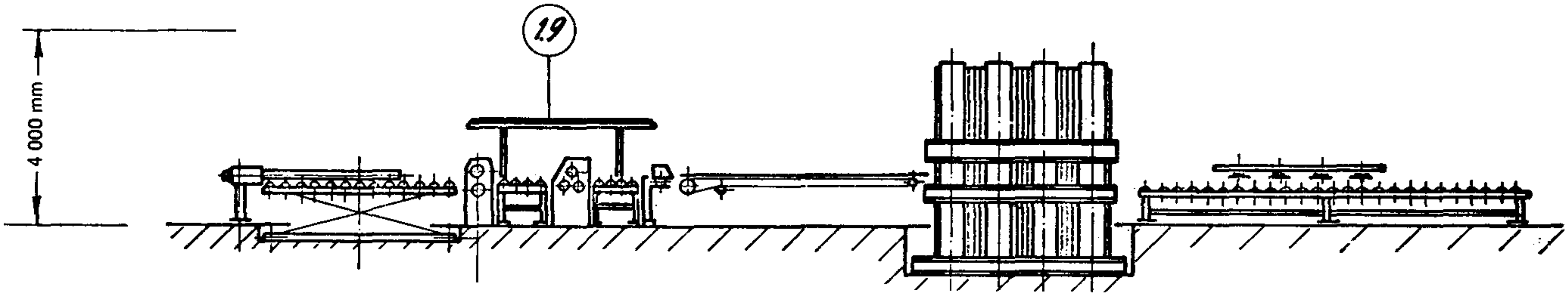




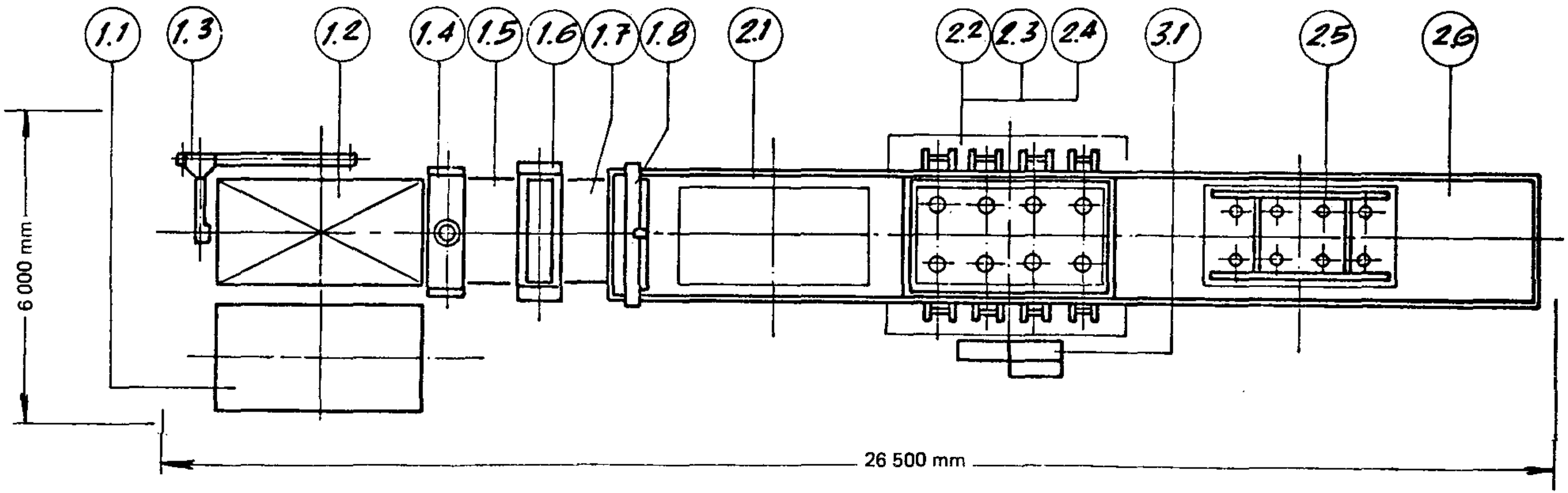
Key:
1 Brass grating belt
2 Single-opening press
3 Oil-hydraulic unit
4 Roller bench
5 Setting up belt
6 Roller bench
7 Gluing machine
8 Platform
9 Pushing arm
10 Electric control desk

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

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 that 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 5-10 kgf/cm². 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 also possible to do hot/hot lamination, as the press can operate at 25 kgf/cm².

Hot/cold laminating system

The hot/cold laminating 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 conveyor elements (in some plants, the top cushioned stainless steel cauls are fixed on the press).

Pressure is 18 to 22 kgf/cm² and pressing time is dependent on the type of resin. The total cycle usually varies from 8 to 20 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 good fluidity on the surfaces subjected to pressure.

Pressing cycles depend on many considerations such as the type and thickness of the panel, the temperature of the laminated surfaces, the types of papers and resins, the pressure used, the manufacturing plant etc. Figures 5 and 6 show temperature versus time relationships for hot/cold cycles.

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 (post-drying 5 min at 160°C).

[b]Fluidity is weight loss during pressing.

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.

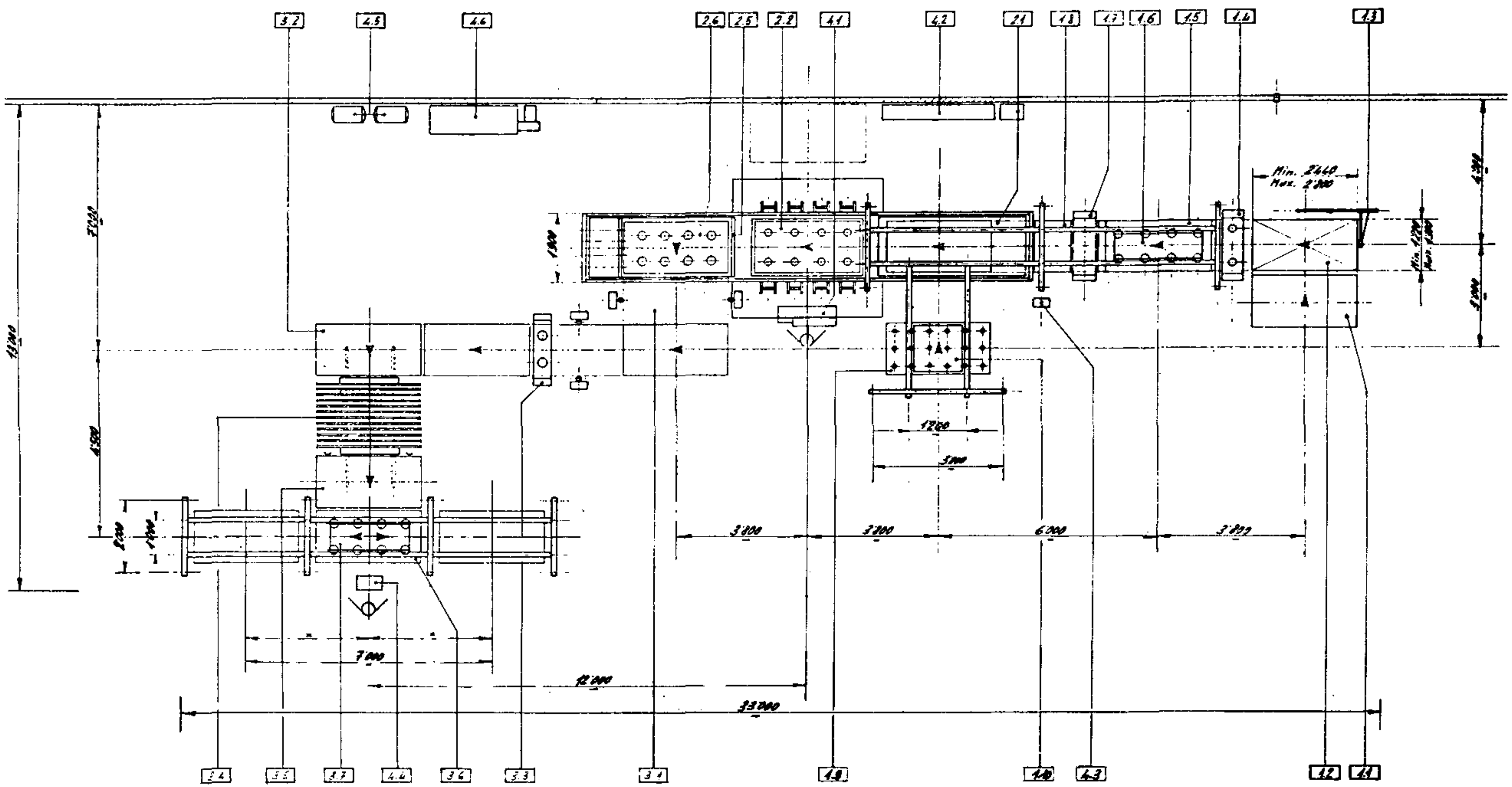
Laminating processes in single-opening presses (quick hot/hot process with conveyor)

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, the rate of heat transmission (this problem is present in all the plants), the type of resin, the time the decorative paper remains without pressure in contact with the hot surfaces of sheets, the closing speed of the press and the time necessary to reach a maximum pressure. For lamination, impregnated papers are used with melamine resins (modified melamine resins) and diallyphtalic resins, which are now very seldom used.

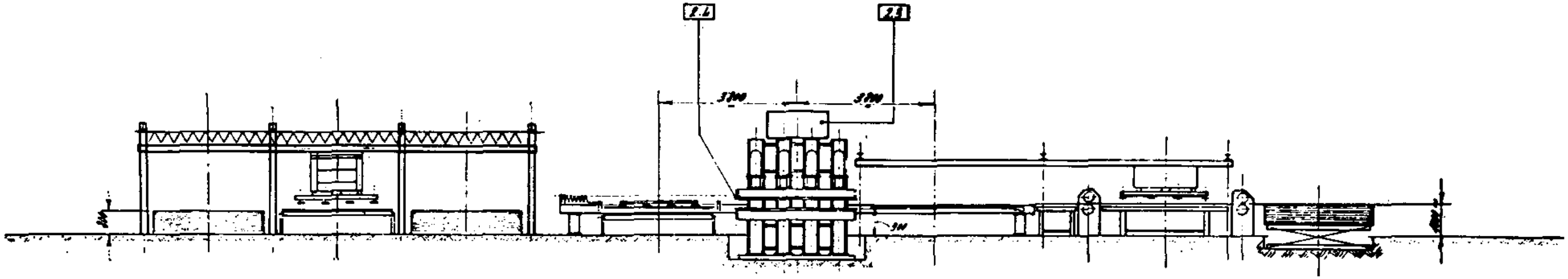
It is possible to laminate particle board with a density lower than 0.65, owing to the very short time during which it is subjected to the elevated pressures and temperatures. For lamination with melamine resins, curing times range from 30 s at 180° C to 90 s at 145° C, with pressures of 18 to 22 kgf/cm² (figure 7).

After the press loading, it is recommended that the sandwich should not be allowed 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 and shadings. Some technicians think the time in the 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 the 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. Pressing line with single-opening press for veneering and short-cycle lamination



A. Top view

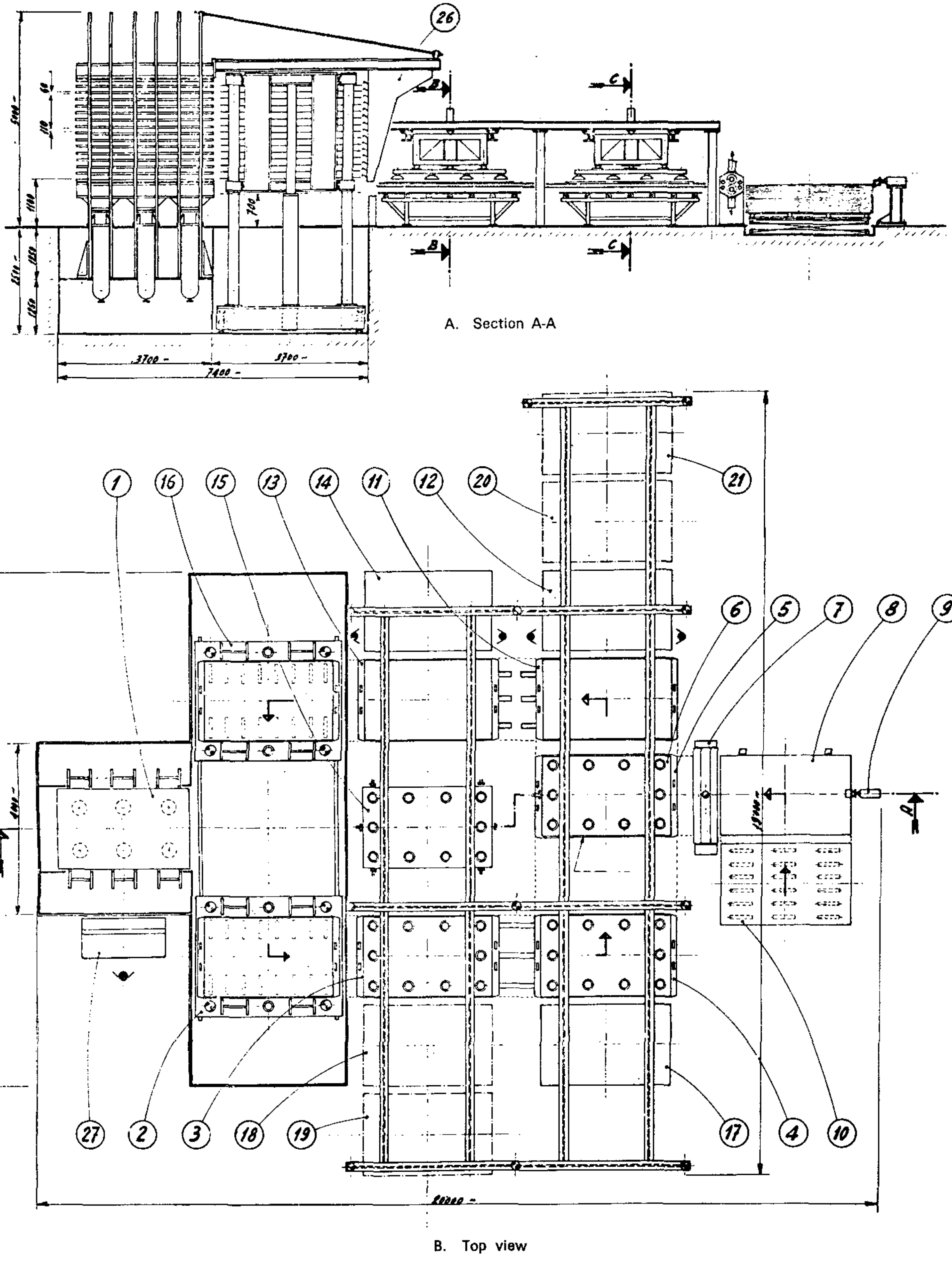


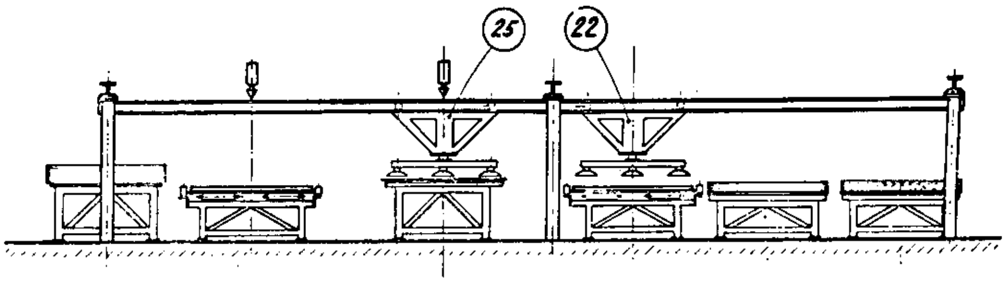
B. Side view

Key:

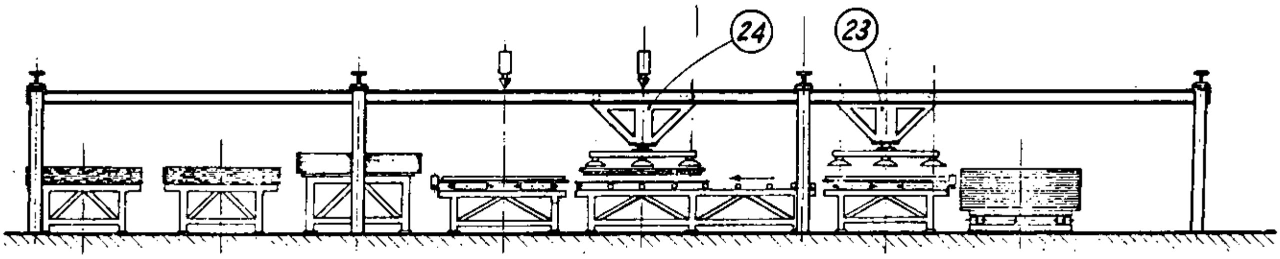
1.1 Motor-driven roller bench
2 Lifting table with motor-driven rollers
3 Pneumatic pusher
4 Brushing station
5 Bench with motor driven wheels
6 Vacuum hoists station for board loading
7 Gluing machine
8 Bench with lamellar motor-driven wheels
9 Laying truck for papers and veneers
10 Vacuum hoists for 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
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 hot/cold laminating system





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

Figure 5. Temperature vs. time in the classic hot/cold process

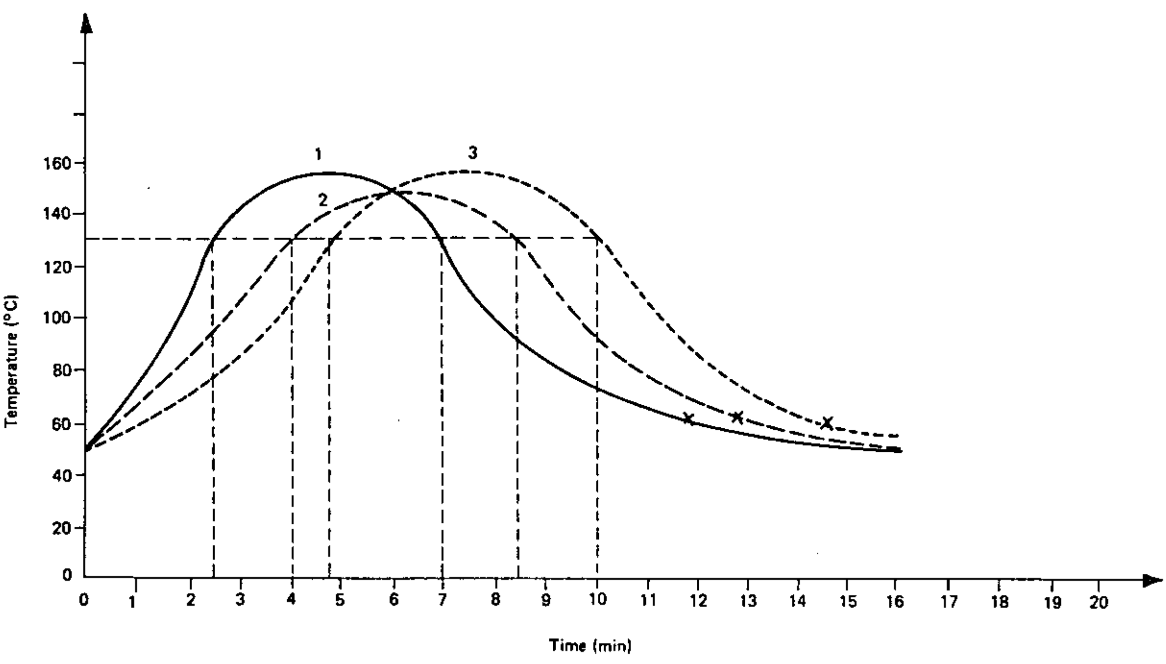


Figure 6. Temperature and pressure vs. time for the hot/cold cycle for two different papers

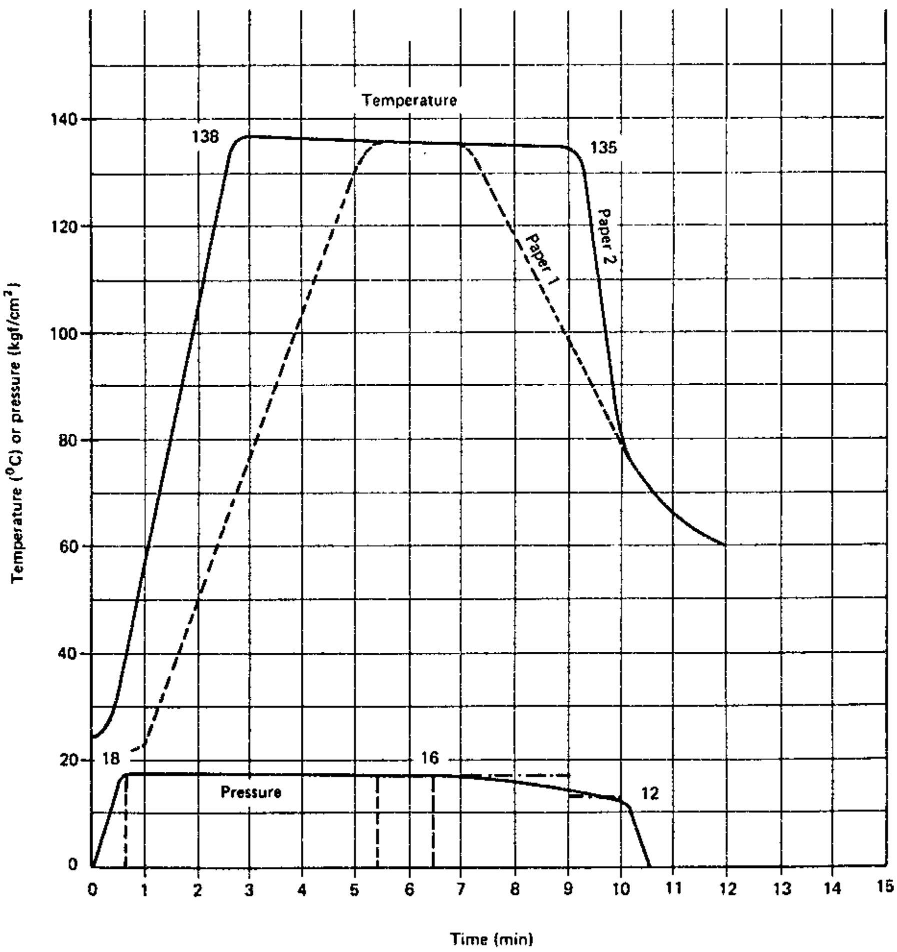


Figure 3 shows a plant for the laminating process with a conveyor. The piece to be laminated and the paper on it (the charge) are set on a belt, and both are then inserted into the press, where the charge is laid down on the hot surface. By this method, the leading edge of the board being inserted into the press is in contact with the platens' hot surfaces longer than the other edge of the board. The difference in this "touch time" amounts to about 4 s and depends on the board's dimensions.

A variation of this system is shown in figure 8. Here the board, once inserted into the press, is not laid down until the conveyor 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 a difference in the time the papers are in contact with the platens' hot surfaces. This innovation, which appeared on the market some years ago, 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

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 to 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 a bakelizing time of about 18 s and total cycle times held down to 34 s. These presses are capable of producing about 70 boards per hour, depending on the kind of papers and resins that 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 that release the charge during press closing, thus reducing the contact time of laminating papers to the platens' hot surface to zero. 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);

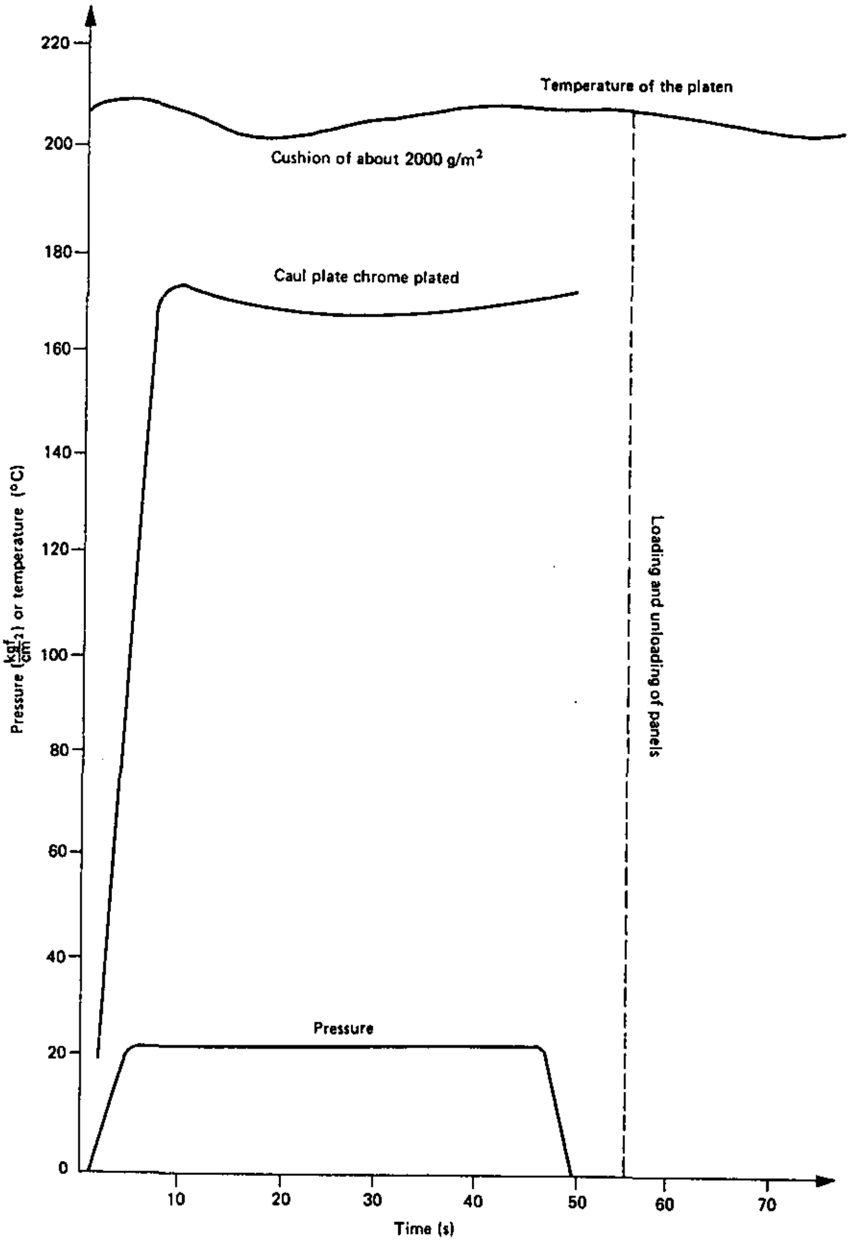
(b) Much lower energy consumption (about 8 times less);

(c) Lower initial investment;

(d) Easier maintenance;

(e) Less labour.

Figure 7. Approximate temperature and pressure vs. time for hot/hot lamination



The increase in productivity will depend on the plant. Negative features in hot/hot system include:

(a) The inability to obtain a glossy 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).

Positive features of the hot/cold system include:

(a) The ability to obtain the preferred finish (satin or glossy);

(b) Superior mechanical surface properties (abrasion, impact, staining resistance);

(c) A much easier and safer process than in the hot/hot system.

Negative features of the hot/cold system include:

(a) Higher initial investment;

(b) Higher energy consumption;

(c) Greater labour requirements.

Process characteristics for the hot/cold and hot/hot process are shown in table 2.

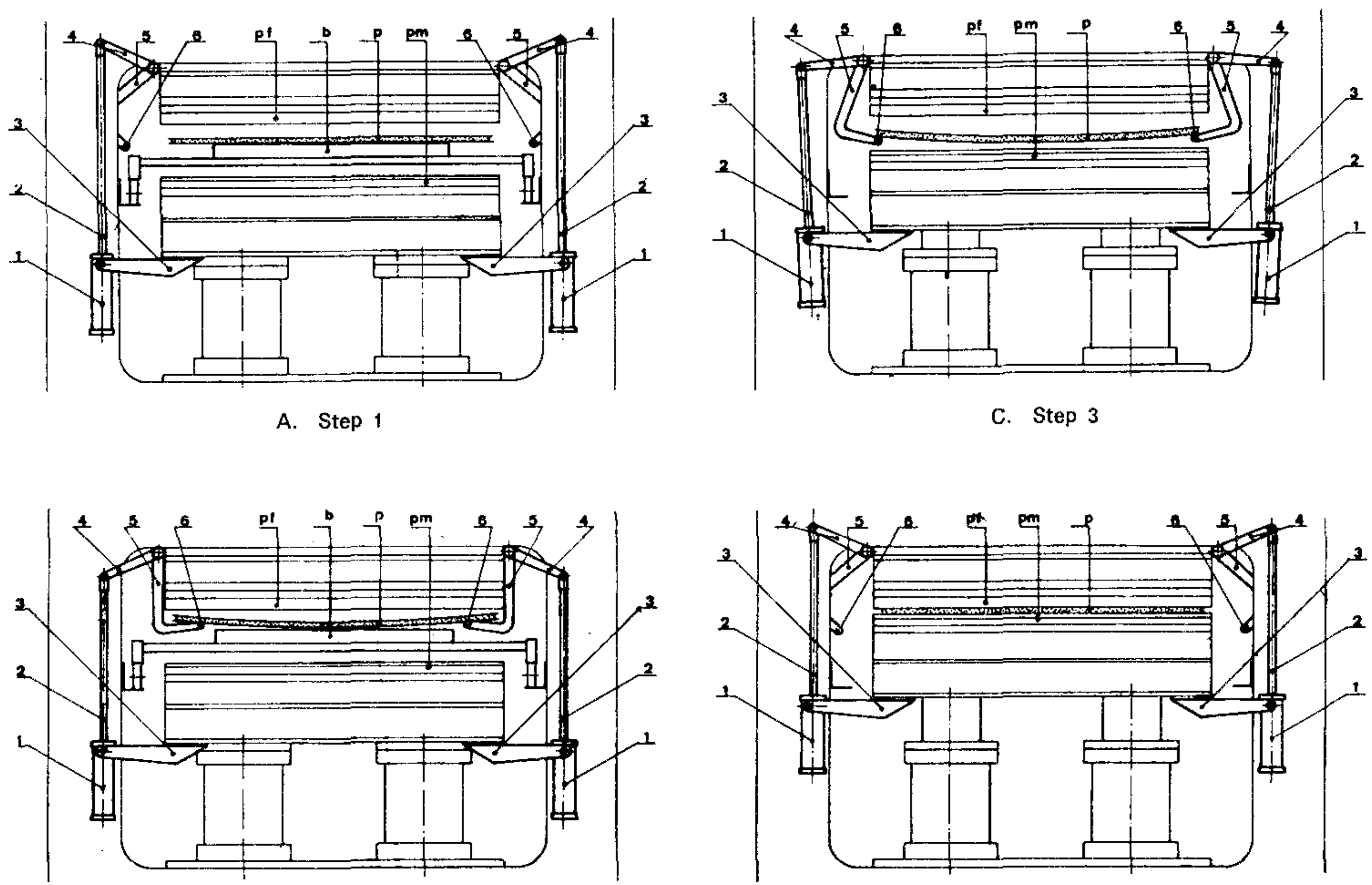
Simultaneous lamination

This laminating system is uneconomical because of the high initial cost and production complications. The system is being further developed.

Lamination with "pore filling" papers

The use of urea impregnated papers ensures finished surfaces that need no sanding and are ready to be printed and lacquered. These may be self-adhesive papers or papers applied on to a board that is usually spread with urea resins.

Figure 8. A pressing cycle using a modified belt tray



A. Step 1

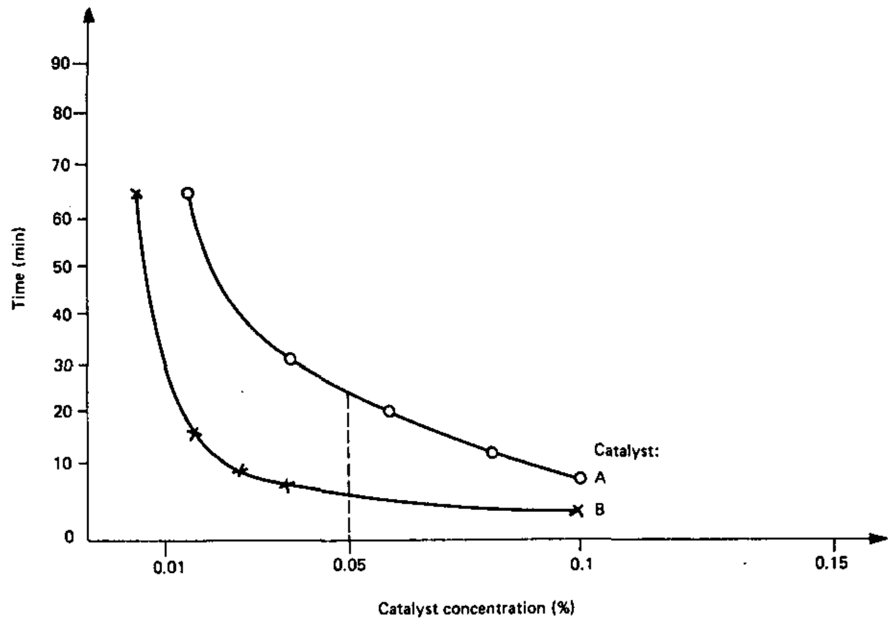
B. Step 2

C. Step 3

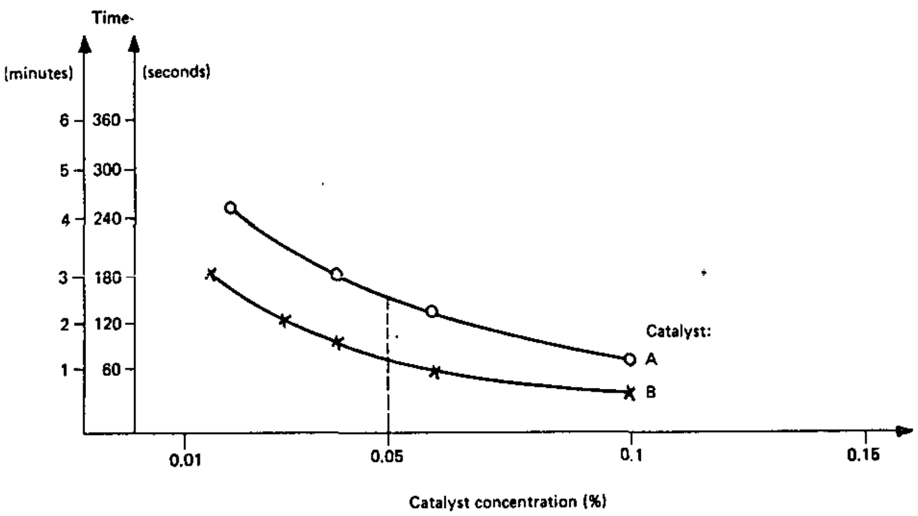
D. Step 4

Key:
1 Pneumatic cylinders
2 Cylinder rods
3 Cylinder support
4 Upper level
5 Lower level
6 Board supporting roller
pf Upper plate
pm Lower plate
p Board
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

Other application systems

In addition to the classic systems described above, other processes have been developed involving variations in raw materials (papers and resins) and in paper impregnating methods. 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

The following types of gluing papers exist:

(a) Impregnated papers suitable for further lacquering, weighing 80-125 g/m^2. They may be used in veneering presses (figure 3);

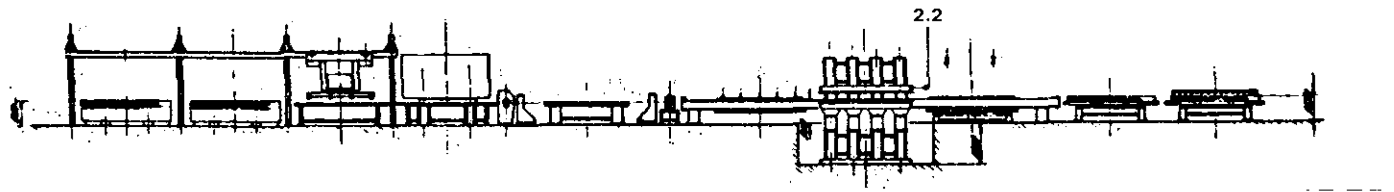
(b) Impregnated papers, containing a coat of lacquer, weighing 80-150 g/m^2. They may be used in veneering presses as well as in quick step plants or in universal type installations;

(c) Semi-finished papers, which may be used immediately after gluing. Weight 80-145 g/m^2;

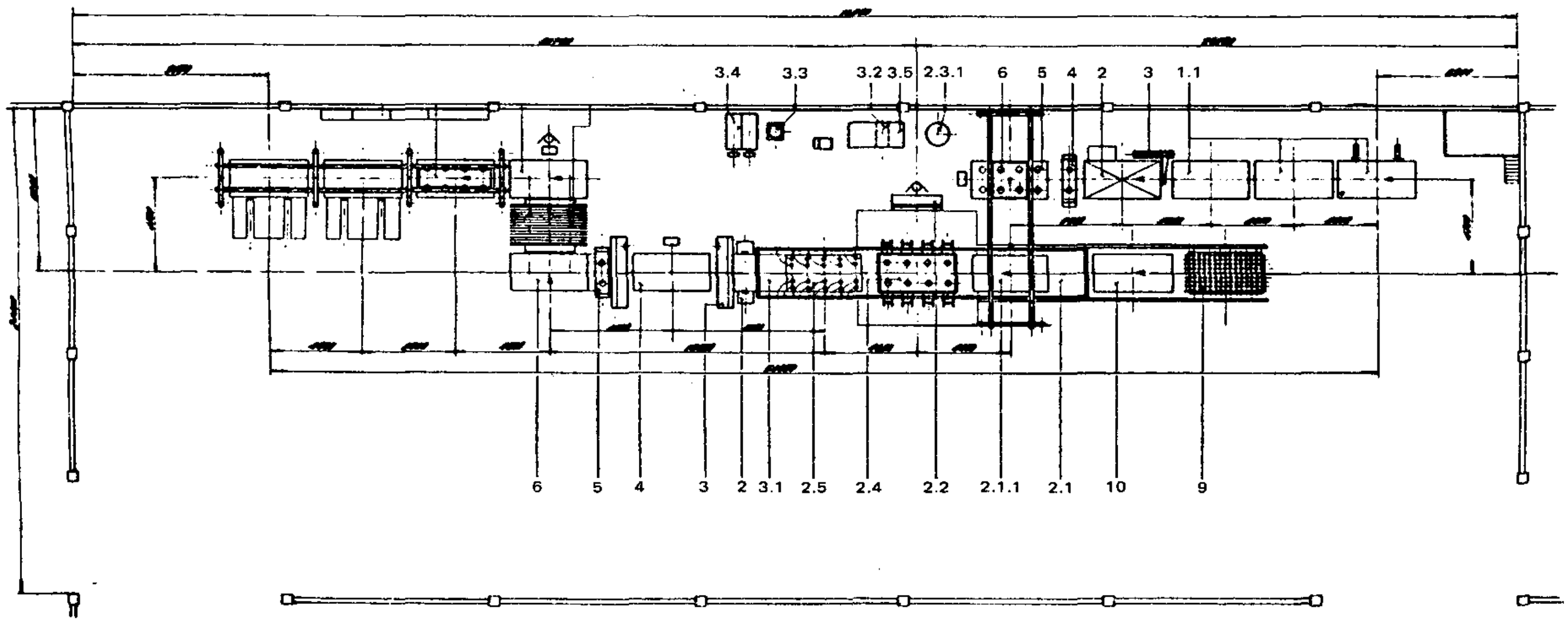
(d) Finished impregnated papers, which replace veneers. These can also be used for edge-banding using the line shown in figure 16;

(e) Glue-coated finished papers. The glue is applied in a melted state on to the reverse side (hot-melt) or a filling glue is applied on the paper's reverse side as micro-crystals during the impregnating process.

Figure 10. Ultrarapid single-opening press with drop loading system



A. Side view



B. Top view

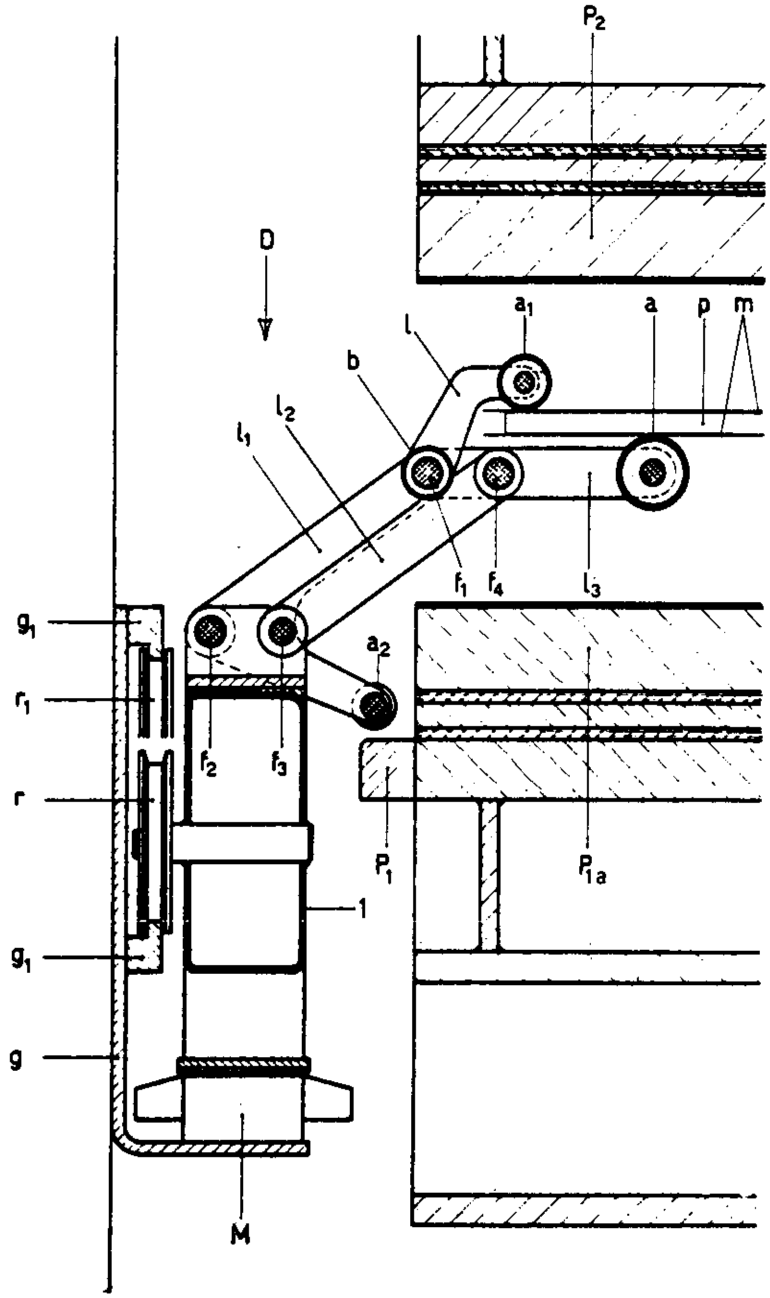
Key:

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

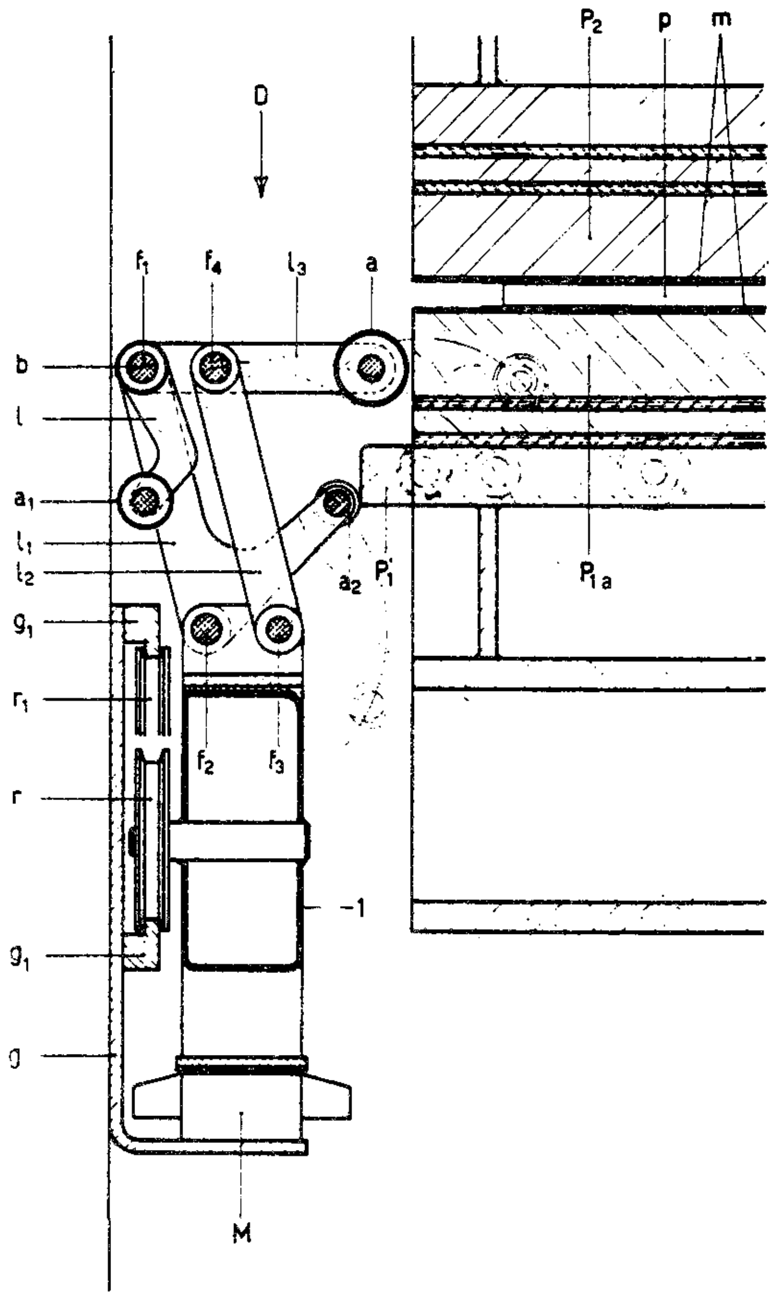
Figure 11. Loading an ultrarapid single-opening press with drop loading system



Key:

a	Board supporting rollers	l	Lever of rotating cylinder
a_1	Pressing rollers	l_1	Lever
a_2	Ball bearings	l_2	Lever
b	Rotating cylinder	l_3	Pair of levers
f_1	Levers pivot	m	Melamine papers
f_2	Levers pivot	p	Board
f_3	Levers pivot	D	Groups of levers
f_4	Levers pivot	M	Linear motors
g	Guides	P_1	Movable locator
g_1	Truck guides	P_{1a}	Lower platen
		P_2	Upper platen

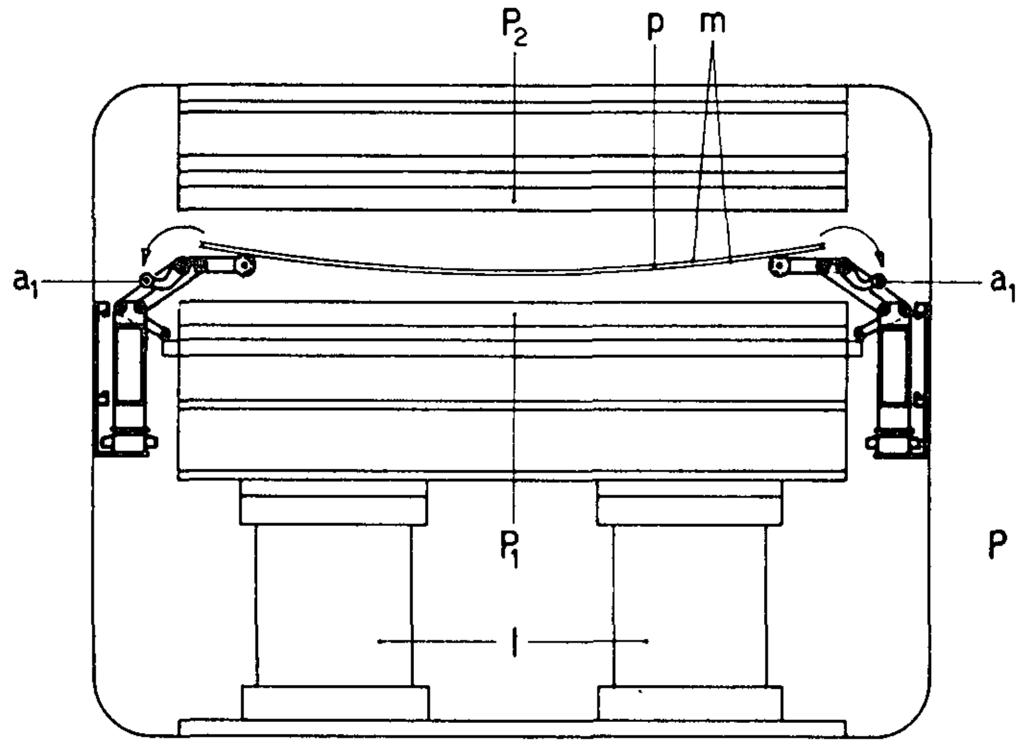
Figure 12. Pressing in an ultrarapid single-opening press with drop loading system



Key:

- a — Board supporting rollers
- a_1 — Pressing rollers
- a_2 — Ball bearings
- b — Rotating cylinder
- f_1 — Levers pivot
- f_2 — Levers pivot
- f_3 — Levers pivot
- f_4 — Levers pivot
- 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

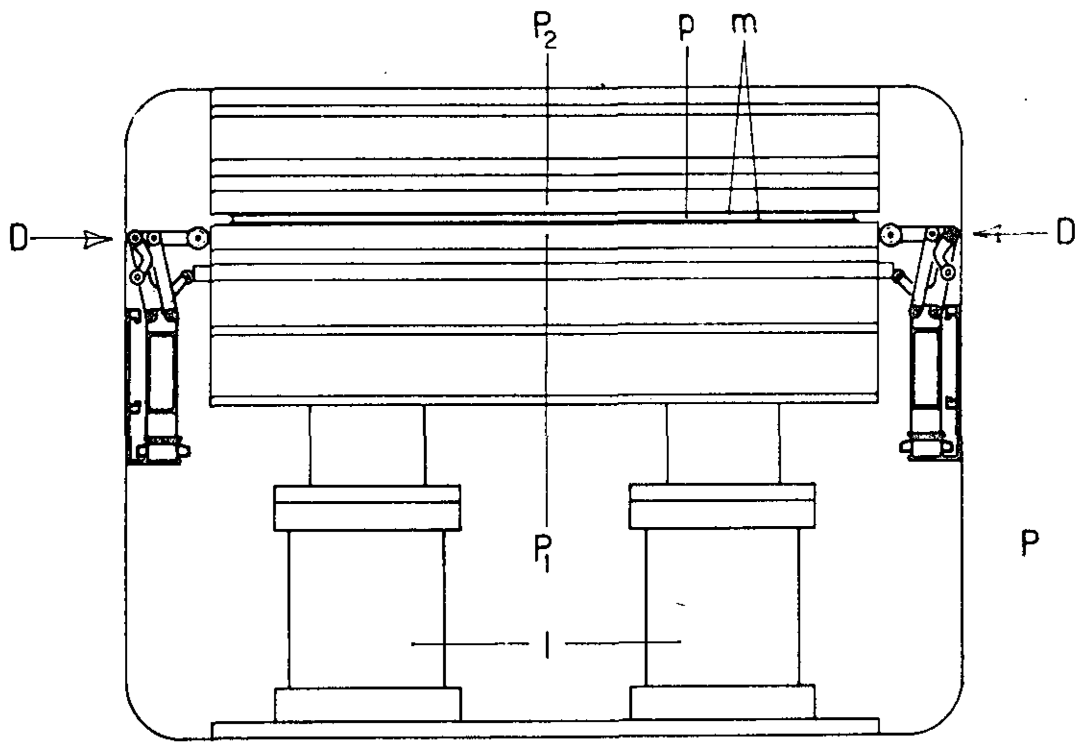
Figure 13. Loading cycle of an ultrarapid single-opening press with drop loading



Key: a1 Pressing rollers; m Melamine papers; p Board; I Hydraulic cylinders; P Press; P1 Lower platen; P2 Upper platen

a_1	Pressing rollers	I	Hydraulic cylinders
m	Melamine papers	P	Press
p	Board	P_1	Lower platen
		P_2	Upper platen

Figure 14. Pressing cycle of an ultrarapid single opening press with drop loading



Key:

m	Melamine papers	P	Press
p	Board	P_1	Lower platen
D	Groups of levers	P_2	Upper platen
I	Hydraulic cylinders		

Figure 15. Resin content vs. weight per unit area for the hot/cold process

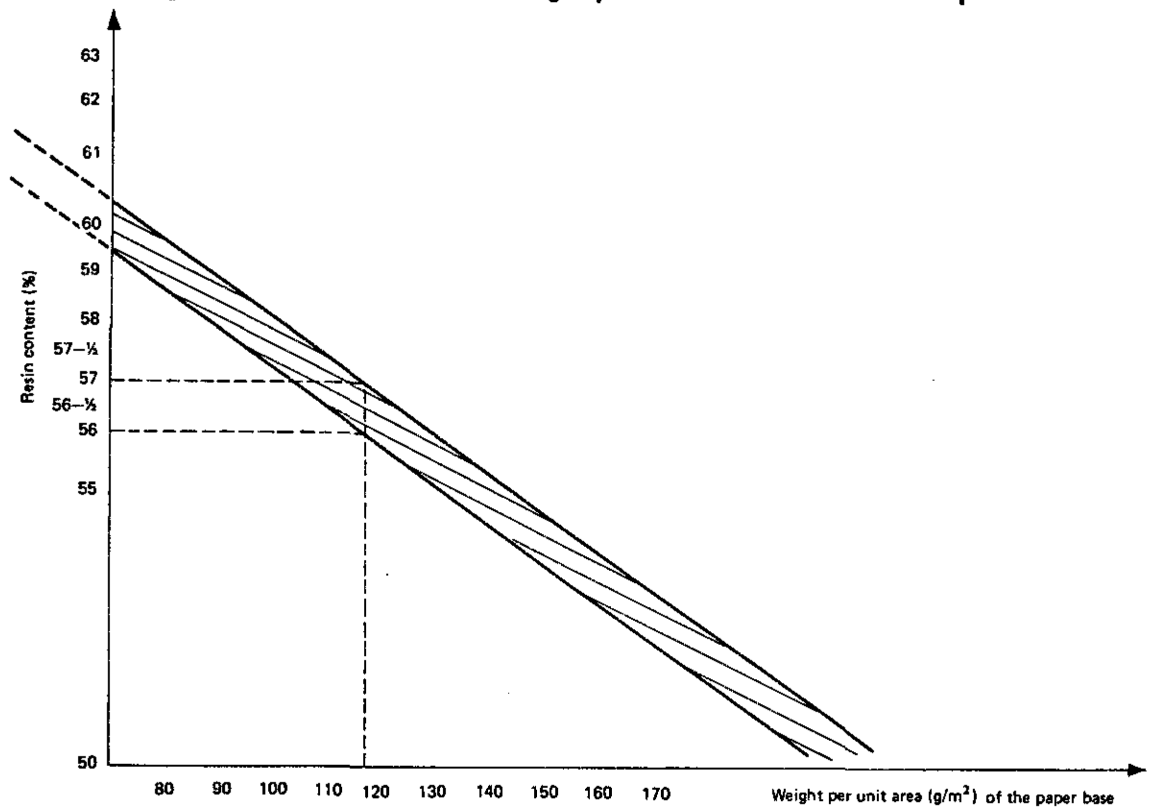
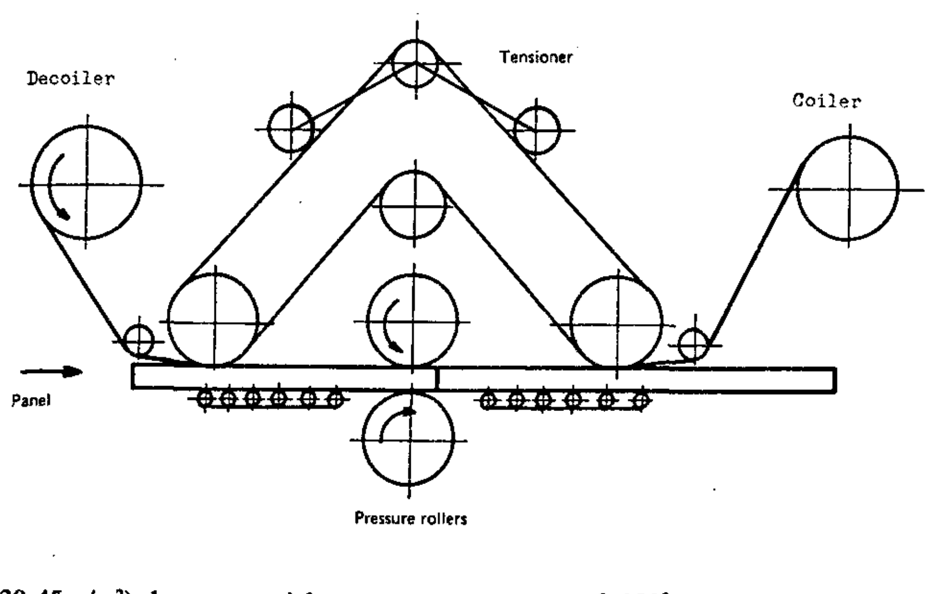


Figure 16. Plastic laminating system



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 conveyor 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. The 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.

Owing 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 17), 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 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 m^2 is too high.

Table 2. Process characteristics

Characteristic	*Hot/cold*	*Hot/hot*
Press type	Multi-opening	Horizontal single-opening
Investment	High	Low
Hourly output per press	High: 20 openings × 5 pressing cycles = 100 boards	Low: 70 boards/hour
Energy consumption	High	Low
Mechanical stress during working	Low	High
Area needed	Large	Small
Cooling in press	Necessary	Not necessary
Cooling of boards after pressing (outside the press)	Not necessary	Necessary (it depends on type of papers and resins)
Sheets and cushion cost	High	Low
Product quality	Very good (glossy 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

Lines for paper application

The "quick step" lamination system is outlined in *figure 18*. The line consists of a gluing machine, winding unit and press, with a conveyor belt, which presses the board with papers. The papers are usually glued, and the temperature is between 110° C and 140° C. The pressing time, depending on the type of glue, is about 8 s. Melamine papers, used in the 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, employs 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 16 shows the operating principle of this system. The board, thus laminated, does not meet standard specifications. Undoubtedly the introduction of calenders in pressing lines will improve the finished product. The application speed varies from 15 to 40 m/min. The roller temperature is approximately 210° C. The touch time depends on the speed (assuming 5 mm of touching area, it will be fractions of a second).

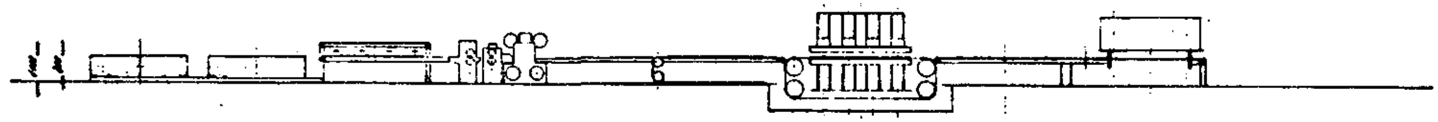
Figure 17 outlines the principle of the transfer application system. This system is being studied mainly with regard to the thickness of layers applied to the substrate, and as well for adhesion properties of paper to particle board surfaces.

Selecting plant equipment

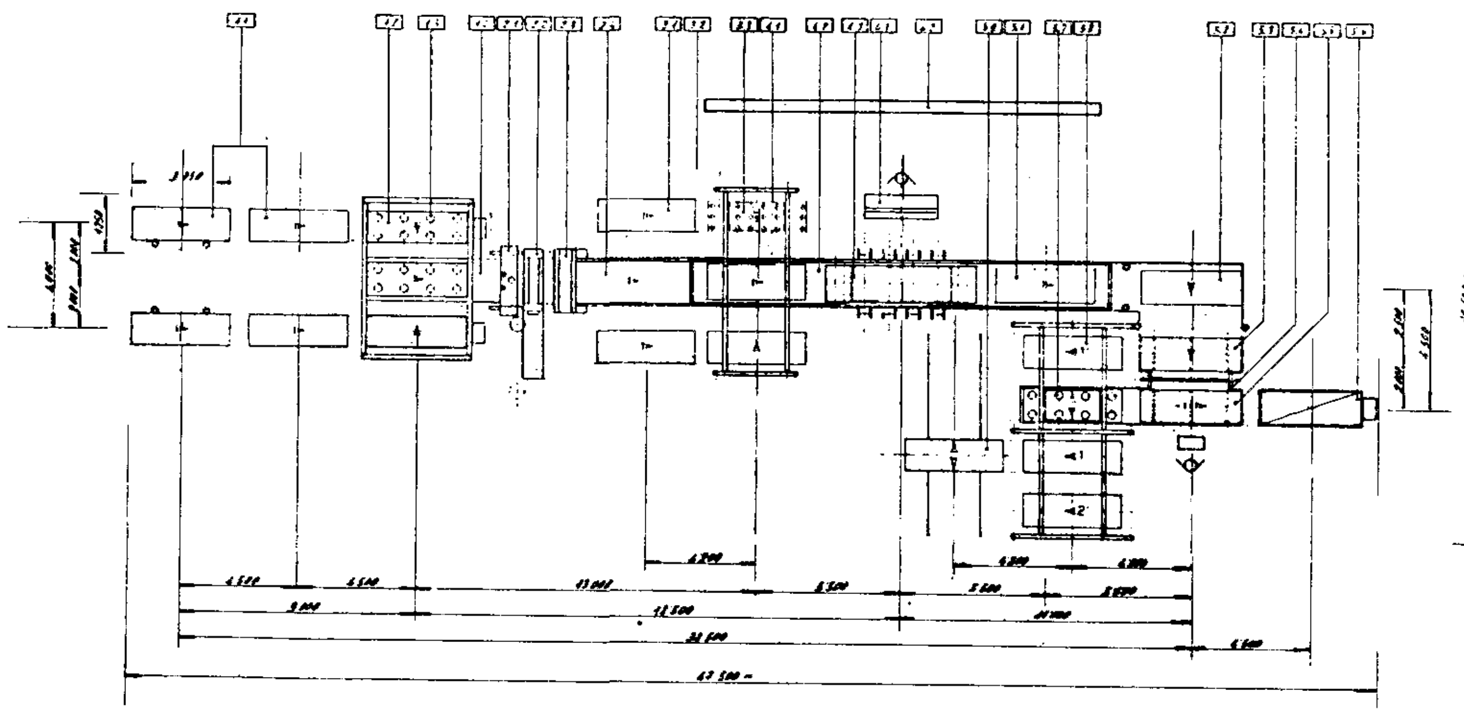
The availability of raw materials, the quality of surfaces and boards, the output required by the market and the needs of users are the determining factors in the plant's product and output. Nevertheless, the choice of a specific type of plant to produce laminated boards will always be mainly connected with the surface quality and the productive efficiency and flexibility of the plant. The initial investment is not always a conclusive factor. Classic lamination, that is lamination by the 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 the 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 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.

Figure 17. Automatic plant for lamination with light papers



A. Front view

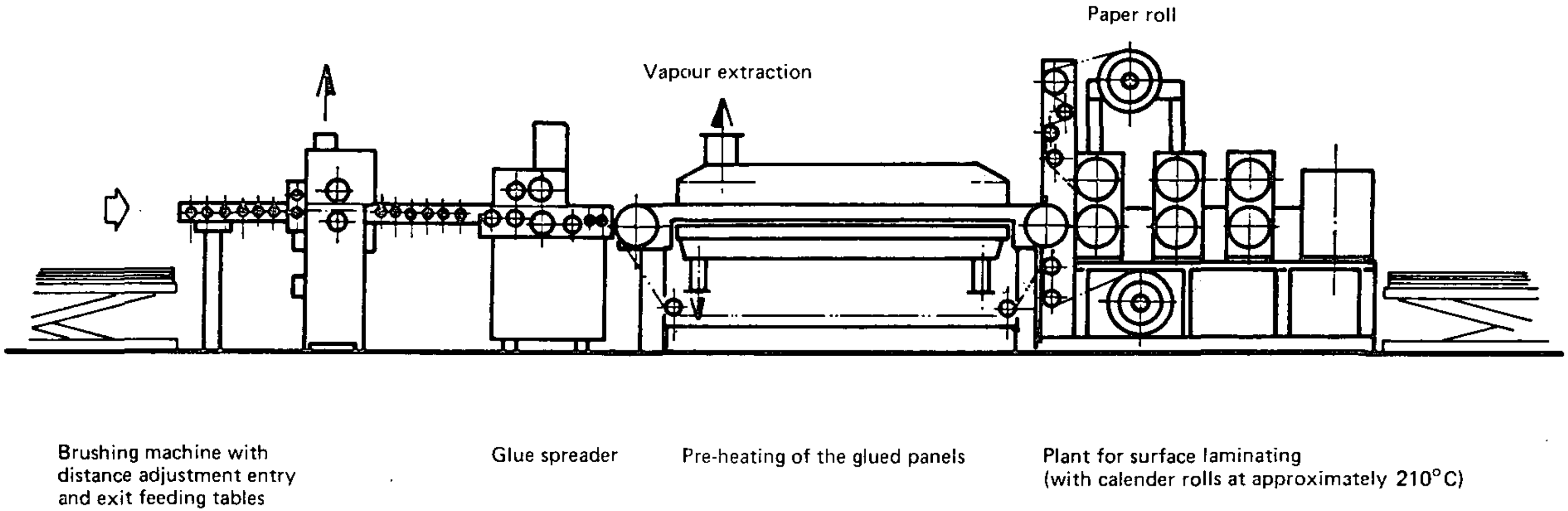


B. Top view

Key:

1.1 Bench with motor-driven rollers
2 Oil hydraulic lifting table
3 Double vacuum hoist for board feeding
4 Belt type conveyor
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 conveyor
3 Single-opening press
5.1 Belt type conveyor
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



Part three

TOPICS OF COMMON INTEREST IN THE PRIMARY AND SECONDARY WOOD-PROCESSING INDUSTRIES

XVII. 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 that are homogeneous from the viewpoint of species, log size and dimensions of the sawnwood 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 band-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 tool maintenance time is relatively short owing to the use of thin blades;

(d) The surfaces obtained are of good quality.

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.

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 aligned 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 the form of 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 stress once mounted 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 is 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 stress once mounted should be approximately 200 N/mm^2 for normal blades and about half of that for very large blades;

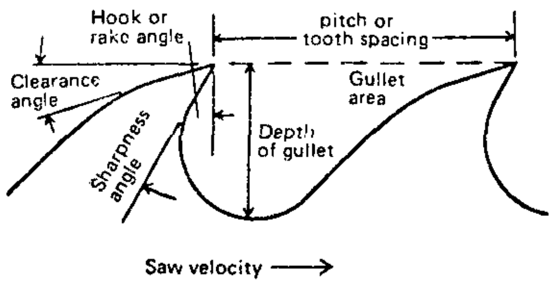
(d) The tensioning constraint is difficult to measure; it is in the order of 80 to 100 N/mm^2.

*By G. Melloni, consultant in the selection of sawmilling equipment. (Originally issued as ID/WG.277/17).

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

Figure 1. Solid saw-tooth nomenclature

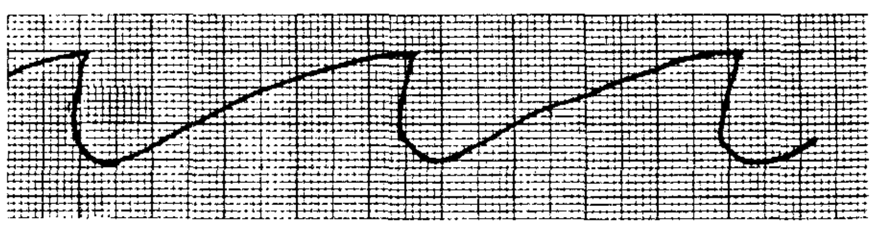


There are very few basic forms of saw teeth. The information provided by the different laboratories is not always based on the same principles. In the case of large tropical logs, the most satisfactory results seem to be those obtained by the "parrot-beak" tooth, the "projected *cutting" tooth or "Belgian" (because of its origin) tooth.* Note their outlines in figure 2.

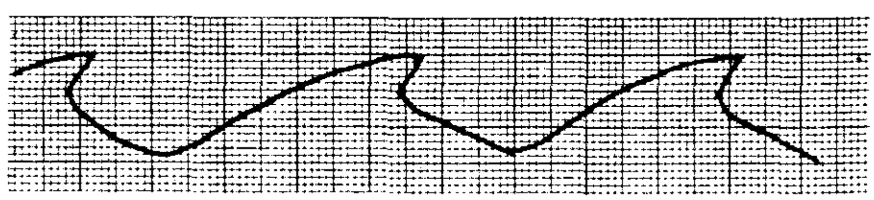
The average pitch values (35-40 mm) are used with relatively small flywheels and timber that is difficult to saw. Higher pitch values (50-60 mm) are for large diameter flywheels and timber that is easy to saw. Swaging and setting are two procedures used to ensure that the saw cuts through the wood more easily. Swaging is the process of widening the tooth near its 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 wood that is easy to work. At present, for large logs from the tropics, the trend is to prefer setting to swaging.

For particularly hard wood or wood that 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 sawing, is extremely important. The blade's tensioning must be checked often and especially each time the saw

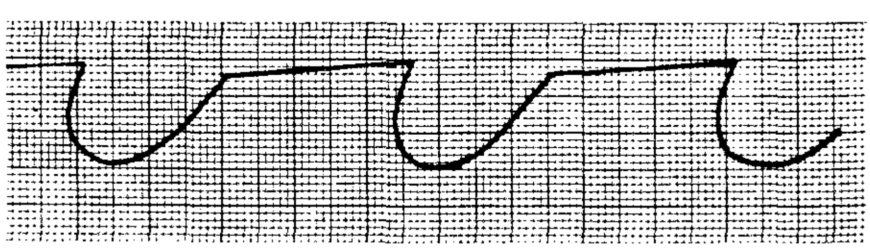
Figure 2. Types of band-saw



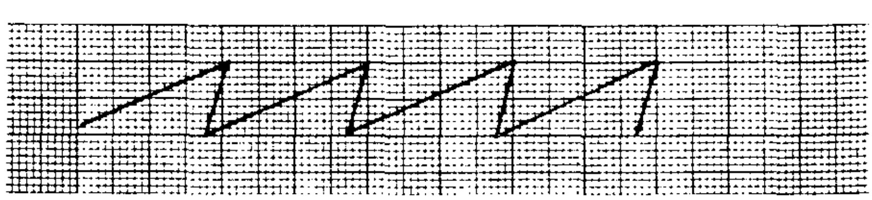
A. Rip-sawing type teeth (Parrot-like)



B. Projected type cutting teeth



C. Belgian type teeth



D. Cross-cutting type teeth

is ground. Satisfactory tools are now available for this purpose. It must be stressed that good results will be obtained only by the proper preparation and maintenance 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 in width, with a thickness of 0.5-1.0 mm. The teeth are generally set at a slanting angle, which render their maintenance easy.

Circular-saw blades for circular-saw benches

These saw-blades are a circular steel disc with punched teeth on their rim. Generally two faces are parallel, but there are certain types with divergent or convergent conical faces. The latter are used especially for the resawing of thick timbers.

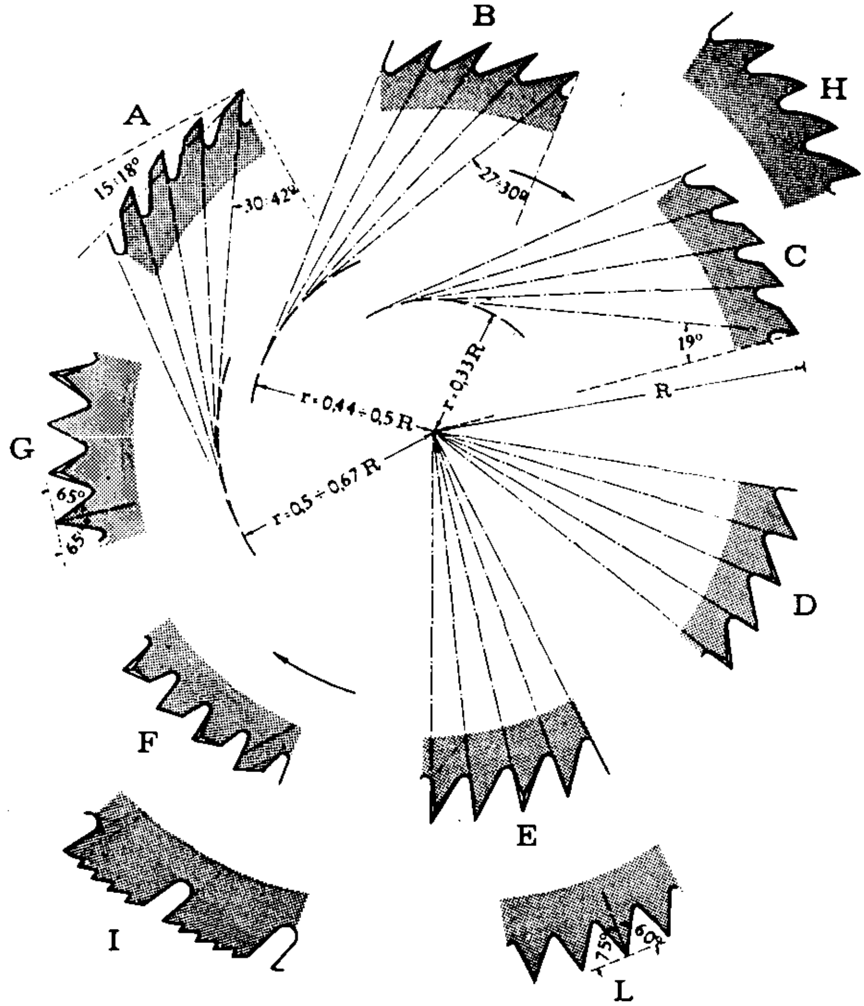
The diameter for workshop operations must remain under 500 mm. The thickness is determined by either one of the two formulae:

(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.

Engineers have conducted considerable research on the form of saw teeth, which are shown in figure 3. For rip sawing teeth types A, B or C are normally used; type H may also be used. For cross cutting, teeth types D, E, F or G are used. 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 both ripping and cross cutting.

Figure 3. Types of circular-saw teeth



For sawing 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. Tungsten carbide* tools are now 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

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. Group K 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 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 1. Characteristics of tungsten carbide alloys in the main chip removal group

(group K)[a]

Chip removal group	*Specific gravity (g/cm^3)*	*Hardness (H 30)*	*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 shows which carbides should be used on which materials.

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 Broad-leaved wood Coniferous wood		K30	K40
Densified wood Treated wood Compressed wood Resin impregnated wood		K20	K30
Composite wood Plywood Laminated wood Compressed laminated wood		K20	K30
Panels Panels faced with various substances Decorative panels Honeycomb panels	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 fibreglass 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 optimal working speed for carbide tools will be somewhere in the upper half of the 25 m/s to 125 m/s operation range. The optimal 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 caused by adding extra devices will pay for itself in a short time owing to the increase in output. Good equipment has important advantages. Among these are that relatively small tools with few edges can be used, and 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 Ausschuss 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

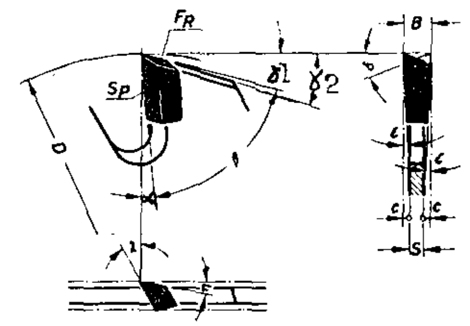
Surface quality with carbide-tipped blades always corresponds to AWF I or AWF II. Carbide-tipped circular-saw blades are designed to make a very narrow kerf. Consequently, the usual large diameter blades are rather unstable, but their stability can be increased by "straightening" and "tensioning".

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
- η 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 δ, which varies according to the chip removal characteristics of the material to be sawn.

Angles δ and λ are partially interdependent. Their ratio influences the lateral stability of the circular-saw blade.

The lateral clearance angle η 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 sawn. 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 of teeth *(Z)* 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 veneered wood across the grain, a large number of teeth are required. For panels that are faced on both sides with plastic material, the maximum number of teeth should be used to prevent splintering.

The pitch *t* is:

$$t = \frac{\pi D}{Z},$$

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:

$$\text{Cutting speed} = \left(\frac{D \times 3.14 \times n}{60}\right)$$

where the diameter (D) is in metres and (n) is the number of rpm.

Blade diameter can be calculated as follows:

$$D = \frac{60\,v}{3.14\,n} \ 20 \ \frac{v}{n}$$

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 $Z = \dfrac{S}{n\,A}$

Table 6 gives the bite per tooth (A) for various materials.

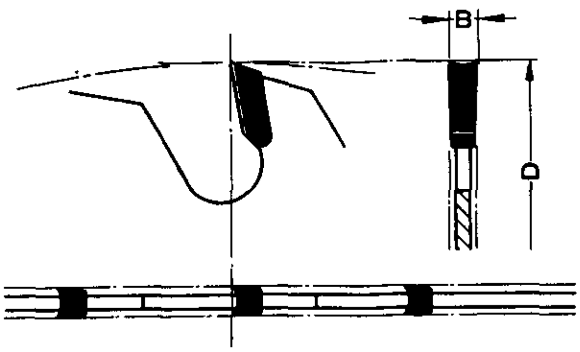
Table 6. Bite per tooth (A)

Material	*Bite/tooth (mm)*
Plastic laminates	0.03-0.05
Thin or coniferous wood panels—sliced wood (veneer) 0.6 mm thick bonded on panels. Low or medium density particle board (with low screw holding force). Extruded or continuously pressed particle board (with tube holes).	
Thermoplastic panels (PVC etc.)	0.05-0.08
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) show different carbide-tipped blades. The applications and advantages of each are described.

Figure 5. Straight teeth



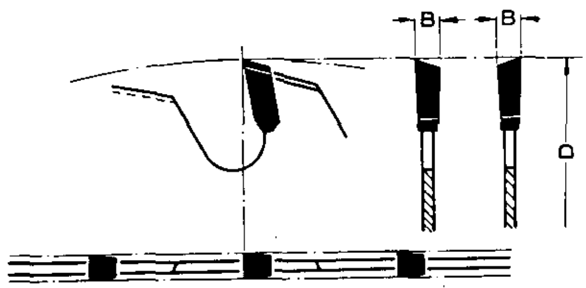
Applications:

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

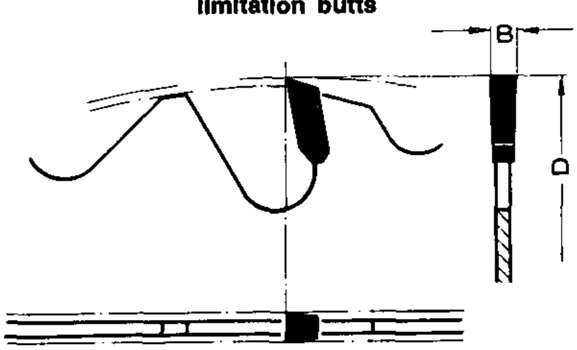
Advantages:

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



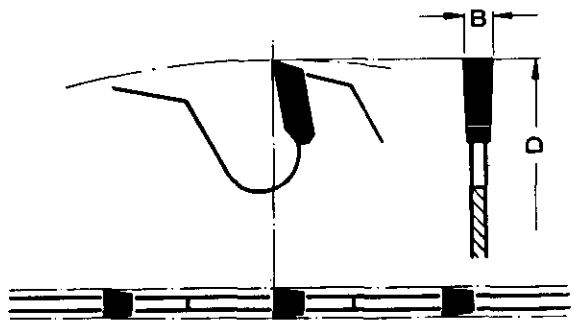
Applications:

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)

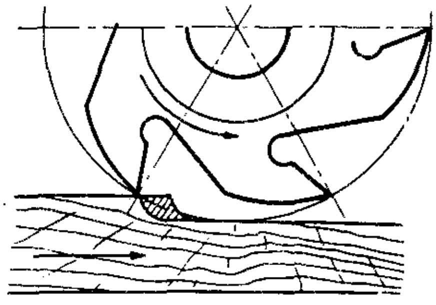
It is important to choose the right material for cutters and to select the right feed rate and cutting speed. If these operations are done correctly, chip thickness will be good and output will increase. Only high-quality materials, such as high speed steel and carbide alloys, can be used for these tasks. The cutter should not be used 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).

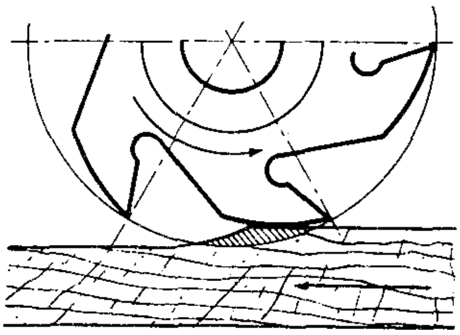
When cutters rotate in the same direction as workpiece travel, the wood will have a better finish, because the cutter starts removing the thickest part of the chip first. Thus the chip is gradually separated from the workpiece without splitting or splintering. Furthermore, higher feed rates can be used. 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 starts 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.

Figure 9. Cutter travelling in same direction as workpiece



Down milling

Figure 10. Cutter travelling in opposite direction of workpiece



Up milling

Cutter characteristics

Woodworking cutters may be made out of:

(a) High-speed steel Cr-W-Mo-V alloy, known commercially as HSS, especially suitable for normal cutting speeds. Such cutters have a reasonable tool life. They are recommended for all types of natural wood; these cutters are no longer widely used;

(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 Hartmetall (HM). 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).

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 11. Rectangular tip shape (swage tooth)

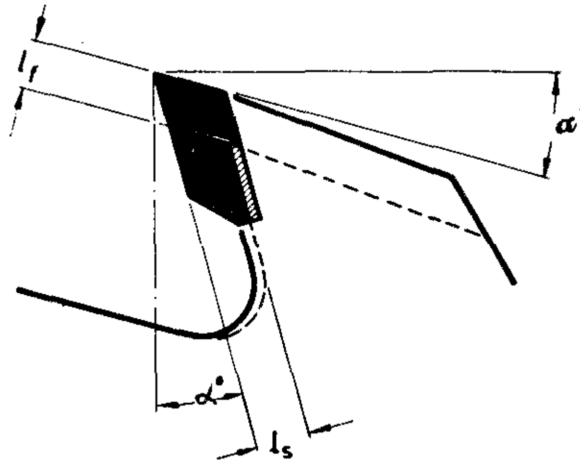
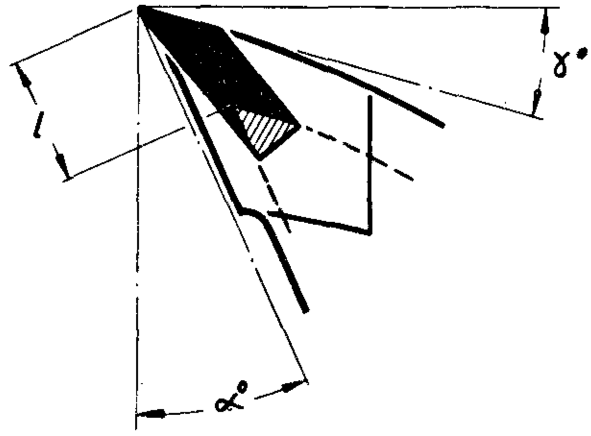


Figure 12. Top bevel tip shape



The front bevel tip shape is normally used on constant profile cutters and on cutters that must maintain their maximum diameter (their maximum diameter must decrease as little as possible during sharpening) (figure 13).

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;

(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.

Figure 13. Front bevel tip shape

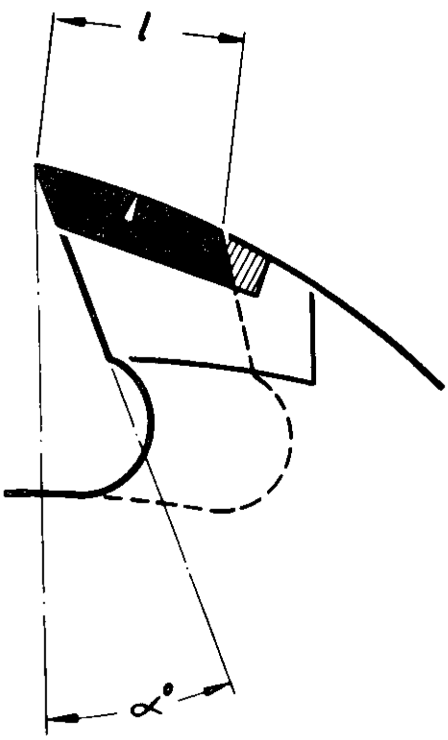
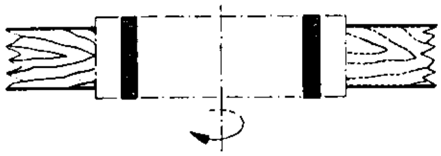
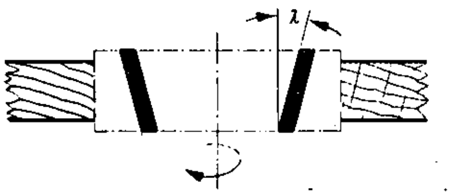


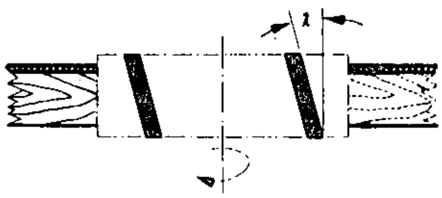
Figure 14. Cutting edge arrangements



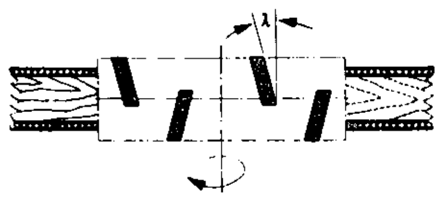
A. Cutting edges parallel to axis



B. Cutting edges inclined in alternate directions



C. Cutting edges inclined in the same direction



D. Pairs of alternating edges

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);

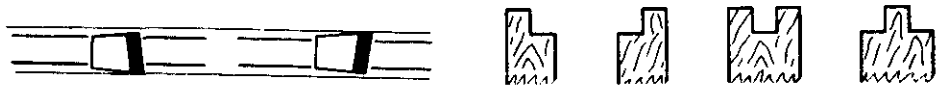
(d) With spurs on one side (either right or left). The edges are inclined in the same direction (figure 15D). (For machining rebates and tenons in veneered or plastic-faced panels when perfect cuts are necessary).

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).

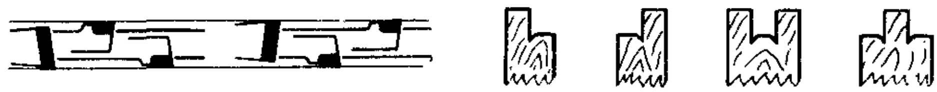
Table 7 shows the working angles for various materials.

Table 8 shows approximate cutting speeds for various materials.

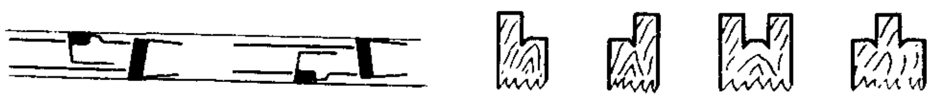
Figure 15. Cutting discs with and without spurs, showing cuts produced



A. Without spurs



B. With spurs on both sides



C. With alternate spurs

D. With spurs on one side

Figure 16. A spur

ü = Spur depth

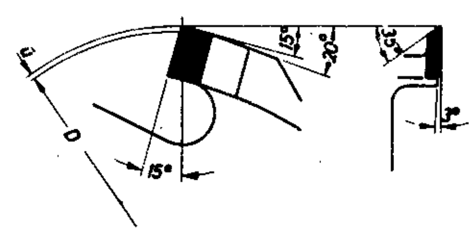


Table 7. Working angles for various materials

(Degrees)

Material to be machined	Working angle: HSS cutters γ	β	α	Carbide cutters γ	β	α	Solid cutter heads 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, plywoood (not compressed)				15	60	15	15	55	20
Compressed and glued laminated wood board				15	63	12	15	63	12*
Thermoplastics				15	63	12	15	63	12*
Thermosettings				15	55	20	15	55	20

*Carbide tipped knives must be sharpened to 0.3 mm edge thickness to reinforce the cutting edge.

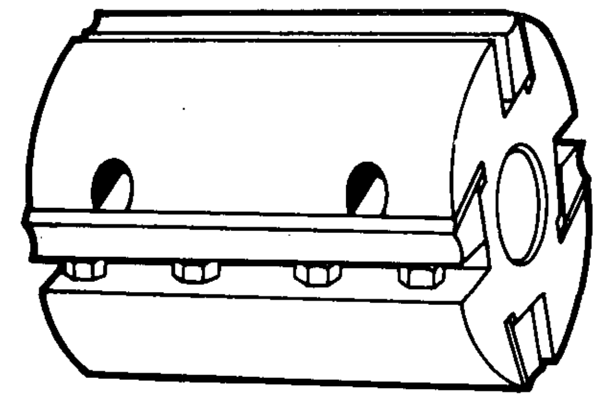
Table 8. Approximate cutting speeds for various materials

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.

Figure 17. Cutter head



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 routers with at least 12,000 rpm.

Routers 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 $\eta = 30°$, the radial rake angle γ reaches the optimum value. This is especially true for chip removal with softwoods.

For larger angles—$\eta \approx 50°$—the radial rake angle γ 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 that 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 an expensive 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. They should never be placed on a hard surface. The tools should always be put 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 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 that 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 that 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.

Figure 18. Single-flute router bits

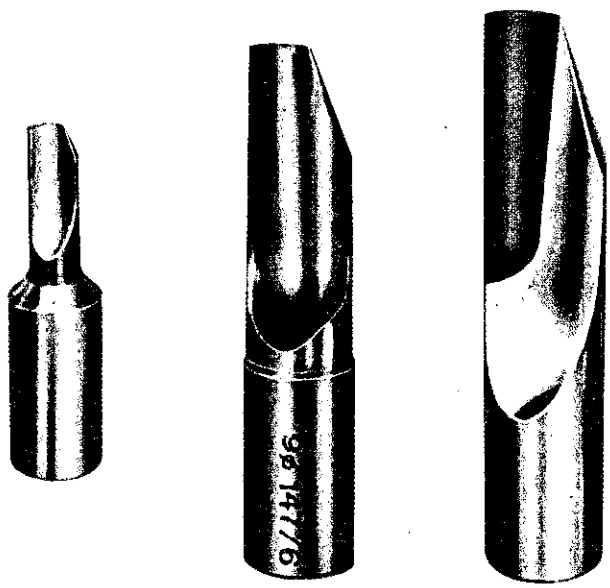
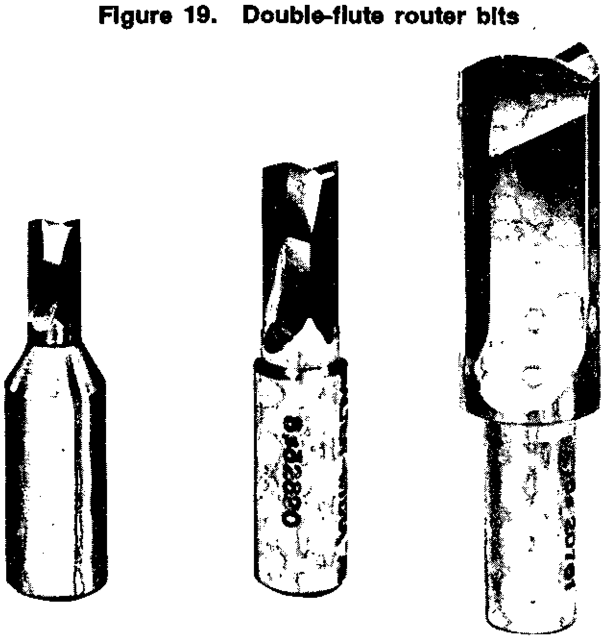


Figure 19. Double-flute router bits



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 and vibration free, and the grinding wheel spindle must be mounted on a bearing that 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 wheels of different diameters. It should have a movable slide mounted on guides and provided with devices for micrometric positioning and a tool holder that can be turned and inclined along each of two axes. It must be provided with a standard disc with 24 divisions and a micrometric screw so the angle can be set correctly. Cutter spindles that 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

The same amount of material should be removed 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; local overheating should be avoided. Grinding wheels with sharp edges and overheating cause initial breakdown in tool steel and make tools dangerous. Cooling fluid should always be used 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.

Figure 20. Sharpening a double "v" flute routing bit by back grinding

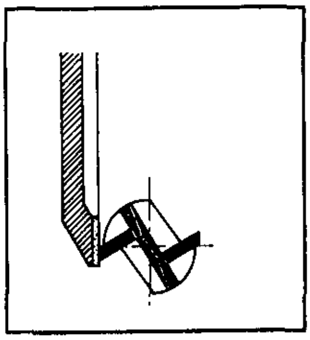


Figure 21. Sharpening a double "v" flute routing bit by face grinding

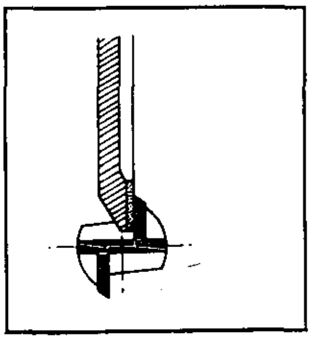


Figure 22. Sharpening a routing bit with a single edge "o" flute

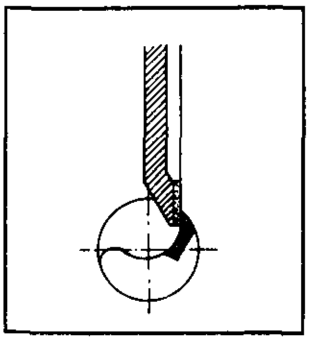
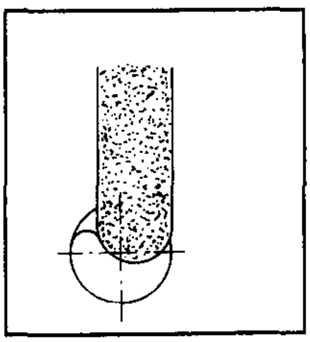
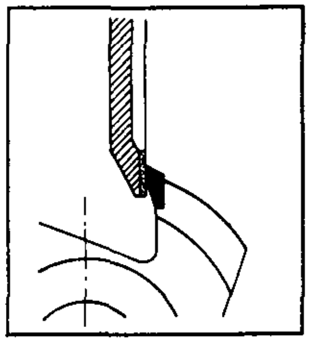


Figure 23. Sharpening a routing bit with a formed grinding disc



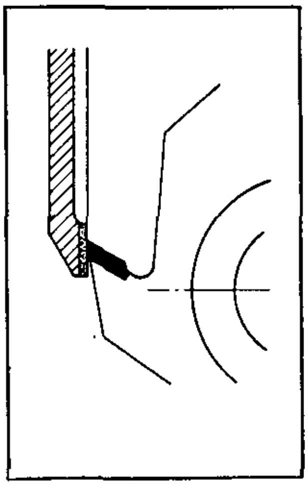
The profiling cutters are always sharpened on the face, without changing the original working angles so that the profile will always be the same (figure 24).

Figure 24. Sharpening a profile cutter by face grinding



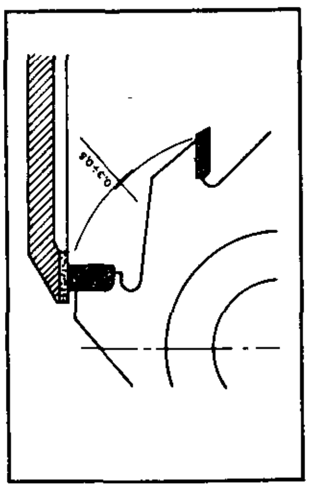
Since the cutters for jointing usually have a constant profile, only the backs of the edges are sharpened so the size of the joint will always be the same (figure 25).

Figure 25. Sharpening the back of a cutting edge



The spurs on rebating and jointing cutters are only sharpened on the back; they must project 0.3-0.6 mm (figures 26, 27).

Figure 26. Sharpening the back of a spur



The chip limitation butt is lowered by circular grinding, so that it is 0.6-0.8 mm lower than the edges (figure 28).

Figure 27. Sharpening a planer knife

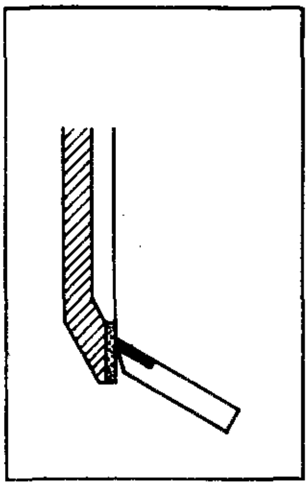
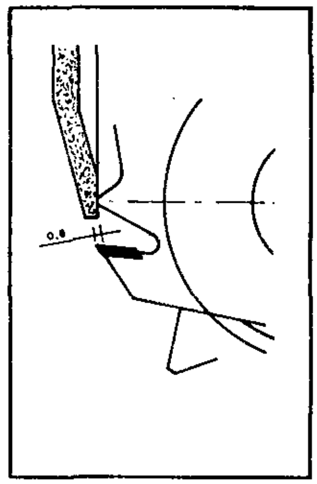


Figure 28. Regrinding chip limitation butt



When sharpening the circular cutter units for double end tenoning machines, the circular edging saw blade is unscrewed; 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. The sides should never be sharpened.

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.

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.

Safety rules

A tool with too big a hole should never be used without using the right reducing bush with calibrated tolerance.

The tool (in relation to the direction of workpiece travel) should never be angled in order to obtain a wider cut.

Broken or seriously damaged tools should not be welded.

Unbalanced tools, usually caused by improper sharpening, should be avoided. The tool must be 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.

All necessary guards must always be mounted before using the tools.

XVIII. Machines and equipment for tool maintenance*

Introduction

The subject of machines and fixtures cannot be broached before the significance of the "maintenance" of cutting tools is clear. It is well known that the efficiency of machine tools in qualitative and quantitative terms of work executed or of production obtained is heavily conditioned by the choice and efficiency of the tools used. There is a wide range of cutting tools for the mechanical woodworking and secondary wood products industries that are highly specialized and technically developed. The study, planning and precise manufacture of these tools result in a relatively high cost; it is therefore necessary to keep these tools in a condition that allows for constant and optimal efficiency with the lowest possible wear, which consequently leads to longer tool life.

For example, a cutting tool loses its efficiency when it loses, completely or partially, its fundamental characteristic of "cutting" in a certain predetermined way. This characteristic is usually lost when the cutting edge is rounded off; it can then be restored by sharpening. Maintenance is often confused with sharpening; although the latter is only one of the maintenance operations, it is the most important and conclusive one. Sharpening has no effect if the causes of wear are not determined. In the case of a moulder, for example, deposits of resin or other material are formed on the cutting edge. These will carbonize and harden because of the heat created by friction and will decrease the efficiency of the tool before the cutting edge is worn out, therefore accelerating wear. Under such conditions, the tool should be thoroughly cleaned and not sharpened. Sharpening would be a costly and vain operation, since the deposits would only be partially removed; consequently, the efficiency of the tool would remain very poor.

*By R. Ruzzenenti, expert in carbide-tipped tools. (Originally issued as ID/WG.369/14.)

The maintenance process

Maintenance encompasses all the operations required to restore a tool to its original condition and efficiency. Maintenance must be rational, accurate and immediate.

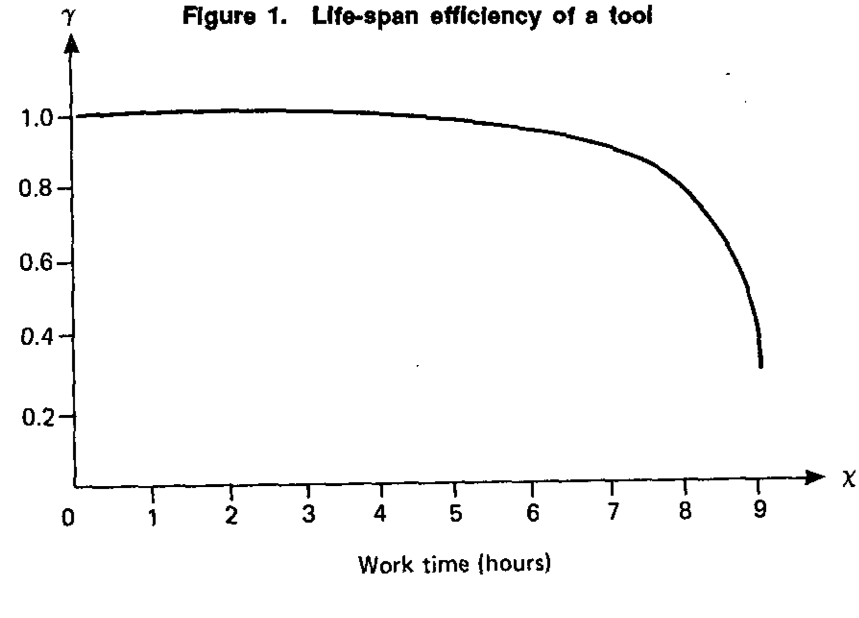
The differences between the various types of tools and the conditions of work do not allow the frequency of maintenance to be predetermined. As a rule, the first time a tool is used or a new type of work is undertaken, the highest efficiency life span of the tool is measured, thus determining the frequency of maintenance with a good margin (usually 20 per cent) below this measured time. By doing so, the tool will not be excessively affected by metal fatigue. It is always good to restore the tool before it has reached its limit of optimal efficiency. As a matter of fact, if the efficiency curve of a tool is drawn (see figure 1), the fall efficiency, which is initially very slow, increases until it becomes vertical; the fall actually becomes important at about 80 per cent of the total highest life-span efficiency.

It is also good to carry out maintenance operations at the end of the working cycle before storing the tool(s), regardless of their condition, to avoid having unfit or partially efficient tools at the beginning of a new working cycle.

Cleaning

This operation is elementary, simple, economic, indispensable and, unfortunately, often neglected. The equipment required is the same for all maintenance centres and

Figure 1. Life-span efficiency of a tool



departments; the only variable is the dimension. Tools are cleaned by immersion for a certain period of time in a suitable solvent or detergent. The container for the solvent or detergent should be large enough so that a certain number of tools can be immersed, either suspended or laid down but separated from each other. The container should be made of plastic and provided with a cover to limit the evaporation of the liquid. Special "tool-cleaning" liquids that offer maximum security, i.e. they do not irritate the skin or emit toxic fumes, are on the market. If such liquids are not available, it is possible to use a solution of caustic soda, but caution should be taken as to the effects of oxidation of the tools and the danger of irritating the skin of workers.

Acids or solvents that are easily inflammable or emit poisonous fumes or vapours should never be used. The residuals of very hard deposits may be removed with a blade, while taking care not to damage the edge of the tools. The liquid must be changed regularly since, when saturated, it loses its solvent and detergent properties. It has been noticed that frequent cleaning extends the cutting life of the tools.

It is possible to clean the tools while they are still fixed to the machine. Tool cleaners are available as concentrates; they are applied with a brush or as spray.

Inspection

Visual inspection and measurements are mainly intended for checking the security and efficiency of the tool. In other words, it is necessary to ensure that a tool has not been deformed, cracked, broken or dented, which could affect its structure and geometry.

After inspection and measurements, a decision is made to either repair or definitively scrap a tool. These decisions are taken after verification of the limit of wear, i.e. whether it is possible to sharpen without affecting the mechanical resistance of the cutters.

Before the sharpening operation is started, the tool is measured precisely to determine the action to be taken. Manufacturers seldom provide the measurements of their tools (especially angular measurements).

For all these operations, it is sufficient to have a good work bench and a series of standard instruments for measuring (a surface plate, rulers and squares, one gauge, one dial comparator and its support, one surface gauge, one micrometer, one compass, one goniometer or universal protractor; a good magnifying lens is also very useful). Specific measuring and control instruments for the various types of tools are available from their manufacturers.

Sharpening

Before describing the sharpening machines, the meaning of sharpening should be made clear. Tools (cutters, drills, knives, circular saws in hard metal (HM)) are usually supplied sharpened and ready for use by the manufacturers. As a matter of fact, the last stage in manufacturing a tool is sharpening. It is after this operation that a tool has the predetermined cutting angle values (rake and inclination etc). Consequently, during maintenance this operation should more correctly be termed "re-sharpening", since it is as close a repetition of all the details of initial sharpening as possible; the cutting edge is sharpened and still maintains its original measurements, except for the natural decreases owing to wear. It is thus necessary to use similar machines to the ones used by the tool manufacturer.

Maintenance machines

Grinding wheel

The statements above about tool conditioning and the efficiency of the machine are also valid for the grinding wheel. The choice and quality of the grinding wheel are very important for good sharpening. The tools to be sharpened on the grinding wheels can be divided in two types: tools from steel (of any quality, homogeneous or with tips that are differently heat-treated) and tools that have bits of metal carbide (Widia etc.).

For the first type of tool, a conventional grinding wheel in aluminium oxide (corundum) and grinding wheels in cubic boron nitride (CBN),[1] can be used. For the second type of tools, only diamond grinding wheels can be used. (Silicon carbide grinding wheels are not discussed here, since they can only be used for rough grinding and for obtuse cutting angles that do not exist in woodworking.) It is not possible to sharpen steel with diamond grinding wheels or to sharpen hard metal with standard or CBN grinding wheels.

There is no universal grinding wheel suitable for all kinds of steel. It is necessary to use the specific grinding wheel that is suitable for each particular type of work. The grinding wheel is selected according to the following factors:

(a) The characteristics of the sharpening machine and of the tool determine the dimensions (diameter, thickness, hole) and shape (flat type, knife-blade type, cup type, cylindrical cup type, shaped type etc.) of the grinding wheel;

(b) The diameter is used, according to the rotating speed of the mandril carrying the grinding wheel, to determine the outside speed, which must be 20-30 metres per second for standard sharpening wheels. It must be kept in mind that an excessive speed "hardens" the grinding wheel (resulting in reduced abrasive capacity and an increased tendency to break) while an insufficient speed "softens" the grinding wheel (resulting in high consumption if compared to the materials removed);

(c) Characteristics of the steel to determine:

- (i) The type of abrasive (type of crystalline structure of the corundum, natural or artificial);
- (ii) The dimensions of the grain or granumolometry (coarse from 10 to 24, medium from 30 to 60, fine from 70 to 180);
- (iii) The hardness or degree of cohesion of the binder (soft from D to K, medium from L to O, hard from P to Z);
- (iv) The structure or spacing index of the abrasive granules (closed, medium, open);
- (v) The binder (vitrified-ceramic or resin).

This information is generally printed on the wheels' labels and allows comparisons in order to modify one or

[1]Also known as Borazon.

more parameters according to the results obtained and desired.

CBN is a synthetic product with a structure similar to that of diamond; it is the second hardest known material. The difference between the two is that CBN has no carbon atoms, thus offering better thermal stability and mechanical resistance. With such characteristics, it is an excellent abrasive to use for high-speed steels and high-alloyed steel (diamond cannot be used) having a hardness of above 55 HRC. It is thus more productive and economic than traditional abrasives (corundum), in spite of its high cost (a CBN grinding wheel is more expensive than a similar diamond wheel).

The manufacturing characteristics of CBN grinding wheels are practically the same as those of diamond wheels; the following discussion is therefore valid for both types of wheels.

CBN and diamond grinding wheels have the same shapes and dimensions as standard grinding wheels. However, they are made by a shaft or support, either in metal or plastic, to which a band of binder (either resin type or metal type that includes the CBN or diamond granules) is attached in the working area. Grinding wheels also exist where the abrasive is deposited electrically, directly on the shaft; however, these grinding wheels are not used in sharpening.

It must be noted that the normal dimensions of the grinding wheel remain practically unchanged for its entire life. (The wear is limited to the band's dimensions, and there are therefore no important variations to the dimensions, as on standard grinding wheels.)

A diamond (or CBN) grinding wheel generally has a wider range of uses than a standard grinding wheel. A CBN grinding wheel, for example, can work a larger variety of steels than a corresponding standard grinding wheel with the same efficiency. CBN and diamond grinding wheels are available with a wide range of characteristics.

The diamond may be natural or synthetic (the latter being mostly used nowadays); both diamond and CBN may be armoured, that is, they may be coated by a layer of copper or nickel, which has two functions: *(a)* to protect the binder from high temperatures; and *(b)* to keep the granules as long as possible for the best adhesion to the resin.

The grain is classified according to different scales; the internationally used one is the Fédération Européenne des Fabricants de Products Abrasifs (FEPA) scale, with numerical values ranging from 46 to 91 for fine grains, from 107 to 126 for medium grains and from 151 to 427 and over for coarse grains.

In diamond and CBN grinding wheels, the concentration of the abrasive is extremely important. This concentration of abrasive is the quantity of abrasive material measured in carats contained in the grinding wheel. It is indicated as follows:

Concentration 100 = 4.4 carats per cm^3 of abrasive band
Concentration 75 = 3.3 carats per cm^3 of abrasive band
Concentration 50 = 2.2 carats per cm^3 of abrasive band

There is also a concentration 25 = 1.1 carats per cm^3 of abrasive band, which is not acceptable for tool-sharpening operations.

From the above, it is clear that, at an equal degree of concentration, it is the band's dimension that determines the value or price of the grinding wheel. The peripheral speeds recommended for diamond and CBN grinding wheels are:

Binder	*Working conditions*	*Diamond (m/sec)*	*CBN (m/sec)*
Resin type	Dry	15-22	15-22
Resin type	Wet	18-28	18-40
Metal type	Dry	Not recommended	
Metal type	Wet	15-20	15-25

To find the correlation between the diameter and peripheral speed of the grinding wheel and rev/min of the mandril, the following equation is used:

$$Vp = \frac{D \cdot n}{60{,}000} \qquad (1)$$

where: D = diameter of grinding wheel in mm
Vp = peripheral speed of grinding wheel in m/s
n = rev/min of the mandril

The grinding wheel should be cooled, since the heat generated during the work causes tempering in the steel or breakage of hard metals. In addition, cooling liquids generally have detergent properties. The flowing of the liquid will remove the abrasive dust and material cut away, which would disperse into the work environment in the absence of an efficient suction plant. Cooling decreases the wear of diamond and CBN wheels (resin binders melt and loosen the granules at the low temperatures easily reached in sharpening operations).

It is advisable, when working in dry conditions, to use diamond and CBN grinding wheels having suitable characteristics for this use. Grinding wheels must be periodically cleaned and dressed. Standard grinding wheels will be dressed with peg-type dressers, with roll dressers or diamond rotating wheels. Diamond and CBN grinding wheels may be dressed with pumice stone sticks or soft abrasives.

Machines

Specific sharpeners, ranging from standard designs to more or less automated ones, are now available for each type of tool mentioned in this chapter. All the machines are described below separately, thus allowing the correct machine for a specific plant to be chosen.

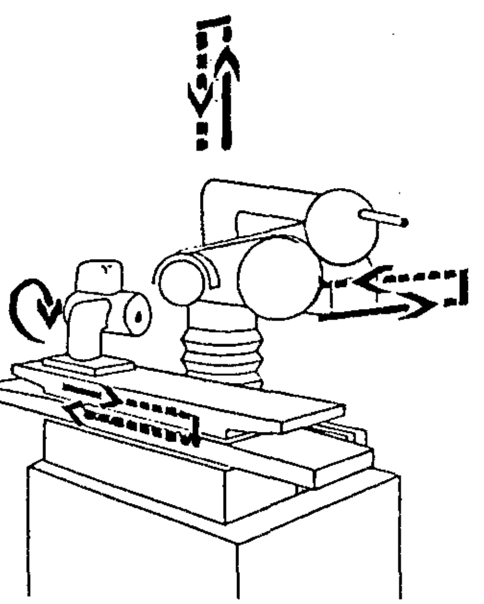
Universal sharpeners

The ideal grinder is the classical hand-operated "universal mechanical sharpening machine". In fact, it is used not merely as a sharpening machine for all kinds of tools but also as a grinding machine for surface and cylindrical grinding as well as for other kinds of machining operations and, therefore, fully deserves the designation "universal".

If complemented with suitable auxiliary equipment, this type of machine sharpens not only solid block cutterheads but also the whole range of cutting tools in woodworking: shredding machines and cutterheads, cutters of all kinds (flat, profile, throw-away, round cutters etc.), drilling and milling bits, tools for the copying lathe, mortise chisels, circular saws with hard metal facing etc.

This sharpening machine is normally used by tool manufacturers and professional sharpeners. As shown schematically in figure 2, the machine is made up of a cast-iron or welded sheet-iron bedplate; the latter is very solid and rather large so as to absorb the vibrations produced by the mobile units it supports. The bedplate houses the cooling system (motor-driven pump and its related liquid collection and decantation tank) and the electrical system (transformer, remote control switches, fuses, isolating switch). Two units are fixed onto the bedplate: the worktable stand, which slides along its longitudinal axis by means of a compound-roller guide system (or other similar system) ensuring smooth running, accuracy and long working life; and the pillow block of the grinding wheel spindle column, which moves along its vertical axis and along its horizontal axis at right angles to the worktable. These two movements are controlled by precision screws and nuts, hence even minute shifts can be obtained.

Figure 2. Universal mechanical sharpening machine



The wheel spindle performs a 360° rotation on the horizontal plane and a more limited one on the vertical plane (generally + 20°); at least two speeds of rotation are available. Power ranges between 1.5 and 2.5 hp (depending on the type of machine). The table has a 350-500 mm longitudinal travel (depending on the type of machine) and a 200-250 mm vertical and transverse travel.

There is a T-shaped alignment groove in the worktable to which the workhead is fixed. The latter is fitted on an articulated mounting through which the workhead can be rotated 360° both in the horizontal and the vertical planes. The index-type workhead is quite strong and is provided with a rather larger female Morse taper attachment (No. 4 or 5) designed to support large-sized tools and to take up the stress that develops during sharpening.

The interchangeable disk dividing system and the relative obturating device enable tools with any number of cutting edges to be positioned; furthermore, verniers and micrometric screws are supplied in order to set and correct angular sharpening values accurately.

Owing to its ability to perform axial shifts along the three orthogonal axes and to its orientability in any desired plane, this type of sharpening machine is capable of aligning cutting edge planes with grinding wheel planes and can, therefore, sharpen all types of solid-block cutterheads or similar tools with the greatest degree of accuracy and thoroughness. It can furthermore repeat the same operation for all similar cutting edges.

A wide range of machines with the above-mentioned functional and dimensional characteristics exist: some are entirely hand-operated, others are partly automated (through mechanical, electrical, pneumatic or hydraulic systems) and still others are fully automatic and their cycles can be programmed electronically (numerical axis control is one of the latest developments in the field). The choice has become even wider, since new types of machines are being marketed. While reducing the size and possible movements (these drawbacks are often offset by brilliant alternative designs), these machines offer considerable advantages in terms of cost. It must be remembered, however, that while economic considerations do play a major role in the choice of machines, such considerations should not be at the expense of quality. The degree of accuracy,[2] the quality and treatment of the materials and the range of possible operations should always be the decisive factors in choosing a machine. The possibility of fitting the machine with ancillary equipment and attachments should also be taken into account.

Universal sharpeners are the basic equipment in any maintenance shop and should, therefore, be employable also for tools which, for whatever reason, are not supplied with specific sharpening machines.

Any machine chosen should have the following attachments:

- Spindle with Morse tapers, including all the possible connections for cutters, bits, blades etc.
- Circular sharpening sets with hard metal facing (there are also automatic ones)
- Special plane cutter rests
- Bit-sharpening devices for rapid and continuous-path positioning (especially for punching machine bits)
- Helix-generating devices for any helicoidal sharpening operations
- Cutterhead supports for sharpening cutters thoroughly without having to remove them
- Special supports for sharpening "throw-away" cutters
- Motor-driven workheads and high-speed wheel spindles for sharpening tools for automatic lathes
- Interchangeable wheel centres
- Scales' supports for irregular indexing or for particular positioning
- Centre-locating system for detecting and setting the cutting angles

Circular saw sharpeners

Another type of tool is the circular saw sharpener with hard metal facing. This may be equipped with:

- Manual devices to be fitted on universal sharpening machines or other solid block cutterheads sharpening machines
- Automatic devices to be employed as above

[2]See Schlesinger: Testing standards for machine tools for machining metal and wood.

Sharpeners specially designed for these blades, entirely hand-operated or partly automated

Fully automated programmed cycle sharpeners (the same as used by blade manufacturers)

In this last class, operators are needed only for fitting and positioning the blade and for programming the relevant features through the various controls (angles, number, shape and sequence of the teeth, diameter and thickness of the blade, type of sharpening). Once the first tooth is positioned, the machine performs the whole cycle and stops when the operation is finished.

The sharpening cycle is generally performed using a cooling jet of liquid or by immersing the tool in the cooling liquid using a composite grinding wheel having two grits of different fineness stuck to one another, which, in a single run, removes the required amount of material and the finish. This cycle is as follows: the tooth that is to be sharpened is positioned by the pusher and locked by a vice; the grinding wheel approaches rapidly and increases its speed according to the amount of material that has to be removed, then slows down and performs the operations slowly; finally, the grinding wheel moves away and quickly returns to its resting position; the vice opens and the next tooth is put in position. If the teeth are alternatively slanted on either side, the wheel oscillates its position.

Sharpening time is very low with these machines (8-12 seconds per tooth) but, what is more important, the results are qualitatively better than those obtained with hand-operated machines. The use of this type of sharpening machine is justified and profitable and, therefore, recommended when 15-20 blades are to be sharpened each week. The greater initial investment required is more than offset by a higher economic yield owing to:

Lower manpower requirements in the operating cycle

Lower consumption of diamond wheels

Lower blade consumption since efficiency is increased through an improvement in the quality of sharpening, which ensures longer cutting-edge life

There are two further problems relating to hard metal maintenance of circular saws that are worth mentioning, namely: *(a)* the rake of the steel on the back of the cutters (in order to prevent interference and any damage caused to the diamond wheel by working the steel); and *(b)* the rewelding of the bits that come off the teeth.

Concerning the first problem, there are special machines that perform this operation automatically, while maintaining the required inclination of the cutters. These machines are also designed to control automatically the desired rake of the chip limiters that are fitted on multi-blade saws. Blade efficiency is impaired when the bits of hard-metal-faced blades detach or break. In such a case, they have to be returned to the manufacturer or sent to special workshops for repair.

As this problem is likely to arise frequently and since it can easily be overcome, it may be more profitable to establish an in-house repair shop, if the size of the company justifies it.

In this event, three additional operations must be performed besides sharpening: *(a)* removal of the damaged bit; *(b)* welding on a new bit; and *(c)* grinding its sides in order to obtain the same rake and thickness as the remaining bits on the blade. Suitable equipment for these operations is available on the market and includes both brazing machines, generally of the high-frequency type provided with a special rest for bit welding, and manual grinding machines for the sides of the teeth, equipped with one or, better still, two wheels (thus, both sides of the tooth can be ground at the same time with the same degree of accuracy). The latter are low-cost, easy-to-use pieces of equipment and are, therefore, specifically designed to meet the requirements of maintenance and repair shops.

Machines for sharpening cutters and bits

There are several different machine tools for sharpening plane cutters. These range from simple adjustable rests for other sharpeners or common lapping machines to hand-operated, semi-automatic and fully automatic sharpening machines that are specially designed for the purpose.

Automatic machines can sharpen the whole set of cutters (2, 3 or 4) of a shaft simultaneously, thus keeping them all equal. With these machines, the stroke (length of cutter) and the amount of material removed with each run and during the whole process can be adjusted, and the operation is stopped automatically when all tips have the required diameter. Other machines fitted with sharpening equipment, such as diamond wheels, hard metal-faced plane cutters, are becoming increasingly widespread.

Particular attention should be paid to the so-called "throw-away" cutters used on special cutterheads and made of tungsten-carbide bits. Although only very small sections of these metal carbides are used, the increasingly high cost of hard metal has led industrialists to reject the original idea of throwing away the cutters as soon as they wear out and to resharpen them. Their use, however, is limited to two or three times at most.

As mentioned above, special rests have been produced that can be fitted onto universal sharpening machines. This solution can only be adopted for occasional sharpening operations or for a limited number of cutters. Where considerable use is made of cutters, special semi-automatic sharpening machines are employed. While sharpening with a constant degree of accuracy, they perform this operation at very high speed (sometimes exceeding 100 cutters per hour).

Another interesting subject is that of cutter (or solid-block cutterhead) forming or shaping. As bevels of various shapes have been re-introduced recently, manufacturers have had to start producing profiled cutters. So-called "copying forming grinders" are available for this operation. With these machines, it is possible to reproduce the profile of a locating template on a cutter (or solid-block cutterhead), removing the material with the grinding wheel as the profile is copied through a tracer point. The wheel head can be moved in several directions to obtain the required rakes. It is thus possible not only to manufacture profiled cutters but also to reshape existing ones or grind solid-block cutterhead profiles.

The machines designed for bit sharpening are simply standard cutter sharpeners with considerably smaller dimensions. This is due to the limited size of the tools that they are designed to sharpen and not due to economic considerations.

Maintenance shop

The following should be borne in mind when drawing up a plan and making estimates for a maintenance shop.

First of all, the range of tools that will require sharpening should be defined as precisely as possible, and calculations about how often each tool will require maintenance should be made. Specific machines for the tools that are used more frequently should be chosen; complementary equipment for the other tools should be used.

Automatic versus manual machines

Automatic machines should be used when set-up time is limited as compared to the time required for actual sharpening and when the latter operation entails considerable repetition, because the care and concentration of the operator decrease rapidly when similar movements are repeated for long periods of time. For example, the face and back of a 60 hard-metal-faced tooth circular saw may need sharpening. If performed manually, this operation requires approximately 30 minutes of the operator's time, 6 of which are needed for positioning the blade and the first tooth. An automatic sharpening machine can effect the same operation in 25 minutes, only 5 of which are taken up by the operation. The advantage appears to be even greater if the blades to be sharpened are similar: with manual sharpening, the time required remains equal or increases or, worse still, the loss of the operator's concentration results in reduced accuracy. With an automatic sharpening machine, however, the operator's work time is even less, while the operation is performed with the same degree of accuracy. Thus, automatic sharpening machines are highly profitable when several blades have to be sharpened consecutively.

If a four-side planer moulder needs sharpening, both a manual machine and an automatic one require roughly 15 minutes for the operation, and more than 10 minutes are needed for positioning and aligning the first cutter. In this case, it is quite clear that there is no point in automating. In addition, there are not likely to be a large number of similar tools that have to be sharpened consecutively; thus, the use of an automatic machine is not justified.

In yet another case, 24 or 36 perforating bits may have to be sharpened while keeping them all equal. The time required for sharpening each bit is 5 minutes, virtually all of which is for positioning (less than one minute for actual sharpening). In this case a device is needed that, after placing the first bit, allows the other bits to be put in position in exactly the same way and within few seconds.

Whatever the size of the maintenance shop, even when it is fitted with a whole set of specific automatic machines, it should always be supplied with a medium-size manual sharpener provided with all the relevant attachments for sharpening the tools employed; thus, all possible requirements are met, and the manual sharpener can be used in case of a temporary breakdown of any of the automatic machines.

The use of simple sharpening machines is taken for granted. This may be due to the limited financial investment required as compared to their usefulness or to considerations of a technical nature (i.e. the inability to obtain other tools meeting current production requirements). Examples of the first case would be the automatic band-saw sharpening machine, the relative setter and the welding machine as well as the (automatic and semi-automatic) plane cutter-sharpening machine. Examples of the second case would be the automatic hard-metal circular-saw sharpener and the complementary machines designed to work such blades.

Work-bench

Another important element of the maintenance shop is the work-bench. It should be large and fully equipped with a vice and tools (wrenches, pliers etc.) as well as with the gauging instruments mentioned above. The shop should also be supplied with a double lapping machine and a small drill.

Conclusions

The role of maintenance and sharpening should never be underestimated. Maintenance and sharpening techniques should become disciplines entailing systematic knowledge and teaching; only thus will the performance of the tools be good. All too often the equipment is missing in maintenance shops. Even worse, owing to lack of information or to routine practice, hand sharpening is still being carried out in some maintenance departments with the consent of the technical staff in charge. It is better to secure the services of a sharpening centre.

XIX. Maintenance of wide band-saw blades in sawmills*

Introduction

Band-saw blades cut more effectively if they are subjected to suitable treatment before being fitted onto the relevant sawing machines. Special tools are absolutely necessary for blade maintenance. Any failure to take precautionary steps will result in serious production losses and unforeseen increases in costs. Blade maintenance is carried out in the same way for all types of band-saws. However, the maintenance of log-sawing blades entails more work and requires more time because the blade is wider.

A brief description of each particular process as well as a list of the auxiliary tools required for each operation is given in the present chapter. The various maintenance operations are set out in the order that seems to be most suitable; it need not be followed to the letter, however. Rather, each operation should be performed after inspecting the blade. The operations are:

Cleaning and inspecting defects
Eliminating cracks
Welding or brazing the blade
Checking the blade flatness (levelling)
Straightening the back of the blade
Tensioning
Swage setting or spring setting of the teeth
Sharpening the teeth

*By M. Paretti, expert in wide bandsaws. (Originally issued as ID/WG.369/9.)

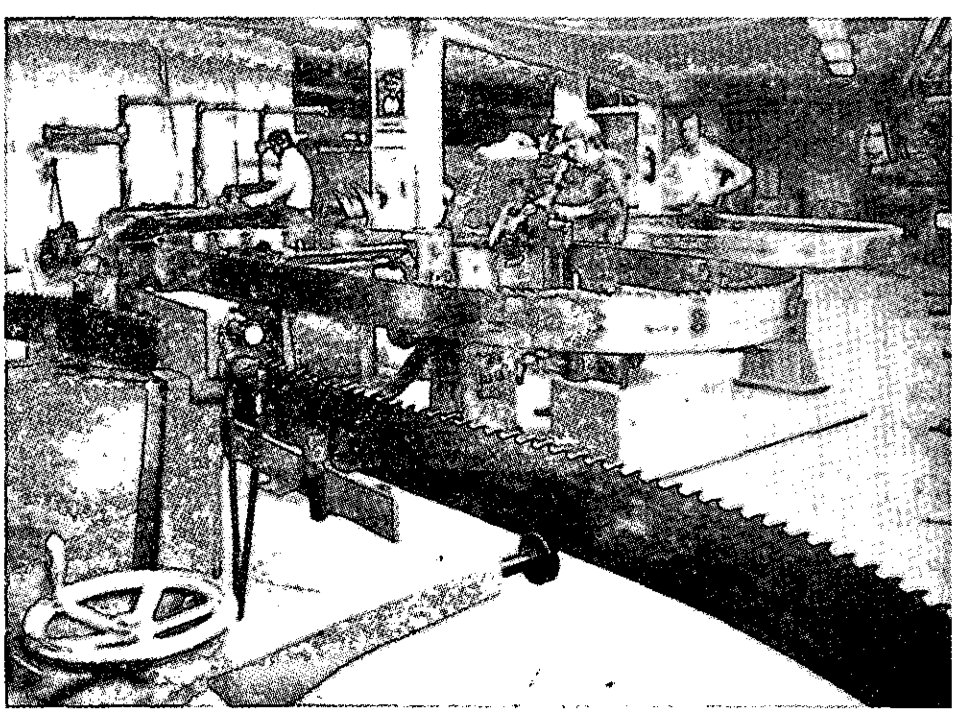
The work environment

All the maintenance operations should be performed in a large and well-lit workshop (see figure 1), with enough room for the machines and blade storage. Blades that are ready or are being serviced should be stored in such a way so as not to hinder the movements of personnel in charge of blade maintenance and prevent bodily harm to the personnel or damage to the blades. The shop should be provided with wooden flooring in order to prevent damage to blades during maintenance; the floor should always be clean and not slippery.

The following equipment should be included in the maintenance shop:

Straightening bench
Sharpening machine (two types)
Automatic swaging devices or equipment for manual swaging and setting
Brazing or welding machine with relevant tools
Hand-lever shears for cutting the blades

Figure 1. The work environment



Cleaning and inspection of defects

Cleaning and inspection of defects should be carried out on the same bench on which the blades are straightened out and tensioned. Sawdust deposits on the blade should be removed, if possible as soon as the blade is removed from the machine when the sawdust is still moist and can be removed easily. Alternatively, the blade can be smeared with an oil and a steel scraper is passed across its whole length, making sure, however, that no transversal scrape marks are produced on the blade, because this may eventually lead to the formation of cracks.

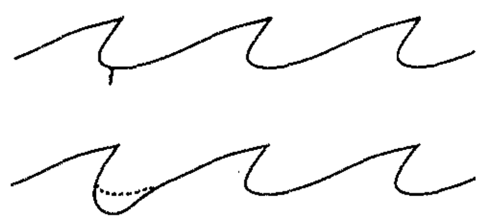
The tooth gullets should also be cleaned since any sawdust residues may set on the grinder during sharpening. A medium-hard brush is recommended for this operation.

Cracks

The saw doctor checks whether there are any cracks in the blade, preferably using a magnifying lens. If there are only a limited number of cracks and their depth does not exceed a few millimetres, they can be eliminated by filing, either by using a round file or by grinding the hollow of the tooth right down the whole length of the crack (figure 2).

In order to prevent isolated cracks from extending to depths exceeding 8 mm, a hole with a diameter of approximately 3 mm can be made at the end of the crack. However, if the cracks are numerous and deeper than 8 mm, the blade should be serrated anew. Longer isolated cracks can be eliminated through "stitching", as described in the section on crack welding, or through re-welding.

Figure 2. Bottom of tooth after the elimination of crack by means of filing



Brazing

Brazing with heated tools

The brazing of a blade requires a considerable amount of time and, above all, utmost care. If care is not taken, this operation will have to be repeated soon afterwards.

The brazing equipment consists of:

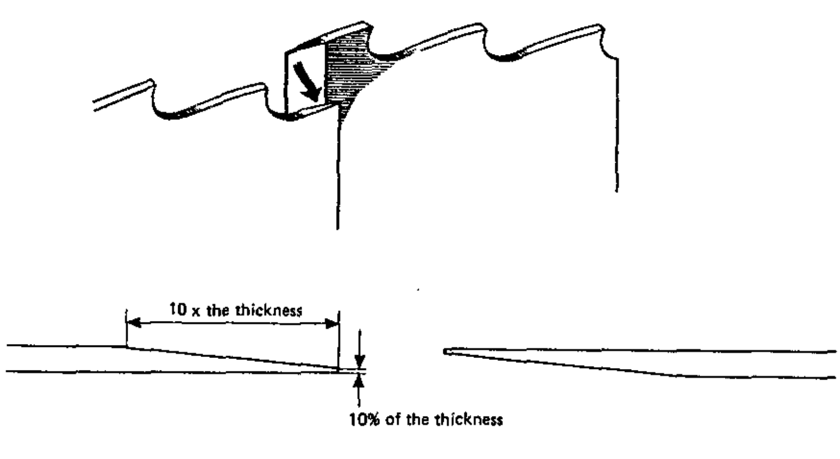
Tool-heating forge or furnace
Brazing clamp
Brazing tools (two units)
Deoxidizing solder
Chamferer or file-chamfering device
Scriber
Vernier gauge
Back square
Hand-lever shears
Forging hammer
Weld-filing rest
Various files
Micrometer

The blade should be marked off and cut exactly where it is to be soldered; in order to do this, the scriber, the square and the hand-lever shears should be used. The ends of the blade should be chamfered either with a suitable machine or manually with a file and the relevant device. This operation should not result in a sharp edge; the chamfered end should instead be left with a thickness roughly equal to one tenth of the original blade thickness (figure 3). The length of the chamfer must be 10 times the thickness.

Cleanliness is of great importance for obtaining satisfactory results. Personnel should not touch the chamfered ends with their fingers or with objects that may foul the surfaces.

The deoxidizer is needed in order to remove any oxide residues and to obtain a better distribution of the solder during brazing. The best deoxidizer is pure borax, finely powdered and dissolved in clean water to the consistency

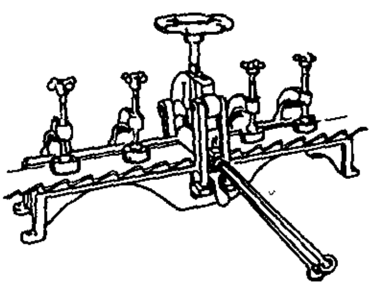
Figure 3. Chamfering



of a paste. The paste is spread on the blade chamfers by means of a small piece of wood. Deoxidizer-containing solders are now available on the market; alternatively, diluted hydrochloric acid or a distilled water-saturated zinc chloride solution can be employed.

The ends should be placed into the brazing clamp (figure 4), resting firmly against the grip, and they should be fixed in this position by means of the set-screws. A vernier gauge or another similar instrument should be used to check whether the pitch of the tooth near the weld is correctly positioned. The solder should be cut in such a way as to exceed the width of the blade by 5 mm on each side. Its width should, furthermore, exceed the overlap by 1 mm. A strip of solder should be cleaned with emery cloth and then covered with the deoxidizing paste. Once the strip is clean, it should not be touched with fingers but should be handled with tweezers or by holding it by the edges.

Figure 4. Brazing clamp with blocking device



The upper end should be lifted with a screwdriver or other similar tool and the solder strip should be introduced into the overlap slit, making sure it protrudes to the extent specified above. The tools should be heated to a suitable temperature for brazing, usually 900° C when the irons turn a pale cherry red, and should be placed on the spots to be welded, on top and under the blade. Before doing this, however, any red-hot shavings and scale that may be present on the tools should be removed. The welding device should be adjusted in such a way that the upper surface of the bottom tool is perfectly aligned with the top of the table (or bench) and, therefore, with the lower part of the blade. Sometimes it is difficult to spot the exact position in which the tool must be set immediately. In this case, the saw doctor should lift the overlap point slightly with a screwdriver, inserting it between the blade and the table and extracting it as soon as the desired position for the tool is found, and should quickly position the upper tool and tighten the screw located at the centre of the brazing clamp. The clamps that are nearest to the braze should be loosened immediately so as to enable the blade to stretch uniformly without being deformed by the heat. Unless this precaution is taken, the stress that develops in the blade may well deform the weld.

Heat-resistant steel tools are recommended, since scale is less likely to form on the surface of these tools during repeated heating processes; more welding operations can thus be effected before the levelled supporting surface is worn. The tools may be worn after four or five applications. On the other hand, flatness and evenness of the supporting surfaces of the tools is essential, because this is the only way to apply pressure uniformly over the whole surface of the braze.

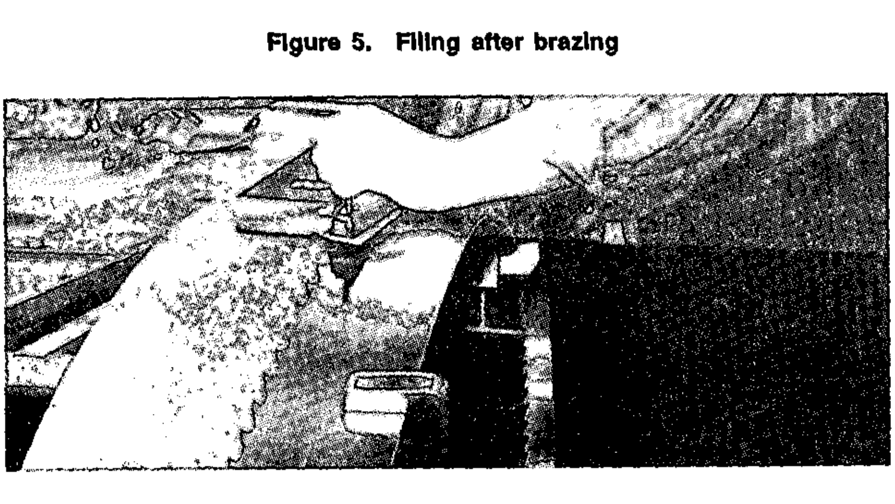
As soon as the tools have cooled off and recovered their original colour (black), the screw at the centre of the brazing device should be loosened and the blade removed. If these precautions are not taken, temper brittleness occurs in the brazed area, with ensuing fractures.

If the tools stick to the weld, they should be removed with a strong hammer blow, delivered in the direction of the braze in order to avoid the risk of reopening it. Any impurities that may be present on the braze should be removed with a cloth soaked in oil. If these instructions are followed, the braze obtained will not be too soft and will preserve the blade's mechanical characteristics.

Flat filing of brazes

Flat filing can be carried out suitably on the straightening bench (on which both sides of the blade can be filed), placing the blade on top or under the bench depending on which side requires filing. A good bearing surface for this operation may be supplied by a simple steel plate 35-50 cm long, 3-5 mm thick and only a few centimetres wider than the blade, which should be bent slightly so as not to strain the blade. The steel plate should be placed on the bench, and the blade should be fixed onto it by means of two clamps, as shown in figure 5. Scale and incrustations should be removed from the brazed section of the blade, and a file should then be used to remove the solder discharged by the chamfer and even out the thickness (roughing). The brazed section is passed through a rolling mill several times until it is flat all over, and this operation is complemented with light hammer blows.

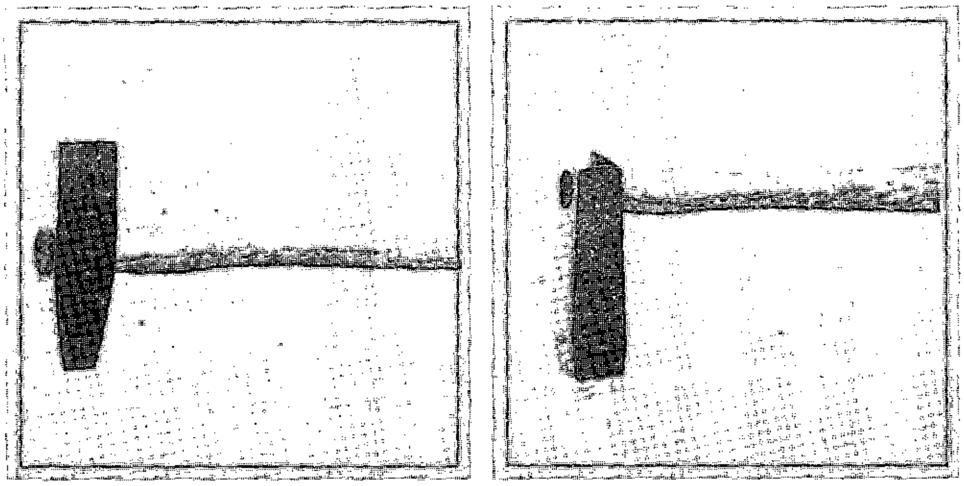
Figure 5. Filing after brazing



The use of the hammer (figure 6), however, should be restricted to a minimum. Hammers produce "imprints" that cause the blade to vibrate and may be dangerous insofar as they can lead to crack formation. Once the brazed section is filed, the saw doctor should make sure that its final thickness is virtually equal to that of the blade.

Should dark spots that are due to depressions appear in the relevant area during the final filing operation, the braze should be flattened with the rolling mill rather than with the file so as not to reduce the thickness of the relevant area too much. When flattening is completed, the welded section should be tensioned, making it even with the rest of the blade. Saw doctors who are not satisfied with the way the blade looks after brazing are well advised not to remove any visible solder residues from the blade. As long as the blade is equally thick along its whole length, these aesthetic blemishes are of no importance whatsoever for practical purposes. The tooth located at the height of the weld should not be flattened or set. This, however, does not mean that it should be hammered down or removed, as is often done without any good reason.

Figure 6. Hammers



Electric brazing

Brazing by means of an electric brazing machine is more desirable than conventional brazing, because it does not require the use of brazing tools that are hard to handle. It can be employed only for blades that are limited in width, however.

The dressing of the blade is done in the same way as in the conventional brazing process. The ends of the blade should be chamfered, then fixed with the clamps of the brazing machine; the deoxidizer and the solder are applied in the same way described for conventional brazing. The current should be connected in compliance with the manufacturer's instruction, and both the welding and the tempering operations should be carried out in accordance with the width of the blade. The finish is effected in the same way as in brazing with heated tools.

Welding

The progress made in welding techniques is leading to the elimination of brazing of band-saw blades. The methods now adopted instead of brazing are flash welding, which is considered better for blades that are not very wide, and metal inert gas (MIG) and tungsten inert gas (TIG) welding for wide ones. With the latter methods, it is also possible to "stitch" cracks.

Flash butt welding (figure 7)

The ends of the blade should be cut and cleaned and fixed in the welding machine clamp. The welding current, the heading pressure and run and the distance between the vice heads should be adjusted following the instructions supplied by the manufacturer of the machine. When the ends come into contact with each other, the welding current runs through them, causing the surfaces that are to be welded to melt. At this stage, the heading pressure comes into play. The ends melt and cool off under pressure.

In order to reduce hardness and eliminate stress, the weld is subsequently tempered through the heat of the resistance while in the clamp of the machine. The band-saw's temperature drops from the welding temperature to the tempering one (550° to 650° C) within one to two minutes.

After welding and tempering, the weld should be carefully filed or ground on both its sides. The saw doctor should grind the gullet and the back of the tooth thoroughly and check the blade for flatness in the welded area.

TIG and MIG welding

The TIG and MIG methods are the most suitable for welding wide-band-saw blades. This process consists of electric arc-welding performed in a neutral argon gas atmosphere in order to prevent the oxidation of the melted metal.

In the TIG method, the welding wire is inserted into the arc separately, while in the MIG method (see figure 8) the welding wire also acts as an electrode and is, therefore, a conductor for the arc.

Figure 7. Flash butt welding

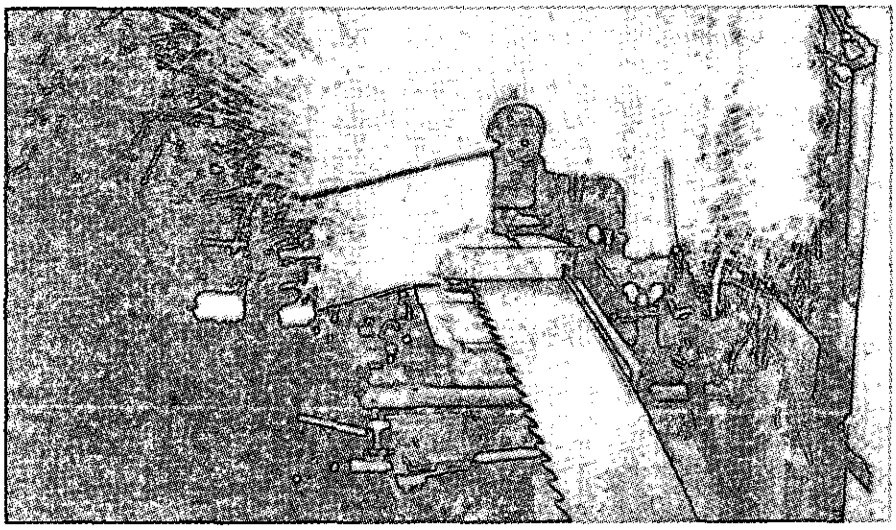
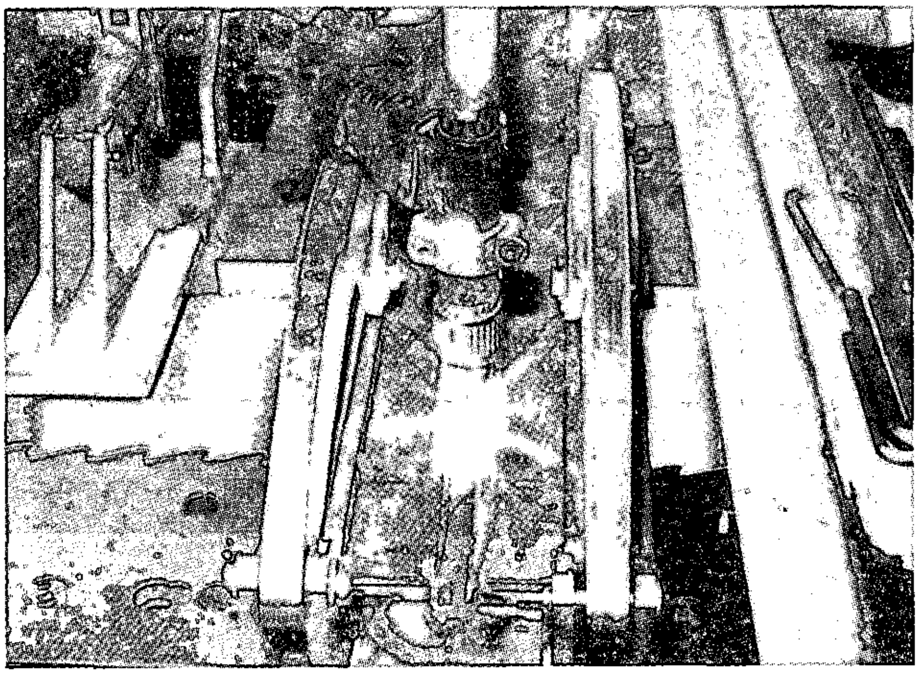


Figure 8. Welding (MIG method)



The MIG method is more widespread and, when combined with devices designed to automate all the welding operations (pre-heating, welding and tempering), it can produce highly reliable seams and "stitching" of cracks. The results are just as good when automatic devices are not employed, but in this case the operation must be performed by skilled personnel.

In the MIG type of welding, ends that are to be joined are cut halfway across the back of the tooth; the blade ends should be cut at right angles and carefully deburred and degreased with trichloroethylene, acetone or alcohol.

The two ends should be carefully set side by side so that the back of the blade is perfectly straight. They are then secured to the welding plane by means of clamps. The teeth should be set facing the operator, and the blade should be laid flat on the bench.

Two small steel off-cuts are placed at the beginning and at the end of the weld (they should be of the same composition as the blade), in order to prevent the formation of blow holes in these areas during welding.

In order to reduce internal stress during welding, the relevant area should be pre-heated at approximately 400° C. In some welding machines, this is done by an electric resistor element placed inside the welding plane; in others, a gas flame is used, and the temperature is checked with special chalks. Where automatic machines are employed, the pre-heating treatment is carried out by resistances and the temperature is checked by a thermostat. The pre-heating process should be performed right before welding and should be carried on through the whole welding operation.

A die-temper steel welding wire should be used and, where the welding operation is carried out manually or with a special control tool, a weld bead should be made that is limited in size and as homogeneous as possible. Any difficulties that may arise owing to the operator's lack of experience can easily be overcome by following the advice of an experienced welder. No such problems arise, however, when automatic welding machines are employed. The distance between the torch and the blade is measured, making sure it complies with the manufacturer's instruction. The operator must determine the desired quantity of gas, adjust the speed of the wire and the intensity of current required by setting the control knobs at the relevant values established by the manufacturer for weld thickness and then press the start push-button. The welding machine operates automatically, and perfect welds are obtained within seconds.

When the cycle is completed, the welding machine is stopped by pressing another push-button. Tempering can be done with a gas flame; it is moved back and forth along the weld bead until the latter as well as the adjacent area turn dark red (roughly 650° C).

Where an automatic welding machine is used, the operator must set the timer at the tempering time indicated by the manufacturer according to blade thickness and then wait until the timer has stopped. After tempering the weld, it is filed or ground, depending on the conditions mentioned in the section on brazing.

Welding of cracks

The process used for welding cracks in the blade is similar to the one used for joining the two ends of a blade. Where the cracks do not run perpendicular to the blade, automatic welding machines should be operated manually rather than automatically, by removing the arc from its support.

Levelling

Levelling equipment includes:

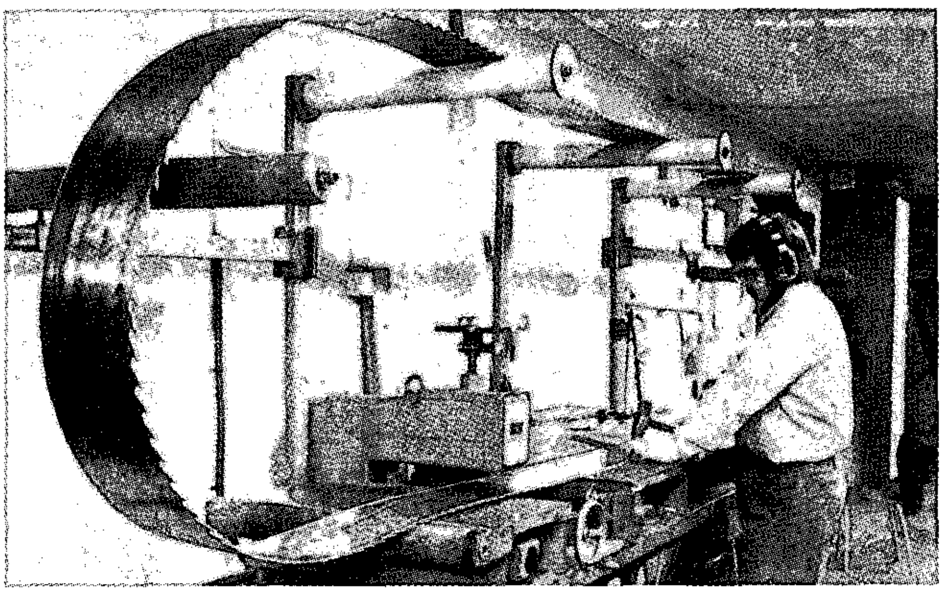
Straightening bench, provided with rests, and a slightly convex anvil of 40 kg

Tensioner equipped with a levelling device and an apparatus for eliminating helicoidal blade deformations (figure 9)

Level check ruler

Cross-face hammer

Figure 9. Tensioner equipped with a levelling device and an apparatus for eliminating helicoidal blade deformations



The blade should be placed on the bench with its back facing the operator and should be suspended so as to slide easily on the work-table. Moreover, it should be perfectly flat when resting on the bench. This operation should be executed in a well-lit part of the room, the light source being placed to the right of the operator (unless the operator is left-handed) and slanting. When the control square is slightly bent forward and kept standing relative to the blade, all the control lights are screened. Thus, any uneven spot on the blade is clearly visible.

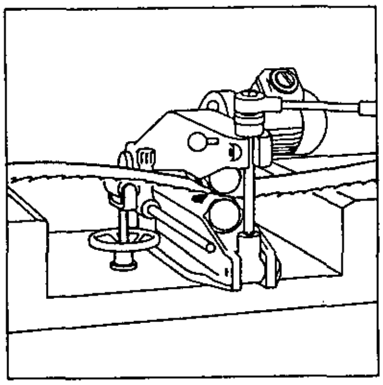
The square is passed across the whole length of the blade while it is laid flat on the bench, and the exact position of all the buckles is marked with chalk. A blade may be considered flat if it is level on both its sides when resting on the work-table.

If the deformations are rather regular and continuous along the blade, they can be flattened with a tensioner. The convex end of the blade is turned upwards and the blade is passed through the tension rollers. Only limited locking pressure should be applied on the rollers (the blade should be pulled only), and a special roller should be placed at a given height, depending on the extent of the defects to be eliminated.

The special roller (figure 10) consists of a 300-400 mm long revolving roller having a diameter of 20-30 mm placed after the tensioner, the function of which is to bend the blade upwards. One or more such cycles are enough to make the blade level.

If the deformations are irregular and include both upward convex sections and downward concave sections, the blade should still be levelled with the tensioner, following the operation described for each single deformed section. A hammer should be used only in very special cases. In these cases, the saw doctor should start hammering at the sides of the deformed area, moving gradually towards the centre. As the process goes on, the results obtained should be checked with the ruler until the required flatness is achieved.

Figure 10. Revolving roller



Sometimes the blade appears corrugated when placed on the work-table. If the saw doctor tries to compress the bulge, another one forms immediately in an adjacent area. When a blade is in this condition, it cannot be repaired through flattening, because the defect is due to the excessive elongation of the middle section of the blade. The defect can only be eliminated by "stretching" the edges of the blade (this process is described below). Only after this operation has been carried out can any residual bulges be levelled out.

Sometimes blades appear to be too flexible in some of the sections: they sag in the middle when the edges are lifted or compressed. This occurs when the central section is too "short", and the only way to eliminate the defect is to stretch the middle section with the tensioner and then level out any deformations still present in the blade.

Straightening

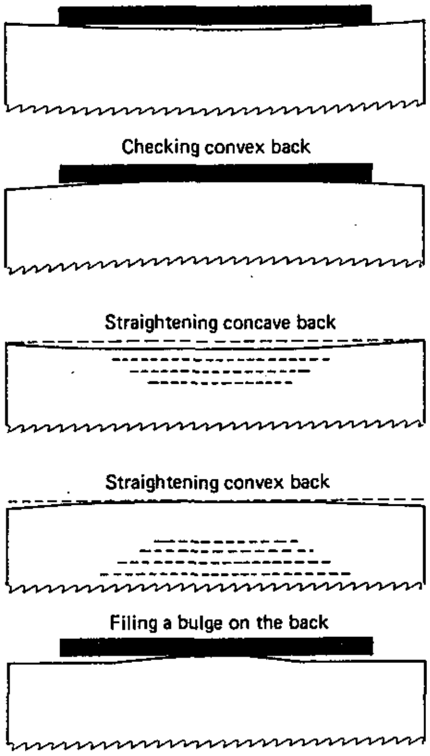
The equipment required for straightening is similar to that needed for flattening but a 1.5-m long ruler, ground at the sides, with a 60 × 3 mm or 60 × 4 mm square section, is needed. The blade is placed on the bench with its back facing the operator, who inspects the whole length of the blade. The best method is to place the control ruler on the back of the blade and inspect it through successive shifts, the extent of each shift being half the length of the ruler.

A piece of chalk is used to mark those spots where the ruler does not adhere to the back of the blade. The blade is straightened out when its back is perfectly rectilinear (figure 11).

When the back of the blade is uniformly concave or convex, or rather long sections of it are deformed, it should be straightened out with a tensioner. At least three runs are made with the tensioner, each on 1/3 of the width of the blade close to the back if it is concave or near the teeth if it is convex. This operation should not be carried out in areas close to the edges of the blade, but at a distance of at least 10 mm.

While the blade is being straightened out through tensioning, the saw doctor should control the operation with utmost care and constantly check the results obtained. There is no point in applying too much pressure on the rollers, because this may simply lead to a similar deformation in the opposite direction. After straightening a blade that has already been tensioned, it should be checked to ascertain whether its convexity has been reduced, as this occurs quite frequently; if so, its original convexity should be restored. (See the following section.)

Figure 11. Straightening procedures



If the deformed sections are short, they should be straightened as described above, operating with the tensioner on each single deformed section. If the back is concave, the tensioner should be applied in this area; if the back is convex, this operation should be performed along the toothed edge.

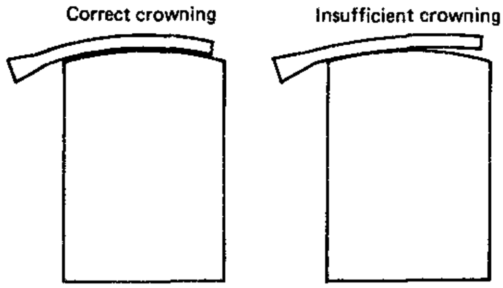
Here, too, after straightening a blade that has already been tensioned, the saw doctor should check whether any changes in tensioning (convexity) have taken place and, if necessary, restore the blade's original shape.

In addition to straightening the back of the blade, the saw doctor should check whether the welded saw band is deformed. Spiral deformations are quite frequent and are due to accidental "seizure" or deflection of the blade during cutting. In order to check spiral deformation, the blade is suspended from a support and its lateral deviation is measured. Spiral deformations are eliminated on the straightening bench. Diagonal hammering is still carried out, but there is another method that is certainly more practical and causes less damage to the blades. It consists of a special tool fitted on the tensioner before the rollers. The tool is designed to lift the blade by the sides, applying considerable force. In this case, the tensioner's only function is to pull the blade.

Crowning (tensioning)

The supporting surface of the fly-wheels is convex. Hence, the blade must also be convex if it is to adhere to the fly-wheels in its whole width (figure 12).

Figure 12. Crowning



When there is too much or too little crowning, the blade slides sideways over the fly-wheels, and this results in imperfect sawing. Moreover, deep cracks may be produced causing blade damage that cannot be repaired. Crowning requires much care and patience on the part of the tool-maker, as well as good vocational training. Crowning equipment includes a work-bench, a tensioner, a control ruler (the same as the one used for levelling) and a round (tensioning) hammer.

In this operation, the blade is stretched through several tensioning cycles, the extent of the stretch being diminished as the worker moves from the middle toward the edges. Before starting the operation it is important to make sure that the blade has been suitably flattened and straightened. The areas where the tensioner must pass (from 3 to 9 depending on the width of the blade) should be marked with chalk. The tensioner should be used, starting from the weld and finishing at the same spot where the cycle was started. This process should not involve the welded area, which is to be machined at a later stage. Too much pressure should not be applied; light runs are preferable. The middle section should be tensioned first, progressing then toward the edges. The pressure should drop regularly with each pair of runs and should be equal for each run of the same pair. The last runs should be carried out at a distance of at least 10 mm from the edges.

Should further crowning be required after the regular tensioning runs, the whole operation should be repeated on the other side of the blade, reducing the pressure by half and interposing the new runs with the previous ones. In order to increase the convexity of the blade, the saw doctor should go over the middle section a few times and perform the same operation near the edges if blade convexity needs to be reduced. Crowning is checked by means of a ruler. It is placed across the width of the blade, and proper crowning is achieved when, upon bending a section of the blade, the light reflected by its surface appears to be fading as it extends from the middle of the blade to the edges. The opposite effect should be achieved when bending the blade the other way and inspecting it from the outer side of the recess thus formed. The crowning operation has been performed evenly if the blade is perfectly flat on the work-bench (figure 13). No exact value can be given for crowning. The operator, however, will be able to establish through experience the right value for a given machine.

Figure 13. Checking evenness of the crowning operation

The average values of the beam of light as a function of the blade width are:

Blade width (mm)	*Beam of light (mm) (camber at the centre of the arc)*
80	0.2
100	0.3
150	0.6
200	0.9
260	1.3
310	1.6

It is also possible to suggest the rough number of tensioning runs as a function of blade width:

3 runs for blades 60-80 mm wide
5 runs for blades 100-130 mm wide
7 runs for blades 140-205 mm wide
9 runs for blades 230-310 mm wide

It is important to check blade crowning frequently and restore it to the blade's original condition whenever needed. Intensive crowning should not have to be done as heavy runs will damage and deform the blade. Frequent crowning ensures that the blade is always in perfect condition.

Hot crowning (hot tensioning)

Hot crowning is an alemative method to roll crowning. The edges are heated rapidly (300-400° C) by means of a welding flame; the ensuing compressive stress causes the edges to contract, hence the crowning. The hot-crowning process can be repeated many times without damaging the steel, as long as the tempering temperature is not exceeded. The average speed of the run should be roughly 1 m/min. This crowning process is not recommended for maintenance shops that have no previous experience in the field.

Spring setting and swage setting

The main goal of the setting or heading process is to reduce the lateral friction of the blade against the cut material and help the blade to penetrate into the cut. The value of both of these processes is closely related to the quality and degree of dryness of the wood that is to be cut. Generally speaking, this value is greater for soft (fibrous or fresh) wood and less for hard (or compact, seasoned or frozen) wood.

As to the choice between the two methods, practical experience indicates that a greater amount of material can be processed through swage than through spring setting. Thus, where both high quality and volume are required, it is better to use blades with swage-set teeth only. This process requires skilled blade-setting operators, however.

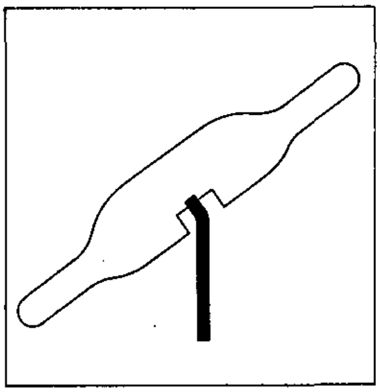
Spring setting

This method should be adopted only when the blades are used to process dirty lumber, which often contains foreign matter. The setting process requires the use of a hand or a mechanical setting device. If operating with a hand setting device, a 1.5-m long special vice is employed to clamp the blade that requires setting at various points. This type of vice is also needed where swaging is done by a manually operated machine. This process will be discussed in the next section.

The teeth should be bent before sharpening. The bend should be made as near the top third of each tooth as possible, not at the root. Usually, the teeth have to be set in turn to the right and to the left. If the blade is used to cut soft wood, one tooth can be left erect to every four set ones in order to obtain a straighter cut.

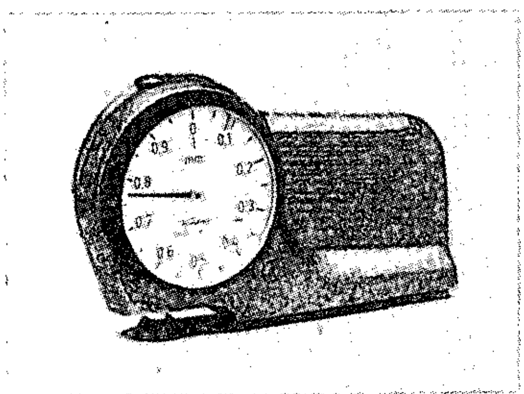
When using a hand setting device such as the one shown in figure 14 to bend the teeth, the operator should make sure that the width of the slot is accurate relative to the thickness of the tooth and that the gripping edge is suitable for obtaining the required setting value. On the other hand, if operating with a mechanical setter, the operator must make sure that the small hammers are adjusted properly so that only the top third of the teeth are bent and check whether the bend is equal on both sides.

Figure 14. Shovel used for bending teeth



Tooth setting is checked by measuring the value of the set through a ten-centesimal micrometer such as the one shown in figure 15.

Figure 15. Ten-centesimal micrometer



Swage setting

The main advantages of swage setting are better cutting quality and harder tooth tops, which mean longer life for the cutting edge. The equipment required includes a hand-operated swaging machine, a vice and blade-supporting stands (or an automatic swaging machine, which does not require a vice), a lateral tooth equalizer (hand-operated) or a grinding machine to even out the sides of the teeth and a micrometer.

Figure 16. Manual swager

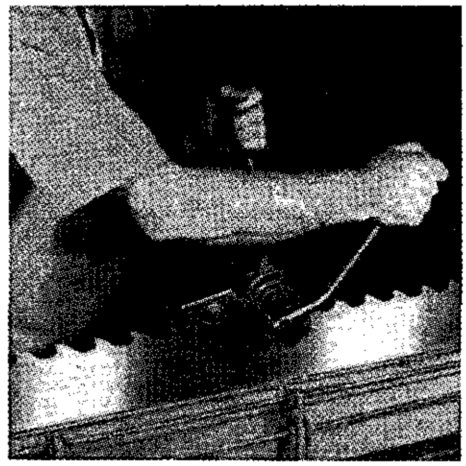
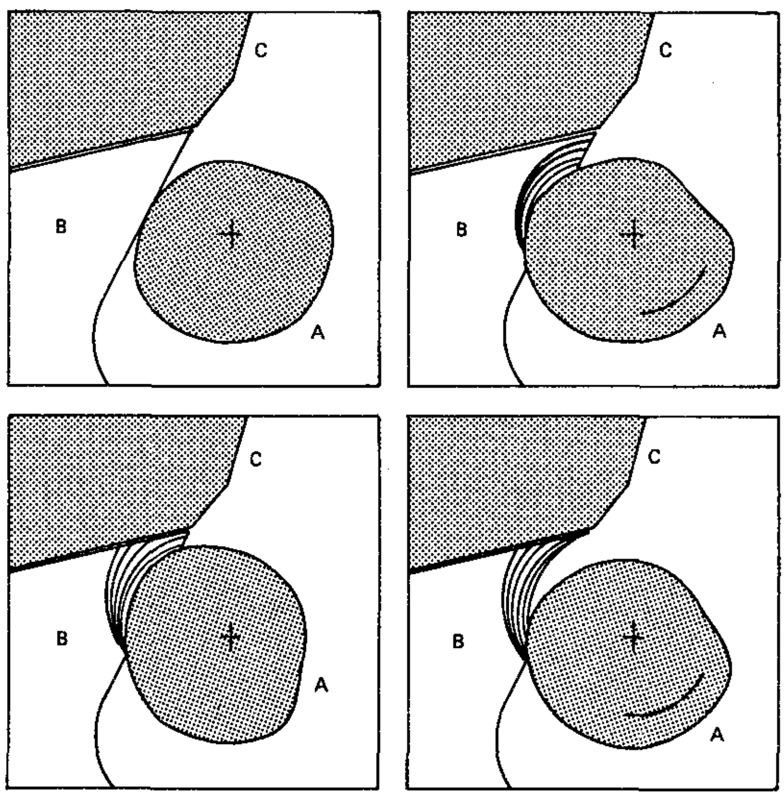


Figure 17. Swaging process



Before carrying out this operation, the blade and the profiles of the teeth should be cleaned carefully by superficial sharpening. The tops that require heading should then be lubricated with a piece of chalk soaked in oil or with a wax pencil marker (the type used to write on wooden boards).

If the process is carried out with a manual swager, the blade should be placed onto the stands (usually the same that are employed with the sharpening machine) and introduced into the vice (the latter should be rather long and included in the stand-sharpener unit) (see figure 16).

The swaging process is illustrated clearly in figure 17. As the cam of the swaging machine rotates through 120°, it compresses frontally as shown in figure 18.

The swager should be introduced into a tooth and suitably adjusted (for the first time) according to the shape of the tooth. In particular, anvil C, which is placed opposite the cam, should be adjusted on the back of the tooth; it should adhere perfectly to the back surface of the tooth (figure 19). In case it does not, the results obtained will be less than perfect (figure 20). After the adjustment, some tests are performed by swaging a few teeth. Depending on the degree of swaging desired, each tooth can be slightly flattened with one or two blows.

The swaging may be short or long, as shown in figure 21.

The advantage of long swagings is that the teeth can be sharpened a greater number of times, while short ones offer less side friction during cutting. The former operation requires a cam with a larger diameter. Swaging machines must be adjusted in the same way; once they are preset, these machines operate automatically (see figure 22).

Figure 18. Frontal compression

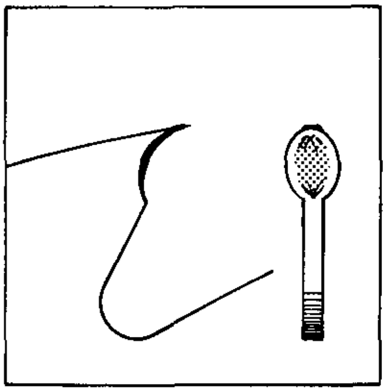


Figure 19. Correct placement of anvil and tooth

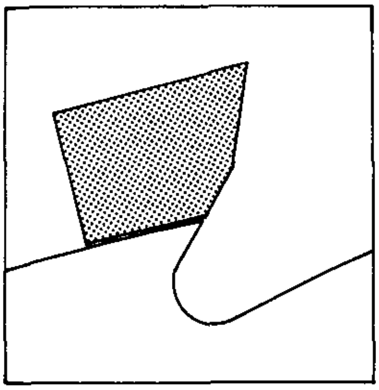


Figure 20. Incorrectly placed anvils

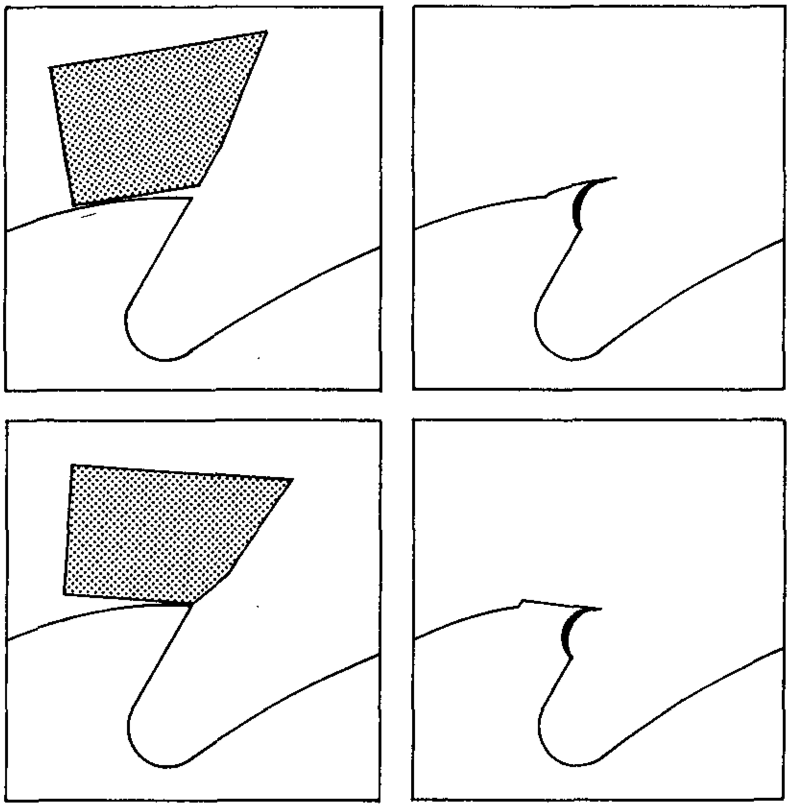


Figure 21. Narrow and wide swaging

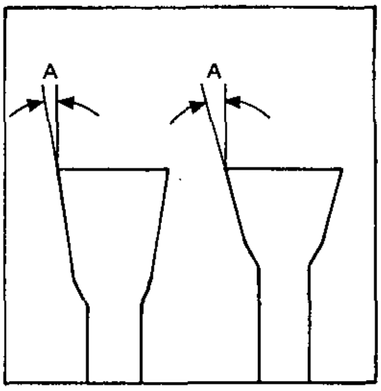
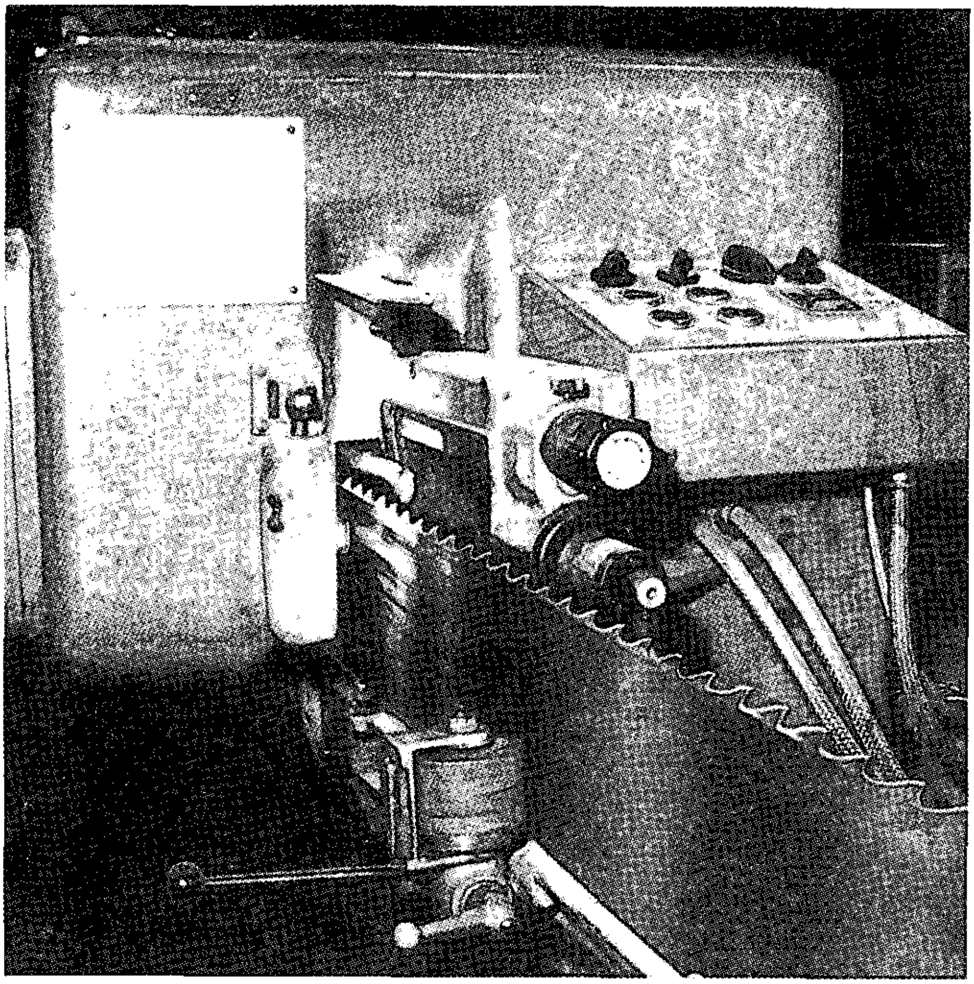


Figure 22. Swaging machine



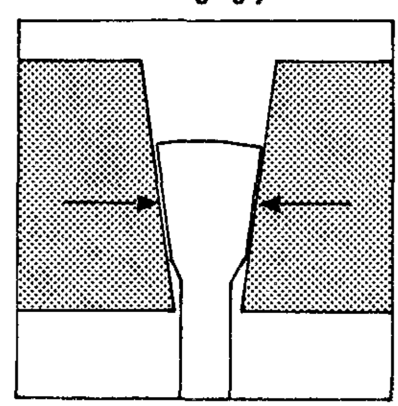
After the swaging operation, the sides of the teeth should be evened out. This can be done with a manual equalizer or with an automatic grinding machine. In the former case, the stands and the vice employed for the manual swaging operation are used. In order to adjust the equalizer, it should be placed on top of a tooth. The bevel edge of the swaging jaws is adjusted depending on the desired type of swaging (long or short). (See figure 23.)

The stroke of the lever should be adjusted so as to obtain the right thickness of the top third of the tooth. A few tests should be made on some of the teeth and to make sure that the shape is symmetrical and the thickness is correct. These checks can be performed with a *micrometer (figure 24).*

If the operation is carried out with an automatic grinding machine, it should be connected in parallel with the sharpening machine in order to be able to use the same blade-supporting stands. Sometimes it is possible to connect the grinding machine to the sharpener by means of a universal joint and to synchronize the two operations so as to perform them simultaneously.

The inclination or the position of the grinders should be adjusted according to the desired type of swaging (short or long), and the symmetry and thickness should be checked in the same way as for the hand-operated equalizing tool.

Figure 23. Adjustment of the bevel edge of swaging jaws



Irregular swaging may result if:

The cam of the swaging machine is worn

The anvil of the swaging machine is worn asymmetrically

Some teeth are damaged and have not been repaired completely by the pre-swaging sharpening operation

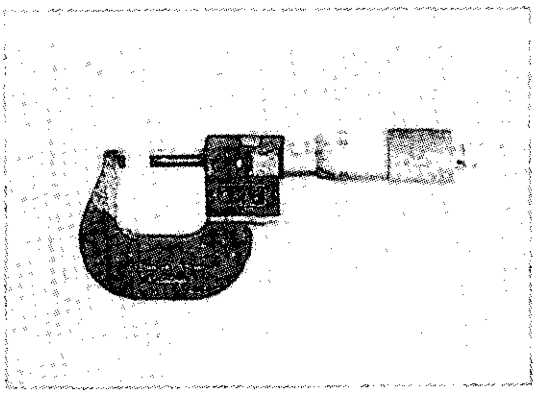
The grinder used for the pre-swaging sharpening operation was not well trued-up with the thickness of the blade

There are marks left by a previous swaging operation

At the end of the operation, the standard swaging values should be the following:

For blades designed to cut very soft wood (e.g. poplar): 0.5-0.7 mm each side
For blades designed to cut soft wood (e.g. Norway spruce): 0.4-0.6 mm each side
For blades designed to cut hardwood (e.g. oak or frozen wood): 0.3-0.45 mm each side

Figure 24. Micrometer

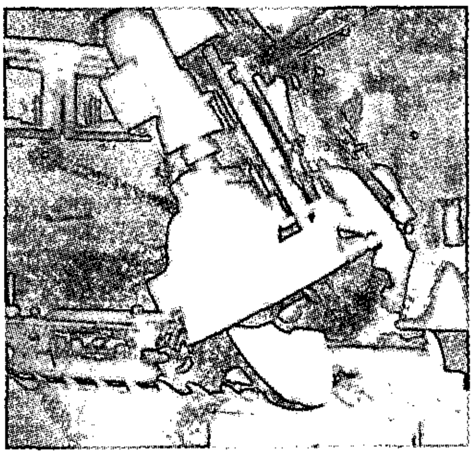


The sharpening operation (the first time only) should be carried out without grinding the front of the tooth. The reason for this is that the cutting edge, hardened through the flattening process, can be utilized fully. However, after two or three regrinding operations, the face of the tooth should also be sharpened.

Sharpening

The only tool required for sharpening is a good sharpening machine (figure 25). The state of the machine is of paramount importance. In particular, the operator should make sure that the grinding wheel bearings, the gears and the guide raising and lowering the grinding wheel are not slack.

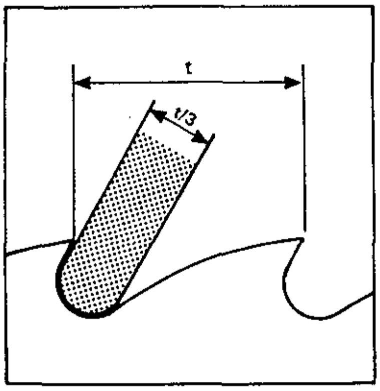
Figure 25. Sharpening machine



A good exhaust fan can prove very effective in limiting the damage produced by the grinding powder. It is best to employ sharpeners that are suitable for sharpening tooth profiles of various shapes and sizes.

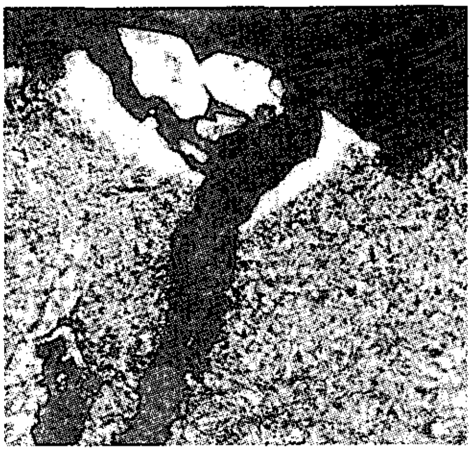
The right grinding wheel must be used. It should sharpen without burning and, therefore, should not be too hard; 60 M5 or similar types are the most suitable. The thickness of the wheel should be roughly one third of the pitch of the tooth, as shown in figure 26.

Figure 26. Correct grinding wheel size



It is worth noting that a great number of the cracks produced during machining occur in burnt areas owing to the use of unsuitable grinding wheels. Although they are not visible to the naked eye, these burns lead to the decarbonization of the steel and to the formation of many micro-cracks (figure 27). Burning often results in shorter cutting edge life.

Figure 27. Micro-crack



The grinding wheel should be dressed frequently in order to restore the cutting edges and remove any resin deposits that may damage them. While restoring the wheel, the roundness and the profile of the cutting edge should also be checked.

The sharpener should be set very carefully. Gear adjustment should be done in accordance with the exact reproduction of the tooth profile. The operator should make sure that the axis of the grinding wheel is trued up with the thickness of the blade (see figure 28), the feed pawl is shaped suitably (figure 29) and the wheel is perpendicular to the blade.

Sharpening is performed automatically. However, the operator should make sure that the runs are light enough so as not to burn the cutting edge and the tooth fillet. Should the pitch of the teeth not be equal throughout the blade, the pitch should be made uniform by means of a double pawl. The double pawl should be used, furthermore, with machines with gears that are subject to backlash.

Figure 28. Positioning the grinding wheel

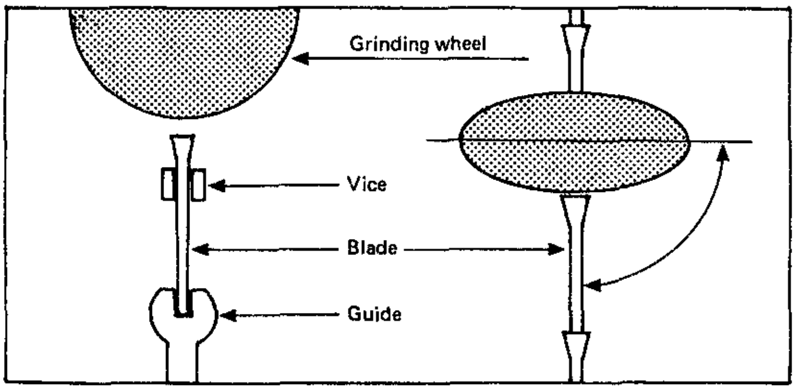
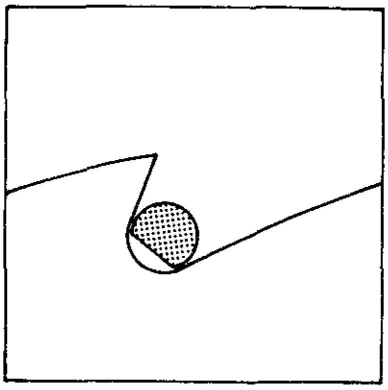


Figure 29. Profile of feed pawl



When new blades are sharpened, the burrs that are produced from punching out the teeth must be removed from the whole profile of the tooth in order to prevent crack formation.

Finally, blades should be sharpened as soon as it appears to be necessary. They should never be kept in operation on the band-saw too long, because this may cause serious damage as well as a negative effect on both the quality and the quantity of the sawn lumber and on power consumption.

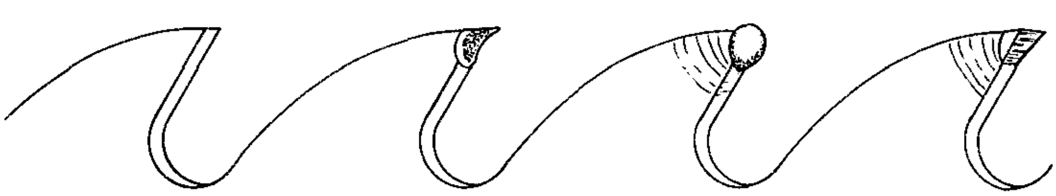
Stellite

Certain wood species cause severe wear, e.g. makoré, sipo, teak etc. These have mineral particles (generally siliceous ones) that tend to concentrate in the heartwood. Often the blade breaks down after a single cut and must be replaced. This results in loss of time and, therefore, of production. Therefore, special blades have recently been devised for cutting such wood. The tops of the teeth of these blades are hardened with stellite, a non-ferrous alloy containing chrome and cobalt.

Stellite is available in various degrees of hardness. Hardness number 12 is the most suitable for band-saw blades. Stellite is supplied and utilized in the form of a rod with a diameter of 2.5-3.2 mm. Thus, any drops obtained are large enough to cover the whole top of a tooth. The stellite coating process is performed as follows: the teeth are compressed and a drop of stellite is welded in the resulting niche, thus filling it up to the top of the tooth (see figure 30). As stellite is applied, the underlying steel hardens, hence the tops must be subsequently flame-tempered up to roughly 450° C. In order to make this operation easier, the blade is suspended vertically so that the tops of the teeth are turned upwards and point in the direction of the welds (see figure 31). Moreover, the blade should be able to slide smoothly up and down (it is best to suspend the blade from rollers).

Figure 30. Stellite coating

A. Chipped tooth *B. Chip filled with stellite*



Subsequently, the teeth are finished by grinding the sides with an automatic grinding machine. The teeth are then sharpened in the usual way with a standard grinding wheel.

Another process that may eliminate the swaging operation is currently being developed. The idea underlying this new process is to automate the operation, doing away with the manual operation, which requires highly skilled labour and entails a considerable loss of time.

The costs required for stellite hard facing are very low considering that the blade will last much longer and that each stellited tooth can be reground approximately

Figure 31. Blade held in such a way that teeth are pointing upward in the direction of the welding

10 times. Blades with a thickness less than 1.1 mm should not be stellited.

The blade should be replaced three to four times a day, in spite of the considerable cutting life of stellited blades. This may be useful in order to limit the frequency of certain operations, such as tensioning and straightening.

Most important of all, only high-grade blades can be stellited. A common steel blade, in fact, buckles too easily and is likely to crack. Stellite is applied by means of a standard oxy-acetylene welding device, with a blowpipe having a capacity of 100 litres/hour and a nozzle 0.9 mm in diameter.

The gas should be kept at very low pressure and the oxygen-acetylene mixture should be controlled so that the length of the flame is roughly three times greater than the length of the internal white flame. The white flame should reach the edges of the teeth just under the back of the recess formed through compression. At the same time, the end of the stellite rod should be directed towards the centre and slightly above the bottoms of the recess (figure 32).

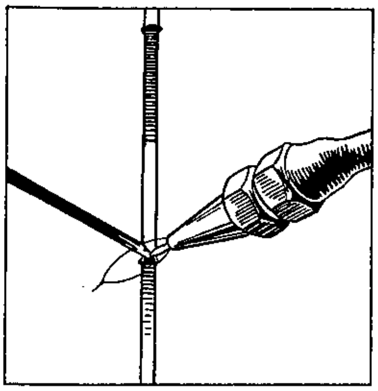
Thus heated, the wire protects the top of the tooth and prevents burning. When the tooth turns light red, the tip of the flame should be directed against the stellite wire and should be kept in this position until a drop falls into the notch. The flame should be removed gradually in order to avoid sudden cooling.

Two operations are of the utmost importance:

(a) Heating the steel of the tooth until it reaches the required temperature;

(b) Forming a suitably large stellite drop.

Figure 32. Positioning the stellite rod



If the temperature of the steel is too low, the stellite clots in the hollow top of the tooth instead of expanding. If the temperature is too high, the steel melts, ruining the top completely. Moreover, the steel and the stellite form an alloy which impairs the basic characteristics of stellite itself.

Exceedingly large stellite drops result in an unnecessary waste of stellite and in increased grinding time. On the other hand, if the drops are too small, they are not able to cover the whole surface of the top of the tooth.

The operation described above is more similar to brazing than to welding. All the various stages must be executed in rapid succession in order to prevent the oxidization of the steel surface. Any worker with some welding experience can gain, within very few hours, the practical knowledge needed in order to master the stelliting technique. The worker should acquire this knowledge by practising with unserviceable blades.

XX. Waste and dust extraction systems*

Introduction

In the modern woodworking industry, particular attention is being paid to the problem of dust and waste extraction. Sawing, planing, turning, sanding machines etc. produce waste of various kinds such as chips, shavings and dust. These wastes must be removed both from the machine and from the work environment and should later be recovered for industrial or energy purposes. Today, priority is no longer given to the machine, which nevertheless should be kept clean in order to ensure smooth operation and prevent damage, but to people and to the ways in which they may be enabled to work in an environment that is as clean and as healthy as possible. In order to achieve this goal, the waste must be extracted, conveyed through a duct system and deposited in a suitable place.

Suction plant

A waste or extraction system is, basically, composed of three components (see figure 1):

A fan
Pipelines ducts
A material collection bin (silo)

The fan is the core of any waste extraction plant. It is a rotary blade machine that continuously supplies energy to the air passing through it. The action of the fan is twofold:

(a) It sucks both air and waste through a duct network connected to the woodworking machines;

(b) It blows the mixture (air and waste) towards the point of collection through a duct (figure 2).

The schematic outlines shown in figures 1 and 2 are only the starting point for examining the type of waste extraction plant that should actually be adopted. The correct choice must be based on the size of the factory in which the plant is to be installed and on the number and type of woodworking machines. Thus, if the size of the factory is rather small and the equipment is simple, unautomated and without on-line machining requirements, small standard units (either fixed or mounted on casters) can be installed, possibly connected to each of the machines operating in accordance with specific requirements. Normally, this occurs when the machines installed exceed the number of workers employed for processing and the operation is not synchronized. Standard units, which include the fan and the filter, come packed in assembly cases. They are connected to the relevant machines by means of flexible plastic pipes (see figures 3 and 4).

*By G. Anselmi, engineer, Balducci, Bresso, Milan, Italy. (Originally issued as ID/WG.369/12.)

Figure 1. Suction plant

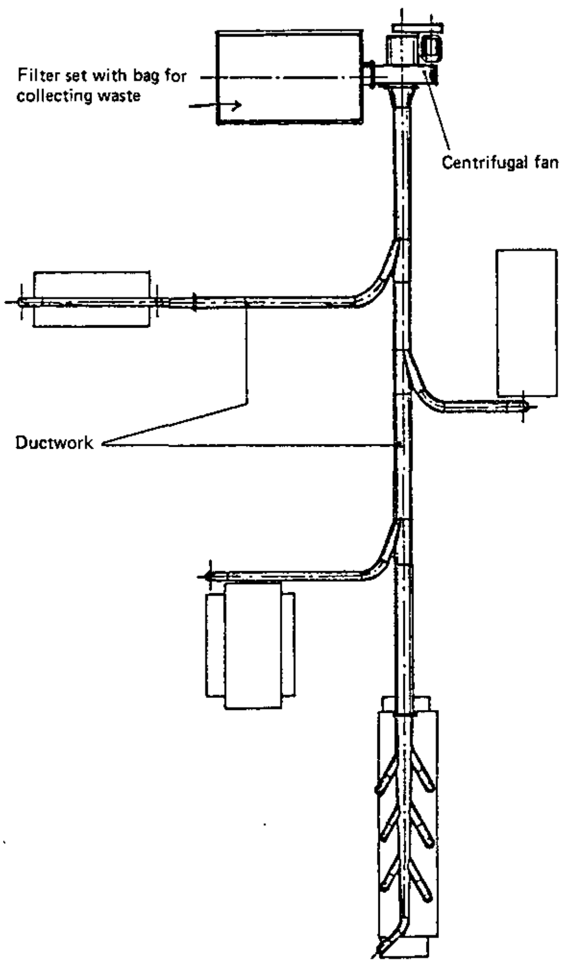


Figure 2. Centrifugal fan

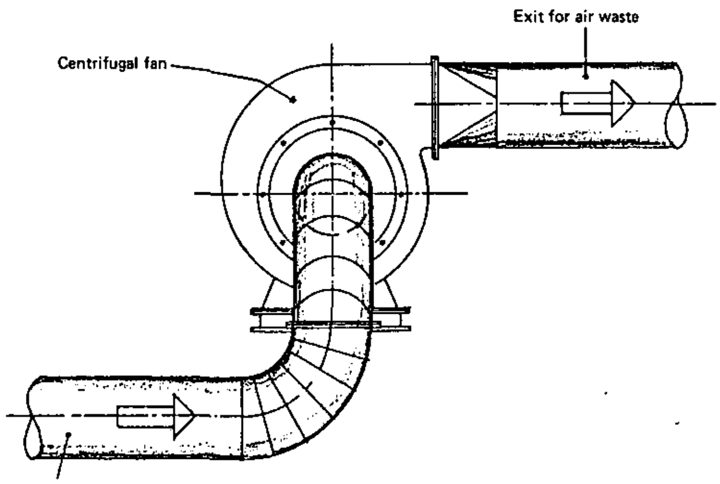


Figure 3. Intake filter set on wheels

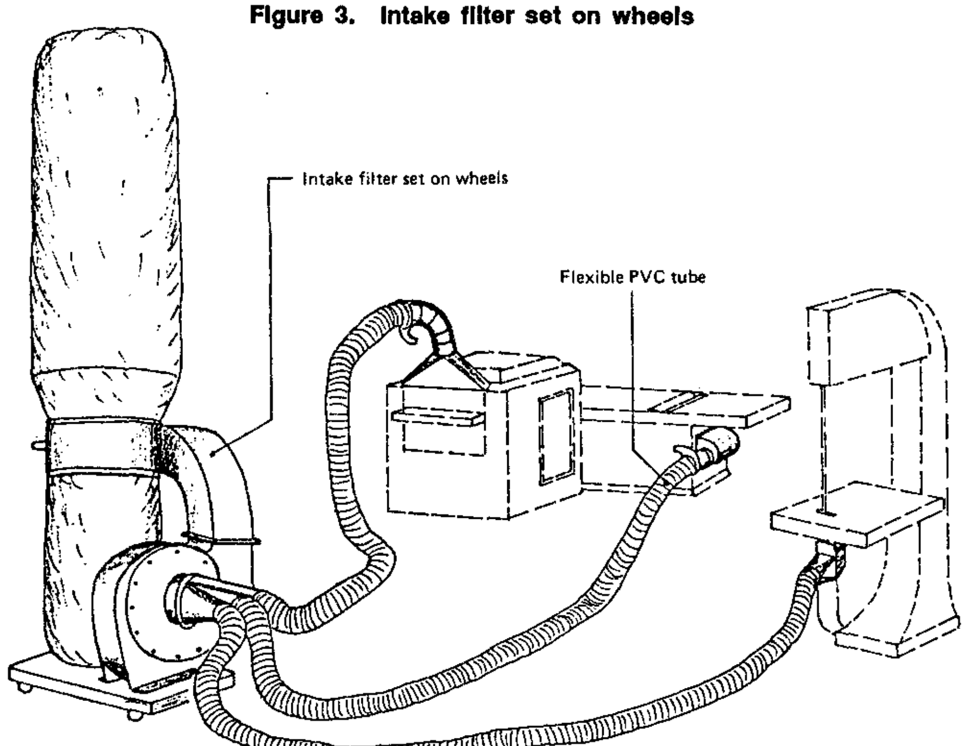
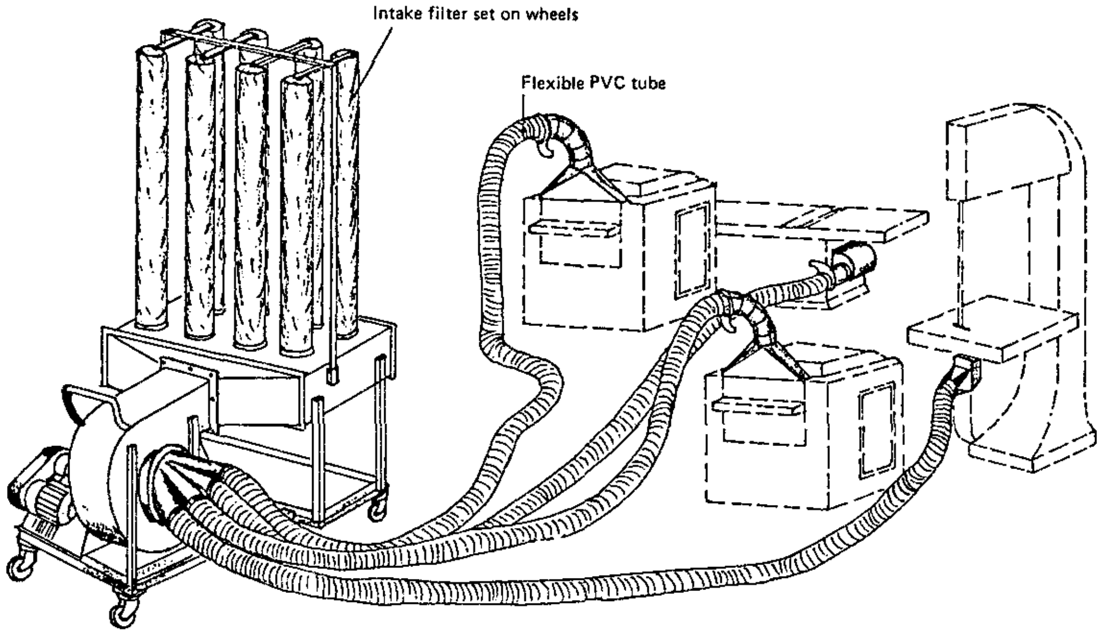


Figure 4. Intake filter set on wheels

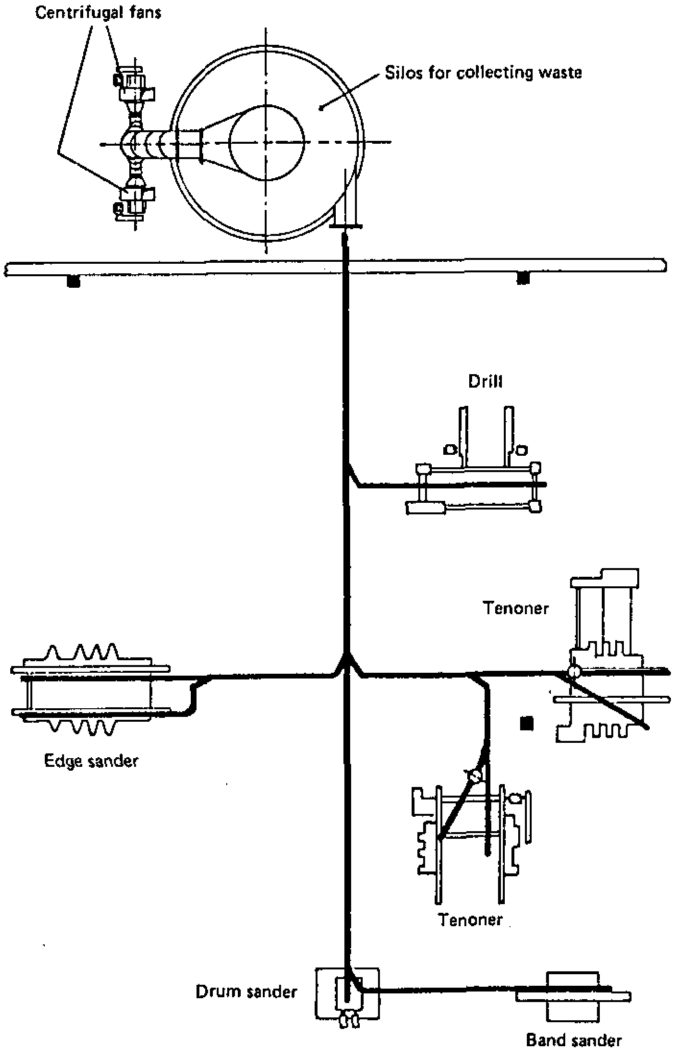


If, on the other hand, the business is of an industrial type, characterized by scheduled on-line processing operations with a considerable number of machines, including automatic ones, and by synchronized operations, a centralized system must be designed in which each of the machines is connected to the waste-collection area via a suitable pipe network. The layout of an industrial plant with a waste-intake installation is shown in figure 5.

Each machine is normally equipped with one or more suction mouths. The size of the latter is calculated as a function of the amount of air normally required in order to ensure the effective intake of the waste material produced.

Since each machine must be connected to the pipe network of the suction plant, it follows that the fan must be capable of sucking in an amount of air equal to the sum of the quantities specified for each of the machines. The air, which thus becomes the vehicle for conveying the waste material, must pass through the entire suction network at a given speed in order to prevent the chips, shavings and dust from settling along the conduits and to make sure they reach the collection silo regularly. Thus, the electric motor driving the fan must have sufficient power to overcome the resistance offered by the air and waste mixture present in the network.

Figure 5. Plan of a waste-intake installation



A suction plant must have, therefore, a quantity of air (expressed as cubic metres/hour), a force to transport the waste (expressed as millimetres of a water column) and a given power (expressed in horsepower (hp)). The choice of one fan over another is therefore crucial in limiting energy consumption (electric power). The formula for calculating the power of an electric motor (in hp) of a centrifugal fan is:

$$hp = \frac{m^3/sec \times Ht}{75 \times \mu} \qquad (1)$$

Where:

m^3/sec is the rate of flow

Ht (as mm of a water column) is the total head

μ is the efficiency of the fan

The efficiency of a fan is important because the greater its efficiency, the less power is required.

Each fan has a specific "identity card", expressed by a characteristic curve which is a function of the various relevant parameters. Efficiency appears to be satisfactory only for a limited portion of it.

The characteristic curves of two "high-efficiency" fans are shown in figure 6; curve A relates to wing-blade fans, while curve B relates to straight-blade fans. The peak efficiency sectors are shown in the shaded area and fan performance should be selected in this area only.

Owing to their features, these types of fans must be installed on systems in which a filter is fitted before the fan; that is, the waste does not pass through the system because the impact with foreign bodies could damage it and, in the long run, the fan wheel could go off balance, just as the wheels of a motor car can be off balance. Hence the fan operates only with clean air. A schematic view of a system of this type, in which a separator is placed between the waste-generating machine and the fan, is shown in figure 7.

A system where the filter is placed after the fan is shown in figure 8. Here the waste runs through the fan because the latter is placed between the machine and the collection pan. Owing to the strength of the fan wheel and the fan itself, this type of plant requires a "conveying" fan, fitted with suitably thick radial blades. The handicap of these fans is their low efficiency and the fact that they require high-power motors. Thus, in order to reach similar performance levels, they need a greater amount of electric energy than the high-efficiency ones described above. "Radial blades" for conveying fans are shown in figure 9.

With very few exceptions, manufacturers in the wood-processing sector have been designing waste extraction plants of the former type for many years.

When designing a waste extraction plant, it is very important to identify the best possible path for the duct network. It should be the most economic path in terms of power and, therefore, as aerodynamic as possible, and it should be, at the same time, compatible with the structure of the factory. This is why any new plan for a woodworking industry should take this important detail into account. Exceedingly long and winding duct installations should be avoided and, if possible, the collection silo should be located at the very centre of the suction system.

A suction system such as the one shown in figure 10 entails higher operating costs than the one shown in figure 11, owing to the longer distance between the waste-collection area and some machines.

The main components of a suction plant are shown in figure 12. Starting from the machines, the components are:

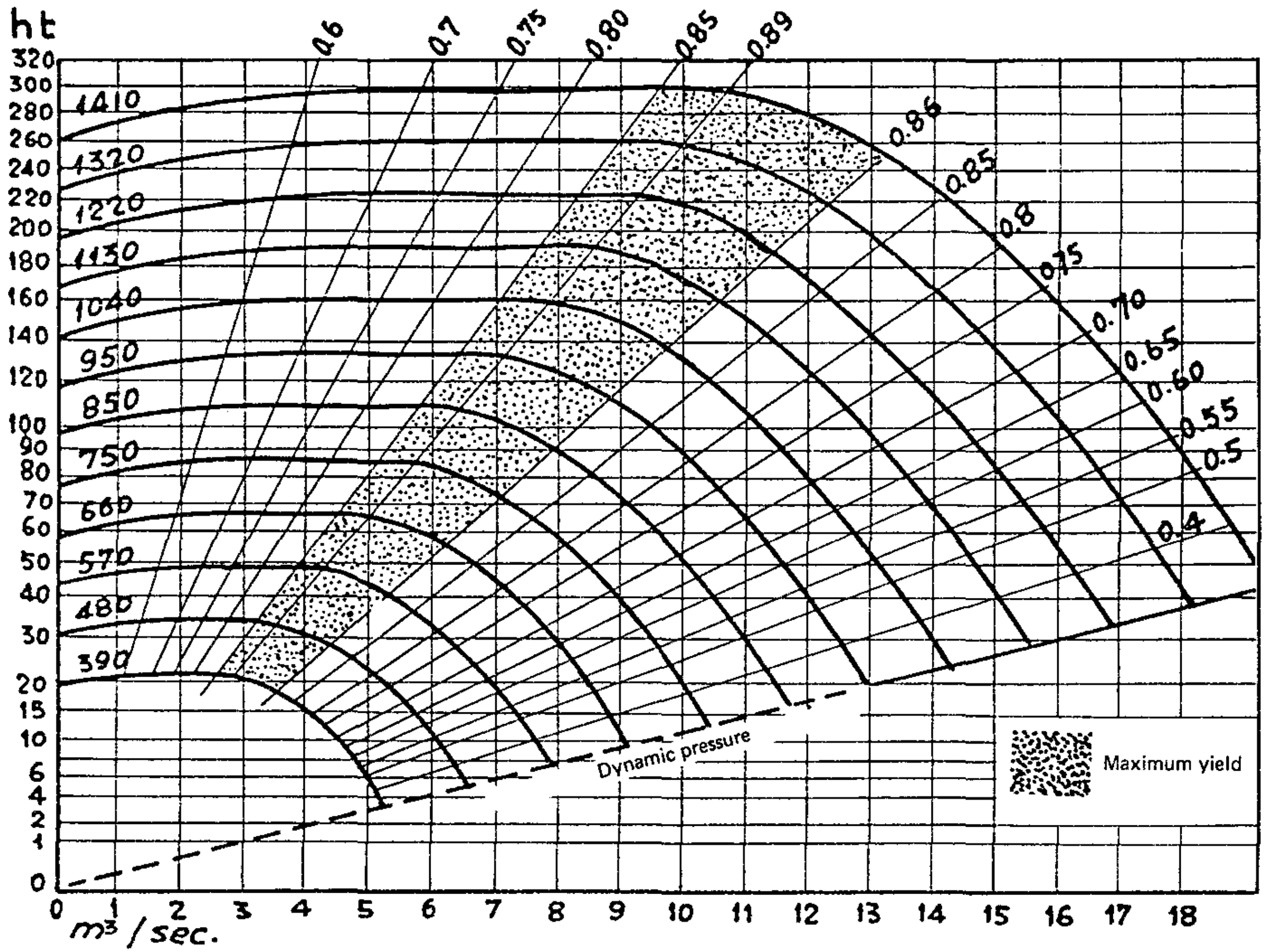
Machine coupling or suction inlet (1)
Vertical connection pipe (2)
Minor horizontal branches (3)
Main header (4)
Waste pan (5)
Centrifugal fan (6)

All these elements are parts of a well-balanced unit designed to ensure effective dust extraction on machines that have different requirements. The actual plan of a dust extraction system in a medium-sized industry is shown in figure 13.

A centralized system can be subdivided into subsystems through the use of suction and filtering substations. This normally occurs when, following the expansion of the company, the system has to be enlarged, a situation that had not been foreseen in the design stage.

Figure 6. Fan capacity

A. Wing-blade fans



B. Straight-blade fan

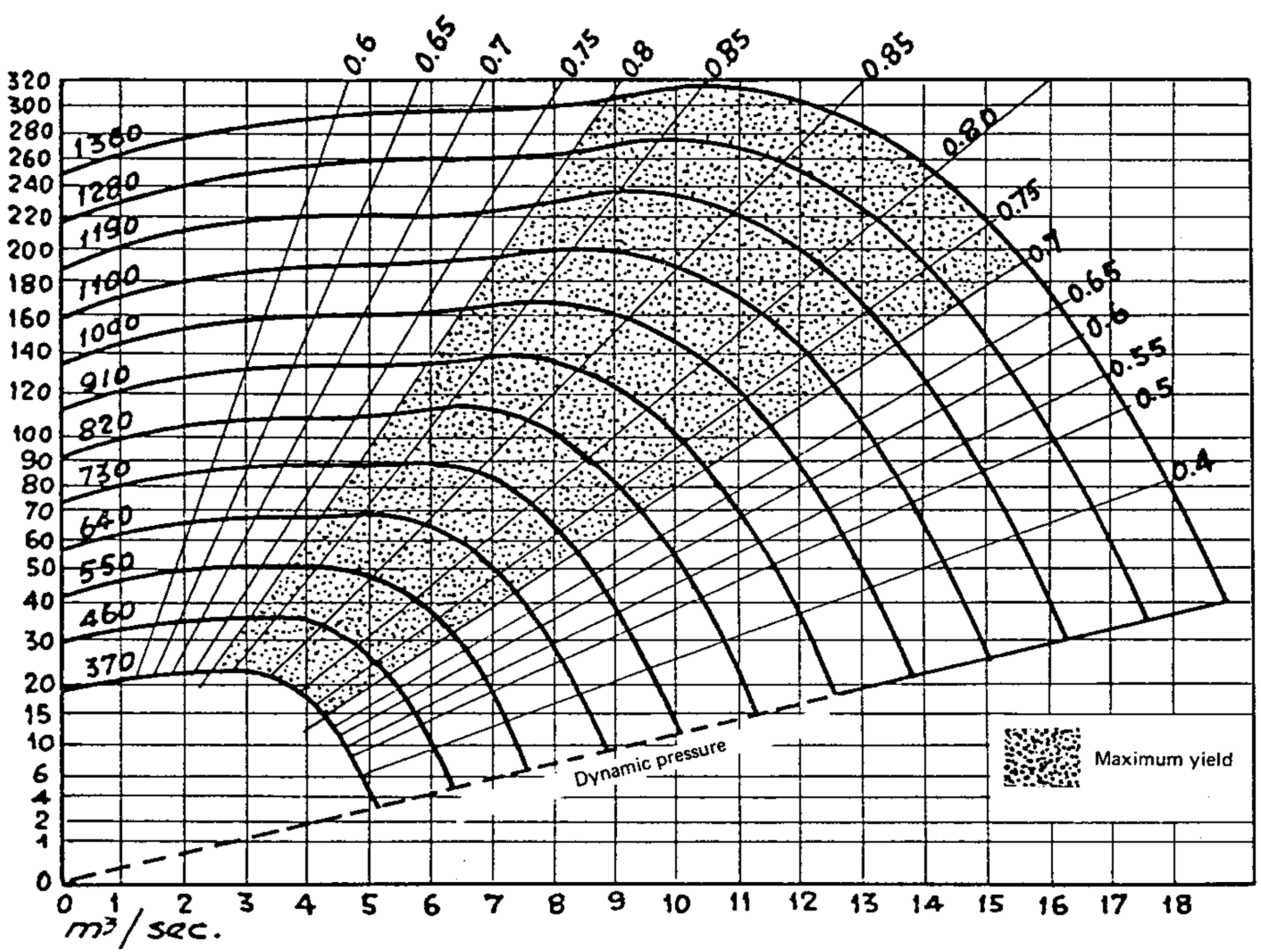


Figure 7. Suction system with the filter before the fan

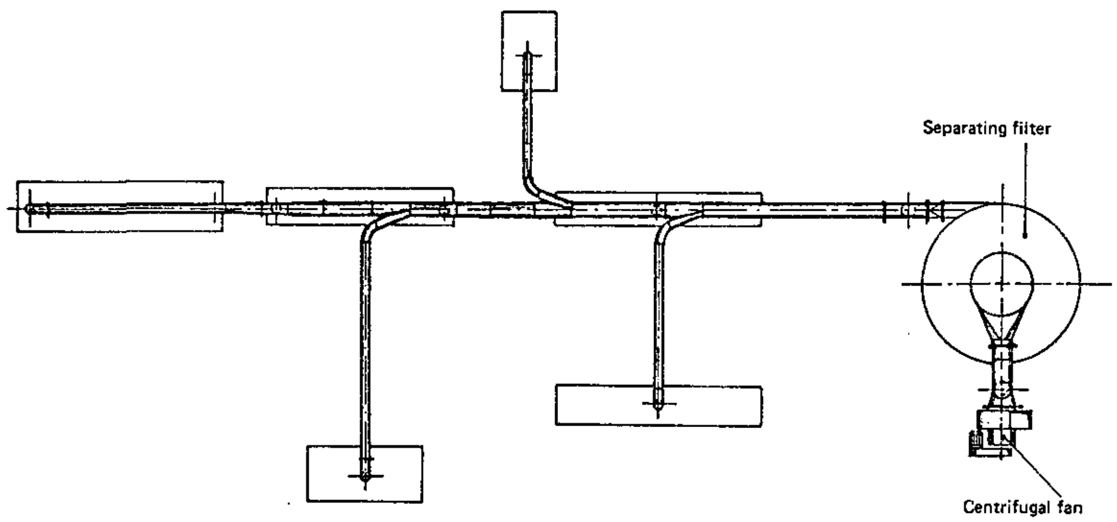


Figure 8. Positive pressure system

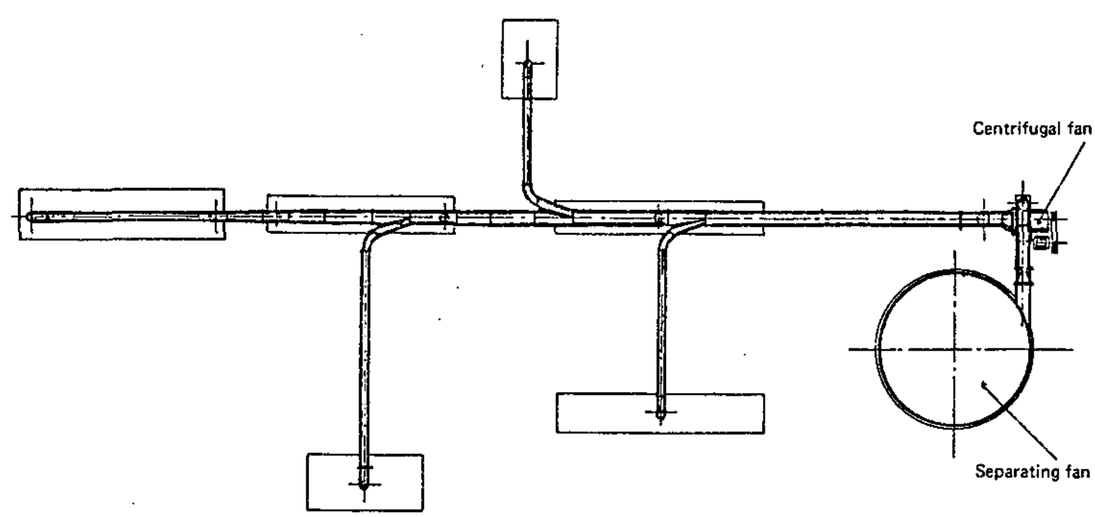


Figure 9. Radial blades

Figure 10. Plan of dust extraction system

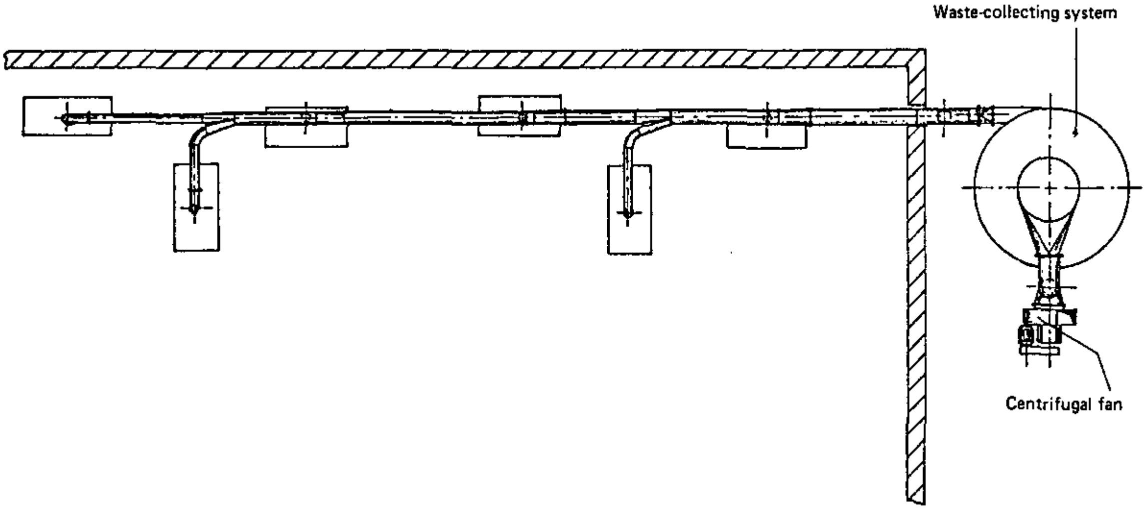


Figure 11. Plan of gravity extraction system

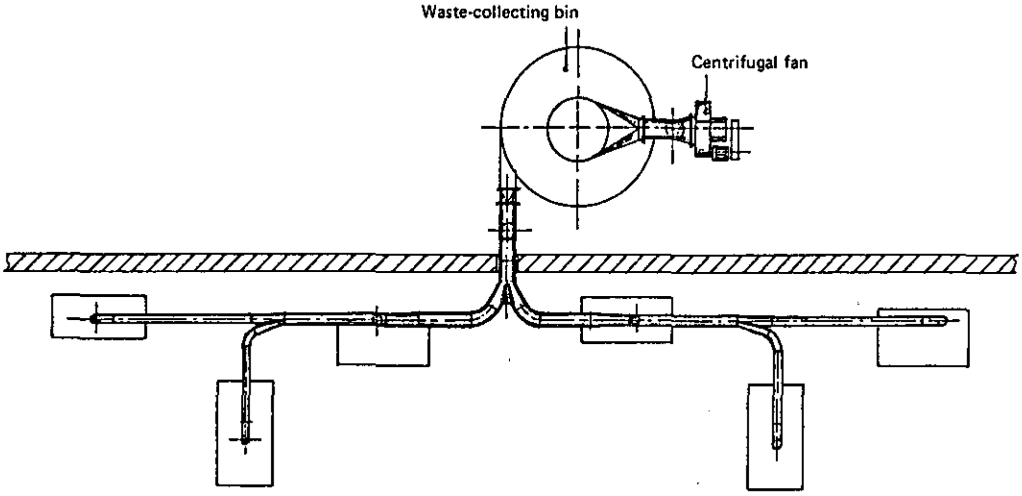


Figure 12. Main components of an intake plant

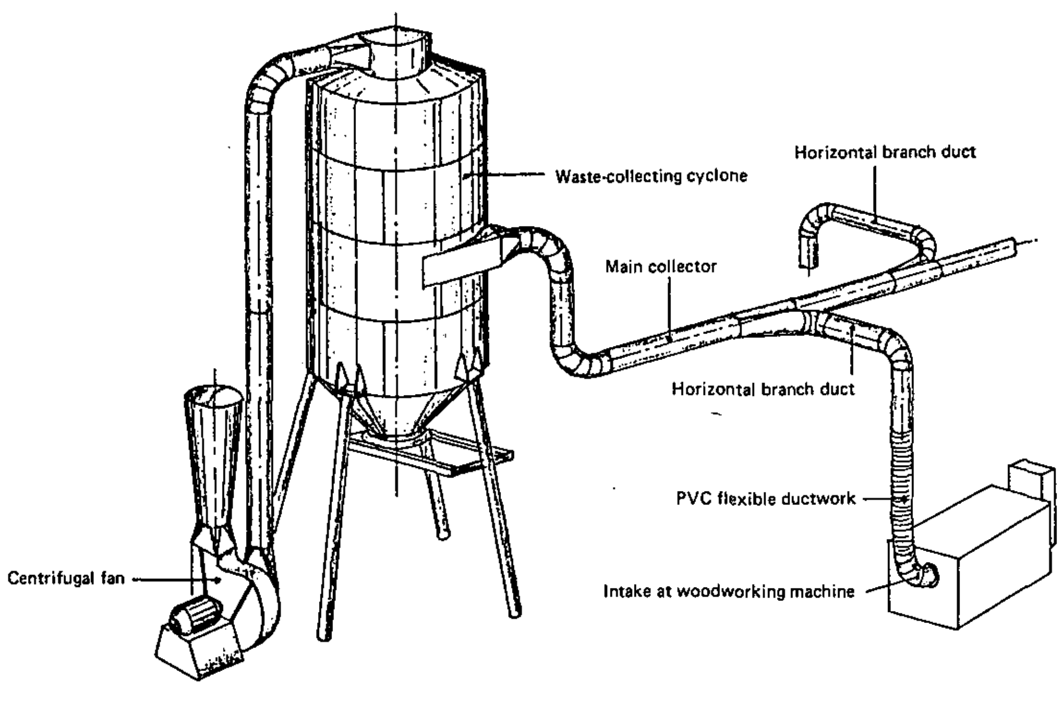
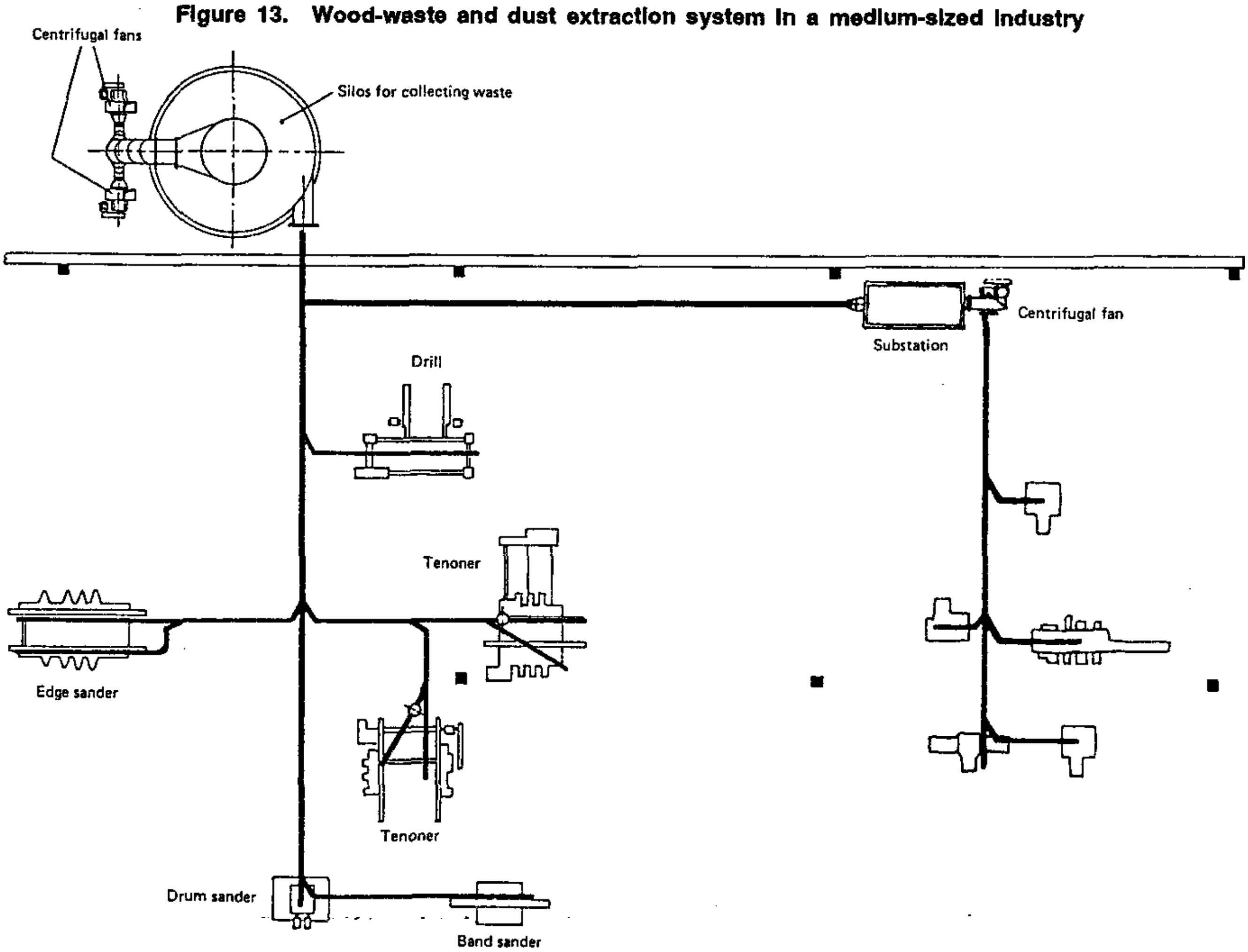


Figure 13. Wood-waste and dust extraction system in a medium-sized industry



In a subdivided system, groups of machines lead to a given substation where the waste is gathered and hence sucked in by the centralized system (figure 14). The advantage of the system is obvious. If the system is not capable of sucking in the waste of, say, five machines that jointly require 10,000 m^3/h, it would be able to take in as much as 1,500 m^3/h, i.e. the amount required for carrying the material discharged by the substation. All 10,000 m^3/h of air needed are treated by the substation. Obviously, the subsystem should be equipped with a controlled exhaust or discharge system. A single plant can include a number of substations (see figure 15).

Figure 14. Substation

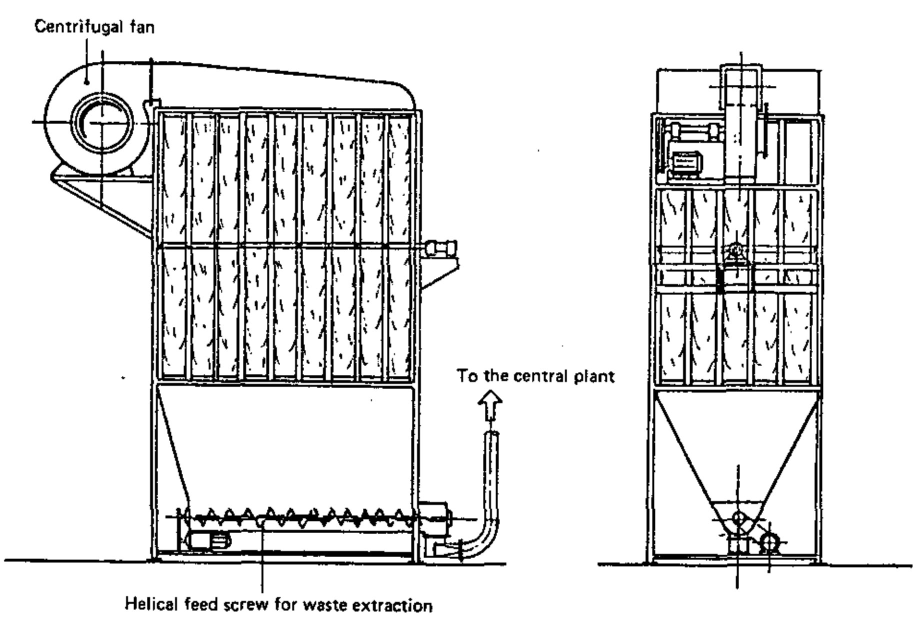
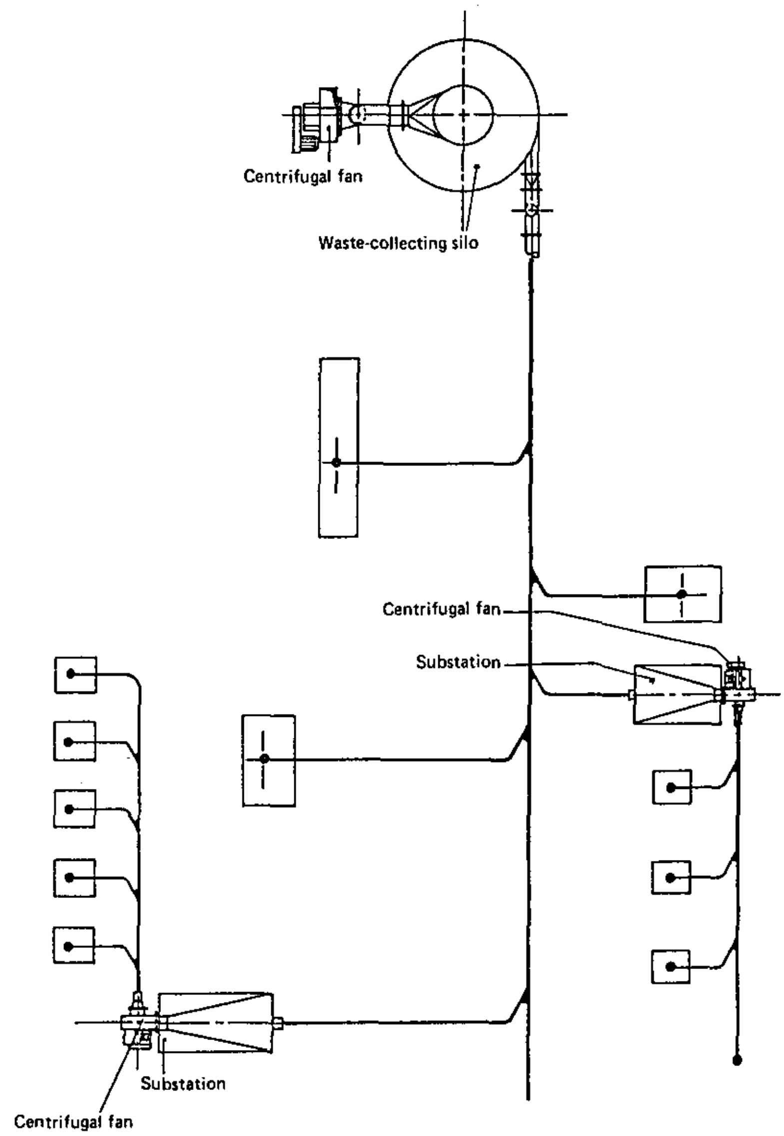


Figure 15. Plant with several substations



Ducting

Advanced wood-processing machines are usually equipped with intakes, but they are not always correctly designed from an aerodynamic point of view. In this case, they should be modified so as to achieve the best possible results.

The machine is connected to the system with a rigid coupling, unless it is provided with mobile parts, in which case the connection is made with a flexible duct. The latter should be made of abrasion-resistant material, especially for some types of machines, in order to prevent damage. Ducts should be made of galvanized sheet iron. Their diameter depends on the requirements of the machine. The recommended diameters of ducts connected to a machine with a rate of flow (cubic meter per hour) corresponding to a speed of 25 m/sec are as follows:

Thickness of duct wall (mm)	*Diameter of duct (mm)*
8/10	100-350
10/10	375-600
12/10	625-900
15/10	950-1,300

The various minor branches meet in the main header, which must grow in diameter so as to enable the air sucked in to flow in increasing quantities while keeping a virtually constant speed. The cross-section area of the header at a given point must at least be equal to the sum of the cross-section areas of the ducts that reach the header before that point. For example, where two ducts each having a diameter of 200 mm (hence each with a cross-section area of 31.416 mm^2) meet, the header should have a diameter of 283 mm (cross-section area 62.902 mm^2).

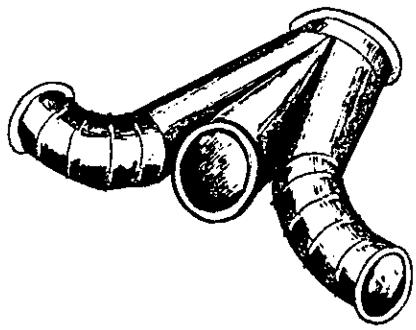
Bend pipes

Bend ducts should be made of galvanized sheet steel, and the duct walls should be thicker than the straight ducts having the same diameter because they are subject to severer wear owing to the impact force of the waste material. That is, the chips etc. cause considerable abrasion when they hit the wall of the elbow.

Branches

Branches are connections between ducts of equal or different diameters that meet in a single header (see figure 16). They should be made in such a way so as to enable the air to run freely across them without being obstructed either by obstacles or by narrow necks. They should be aerodynamic in shape.

Figure 16. Three-way connector



Locks

Locks are cut-off devices that are designed to disconnect one or more machines from the system if the machine is temporarily out of order for maintenance or if it is not being used.

Filter separators

Whatever the waste-conveying system chosen for carrying the material from where it has originated to the silo, the waste must be separated from the air before its storage. Thus, once the air has fulfilled its function as a waste-conveying vehicle, it must be separated from the waste itself. There are two standard systems for doing this: cyclones and filters.

A cyclone is a gravity separator which, owing to its conical/cylindrical shape, reduces the speed of the material contained in the conveying air as a result of the friction it undergoes when penetrating the apparatus tangentially (cyclone). The air is led out through the top while the waste, which is heavier than the air, settles on the bottom. Cyclones vary in performance. They should be selected on the basis of the specific nature of the waste (powdery, fine, coarse, moist) and of its density (see figure 17).

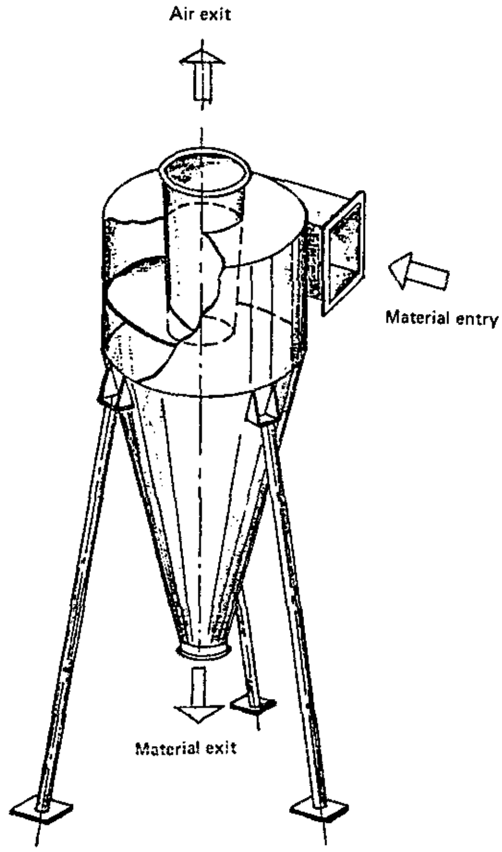
A filter is a system supplied with an intermediate element designed to stop the waste while letting the air through. The type normally used in the woodworking industry is composed of a large metal housing containing a number of cloth sleeves (cotton, flax-wool, polyester, nylon etc.), each characterized by a different degree of permeability to air and filtering efficiency.

It is very important to keep these elements clean in order to ensure the constant efficiency of the filter. There are two methods generally adopted for doing this: mechanical shaking and compressed-air counter-current. The two methods are shown in figures 18 and 19, respectively. The choice between the two systems depends on the nature of the waste.

Silos

Silos are the actual containers of the waste produced by the machines and conveyed by the suction plant. Their size should be calculated on the basis of the amount of waste produced. They may be constructed of bricks, reinforced concrete or steel. For many years industries have been using mostly steel prefabricated and sectional silos because it is possible to move them, if necessary, and to alter their capacity by fitting one or two sectors or rings onto them.

Figure 17. Separating cyclone



Silos may be equipped with automatic extractors or simply with openings for discharging the waste through gravity (see figures 20 and 21). The extractor-equipped silo is used when the waste must be utilized in order to obtain heat energy or when it must be compacted with special machines to reduce the cost of transport.

The silo of any modern plant is made up of three main parts:

The filter
The container
The automatic extractor

There are, however, other important fittings, such as: explosion-proof doors; a sprinkler system; inspection doors; stairways; platforms; level indicators etc. Cylindrical silos are preferable because they reduce friction while polygonal or square structures enhance it.

Extractors

There are a number of different models of extractors available on the market. Normally, each extractor is equipped with mechanical units designed to perform the relevant operation (cochleas, chains, leaf springs or any combination thereof). All models perform well enough. Three types of extractor are shown in figures 22, 23 and 24.

Figure 18. Filter with mechanical vibrator

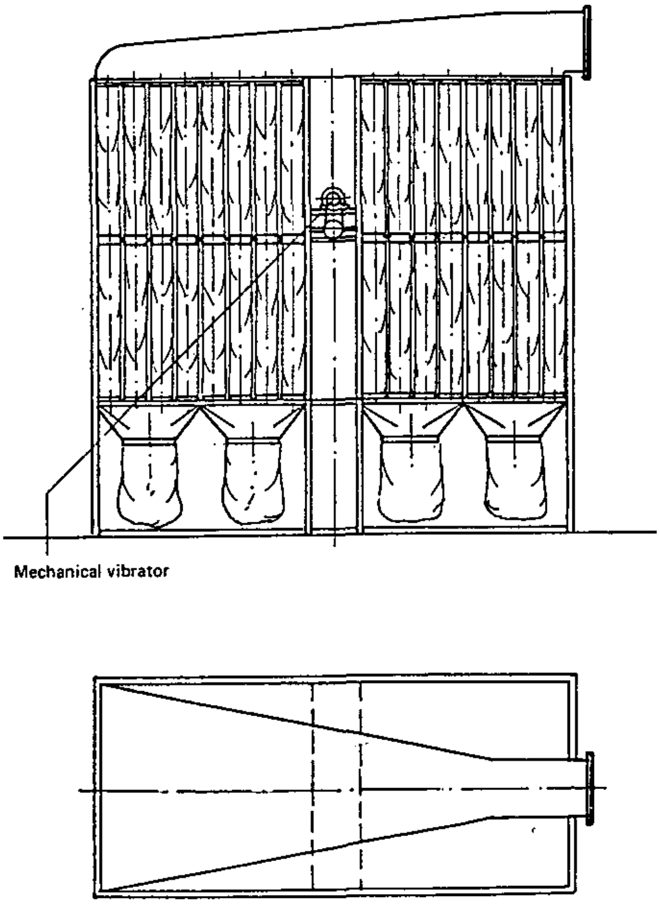


Figure 19. Filter with counter-current compressed-air cleaning

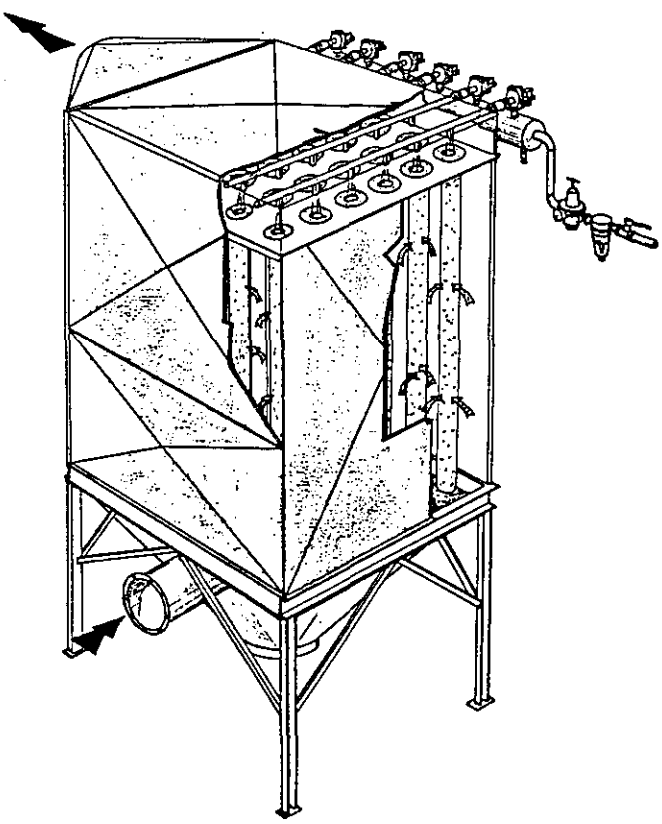


Figure 20. Metal silo with extractor

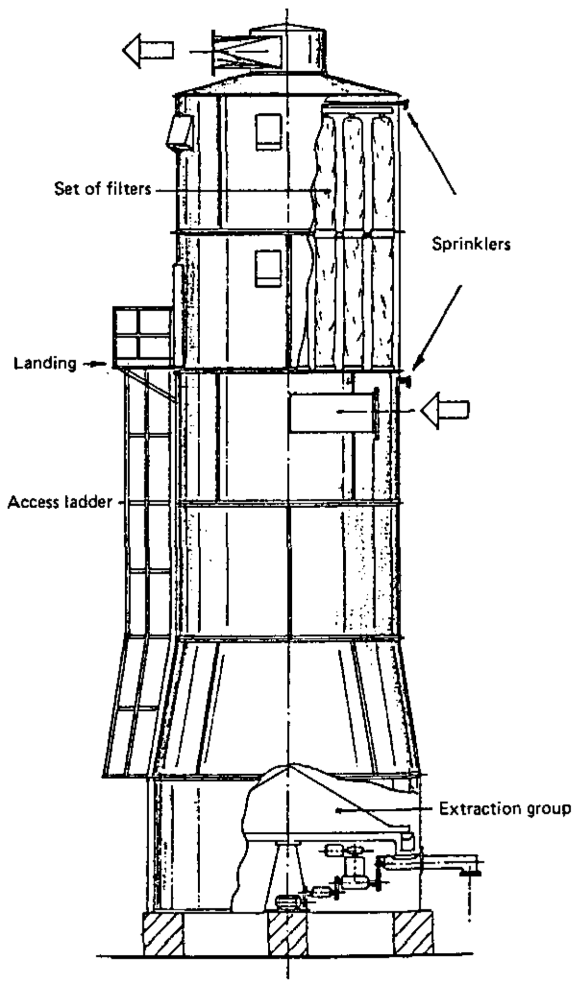


Figure 21. Metal silo on reinforced concrete supports

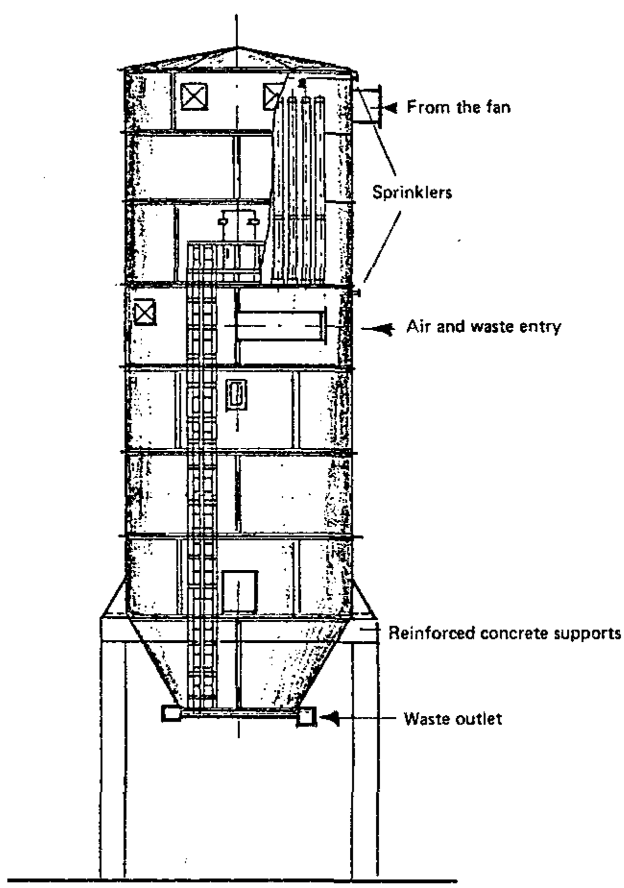


Figure 22. Automatic extractor

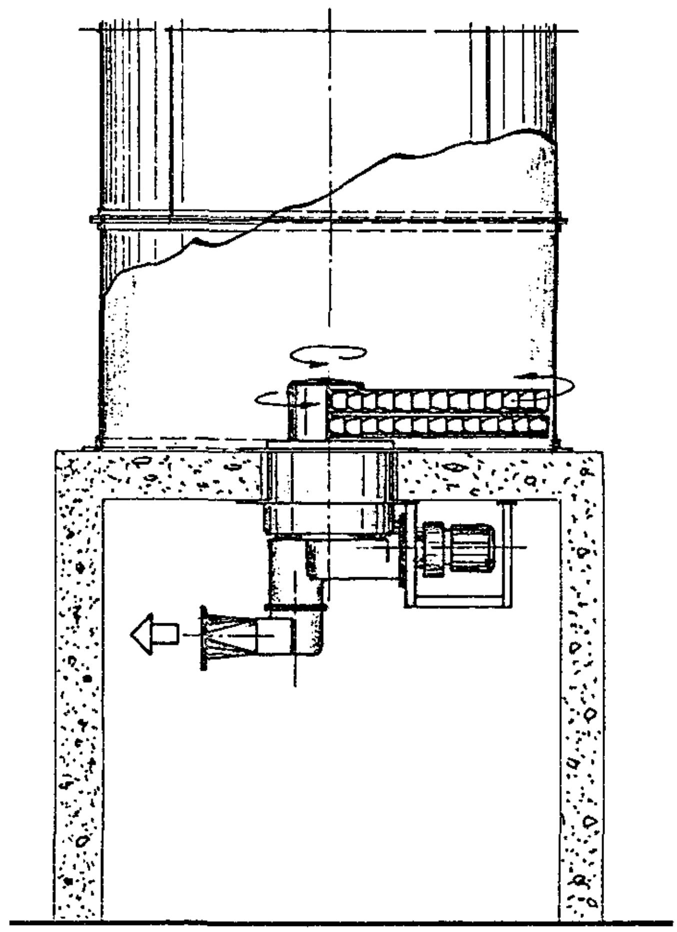


Figure 23. Automatic extractor

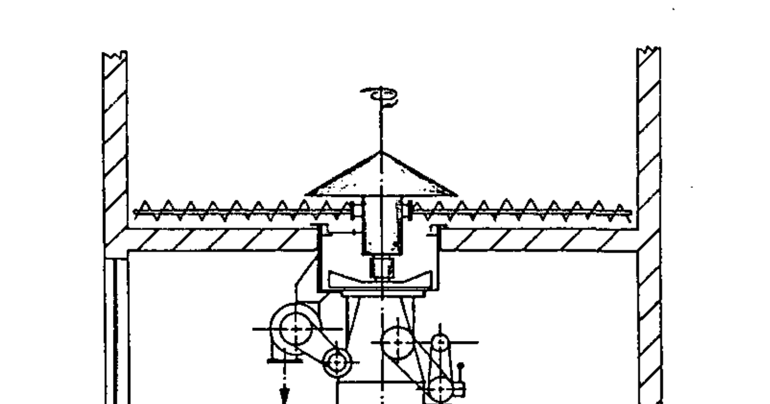
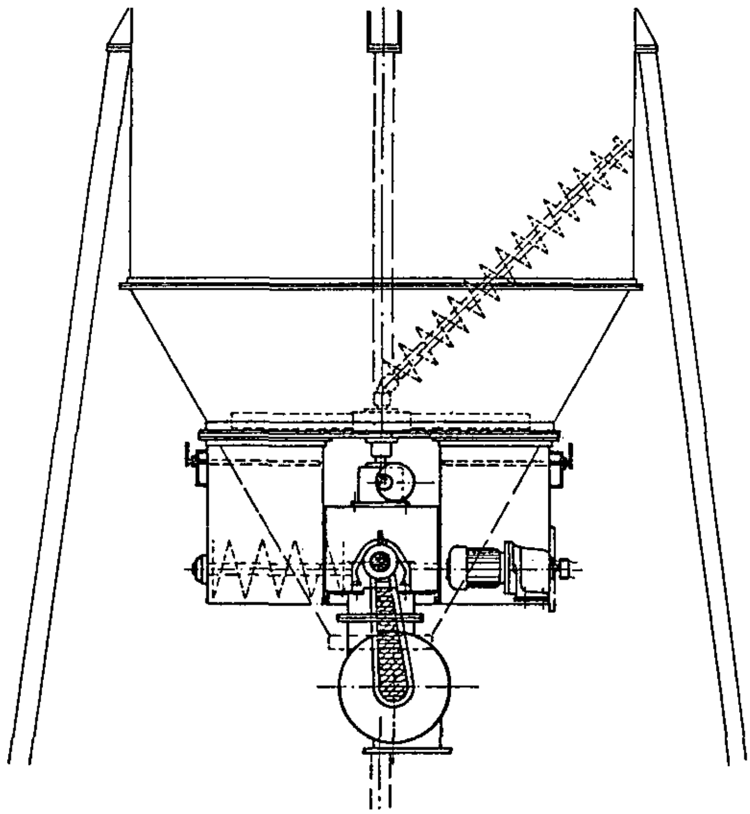


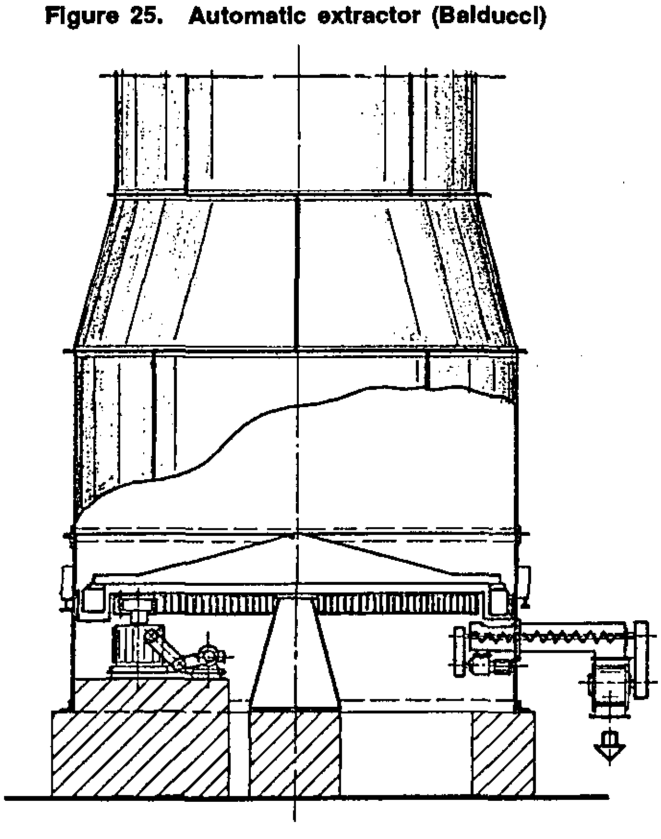
Figure 24. Automatic extractor



There is only one model that does not make use of the above mechanisms for extraction of waste (see figure 25). This model is characterized by the rotating, power-driven motion of the floor of the storage depot, and it deserves particular attention, especially because of its energy-saving characteristics, and therefore may be of interest in coutries in which the cost of traditional fuels have reached extremely high levels.

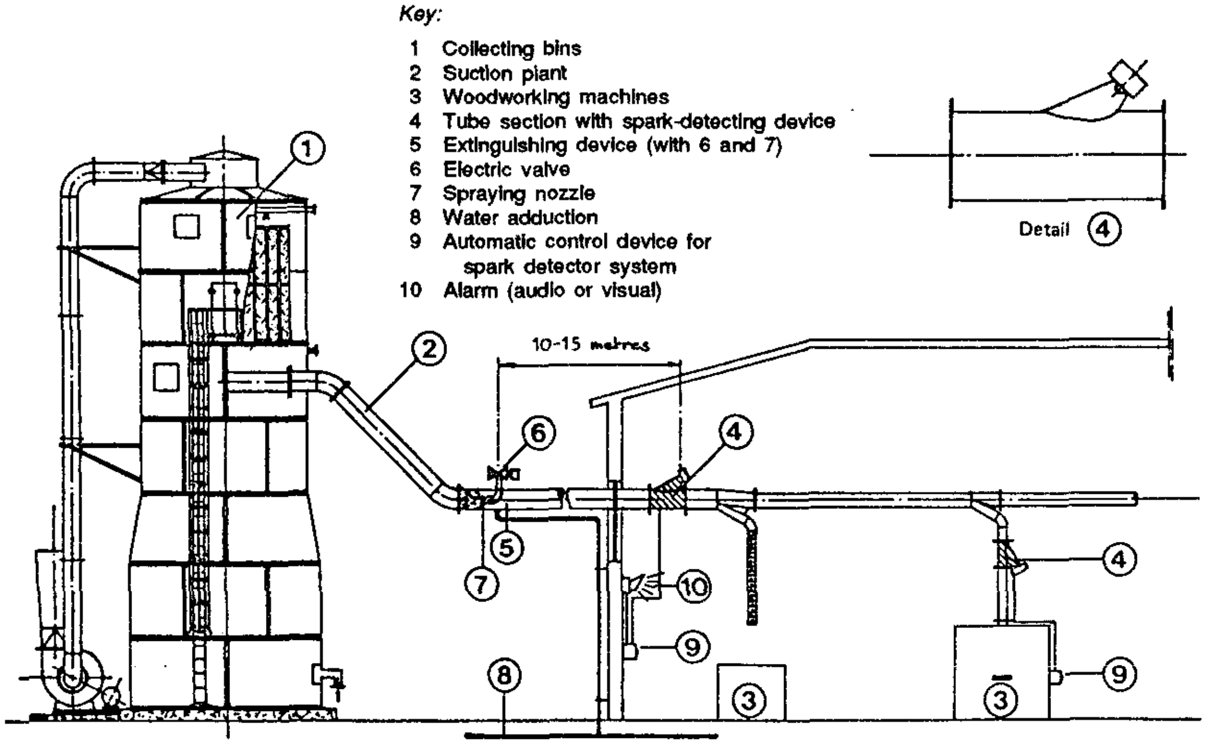
The possibility of recovering waste because it supplies good fuel was mentioned above. Therefore, the problem of fire prevention in silos must also be dealt with, since the silo is a reservoir of solid fuel. Silos are normally

Figure 25. Automatic extractor (Balducci)



provided with ducts that are able to extinguish, through sprays activated manually or automatically, any fire that may develop inside them. One system, however, is capable of actually preventing fire itself. This system is supplied with spark or flame detectors that are sensitive to infra-red rays, which send an impulse to a sprinkler system working with water or some other product with fire-extinguishing properties. The system extinguishes the spark or flame in the main header before it reaches the silo. One example of the system is shown in figure 26.

Figure 26. Plan of an installation with one or more spark detectors with automatic extinguishers



XXI. Wood drying*

Why and how wood dries

New facts about the physical nature of wood and its drying processes have contributed to the development of modern wood-drying techniques. Generally, softwood has relatively dry heartwood (water content 100 kg/m^3, moisture 31-35 per cent), while its sapwood has a high moisture content (570 kg/m^3, 120-160 per cent). Exceptions are Weymouth pine with a heartwood moisture content averaging 80 per cent and the "wet heartwood" of the silver fir with a moisture content of up to 220 per cent (800 kg/m^3). Hardwood is moister, and the differences between the moisture content of the sapwood and of the heartwood are less marked.[1] Generally, the wood gets moister towards the top because the sapwood prevails in this area. Moisture diminishes with age, hence the wood supplied by young forests is damper than that obtained from mature ones. Similarly, wood coming from mature trees is drier than that from young trees. Since only mature trees are felled on plantations, the sawn wood obtained tends to be drier than that from clear felling a natural forest.

Part of the water contained in the wood runs freely in the cellular and intercellular cavities (free water). The rest, however, is enclosed by the cell walls (hygroscopic humidity). Hygroscopic humidity accounts for 30 to 38 per cent of the weight of the dry ligneous substance (saturation point of the cell walls).

In an unsaturated environment (unsaturated air), free humidity, i.e. the humidity that exceeds the saturation point of the walls, is subject to evaporation.

As to the water present in the cell walls, wood may be considered a hygroscopic material, which means that it is subject to changes in humidity in the air. On a humidity scale ranging from 0 to the wall-saturation point, the wood acquires a degree of moisture that is in equilibrium with the relative humidity and the temperature of the surrounding air (table 1). If it is moister than the point of equilibrium, it dries; if it is drier than the point of equilibrium, it grows moist.

The two processes are not wholly reversible and it has been established that, the difference in pressure being equal, the degree of moisture in the wood that is obtained through absorption is less than that obtained through drying. This phenomenon, which is known as hysteresis, entails a 2-4 per cent difference in wood moisture between the two respective processes and is explained by the theory that part of the OH remains linked to one another and through the reduction in wettability of the dry surfaces. This phenomenon is also associated with the fact that the drying speed is far greater than the water absorption speed. The wood thus has a certain degree of hygroscopic inertia, which is stronger for the increase than for the reduction in humidity.

*By R. Cividini, Professor of Wood Technology, University of Florence, Italy. (Originally issued as ID/WG.369/11.)

[1]The humidity of fresh wood, e.g., beechwood, is between 80 and 90 per cent, which means a water content of 450-500 kg for each m^3 of wood, while the degree of humidity of poplar wood may exceed even 200 per cent (i.e., more than 600 kg of water in each m^3 of wood).

Table 1. Moisture content at which wood stabilizes (moisture content equilibrium) as a function of the temperature and humidity of the surrounding air

(Percentage)

Relative humidity of air as a percentage of saturation	*Temperature of air*							
	0°-5° C	*5°-10° C*	*10°-15° C*	*15°-20° C*	*20°-25° C*	*25°-30° C*	*30°-35° C*	*35°-40° C*
20-25	5	5	5	5	5	5	5	5
25-30	6	6	6	6	6	6	5	5
30-35	7	7	7	7	7	6	6	6
35-40	8	7	7	7	7	7	7	7
40-45	8	8	8	8	8	8	8	7
45-50	9	9	9	9	9	9	8	8
50-55	10	10	10	10	10	9	9	9
55-60	11	11	11	10	10	10	10	10
60-65	12	12	12	11	11	11	11	11
65-70	13	13	13	12	12	12	12	12
70-75	14	14	14	14	13	13	13	13
75-80	16	16	15	15	15	15	14	14
80-85	18	18	17	17	17	17	16	16
85-90	20	20	20	19	19	19	18	18
90-95	23	22	22	22	22	21	21	21
95-100	27	26	26	26	26	26	25	25

When the hygroscopic humidity diminishes, the wood shrinks (i.e., it diminishes in size), when it rises, the wood swells up again. The anisotropy of the shrinkage (the ratio between the three linear shrinkages) for most types of wood is approximately:

$$\beta_l : \beta_r : \beta_t = 1 : 10 : 20 \qquad (1)$$

Where:

β_l is the linear shrinkage
β_r *is the radial shrinkage*
β_t is the tangential shrinkage

Shrinkage is a specific feature of each wood species, although it extends over a rather wide range, even for samples of wood belonging to the same species. The ratio between tangential shrinkage and radial shrinkage, which may be used as an index of wood deformability, is shown in table 2. Wood deformity, in fact, increases with any increase in the β_t/β_r ratio.

Shrinkage begins when the average moisture content of the wood is considerably higher than 30 per cent, because the outer layers start to yield their saturation moisture while the inner layers are still very damp. The average degree of humidity marking the beginning of the shrinkage process depends, basically, on permeability, thickness, initial moisture content, intensity of drying and mechanical resistance (plasticity when subjected to tension and to compression).

Table 2. Wood-air moisture content equilibrium and shrinkage-swelling in the 60 and 90 per cent relative air moisture (RM) range at an air temperature of about 20 °C

Ligneous species	*Moisture content per RM*		*Shrinkage-swelling in 60 per cent and 90 per cent RM range*				*Dimensional Instability*	*Deformability*
			Tangential		*Radial*			
	90 per cent	*60 per cent*	$\Delta\beta_t$*	k_t*	$\Delta\beta_r$*	k_r*	k_t/k_r	$\Delta\beta_t/\Delta\beta_r$
Obeche (Wawa, Samba)	19	12	1.25	0.18	0.8	0.12	0.30	1.5
Afrormosia	15	11	1.3	0.32	0.7	0.17	0.49	1.9
Maple	23	13.5	2.8	0.29	1.4	0.15	0.44	1.9
Birch	21.5	12	2.5	0.26	2.2	0.23	0.49	1.1
Beech	20	12	3.2	0.40	1.7	0.21	0.61	1.9
Oak (Europe)	20	12	2.5	0.31	1.5	0.19	0.50	1.6
Ash	20	12.5	1.8	0.24	1.3	0.17	0.41	1.4
Iroco	15	11	1.0	0.25	0.5	0.12	0.37	2.0
Cherry	19	12.5	2.0	0.31	1.2	0.18	0.19	1.7
Larch (Europe)	19	13	1.7	0.28	0.8	0.13	0.41	2.1
Limba (Frakè)	18	12	1.3	0.22	1.0	0.17	0.39	1.3
Khaya grandifolia	23	14	1.9	0.21	1.5	0.17	0.38	1.2
Khaya ivorensis	20	13.5	1.5	0.23	0.9	0.14	0.37	1.6
Mahogany (Swietania)	19	12.5	1.3	0.20	1.0	0.15	0.35	1.3
Makoré	19	13	1.8	0.30	1.1	0.18	0.48	1.7
Bété	20	12	2.3	0.29	1.3	0.16	0.45	1.8
African walnut	18	13	1.3	0.26	0.9	0.18	0.44	1.4
European walnut	18.5	11.5	2.0	0.29	1.6	0.23	0.52	1.3
Red oak	18.5	11.5	2.4	0.34	1.3	0.19	0.53	1.8
Elm	22	13	2.4	0.27	1.5	0.17	0.44	1.6
Sapeli	20.5	13.5	1.8	0.26	1.3	0.19	0.45	1.4
Teck and Padouk	15	10	1.3	0.26	0.8	0.16	0.42	1.6
Wengé	15	11.5	0.9	0.26	0.65	0.19	0.45	1.4
Abura	—	11.5	—	0.20	—	0.08	0.28	2.5
Sipo	20	14	—	0.20	—	0.15	0.35	1.3
Kosipo	22	15	—	0.18	—	0.13	0.31	1.4

Source: Forest Products Research Laboratory, Princes Risborough.

*Shrinkage coefficients for a 1 per cent loss of moisture of the wood between the moisture content equilibrium values shown in the table.

Finished wood products tend to adjust to the environment in which they are placed; their moisture content equilibrium should therefore be based on local climatic conditions in order to stabilize them in both their dimensions and their shape. The wood moisture regulations for products manufactured for different environments, exposures and microclimates are shown in table 3.

Environmental conditions normally vary throughout the year in accordance with the different seasons and room conditioning equipment. If the variations do not exceed the hysteresis limits, wood moisture does not vary as long as the wood has been treated in such a way that it reaches the lower limit. Owing to hygroscopic inertia, wood moisture does not vary even when subjected to occasional changes exceeding the above-mentioned limits. Hygroscopic inertia increases with the volumetric weight and thickness of the wood as well as with the degree of thoroughness with which the wood has been varnished and the water-repellent characteristics of the products used for treating the wood.

Any variation in the saturation moisture content results in dimensional changes and deformation of the wood (see table 2 above). Through drying, therefore, relative stabilization is obtained.

Wood permeability is the single most important factor in the drying process. Radial permeability is considerably greater than tangential permeability; thus, lateral boards dry in considerably less time than central ones. Radial permeability increases with the size of the rays. Unfortunately, as the size and frequency of the rays increase, the resistance of the wood to transversal tensile stress diminishes, and this, eventually, leads to clefts in the wood.

Shrinkage begins when the average moisture content of the wood is considerably higher than 30 per cent, because the outer layers start to yield their saturation moisture while the inner layers are still very damp. The average degree of humidity marking the beginning of the shrinkage process depends, basically, on permeability, thickness, initial moisture content, intensity of drying and mechanical resistance (plasticity when subjected to tension and to compression).

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Table 3. Recommended final wood moisture for selected products

	Percentage of moisture
Commercial lumber	16-20
Building timber	12-18
Barrack timber	12-15
Panels (plywood, built-up boards, particle boards etc.), veneering boards	6-8
Commercial veneerings	12-16
Cores for built-up boards	6-7
Outside frames	12-15
Inside frames	8-10
Parquet floors and interior match-boarding	6-8
Furniture for interiors and sundry fittings	6-10
Furniture and tools to be used outdoors (for gardening etc.)	12-16
Agricultural machines and coachwork	12-18
Motor-car coachwork	7-10
Railway carriages (internal parts)	6-8
Aircraft constructions	6-10
Water crafts	12-16
Sporting equipment	8-12
Toys to be used indoors	6-10
Toys to be used outdoors	10-15
Wooden lasts	6-9
Rifle butts	7-12
Electrical equipment	5-8
Musical instruments	5-8
Dies	6-8
Frames	6-10
Casks, cases	12-16

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Unless the wood is soaked in water immediately, the drying process begins as soon as the tree is felled, because the free water tends to evaporate from the surface of the wood (phase I in figure 1). As this process extends to ever-deeper levels through the diffusion of the vapour that develops in depth as a result of wood porosity and, partly, of capillary movement in permeable wood, a fairly regular parabolic gradient for thickness moisture is obtained even before the first critical point is reached. In wood characterized by medium permeability, vapour diffusion and capillary movements are more limited, and the water tends to be diffused mainly through the cell walls. Hence, the moisture gradient in the thickness is sharper, and the parabolic shape is reached as soon as the outer layers establish a condition of equilibrium with the surrounding air. The surface moisture of impermeable wood reaches a condition of equilibrium with the air very shortly after the beginning of the drying process, whereas the greater part of the inner layers preserve their initial moisture content. In this phase, mechanical resistance is at a minimum and high temperatures are dangerous.

Shrinkage starts when the cell walls of the peripheral layers reach the saturation moisture content. As this process begins, the layers are subjected to tensile stress; the latter is more readily observable in medium-permeability wood (first critical point). At the same time, the speed of drying begins to slow down (phase II). The average moisture content of the wood at the first critical point is approximately two thirds of the initial moisture content + 10 per cent for permeable wood and about two thirds to three fourths of the initial moisture content for wood with medium permeability.

This is the phase in which the checks appear. They extend from the surface of the wood towards the centre (mostly along the rays), and, if viewed sectionally, they appear to be wedge-shaped.

As a 21-24 per cent average moisture content is reached, the drying process enters into phase III, where:

(a) The tensile stress is inverted (stress applied at the centre);

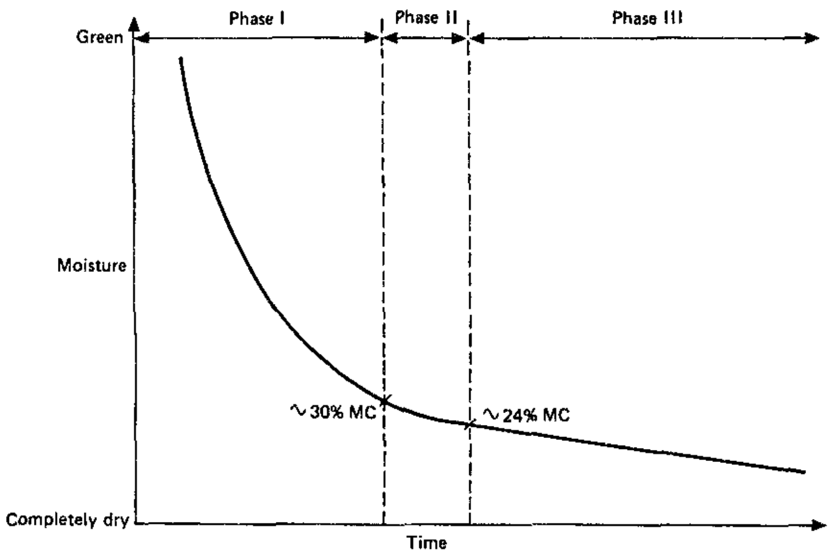
(b) The outer layers are, in all cases, in equilibrium with the final climate, which is normally very dry (2-5 per cent).

The mechanical resistance of the wood increases during this phase. The drying process slows down, because the diffusion of water occurs mainly through the cell walls. During this phase, the surface checks close, and the wooden pieces stretch and grow wider at the centre.

Drying speed is directly proportional to permeability, temperature and air circulation speed (air losing its effectiveness in phase III), and inversely proportional to density, the size of the pieces and the relative humidity of the air.

The drying stage in which the moisture content drops from 45 to 25 per cent is the one in which wood is most vulnerable to the action of blueing fungi and of other wood-damaging organisms. The longer the wood moisture remains at this stage, the greater the danger.

Figure 1. Drying process after the tree has been felled



In this connection, particular attention should be paid to the drying of biodegradable fresh wood, which tends to be subject to fungal attack. This category includes the sapwood of all wood species and wood species characterized by an undifferentiated heartwood (such as beech), particularly the "whitish" tropical species (ramin, ilomba, koto, obeche, aniegre etc.).

Another problem is posed by internal blackening. Owing to the catalyzing action of temperature when water or vapour are present, the ligneous species containing glucosides, polphenols and acids are subject to chemical reactions that can blacken the inside of the sawn logs. Temperatures of about 35 °C provide optimal conditions for the xylophagous organisms, while any rise in temperature above this value enhances the danger of internal blackening. The only safe method that can be used against fungal attack and biodegradation besides complete saturation is a chemical inhibiting treatment. This kind of mould should be dried by treating it at low temperatures and at low relative air humidity levels.

Here, too, each case should be considered separately, taking into account the savings afforded by kiln-drying, on the one hand, and the fact that, even when the seasoning process is not induced artificially, fungal attack may occur and temperatures leading to internal blackening may be reached, on the other.

The tropical woods display some peculiar features and defects that extend the range of problems connected with drying. This is true in particular for species in South-East Asia that are not well-known and characterized by less foreseeable and more variable reactions. Tropical wood is almost exclusively diffuse-porous hardwood; many of the species, however, contain gum and gum canals, both in the wood and in the parenchymatic rays. The accumulation and hardening of these substances in the outer layers during drying form an exceptional barrier for water, which cannot flow freely to the surface. This phenomenon often results in collapse and in the formation of water pockets inside the wood. Generally, the differences in permeability are sharper, even within the same species, and so are the differences between the sapwood and the heartwood and, therefore, between different boards drawn from the same log.

Some wood species contain substances that emit vapours with a bad odour (ramin and others). Consequently, air emitted from the dryer during the drying process pollutes the environment. Some factories located in the proximity of built-up areas have had to install special plants for filtering the air emitted by dryers.

Many kinds of wood contain salts in varying quantities that interfere with the electric measurement of the wood moisture content, which often leads to variations from standard values, preventing the automatic devices from operating normally.

Woods characterized by interlocked grain, softness of heartwood and growth stresses pose particular problems.

As far as permeability is concerned, the following rough classification can be taken as a guideline:

Permeable wood. All types of hardwood endowed with tracheids. Generally speaking, kinds of wood with undifferentiated heartwood are most commonly classified among the diffuse-porous species, e.g. beech, lime, poplar and the "whitish" tropical species such as obeche, abura and jelutong and the sapwood of all kinds of hardwood

Medium-permeable wood. Undifferentiated sapwood and heartwood of conifers, owing to the areolated pits

Impermeable wood. Hardwood with closed vessels owing to tyloses, such as oak, chestnut, many tropical and southern kinds of wood as well as the false heartwood of undifferentiated hardwood

It follows that any wood-drying operation requires specific techniques or should at least be controlled in such a way as to:

(*a*) Increase the speed of the drying process;

(*b*) Avoid damage such as biodeterioration, splitting and checking of the wood, distortion and stresses;

(*c*) Obtain the desired final moisture content, i.e. the *stabilization of shape and dimensions.*

Drying

Air and combustible gas

The main characteristics of air are: temperature, pressure, specific volume, volumetric weight, humidity and heat content (enthalpy). These characteristics are interdependent in accordance with well-known basic laws, from which it follows that:

(*a*) The weight of the air is proportional to its pressure;

(*b*) Water vapour tends to spread to where the pressure is lowest;

(*c*) If the atmospheric pressure of the moist air is kept constant, a rise in temperature causes the dry air to expand and its pressure to drop, hence a rise in the pressure of the water vapour. A rise in temperature enables the air to include larger quantities of moisture.

The maximum pressure that steam can reach in the wet air is called "saturation pressure". If the actual pressure of steam (P_v) for a given temperature is less than the saturation pressure (P_{vs}), the air is not saturated. The ratio between the two quantities is called "relative moisture of air". It is usually expressed as a percentage by multiplying the ratio by 100. The moisture of air can be expressed as the ratio between the weight of the water vapour contained in the air and the weight of the water vapour in its saturation condition. If the relative air/moisture is less than 100 per cent, it follows that the pressure of the water vapour contained in the air is less than the saturation pressure and, therefore, the air can absorb the moisture from those areas where the pressure of the latter is highest. This process is known as "evaporation".

Exactly how much moisture the air can contain depends on the temperature. The maximum content (saturation moisture) for some temperatures is shown in table 4, which applies to a pressure equivalent to a 760-mm mercury column.

Table 4. *Air saturation pressure and moisture at various temperatures*

Temperature	*Saturation pressure (mm Hg)*	*Saturation water (g/m^3)*	*Absolute saturation humidity (g per kg of dry air)*
10° C	9.2	9.4	7.6
20° C	17.5	17.3	14.7
30° C	31.8	30.4	27.2
40° C	55.3	51.1	48.8
50° C	92.5	82.1	86.2
60° C	149.4	130.1	152
70° C	233.7	198	276
80° C	355.1	293.9	545
90° C	505.8	423.1	1 400
100° C	760	600	Dry air is absent

The heat of wet air is equal to the sum of the heat content of dry air and the steam contained in it. Thus, the heat content of air at a given temperature increases when the humidity increases.

In the drying process, air can fulfil a two-fold function: heating the material (wood and water) and discharging the water (evaporation). Alternatively, it may fulfil only the latter function. In either case, the air undergoes variations in temperature and humidity that can be reversed through conditioning. In its narrowest sense, air conditioning consists of the following processes:

(*a*) A rise in temperature through heating, i.e., through the addition of heat;

(*b*) A fall in temperature through cooling, i.e., through the reduction of heat;

(*c*) An increase in relative humidity through moistening, i.e., the addition of water vapour;

(*d*) A drop in humidity through drying, i.e., through the removal of water vapour. This can be executed through a partial change of air or through the partial condensation of the moisture contained in the air.

Combustible gas has similar characteristics to those of air; moreover, it can be mixed with air and water for conditioning purposes.

Steam

The hygroscopic equilibrium of wood in saturated steam at standard atmospheric pressure is just a few per cent below the saturation point of the cell walls.

Superheated steam is steam that has a higher temperature than the saturation temperature with respect to a given pressure. Saturated steam, e.g., with a temperature of 115° C, should have a pressure of 1.7239 kg/cm², according to the steam content table. Superheated steam is unsaturated (in this example, its relative humidity is 1.032/(1.7239 = 0.6); therefore, it tends to bring about an evaporation process, namely, to absorb the steam and to heat. In short, it tends to release heat energy by cooling down even before its condensation. Because of its peculiar qualities, it can be employed for the kiln drying of wood.

Vacuum

The distinctive feature of vacuum is that it lowers the boiling temperature of water, as follows:

Absolute pressure (P_0 mm Hg)	*Boiling temperature (t_{eb}° C)*
760	100
355	80
150	60
55	40
18	20

Because of its peculiarity, vacuum has already been applied successfully in the medical and biological fields and in the food industry to dry highly sensitive, perishable materials. Similarly, efforts have been made to apply vacuum to the drying of wood species that are particularly sensitive to high temperatures.

Vacuum drying can be performed either through the evaporation of water or through the sublimation of ice; in the latter case, however, very high vacuum is required (P_0 = 0.2.2 mm Hg), because the operating temperature is −30° C.

High-frequency electric power

Since wood is a strong dielectric, high-frequency current can be applied as a source of heat in the hygrothermal treatment of wood, using frequencies between 2 and 40 MHz.

Internal heating tests have been introduced recently, using microwaves that operate in a frequency range exceeding 900 MHz.

Infra-red rays

Infra-red ray absorption is very high in wood (1 . . . 2μ), but its permeability to these rays is almost irrelevant: they are not able to go any further than 4-5 mm in depth. Wood hardly reflects the rays, so it can be heated without energy losses. Owing to the limited depth of penetration within the wood, the effect and development of the heating process is similar to the one experienced with the propagation of heat by convection or by contact.

Liquids

Among the various hydrophobe liquids (liquids that do not mix with water), those with a boiling temperature higher than that of water are used: flax oil, coal tar oil and, above all, the solid residues of petroleum distillation, which in Italy are usually referred to as paraffins and are composed of paraffin, ceresine and high viscosity oils (basically, a yellow mass that melts at a temperature of 50° C and boils at 250° C). These materials are not toxic; their density is 0.9. The process takes the form of a bath treatment.

Azeotropic mixtures reach their boiling point at a lower temperature than that of their individual components. For example, mixtures containing water boil at temperatures below 100° C (the tetrachloroethylene-water mixture boils at a temperature of 87° C). This specific feature is of great help for eliminating part of the water present in wood, because the mixture vapours condense and, therefore, can be separated.

Polar hydrophile organic solvents, which are soluble in water, are particularly suited to eliminate both water and wood extractives. Either acetone or alcohols can be employed for this purpose. After their extraction, the solvents are redistilled (rectified).

Organic solvent vapours

Organic solvents that are not soluble in water, for instance, xylol, toluol, tetrachloroethylene, or fractions of tar distillates having low boiling temperatures, must be used for vacuum drying. The heat of vaporization of these solvents is less than that of water, and the heat transmission coefficients are very high.

Saline solutions

The pressure of the vapour in a saturated saline solution is less than that of steam. For this reason the water flows from the wood into the solution. Salts or hygroscopic compounds such as common salt, urea, treacle or invert sugar or polyethylene glycol are used in two- or even three-component solutions for other purposes besides wood drying, in particular in order to reduce the hygroscopicity of wood and improve its dimensional stability.

Solar energy

The research conducted on the controlled use of solar energy for the drying of timber has yielded positive results. Considering the cost of fuel and electricity used in the kiln drying of timber, the use of solar energy is a cost-effective alternative. Solar energy offers cheaper drying with lower capital costs.

So far, two main categories and a number of subcategories have been identified and experimented with. These are:

(a) Greenhouse types, where part of the kiln structure is transparent (translucent). These can be simple enclosures:

- (i) With conventional circulation and natural venting;
- (ii) With fan-assisted circulation;
- (iii) With fan-assisted circulation and humidity/venting control;
- (iv) As (ii) or (iii), but with integral solar collectors;

(b) Kiln chambers with external solar collectors. The solar-energy collectors may be the only means to increase the temperature in the kiln chamber or may be used to supplement other conventional heat sources. The collectors can either be fluid- or air-cooled.

In general, solar dryers range from low-cost transparent or translucent tent-like structures to fully engineered kiln structures with microprocessor control.

Natural seasoning

The main purpose of seasoning is to reach the degree of humidity at which the wood is safe from deterioration caused by micro-organisms and insects (18-20 per cent).

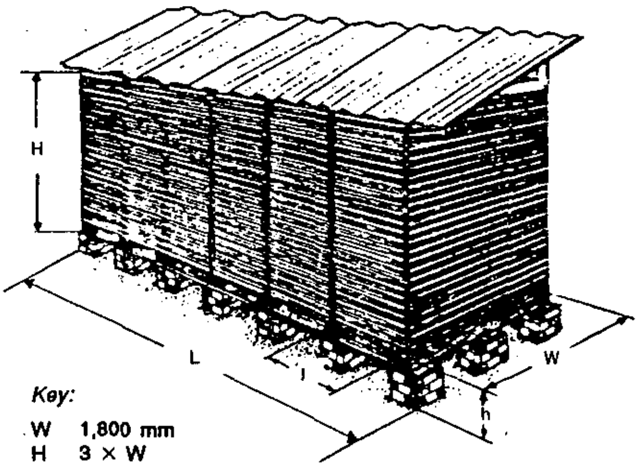
The minimum moisture content attainable through seasoning depends on micro-climatic and other local conditions and is likely to vary between 8 and 20 per cent, depending on seasonal trends. The humidity of seasoned wood left in the open air varies during the year according to climatic changes.

Sawn lumber is usually left to season in open yards, which are selected on the basis of their drying factors and laid out in fields and sectors in which the wood piles are placed. Partition corridors and wider passages for transport of sawn wood should be placed between the various sectors. The land should be consolidated, made thoroughly level with a suitable inclination for draining the discharge and rain waters and cleared of any existing vegetation or other organic matter.

The size and number of the piles depends on the haulage system and on climatic conditions: the more ventilated and drier the area, the wider the stacks (1.2-4 m). On the other hand, the distance between piles ranges from 0.75 to 2 m. The direction of the boards should be established in each separate case, depending on the direction of prevailing wind. A recommended stack construction is shown in figure 2.

As soon as it is sawn, the lumber that is to be seasoned should be brushed and cut to the length of the piles. Lumber subject to deterioration and biodegradation, as well as any subsidiary material, should be treated with antiseptics. This applies especially to the kinds of wood that are more likely to be attacked by fungi. The lumber *piles should always be covered, and any high-quality* material should be suitably protected at the cross-cut ends.

Figure 2. Recommended size of a pile for the air drying of wood



Key:
W 1,800 mm
H 3 × W
h 300-500 mm
L Length of boards
l 600 mm

The piles should be placed on concrete pillars and cross-ties made of (treated) wood or reinforced concrete. Thus, the bottom boards are roughly 30 cm above ground level.

The piles should be covered with roofs of the weathered type so as to permit aeration and also to protect the sides of the piles from rain and sunlight. Piles that are too exposed to sunlight should be entirely protected along the sides by means of rejected boards etc. The planks in the horizontal rows are spaced out, and the damper the climate, the wider the space between one board and the next should be (a vertical empty space can possibly be formed at the centre of the stacks). The piles may reach up to 7 m in height, but they usually do not exceed 4.5-5 m. Each stack should include only wood of one species, and it should have the same thickness and initial moisture content.

Lumber can be stacked in other ways, depending on specific requirements. "En boule" sawn lumber is stacked following the original position occupied by each board in the log; the splined friezes are stacked together in piles up to 7 m long and up to 1.5 m wide, sometimes standing on edge in order to dry more quickly. If they are very short, semi-finished boards are arranged with a given distance between them.

High-quality lumber is seasoned in sheds (or under fixed protective roofs) provided with adjustable openings in order to ensure good air circulation. Methods for enhancing the seasoning process are: standing the boards upright (for pre-seasoning species of wood that have a high moisture content and are likely to darken in colour such as birch, maple and poplar); compression and centrifugation, possibly combined with the action of gravity; artificial ventilation; and solar energy. These methods, however, are applied only in special cases because they usually entail higher costs.

Bulk-storage capacity for seasoning is highly variable, because *it depends on a number of factors connected with* stacking. On average, however, standard boards in piles 5 m high require a capacity ranging from 0.5-1 m^3 per m^2 of yard area.

Kiln drying

In practice, industry basically adopts three kiln-drying methods: *(a)* conventional drying; *(b)* condensation drying; and *(c)* vacuum drying. Other drying methods, even though technologically advanced, such as the saturated-steam method and the high-frequency method, are used only in exceptional cases. The condensation and vacuum-drying methods, which are adopted at present, were first introduced and developed in Italy.

Conventional drying

A so-called classical (or conventional) dryer is one in which the air is recirculated artificially, heated through steam or hot water radiators and conditioned through a partial change of the air itself and in which the wood is dried at a temperature between 40° and 100° C. (A typical small-size conventional kiln is shown in figure 3.) Air fulfils a two-fold function: heating by convection and discharging the water (vaporization). If necessary, the air is humidified through the injection of steam or nebulized water.

From an economic point of view, drying by convection is the most profitable method, especially in order to save energy. This drying method consists of closet or conveyor ovens made of stone or sheet iron and fitted with machinery for recirculating and conditioning the drying means (air). Both the closets and the conveyors must be waterproof, corrosion-resistant and insulated in order to avoid losses of heat, condensation and imbalances in the air-conditioning process. The types of construction vary considerably, especially as far as the position of the fan is concerned. All types perform well as long as the air circulates uniformly through the stack.

Chamber tunnel dryers equipped with overhead fans are the most widespread dryers in central Europe, because research there tended to focus on the uniformity of the air circulation in this type of dryer. Moreover, the method *involving a partial change of the air contained in the* dryer has prevailed over the water cooling condensation method. With automation, however, the system based on the continuous measurement of wood moisture is the prevailing one.

Where large quantities of timber are handled with fork (pallet) trucks and pile systems are used, it is most rational to build large cells (or closets) into which the pile can be introduced directly, especially when the boards are of considerable size and density. The capacity of these cells may reach 500 m^3.

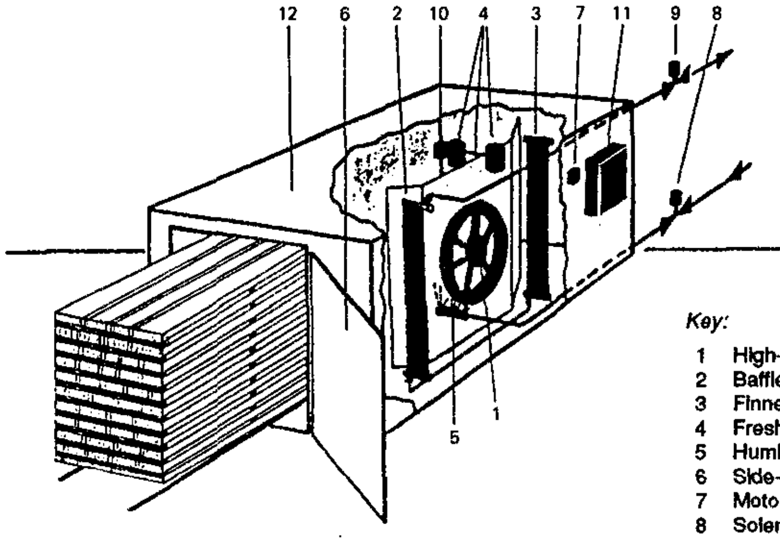
Artificial drying processes include:

(a) A preliminary pre-heating treatment;

(b) The actual drying process;

(c) Several treatments designed to improve the state of the material (the quality of drying), i.e. after-treatment.

Figure 3. Typical small-size conventional kiln

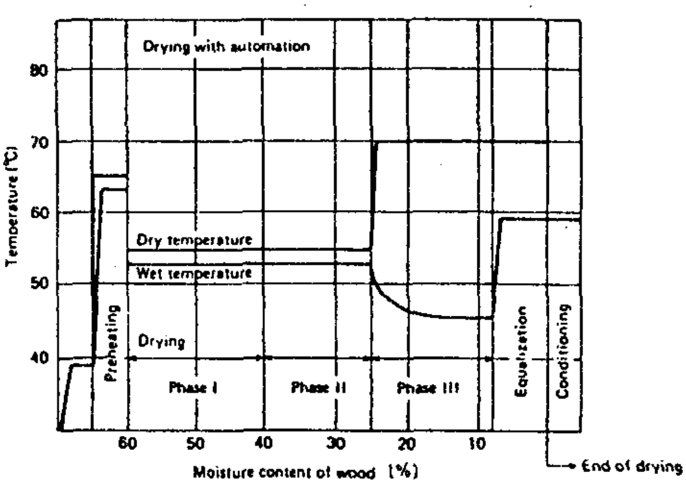


Key:

1 High-capacity axial fan
2 Baffle
3 Finned bimetal heat exchanger
4 Fresh and exhaust-air dampers
5 Humidification spray device
6 Side-opening kiln door
7 Motor protection relay
8 Solenoid valve for spraying device
9 Solenoid valve for heating line
10 Motor for dampers
11 Kiln control unit
12 Insulated kiln casing

A comparison of the temperature versus the moisture content for wood dried with electric control is shown in figure 4.

Figure 4. Temperature versus moisture content for wood dried with electric control



The initial conditions required in order to dry the material successfully are:

(a) The wood characteristics (with reference to permeability and density), the thickness and the initial moisture content should be uniform;

(b) All the boards should be derived from the same parts of the logs and should be without bark and not subject to internal stresses;

(c) There should not be substantial differences in temperature among different parts of a single board.

The pre-heating treatment can be effected simply with the initial drying climate, raising the temperature by 10-15° C. This treatment lasts as many hours as the centimetres of thickness of the wood.

Factors guiding the choice of treatment are the thickness of the boards, the density of the wood, the content of extractives and other substances (grease, oils) and the air circulation speed. The greater the value of these factors, the lower the temperature and the higher the relative humidity of the air. These conditions must be met if the treatment is to be effected successfully.

Modern wood technology has discovered that the drying process should be carried out:

(a) With a constant degree of dryness, at least during the first two phases (the degree of dryness is the ratio between the humidity of the outer layers of the wood and the moisture content equilibrium of the wood with the drying air climate);

(b) With a constant low temperature in the first two phases, increasing the temperature in the third phase;

(c) Keeping the relative humidity of the air constant in the first phase and reducing it progressively in the following phases.

As the drying process progresses, control samples, which should have the same initial moisture content displayed by the test pieces, should be weighed. Where large chambers are employed, the drying process should be managed automatically through the continuous electric measurement of the humidity present in the control boards.

The drying process can also be timed when certain species of wood are treated (Norway spruce and pine as well as whitish tropical hardwoods) and when the dry wood need not be of the best quality.

It is extremely difficult to state in advance how long a drying process should last, because of the number and complexity of the factors involved.

Whatever method is followed for calculating process time, the time should be considered merely a rough estimate. Moreover, calculations may be useful in order to find out where the critical points are reached and to control the final stages of the drying process, even though contact with the real process is lost.

In spite of the care with which the drying treatment has been carried out, at the end of the process boards often have different moisture contents and a more or less sharp humidity gradient is found in the cross-sections of the pieces with ensuing stresses on the inner layer. This is why the material should undergo equalizing and conditioning treatments.

Usually only the humidity-equalizing treatment is applied. The purpose of this treatment is to ensure that all the planks have a roughly equal humidity content. The final moisture content required for the wood is obtained through the use of conditioned air while, simultaneously, raising the temperature.

The final conditioning treatment is designed to equalize the humidity contained in the boards by reducing the sharpness of the humidity gradient. In particular, this treatment is required for eliminating water pockets (in silver fir or oak) and final stress. It is carried out through the use of very hot and wet air (the air humidity should be 3-4 points higher than the average humidity present in the wood). This operation is more likely to be successful if performed towards the middle of the third phase rather than at the end. The treatment is also useful for sterilizing and eliminating moulds that may appear in the course of drying.

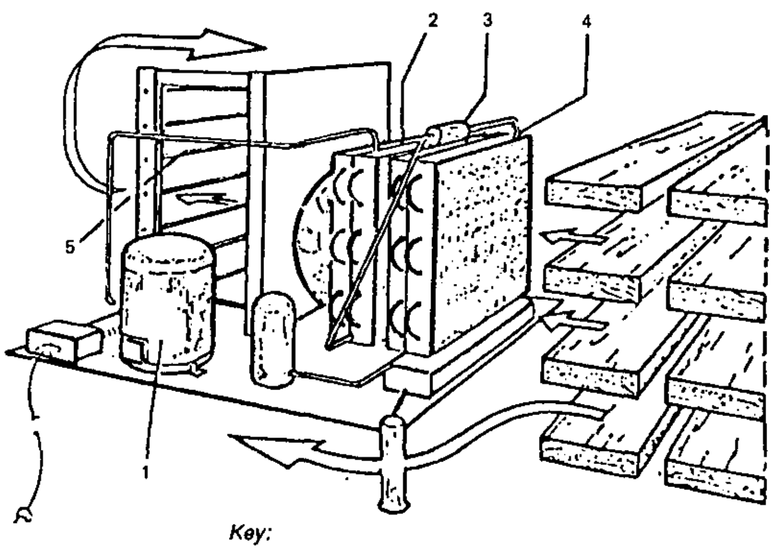
Kiln-dried lumber should be stored in places where it is not subject to seasonal climatic changes. In particular, boards that are very thick and are to be subjected to further resawing and cutting should be stored for some time after drying, as the elimination of stresses in the dryer, which is absolutely necessary in these cases, entails high costs and is difficult to achieve. The stresses present in stored lumber lessen over time as the tissues undergo slow plastic deformations. If the humidity is not too low (12-14 per cent) and the boards are stacked in contact with one another, the material can be stored in closed stores with adjustable ventilation. If, on the other hand, the percentage of humidity is low (6-8 per cent) and the lumber remains stacked when it leaves the dryer, the store should be supplied with air-conditioning facilities. The relaxation of stresses is best in stacks where the planks are in contact with one another.

Condensation dryer and drying method

Condensation dryers and the condensation drying method were successfully introduced about 25 years ago; at that time, the method was publicized as a stabilizing treatment. The condensation drying technique is based on the same principles as the conventional partial air-change technique. Here, too, the drying means is air, which circulates through the wood stack at normal atmospheric pressure and causes the water to vaporize through the surface of the wood, as the convection (exchange) of heat takes place.

The dryer is composed of a chamber, in which the sawnwood is stacked and of a drying machine. The latter, in its turn, includes a heat pump, a recirculation fan, a compressor, a condenser, an evaporator and an additional heating set. The whole unit is enclosed by a sheet-metal casing. Some of these parts are shown in figure 5.

Figure 5. Condensation dryer



Key:

1 Compressor
2 Condenser
3 Exapansion valve
4 Evaporator
5 Supplementary heater

From a functional point of view, there are two different systems, one is based on a partial recirculation of the air through the drying machine and the other involves the total recirculation of the air through the drying machine.

The following steps comprise the first system:

(a) The air penetrates into the wood stack in relatively dry conditions;

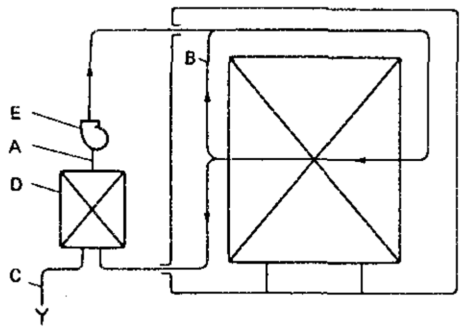
(b) The air that comes out of the stack has a lower temperature and a higher degree of humidity;

(c) Part of the air is sucked in and passes through the drying machine, while the rest continues to circulate in

the chamber. The air that passes through the machine is cooled until it reaches its dew point or an even lower temperature; this leads to the condensation of the humidity contained in the air; thus, the initial conditions (in point *(a)*) are restored (see figure 6);

(d) The air must be heated until it reaches, in the mixture, the initial conditions of point *(a)*.

Figure 6. 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

In total recirculation dryers, the initial conditions are restored by heating all the air in the drying machine. The system involving the total recirculation of air throughout the stack has several advantages, namely:

(a) All the various parts of the machine are included in a single casing, which can be connected to the chamber without further assembling;

(b) All the controls are placed together;

(c) The climate can be adjusted more readily and more efficiently.

Also, higher drying temperatures and better air-conditioning can be obtained without having to install additional equipment inside the chamber. One disadvantage, however, is that it is much more difficult to distribute the air evenly throughout the stack. The machine can be fitted either inside the chamber or outside it.

Condensation dryers have developed considerably since they were first invented. In their first stage, condensation dryers were constructed with extremely low air-circulation speeds, and their working temperatures did not exceed 35° C. Both the dryer and the additional set were powered only by electric energy, and there was no possibility of performing a total conditioning treatment. The drying process was very slow, and the moisture contents attainable were in the region of 25-30 per cent, because the time and costs required for reaching a lower moisture content were too high. In retrospect, this could be considered merely a pre-drying process.

Condensation dryers have since been improved in order to obtain complete air-conditioning (through the introduction of spray nozzles) and in order to operate at temperatures exceeding 50° C. The additional heating unit can operate either with hot water or with steam (which may reduce operating costs considerably), while the air-circulation speed can be programmed according to specific drying requirements. Moreover, where multi-cell units are employed, the heat emitted by the additional condenser can be recuperated and used for heating the other chambers when operating alternatively. Owing to these improvements, the functions of condensation dryers are now very similar to those of conventional dryers. Thus, the condensation drying method is used in almost all the relevant industries. It can be used best with hardwoods and wherever electric power can be obtained at a low cost. Recent designs use the heat pump also for preheating, exploiting the heat of the outside air. Heat-pump condensation dryers have proved exceptionally efficient energy-wise (the total consumption of energy is in the region of 0.5-1.5 kWh per kg of water).

Further developments, especially with regard to temperature, are expected to take place in this field.

Vacuum dryers and drying method

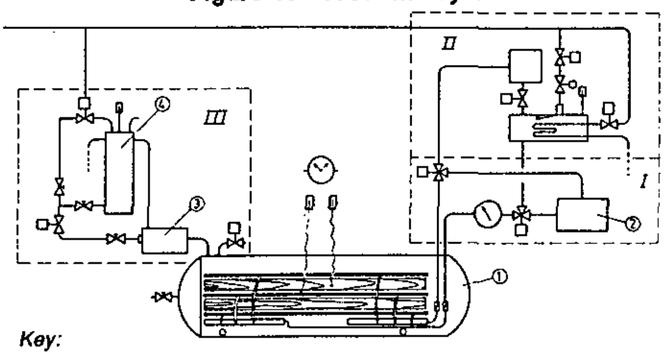
The vacuum-drying method was first used some 20 years ago with the introduction of the first plate-heating vacuum dryers. For a long time interest and research have focused on the drying process. Two main characteristics provided the starting point for further investigation, namely that a pressure gradient leads *(a)* to an increase in the speed of wood moisture movement; and *(b)* to a fall in the boiling temperature of water. Owing to these circumstances, drying time becomes exceptionally short and the quality of drying is improved considerably, especially with regard to the even distribution of humidity in the wood.

The vacuum-drying system that was first used in Italy was based on the repetition of the following three-phase cycle: *(a)* contact heating by means of the hot water plates; *(b)* cooling of the surface of the lumber; and *(c)* vacuum pumping up to 20-40 mm Hg, condensation occurring in the circuit of the vacuum pump equipped with a condenser and, partly, on the lining of the autoclave.

Tests carried out in the course of several years have shown that, through contact heating, drying can be performed as an almost continuous process. The method now consists of two-phase cycles, namely a vacuum-pumping phase and a subsequent phase during which this operation is stopped. The heating operation is continuous. In a recent design, the vacuum is continuous and the steam condenses in the cylinder placed above the water-cooling set (figure 7).

A further contribution to the development of this system has been made through the introduction of convection heating with conditioned air circulated artificially (figure 8). The wall of the autoclave acts as an air-heating unit, which is heated by the hot water (or steam) that is introduced through the interspace formed by another external cylinder. The air is moistened through steam spraying. The cycles are two-phased: *(a)* heating by means of air that is recirculated through side fans; and *(b)* vacuum pumping, during which vaporization occurs. Steam mixes in the pump with the relevant liquid and is condensed in a heat exchanger; finally, the condensate is separated from the liquid. Through the heat exchanger, a suitable way of recuperating condensation heat has been found, because it can be used to heat the water contained in the heating circuit. It has been discovered that, in an alternating two-cylinder set, the heat obtained through recuperation is sufficient for heating the wood. Therefore, once the first heating operation is carried out, the boiler can be cut out from the heating circuit of the dryer. Efficient insulation is of great importance for this new type of dryer.

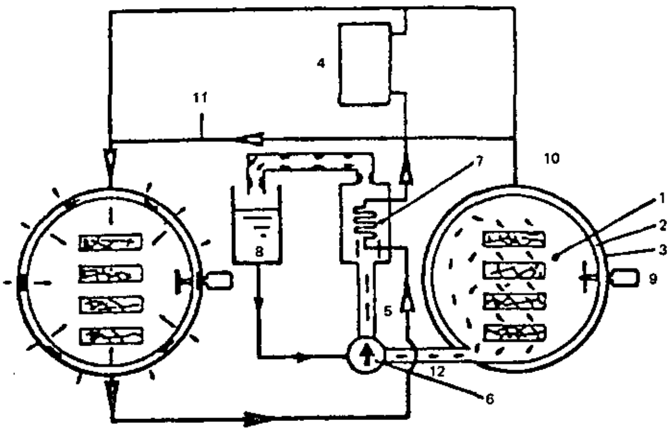
Figure 7. Vacuum dryer



Key:

I Heating
II Cooling system
III Vacuum pump unit
1 Autoclave
2 Boiler
3 Vacuum pump
4 Condenser water feed

Figure 8. 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

Another highly relevant feature of this new system is the possibility of performing the heating operation at temperatures exceeding 100° C, because the steam-liquid mixture of the pump reaches temperatures in the region of 140° C.

The new convection-heating vacuum-drying system ensures high-quality drying that can be seen primarily in the absence of a humidity gradient in untylosed[2] hard lumber (even when the boards are large) at the end of the drying process. Another advantage is the system's ability to carry out final treatments and hence improve the state of species of wood with vessels that are obstructed by tyloses. The material can be heated with conditioned air. The transport, loading and unloading operations are simplified, and plate maintenance costs are eliminated. Total drying time is reduced, although the heating phases last somewhat longer. The versatility of the vacuum-drying system is thus increased considerably and is in a position to deal with almost all possible situations. Its radiant efficiency is also exceptionally high, owing to the recuperation of heat through the connection of the heat exchanger, and it can be almost total, as in the heat pump.

Automation of the drying process

Recent efforts, at both the experimental and productive stages, to automate kiln drying are based on one of three methods used for recording variations in the state of the material while it is in the chambers:

(a) Weighing the whole stack of lumber with the application of so-called "load cells";

(b) Measuring pile shrinkage;

(c) Continuously measuring the moisture content of the wood and of the climate through electric resistance (conduction).

The third method is the one usually adopted in industrial practice because it is the most flexible, if not the most accurate. An electronic computer controls the drive units in accordance with drying programmes that are stored or periodically modified. The development of this system has paralleled the development of electronic computer systems, with a gradual reduction in system rigidity, resulting in losses of time and energy. Today the problem of rigidity and uncertainty in measuring the wood moisture content above the saturation point of the cell walls has been dealt with by micro-processors. A terminal video system has been introduced recently; besides enabling the storage of the desired programme, it is capable of supplying multiple information processing.

There are two fundamental drawbacks to the automation of the drying operation however. First, the field of measurement is limited by the point of saturation of the cell walls, and, secondly, measurement itself is unreliable when salts are present. Micro-processing techniques are being used to cope with these problems; however, they should be taken into account. Problems with automation that have been observed also in the conventional types of dryers are that:

(a) Automation often slows down the pre-heating phase, especially if there is not enough steam available for moistening the air;

(b) The conditions underlying the conditioning treatment as performed by existing automated systems have no clear technological foundation. In fact, this operation is something between an equalizing and a conditioning treatment, and, what is worse, it is timed;

(c) Probes often show inaccurate values for average wood moisture and exceedingly high values for tropical types of wood that contain salt. Hence, drying time is increased;

[2]Lumber with vessels that are completely clear of any obstruction owing to tyloses.

(*d*) The printed electronic cards are subject to wear, and the instruments often deviate from their original calibration.

In any case, automation does not replace people, and these processes cannot be managed without human intervention. Automation has proved very helpful, however, and has greatly increased operational safety, particularly where the climate must be kept constant. The determination of initial and final moisture content for large and dense lumber piles, tensile tests and the determination of the humidity gradient in the wood are still the basic conditions for ensuring high functional quality. Automatic apparatuses must constantly be checked and calibrated, and control boards must be used in order to make sure the desired results are obtained. Hence, the reservations expressed by Italian manufacturers with regard to total automation are justified. The industries producing dryers and automatic equipment should be more responsible when advertising their products; statements to the effect that dryers equipped with automatic apparatuses do not require qualified operators cannot be accepted.

Selecting a dryer and drying system

There is no general rule for selecting one dryer rather than another one. The actual conditions of each dryer must be appraised carefully, especially from the point of view of savings and capacity. Above all, the ratio between the costs of mechanical energy and heat energy should be considered.

The criteria in this section are based on the experience of the author and are based on specific conditions, namely the low cost of heat energy obtained through the recuperation of waste and the high cost of electric energy. In Italy these ratios vary between 1:5 and 1:20 (table 5).

Table 5. Comparison of three main lumber-drying systems

(1 is the lowest score, 3 the highest)

Characteristic	*Classical dryer*	*Condensation dryer*	*Vacuum dryer*
Investment	2	3	1
Assembly	1	3	2
Maintenance	2	3	1
Universality	3	2	2
Flexibility of capacity	3	3	1
Ability to deal with:			
Hardwood with vessels obstructed by tyloses	1	3	2
Hardwood with vessels that are not obstructed by tyloses (hard)	1	2	3
Hardwood with vessels that are not obstructed by tyloses (soft)	2	1	3
Conifers	3	1	1
Speed of drying	2	1	3
Quality of drying	2	1	3
Discharge of oils and resins	2	3	1
Chromatic alterations	1	3	2
Sterilization, moulds	2	1	3
Equalizing	3	2	3
Conditioning	3	1	3

As far as cost is concerned (capacity being equal), the condensation dryer is in first position, followed by the classical type of dryer and by the vacuum dryer, which is the most expensive. The productive capacity of the dryers is the reverse.

As to the costs entailed by drying all types of permeable wood (i.e. with vessels that are not obstructed by tyloses), the vacuum dryer is certainly the most advantageous, the condensation dryer is best for hardwoods with low permeability, and the classical dryer is best for softwoods (conifers and light hardwoods).

Condensation or classical dryers are best where considerable drying capacity is required.

As to drying speed, vacuum dryers are the fastest; the classical and condensation dryers follow in that order. However, condensation dryers perform just as well as the classical dryers for drying wood with low permeability, since in both cases relatively low temperatures must be applied.

As far as the quality of drying is concerned, vacuum dryers seem to perform best. Condensation and classical dryers attain theoretically equal performance levels, and condensation dryers ensure better conduction for hardwoods because they operate at relatively low temperatures.

Considering the extremely great variety of wood species that must be dried, classical dryers prove to be the most adaptable (i.e. the most universal) ones; vacuum dryers are second, and condensation dryers are third.

Condensation driers are the simplest to install. Standard versions do not even require the installation of a boiler. Vacuum driers follow, while classical dryers are the most difficult to install. Standard vacuum and classical dryers require a boiler.

Climate adjustment is more accurate for total-conditioning condensation dryers, especially during the summer when the temperature and the humidity of the surrounding air are rather high.

Vacuum dryers are the best for extracting and bringing oils and resins to the surface; classical dryers are second best, and condensation dryers are the least effective. Vacuum dryers are the best for sterilizing the wood and protecting it against moulds; condensation dryers are the least effective in that connection. From the ecological point of view (pollution of the environment), condensation dryers are better than conventional dryers.

Condensation dryers require less maintenance and fewer repairs than the other types of dryers.

The first step in the design of a drying system should be to calculate the capacity and the economic costs as a function of the actual production planned (quantity, ratio between species and specifications, initial and final moisture content of the wood, required quality of drying) for different drying systems and drying methods. A rational choice is always based on the adoption of a single drying system. The size of the chambers should be a function of: (*a*) the daily capacity of the production cycle; (*b*) the transport system; (*c*) the size of the wood; and (*d*) the size of the stack. Any plan that may require a change in the direction of the piles or restacking should be ruled out.

Where large volumes of wood, especially hardwoods, must be dried, a small additional dryer, operating on the same system as the main one, should be added to carry out preliminary tests to ascertain the most suitable conditions of treatment.

The data (prices, time values, energy consumption) supplied by manufacturers and research institutes can be used for the economic and capacity calculations. Data concerning drying time that were made available by dryer manufacturers are shown in tables 6 and 7.

Table 6. Estimate of the time required (hours) for attaining a 10 per cent final moisture content using a vacuum dryer

	Thickness of wood with 80 per cent initial moisture content				*Thickness of wood with 40 per cent initial moisture content*			
Species	*30 mm*	*50 mm*	*70 mm*	*90 mm*	*30 mm*	*50 mm*	*70 mm*	*90 mm*
Quercus robur, chestnut, red lauan and other impermeable species	230	350	—	—	120	170	210	240
Beech, walnut, hornbeam, cherry, sipo, African mahogany	110	138	182	218	57	75	104	130
Ash, maple, afrormosia, bété, white lauan	46	122	158	194	48	70	96	122
Douglas fir, pines, larch, obeche	67	82	108	132	37	53	73	92

Note: Pre-heating time is not included.

Table 7. Estimate of condensation drying time during peak production periods

(Hours)

(Final moisture content = 12 per cent)

	Thickness of wood with 80 per cent initial moisture content				*Thickness of wood with 40 per cent initial moisture content*			
Species	*30 mm*	*50 mm*	*70 mm*	*100 mm*	*30 mm*	*50 mm*	*70 mm*	*100 mm*
Fir, cedar, Swiss pine, Douglas cypress, larch, pine, pitch-pine, birch, hornbeam, mulberry, ilex; French elm *(Ulmus campestris)*, alder, poplar, willow, linden, jelutorg, light-red meranti, sepetir, seraya, torentong	8-10	12-15	16-18	21-23	4-5	7-9	12-14	14-16
Fromager, balsa wood, dibetou, obeche (Samba, Ayous)	8-10	12-15	18-20	21-29	4-5	7-9	12-14	14-16
Chestnut, cherry, beech, ash, apple, walnut, wych-elm *(Ulmus montana)*, dark-red meranti, mengkulang, kauri kempas, keruing, Ramin, teak, nyatoh, kalam, abura, bossé, aiélé; framíre, limba, sipo, niangon, padouk, mecrusse, tiama, mahogany, sapelli, bété	10-12	13-16	20-22	23-25	6-7	8-11	14-16	16-18
Maple, Turkey oak, eucalyptus, locust, English oak, pear, olive, balau, lauan, kéranj, merawan, ebony, bété, iroko, mugwort pau, rosewood, ramin, sandalwood, afrormosia, teak, aningré, doussié	12-13	15-18	22-25	26-28	8-9	10-12	16-18	18-20

XXII. Wood preservation*

Introduction

The steady increase of wood consumption, on the one hand, and the general impoverishment of natural forest resources, on the other, means that wood production must be increased by rational reforestation and by industrial plantations. Furthermore, the wastage of raw material must be eliminated, and the life of lumber used in construction and joinery must be prolonged as much as possible.

Specialists in the field of wood preservation must defend wood from all the various causes of deterioration and destruction in wood: bacteria, fungi, insects and mollusc and crustacean marine borers (the latter two attack wood in salt water). The problem of protecting living trees from attack by insects and fungi that may kill them sooner or later and damage the wood is a problem for phytopathology, entomology and forestry to handle. In this chapter, only the methods of protecting wood from the different agents that attack it are discussed.

Specialists in wood preservation must have exact knowledge of the relationship between the tree, the wood, the environment and the biology of the destructive organisms (often incorrectly called "xylophagous"). From the time the tree is felled to the time its wood is used, there are a succession of phases in which there is danger of deterioration. The deterioration varies both in type and in seriousness, and the specialist therefore must be prepared to solve many different types of problems.

Since most of the developing countries are in tropical or subtropical areas, the problems concerning woods that come from those areas will be emphasized in the present chapter. Special consideration will also be given to the fact that in many developing countries it is often difficult to install expensive equipment that has to be run by specialized personnel.

Treatment stages

Felling and transport of wood from the forest

In all the forests of the world, both in the temperate zones and in the tropics, standing trees are subject to attack by many types of fungi and insects; once the moisture content of the wood has been lowered (by air or kiln drying) to less than 18-20 per cent, however, all fungi and most insects cease their activity. The most common type of attack is by insects of the Platypodidae and Scolytidae families, the ambrosia beetles. The tunnels dug by these insects are less than 2 mm in diameter, and they are almost always surrounded by a blackish halo caused by the fungi these insects feed on. The large number of tunnels and the blackish colour seriously damage the wood. While there is no preventive treatment for live trees, once the trees have been felled and the wood is being dried the insects die for lack of food (the fungi cannot thrive) and the attack is stopped. Drying is really the only necessary treatment.

Attack by powder-post beetle (Lyctus) is much more serious. These insects are smaller (maximum 2 mm wide and 6 mm long), and they can attack freshly cut wood, which is still full of sap, or wood that has been partially dried. They are very common in the tropics in all forest residues and in log and lumber yards. Hardwoods with large enough vessels and with a high content of starch (which the larvae feed on) are subject to attack by powder-post beetles. Many wood species fall into this category: obeche, limba, ilomba and fromager in Africa; meranti, lauan, jongkong and jelutong in Asia; and abarco, assacu, bacouri, caixeta, carano, copaia, marupa, sande and virola in Latin America.

Attacks of powder-post beetles occur on a large scale and can cause very serious damage during all phases of production. If a wood preservation treatment is planned for finished products only, there is a risk that the wood will already be seriously damaged when it reaches the production line. Treatment must start immediately after the tree has been felled; a delay of only 15-20 hours may mean that the treatment will not be effective. Thus, it is highly recommended to treat logs on the day the tree is felled and bucked.

The treatment consists of spraying or brushing the preservative on all the surfaces where the wood has been bared: both ends of each log; where branches have been cut off; and at each point where the bark has been damaged and the bare wood shows. For obvious reasons, the preservative should be water-resistant, preferably of the oil type. Preservatives in powder form that can be dissolved in water or organic liquids can be found on the market. This type of preservative, however, does not give a constant performance because it can be washed away if the solvent is water and because some petroleum-derived solvents attract insects when the preservative has leached off.

If the logs are going to be hauled by vehicle, there is no point in debarking them; if they are going to be floated or if they will be in sea water for some time before being loaded on board ship, it is advisable to debark them and treat the whole log with a perfectly water-resistant product. An atomizing hand pump or, better yet, a compressed-air spray gun is used to treat the logs. This equipment must resist corrosion by the preservative used.

Log storage before sawing and peeling

If logs are to be exported and stored in a country with a temperate climate, the danger of new attacks by insects or fungi is quite small and there is no need to treat them

*By G. Giordano, professor of Wood Technology and Forest Utilization, University of Florence, Italy. (Originally issued as ID/WG.369/1.)

again (if they were properly treated after felling). If logs are to be stored in a hot and humid climate, however, the danger of a new attack persists. In order to keep this danger to a minimum, the following general rules for the rational management of log yards should be followed:

(a) All the bark and all types of waste (edgings, sawdust etc.) should be burned;

(b) Very good soil drainage should be provided in order to prevent the formation of a humid environment around the logs at the bottom of the piles. If it is impossible to place a layer of concrete over the whole surface of the log yard, the ground must at least be covered with well-washed pebbles or clinker;

(c) The piles of logs should be treated periodically (at least two or three times a year) by nebulization. All the wood structures in the yard (beams, supports etc.) must also be disinfected.

The best system for preserving logs is still immersing them in sweet water; the water in the basins must be changed periodically.

Machined wood

To protect wood against fungi attack, it must first be dried properly to less than 16 per cent moisture content. If the ambient humidity is higher and the wood has a higher moisture content (wood in contact with the ground or exposed to the weather), an appropriate treatment will be necessary. To prevent attack by insects, all types of wood that do not have a natural resistance to them have to be treated, regardless of the final use. In order to avoid treating the wood twice, a special mixture of preservatives can be used to give double protection against fungi and insects.

Methods of application

Sap displacement process

For small posts or poles (less than 12 cm in diameter and less than 5 m long) rather satisfactory results can be obtained by dipping the material vertically for at least six tenths of its height in a preservative solution of water-soluble salts. The essential conditions for this treatment are: the wood must have been cut very recently (not more than two days before); and it must have all its bark, branches and leaves. The preservative displaces the rising sap and penetrates deep into the wood. When the leaves have withered, the wood is removed from the solution and the crown and the branches are removed. The logs are then piled up under a plastic covering and left for 15 days to allow the product to penetrate completely. Best results can be obtained by dipping the wood in the solution again after the branches have been removed with the small end down.

For this type of process a tank with a 200-250 litre capacity is needed. If the poles are rather large and weigh more than 50 kg each, a small scaffolding will have to be built around the tank, and a small swivelling crane should be mounted on it for handling the poles.

For larger poles (for power lines, for example) a modified Boucherie process is often used. Originally, this process was used for standing trees: a cut was made around on the tree and the antiseptic was sucked up. Practical application of this process proved to be rather difficult, so yards were developed in which the poles with the bark still on them are placed on supports that hold them in a slightly inclined position with the small end down. A rubber bag, or better yet a tightly sealed metal cap, is attached to the large butt, and the preservative is fed under pressure, either by raising the preservative supply tank or by using a pump. This process is particularly suitable for softwood poles; the equipment is not sophisticated and is very easy to build.

Pollution caused by the preservative that runs out of the small end of the poles is limited but hard to eliminate.

Osmosis process

The preservative can be applied to limited areas, and it penetrates deep into the wood by osmosis. This type of treatment is used only for poles. The preservative can be a paste that is applied to the base (or the whole surface) and both ends of the poles, or it can be applied in the form of bandages (which must be protected from rain by a waterproof covering). Neither of these methods requires any tools.

With the cobra system, the preservative is shot into the wood by a lever-operated metal syringe.

Pressure-application processes

There are several pressure treatments, which can be broken down according to the initial pressure conditions (with or without initial vacuum).

Initial vacuum

An initial vacuum can be used to achieve maximum penetration of the preservative; this is called the Bethell or full-cell process because the preservative almost completely fills the cell cavities. It is often used for treating power-line poles, mine timber, railroad ties, posts and other structural elements exposed to particularly difficult conditions (e.g. cooling towers).

Wood is placed in a vacuum (from −400 to −600 mmHg) for one hour. The preservative is applied and the pressure is brought up to 10-12 atm for two hours. The wood is again subjected to a vacuum (−600 mm Hg) for about one hour to recover some of the preservative. Preservatives are generally creosote heated to about 100° C or salt solutions or mixtures. The equipment is basically the same as that used for the pressure-application process without an initial vacuum (see below).

An important variation to this method consists of using pentachlorophenol dissolved in a solvent with a high vapour pressure at room temperature, such as butane. In this case the pressure need not exceed 7 atm but the vacuum must be applied gradually and it should be held for three hours.

Tributil-tin oxide from liquid petroleum gas (LPG) can also be used. This process, called Drylon in Europe and Cellon in the United States, is particularly suitable for poles and construction timbers made out of wood species that are hard to treat with the ordinary systems, but it requires very complex equipment (both to liquefy the gas and to make the plant safe) and perfectly trained workers and technicians.

Without initial vacuum

Processes that do not use an initial vacuum are particularly suitable for applying creosote, which is known throughout the world for its excellent fungicide and insecticide and good water repellent properties, to poles and railroad ties. The most widely used system is the Rüping d'épargne or empty-cell process. The wood moisture content is brought to almost the cell-wall saturation level (about 30 per cent); the wood is then loaded into an autoclave, and the pressure is raised to 3-4.5 atm. Creosote at 105°-110° C is fed in under pressure of 7-10 atm, and this pressure is maintained for at least 45 minutes (up to three hours for difficult-to-treat woods). The preservative applies the same pressure on the air inside the cells, and it partially fills the cell cavities. When the vacuum (−600 mm Hg) is applied after the compression phase, the air escapes and most of the preservative leaves with it, leaving a thin layer on the cell walls, which is sufficient to give the necessary protection.

Several modified versions of this process are used:

(a) Repeating the whole cycle after the first impregnation has been completed (for difficult woods);

(b) After the empty-cell treatment with creosote has been completed, the wood is impregnated by the full-cell process with a hot solution (60°-70° C) of sodium fluoride;

(c) Wood is preheated in creosote if there is no possibility of drying it before treatment;

(d) Incising the lumber to improve penetration.

The following plant and equipment are required for pressure treating with creosote:

(a) An autoclave that is properly equipped so it can be connected to:

A preservative storage tank
Equipment for measuring the quantity of preservative
A tank for heating the preservative
A compressed-air tank

(b) Necessary valves, piping and fuses;

(c) Two pumps, one for transferring the creosote and one for compressing the preservative;

(d) A vacuum pump for the final vacuum.

The autoclave must be airtight, but it should also permit rapid opening and easy access for the carts on rails on which the lumber is stacked.

Personnel requirements include a specialist to run the heating equipment and an experienced technician capable of controlling all the details of preservative retention and of guaranteeing perfect plant operation and maintenance.

The use of creosote does not create any real pollution, but the autoclave, the tanks and the piping have to be cleaned frequently so the surfaces near the plant become covered with layers of sticky dirt.

Pressure processes can also be used with salt-based preservatives or soluble or emulsifiable products. Since in this case the preservative does not have to be heated, the plant can be simplified by eliminating the heating equipment (and the specialist to run it). There are two other advantages: shorter cycle times and the possibility of using mobile plants with limited capacity. Energy can be supplied by a diesel engine or by a tractor power take-off.

One variation of the classic pressure process is the Lowry process, in which the preservative is fed into the autoclave without compressing the air beforehand.

Dipping processes

Dipping lumber in a preservative solution is the simplest means of protecting wood from attack that may occur after it is in use. The duration of this process depends on the penetration rate of the preservative in the wood species and on the required depth of penetration.

Dipping equipment is relatively simple; it can consist of a manually operated vat with a triangular cross-section for dipping the lumber or a mechanized conveyor chain. Both need to ensure complete immersion. This equipment is shown in figures 1 and 2.

Figure 1. Dipping vat with a triangular cross-section

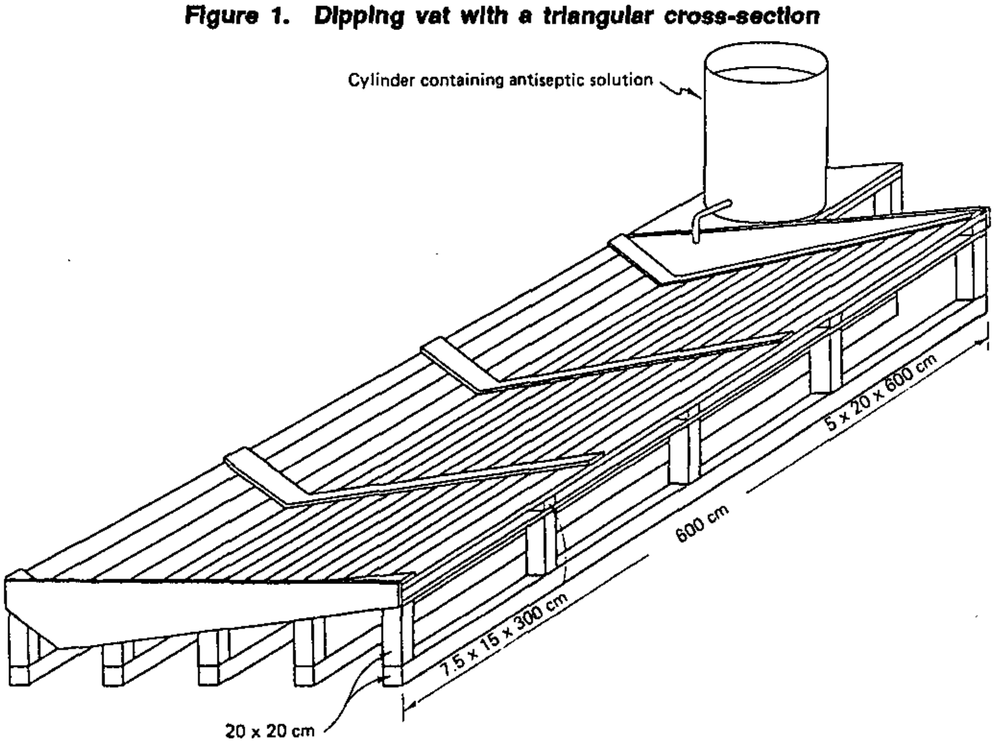
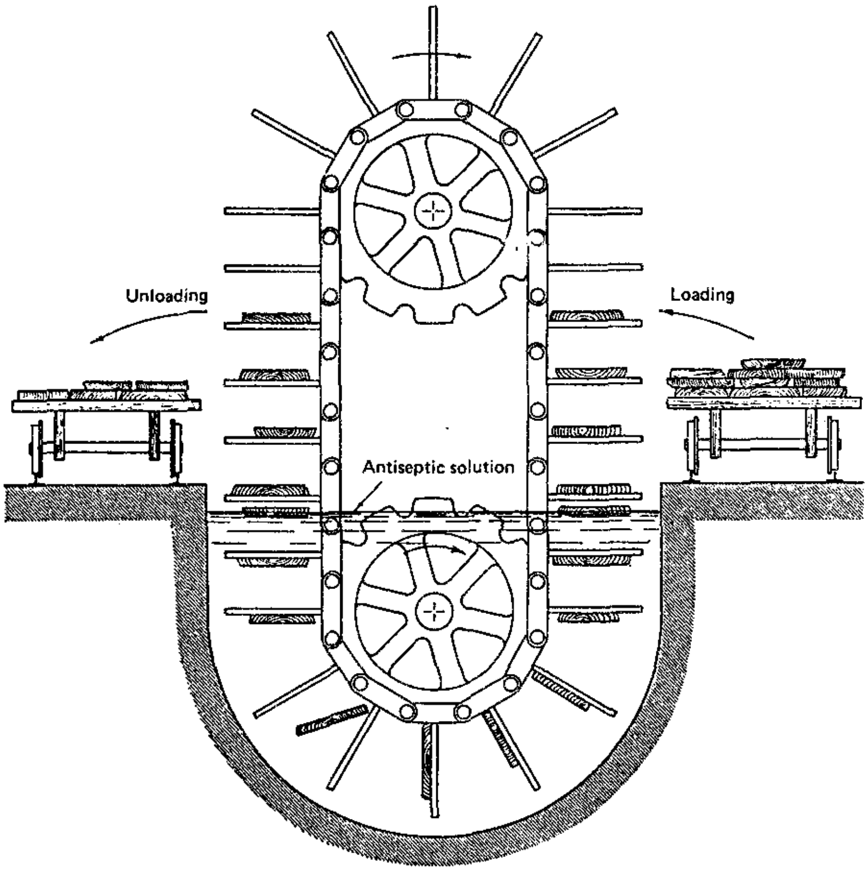


Figure 2. Mechanized dipping chain



Hot-and-cold-bath processes represent an improvement on plain dipping. The lumber is heated by steam (or by soaking in hot water) to 70°-80° C, then dipped in a cold solution of preservative. Cooling decreases the volume of air in the cells and improves penetration of the preservative. A rational plant includes: an autoclave for steam heating the wood, which is stacked on carts on rails; a vat for the preservative; and lifting equipment for handling the "packages". The autoclave can be eliminated by heating the wood directly in the preservative solution, which will then have to be cooled. Obviously, this variation has longer cycle times.

Surface-application processes

Surface application processes should only be used for finished products (such as mouldings, wood for joinery etc.) that will not be exposed to very high humidity and for lumber that has to be protected temporarily before its final transformation. Treatment can be carried out by brushing or by spraying. The operation can be greatly simplified by feeding the lumber through a long tunnel in which it is sprinkled from all sides by a series of nozzles. The preservative that is not absorbed runs into a small container at the bottom of the tunnel and is returned to the tank and reused.

Part four

SECONDARY WOOD-PROCESSING INDUSTRIES

XXIII. Materials for surface finishing and appropriate application equipment*

The type of equipment that should be selected for surface finishing will depend on the type of material to be applied and the quality the manufacturer wishes to have. Thus, this chapter begins with a discussion of the composition and types of material that can be applied and the problems that can arise followed by a discussion of equipment. The definitions and descriptions of surface coatings have appeared in wood magazines from the United States of America.

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 (see below) 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 are fast drying owing to evaporation and the formation of uniform films with good physical and chemical properties. These latter properties can be controlled for specific production requirements. The manufacture and control is straightforward owing to the nature of the ingredients.

The primary disadvantages of lacquers are their low solids content and their relatively high cost. A partial answer to the cost and solids content drawbacks has been the development of the 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.

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.

*By G. D. Beccaria, expert in surface finishing. (Originally issued as ID/WG.277/7/Rev.1.)

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 techniques 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, the 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 a failure to maintain the proper distance between the gun and the 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. A 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 that 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 that react most readily and are the fastest drying 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.

There are many problems that occur in varnish application. Most of these relate to faulty application technique or improper handling of the material.

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 is generally 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. 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, 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. 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 lacquer product 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 lacquer products 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 peroxides 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 tremperature 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 lacquer product 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 ultraviolet installations are those for which the absorbed power is lower than approximately 1 watt per centimetre of lamp length. High-power ultraviolet installations are those with lamps whose absorbed power is equal to or greater than 30 watt per cm lamp length.

Table 1. Coating products and the appropriate application technique

	Coating equipment							
Coating/lacquer product	*Brush*	*Spray*	*Airless*	*Roller*	*Roller curtain*	*Curtain, 1 head*	*Curtain, 2 heads*	*Electrostatic spray*
Polyurethane	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Polyester	Yes	Yes	No	Yes[a]	Yes	No	Yes	Yes
Polyester direct gloss	Yes	Yes	Limited	Yes[a]	Yes	No	Yes	Yes
Urea acid catalysed	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Nitrocellulose	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

[a]Only products dryable with ultraviolet heating.

Table 2. Drying conditions for varnish products

	Drying conditions						
Coating/lacquer product	*Drying at room temperature*			*Air-tunnel drying (20°-70° C)*	*Low-intensity ultraviolet drying*	*High-intensity ultraviolet drying*	*Infra-red drying and forced air*
	10°-15° C	15°-30° C	30°-35° C				
Polyurethane	Yes	Yes	Yes	Yes	No	No	Yes
Polyester	No	Yes	Limited	Yes	Yes	Yes	Yes
Polyester direct gloss	No	Yes	Yes	Yes	Yes	Yes	Yes
Urea acid catalysed	Yes	Yes	Yes	Yes	No	No	Yes
Nitrocellulose	Yes	Yes	Yes	Yes	No	No	Yes

For infra-red sources, short, medium and long wavelength may be used in most cases. In the case of ultraviolet and infra-red 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, 1-2 minutes must be added to the times for the cooling with forced air at temperatures not exceeding 25° C. In the case of ultraviolet drying, it is practically impossible to use pigmented products. Generally, 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 have 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.

Drying times for the polyester coating products that give glossy finishes are shown in table 4. 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; in order 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 3. Minimum drying times to obtain opaque finishes for lacquer products

Coating/lacquer product	*Drying conditions*				
	At room temperature (hours)	*With air-tunnel (20°-70° C) (minutes)*	*With low-intensity ultraviolet (minutes)*	*With intensity ultraviolet (seconds)*	*With medium wavelength infra-red (minutes)*
Polyurethane	4-6	12-16	Unused	Unused	8-16
Polyester	2-4	12-16	4-5	5-30	8-16
Polyester direct gloss	24-36	Unused	4-5	5-30	Unused
Urea acid catalysed	4-6	20-25	Unused	Unused	8-16
Nitrocellulose	2-4	12-16	Unused	Unused	8-16

Table 4. Drying times and hardening times at room temperature for gloss finished products

Coating/lacquer product	*Drying conditions*		
	At room temperature (hours)	*Tunnel forced air (20°-70° C) (hours)*[a]	*Low-intensity ultraviolet (hours)*[a]
Polyurethane	24	—	—
Polyester	6-8	1 + 3	—
Polyester direct gloss	24-36	—	0.1 + 2
Urea acid catalysed	—	—	
Nitrocellulose	6-8	0.5 + 1.5	—

[a]The first figure is the drying time; the second is hardening time.

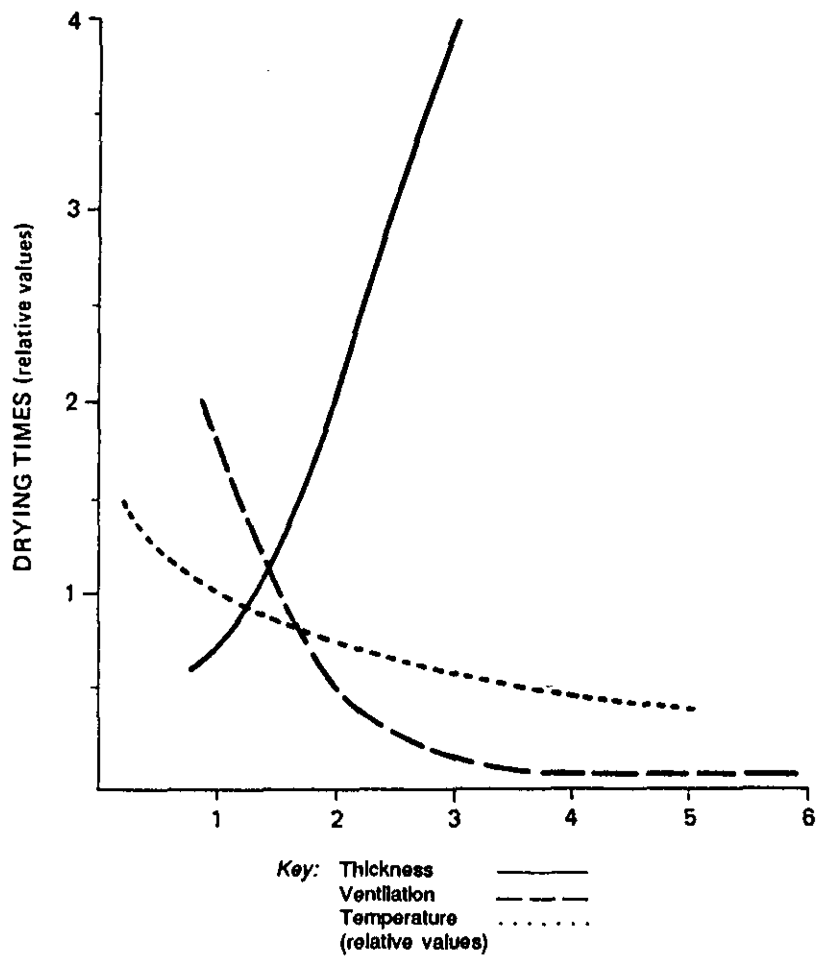
The figure indicates, in a totally qualitative manner, the influence of thickness, ventilation and temperature on drying times. It also highlights the effect of the increase in thickness on drying time. If the thickness doubles, under constant ventilation conditions and at constant temperature, drying time increases three to four 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), 10 m/s could also be used. This is to prevent the air from moving the applied film and giving surface defects.

A qualitative relationship of drying times vs. thickness, ventilation and temperature



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.

With regard to yellowing, a distinction must be made between the yellowing of pigmented products and that of transparent products. In the case of pigmented products, it is important that the yellowing that is due to the binder and to the pigment is 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 ultraviolet rays in sunlight is more important. This protection is obtainable through the addition of suitable ultraviolet 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.

Table 5. Mechanical and chemical characteristics of coated finishings

Coating/lacquer product	*Characteristics*[a]										
	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	O	G/O	O	G/O	O	O	G/E	E	E	S/E	O/E
Polyester	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	G/O	G/E	S/G	G/S	S/G	S	S/G	S/G	I/S	G/O	O/E
Nitro-cellulose	G/O	G	S/G	G/S	I/S	I/S	I/S	I/S	G	S/G	I/S

[a]The following abbreviations have been used:
E *excellent*
O optimum
G good
S sufficient
I insufficient

Table 6. Characteristics of prime coats

Coating/lacquer product	*Characteristics*[a]						
	Elasticity	*Resistance to thermic oscillations*	*Adhesion on wood*	*Inhibition by rosewood*	*Hand sanding*	*Machine sanding*	*Over-spraying*
Polyurethane	O	G/O	O/E	No	G/O	O/E	O/E
Polyester	S/G	S/G	G/O	Yes[b]	I	G/O	O/E
Polyester direct gloss	G	G	G/O	Yes[b]	S/G	G/O	O/E
Urea acid catalysed	S/G	S/G	S/G	No	G	G	G/O
Nitrocellulose	S/G	S/G	G/O	No	O/E	O/E	S/G

[a]The following abbreviations have been used:
E excellent
O optimum
G good
S sufficient
I insufficient

[b]May be applied on rosewood prior to application of a polyurethane sealer.

In particular, the two characteristics that clients seek in a prime base are sandability and resistance to overspray. A good sanding allows work to be done rapidly and a perfect surface to be attained. Good resistance to overspraying prevents the prime coat from 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.

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.

Using table 8, it should be possible to determine approximately the amount of lacquer product and the number of coats necessary to obtain a given filling.

Table 7. Amount of varnish product per coat

Coating/lacquer product	*Quantity (g/m²)*	
	At time of application	*Dry product*
Polyurethane	140-180	60
Polyester	340-380	340
Polyester direct gloss	200-250	180
Urea acid catalysed	120-140	50
Nitrocellulose	120-140	45

Table 8. Amount of coating used (ready at application)

Wood type	*Quantity (g/m²)*	
	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 (annex I) and the questionnaire (annex II) can be used 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, the instructions provided by a reputable lacquer material producer should be followed. 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 aging. In such a case, it is necessary to guarantee both the uniformity of the production from series to series and that artificial aging 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 and several metres wide and long (2 m × 3 m; 2 m × 5 m) are common. It is necessary in such cases to give a 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 the improper selection of coating lines and to a non-functioning production line owing 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 to 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

The choice of equipment for lacquer coating is not straightforward but depends on many factors. Among 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 the 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 quality and productivity.

Another point worthy of consideration is 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 not be 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/m² instead of 110 g/m² 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.

Manual coating operations

The manual application of coating products is used only for work 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.

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 that allow the surfaces to be coated while passing through the opening. The lacquers used are normally nitrocellulose lacquers with a high viscosity.

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. The 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 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.

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 m³/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 and 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-catalysed (synthetics, nitrocellulose) coatings can be sprayed. The results, which may be excellent, depend largely on the 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 the supplier's instructions (pressure of air, diameter of the nozzle, thinner and viscosity of the product). Also important are the correct distance of the spray-gun from the object to be coated and the speed and manner of application. Proper environmental conditions (temperature, ventilation and absence of dust) are necessary for perfect atomization.

The 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 spraying system 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 the 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 now replacing the dry filter systems.

A problem that remains unsolved is that of the disposal of spray-cans for lacquer materials and of the aerosol 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 conveyor belt and made to pass under two to three

adjustable spray-guns so that the piece will be completely coated. The spray-guns are controlled by servo mechanisms. Below the conveyor 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 conveyor belt right below the spray-gun which has adjustable, hydraulically or mechanically controlled alternating 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 conveyor 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. When ambient air conditions are relatively dry, 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 10^9 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 that 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 three dimensional (already assembled) or round items such as furniture legs, chairs, radio-TV furniture, rifle-butts, billiard-cues etc.

Flood coating systems

Dip coating

Dip coating is especially used for objects that have a small section or are 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 does 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 as near to the vertical as possible. 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 pretreatment 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 that have dripped off the pieces; the cover is for use during non-working hours to avoid fire risks.

Flow-coating

The flow-coating method is not normally 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, 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 curtain coating nearly 30 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 angles 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 conveyor 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 conveyor 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 while the polyester containing an accelerator goes into the second head. The normal hardening process of the coat follows.

The coated films obtained through the use of the curtain coater are 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 conveyor 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 smooth or engraved chromed steel; by varying the position to the spreading roll, the quantity of the coating material is regulated. The spreading roll is a rubber-coated steel drum that spreads the material on the product to be coated. The nip-roll is a rubber-coated steel drum that 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 ultraviolet 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/m^2 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 ultraviolet 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/m^2. The maximum quantity to be applied for ultraviolet drying products is from 100 to 120 g/m^2. 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 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 that 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 conveyor 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 ultraviolet. 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 for emissions to be maintained below the maximum permissible concentration (MPC) 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 MPC 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/lacquer product	*Time for satin finish (hours)*
Polyurethane	2-3
Polyester	0.5-1
Urea acid catalysed	2-3
Nitrocellulose	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 conveyor system is a tunnel-type dryer with roller or belt conveyors 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 conveyor type dryers are best used for drying panel products.

Multi-deck drying tunnels are similar to conveyor systems. The conveyor belts are arranged in multi-decks (up to 10). 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 the relatively small floor area it requires.

The vertical merry-go-round system is equipped with trays which are linked together. Completely automatic loading and unloading is maintained by synchronized conveyor 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 m^2.

Coating/lacquer product	*Drying time for satin finish (hours)*
Polyurethane	0.5-1
Polyester	0.3-0.8
Urea acid catalysed	0.5-1
Nitrocellulose	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.

Infra-red drying can be carried out by using various infra-red sources. There are three major sources. Each is characterized by a maximum amount of radiation at three different wave lengths: 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 infra-red. For safety reasons, the short- and medium-wave radiators are used.

In Italy, infra-red 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 conveyor belt above which an infra-red ray dryer is installed.

It should be pointed out that infra-red ray drying should be well ventilated because the infra-red 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.

Ultraviolet systems are used to apply the prime coats on absorbent substrates such as particle boards and fibreboards. Ultraviolet systems are used to coat interior surfaces. Coating begins with a prime coat of ultraviolet sensitive material, generally applied by roll coaters. The work is finished with traditional materials.

Ultraviolet 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 ultraviolet plants, both for avoiding explosive mixtures as well as in certain cases to enable the paraffin of the polyesters to come to the surface.

Ultraviolet drying systems are available in different versions:

(a) Systems with low intensity light. These have been widely used for drying of ultraviolet polyester materials applied with a coating film of 250 to 280 g/m^2. Drying times vary from 3 to 5 minutes. Ultraviolet plants are usually equipped with conveyor belts and overhead ultraviolet 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 conveyor 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 ultraviolet 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 conveyor 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

REQUEST FOR FINISHING OPERATIONS FORM

	Amount to be applied	*Application concentration*	*°C*	*Drying conditions*	
Operations	*(g/m^2)*	*%*	*With*	*Ventilation*	*Time Machine*
Sanding					
Colouring					
Drying					
Stacking					
Printing					
Drying					
Printing					
Drying					
Stacking					
First coat					
Drying					
Second coat					
Drying					
Third coat					
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 ______________________

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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
- ☐ individual type
- ☐ office
- ☐ standard
- ____________
- ____________

PARTS OF MANUFACTURES TO VARNISH

- ☐ Internals
- ☐ Externals
- ☐ Edges
- ☐ Rears

TYPES OF COATING MATERIAL

- ☐ Pigmented
- ☐ Transparent

DIMENSIONS OF PRODUCTS

- ☐ Thickness ________
- ☐ Width ________
- ☐ Length ________
- ☐ Depth ________
- ☐ Height ________

SUBSTRATE USED

- ☐ Plywood
- ☐ Particleboard
- ☐ Plywood/ laminated plastic
- ☐ Blockboard
- ☐ Honeycomb core/ laminated/plastic
- ☐ Hardwood (Solid)
- ☐ Fibre

TYPE OF SURFACE TO BE COATED

- ☐ Rough
- ☐ Fibre
- ☐ Paper
- ☐ Assembled
- ☐ Veneered
- ☐ Coated

Supplying firm ______________________

____

FILLING

- ☐ Open pore
- ☐ Closed pore
- ☐ Semi-open pore
- ☐ Semi-closed pore

- ☐ Gloss
- ☐ Strongly opaque
- ☐ Opaque
- ☐ Semi-opaque
- ☐ Calendered
- ☐ Semi-bright
- ☐ Semi-sparkling
- ☐ Sparkling

As our product ______________________

PARTICULAR NEEDS

Is there a description of the cycle?

- ☐ Yes
- ☐ No

If "yes", please attach.

GRAIN PRINTING

- ☐ Embossing
- ☐ Printing
- ☐ Transparent
- ☐ Covering
- ☐ Semi-covering

NOTES ____

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XXIV. Economic production of doors and windows*

Introduction

Manufacturing large volumes of products calls for building equipment around the product, rather than manufacturing products around the equipment. Thus, there are many factors governing the choice between standard (traditional or basic) and special (automatic) machines such as: production rate, volume, work-hours, floor space, depreciation and degree of adaptability of standard machines. Much thought and planning is required to determine when it is profitable to operate with adapted traditional machinery and when to utilize the advantages of automatic machinery particularly suited to the production schedule. In the manufacture of windows and doors, it is sound engineering practice to compare, at the outset, the advantages of both automatic and traditional machines. From these findings, decisions can be made, resulting in fewer difficulties and greater profits.

The concept of adapting standard machines to volume production is outmoded; however, standard machines cost less and can be used if their application is practical. It has been shown, however, that a vast number of jobs could be more profitably handled with specially built equipment, when all cost factors are taken into account. In many cases the use of specialized machinery has resulted in lower initial investment and process cost than the use of standard machinery. In the woodworking industry, and especially in the manufacture of doors and windows, there is more of a tendency to adapt unsuited machinery than to utilize equipment that is "right for the job". This is probably due to a certain skepticism on the part of entrepreneurs towards special equipment and, also, to the fact that (especially in developing countries) labour is cheaper than automatic equipment, although, in the last decade, the dramatic increases in labour costs and unstable labour-management relations have resulted in an inversion of trends.

Manufacturers should realize that under competitive market conditions production, sales and profit are dependent on utilizing efficient production methods that will ensure proper quality at a low unit cost. Furthermore, they should realize that short-pay-off and return-on-investment theories must be recognized for what they are and, therefore, that the idea that a machinery purchase is justified only if it saves its cost in direct labour in a relatively short period of time generally tends to work against the replacement of equipment that is costly to operate.

The economic production of doors and windows means, above all, the most economic choice of equipment and the successful blending of all the human and material resources of production. However, there is another important aspect of manufacturing that should be considered, namely work planning or, to put it more simply, what has to be done, where and by whom in order to transform, say, a piece of timber into a window or door component.

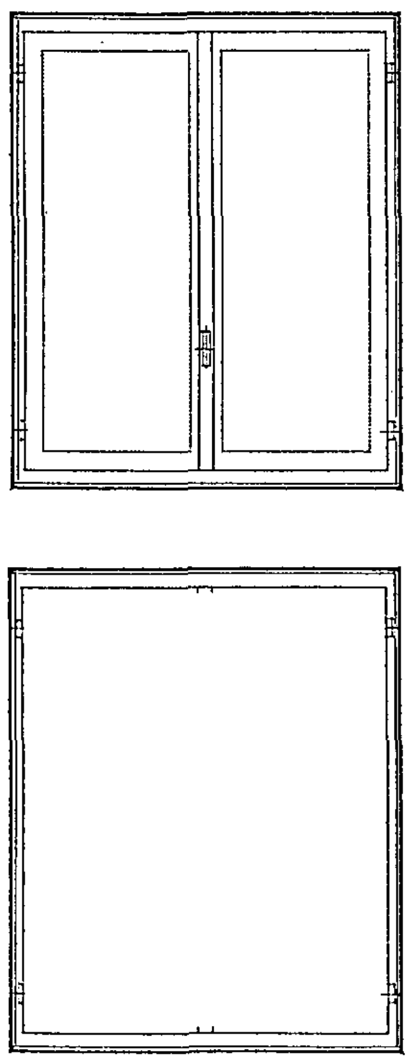
*By I. R. Traversa, engineer, SCM Engineering. (Originally issued as ID/WG.369/8.)

Technical terms and description of door and window components

Window components

A window (figure 1) consists of the casement (fixed frame), the shutters (movable), the glass and the accessory fittings (hinges, handles, locking devices).

Figure 1. Window



The casement is the part of the window that is fixed to the wall of the building. It is the structure that bears the shutters, and is sometimes called the "master frame". The elements of the casement are shown in figure 2.

Shutters are the movable (opening) parts of the window that flap against the casement. They support the glass and part of the window fittings. The elements of a shutter are shown in figure 3 A. Shutters may have a left-hand or a right-hand wing, or both (see figure 3 B, C and D).

Door components

The door (figure 4) consists of a casement (fixed frame), the decorative casings, the door panel (movable) and accessory fittings (hinges, handle, lock).

The casement (figure 5) is the bearing frame of the door, which is fixed to the walls; it is complete with lock face plate, hinges and casings.

Figure 2. Window casement

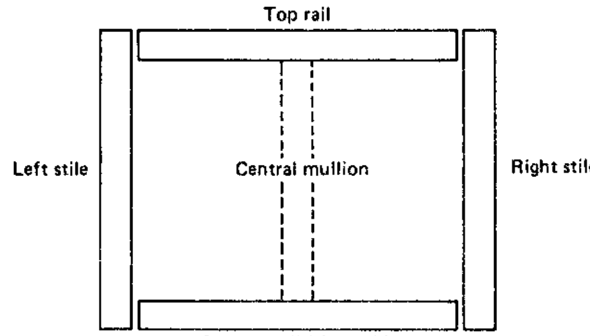
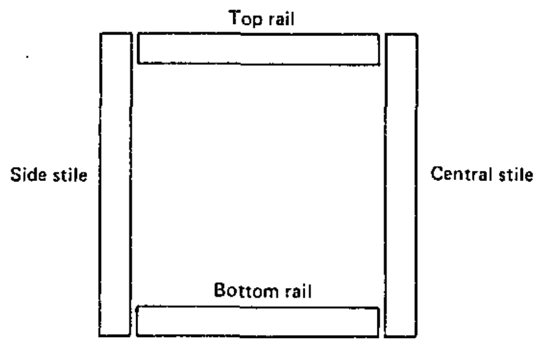
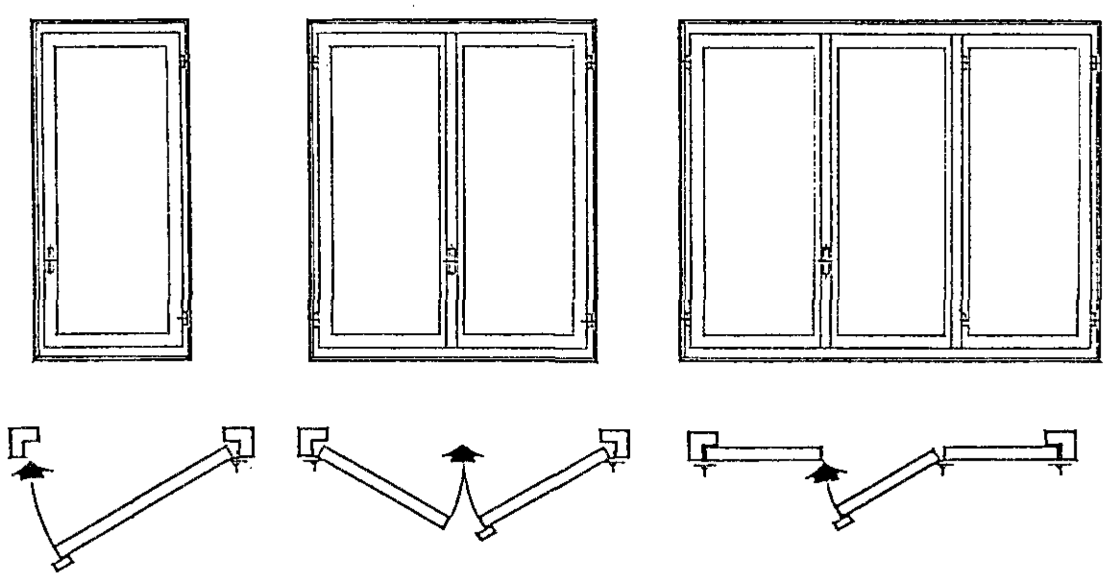


Figure 3. Shutters



A. Elements of a shutter



B. Single-shutter window

C. Two-shutter window

D. Three-shutter window

The door panel (figure 6) is the moving part of the door proper and is complete with hinges, lock and latch and handle. There are several types of door panels; the main types, which are dealt with in the present chapter, are institutional doors with wood or plastic-laminated skins. These may be full-core flush doors or cut-out doors (figure 7), and both may be lipped or unlipped. Cut-out doors may have glazed panels or raised panels, or both.

Figure 4. Door

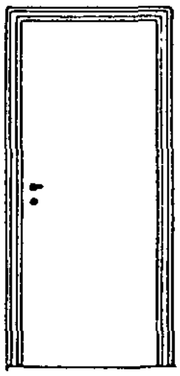


Figure 5. Door casement

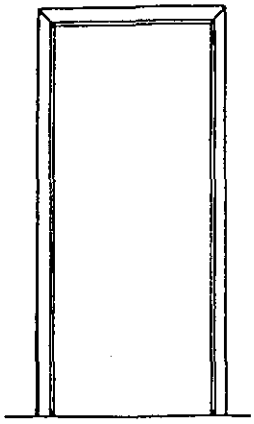


Figure 6. Door panel

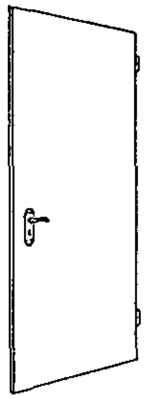
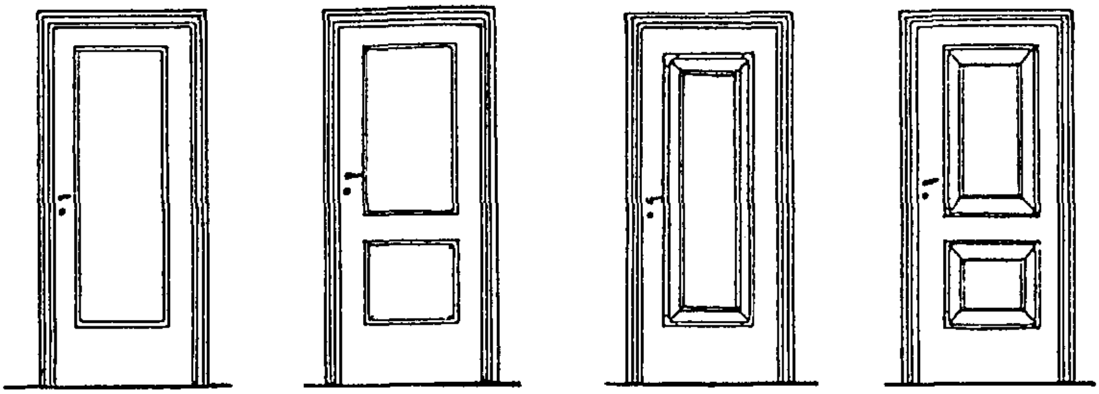


Figure 7. Common types of cut-out doors



A. Single aperture glazed panel

B. Double aperture glazed panel

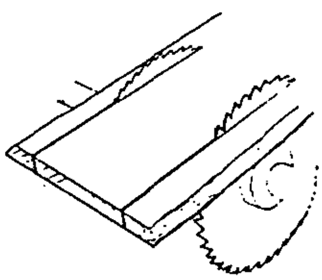
C. Single aperture raised panel

D. Double aperture raised panel

Basic machining operations in the manufacture of doors and windows

Ripping is the operation in which a lengthwise cut is made through a board (figure 8).

Figure 8. Ripping



Resawing is the ripping of a thick board to make a thin board (figure 9).

Cross cutting is sawing through (across the grain) a piece of stock or cutting across the narrowest dimensions of a piece of stock (figure 10).

Planing (figure 11) is the trueing up of the faces of a board or a piece of stock along the wood grain. There are two distinct planing operations:

(a) Surface planing is the first operation that is usually performed in machining the sawn timbers. Its purpose is to obtain a plane surface out of a roughly sawn surface;

(b) Thickness planing is an operation whereby an almost perfect parallel board surface can be obtained from a surface previously obtained by the surface-planing operation.

Figure 9. Resawing

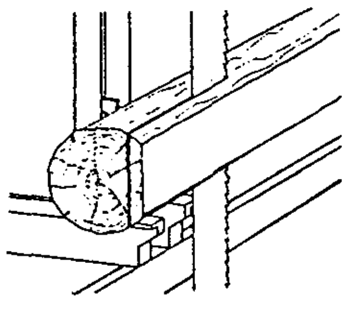


Figure 10. Cross cutting

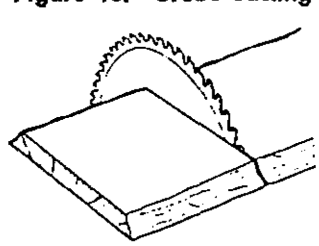
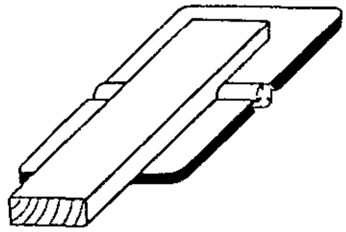
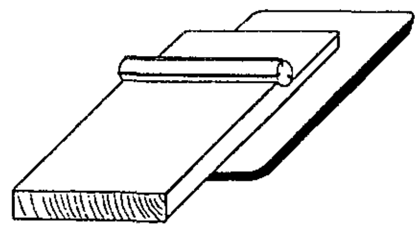


Figure 11. Planing



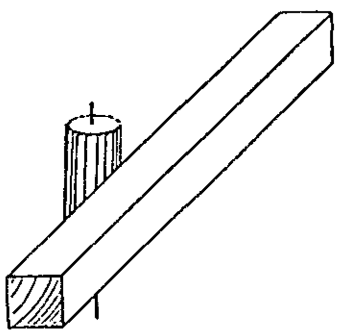
A. Surface planing



B. Thickness planing

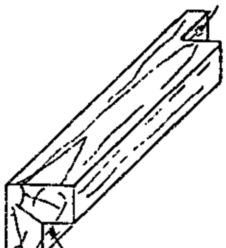
Jointing is carried out to true up or straighten a board or a piece of stock edgewise (figure 12).

Figure 12. Jointing



Rabbeting (figure 13) is an operation whereby a cut is made along the edge of a board or a piece of stock so as to remove a corner along the length of the stock (edge rabbeting) or at the end of the stock (end rabbeting).

Figure 13. Rabbeting



In moulding, a shape is cut on the edge or face of a workpiece. The moulding operations most frequently encountered in manufacturing doors and windows are:

(a) Those performed on the inside profiles of the windows components such as top rails, sashes, sills and stiles (figure 14 A);

(b) Those performed on the door components such as lipping, astragals, ornamental casings, back bands, wainscots, raised panel lips, jambs and heads (figure 14 B).

The purpose of tenoning is to reduce the thickness of a piece at stock's ends so that the stock can be fitted into the corresponding mortises to form mortise and tenon joint assemblies. Examples of tenons most commonly used in manufacturing doors and windows are shown in figure 15.

Mortising is an operation that consists of removing material from the ends or the faces of a piece of stock in order to create a seating or a slot for a corresponding tenon. Typical mortises used in doors and windows are shown in figure 16.

Pressing is the operation whereby, by means of pressure and glue, a cored door panel or "sandwich" panel is formed. Sandwich panels may have three or five layers (figure 17).

There are several types of presses, but the most commonly used presses can be divided into two main categories, hydraulically operated hot-platen presses and cold-platen presses. The characteristics of these presses are given below.

Hydraulically operated hot-platen presses. These presses may be automatic or semi-automatic, multi-platen or single-platen presses. The type of press used should depend on the quantity of doors to be produced in a given time. Furthermore, the pressing cycle depends, among other factors, on the thickness of skins, the temperature of the hot platens and the kind of glue used. The following parameters may be used as a guide:

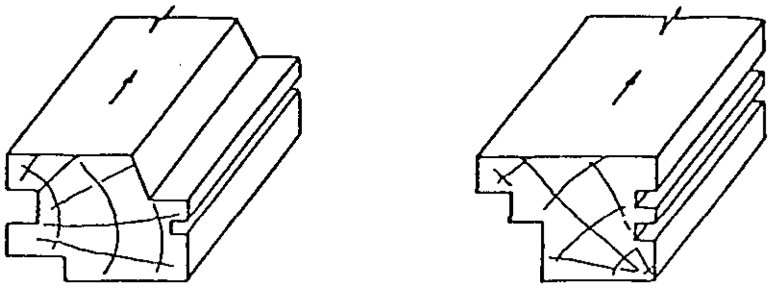
(a) Glue. Urea formaldehyde, viscosity 30 to 40 poises, 100 parts by weight charged with 30 parts of flour (starch, rye etc.), mixed with 25 parts of water and 10 parts of hardener solution. The quantity of glue to be spread over each skin varies between 160 and 220 g/m^2, depending on the nature of the skin material as well as on the skeleton's species;

(b) Time/temperature. In practice it is considered that, at a press platen temperature of 95° C, the pressing time should be calculated at 1 minute per each millimetre of skin thickness. A veneering cycle, employing 0.7-mm veneer overlays, would take around 40 to 45 seconds;

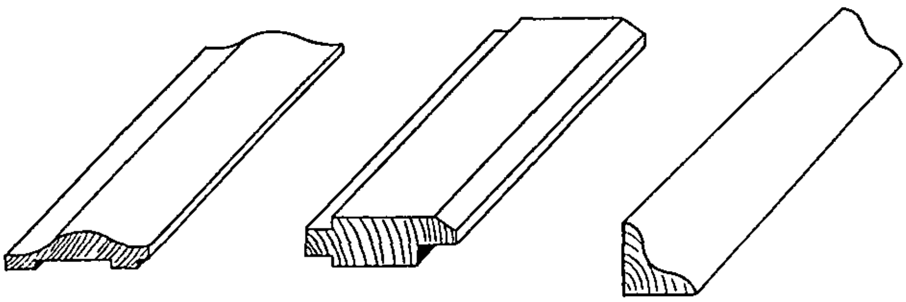
(c) Pressure. The press gauge pressure should be set between 2 to 3 kg/cm^2 for a three-layer sandwich and between 4 to 6 kg/cm^2 for a veneering cycle.

Cold-platen presses. These are usually "single daylight" presses, featuring a top platen and an iron girder. The top platen is movable and may be operated either hydraulically or mechanically by jack screws. The number of doors that can be pressed depends on the press' daylight clearance; standard presses usually have a clearance ranging between 400 to 800 mm. The pressing times are relatively high. The glue most commonly used has the following formulation: urea formaldehyde, 100 parts by weight charged with 5 parts of starch or rye flour mixed with 5 parts of kaolin. Cold pressing is particularly indicated when door skins are of PVC, PVA or other materials that are susceptible to temperature, when a suitable heat source is not available or, at any rate, when energy saving may be a predominant economic factor and the production rate is low.

Figure 14. Moulding



A. Window components



B. Door components

Figure 15. Tenoning

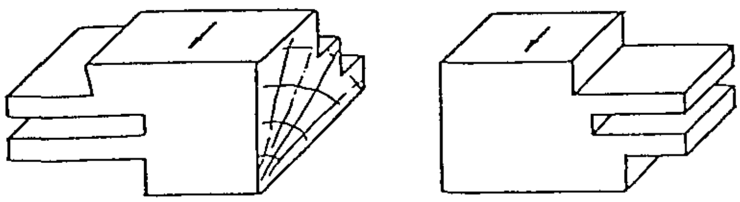
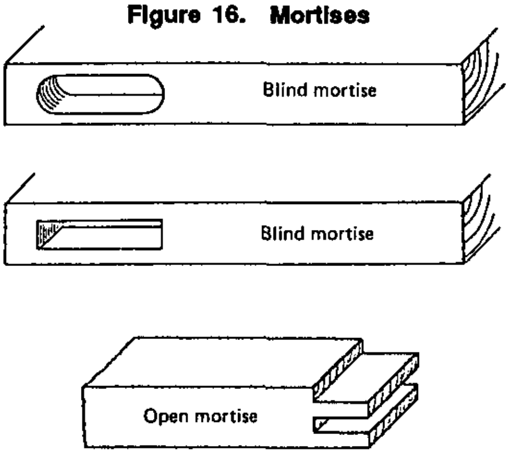


Figure 16. Mortises



In the present context, assembly means joining all the elements of shutters or casements for window construction together by means of clamps or frame presses. For door panels, assembly means joining all the elements of the door skeletons together (stiles, rails, hinge blocks, lock blocks, core material (expandable honeycomb or rigid core)) by means of staples, nails etc.

Dimensioning is done by trimming off and/or moulding, rabbeting, notching, edging etc. all four edges of shutters and doors in order to obtain perfect parallelism, hence squareness, of the manufactured edges.

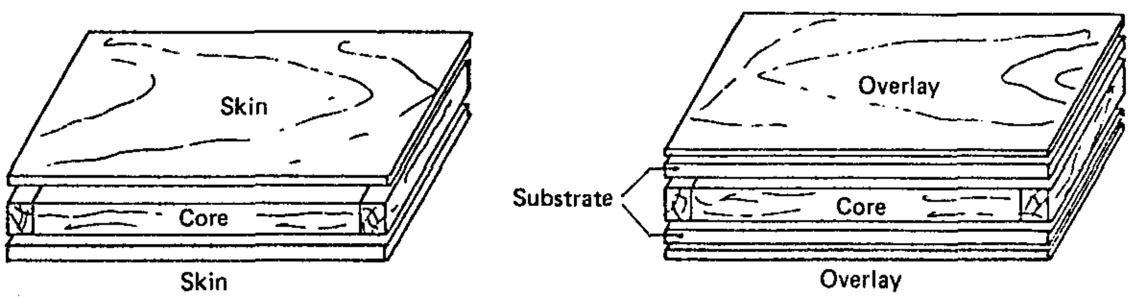
In edgebanding, the edges of a door panel (usually the longitudinal edges) are covered with a lipping strip of solid wood, veneer or other laminating material to hide the exposed edges of door skins.

The purpose of sanding operations is to reduce products to correct gauge thickness (thickness or gauge sanding) or to remove any surface defects prior to the veneering operation (for doors) or to the surface finishing operations (finish sanding). Sanding is planing using abrasives, and there are many types of sanding machines. The most common ones are portable tools, belt sanders, disc sanders and drum sanders.

Surface finishing is the process of applying stains or paints to finished products in order to preserve their surfaces from weathering effects and to give them a pleasant appearance. (The characteristics of the finishing products and the application techniques are beyond the scope of the present chapter. See chapter XXIII).

Hardware fitting includes all operations, manual or mechanical, that involve the application of hardware and accessories such as hinges, knobs, handles, locks and glass onto the products to make them functional and ready for use.

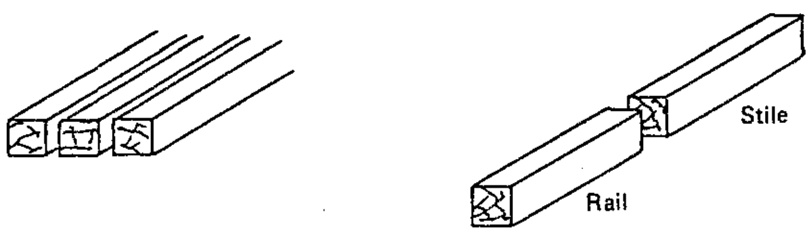
Figure 17. Core or "sandwich" panels



A. Three-layered panel

B. Five-layered panel (three/layer panel and overlays)

Figure 18. Ripping and cross cutting



A. Ripped pieces

B. Cross-cut pieces

Figure 19. Orthogonal faces that are surface planed

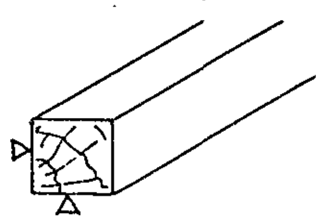
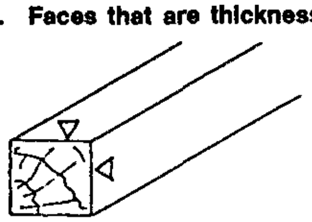


Figure 20. Faces that are thickness planed



Manufacturing methods for windows

The manufacturing methods and hence the work sequence to be adopted vary according to the types of machines installed in the factory. There are two classes of machines:

Traditional or basic machines
Automatic machines

The timber used in the construction of typical windows, using either traditional or automatic machines, should have a moisture content ranging between 12 and 14 per cent, should be free from defects and usually should not need special preservation treatments.[1] The machining sequences using traditional or basic machines are described below.

Step 1

A band-saw or circular saw is used for ripping (figure 8) and cross cutting (figure 10) timber into pieces (figure 18).

Step 2

Surface planing (figure 11 A) is carried out on two orthogonal faces (figure 19) using a surface planer with a jointer attachment.

Step 3

Thickness planing (figure 11 B) is carried out on the remaining orthogonal faces using a thickness planer (figure 20).

Step 4

The tenoning of the stiles and rails of casements and shutters (figure 21) is carried out using a spindle moulder/tenoner or combination moulder/circular saw.

Step 5

Moulding the inside profiles of the stiles and rails of casements and shutters (figure 22) is done with a spindle moulder or combination moulder/circular saw.

[1]Cases occur where specifications call for treatment of the timber against fungal or insect attack, but this treatment is not covered in this chapter. It usually occurs after machining and before assembly of the elements.

Figure 21. Stiles and rails after the tenoning operation

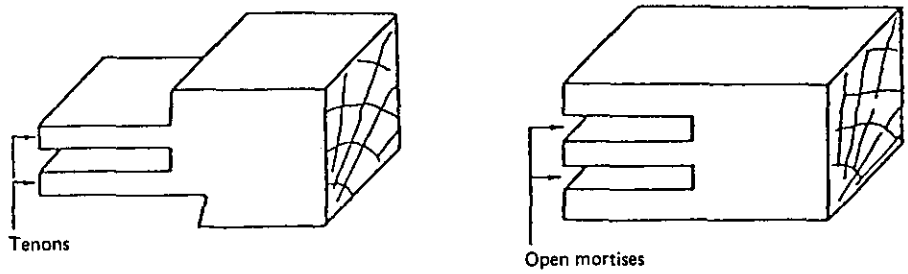


Figure 22. Stiles and rails after the moulding operation

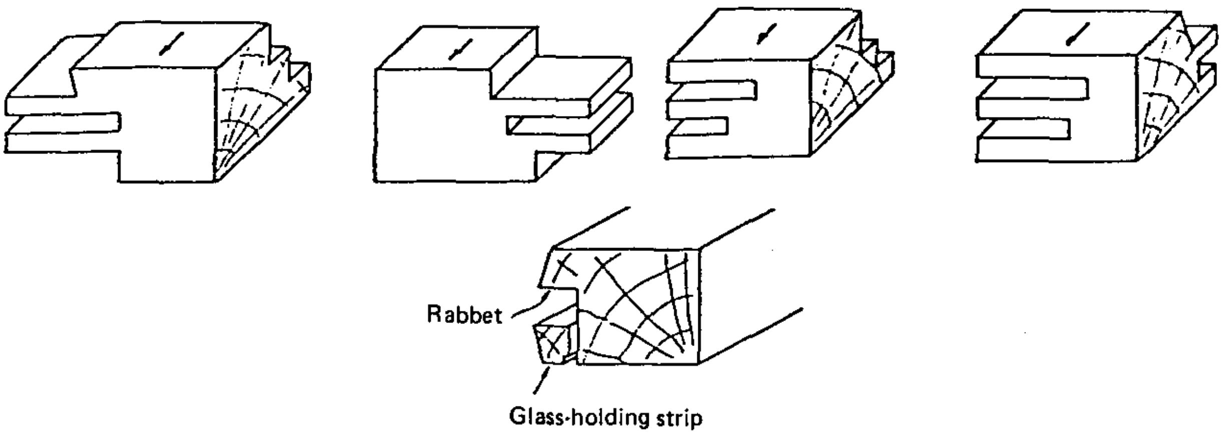
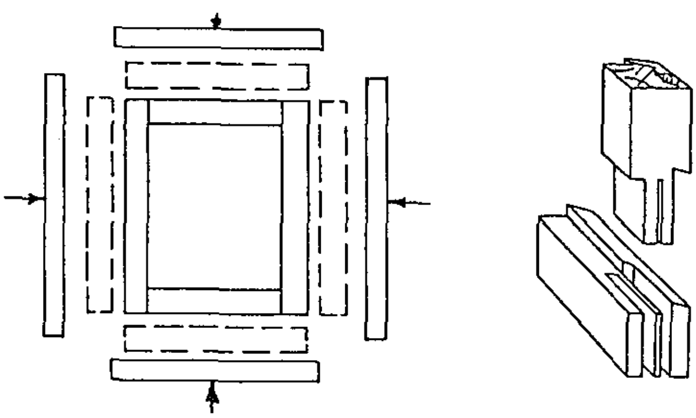


Figure 23. Assembly of casement or shutters



Step 6

The casement or shutters are assembled (figure 23), held by a frame clamp (press).

Step 7

A spindle moulder or combination moulder/circular saw is used for dimensioning the assembled shutters. The long side is dimensioned first, followed by the broad side (figure 24).

Step 8

The surface sanding of dimensioned shutters is carried out using a belt sander, drum sander or portable sander (figure 25).

Step 9

In the surface-finishing operation, a spray gun is used to apply paint to the shutters in the order shown in figure 26.

Step 10

The final operation is to fit hardware on shutters and casements. The operation consists of drilling and driving hinge pivots into casement stiles, drilling and driving hinge sockets into wings, driving and screwing locking mechanisms and handles into wings and drilling and driving eye-bolts or sockets into casement head rails and sills. Portable power or pneumatic tools such as drills, nailing guns, hinge drilling and sinking attachments and screwdrivers are used. The window assembly is then tested for good matching and performance. The window glass is generally fitted at customer's site, after the window casement has been fixed to the wall of the building.

Figure 24. Long sides (1 and 2) and broad sides (3 and 4) of the shutter for dimensioning

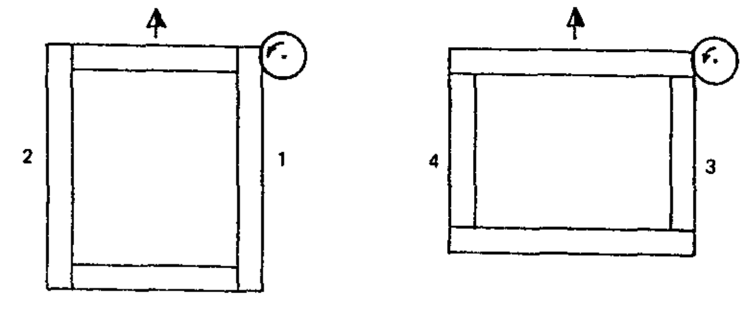


Figure 25. Surface sanding

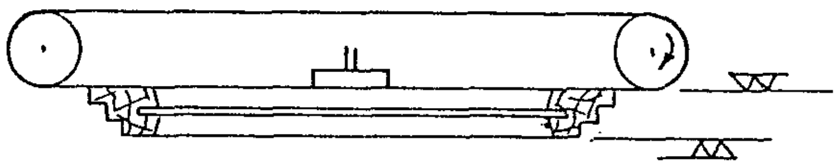
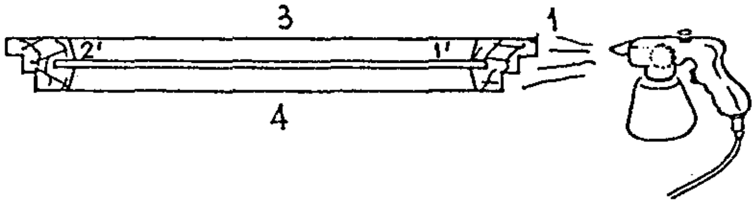


Figure 26. Surface finishing



For window production using automatic machines, the manufacturing sequence does not change. Instead, the factory productivity changes in that the use of automatic machines diminishes the number of operations and increases production output. The steps in the manufacturing sequence are outlined below.

Step 1

In this operation, stiles and rails are cross cut to the correct lengths. In order to fully exploit the capacity of both the multiple ripsaw and the machines downstream from it (for example the multi-spindle moulding machines and the double end tenoners), it is advisable to perform the cross-cutting operations in multiples prior to the ripping operation. This procedure will eliminate the need to install costly high-capacity cut-off saws between the multiple ripsaw and the multi-spindle moulders because a heavy-duty, good quality cross-cut saw, placed before the multiple ripsaw, should be able to easily keep pace with the ripsaw's capacity.

Step 2

Ripsawing is carried out on a multiple ripsaw (or gang ripsaw) which can cut dimension stock in multiples. Up to four staves can be ripped off in one single machine pass from a board on 50-hp multiple ripsaw with 300-mm cutting width capacity, at an effective machine feed of around 8 metres per minute. The machine is run by two operators. Due allowance being made for machine set up, tooling up and operators' idle time, it is possible to produce around 14,000 lineal metres of stavings per day or, in the case of a standard two-shutter window (1,400 × 1,500 mm), a multiple ripsaw may produce sufficient stock pieces for about 1,000 windows in an eight-hour day and could comfortably feed two to three multi-spindle moulders.

Step 3

This operation involves the moulding of inside profiles of stiles and rails for casements and shutters. Whereas the use of traditional or basic machines demands that two machining operations must be carried out prior to profiling, namely surface planing on two orthogonal faces and thickness planing, the installation of a suitable multi-spindle through-feed moulder, for instance, would enable the profiling job to be performed in one single operation. The main advantages to be gained by the use of such machines are: higher production volume, higher work quality and long-range economies in labour and overheads. In fact, a good automatic moulder, suitably equipped, can machine a sufficient number of rails and stiles for about 200 standard two-shutter windows (1,400 × 1,500 mm) per eight-hour working day with only two semi-skilled machine operators.

Step 4

The tenoning and mortising operations on the two extremities of rails and stiles must be performed in two steps when using basic machines: one end is machined, then the piece is turned around and the other end is machined. This is rather awkward and requires fairly skilled operators. An automatic double-end tenoner, however, can work both ends of the stocks with extremely high precision and rate of execution. The operator does not need to work with jigs or any other attachments, machining times are reduced, and productivity increases. The machine operators must only feed the work to the machine at one end and catch it at the other once the machine has been set up and tooled up. A double-end tenoner can machine up to 4,000 pieces per day, or a sufficient number of rails and stiles for 500 standard two-shutter windows per eight-hour working day with two semi-skilled machine operators.

Note: Special purpose n.c. moulders, with a wide range of cutters mounted vertically on a shaft have been developed specially for window production. Machine setting and tool changing is thus reduced to a minimum. A machine has also been developed capable of carrying out steps 3 and 4. These (high cost) machines permit the production of very small batches using industrial methods at economic costs. These machines also carry out step 6 below.

Step 5

In a modern window factory, the assembly operation may represent a serious bottle-neck if adequate assembly facilities are not provided. There are two ways of speeding up the assembly process:

(a) By installing a suitable number of frame clamps and thus employing many people to do the job;

(b) By installing a hydraulically operated automatic frame press and automatic glue-spreading equipment in order to speed up operations and keep the number of workers to a minimum.

Step 6

A properly tooled up automatic double-end tenoner also performs the dimensioning operation on the shutters. It can trim and rabbet the wings of shutters in only two machine operations; while each side must be trimmed and rabbeted separately using basic machines, the double-end tenoner can perform this operation on both long sides, or both broad sides, simultaneously. (See figure 27.) Other advantages are:

(a) Greater dimensional control;

(b) Good and splinter-free surface finishes, owing to the possibility of equipping the machine with several work stations and with automatic tool heads;

(c) Increased production capacity. Up to 600 standard shutters per eight-hour shift (equivalent to 300 standard two-shutter windows) can be dimensioned on an automatic double-end tenoner, which requires only two operators.

Step 7

The next operation is the surface sanding of dimensioned shutters. Owing to the high productive capacity of the machines upstream, traditional manual sanding operations performed in workshops equipped with basic machines would constitute a serious bottle-neck in a modern factory. Thus, it is necessary to install a surface-sanding unit capable of coping with the situation. An automatic overhead wide-belt sanding machine (figure 28) can perform, in two steps, the sanding operations needed prior to the surface finishing of the shutters.

The sanding machine can be equipped with two sanding units, a sanding cylinder and a pad, thus enabling it to perform both the abrasive planing and the pre-painting surface-preparation operations.

The automatic wide-belt sander can surface sand two faces of up to 600 standard shutters in an eight-hour shift (300 standard two-shutter windows per day) and requires only two semi-skilled workers to operate it.

Step 8

The next step is the surface finishing of shutters and casement components. In step 5, the assembly of casements was not mentioned at all. There are special reasons for this:

(a) Hinge fitting is done by automatic machines; hence, it is not practical to install the hinges on cumbersome frames. Therefore, the hinges should be driven in after the painting operation;

Figure 27. Dimensioning using a double-end tenoner

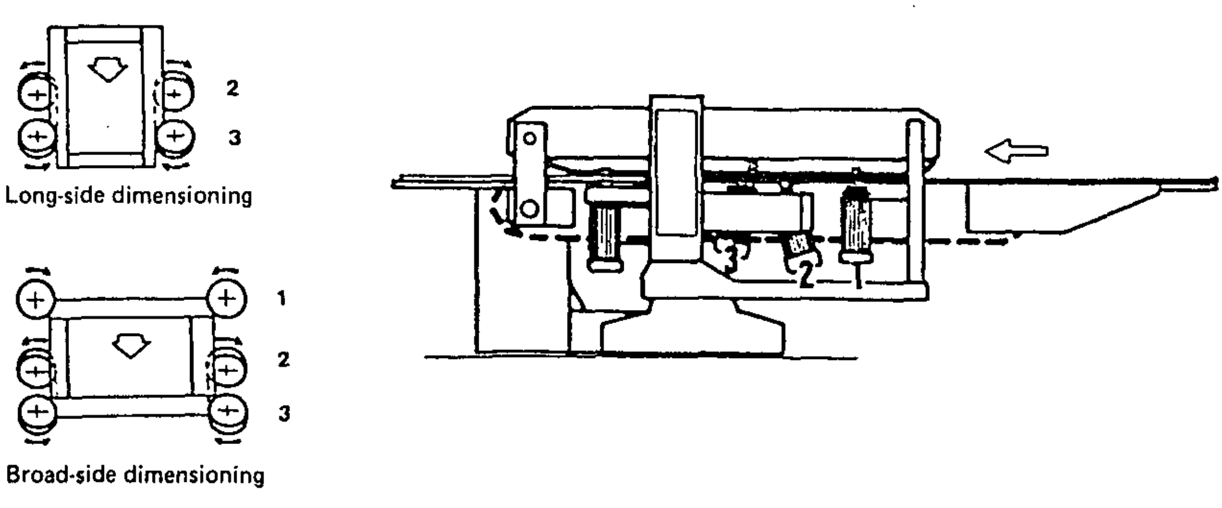
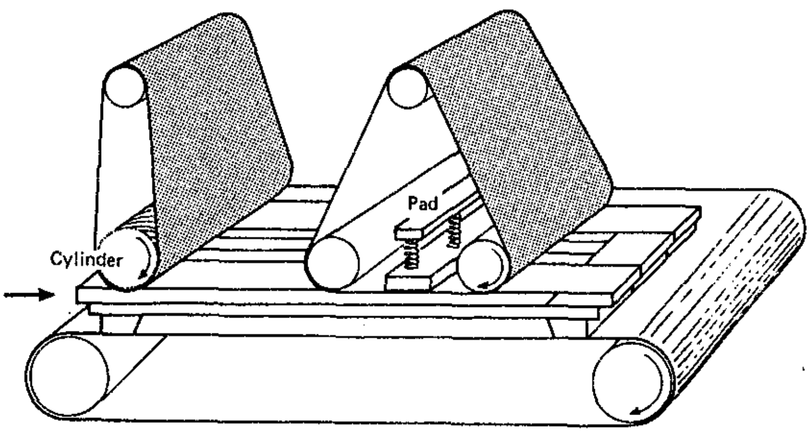


Figure 28. Automatic overhead wide-belt sanding machine



(b) It is much easier and saves paint to finish a single component rather than the whole casement assembly;

(c) It is much easier to carry, say, four unassembled stock pieces around the factory than a cumbersome casement frame.

Thus, the surface finishing equipment should be characterized by one painting line for moulding and one for shutters. The lines should be of a suitable size and sufficiently mechanized to meet the production requirements of the factory. Typical finishing equipment consists of:

A stain dipping tank
An overhead transporting conveyor
A water-wash spraying booth with spraying guns
A paint-curing oven
Some sanding benches
An automatic spraying machine for mouldings
A profile automatic sanding machine
A paint-curing oven for mouldings

Step 9

The hinge-fitting operations for both casement components and shutters are usually carried out by an automatic universal hinge boring and inserting machine. A great variety of such machines exists on the market, and the choice of machine depends on the type of hinges, on the size of windows and on the production quantities to be achieved. One-, two-, three- or four-head hinge-inserting machines with capacities varying from two up to six hinges inserted per minute are available.

The fitting of hardware accessories other than hinges, such as locking mechanisms for shutters, handles, eye-bolts, glass and any other accessory that may be required, is usually performed manually on special assembly benches equipped with suitable jigs and fixtures.

Step 10

The assembly of casements is usually carried out by means of hydraulically operated horizontal frame presses equipped with glue-spreading facilities and suitable tools for the assembly of hardware accessories.

Manufacturing methods for doors

A door assembly is composed basically of a casement, decorative casings, a door panel and some accessory fittings. The construction details and the manufacturing sequence of each door component, employing both basic and automatic machines, are described below. In both cases, it is assumed that the timber species to be used has a moisture content ranging from 8 to 10 per cent and is free from relevant defects. The basic details for the construction of door casements are shown in figure 29.

The important features of the rabbet joint in combination with the bolt and socket are:

Ease of machining
Ease of assembly
The casement can be delivered in knock-down form to the customer, which results in considerable savings in transport costs.

The machining sequence for door casements using basic machines is given below.

Step 1

The kiln-dried, rough-sawn timber is ripped using a band-saw or circular saw (figure 30).

Step 2

The ripped pieces are cross-cut to the correct length using a band-saw or circular saw (figure 31).

Step 3

The four faces are planed to the correct cross-section using a surface planer with a jointer attachment and a thickness planer (figure 32).

Step 4

A lengthwise rabbet is made using a spindle moulder or combination moulder/circular saw (figure 33).

Step 5

An end rabbet is made on one end of the jamb only (i.e. the end that joins the casement head) using a spindle moulder, combination moulder/circular saw and tenoner (figure 34).

Figure 29. Door casement construction

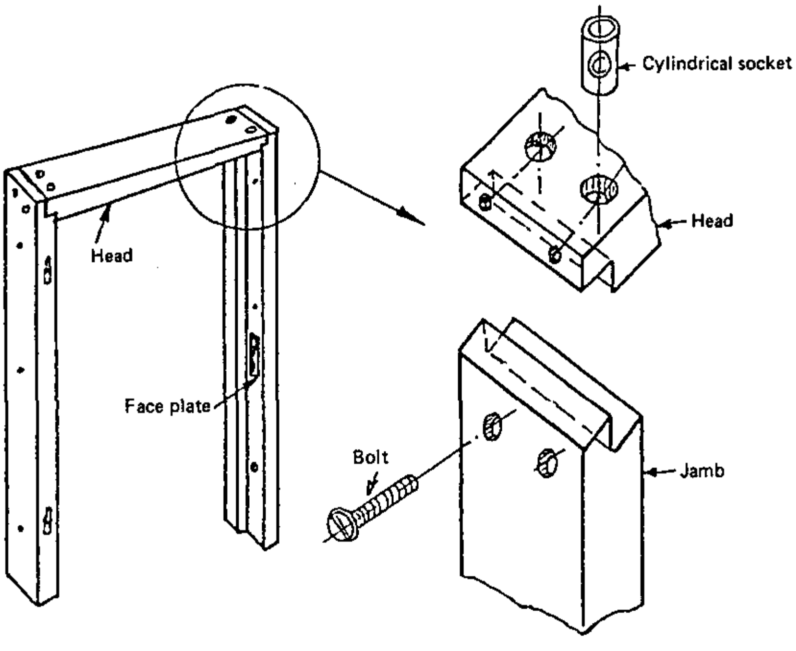


Figure 30. Ripping

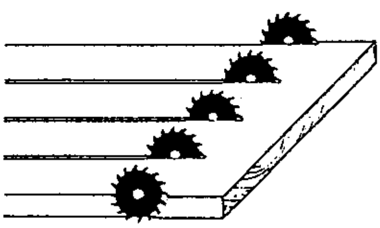


Figure 31. Cross cutting

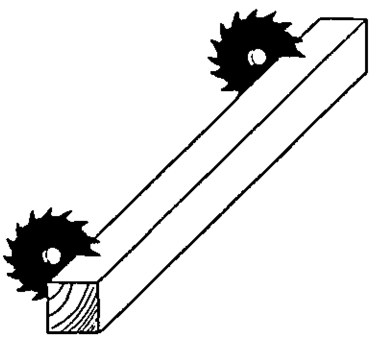


Figure 32. Planing

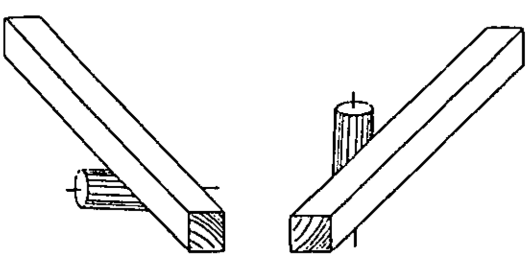


Figure 33. Lengthwise rabbet

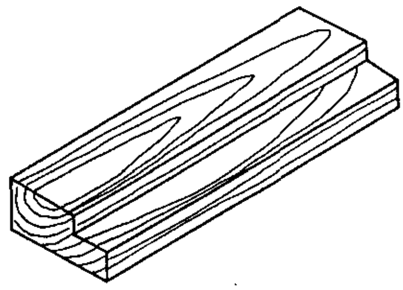


Figure 34. Rabbeting on jamb

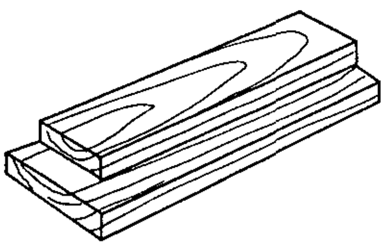
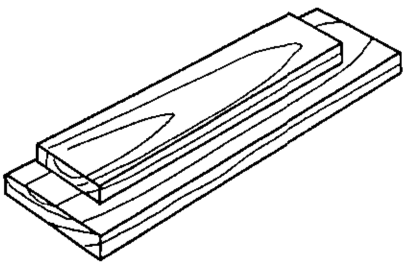


Figure 35. Rabbeting on head



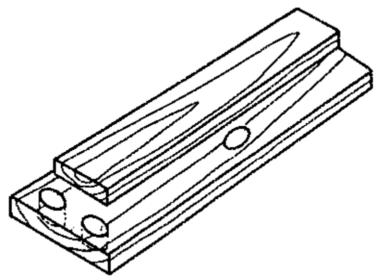
Step 6

End rabbets are machined on both ends of the head using a spindle moulder, combination moulder/circular saw and tenoner (figure 35).

Step 7

Two holes are drilled through the jamb end for joining with the head, and three holes are drilled on the lengthwise rabbeted face for fixing the casement to the building using a drill press, portable drill or bench drill (figure 36).

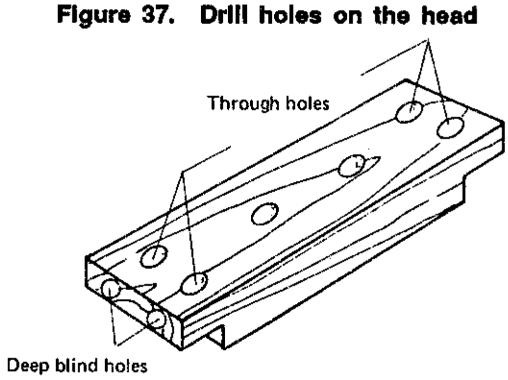
Figure 36. Drill holes on the jamb



Step 8

Two deep blind holes and two through holes are drilled on each end of head for joining the head with the jambs; two through holes are drilled on the rabbeted face for fixing the head to the building (figure 37). A drill press, portable drill or bench drill can be used.

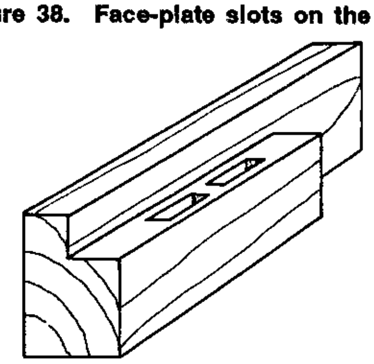
Figure 37. Drill holes on the head



Step 9

Face-plate slots are machined on one jamb (right or left, depending on the direction in which the door opens) using a portable router, drill press and chain and chisel mortiser (figure 38).

Figure 38. Face-plate slots on the jamb



Step 10

Visible surfaces of jambs and the head (edges and rabbets) are painted using a manual spraying gun.

Step 11

Hinges are inserted on one jamb, and the face plate is fitted on the other jamb. Cylindrical socket and relative bolts are fitted to the ends of the head using a portable drill and a portable screwdriver with a hinge-driving attachment or a hand screwdriver.

The great advantages of using automatic machines for the manufacture of door casements are:

(a) Steps 3 and 4 of the manual operation can be performed simultaneously in one machine pass; if the width of the jambs and heads allows, in many instances steps 1, 3 and 4 can be performed simultaneously;

(b) Steps 5, 6, 7, 8 and 9 can be performed on one single machine in one pass;

(c) Step 10 can be performed very quickly on an automatic spraying machine.

The machines used in automatic operation are (in order of use):

(a) Automatic cross-cut saw, which cross cuts stock to correct jamb and head length and trims off defective ends;

(b) Automatic multi-spindle throughfeed moulder, which machines the jambs and heads to the correct finished cross-sections. If a universal spindle is available, it is possible to work two sides at a time and then split the piece (figure 39);

(c) Automatic double-end tenoning and boring machine, which simultaneously trims off the ends of jambs and heads to the correct finished length. It machines the end rabbets, drills holes on ends and on faces, automatically drives in cylindrical sockets (an optional head that is not always advisable before painting operations) and routs face-plate slots;

(d) Automatic profile spray-painting and varnishing machine, which automatically paints jambs and heads on edges and rabbets. This machine has a high production capacity: the machine feed can be as high as 80 ml/minute. In order to use this machine, however, a paint-curing oven for mouldings must be installed downstream of it and, depending on the degree of surface finishing, an automatic profile-sanding machine might have to be installed upstream of the spray-painting machine;

(e) Automatic hinge-inserting machine, which fits the hinges on the door-carrying jamb automatically. Depending on the volume of production, such a machine can be equipped with one or more drilling heads with relative hinge-feeding magazines so that the operator only has to load and unload the workpieces.

The face-plate fitting operation on the other jamb is usually performed manually by the operator.

Flush door construction

The parts of a door are identified in figure 40.

The machining sequence for flush doors employing basic machines is described below.

Step 1

Rough sawn timber (kiln dried at 8-10 per cent humidity) is ripped using a band-saw (figure 41) or circular saw.

Figure 39. Moulding with a universal spindle

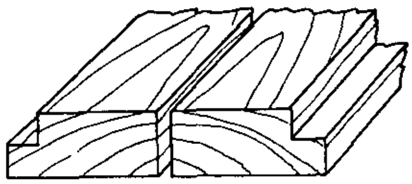
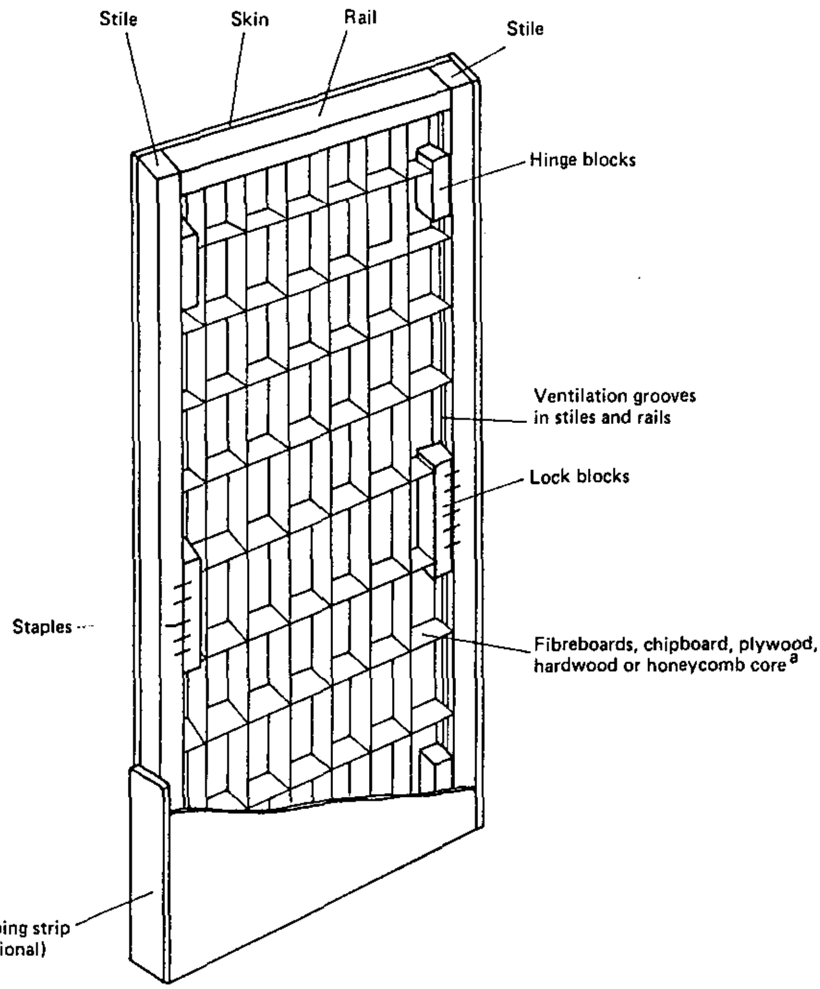
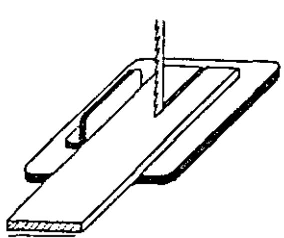


Figure 40. Door construction



[a]An alternative core material would be expandable honeycomb core. Despite its many advantages, however, this kind of material is not available everywhere.

Figure 41. Ripping using a band-saw



Step 2

The ripped staves are planed and straightened on three faces using a surface planer with jointer attachment and a thicknessing planer (figure 42).

Step 3

Ventilation grooves are made on the fourth face of the planed staves using a spindle moulder (figure 43).

Step 4

Staves are cross cut to the correct lengths for stiles, rails, hinge blocks and lock blocks using a band-saw or circular saw (figure 44).

Step 5

Fibreboard, particleboard or plywood (or hardwood strips that have been planed) are ripped to the correct width (equivalent to the core-frame thickness) using a circular saw (figure 45).

Figure 42. Planing and straightening

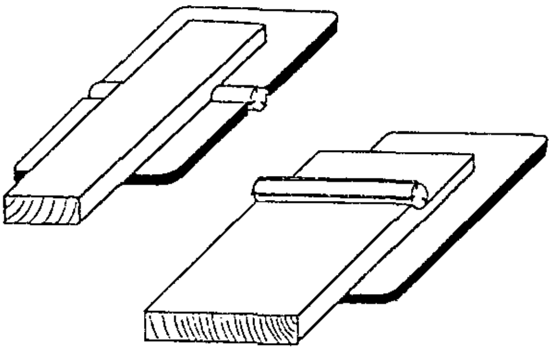


Figure 43. Stave with ventilation groove

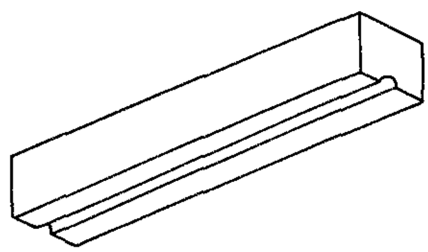


Figure 44. Cross-cut pieces

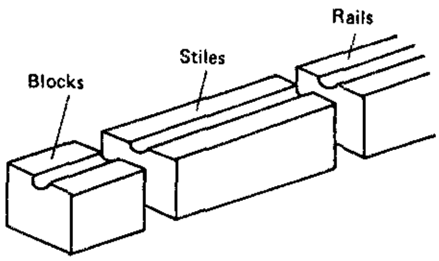
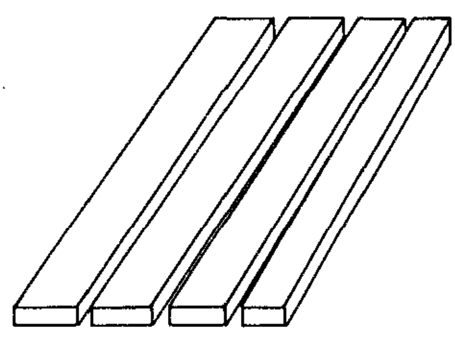


Figure 45. Panel ripped to the thickness of the core frame



Step 6

Core slits are cross cut to the correct length using a band-saw or circular saw (figure 46).

Step 7

A kerf is made on longitudinal and transversal core slits using a circular saw (radial-arm saw with a kerf-spacing attachment) (figure 47).

Step 8

Skin panels are cut to the size (lengthwise and crosswise) of the door, allowing for some excess material, using a dimension circular saw or double-end saw (figure 48). In case of cut-out doors, it is advisable to rout apertures on skins prior to the pressing operation.

Figure 46. Core slits

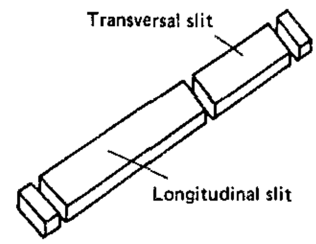


Figure 47. Kerf on core slits

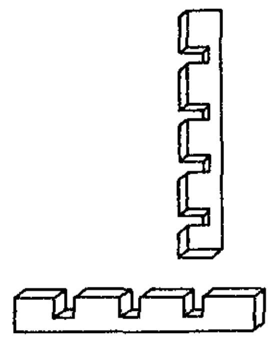
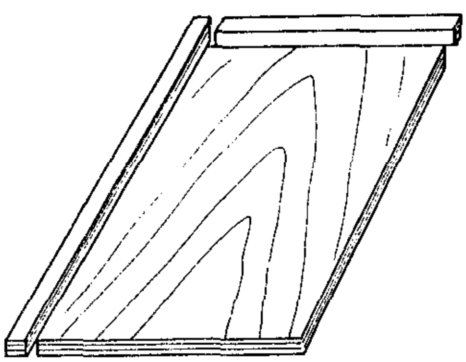


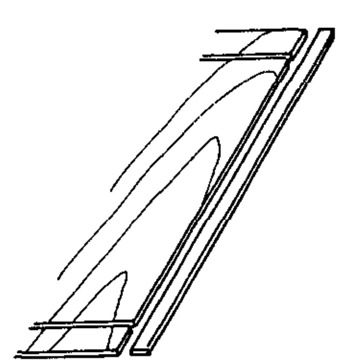
Figure 48. Skin panel



Step 9 (optional)

Veneer overlays are clipped to size using a knife guillotine (figure 49). This operation is carried out only for door panels with upgraded veneer faces.

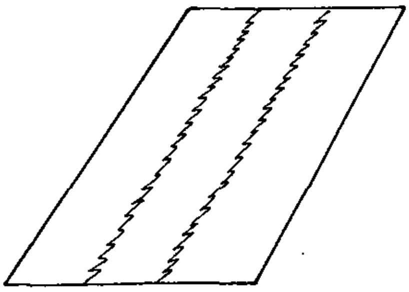
Figure 49. Veneer panel



Step 10

Veneer overlays are spliced together (the size should be a little larger than the size of the door) using a portable tape-veneer splicer or portable thread-veneer splicer (figure 50).

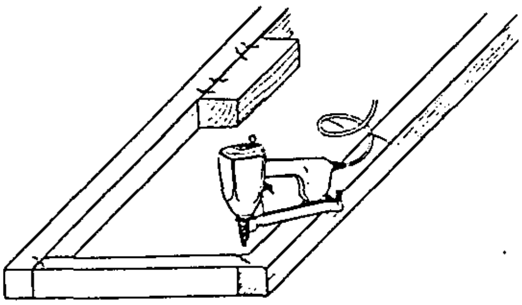
Figure 50. Veneer overlays



Step 11

Door skeletons are assembled by fitting together stiles, rails, hinge blocks, lock blocks and core slits with staples on an assembly bench using a portable stapling gun (figure 51).

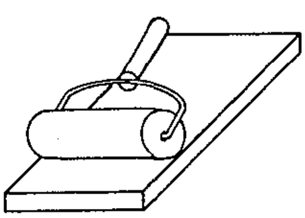
Figure 51. Assembly of door skeleton



Step 12

Glue is spread over skin panels on a glue bench using a brush or squeegee roller (figure 52).

Figure 52. Glue spreading using a roller



Step 13

The door sandwich is assembled on a workbench and loaded into a press in the following order (figure 53):

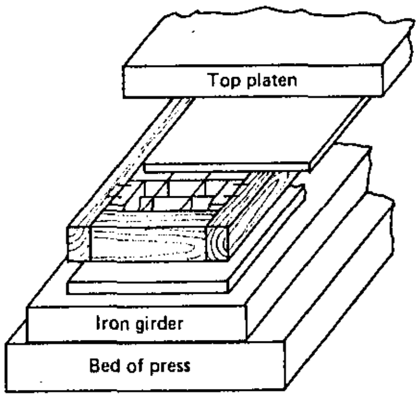
(a) The first door skin is placed on the bench, ensuring that the glued surface of the skin is facing upwards;

(b) The assembled door skeleton is placed on the skin;

(c) The second door skin is placed over the door skeleton, ensuring that the glued surface of the skin is facing downwards;

(d) The assembled sandwich is loaded into the press. The hot press is hydraulically operated, the cold press mechanically operated.

Figure 53. Assembling and pressing the door sandwich



Step 14

After the pressing operation, the door panel should be allowed to cure for at least eight hours (depending on type of glue) before performing the next operation.

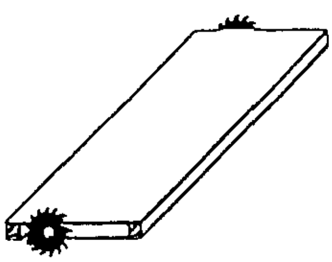
Step 15 (optional)

In the case of door panels with upgraded veneer, it is advisable to gauge-sand both surfaces of the door panel using a portable sander, belt sander or drum sander before veneering. The first veneer skin is then placed on the workbench, and glue is applied on the surface of the door skin. The door panel is placed over the veneer skin (the glued surface should be placed facing the first veneer skin). Glue is spread over the second door skin (now facing upwards), the second veneer skin is placed over the door surface that has just been glued and the door is loaded into the press. The glue should be allowed to cure before beginning the next operation.

Step 16

The door panel is dimensioned lengthwise and crosswise (rabbets on long edges should be machined) using a dimension saw with a scoring saw unit or a combination spindle moulder/circular saw with scoring unit (figure 54). If lippings are required, they are fit on after dimensioning and horns are trimmed off using a circular saw with scoring unit.

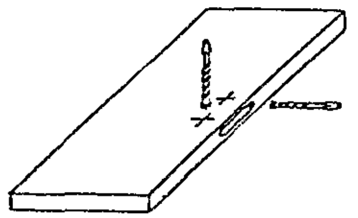
Figure 54. Dimensioning the door panel



Step 17

The lock slot, handle and key holes are mortised using a chain and chisel mortiser (figure 55).

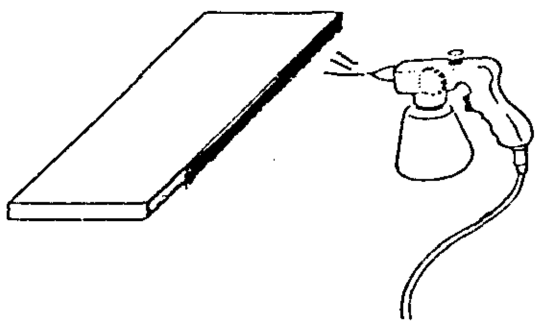
Figure 55. Lock slot, handle and key holes



Step 18

The edges and surfaces are finished using a brush or spraying gun (figure 56).

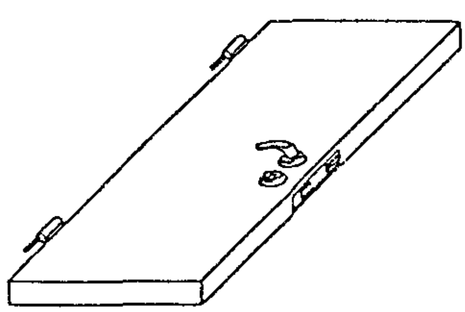
Figure 56. Finishing using a spray gun



Step 19

Hardware such as hinges, lock, handles or knobs and key-plate are fitted using a portable drill and screwdriver with hinge-inserting attachment (figure 57).

Figure 57. Door complete with hinges, handle, lock and key-plate



In the case of cut-out doors, the apertures should be trimmed off after the dimensioning operation by means of a portable router, portable saw or fretting saw. Assembly might then include the fitting of raised panels (or glass), fittings and decorative moulding using a hammer and tacks or a portable tacking gun.

The use of special machines in modern door manufacturing does not change the manufacturing sequence substantially. It does, however, reduce the number of operations and, consequently, the number of material-handling operations, in that several sequences may be performed simultaneously on a special machine. Furthermore, since special machines are equipped with work-feeding units, it is possible to achieve great savings in labour and production time. The machining sequence, when automatic machines are installed, is as described below.

Step 1

Rough sawn timber (kiln dried to 8-10 per cent moisture content) is cross cut to correct the length of stiles and rails using an automatic cross-cut saw.

Step 2

Stiles and rails are machined to the correct cross-section size in multiples, and ventilation grooves are cut at the same time. This operation can be carried out on an automatic throughfeed five-spindle moulder equipped with a gang ripsaw attachment or on a universal spindle fitted with a gang ripsaw arbor.

Step 3

Hinge blocks are cross cut to correct lengths in multiples (the lock blocks are cut to required sizes from hinge blocks). The right cross-section of staves for hinge and lock blocks is obtained during step 2. Suitable cross-cutting machines for this step depend on the quantities to be produced; such machines are multiple cross-cut saws (drum type), automatic cross-cut saws with automatic stock feed and rotating platform cross-cut saws.

Step 4

Skin panels and core strips are sized to the correct dimensions on an automatic panel saw.

Step 5

Veneer overlays are clipped lengthwise and crosswise on an automatic veneer guillotine (slicer).

Step 6

Veneer overlays are joined on an automatic veneer splicer.

Step 7

The door skeleton is assembled by fitting together stiles, rails, hinge blocks and lock blocks by means of an automatic frame-composing machine. There are machines of different capacities, ranging from 50 to 150 frames per hour, which should be selected according to the capacity of the factory.

Step 8

The core is assembled by means of an automatic kerfing and core-composing machine. Again, there are various types of machines that produce from 20 up to 80 cores per hour, and the machine should be suited to the size of the factory.

Step 9

A door sandwich is formed on the pressing line. A pressing line may be automatic or semi-automatic. An automatic line should be contemplated if daily production exceeds 300 door panels per work shift and the veneering of doors is required. Such a line is generally made up of the following machines connected together:

Four-roll glue spreader (automatic feeder optional)
Powered edge-knife disc conveyor
Sandwich-preparation belt conveyor
Press-feeding conveyor
Hydraulically operated hot-platen press (of the short-cycle type or single daylight, multi-daylight type with 2 to 6 hot platens)
Press-outfeed conveyor (automatic stacking unit optional)

A semi-automatic pressing line would be composed of the following machines:

Four-roll glue spreader
Idle edge-knife disc conveyor
Sandwich-preparation bench
Hydraulically operated hot-platen press (it should not have more than six daylights, although presses with only one daylight are also used).

If the veneering operation is required, the doors should be thickness sanded or gauge sanded on both faces before returning them to the press, and the sanding operation should be performed at least eight hours after the door panel has been discharged from the press. Depending on the quantity of doors, the sanding operation may be done on a top and bottom automatic wide-belt sander (over 400 doors per shift) or an overhead wide-belt sander (up to 400 doors per shift).

Step 10

Door dimensioning is carried out either on a single-side automatic trimming and edging machine (maximum production capacity about 100-150 doors per shift, depending on the operator's skill), on a double-end automatic trimming and edging machine (maximum capacity around 300-350 doors per shift) or on an automatic edging line consisting of two double-end automatic trimming and edging machines connected by an automatic panel turning device long-to-broad side. Such an edging line can machine about 700-800 doors on four edges per shift. Its machining potential may be further increased up to 1,000-1,200 doors per shift, if an automatic feeder and stacker are connected to the line.

Step 11 (optional)

When doors have to be fitted with solid-wood lippings or with veneer edges to cover up the exposed edges of skins (for high-quality doors) use is made of automatic or semi-automatic edge-banding machines. Again, such machines should be considered if production exceeds 300 doors per day. The double-end automatic edge-banding machines can be installed in line with the automatic double-end trimming and edging machines, thus forming an integrated process line of very high productive capacity.

Step 12

Door finishing can be carried out in several ways, depending on the volume of production, on the degree of surface finish required and, also, on the kind of paints and varnishes required. The choice of surface finishing equipment and facilities should always be made by specialists in the field, because the quality of the product depends primarily on good surface finishing. The machines and equipment required are:

Lacquer spraying booth and spraying guns
Automatic lacquer-sanding machines
Automatic roll-coating machines
Paint-curing ovens (infra-red, ultraviolet, hot air etc.)

Step 13

The hardware-fitting operations (hinges, locks) are carried out automatically on machines capable of making mortises, drilling holes and inserting hinges and locks simultaneously. Hardware-fitting machines may be semi-automatic or automatic. Semi-automatic machines differ from automatic ones in that the workpiece is not fed automatically, and, consequently they require more manual labour. The choice of one or the other machine depends on the volume of production; semi-automatic machines are suitable for a production capacity of up to 200 doors per hour, while automatic machines can handle from 30 to 120 doors per hour. Downstream of the hardware-fitting machines, a suitable number of assembly benches are usually installed for glass, raised panels, mouldings and door handles; the benches are suitably equipped with portable power tools.

Outline of a medium-sized door and window factory

This final section is devoted entirely to the basic engineering problems associated with the layout of a medium-sized manufacturing plant for doors and windows. Before the factory layout for a new installation can be completely developed, the equipment must be selected, and decisions must be taken as to the type, capacity, number of units, size and other factors. For this purpose, it is necessary:

(a) To obtain drawings or sketches of the products along with their specifications. The materials and parts required must then be listed and analysed;

(b) To establish the volume and rate of production;

(c) To obtain and develop operation sheets for the parts, sub-assemblies and final assembly or assemblies;

(d) To list operations according to the type of equipment on which they will be performed;

(e) To obtain estimates of the time necessary for each operation, allowing for the use of jigs and fixtures, acceptable methods of processing and the introduction of semi-automatic or automatic machines. The daily capacities of the machines that are to be installed should be calculated and the number of each machine required should be determined;

(f) To select the types or makes of machines that appear the most suitable for the installation;

(g) To develop a layout for the proposed installation; if the equipment has to fit in an existing building, the layout will have to be adjusted to tie in with other machines and departments. Floor loads must be calculated

for heavy machines, and sometimes such machines may have to be taken out of their desired location and placed on the ground floor where separate foundations can be put in;

(h) To investigate the possibility of expanding production, which might require certain machines with greater capacity or might call for a modified layout that provides for areas available for later occupancy;

(i) To establish manpower and energy requirements.

In the present context, only points *(b)*, *(c)*, *(d)*, *(e)* and *(i)* will be examined, as point *(a)* has been discussed above and points *(f)*, *(g)* and *(h)* are beyond the scope of this chapter.

Volume and rate of production

For the purpose of this analysis, a production rate of 25,000 casement two-shutter windows/year and 25,000 flush doors/year, complete with casements, has been assumed. The products will comply to the following specifications:

(a) All windows should be treated against degrading and aging (insects, mould, weathering) and finished with a gloss paint;

(b) Fifty per cent of the doors are cut-out, with a single-aperture raised panel, veneered and finished with matt paint. The remaining 50 per cent are fully cored with plastic pre-laminated skins and hardwood lippings on two long edges. The core material is of hardwood strips, and the door skeleton is of softwood; the cut-out doors are edge-banded with veneer skins on long edges only;

(c) Door casements are of good quality hardwood, painted like the cut-out doors, and are to be delivered in knock-down form;

(d) The raw material for windows is Douglas fir timber;

(e) Doors and windows are to be delivered complete with hardware and accessories, but window panes do not have to be assembled at the factory.

(f) Average window dimensions are 1.4 m wide × 1.5 m high; finished sections of all components are 68 mm wide by 54 mm thick, with glass-holding strips;

(g) Average door dimensions are 0.8 m wide × 2.1 m high by 45 mm thick, with the finished section of casements being 105 mm wide × 70 mm thick;

(h) The factory will work 250 days/year on a single shift of eight hours/day.

Operational flow-sheet

On the basis of the specifications and following the steps described in previous sections, an operational flow-sheet can be drawn up. The general production-flow diagram, which summarizes and illustrates the content of the operational flow-sheet, is shown in figure 58.

Machine loading and estimating

Based on the description of operations on the general production-flow diagram, the following list of operations (machine loading) can be drawn up:

(a) Cross-cut saw, which cuts all solid wood components for the windows, door core, door lippings and raised panels and decorative mouldings to length. It also trims off defective ends;

(b) Multiple ripsaw, which machines to the correct cross-section all solid-wood components, in multiples, such as: window casement rails and stiles, shutter rails and stiles, door skeleton rails, stiles, hinge and lock blocks, door lippings, mouldings, door casement jambs and heads and door core strips. The specifications are as follows:

Machine capacity	10 000 m/day
Required output	7 000 m/day
Number of machines required	1

(c) Multi-spindle moulder, which corrects the cross-section of all solid-wood components: window casement stiles and rails, shutter stiles and rails (also glass-holding strip), decorative mouldings on raised panels (astragals) in multiples, and door casement jambs and head (two at a time). The specifications are as follows:

Machine capacity	4 000 m/day
Required output	3 000 m/day
Number of machines required	1

(d) Double-end tenoner, which machines tenons and opens mortises on windows components, machines rabbet joints on door casement jambs and head, dimensions door panels lengthwise and widthwise and dimensions window shutters lengthwise and widthwise. The specifications are as follows:

Machine capacity	2 800 pieces/day
Required output	2 100 pieces/day
Number of machines required	1

(e) Frame press, in which the window shutter components are assembled. It is used in conjunction with a work-bench and gluing facilities. The specifications are as follows:

Machine capacity	400 pieces/day
Required output	300 pieces/day
Number of machines required	1

(f) Surface sander, which sands window shutters on both faces and door panels on both faces prior to the veneering operation. The specifications are as follows:

Machine capacity	1 200 m/day
Required output	1 350 m/day
Number of machines required	1

The shortfall in capacity versus output would have to be covered by overtime;

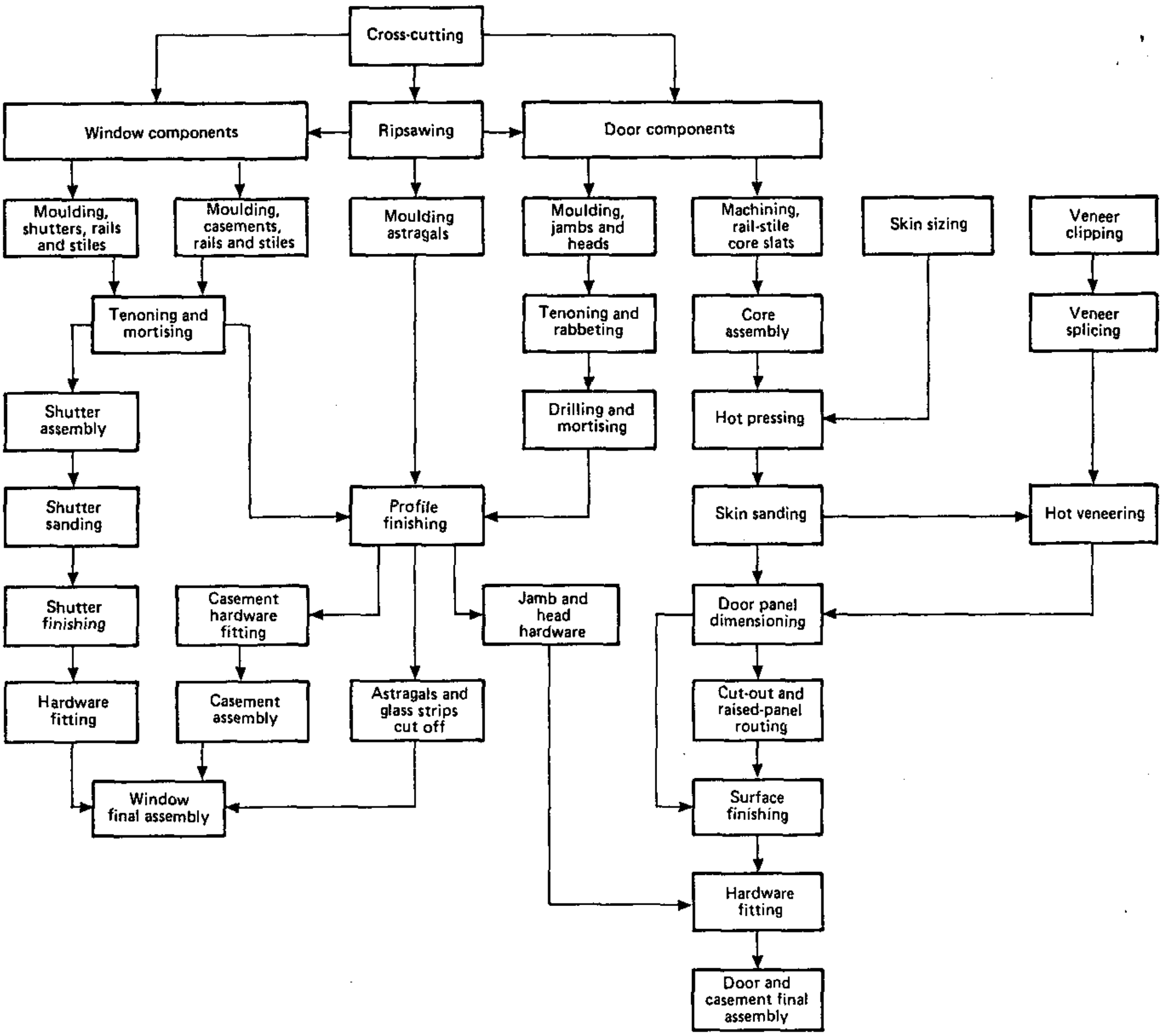
(g) Profile-finishing line, which is composed of the following machines:

Profile sander
Profile painting and varnishing machine
Hot-air paint-curing oven

On this line, window casement stiles and rails, door jambs and heads, glass-holding strips on shutters and door mouldings are completely finished in two passes. The specifications are as follows:

Line capacity	4 000 m/day
Required output	3 000 m/day
Number of lines required	1

Figure 58. General production-flow diagram



(h) Window shutter and flush door finishing line, which is composed of the following equipment:

Impregnation dipping tank for window shutters
Automatic painting and varnishing machine with oscillating guns
Hot-air curing oven

On this line, the edges and surfaces of window shutters, flush doors and raised door panels are completely finished in four passes. The specifications are as follows:

Line capacity	3 200 m/day
Required output	2 600 m/day
Number of lines required	1

(i) Mitre saw, which cuts off, to correct length and angles, glass holding strips for shutters and holding strips for raised panels (astragals). The specifications are as follows:

Machine capacity	1 800 pieces/day
Required output	1 600 pieces/day
Number of machines required	1

(j) Radial-arm saw, which machines kerfs on door strip cores. The specifications are as follows:

Machine capacity	1 200 cuts/day
Required output	750 cuts/day
Number of machines required	1

(k) Double-end panel saw, which cuts skin panels to size. The specifications are as follows:

Machine capacity	4 m^3/day
Required output	1.5 m^3/day
Number of machines required	1

(l) Veneer clipper, which cuts to size sorted veneer skins. The specifications are as follows:

Machine capacity	1 300 m^2/day
Required output	250 m^2/day
Number of machines required	1

(m) Veneer splicer, which joins veneer strips to make suitable door sizes. The specifications are as follows:

Machine capacity	650 m^2/day

Required output	250 m^2/day
Number of machines required	1

(n) Single-side edge bander, which applies lippings and/or veneer edges on doors. The specifications are as follows:

Machine capacity	1 000 m/day
Required output	400 m/day
Number of machines required	1

(o) Hot-pressing line, which is composed of the following machines and equipment:

Two-roll glue-spreading machine
Idle edge-knife disc conveyor
Sandwich preparation bench
Hydraulically operated four-daylight hot-platen press

The specifications are as follows:

Line capacity	400 m^2/day
Required output	350 m^2/day
Number of machines required	1

(p) Automatic router, which machines cut-outs and raised panels on doors. The specifications are as follows:

Machine capacity	200 pieces/day
Required output	100 pieces/day
Number of machines required	1

(q) Universal drilling machine, which drills holes on door jambs and heads and on window casement rails for water drainage and lock rod. The specifications are as follows:

Machine capacity	800 pieces/day
Required output	500 pieces/day
Number of machines required	1

(r) Universal chain and chisel lock mortiser, which machines lock slots, key and handle bores on flush door panels; face-plate slots on door jambs; and slots and bores for locking mechanisms on window shutters. The specifications are as follows:

Machine capacity	200 pieces/day
Required output	300 pieces/day
Number of machines required	2

(s) Hinge-drilling and inserting machine, which prepares holes for and inserts hinges in an automatic cycle on door jambs, door panels, window casements and window shutters. The specifications are as follows:

Machine capacity	400 pieces/day
Required output	600 pieces/day
Number of machines required	2

(t) Fully equipped work-bench, with portable power tools such as screwdriver, drill and nailing gun. It is used for performing minor manual assembly operations on doors, windows and casements prior to delivery. Four benches are required;

(u) Material-handling equipment. A suitable number of pallet trucks, fork-lifts, containers and roller conveyors and trolleys are needed for moving raw materials, semi-finished stock and finished products around the factory floor.

The factory is of the batch-production type. The layout will be based on the process. The main advantages of this factory are:

(a) It is extremely flexible;

(b) The machine utilization is high, with a correspondingly low capital investment;

(c) The individual operator's efficiency tends to be high, since operators are required to be versatile and have some degree of skill (see below).

The only disadvantages of this type of factory are:

(a) Substantial pre-production planning is required if machine loading is to be high;

(b) Control is difficult.

Manpower requirements

The following workers are needed in the factory:

Skilled	14
Semi-skilled	18
Unskilled	8
Total	40

Energy requirements

From the list of machinery and equipment proposed, the following energy requirements can be calculated:

Power	250 kW
Compressed air at 6-8 atm	4 000 normal litres/min
Dust and chip extraction	35 000 m^3/h
Heat (hot water at 80-100° C)	1 046 000 kJ/h (250 000 kcal/h)

It should be noted that:

(a) Power includes the power to run the production machinery, the air compressors, the dust and chips extraction fans and a small boiler plant for hot water generation;

(b) Power has been calculated using an overall operating factor of 0.6.

Conclusions

In the present chapter, the foundations for the design of an economic model factory for the production of doors and windows of medium physical dimensions have been discussed, assuming a relatively high return on capital investment. Upon examining the productivity of the factory it would be seen that each worker will produce 2.5 casement windows plus 2.5 flush doors per day. In terms of money (reflecting the prices and costs of labour in Italy in 1983), this means that each worker would produce:

2.5 windows × Lit 240 000	Lit 600 000/day/worker
2.5 doors × Lit 90 000	Lit 225 000/day/worker
Total	Lit 825 000/day/worker

Based on the current costing situation in doors and windows manufacturing, a worker would yield about seven times the cost value. Of course, this does not take into full account such factors as the depreciation of machinery and equipment, interest on invested capital and other cost items. But it has been assumed that these items of cost, as well as raw materials and indirect materials, should be covered by the sales price of the products and by labour cost.

XXV. Production of chairs and other wood components*

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 derivatives 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 solid wood manufacture. Therefore, the information presented here is applicable to the production of a wide range of products from solid wood.

General features of the Italian chair industry

Furniture is a major industry in north-east Italy, particularly in the Friuli Venezia Giulia area. All the 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-contractors.

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 the quality of products and services.

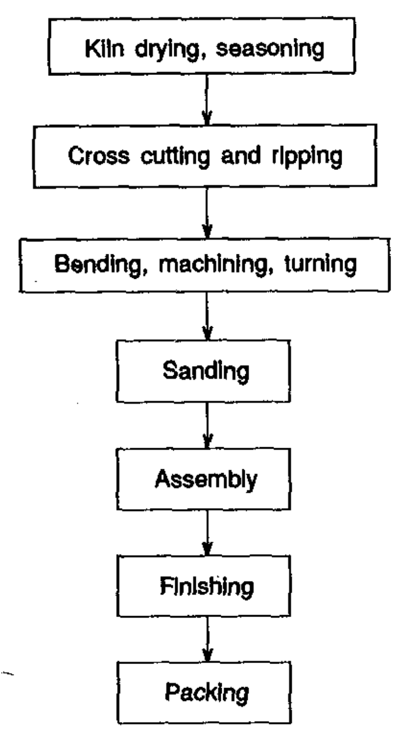
Alternative *(a)* offers the possibility of establishing highly automated and productive manufacturing lines using specialized machines. This is also possible for alternative *(b)*, although not to the same extent, because the various models are technically compatible but less productive. In the last case, *(c)*, which 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

The "integral cycle" plant for the production of chairs is a plant where production starts with the sawn timber and ends with a fully finished and packaged product.[1] 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

*By A. Speranza, Director of CATAS, San Giovanni al Natisone (UD), Regional Centre of Technical Assistance for Manufacturers of Chairs and Wooden Furniture, Azienda Speciale della Camera di Commercio di Udine. (Originally issued as ID/WG.277/2/Rev.1).

[1] The upholstering of chairs and the bending of wood by steam will not be considered because these are specialized operations carried out by specialized firms.

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-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 XXIII 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 be either seasoned in an 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 XXI. 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, owing to its simplicity and speed.

Cross-cutting and ripping

Kiln-dried lumber should be sawn to rough dimensions 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 pendulum 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 on the same shaft spaced at pre-set distances. Several sticks can be obtained simultaneously 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 two parallel 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 speeds, selected by the operator, 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 worker. 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.

Shaping

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 pre-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.

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, power 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. This cross-cutting machine can cut both ends to length simultaneously. Consideration should also be given to the widely used multi-purpose machine (e.g. tenoner). 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 a 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. 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 with pistons which assemble the components of the chair or other products rapidly. The clamps are mounted on a sufficiently rigid frame. Their relative position can be easily modified as required.

Finishing (see also chapter XXIII)

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 or curtain coating. The use of the gun requires a high rate of material consumption, gives a better quality of finish but a slower finishing rate. Curtain 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 conveyor 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. Under optimal conditions, 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 a special nozzle, has recently been used for painting chairs with further savings in operation time and material consumption. 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 exhaust systems. These 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. The 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 and chamfered, 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. (For further information on machines and equipment for tool maintenance, see chapter XVIII.)

In the case of mass production of only a few models, 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. 4-side 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 one or two belts above feed table, 1,100 mm working width
16. 4 horizontal sanders with a 2.2 m long table
17. Brush sander with abrasive holder
18. Bench sander
19. Dust exhaust system for 12 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 (if ambient climate justifies them)
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 7 cutter heads

(e) Maintenance room:

35. Grinding machine
36. 3 kW portable welder
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 exhaust, 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 tonnes

(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

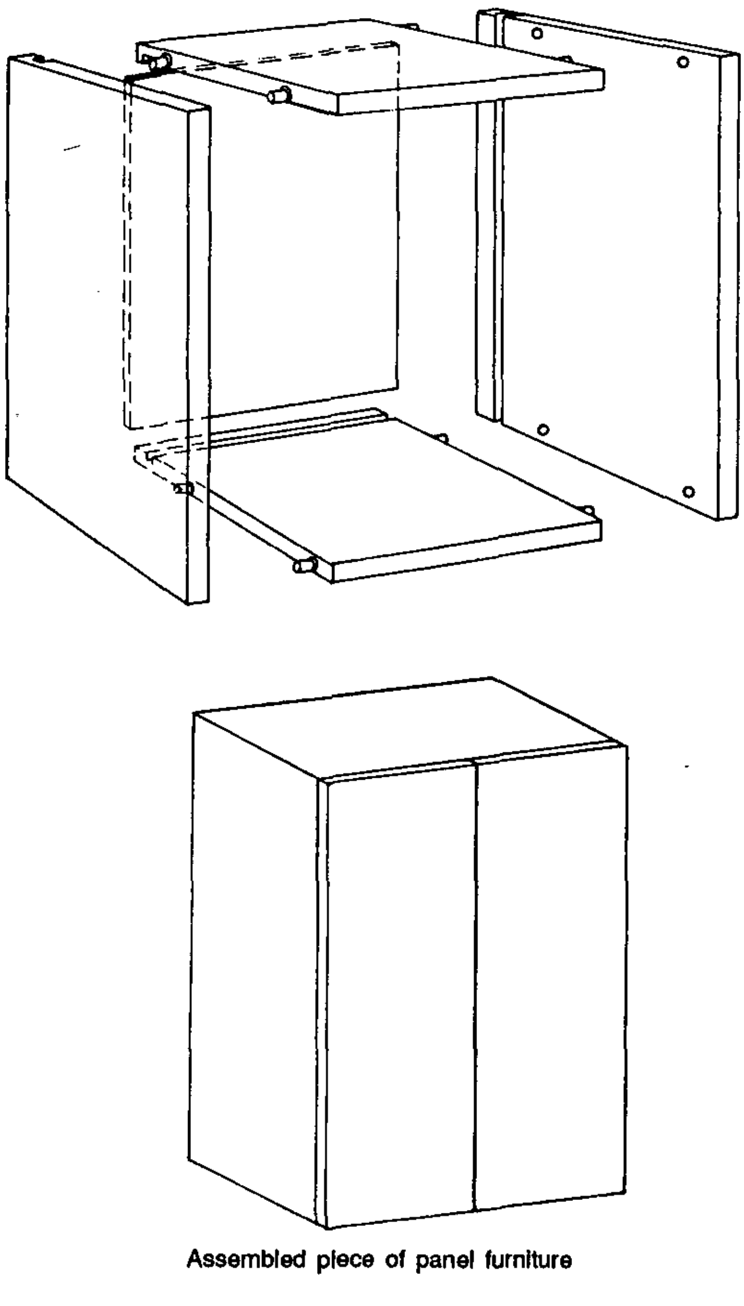
XXVI. Technology and machinery for the production of casegood furniture*

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 that 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 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:

*By A. Schiavo, industrial management/planning consultant, expert in the furniture sector. (Originally issued as ID/WG.277/8/Rev.1.)

Figure 1. Assembling of carcass components



Assembled piece of panel furniture

(*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 lamin board;

(*d*) Particle board coated with melamine laminates;

(*e*) Particle board for coating with paper or PVC;

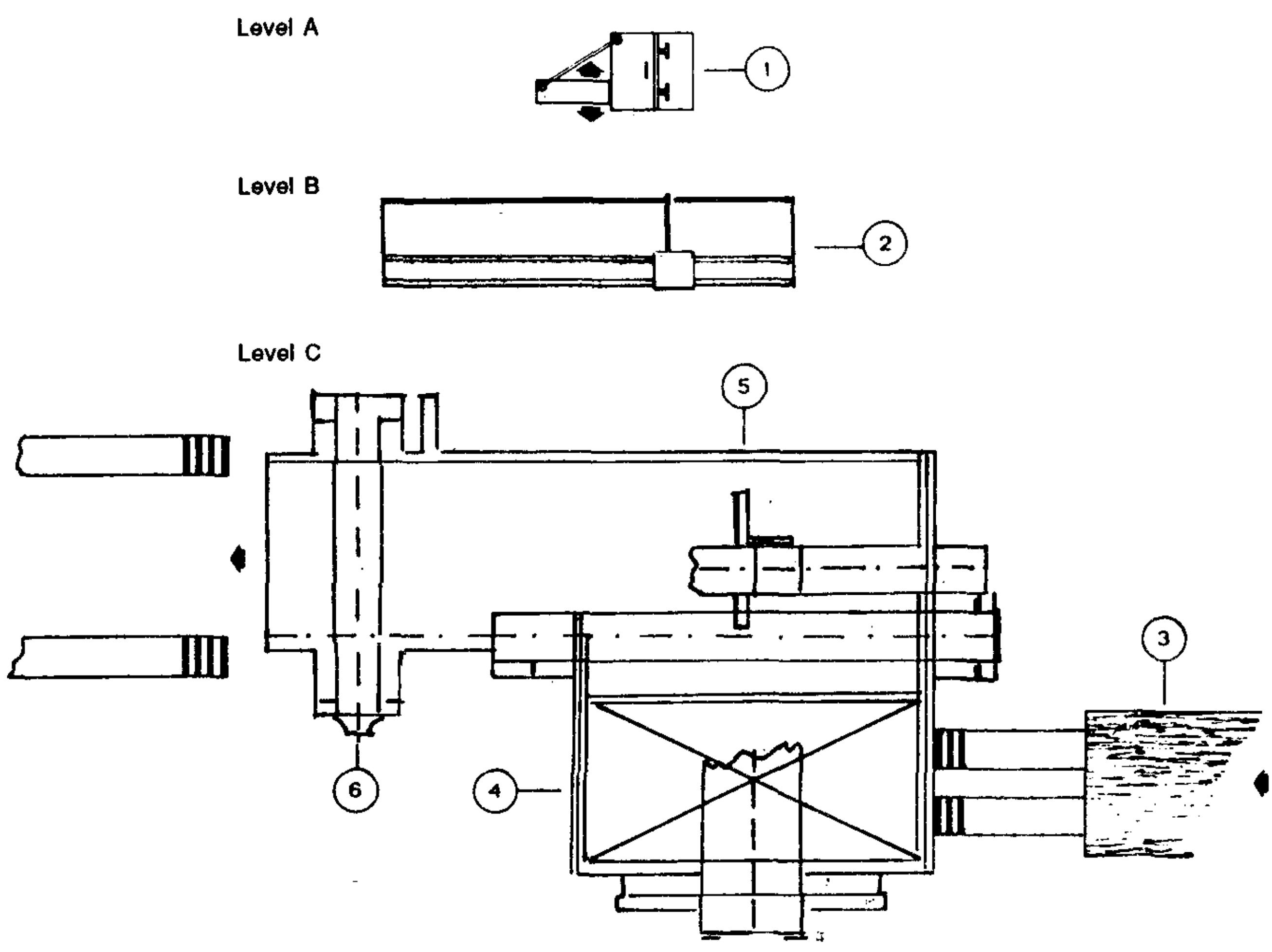
(*f*) Plywood;

(*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.

Figure 2. Layout for panel sizing



Key: 1 Circular saw with sliding table
2 Vertical single bakle panel saw
3 Panel storage infeed
4 Automatic loader
5 Panel rip saw
6 Panel crosscut saw

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 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 m³ 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:

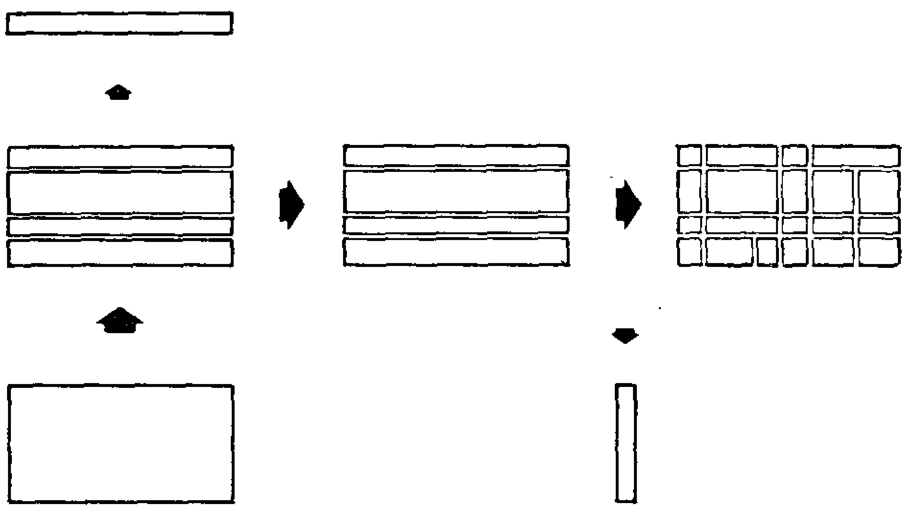
(a) A machine equipped with multiple blades for lengthwise sawing of panel packs; a top sawing unit is placed for crosswise sawing;

(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 (see figure 3). The entire pack or the single strips are moved by a conveyor.

On all plants of level C both lengthwise and crosswise sawing can be controlled mechanically or by numerical programme. Automatic loaders and stackers 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 on 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 UF glue on both sides. The covering panels are applied and curing follows in a one-opening hot press.

The temperature of the water circulating in the platens is 90° C. The length of the curing cycle depends on the thickness of the face 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 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;

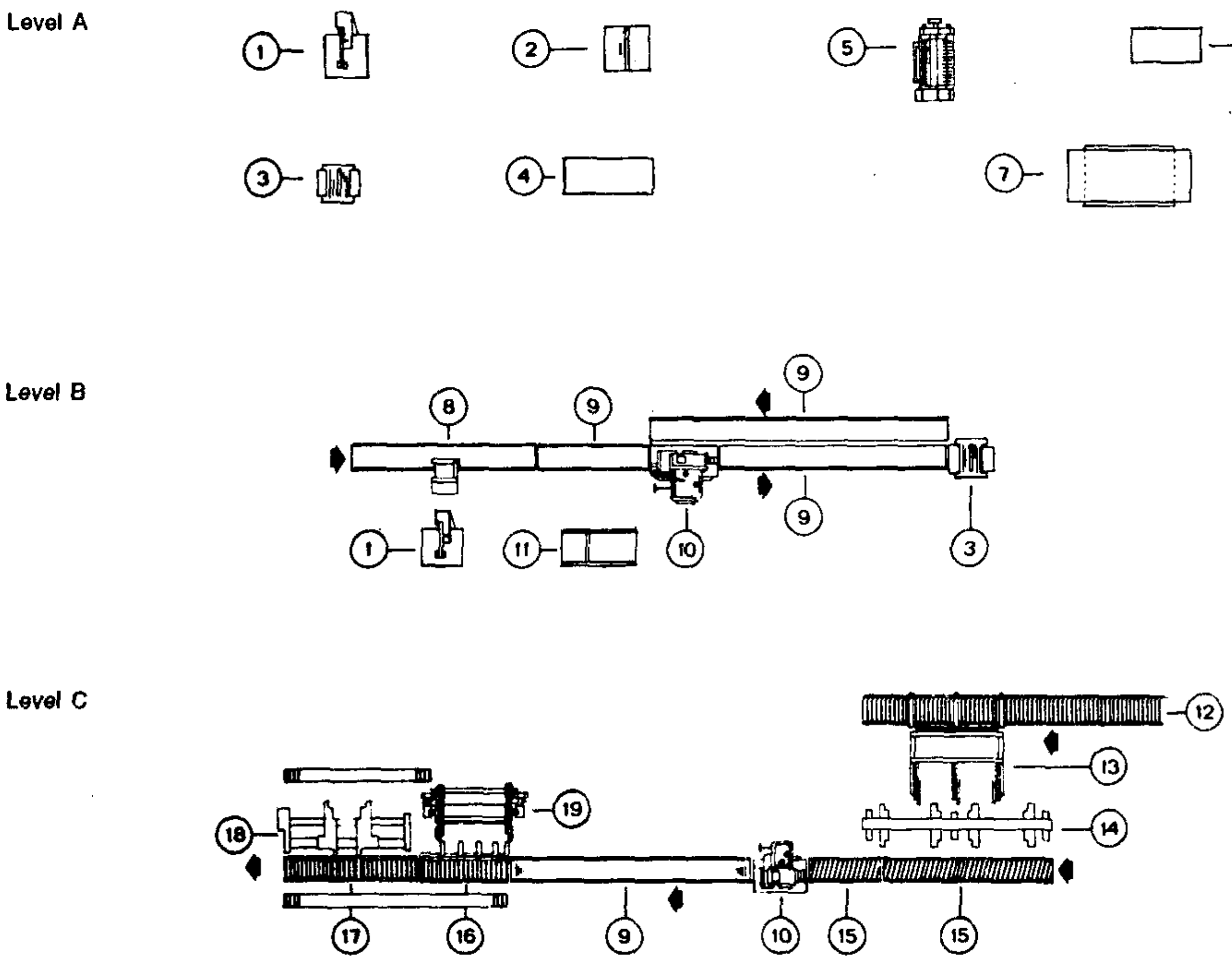
(h) A disc conveyor linking the glue spreader and the press.

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 conveyor. 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.

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 conveyor
7 Hot platen press
8 Cut off saw
9 Conveyor 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

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;

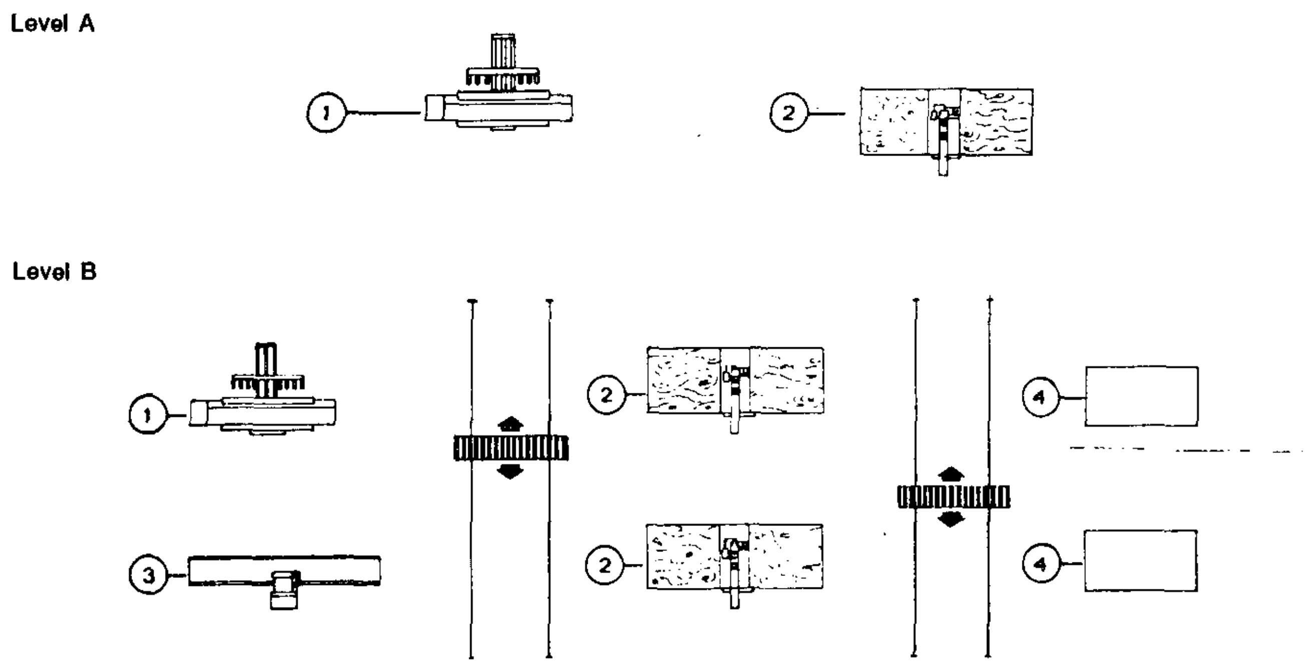
(c) Splicing machine;

(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.

Figure 5. Layout for preparation of veneers



Key: 1 Trimmer
2 Splicer
3 Saw
4 Inspection tables

Panel coating

As mentioned before, oversize panels are machined to size. Assembled hollow core boards or particle boards are processed by veneering, by the application of finished materials (papers or soft laminates such as PVC) or by the application of fillers or prime coats.

Veneering

After glue spreading,[1] the veneer is placed on the panel, pressed and cured. Machines and equipment vary according to the production level. A possible layout for veneering is shown in figure 6.

For low-level production, after preparation, the glue is applied to the panel (by hand) with a roller glue spreader and it is placed on a sheet of already prepared veneer. Another sheet is placed on top of the panel. All three are then placed in a single daylight hot press (90° C). 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 3 minutes. Pressure is about 3.5 kgf/cm^2.

For medium-level production, as the panels have to undergo successive operations on precision sanding machines, 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 through 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 conveyor 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.

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 conveyor 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 conveyor are fed in. The conveyor on the outfeed end also acts as an automatic unloader.

Laminating synthetic materials

Owing 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.

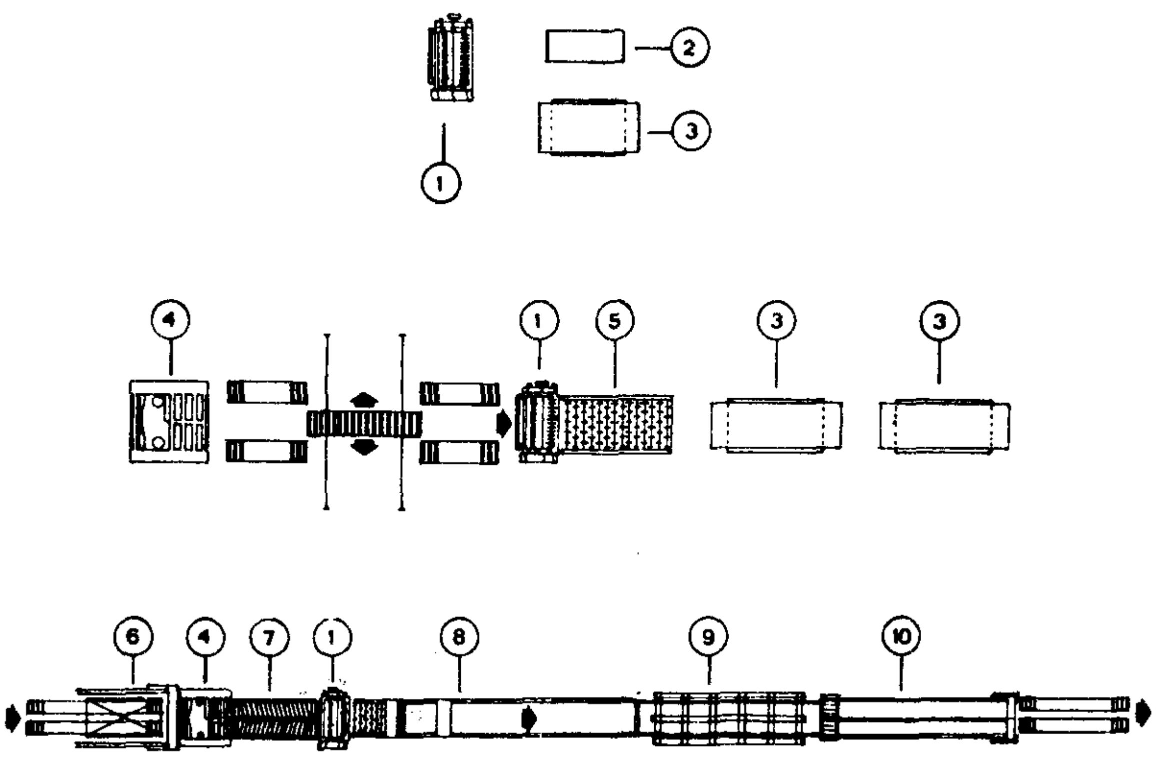
[1]For additional details on application of glue, see chapter XV.

Figure 6. Layout for veneering

Level A

Level B

Level C



Key:
1 Glue-spreading machine
2 Preparation table
3 Hot press
4 Sander
5 Disc type conveyor
6 Automatic loader for pressing line
7 V-Roller conveyor
8 Conveyor belt
9 Automatic press
10 Outfeed conveyor belt

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 PVC.

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 conveyor belt and final roller press.

Owing 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/m^2.

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.

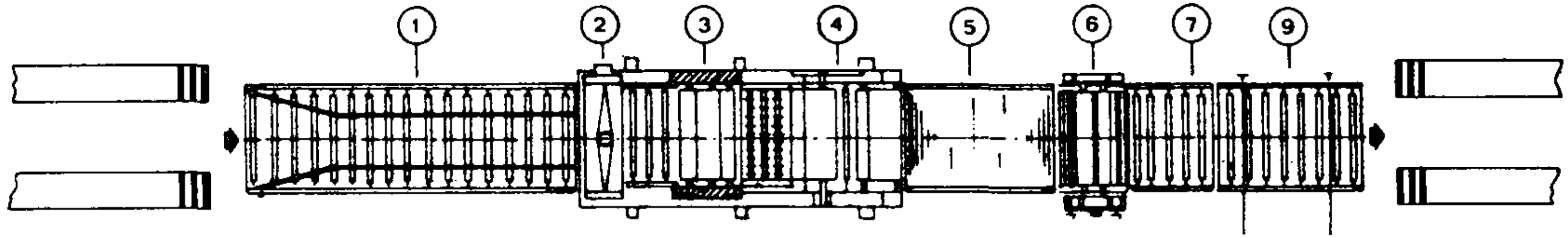
For production level B (medium level) a single face sanding machine, a filling machine, and an ultraviolet dryer is required for applying fillers. Drying time for the coat (10 s to 30 s) varies according to type of ultraviolet light used and is of the same order as for veneered panels.

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.

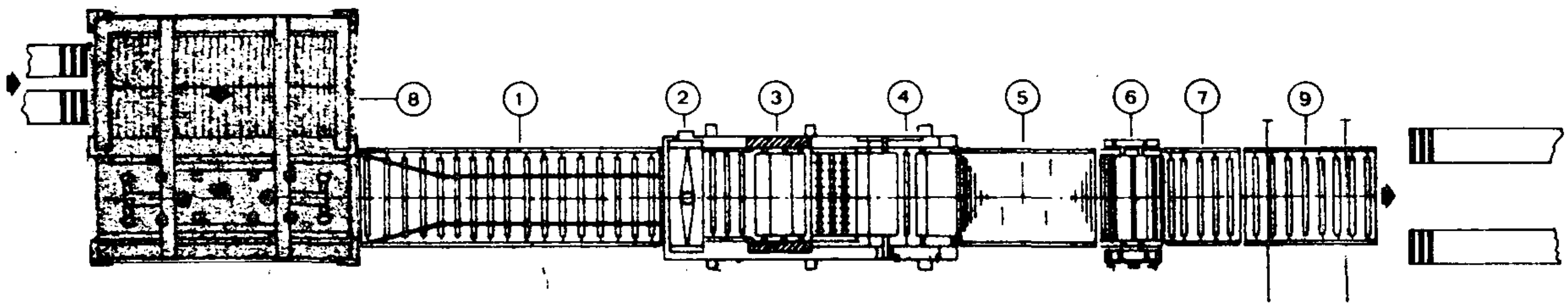
A floor plan for the application of fillers is shown in figure 8.

Figure 7. Layout for application of synthetic materials

Level B



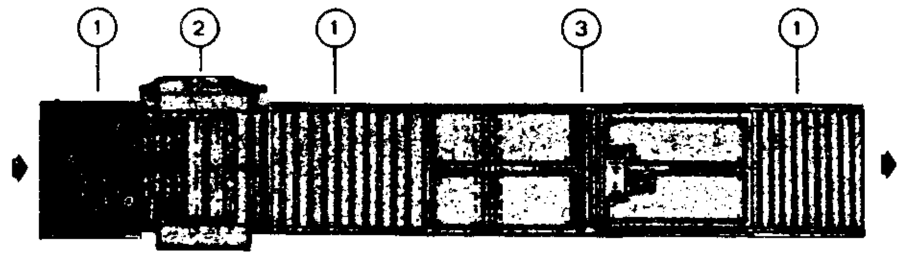
Level C



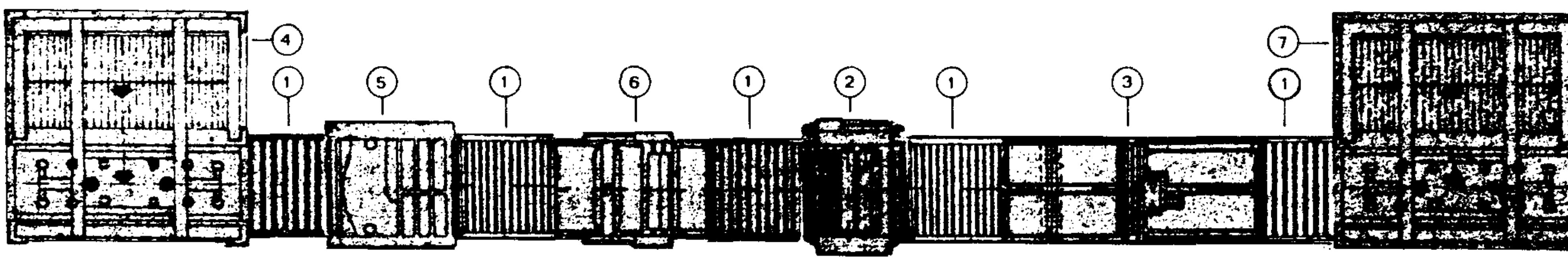
Key:
1 Infeed unit
2 Brusher
3 Unreeler
4 Clipper
5 Conveyor belt
6 Roller press
7 Outfeed conveyor
8 Automatic loader
9 Conveyor slide

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

Sizing, edge banding and boring

So far this chapter has 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 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 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 conveyor 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. The possibility of having a machine that can apply moulded solid wood lippings must be envisaged, if the programme of production calls for such an edge treatment;

(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) A double edge-banding machine (for plastic, veneer or solid wood edges);

(d) A board-turning unit;

(e) A panel-sizing machine;

(f) A double edge-banding machine (for plastic, veneer or solid wood edges);

(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;

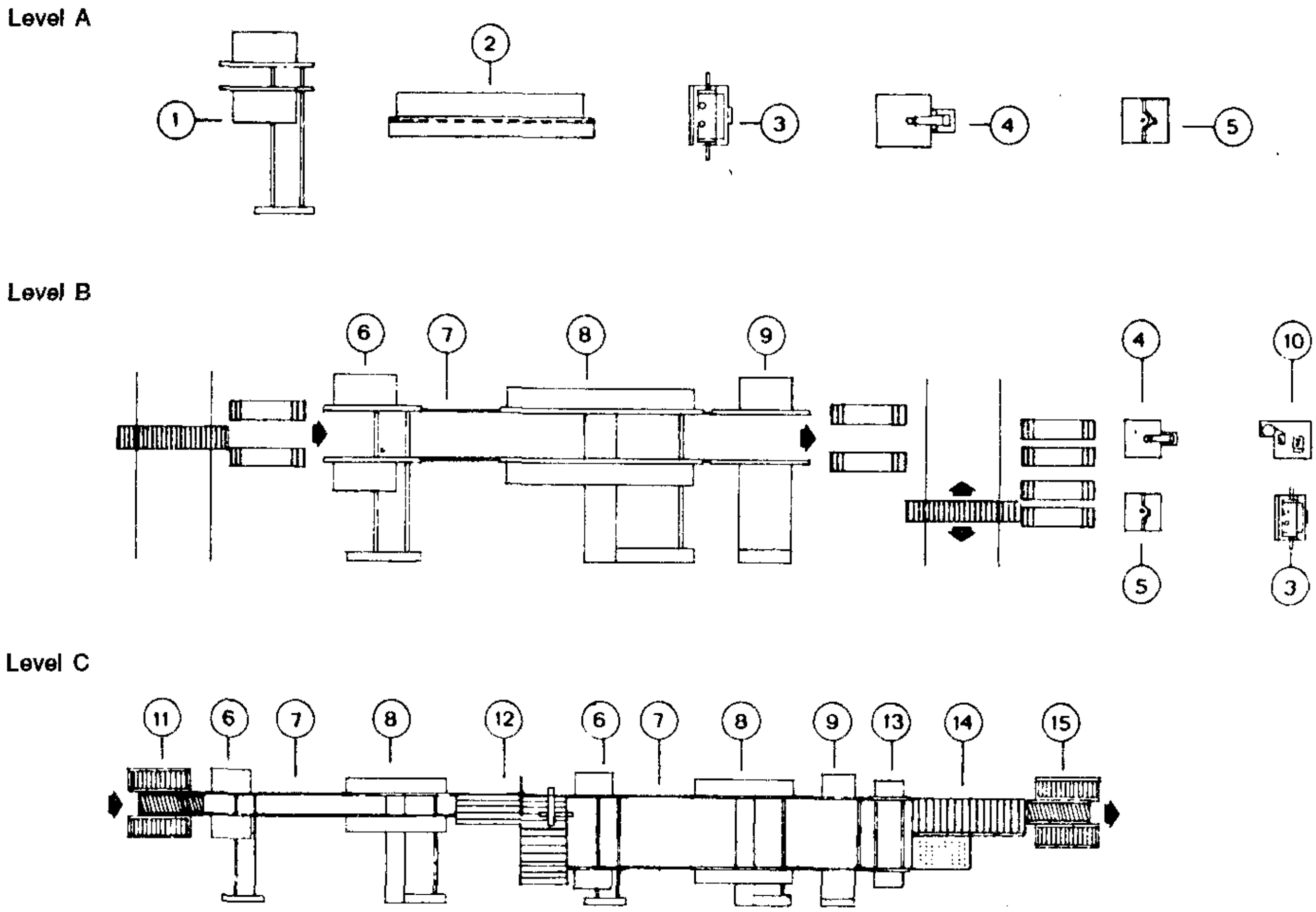
(j) A double station unloader.

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 the 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 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 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

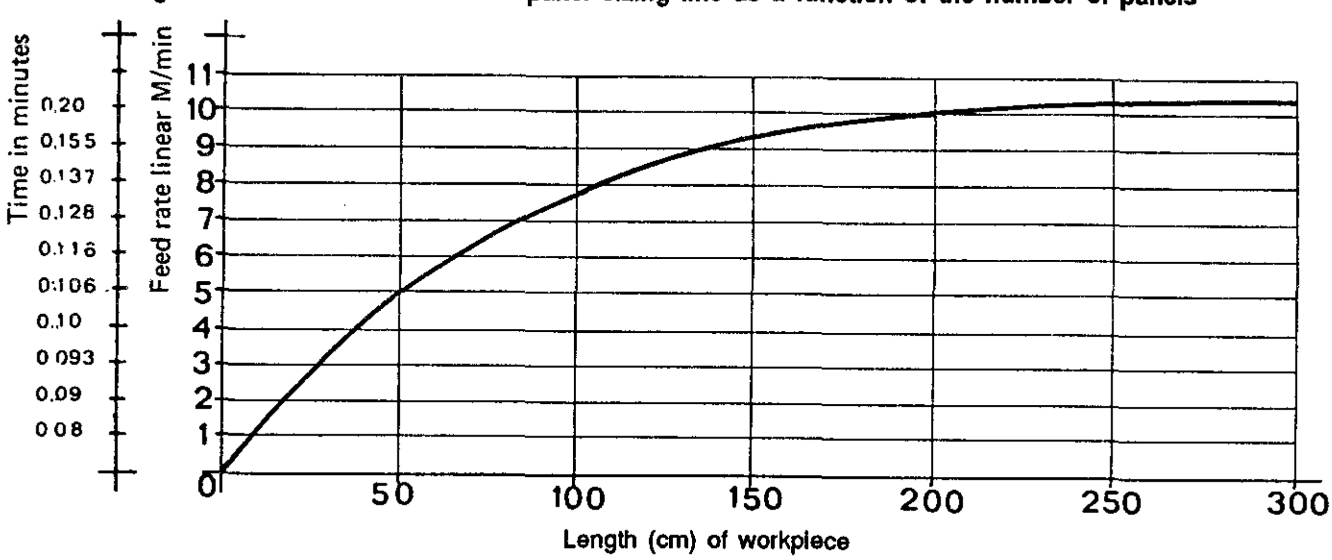


Figure 11. Production diagram of a panel-sizing line as a function of panel length

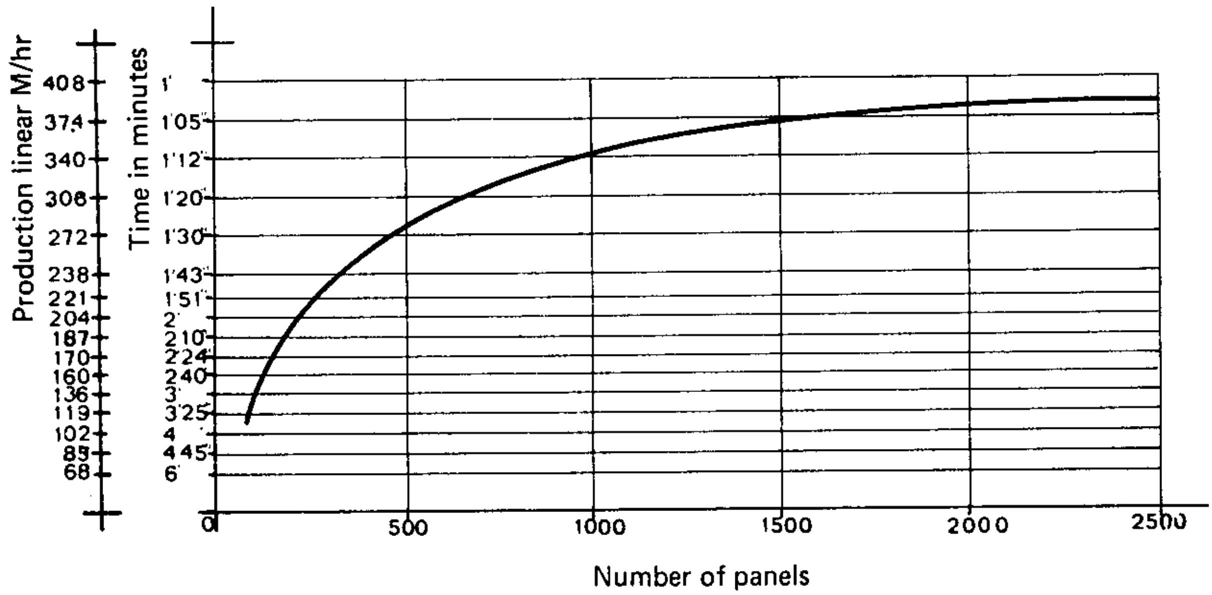
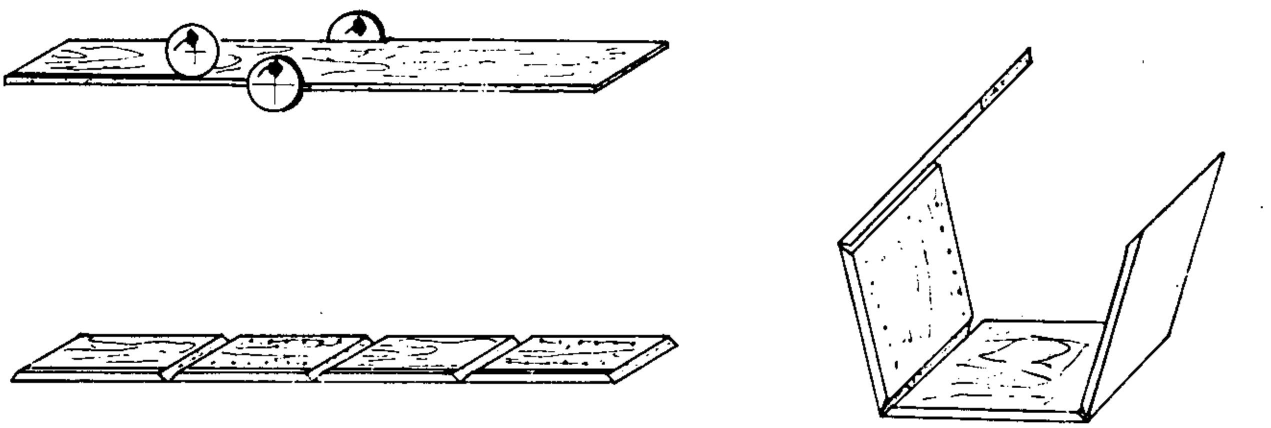


Figure 12. Sizing and edge banding (done lengthwise only). (The board is passed through an integrated linear system, is bored, grooved and folded to emerge as a furniture shell.)



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.

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 XXIII.

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 stack 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;

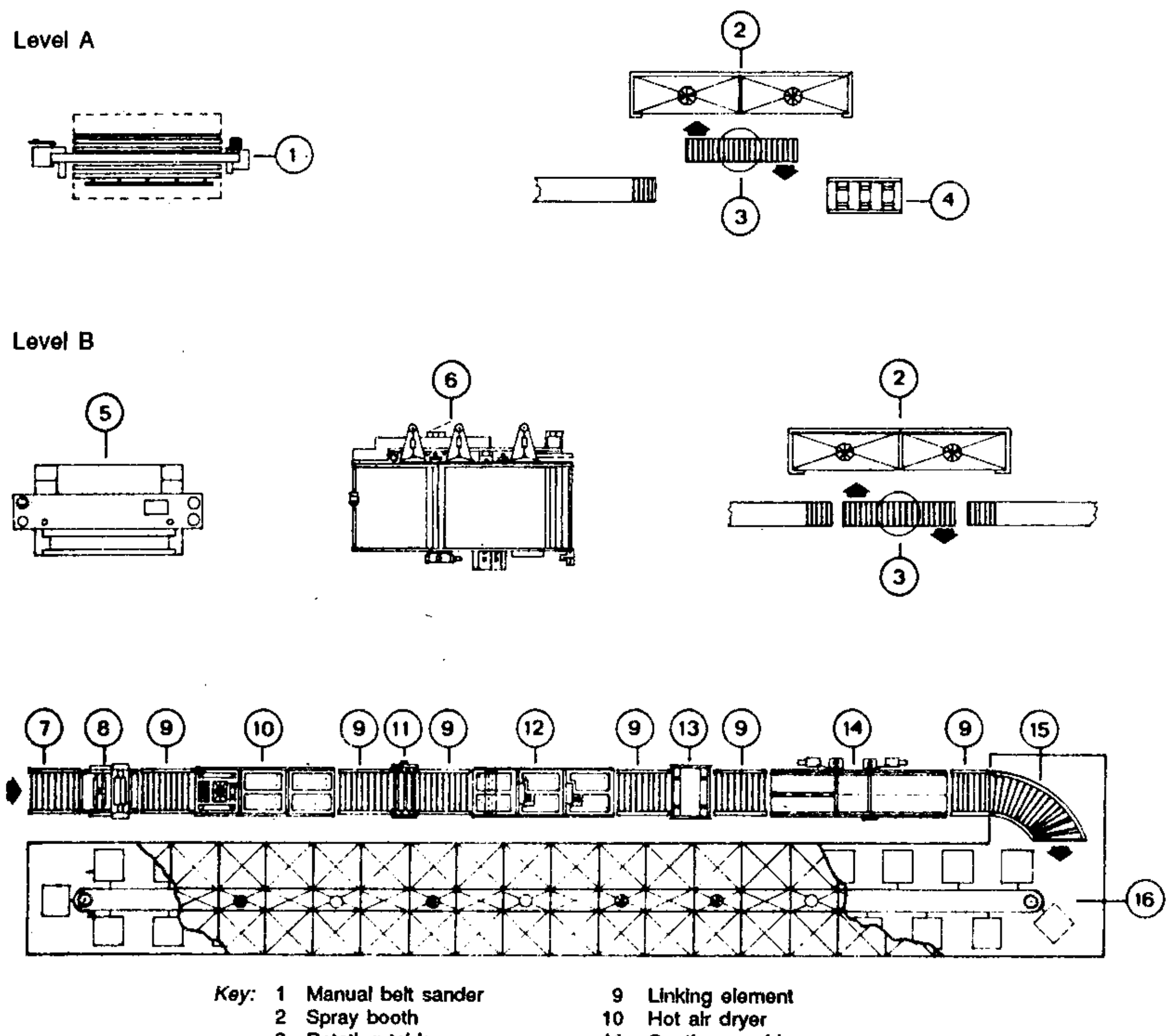
(*e*) A lacquer-sanding machine for denibbing raised grain;

(*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 conveyor, 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.

Figure 13. Layout for lacquer coating



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

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 conveyors 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.

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.

Pre-assembly—assembly—packing

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 the 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 the latter 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;

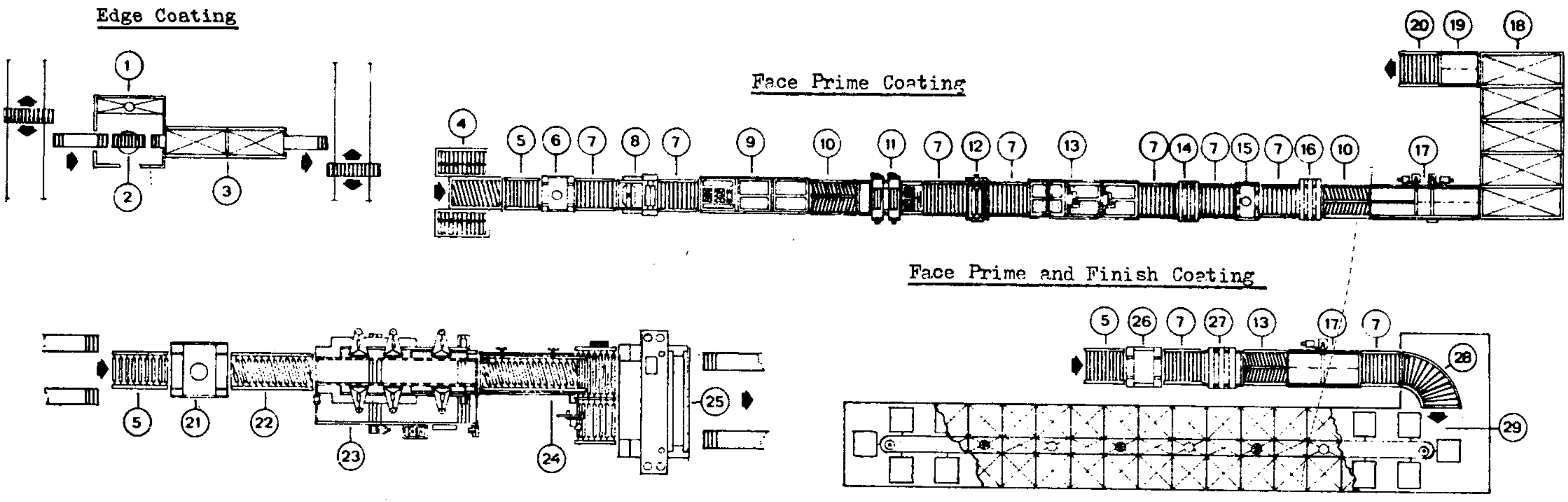
(c) Mat type or slotted conveyor belts, operated by variable-speed motor-drive reduction gears for pre-assembly, with structures for holding the equipment and with overhead pneumatic tools and hardware containers so that the operator has, within reaching distance, the right piece of hardware and the right tool for the operation involved;

(d) Clamps for squaring up the units;

(e) Automatic tippers;

(f) Slotted conveyors, variable in height (even automatically variable), for applying doors, drawers or other parts to the units as they advance at a pre-established rate.

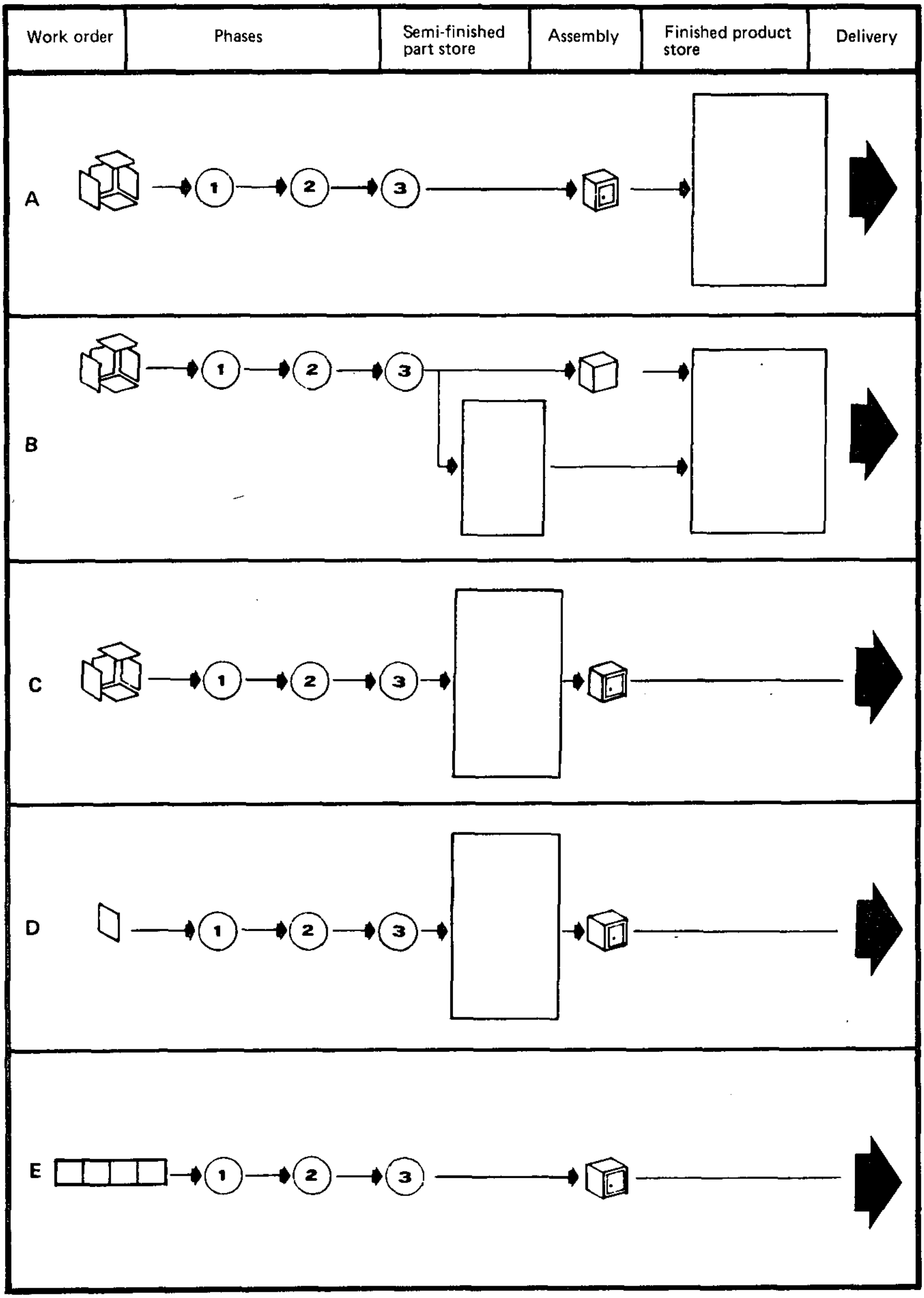
Figure 14. Layout for lacquer coating (level C)



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 Transferse 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

Figure 15. Main flow diagrams for pre-assembly, assembly and packing



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. 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 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 that 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 conveyor belt at 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.

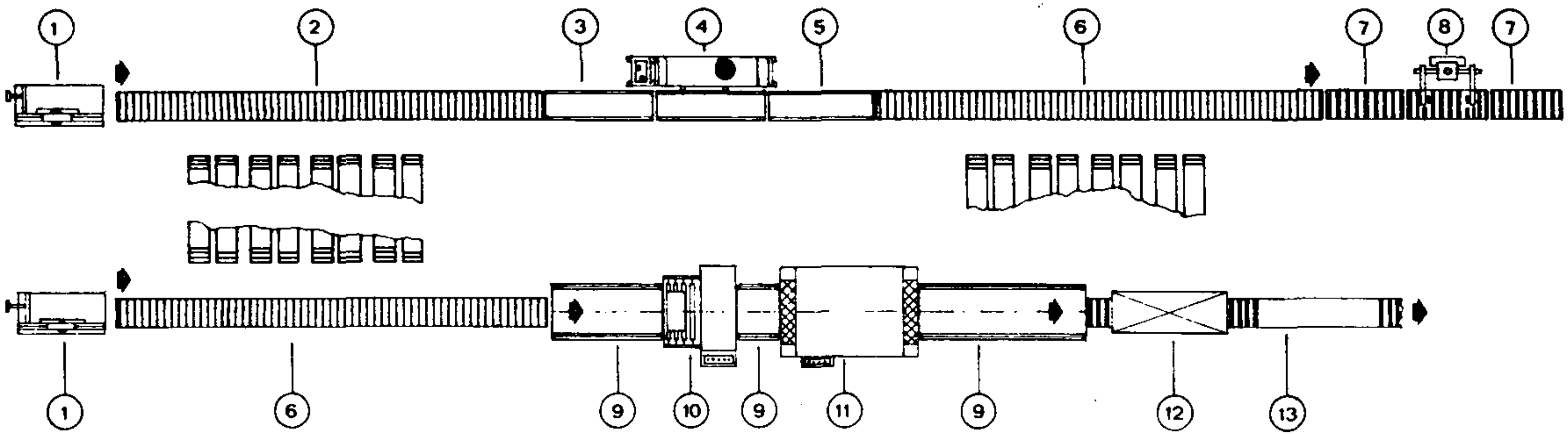
After assembly, the furniture units can be stored for delivery against orders and dispatched to the customer. Alternatively, they leave the assembly and packing lines ready to be sent to the customer.

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.

Figure 16. Layout for assembly and packing (furniture units with finished panels)

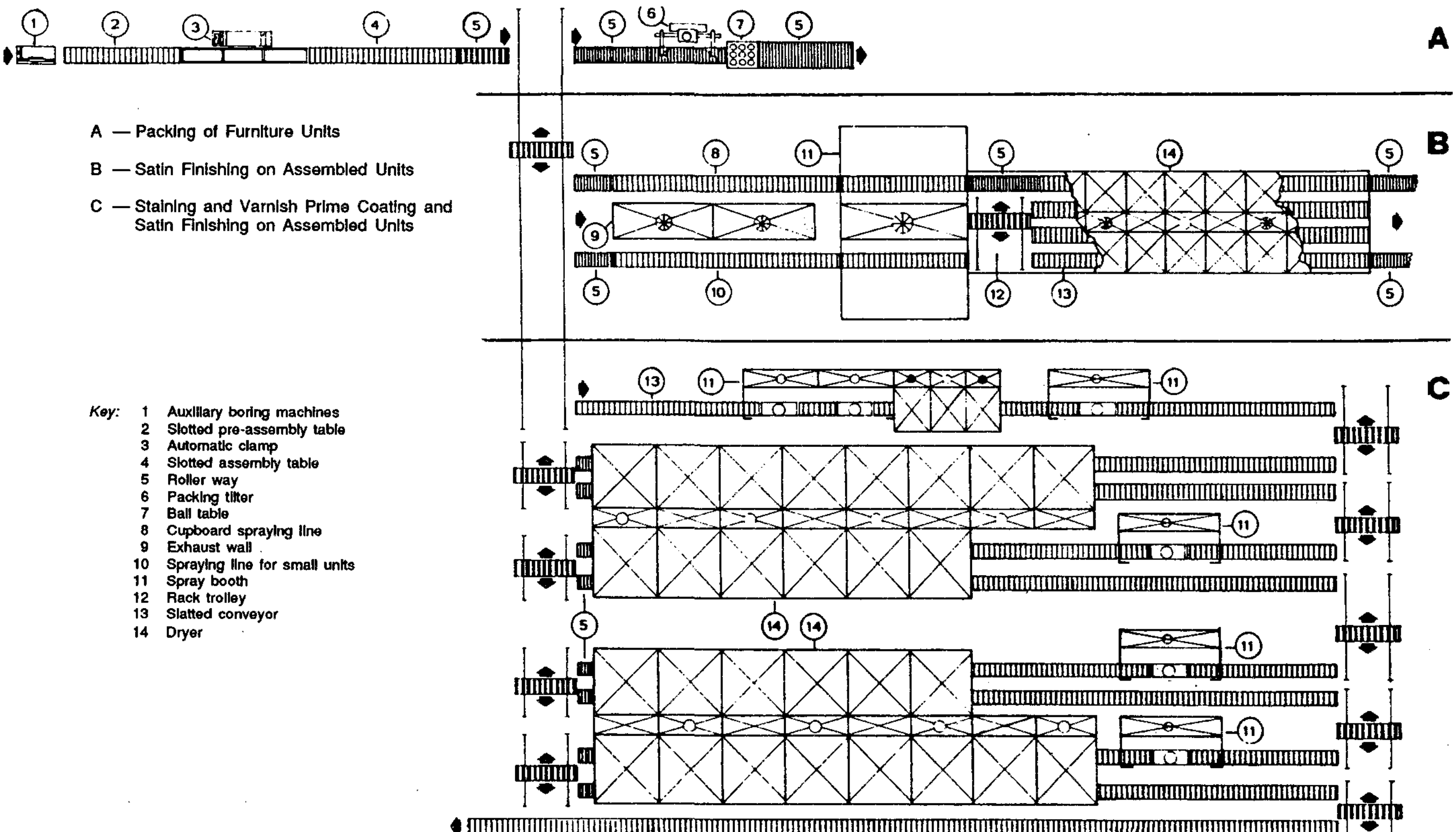
Levels B and C



Key:

1 Auxiliary boring machines
2 Slotted pre-assembly table
3 Infeed unit
4 Automatic clamp
5 Loading conveyor
6 Slotted assembly conveyor
7 Dead roller way
8 Packing tilter
9 Conveyor belt
10 Reeler for shrinking foil wrapping
11 Electric dryer
12 Lift
13 Unloading roller conveyor

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 conveyor
14 Dryer

XXVII. 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 pre-manufacturing 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 hardwoods or wood available contain silicon which requires special toolings
The annual output is approximately 250,000 m^2 for the mosaic flooring and 500,000 m^2 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 parquet 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 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 masonry.

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 XXI.

Parquet machinery for mosaic parquet

The selection of machinery for mosaic parquetry depends on the 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 cutter-blocks. 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 size of the workforce and assuming more or less an uninterrupted supply of 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

*By G. Gazzotti, consultant in the manufacture of parquet. (Originally issued as ID/WG.277/15.)

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 horsepower 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 (or a small tenoner to mould male and female grooves on the ends of the strips). These machines are usually linked.

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.

XXVIII. Wooden packaging for fruit and vegetable products*

Wooden packaging has a variety of uses: for fruit and vegetable products, for industrial products and as pallets. Each type of packaging is quite different, and different machines are involved in making and assembling each type.

Wooden packaging for fruit and vegetables

These so-called "lightweight" containers for fruit and vegetables are typically used for harvesting, storing, preserving, refrigerating and marketing the products. Their shape is generally rectangular, and they are normally 400-600 mm long, 300-400 mm wide and 80-280 mm deep. These containers can be either open (lidless) or closed (with lid).

The various types of wooden packaging for fruit and vegetables are illustrated in figures 1 and 2.

Preparation of parts for assembly

The parts to be assembled are:

Boards for making end panels (short side)

Boards for making side panels (long side)

Boards for making bottoms and lids

Slats or strips for making bottoms, lids and handles

Triangular angle blocks or corner stiffeners

"Chamfered" square-sawn sections for making wire-bound boxes

Preparation of sawn parts

Timber logs reach the factory in standard lengths. The layout of the machinery needed to prepare sawn parts is shown in figure 3, items 1 to 7. The corresponding steps are:

1. Debarking of logs
2. Sawing of logs into planks
3. Longitudinal trimming of planks
4. Cross cutting of planks into suitable lengths for boards
5. Cutting of logs with a gang saw into square-section lengths for making angle blocks
6. Automatic sawing of plank lengths into boards, slats and strips
7. Cutting off and diagonally splitting of square-sawn sections into triangular angle blocks

*By D. Castelli, engineer, Corali S.p.a., Carobbio degli Angeli, Bergamo, Italy. (Originally issued as ID/WG.369/13.)

Preparation of sawn and sliced veneer parts

For preparing sawn and sliced veneer parts, steps 1 through 7 remain the same, and one step is added (see figure 4):

8. Plank cutter for cutting pre-steamed planks into boards, laths and strips, especially those for making storage tray bottoms and also tray and box frames, when the timber is suitable for slicing

Preparation of sawn, sliced and peeled veneer parts

In figure 5, machines 1 to 6 and 8 are the same as those in figure 4. The following machines have also been added to increase the hourly production rate (1,000-1,200 trays) by producing veneered boards and strips:

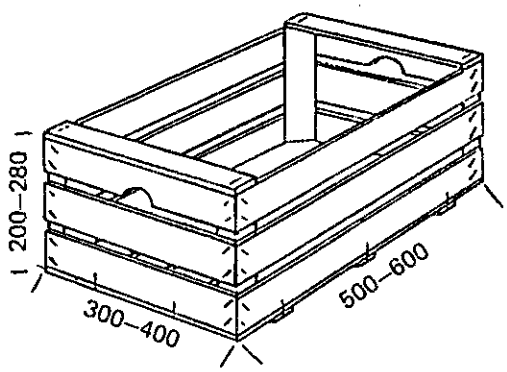
18. Cross-cutting saw for cross cutting the logs to sizes suited to veneering into boards, strips and laths of required length
20. Rotary veneer lathe, with log-lifter arm and centre-square device, for obtaining suitable veneer thicknesses for making container parts
22. Veneer slicer for cutting veneers into suitable widths for making various container parts (boards, strips etc.)
24. Square-sawn length cutter for cross cutting square lengths into suitable sizes for making triangular angle blocks
27. Angle-block cutter for longitudinally cutting square-sawn lengths into two triangular angle blocks

Another manufacturing line with an even higher hourly output rate of 2,000 to 2,200 storage trays is shown in figure 6. It includes machines 1 to 6 and 8, 18, 19, 21, 24, 25 and 26 of figure 5. To increase the line's automation even further, the screw-type centre-square device mounted on a veneer cutter (machine 20, figure 5) has been replaced with an automatic horizontal centre-square version (machine 36, figure 6). The two-bladed veneer slicer in figure 5 (machine 22) has been replaced with a four-bladed version (figure 6, machine 37), and the standard model angle block cutter (machine 27, figure 5) has been replaced by a double angle block cutter (machine 38, figure 6).

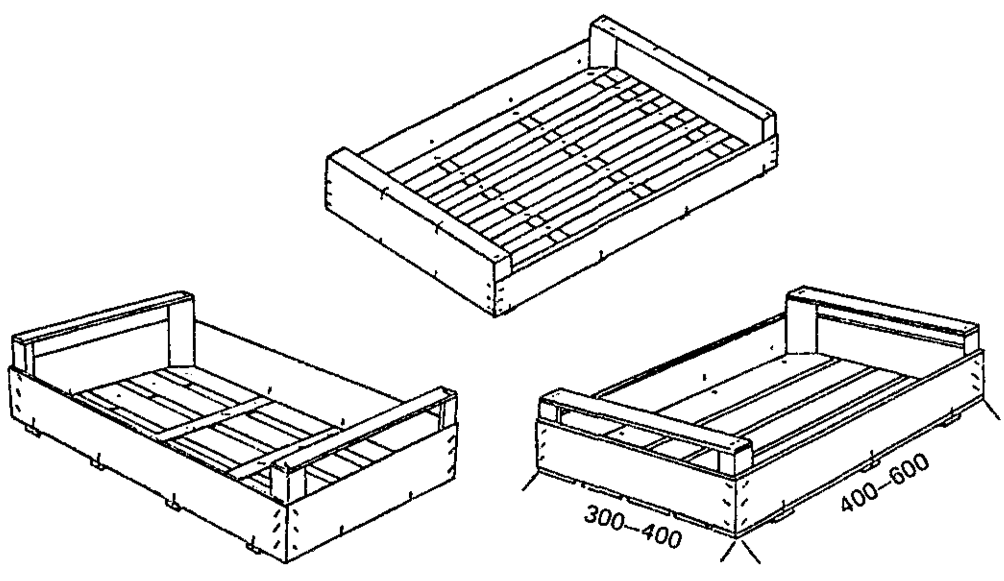
The machines included in the various lines will not be discussed in detail in the present chapter, but reference will be made to the specific operations performed by the machines in each specific plant situation (other uses may be made of the same machinery for making other types of packaging containers). In addition, no details will be provided about materials handling or operations related to the transfer of parts between machines.

Figure 1. Packaging for fruit and vegetables

A. Boxes for apples or vegetables



B. Trays for fruits



C. Box for cabbage, lettuce etc.

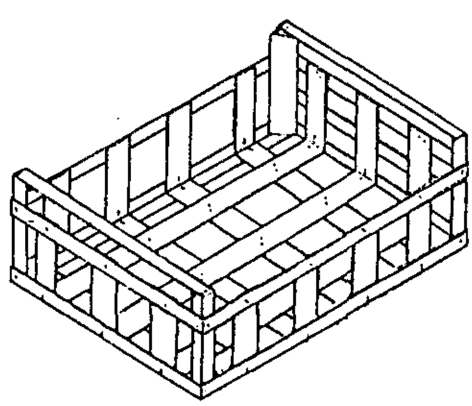


Figure 2. Baskets

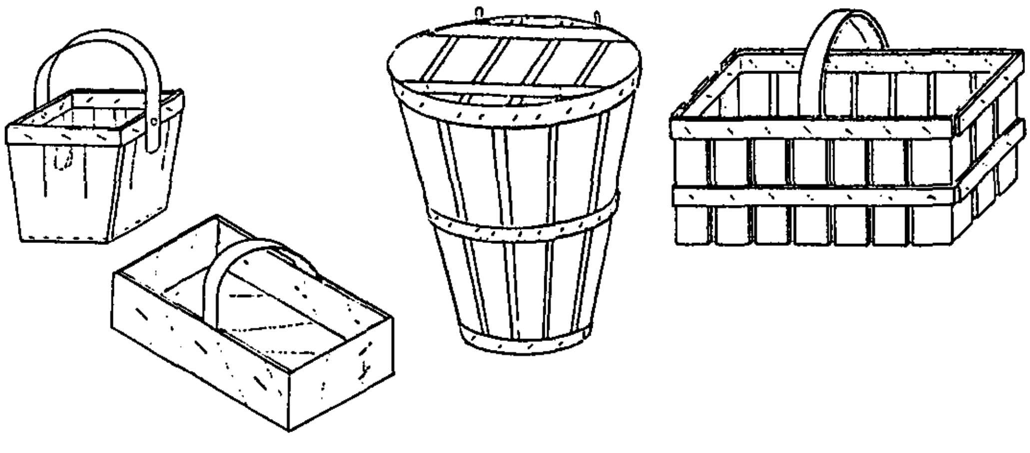
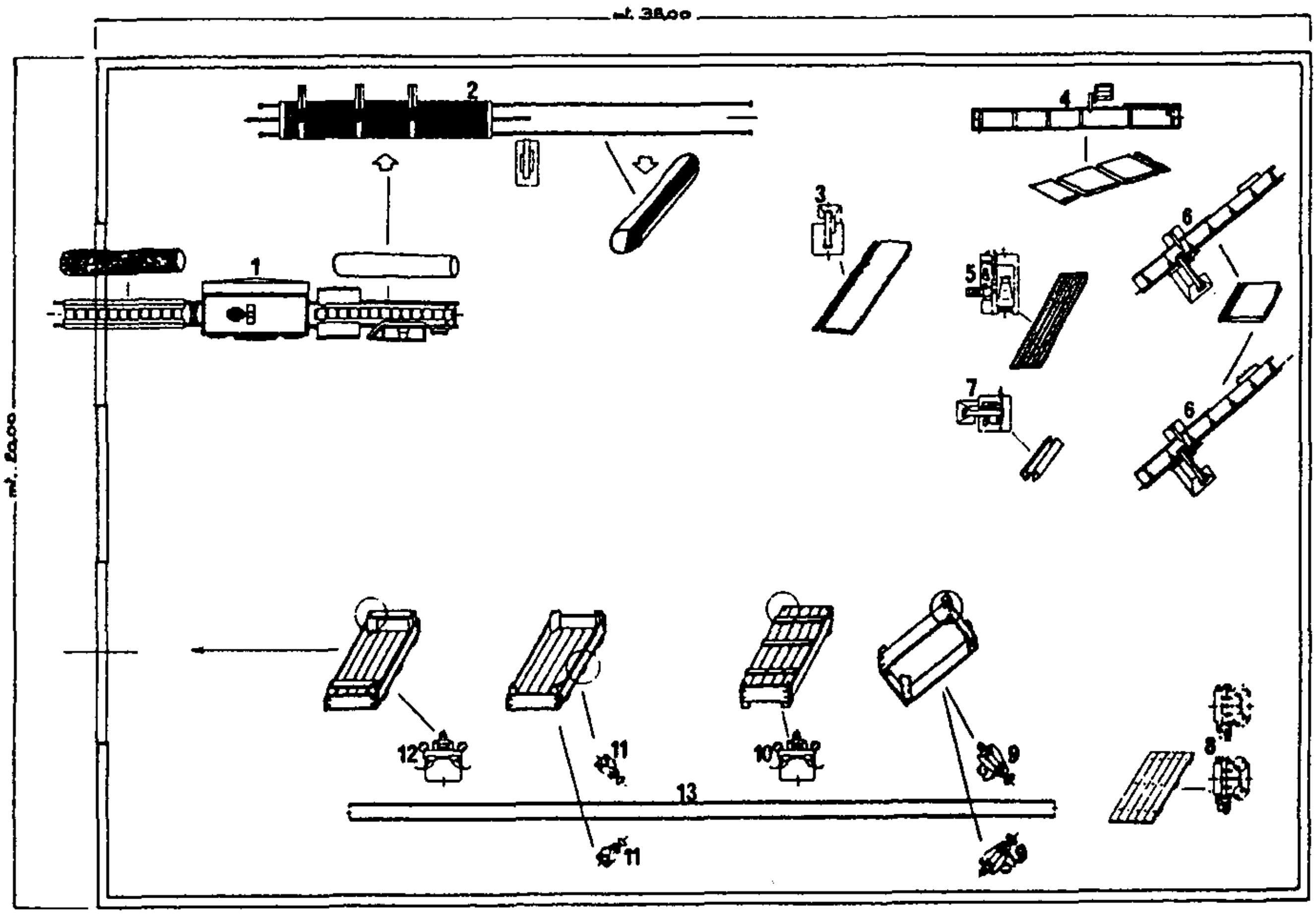


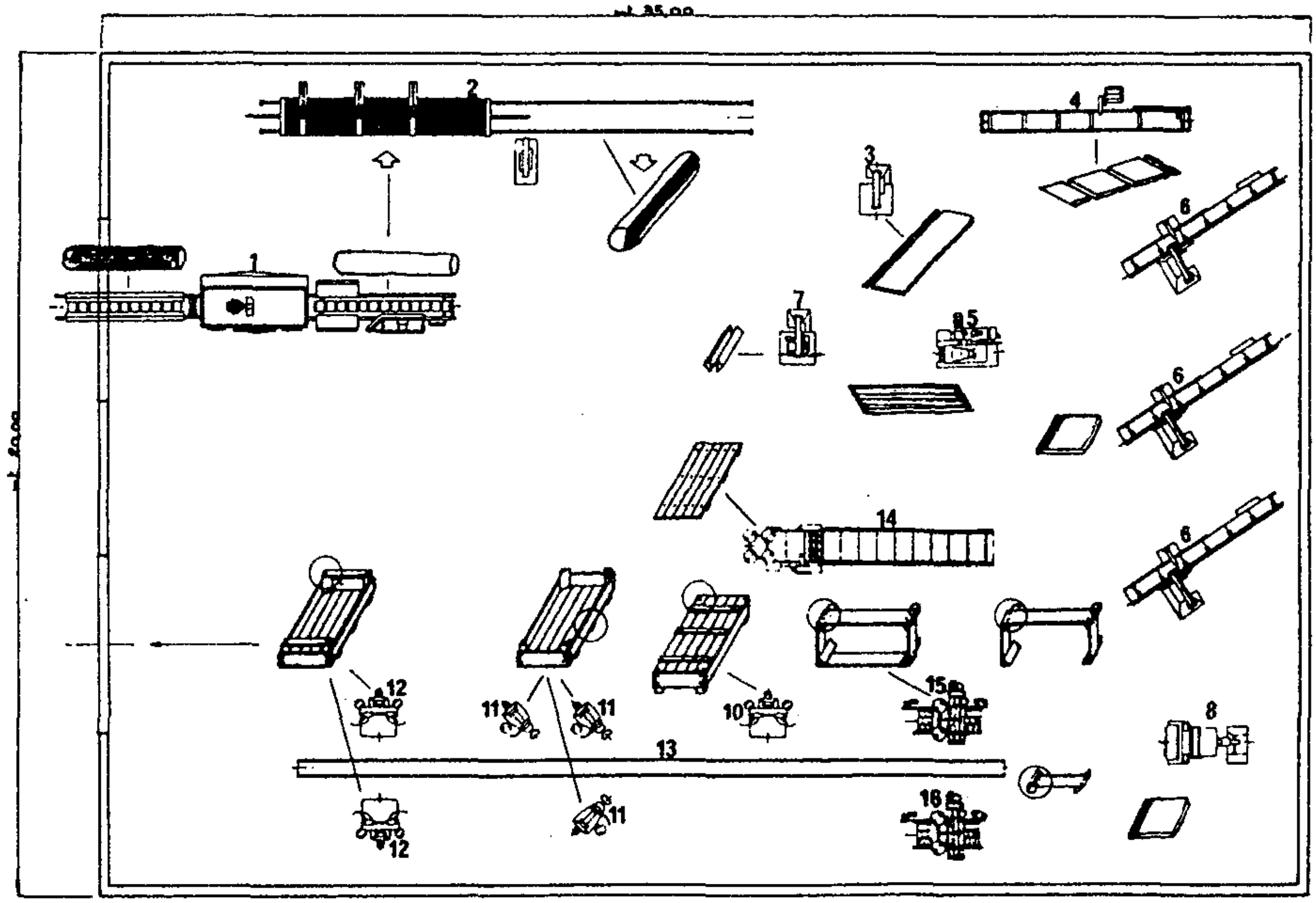
Figure 3. Layout of a unit for preparing sawn parts
(Hourly production rate: 500-700 trays; 200-220 boxes (three-slatted))



Key:

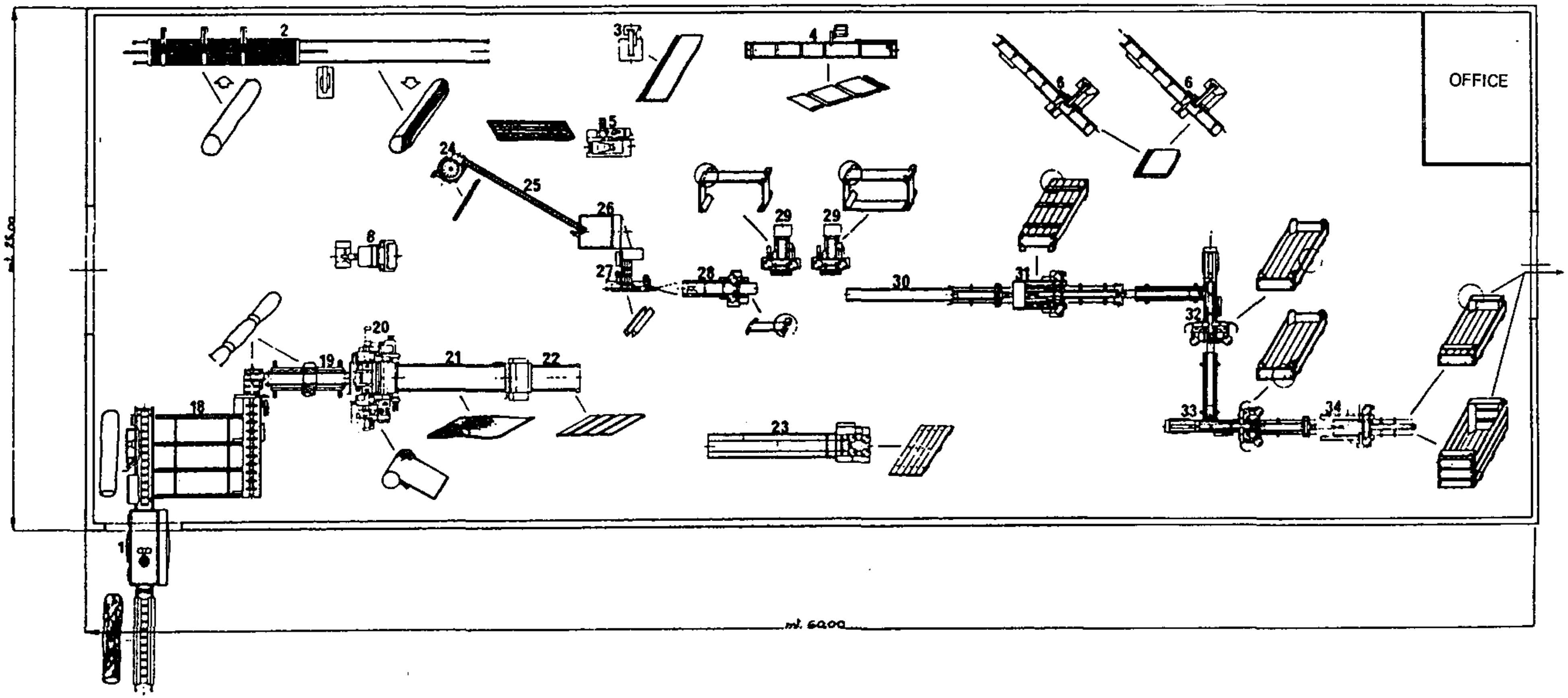
1 Debarking machine
2 Band-saw with carriage, 1,110 mm in diameter
3 Band-saw for final trimming operations, 1,000 mm in diameter
4 Pendulum saw
5 Multi-blade circular saw
6 Lath cutters (two)
7 Angle-block cutter with band-saw
8 Stitching machine with two or more heads for stitching box bottoms
9 Stitching machines for assembling frames (two)
10 Stitching machine for assembling frames to box bottom
11 Bottom-stitching machines (two)
12 Handle-stitching machine
13 Conveyor belt

Figure 4. Layout of a unit for preparing sawn and sliced veneer parts (Hourly production rate: 700-900 trays; 250-300 boxes (three-slatted))



Key:
1 Debarking machine
2 Band-saw with carriage, 1,100 mm in diameter
3 Band-saw for final trimming operations 1,000 mm in diameter
4 Pendulum saw
5 Multi-blade circular saw
6 Lath cutters (three)
7 Angle-block cutter with band-saw
8 Plank cutter
10 Stitching machine for assembling frame to box bottom
11 Bottom-stitching machines (three)
12 Handle-stitching machines (two)
13 Conveyor belt
14 Bottom-stitching machine
15 Stitching machine for assembling frames
16 Stitching machine for assembling end panels

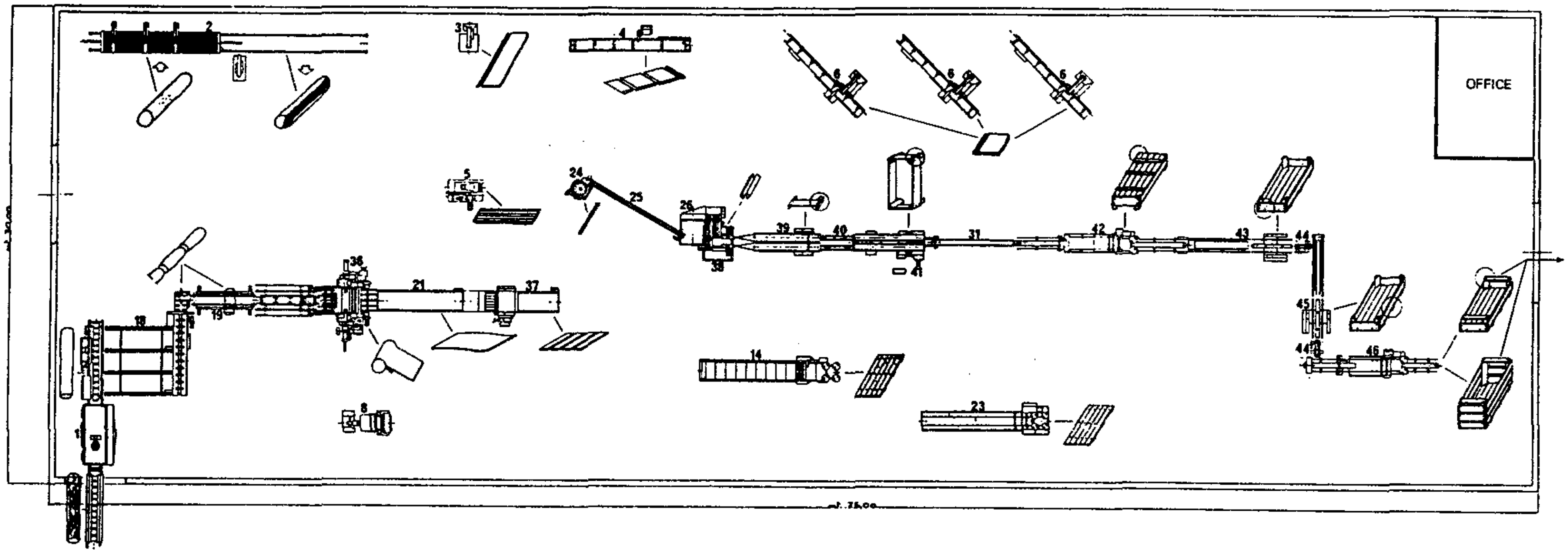
Figure 5. Layout of a unit for preparing sawn, sliced and peeled veneer parts



Key:

1 Debarking machine
2 Band-saw with carriage, 1,100 mm in diameter
3 Band-saw for final trimming operations, 1,000 mm in diameter
4 Pendulum saw
5 Multi-blade circular saw
6 Lath cutters (two)
8 Round section and plank slicer
18 Cross-cutting saw
19 Log chain conveyor
20 Rotary veneer peeler with screw-type centre-square device
21 Veneer conveyor belt
22 Veneer slicer
23 Bottom-stitching machine
24 Machine for cutting off lengths of square-sawn timber
25 Conveyor belt for square-sawn lengths
26 Storage bin for square-sawn lengths
27 Angle-block cutter
28 Automatic end panel stitcher
29 Semi-automatic frame stitchers (two)
30 Frame conveyor belt
31 Stitching machine for attaching bottom panel corners to frame
32 Stitching machine for attaching bottom panel to frame (end panel)
33 Stitching machine for attaching bottom panel to frame (side panel)
34 Handle-stitching machine

Figure 6. Layout for a unit for preparing sawn, sliced and peeled veneer parts (Hourly production rate: 1,800-2,000 trays; 800-1,200 boxes (three-slatted))



Key:

1 Debarking machine
2 Band-saw with carriage, 1,100 mm in diameter
3 Band-saw for final trimming operations, 1,000 mm in diameter
4 Pendulum saw
5 Multi-blade circular saw
6 Lath cutters (three)
8 Round section and plank cutter
14 Box-bottom stitcher
18 Cross-cutting saw
19 Log chain conveyor
21 Veneer conveyor belt
23 Bottom stitching machine
24 Machine for cutting off lengths of square-sawn timber
25 Conveyor belt for square-sawn lengths
26 Storage bin for square-sawn lengths
31 Frame conveyor belt
36 Rotary veneer peeler with horizontal centre-square device
37 Veneer slicer
38 Double angle-block cutter
39 Automatic end-panel stitcher
40 Overhead end-panel conveyor
41 Frame-stitching machine
42 Stitching machine for attaching bottom panel corners to frame
43 Stitching machine for attaching bottom panel to frame (end panel)
44 Fast conveyors (two)
45 Stitching machine for attaching bottom panel to frame (side panel)
46 Handle-stitching machine

Preparation of bottoms

The boards, slats or laths that make up box or tray bottoms are no longer nailed manually or tacked together but are joined by means of stitchers. Stitchers are machines that make stitches out of wire that is drawn automatically and continuously from skeins of various sizes supplied by wire manufacturers (figure 7). Such stitchers must not be mistaken for mechanically or pneumatically powered staplers or stitchers that use prefabricated staples.

Different types of stitchers, with various degrees of automation, are shown in figures 3 to 6, as follows:

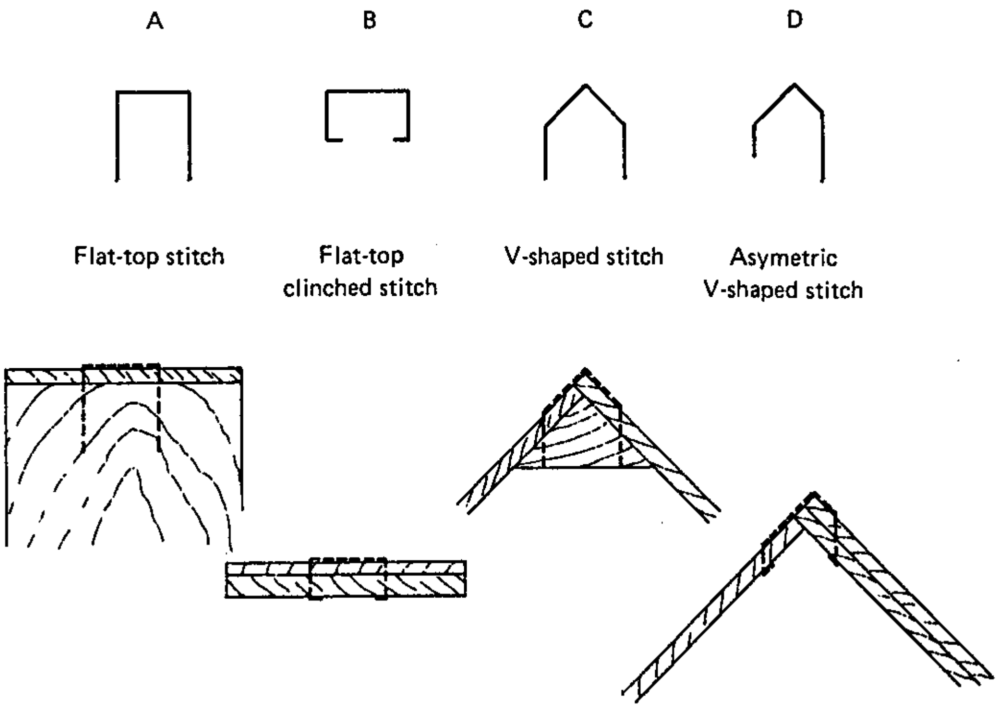
(a) The simplest line (figure 3), features a non-automatic stitcher (8) with two or more stitching heads. The speed of the stitcher depends largely on the capability and speed of the operator handling the machine and of the workers placing and positioning the boards and strips in the containers on the stitching line;

(b) An electronic, automatic conveyor belt type stitcher with two or more heads is shown in figure 4 (14). The same number of workers can achieve a production rate two to three times higher than that obtainable with the previous machine;

(c) The same type of high-speed conveyor-belt stitcher with two or more stitching heads is featured in figures 5 and 6 (23). This model, however, is capable of attaining even higher output rates.

The automatic conveyor-belt-type stitcher with two or more heads has a "loading belt" that is in continuous motion during the operation. The loading line conveys a series of containers (or holders) that are designed and arranged to receive the boards and slats that go into making up box and tray bottoms. The stitching heads (and respective strikers) are supported and fixed to swinging bars so that efficient stitching is ensured, even when the belt is moving. The heads are electronically controlled and only operate when the containers pass under them. As the machine is totally automated, no specially skilled workers are required; the job consists simply of filling the containers moving along the line with appropriate parts.

Figure 7. Types of stitches



Preparation of lids

Lids (figure 8) are prepared and stitched like bottoms, using the same stitching machines. In Europe, very limited use is made of fruit and vegetable trays or boxes with lids. Thus, the four factory layouts do not include lid-stitching machines. If necessary, lids can be stitched on the same machines used for making bottoms.

Assembly of packaging containers

Assembly plant for 500-700 storage trays or 200-220 three-slatted boxes per hour (figure 3)

The machinery in figure 3 is the simplest possible machinery available to replace the old hammer-and-nails assembly method. A separate stitching machine (9) is used to attach short (end) and long (side) panels to the triangular angle blocks at each corner (see figure 9). The "frame" thus assembled is transferred to the two-headed stitcher (10), where the bottom panel is fixed to the four angle blocks by flat-topped full-depth stitches.

Following this operation, the frame, with the bottom panel "tacked" at each corner to the four angle blocks, moves on to another stitcher, where the bottom panel is secured to the two long side panels and, if necessary, to the end panels with V-shaped stitches on the strips reinforcing the bottom (supporting strip).

The handle strips are attached to the four angle blocks by means of flat-topped full-depth stitches made with the two-headed stitcher (12).

Figure 8. Types of lids

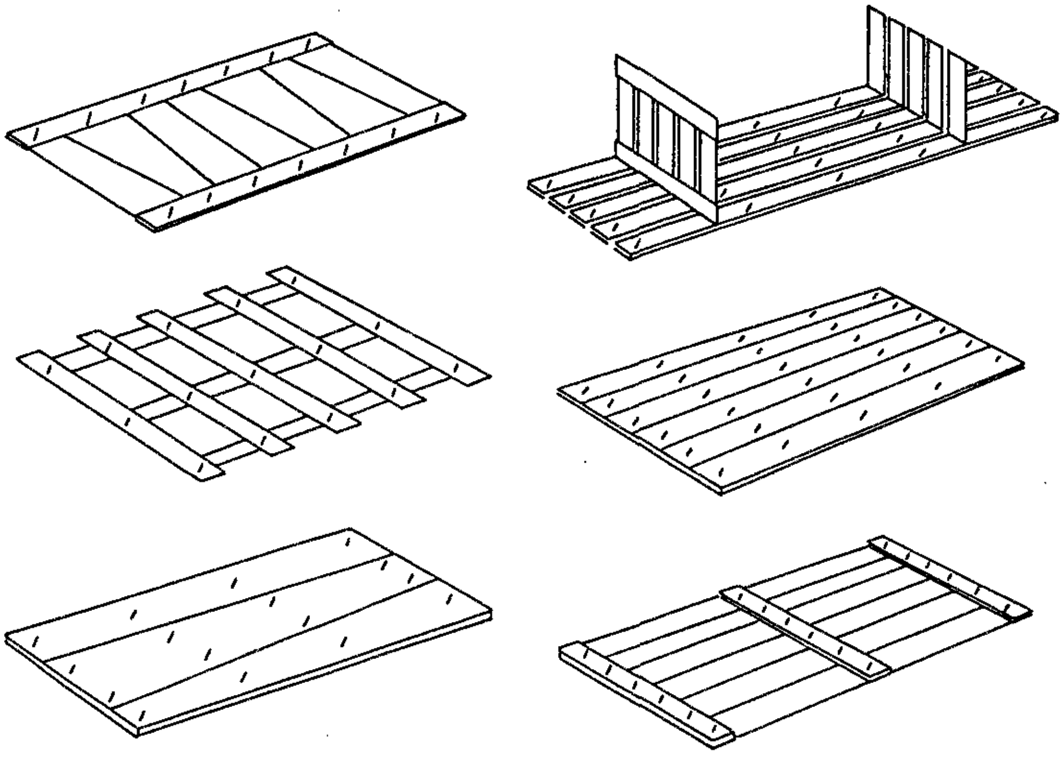
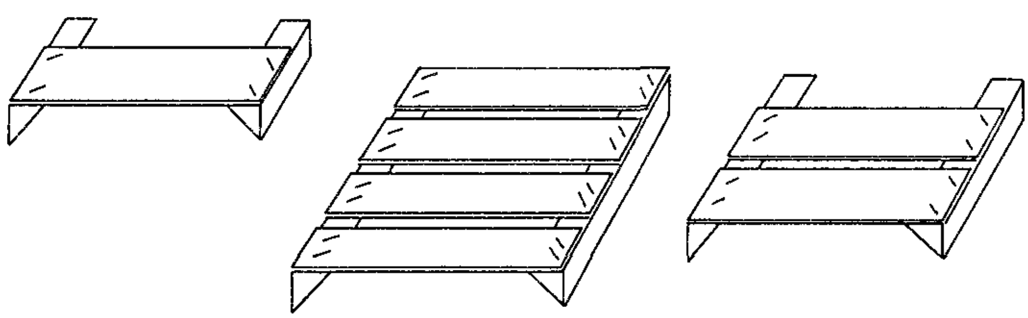


Figure 9. Heights of ends showing position of stitches



Assembly plant for 700-900 storage trays or 250-300 three-slatted boxes per hour (figure 4)

This line has a 40-60 per cent higher production rate. This productivity can be obtained by installing two automatic two-headed stitching machines with two synchronized carriage units (15 and 16). The first stitcher applies flat-topped full-depth stitches to join together end panels and angle blocks. The end panels are then put into the carriages of the second machine in pairs, and the side panels are fixed by means of the same stitches to the angle blocks.

Subsequent stitching operations are performed on the same machines as described for the first assembly line, plus the following:

(a) A two-headed stitcher (10) designed to apply flat-topped full-depth stitches to join the bottom panel with the four angle blocks;

(b) Three stitchers (instead of two) for carrying out the final attachment of the bottom panel to the long side panels (11), by means of V-shaped stitches on the reinforcing strips across the bottom;

(c) Two two-headed stitchers (instead of one) (12), designed to attach the two upper strips (handles) to the four angle blocks with flat-topped full-depth stitches.

Assembly plant for 1,200-1,500 storage trays or 400-600 three-slatted boxes per hour (figure 5)

The plant in figure 5 is semi-automatic and designed to provide trouble-free production changeovers, thus ensuring the utmost versatility. Changeovers from the assembly of storage trays to boxes, and vice versa, require only relatively simple adjustments and modifications, involving the addition or removal of tools and/or parts of loaders etc.

Once the bottom panels have been prepared, the following operations take place in the order listed in figure 5:

(a) On emerging from the angle-block cutter (27), the triangular angle blocks automatically slip into the guides that channel them onto the loading line of the automatic two-headed stitcher (28), which produces finished end panels. To make the end panels, the machine

operator has to place the boards or strips in the loader; a moving conveyor then automatically deposits them on the angle blocks, to which the stitcher secures them with flat-topped full-depth stitches;

(b) The end panels are brought to the automatic two-headed frame stitchers (29), which a worker manually feeds with side panels in special loaders located at the back of the machines, while another worker (one per machine) loads the two end panels that will form the frame into the front of the machine. As soon as the operator inserts the two end panels, one of the two strips needed to complete the frame will automatically come to rest upon them; the machine then stitches the strip to the angle blocks using the usual flat-topped full-depth stitches. The resulting half-frame is then upturned by the operator and once again placed on the stitcher, which automatically attaches the second side panel, thus completing the frame;

(c) The operator then places the frames on a conveyor belt that takes them to the automatic two-headed stitcher (31), which they enter automatically. Once the frames are on the loading line, an operator places a bottom panel on top of each; the stitcher automatically joins the bottom panel to each of the four angle blocks by means of four flat-topped full-depth stitches;

(d) The next step involves the automatic two-headed corner stitcher (32), which stitches the bottom panel to the two side panels by means of V-shaped corner stitches;

(e) Another automatic stitcher (33) makes more V-shaped corner stitches so as to join the bottom panel to the two end panels;

(f) With the bottom panel securely fixed to the four side panels forming the frame, the storage tray is automatically conveyed to the loading line of the next automatic two-headed stitcher (34). An operator places two strips (handles) in the two special side loaders. Prior to the actual stitching operation, the conveyors that direct the box or tray under the stitching heads also pick up these two strips, which are eventually fixed to the four angle blocks by means of four flat-topped full-depth stitches, thus forming the handles.

Assembly plant for 1,800-2,000 storage trays or 800-1,200 three-slatted boxes per hour (figure 6)

This plant layout is among the most advanced, most automatic and most productive available world-wide for the production of storage trays and boxes. Once the pre-stitched bottom panels are ready, the operation continues as described below.

After being cut into suitable lengths by a special cutter (24) fed by an operator, the square-sawn sections (which will later become angle blocks) travel by conveyor (25) to a storage bin (26), from which they are dropped into the angle-block cutter (38). Here they are cut diagonally to form triangular angle blocks of appropriate length and finally removed by an operator in preparation for the next operation.

The triangular angle blocks are automatically channelled on to the loading line of the automatic four-headed end-panel stitcher (39), which makes flat-topped full-depth stitches on two end panels at the same time. The operator in charge of the automatic stitcher feeds the automatic loader-distributors with the laths making up the two end panels. The machine stitches the end panels, which are automatically conveyed to the next operation, performed by an automatic four-headed frame stitcher (41). Another operator feeds side panels (long side) into the machine's automatic loader-distributors; the stitching heads make flat-topped full-depth stitches to join these side panels to the angle blocks at each corner.

The "frames" emerging from the automatic stitcher (41) all fall in exactly the same position on the conveyor belt (31), which takes them at a pre-set pace to the conveyor-loader of the automatic two-headed stitcher (42). Here, an operator places a bottom panel on each frame moving towards the stitching heads. The two parts are stitched together at each corner by means of two flat-topped full-depth stitches.

Two automatic two-headed stitchers (43 and 45) finally join the bottom panel to the end panels and side panels by means of V-shaped corner stitches. The tray is automatically fed into these two stitching machines, upturned, stitched, withdrawn and ultimately conveyed to the next two-headed stitcher (46), where the operator in charge feeds the strips that are to become the handles into the two loader-distributors. The machine stitches these two handles to the four angle blocks by means of flat-topped full-depth stitches.

The result is a finished tray which, as in the previous assembly lines, is stacked on pallets, loaded and conveyed to factories where the fruit and vegetables are cleaned, sorted and packed prior to their storage, preservation and marketing.

Wire-bound boxes

A special type of box is the wire-bound box. While its component parts (boards, laths etc.) are similar to those for other boxes and trays, its construction and assembly differs.

Preparation of parts (laths)

The same machines are used for making laths as for making the box and tray parts described above (band-saw, veneer slicer, veneer cutter). The only special machine needed on the factory line is the chamfer-cutter, used for precision cutting and chamfering plank lengths to the required size. Once machined, the parts then pass through the multiple-blade saw, which delivers the square-sawn lengths, cut-off and chamfered to perfection, required to make the box.

Parts assembly

Open frame

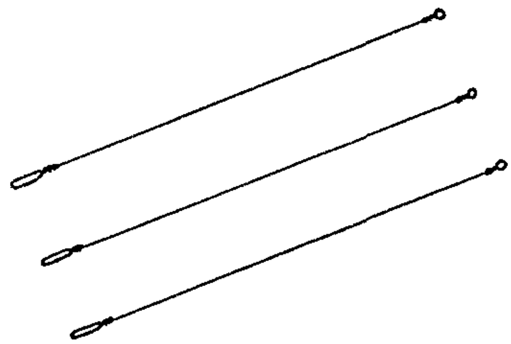
Box frames can be circled with reinforcing wire by means of a separate conveyor-belt-type stitcher. Laths and square-sawn lengths are positioned on the stitching line, and pre-looped band wire is used to join them (figure 10A). Band wire is available from suppliers in pre-looped form and in the required sizes, or it can be looped as needed using a cutting and looping machine handling skeins of continuous wire.

The stitcher either comes equipped with hooks or pins designed to handle pre-looped wire or is built to handle skeins of continuous wire. In the latter model, the wire is cut to a specific length by special rotary shears mounted on the machine at the exit of the stitched frame.

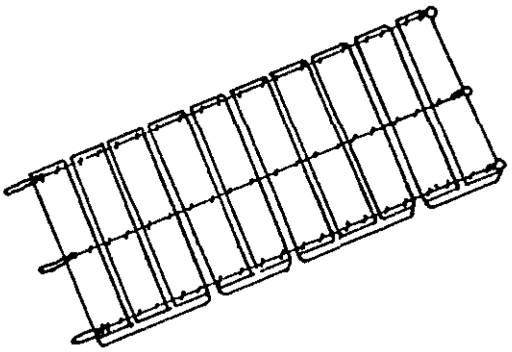
Thus stitched, and with the band wires cut, the frame is placed on a bench where two workers equipped with a sort of hammer-cum-pliers tool, loop the wire ends and hammer them into the wood (figure 10B).

Box frames can be assembled and looped on an automatic line employing a continuous supply of skein-fed band-wire. The line comprises two machines. An automatic electronic multiple-head stitcher continuously stitches band wire to the strips and square-sawn sections (figure 11A) (there are no square-sawn sections in the central parts); the second machine, an automatic wire looper that is synchronized with the first machine, cuts off the wires, loops them and flattens the ends against the wood (figure 11B), in a fully automated process.

Figure 10. Sheet manufacturing technique for wire-bound boxes

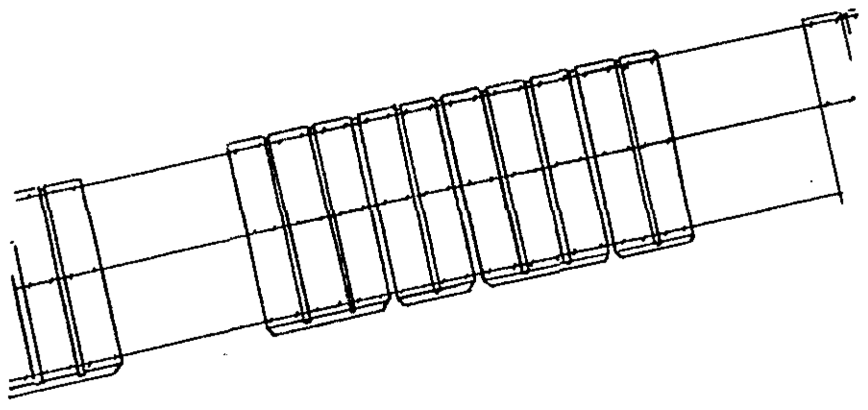


A. Previously looped band wires

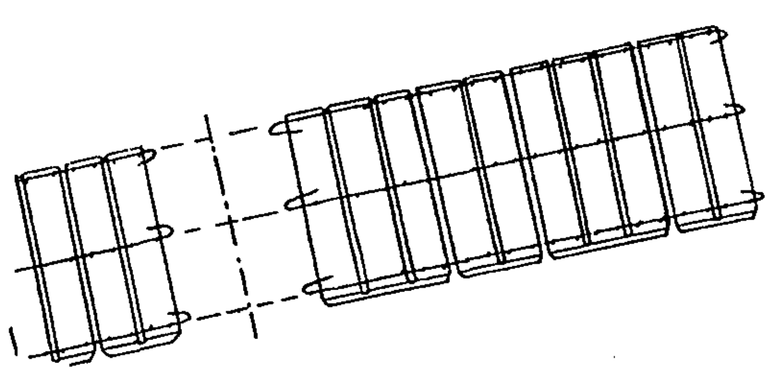


B. Continuous looping of band wires on TESTAR machine

Figure 11. Sheet manufacturing technique for wire-bound boxes



A. Continuous stitching and band wire supply on TESTAR machine



B. Cutting and automatic looping of band wires on looping machine

End panels

End panels can be made out of a single piece of plywood or fibreboard or any other similarly strong, flexible, bonded material, or they can be made out of wooden boards, joined by stitched strips (figure 12A). End panels can be reinforced with pre-looped band-wire or with continuous band-wire (figure 12B) cut after stitching and then hand-looped, or they can be reinforced on a two-machine reinforcing line, consisting of an automatic electronic stitcher and a synchronized automatic loop-former (figure 12C). A separate type of semi-automatic looping machine can be used for applying the looped wire to the plywood, fibreboard or woodstrip end panel (figure 12D).

End panels consisting of boards and strips are stitched by the same stitchers used to make box and tray bottoms.

Other types of packaging containers

The boards, laths and strips that are processed for the production of crates are prepared on the same machines that are used for working box and tray parts, i.e. automatic or semi-automatic bands-saws, veneer slicers, as well as circular gang saws and angle-block cutters for forming the angle blocks generally present on all crate types. The machine that is of major importance in making baskets is the rotary veneer cutter.

To make the square baskets and round tapered containers illustrated in figure 2, the rotary veneer cutter must be fitted with a back-roll unit and with roughing knives as well as the usual lateral veneer cutting knives. "Back-roll" is the name given to the unit complete with roughing roller (a cylinder embedded with knives). While the rotary cutter is operating, the roughing roller presses down on the rotating log, cutting it to the required width, shape and depth prior to the actual veneer cutting operation, so that the result is not a continuous veneer sheet but a series of boards, or parallel or tapered laths, all perfecty finished and in the desired shape.

The rotary veneer cutter thus mounted with the back-roll unit can also be installed in plants manufacturing storage trays and boxes only (no baskets or crates at all). In this case it can produce boards or laths without necessarily having to cut the veneer to size using a separate veneer slicer. The veneer slicer is nevertheless essential, since not all logs suitable for veneering can also be handled by the back-roll unit to convert them into boards or laths. In many cases it is either unadvisable or impractical to employ the back-roll unit. For instance, the back-roll unit cannot be used for making boards or laths over 3-4 mm thick out of beech logs measuring more than 600-700 mm that have not been steamed, while the same logs, measuring the same length can be peeled using a rotary veneer lathe into sheets even 6-8 mm thick.

The same stitching machines used for making storage trays and boxes can be utilized for manufacturing crates. The manufacture of baskets, however, requires at least one special stitcher capable of applying flat-topped staple-type stitches. The baskets pictured in figure 2 are assembled as follows:

(a) The baskets in figure 2A typically come in four different sizes, designed to hold 10, 5, 3 or 2 kilograms of carrots, onions, fennel roots, celery, artichokes etc. It is stitched "open" by means of an automatic electronic conveyor-belt-type stitcher equipped with multiple stitching heads. The machine is fitted with special hook-on receptacles or holders arranged to handle the strips and weave them (mainly for the bottom of the basket). After stitching the open element, a worker uses a separate stitcher featuring a stitching arm and striker (no bench is involved) to securely close and stitch the basket by means of flat-topped staple-type stitches;

(b) The basket in figure 2B is assembled by means of a special automatic stitcher, which makes flat-topped staple-type stitches on both sides. The stitcher features a moving loading line, to which special receptacles or forms are attached. The forms receive the following parts in this order: the lath that forms the bottom of the basket and two sides; the handle; and the strip previously shaped into a frame by means of a separate stitcher applying flat-topped staple-type stitches. The first stitcher simultaneously fixes the frame to the two sides and attaches the handle with a stitch to the centre of the same two sides;

(c) For the basket in figure 2C, an automatic electronic multiple-head stitcher joins the various parts together (minus the handle) with flat-topped full-depth stitches. The resulting "open" element is then closed by means of a separate stitching machine that makes flat-topped staple-type stitches. The handle is then riveted on so it can be folded down for stacking during transportation and also to avoid damage;

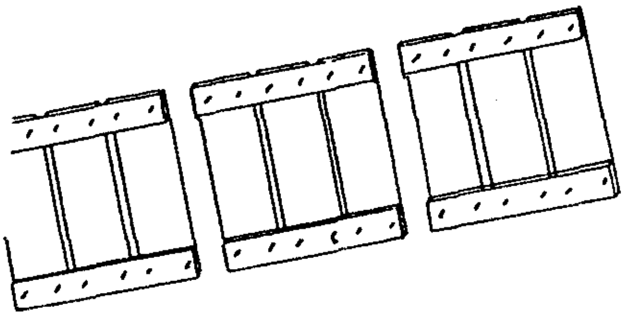
(d) The lid and bottom of the basket in figure 2D are stitched by means of an automatic electronic multiple-head stitcher (the same model used for making storage trays). The stitcher fixes the lid and bottom to the frame by means of wire loops or pre-looped wire (the same used for reinforcing wirebound boxes). The frame is stitched by means of an automatic stitcher that applies flat-topped staple-type stitches. The machine is also fitted with a special device to which a rotating container of the same shape as the basket is attached. As many tapered box veneers as are needed to form the frame are placed vertically in the container and immobilized. The stitcher then applies flat-topped staple-type stitches to the three horizontal veneer strips holding the standing box veneers in place.

Packaging for industrial products

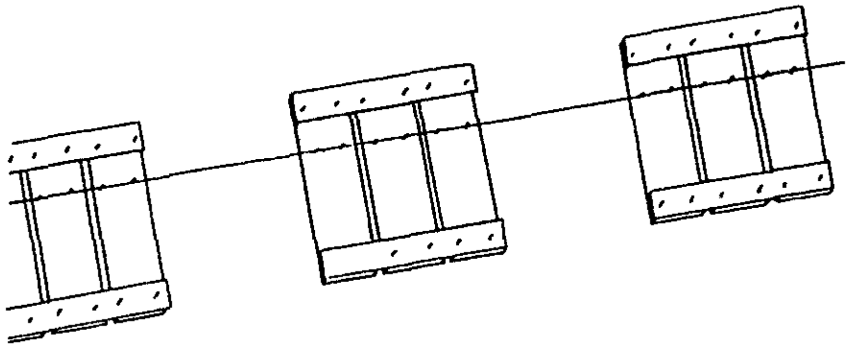
There are three major types or categories of wooden packaging for industrial uses; heavy-duty boxes (for sea transportation); standard boxes; and crates. These types of packaging are available in many shapes and sizes, and all are designed to contain a vast variety of goods and to cover long or short hauls, either overland (by road or rail) or by sea or air.

As regards the preparation of the various wooden components (planks, boards, strips, beams, laths etc.) for such packaging, so much depends on the type of timber used and on the country in which it is worked that no detailed information can be provided.

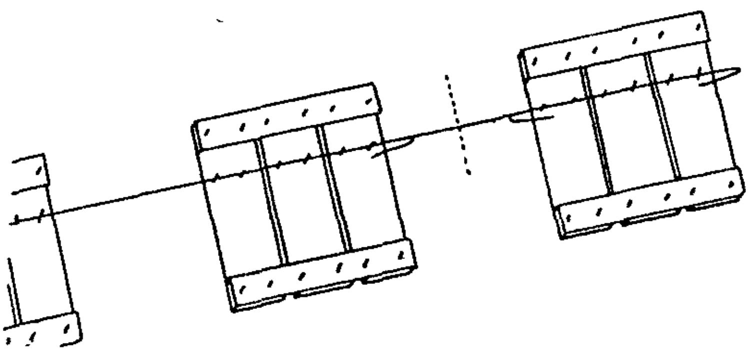
Figure 12. End-panel manufacturing technique for wire-bound boxes



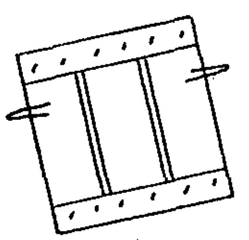
A. Wooden boards joined by stitched strips



B. Continuous stitching and band wire supply on TESTAR machine



C. Cutting and automatic looping of band wire on looping machine



D. Semi-automatic looping

In relation to the assembly of the various box and crate parts (bottoms, lids and sides), if part sizes are such that nailing or stitching machines can be used to assemble them (on average up to 1,200 × 1,400 mm), and the machinery investment is justified by the demand, the equipment described above featuring the necessary degree of automation can be chosen. If, however, output is limited and the size range is broad, assembly operations are generally performed utilizing manual stitchers (applying ready-made staples) or manual nailing equipment (usually pneumatically driven) fed with suitable nails.

Special light-weight goods transported overland or by air can also be placed in lighter looped-wire crates and boxes. These containers have successfully solved the problem of storage in confined spaces, since the three parts of the packaging container (lid, side and bottom) can be stored unassembled. The boxes or crates are assembled (by inserting wire loops into slots) only when required; once they have been emptied, they can again be dismantled and shipped flat, ready for immediate re-use. This leads to valuable savings in transportation costs, even over long distances.

Manufacturing wooden pallets

The purpose of this section is not to describe the latest and most advanced machines and technologies available for the preparation of pallet boards, cubes (or blocks) and strips but rather to furnish information on the most advanced technologies for assembling normal and double-face two-way-entry and American and Pool (EUR) type four-way-entry pallets.[1]

Pallets may be stitched or stapled. There are two kinds of staples. Those supplied ready-made for use with staple guns (the least suitable method of making medium- to heavy-duty pallets) and those made automatically by the stitching machine out of continuous wire drawn from reels. The latter type are ideal for stitching pallets and can be made to measure up to 90 mm in length, with a wire diameter of up to 3.2 mm.

Pallets assembled using the second method have proven to be far superior to pallets constructed using normal or helical nails.[2] They are stronger and last longer than nailed pallets.

Pallets made of hardwood require pre-perforation prior to nailing operations, even if special hardwood nails are used; no pre-perforation is required prior to stitching. Pallets assembled with ready-made staples applied by special staple guns are fast losing popularity, since they are known to be far weaker than either nailed or machine-stitched pallets. However, these pallets are lightweight and disposable and are still used for palletizing light, low-cost goods that do not require tough, durable pallets.

[1]Two-way entry pallets are open and can be entered on two (opposite) sides and closed on two sides; the fork lift can enter the pallet on all sides of the four-way pallet. (Figure 14.)

[2]Comparative tests were conducted by the following specialized organizations: Delft Packaging Institute (Netherlands); Politecnico di Milano (Italy); Politecnico di Torino (Italy); and Centre national de l'emballage et du conditionnement, Paris (France), on behalf of the French Railways.

Nailed pallets

If a small number of pallets (100-200 pallets daily) of different sizes are to be produced, manufacturers tend to prefer nailed pallets assembled using either pneumatically powered nailing guns with ready-made nails (supplied in sticks or rolls) or guns fitted with automatic magazine-type loading units providing continuous nail feed. Various types of nailing machines are available; however, in all versions, the nails are fed automatically and continuously into a channel or duct that takes them under the gun's percussion pin, which then drives them into the wood.

Manufacturing lines featuring hand-operated mechanical or pneumatic nailing guns are labour-intensive and require trained personnel willing to withstand tiring and stressful work.

Larger-scale manufacturers with a daily output rate of over 400 to 500 pallets of similar type but different sizes typically choose automatic machines or lines.

Nailed pallets—pool-type four-way-entry (EUR)

As illustrated in Figure 13, a single 36-nail nailing machine is sufficient for an hourly output of 40-60 pallets. This machine assembles the bridges (or skis) on one side and attaches the upper part of the pallet to the bridges on the other. After being stitched, the bridges return to the workers, who turn them around and move them to the other side of the cross slide. The machine can handle different sizes of nails (both normal and helical), since the reciprocating cross slide can be programmed to simultaneously nail together all the parts of the four-way-entry-type pallet.

Other equipment can be combined and synchronized with the nailing machine to form an entirely automated line producing finished pallets, i.e. pallets featuring chamfered corners, milled edge strips to facilitate fork-lift truck handling operations and branded cubes or blocks. The pallets are either stacked on top of one another or inside one another to save space, as shown in the layout in figure 13.

Higher production rates of up to 200 pallets per hour can be achieved by combining and synchronizing several nailing machines (with 6 to 8 workers in attendance). Such a high output level would obviously demand minimum variations in the range of types and sizes produced.

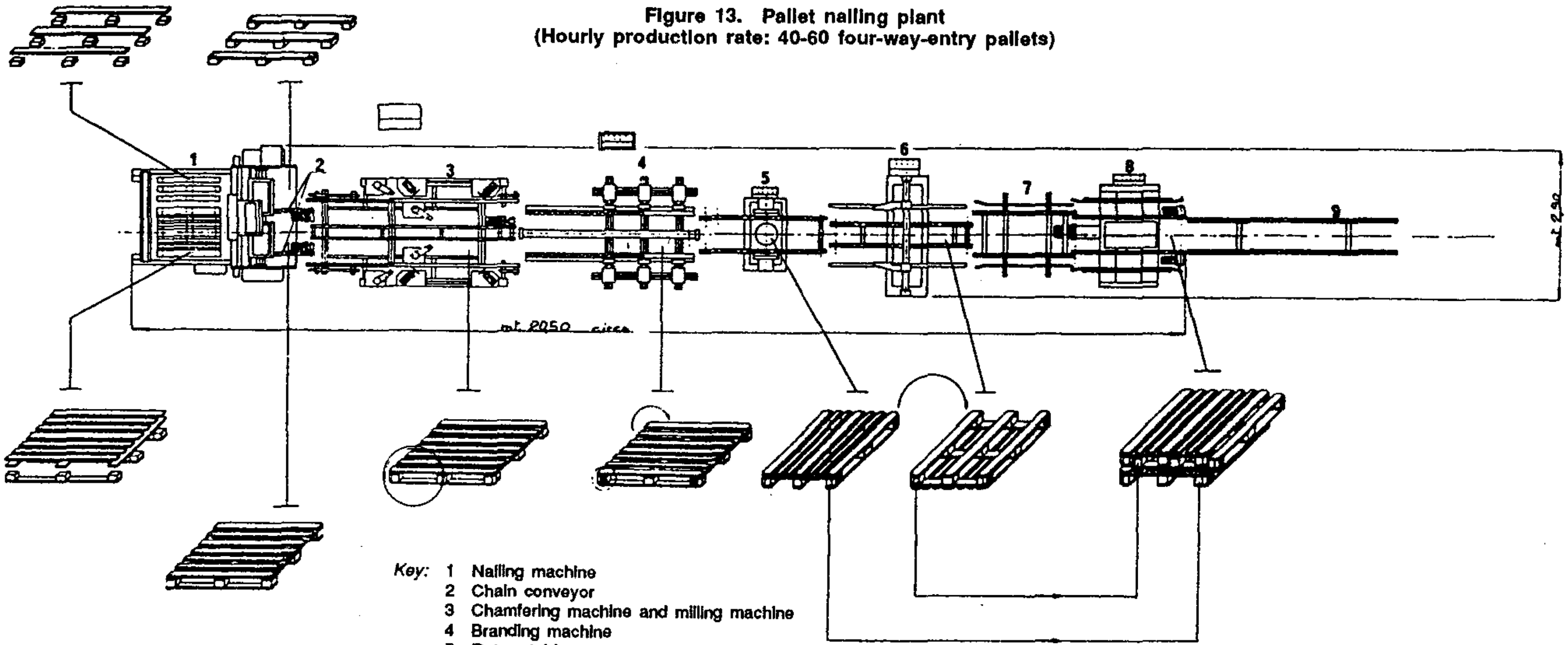
Stitched pallets—pool-type four-way-entry (EUR)

A pallet stitching line for 40 to 60 pallets per hour is shown in figure 14.

One three-headed stitching machine is sufficient both to stitch the bridges and to attach them to the boards forming the upper surface of the pallet, once one of the attendants has rotated the pre-stitched bridges and placed them in the container on the conveyor. The machine features an automatic reciprocating traverse-reverse slide. The machine's stitching programme is operator-controlled, and the finished pallets are ejected mechanically.

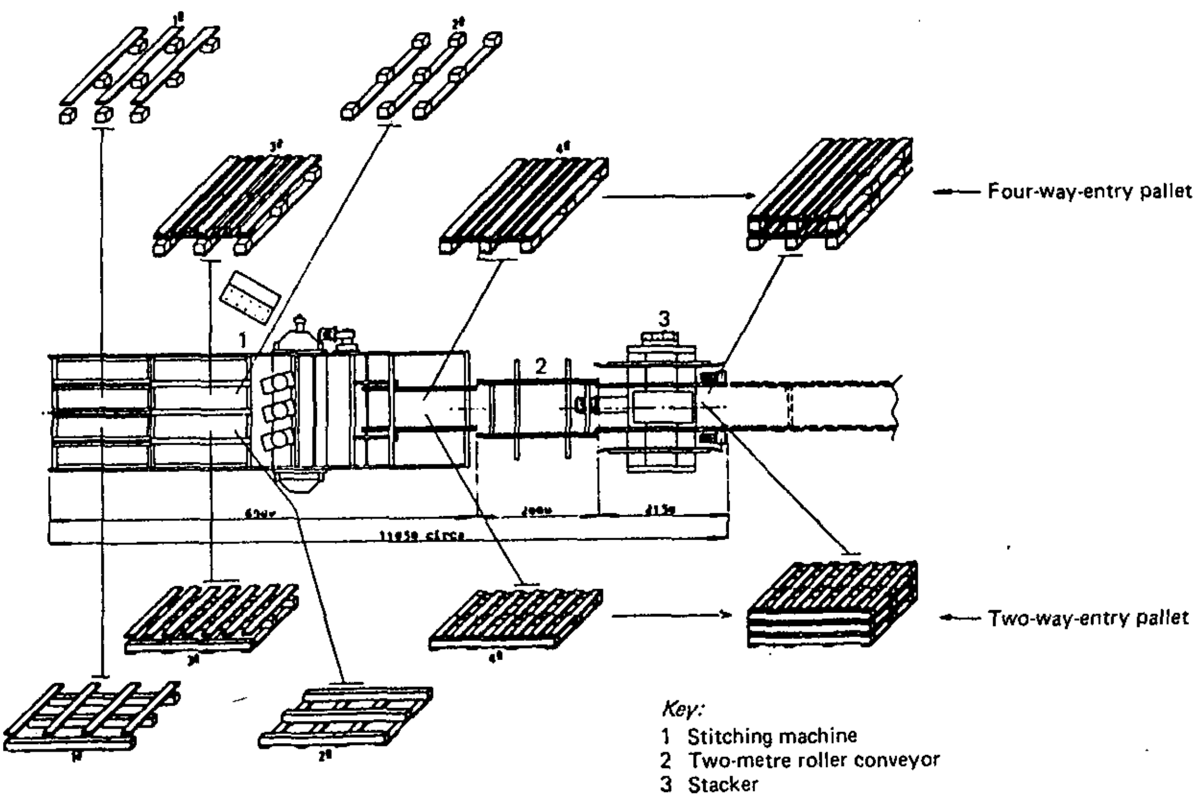
The slide has two work stations: the first stitches the underside of the pallet and the second stitches the upper side. The machine may be fitted with from three to five stitching heads, depending on the type of stitch required and on the diameter of the wire out of which the staples are made.

Figure 13. Pallet nailing plant
(Hourly production rate: 40-60 four-way-entry pallets)



Key:
1 Nailing machine
2 Chain conveyor
3 Chamfering machine and milling machine
4 Branding machine
5 Rotary table
6 Flip-over mechanism
7 Two-metre link-up roller conveyor
8 Stacker
9 Four-metre roller conveyor

Figure 14. Pallet stitching line
(Hourly production rate: 40-60 two-way entry pallets and four-way-entry pallets)



Stitched pallets may be either stacked directly or fed into subsequent machines synchronized with the stitcher to form a complete line producing finished pallets with chamfered corners and branded cubes (or blocks). These pallets may either be stacked on top of one another or upside down inside one another to save space.

Stitched pallets—double-face two-way-entry or American type four-way-entry

80-90 pallets per hour

An hourly production rate of 80 to 90 double-face two-way-entry or American-type four-way-entry pallets can be obtained by using a three- to five-headed stitcher featuring a reciprocating slide attachment, appropriate stitching programme, two work stations and an automatic pallet flip-over mechanism that enables pallets to be stitched on both sides. The automatic stitcher may be included in a synchronized production line arrangement, ending up with stacked, finished pallets (figure 15).

250-300 pallets per hour

A line comprised of two stitching machines that enables a limited number of machine attendants loading the pallet parts to produce from 250 to 300 pallets per hour is shown in figure 16. Just one of these stitchers is capable of stitching 250-300 single-face two-way-entry pallets per hour; no more than three or four workers are necessary.

Automatic stitching line for double-face pallets

An automatic stitching line (using staples) requiring only five people to load and/or feed pallet parts can produce 160-200 pool-type four-way-entry (EUR) pallets or 250-300 double-face two-way-entry or American-type four-way-entry pallets per hour. This is among the most highly automated, least labour-intensive and fastest line ever achieved world-wide (300 pallets per hour).

A layout of such a line is shown in figure 17. The sequence of operations involved in assembling pool-type four-way-entry pallets (EUR) is as follows:

1. Three-headed stitcher for assembly of the upper surface of the pallet, consisting of three boards, across which five to seven laths are stitched;

2. Stacker for stacking and packing scheduled batches of pallet tops;

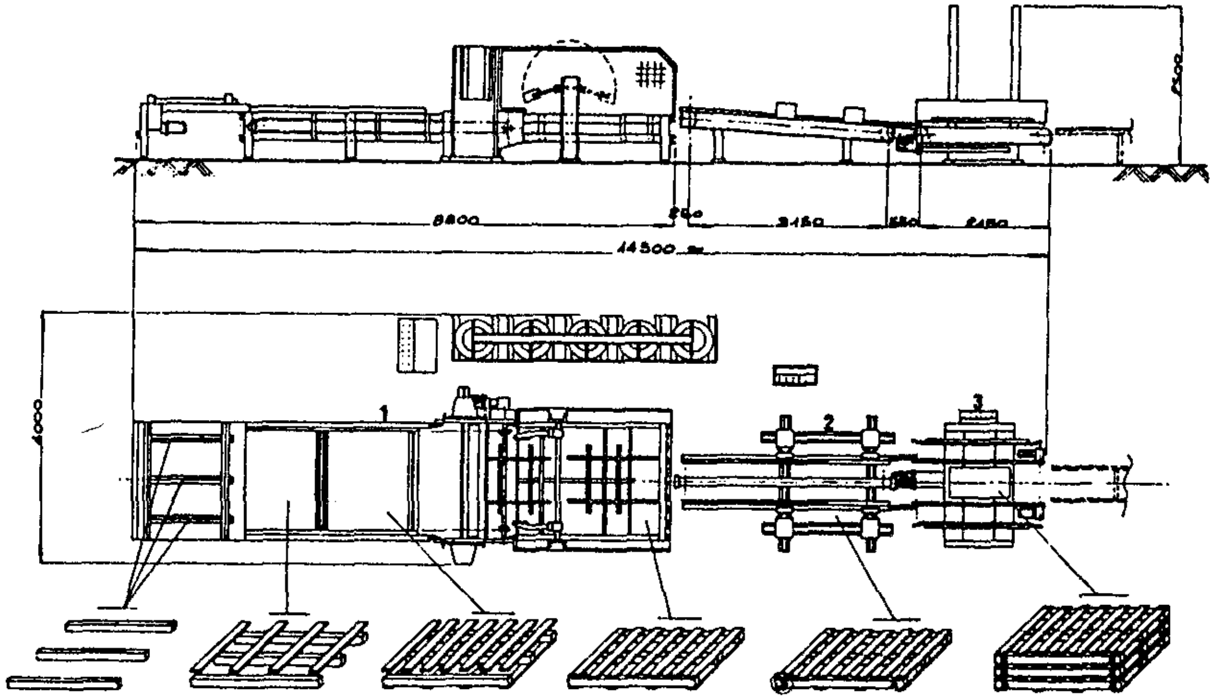
3. Destacker, upon which the batches of pallet tops are shifted. The destacker is located on the roller conveyor at the delivery end of the stacker;

4. Three-headed stitcher. An operator feeds the stitching line with pallet cubes (blocks). These are conveyed until they are located under the pallet top that has already been automatically removed from the stack and brought to the line. The pallet top is thus lowered on to the cubes and stitched to them;

5. Pallet flip-over mechanism. The pallet top, now stitched to the cubes, is grasped by the flip-over mechanism arm and placed (upside down) on the conveyor belt that takes it to the next machine;
6. Three-headed stitcher. The operator loads the appropriate laths on to the stitcher line receptacles. The laths are placed on the pallet in arrival from the previous operation and the entire element is then passed under the stitching heads;

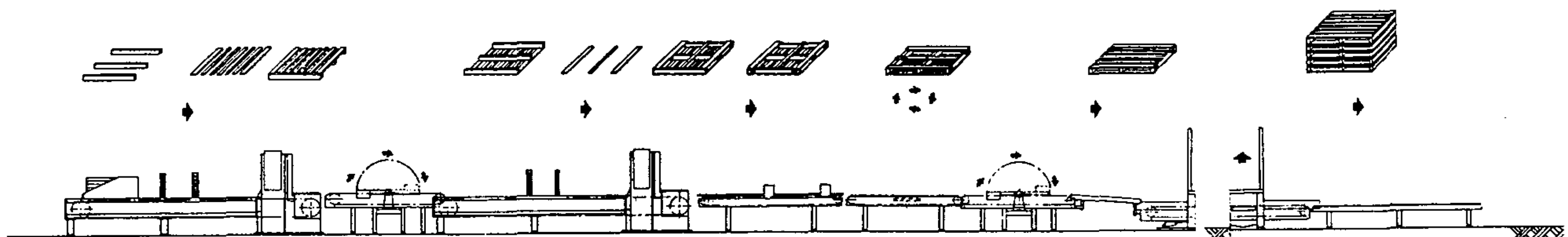
7, 8, 9, 10, 11 and 12. Subsequent operations (chamfering, milling, branding and stacking) are all automatic. The scheduled number of fully stitched and finished pallets thus emerges on the roller conveyor at the delivery end of machine (10).

Figure 15. Pallet stitching line
(Hourly production rate: 80-90 two-way-entry pallets)



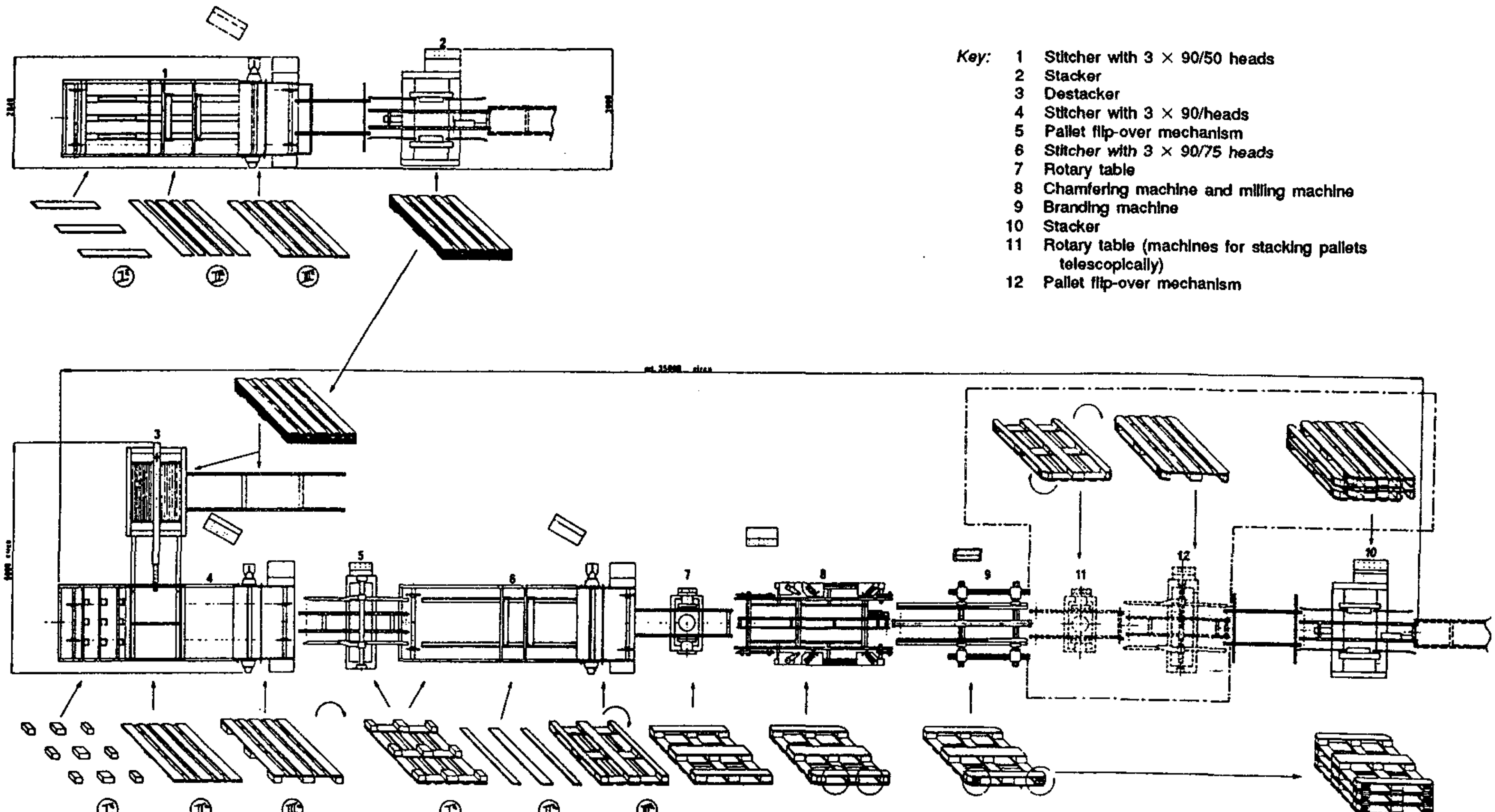
Key:
1 Stitching machine
2 Branding machine
3 Stacker

Figure 16. Automatic stitching line for two-way-entry pallets



Key: 1 Stitcher
2 Flip-over mechanism
3 Branding machine
4 Stacker

Figure 17. Pallet stitching line
(Hourly production rate: 160-200 four-way-entry pallets; 250-300 two-way entry pallets (excluding positions 1, 2 and 3))



Key:

1 Stitcher with 3 × 90/50 heads
2 Stacker
3 Destacker
4 Stitcher with 3 × 90/heads
5 Pallet flip-over mechanism
6 Stitcher with 3 × 90/75 heads
7 Rotary table
8 Chamfering machine and milling machine
9 Branding machine
10 Stacker
11 Rotary table (machines for stacking pallets telescopically)
12 Pallet flip-over mechanism

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Printed in Austria
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UNIDO publication
Sales No. UNIDO.92.1.E
ISBN 92-1-106257-8

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